JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

Republic of Mozambique

THE DATA COLLECTION AND PREPARATORY STUDY FOR RENEWABLE ENERGY UTILIZATION PROJECT ALONG THE NACALA CORRIDOR

FINAL REPORT

March 2012

CTI ENGINEERING INTERNATIONAL CO., LTD.

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COUNTRY AND PROJECT AREA MAP

TABLE OF CONTENTS

CURRENCY EXCHANGE RATES USED IN THIS REPORT:

JPY80 = USD1 = MTK26

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AC	Alternate Current
AIDS	Acquired Immune Deficiency Syndrome
BTC	Belgium Development Agency
DVD	Digital Versatile Disc
EDAP	Energy Development Access Program
EDM	Mozambique Electric Co. (Electrocida de Mozambique)
ERAP	Energy Reform and Access Program
FUNAE	National Energy Fund (Fundo de Energia)
HIV	Human Immunodeficiency Virus
JSO	Jatropha Straight Oil
JST	Japan Science and Technology Agency
JPY	Japanese Yen
kW	kilowatt
kWh	kilowatt hour
LED	Light Emitting Diode
ME	Ministry of Energy
MREM	Ministry of Mineral Resources
MW	Megawatt
NCEP-FNL	The National Center for Environmental Prediction - Global Forecast System Final
NEDAP	National Energy Sector Development and Access Program
NGO	Non-Governmental Organization
PARPA	Plan of Action for Poverty Reduction
PQD	Five-Year National Development Plan
PV	Photovoltaic
SADC	Southern African Development Community
SH	Staff House
SWOT	Strengths, Weaknesses, Opportunities, Threats
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollar
USGS	United States Geological Survey
VAC	Alternate Current Vaccine Refrigerator

CHAPTER 1. Introduction

1.1 Study Background

More than 90% of the total power for the Republic of Mozambique is produced by the Cahora Bassa Hydropower Plant (installed power generation capacity: 2,179 MW) and the balance is produced by either diesel power plants or natural gas power plants. While around 80% of the annual power output of the Cahora Bassa Hydropower Plant (approximately 12,500 GWh) is exported to South Africa and other southern African countries through the African Power Pool, a considerable volume of electricity is imported from South Africa. The country's electrification ratio is quite low, which is around 14%, especially in rural areas where around 80% of the total national population resides. The Government of Mozambique has been promoting both on-grid and off-grid electrification utilizing renewable energy in rural areas because stable power supply is a requisite in alleviating poverty and promoting economic growth in rural areas (see details in Appendix 1, Chapter 2).

On-grid rural electrification has been progressing, extending the grid network to the center of 128 cities and towns throughout the country. However, electrification in the central and northern regions has substantially lagged behind. The connection to the power grid in rural areas is limited only to institutions and a few commercial facilities located in the central part of the cities, while household connection is quite limited (see details in Appendix 1, Chapter 2).

Hence, the Government strongly promotes off-grid rural electrification utilizing renewable energy in rural areas while giving consideration to environmental protection. Aside from the installation of off-grid power generation systems at administrative facilities in every province and district, schools and health centers are also electrified to improve education and health services in rural areas. The technology used to provide power to schools and health centers is solely the independent photovoltaic (PV) power generation system or technology, or the solar power generation system (see details in Appendix 1, Chapter 5).

In 2005, the Government obtained a World Bank loan to provide 150 schools and 150 health centers with PV systems for their electrification. As of this writing, all the units are still operating. Meanwhile, procurement procedures for the electrification of 195 schools, 79 health centers, and 77 administration posts in Manica, Sofala, and Zambezia provinces also under the same loan are ongoing. This electrification project along the Nacala corridor, however, does not include the provision of PV systems in Nampula Province (see details in Appendix 1, Chapter 5).

1.2 Study Objectives

In 2011, the Government of Mozambique requested the Government of Japan to fund an electrification project in Nampula Province. Toward this end, the Japan International Cooperation Agency (JICA) has funded a preparatory study, entitled "Data Collection and Preparatory Study on Renewable Energy Utilization Project along the Nacala transport corridor," to initially assess the said project. The JICA study aims to: (i) examine the impact of the electrification project, assuming that the primary schools and rural health centers scattered along the Nacala corridor and its influence areas have been electrified; (ii) determine a highly sustainable approach to electrification; and (iii) present the most appropriate and practical technologies to be applied for the requested Nampula electrification project.

1.3 Study Team Members

The members of the JICA Study Team are as shown below.

Table 1.3.1 JICA Study Team Members

KOIKE Isamu	Team Leader (Power and Energy Cooperation Program)	CTI Engineering International Co., Ltd.
GOTOH Shinichi	Renewable Energy (Solar Power)	CTI Engineering Co., Ltd.
TAKEISHI Tadahiko	Renewable Energy (Wind Power)	CTI Engineering International Co., Ltd.
IWASHITA Yumi	Administrative Coordinator (A)	CTI Engineering International Co., Ltd.
TSUJI Keiko	Administrative Coordinator (B)	CTI Engineering International Co., Ltd.

1.4 Study Period

This JICA study started in November 2011 and has been carried out in the time frame shown below.

Table 1.4.1 JICA Study Duration

Particulars	2011		2012		
	November	December	January	February	March
First Home Office Work					
First Field Study					
Second Home Office Work					
Second Field Study					
Third Home Office Work					
Final Report Preparation and Submission					△

1.5 Study Team Itinerary

The itinerary of the Study Team is as shown in Addendum 1.

1.6 List of Persons Met

The persons met during the course of the study are as listed in Addendum 2.

CHAPTER 2. Confirmation of Basic Information

2.1 Confirmation of Project Objectives

The objective of the Nampula electrification project requested officially by the Government of Mozambique from the Government of Japan in 2011 is to upgrade the living standards of rural communities through the electrification of primary schools and health centers located along the Nacala transport corridor which starts from the Nacala Port and ends in Malema, Nampula Province. The project is designed to install power sources for lighting to allow the conduct of night classes (17:00H–22:00H) in primary schools to increase the literacy rate among adults (present illiteracy rate is around 60%); to increase the quality of education by using audio-visual equipment such as TV, DVD and radio; and to improve health services through the installation of refrigerators for storing vaccines and the provision of lighting to allow night births.

It has been confirmed through the studies and surveys that the electrification of schools and health centers will directly contribute to increased living standards and better quality of basic education in rural areas. Furthermore, it was confirmed through field surveys that the electrification of primary schools and rural health centers contribute not only in upgrading the level of basic education and quality of health services but also in allowing primary schools to function as community centers at night to support community activities.

2.2 Confirmation of Contents of Request

The Nampula electrification project requested in 2011 involves the installation of power generation facilities to electrify 43 primary schools and 47 health centers (or a total of 90 sites) utilizing renewable energy. Candidate schools and health centers surveyed in this study totaled 67 and 31, respectively, or a total of 98 sites (see details in Appendix 3).

In Nampula Province, there are 11 districts that directly access the Nacala Corridor (Nampula Province is composed of 21 districts and six cities). The total number of primary schools in those districts is around 2,200 (2,500 in total in Nampula Province). On the other hand, the total number of health centers in those districts is 142 (209 in total in the province). Of these numbers, 60 schools (or 3% of the schools) and 82 health centers (or 57.8% of the health centers) are already electrified. The Government of Mozambique expressed its desire to electrify not only the schools and health centers identified in this preparatory study but as many as possible in the coming years.

2.3 National Plans and Electrification Policies

2.3.1 National Development Plan

The following national plans, provincial development plans, laws, and regulations can be considered as relevant to the study (see details or outlines in Appendices 6, 7, and 8):

- Five-Year National Development Plan (PQD)

- Plan of Action for the Reduction of Poverty (PARPA), 2011–2014
- Development Strategy of Nampula Province, 2010–2020

(1) Five-Year National Development Plan

In the Five-Year National Development Plan, the following guidelines are clearly stated in the development of the education and health sectors:

(a) Infrastructure Development

Energy Sector:

Energy is a major factor in the country's socio-economic development and improvement of the people's quality of life and is indispensable in preparing a solid foundation for social and economic activities. The issues to address are the improvement of access to sustainable energy by providing power generation facilities so as to eradicate poverty, upgrade welfare, and contribute to the socio-economic development of the nation.

Strategy:

(i) Expand the geographical coverage of infrastructure services and supply of energy so as to expand the access to energy at the least cost.
(ii) Develop the ability to utilize the technologies for the production and installation of new and renewable energy, such as solar, wind and hydraulic power, and promote them for use by primary schools and health centers.
(iii) Utilize as much as possible domestic resources for power generation and focus on the installation of small and medium-size power generating facilities utilizing renewable energies.
(iv) Promote the production of bio-fuels and maximize the utilization of natural gas and reinforce fuel supply for domestic consumption.
(v) Promote effective and productive use of energy for agriculture and industries in particular.

(b) Village Electrification Program

(i) Electrify all administrative offices in districts that have not been connected to the power transmission grid.
(ii) Expand power supply to productive areas.
(iii) Prepare a wind resource map by erecting masts for wind power measuring equipment at various locations throughout the country.
(iv) Continue to install power mills for water pumping and irrigation purposes.
(v) Continue to install solar power systems in all primary schools and health centers with highest priority in rural areas throughout the country.
(vi) Electrify some villages in each province throughout the country.

(c) Bio-Fuel Production

(i) Continue the activities needed to produce bio-fuel.

(ii) Promote bio-fuel production.

(d) Education

The Government considers education as the tool to unify all citizens who own the basic human right and act socially, economically and politically, an indispensable factor to construct the society of Mozambique that is based on freedom, democracy and social justice. Therefore, the Government shall address the field of basic education intensively so that all children could access and complete the 7th grade successfully. At the same time, in the field of secondary education, the curriculum to upgrade the skills for better life, employment and self-management shall be integrated aiming at the upgrade of overall welfare. In the field of higher technical education, the reformation shall continue so as to upgrade the quality of education to provide the human resources having appropriate skills to the market. For adult education, the learning of skills for upgrading life and self-employment is to be the major subject.

Strategy:

(i) Institutional and Operational Support: Reinforce control on the educational management system and to ensure equal opportunity for education throughout the country.

(ii) Primary Education: Exercise quality education extensively and to encourage all children to receive the basic education by 2015.

(iii) Literacy Education for Adults: Improve access to literacy programs for adults and skills upgrading programs for young people through the integration and coordination of various measures.

(iv) Secondary Education: Expand proper quality secondary vocational training programs continuously through regular distance education.

(v) Vocational Training and Technical Education: Expand the educational system through the reformation and integration of informal education to expand the opportunity for learning of out of school youths.

(e) Primary Education

Achieve the goal set out by the Millennium Development to ensure that all children will have the opportunity to receive classes through the following activities:

(i) By various measures and partnership, construct 1,500 new schools annually throughout the country with the use of local materials and expand the school network.

(ii) Ensure gender equality for primary education.

(iii) Reinforce and expand the accelerated construction of classrooms.

(iv) Construct, improve and expand the training facilities for teachers throughout the country.

(v) Establish a simple mechanism to employ the retired teachers for primary education (1st and 2nd grade) by utilizing their experience of teaching languages.

Target all children studying in schools acquire basic knowledge and skill of reading, writing and calculation through the following activities:

(i) Promote ethic, cultural and patriotic education.

(ii) Increase reading and writing skills.

(iii) Establish a teaching method of Portuguese as the second language and expand bilingual education.

(iv) Increase lessons from 36 weeks to 40 weeks per year and total learning hours from 500 hours to 900 hours a year by 2014.

(v) Provide basic resources for each school by distributing textbooks free of charge by means of improving management method.

(vi) Continue reformation and reinforcement of teacher training (teacher training for new and servicing teachers by man-to-man or distance education methods) by means of integration of cross-cutting issues such as capacity building for teacher training, gender, HIV/AIDS, school construction, special education, etc.

(f) Adult Education

The Government shall take the following actions for the expansion and upgrade the quality of education for adults.

(i) Continue and expand the existing literacy program for adults.

(ii) Continue and expand the literacy education.

(iii) Improve the literacy program and quality of education by focusing on the following items:

- Develop and execute the curriculum for literacy and adult education, teachers' training program and framework.
- Develop a program that will make it possible to tie up the literacy program and non-formal education through partnership with civil society.
- Integrate and execute new curriculum for literacy and adult education by linking the literacy and skills upgrading for life.
- Reinforce the role of INEA (National Adult Education Institute) and CFQAEAs (Teacher training, literacy, adult education center).

(g) Health

The central target of Government is promotion of the health sector to improve the health conditions of Mozambique people and provide proper quality healthcare free of charge or in an affordable range of charge to pay.

Strategy:

(i) Focus on the health of women, children and other socially weak people by promoting equal access to healthcare services.

(ii) Reduce the adverse influence of malaria, TB, HIV/AIDS, diarrhea and other infectious diseases and contribute to reduce the ratio of pollen diseases, malnutrition, etc.

Priority Actions:

For health of women and children:

(i) Increase the ratio of delivery in health centers to 66%.

(ii) Increase the ratio of immunized children of less than 12 months to 80%.

(h) Village Development

Most of the population and producers are scattered around the rural area and living on agriculture, forestry, livestock rearing, etc. The areas where high poverty incidents occur are the rural villages.

Strategy:

(i) Reinforce the productivity of rural area to increase competitiveness so as to increase the stocks.

(ii) Reinforce human resources and promote technological innovations.

(iii) Develop organization and promote infrastructure development.

(iv) Formulate plans and promote good governance for market economy.

Priority Actions:

(i) Expand and promote bank and financial services in rural areas.

(ii) Supervise and improve the management mechanism of the district development fund so as to increase its impact.

(iii) Utilize the domestic experiences stocked to prepare the farm market promotion program.

(iv) Promote the development of small-medium size enterprises in the rural areas.

(v) Develop and promote the rural economic development method by focusing on district's economy.

(vi) Ensure the contribution of utilization of natural resources to the improvement of livelihood of village population.

(vii) Promote the establishment of natural resources management cooperatives on the community level.

(viii Promote small-scale family forest development.

(ix) Establish the institutional framework aiming at village network development.

(x) Promote vocational training and adult literacy education.

(xi) Promote cooperative organizations as an engine for rural village community development.

(xii) Support the organization of village cooperatives so as to reinforce and increase the specialized knowledge of village farmers and science technologies.

(2) Nampula Province Development Strategy (2010-2020)

The Local Government of Nampula Province has formulated a development strategy. Outlined below are the key action plans related to the Project.

(a) Infrastructure Expansion Program (PROAI)

PROAI has aimed to contribute to the realization of better society by providing socioeconomic infrastructures.

Strategy:

Organize human resources and funds for the promotion of socio-economic infrastructures.

Priority Actions:

(i) Construct schools focusing on special skills education and ESG.

(ii) Construct health centers and improvement of existing medical facilities.

(iii) Construct educational centers for literacy and adult education.

(iv) Expand power distribution network.

(v) Research and develop alternative energies such as bio-diesel, solar and wind power generation.

(vi) Construct hydropower station at the River Lurior.

(b) Program for Upgrading Quality of Education

The program designed for increased quality of education will contribute to the creation of human resources which will contribute in the development of area socially, economically and culturally.

Strategy:

(i) Upgrade the quality of existing infrastructure and human resources in the field of education and apply the existing educational curriculum based on the area.

Priority Actions:

(i) Modernize technical schools in general (vocational school and secondary school).

(ii) Train teachers at all levels.

(iii) Introduce educational curricula matching the local conditions.

(iv) Promote functional curriculum for literacy education matching the need of local society.

(c) Improvement Program of Health Care and Social Support

This program shall be prepared to create the foundation that will allow people's access to quality health services.

Strategy:

(i) Reinforce the network of health and social services with the utilization of high quality human resources and the existing institutional setup and infrastructure to enable people's access to health and social services and reinforce the preventive medical care services.

Priority Actions:

(i) Reinforcement of preventive medical care and measures against major diseases and epidemics.

(ii) Reinforcement of linkage between modern health centers and traditional medical care services.

(d) Consistency of the Project with the National Plan and Provincial Policies

As stated in the Five-Year National Development Plan and the Nampula Provincial Development Strategy, the provision of power generating facilities to primary schools and health centers by utilizing renewable energy is expected to contribute to the promotion of increased quality of primary education, increase of literacy rate with the improvement of adult education, promotion of economic development by means of reinforcement of rural community, etc., and reinforcement of preventive medical care and epidemics, ensuring safe delivery of children, etc., with the increased quality of health services. Therefore, it has been confirmed that the Project is consistent with the policies set out at both national and provincial levels.

2.3.2 National Power and Electrification Policy

In line with the policy directions set out in PARPA-II (Plan for Reduction of Absolute Poverty II) mentioned above, the policies and following plans for energy and power sector development have been formulated (see details in Appendices 9 and 10):

- National Energy Sector Development and Access Program (NEDAP)

- National Bio-Fuel Strategy

(1) National Energy Sector Development and Access Program (NEDAP)

NEDAP was the policy formulated by the Government of Mozambique aiming at the promotion of electrification at urban areas and for obtaining support from various donors. This policy was the basis for the implementation of both the Energy Reform and Access Program (ERAP) that was formulated under the technical assistance program of the World Bank in the period 2003–2007 (Total Project Cost: USD81.5 million) and the Energy Development and Access Project (EDAP) that was implemented in the period 2008–2011 (Total Project Cost: USD85.0 million). As such the project has been implemented two times continuously for over 10 years. Almost 50% of the project cost was financed by the loan provided by the World Bank. The electrification projects are as outlined below.

(a) On-Grid Electrification (USD41.0 million under ERAP and USD25.0 million under EDAP)

The execution agency of these projects was EDM. Around 500 km long MV transmission lines, 1,100 km of LV transmission lines, and 20 power distribution facilities were to be provided at 265 sites throughout the country, and around 40,000 facilities have been connected.

(b) Independent Mini-Grid Electrification Project (USD15.0 million under ERAP and USD10.0 million under EDAP)

This project was designed to promote the mini-grid electrification by the private sector based on the demonstration project undertaken by the government.

(c) Independent Power Generation Project based on Utilization of Renewable Energy (USD3.0 million under ERAP, and USD33.0 million under EDAP)

FUNAE was the implementation agency for this project which was designed to promote electrification in the rural areas with the introduction of photovoltaic power generation units. The target facilities to be electrified in such a way were 150 elementary schools and 150 health centers (300 units). The target number of the subject sites under EDAP was 500 in total.

The core component of EDAP was the installation of photovoltaic power generation systems to electrify 100 schools and 100 health centers. Thus, it was called the "100 Schools 100 Health Centers Project." On the other hand, the rural electrification project which utilizes renewable energy to electrify administration posts, as well as educational and health facilities, was exclusively managed by FUNAE (see details in Appendix A1, Chapter 5).

The major targets of EDAP were to promote electrification in and around the urban and rural areas with particular attention to the use of renewable energy in rural areas as well as reinforcing the capacity of the Ministry of Energy, EDM and FUNAE.

(a) General Idea of Project Implementation of Electrification

The EDM that undertakes the extension of power distribution lines limits its work to the urban perimeters where means of access including roads are available, and targets the provision of MV power transmission lines of less than 0.8 km and LV power transmission lines of less than 0.5 km from the existing power trunk lines. The target of the power distribution project under EDAP was to connect around 9,500 households and facilities by providing MV power distribution lines of 95 km in total and LV power distribution lines of 10 km in total.

(b) Rural Electrification

NEDAP gives the highest development priority for rural electrification on the utilization of renewable energy because of its abundant potential resources. FUNAE was appointed as the core implementing agency for this program. The major component of the rural electrification program is the provision of off-grid type small and medium size independent power systems using renewable energy such as photovoltaic power system and its major objective is to improve the access to power by rural administrative organizations such as elementary schools, health centers and hospitals. FUNAE is about to implement some village electrification projects with the use of large-scale PV systems in Niassa, a neighboring Province of Nampula, with the loan made available by the Korea Export and Import Bank.

(2) National Bio-Fuel Strategy (2009)

The rural electrification project implemented since 2000 with financial assistance from the World Bank was formulated based on the Energy Reform and Access Program (ERAP), which was prepared with technical assistance from the World Bank as well. The core of this rural electrification program was village electrification with the use of diesel engine power generator (DG).

The implementation agency of this rural electrification program was FUNAE. Table 2.3.1 shows the number of village electrification projects undertaken. The type of electrification is the mini-grid and the power source is the DG with the average output of 80kVA. However, the operation of most of these projects has been suspended or abandoned. The major reason for this suspension is that nobody could afford to pay the power bills that have escalated due to increased price of petroleum products.

Table 2.3.1 Village Electrification Projects Undertaken by FUNAE (Diesel Power Generator)

Year	Project	Beneficiary	Design Installation Capacity	No. of Beneficiaries per Project	Average Installation Capacity
	No.	Person	kW	Person	kW
2001	4	19,845	63.8	4,961	16.0
2002	0	0	0.0	0	
2003	1	1,325	400.0	1,325	400.0
2004	0	0	0.0	0	
2005	5	25,017	308.0	5,003	61.6
2006	7	25,371	256.0	3,624	36.6
2007	4	9,018	156.8	2,255	39.2
2008	13	251,818	1,333.6	19,371	102.6
2009	19	90,663	1,844.0	4,772	97.1
2010	10	91,448	1,026.4	9,145	102.6
Total	63	514,505	5,388.6	8,167	85.5

Source: JICA Study Team based on information collected from FUNAE

Full village electrification would possibly be realized if the fuel is switched from petroleum to bio-fuel. In line with the National Bio-Fuel Strategy, the use of Jatropha bio-diesel as fuel for the diesel generators (DG) can be considered if the projects are found to be viable.

The National Bio-Fuel Strategy emphasizes the use of Jatropha which is considered as an important energy source since the natural environment of Mozambique is appropriate for the growth of Jatropha. The combination of photovoltaic power system and the diesel power generator of which fuel is the Jatropha based bio-fuel should be given appropriate consideration.

2.3.3 Renewable Energy Utilization Policy

Table 2.3.2 shows the records of FUNAE on the electrification of primary schools and health centers which commenced in 2005 and planned to be implemented up to 2015. As stated in this table, the total number of schools and health centers to be supplied with electricity by the installation of PV systems up to 2015 would be 1,656, or six times larger than the present number of 300 projects. As shown in Table 2.3.2, the number of projects up to 2015 in the provinces of Cabo Delgado, Niassa, and Nampula will be 353, 386 and 100, respectively.

Table 2.3.2 Off-Grid Electrification Projects Undertaken by FUNAE

Off-grid Electrification Project of FUNAE

	Total	Northern Region			Central Region				Southern Region			Implementation Period	
		Cabo Delgado	Niassa	Nampula	Tete	Zambezia	Manica	Sofala	Inhambane	Gaza	Maputo	From	To
Installed Unit													
School	150	8	8	50	8	50	5	6	6	6	3		
World Bank-ERAP	150	8	8	50	8	50	5	6	6	6	3	2005	2011
Health Center	150	3	28	50	18	50	0	1	0	0	0		
World Bank-ERAP	150	3	28	50	18	50		1				2005	2011
Total	300	11	36	100	26	100	5	7	6	6	3		
On-going and Planned													
School	745	175	175	0	100	90	75	80	50	0	0		
World Bank-EDAP	250	75	75				50		50			2012	2014
World Bank-New	300	100	100		100							2013	2015
Belgium	195					90	25	80				2012	2014
Health Center	721	167	175	0	100	59	50	70	50	50	0		
World Bank-ERAP	100							50		50		2005	2011
World Bank-EDAP	242	67	75				50		50			2012	2014
World Bank-New	300	100	100		100								
Belgium	79					59		20					
Total	1,466	342	350	0	200	149	125	150	100	50	0		
Total Up To 2015													
School	895	183	183	50	108	140	80	86	56	6	3		
World Bank	700	183	183	50	108	50	55	6	56	6	3		
Belgium	195					90	25	80					
Health Center	871	170	203	50	118	109	50	71	50	50	0		
World Bank	792	170	203	50	118	50	50	51	50	50	0		
Belgium	79					59		20					
Sub-total	1,766	353	386	100	226	249	130	157	106	56	3		
Administration Post	77	0	0	0	0	38	10	29	0	0	0		
Belgium	77					38	10	29					
Sub-total	77	0	0	0	0	38	10	29	0	0	0		
Grand Total	1,843	353	386	100	226	287	140	186	106	56	3		

Village Electrification

	Total	Northern Region			Central Region				Southern Region			Implementation Period	
		Cabo Delgado	Niassa	Nampula	Tete	Zambezia	Manica	Sofala	Inhambane	Gaza	Maputo	From	To
Executed Project													
Project	75	1	1	6	1	0	0	5	31	21	9	2008	2011
Mozambique Governmnt	75	1	1	6	1			5	31	21	9		
On-going Project													
Project	84	11	17	6	5	14	6	4	15	5	1	2011	2014
World Bank-EDAP	30	10	10						10				
EU	4	1	1	2									
Portgal	50		6	4	5	14	6	4	5	5	1		
Total Up to 2014													
Project	159	12	18	12	6	14	6	9	46	26	10		
World Bank	30	10	10	0	0	0	0	0	10	0	0		
Mozambique Governmnt	75	1	1	6	1	0	0	5	31	21	9		
EU	4	1	1	2	0	0	0	0	0	0	0		
Portgal	50	0	6	4	5	14	6	4	5	5	1		

Note:
1 Mini-grid PV system in Niyassa. 550kW at Mavojo, 400kW at Muemba, 350kW at Meula.
Total Project Cost is estimated at US$41 million of which US$36 million is the project loan provided by the Korean Exim Bank. Tendering in 2012.

Most of the electrification projects for schools and health centers managed by FUNAE, mostly PV systems utilizing renewable energy, have been or are being implemented with financial and technical assistance from the World Bank and the Government of Belgium. In addition, there is an ongoing off-grid rural electrification project in Niassa Province to the northwest of Nampula Province which aims to install mega-solar systems in Mapojo (550kW), Memuke (400kW), and Meula (350kW) using a project loan from the Korea Export and Import Bank. Contracting the needed services is already under preparation.

The implementation of these projects is considered as a clear sign that the government gives high priority to off-grid electrification utilizing renewable energy. Based on the discussions in the preceding sections, the Project complies with the national energy and power policies because it envisages the electrification of schools and health centers by utilizing renewable energy as executed under EDAP.

As described in the preceding section, the distance of extending the power distribution lines from the existing power distribution trunk line for on-grid electrification under the EDAP program is limited to 0.8km for MV power distribution line and 0.5km for LV power distribution line. Since most of the elementary schools and health centers are quite far from the power distribution trunk lines, the electrification of elementary schools and health centers may be realized, but in the far future.

Therefore, the off-gird electrification of elementary schools and health centers will still continue in the future.

2.3.4 Consistency of the Project with the National and Provincial Government Policies

As discussed in the preceding sections, the National Five-Year Plan, PARPA and the Nampula Province Development Strategy emphasize the electrification based on the utilization of renewable energy especially for the electrification of elementary schools and health centers aiming at pushing the social and economic development by improving the quality of education in primary schools, increasing the level of literacy with the improvement of adult education, reinforcing community organizations, etc., in elementary schools, as well as increasing the level of health care and disease prevention, reinforcing measures against epidemics, safe delivery, etc., in the health centers.

Furthermore, the NEDAP and power access plans stress that rural electrification is to be promoted based on the use of renewable energy. In addition to these policies, the target of on-grid electrification is limited to the provincial administration centers and with the limitation of distance for the extension of power distribution lines from the trunk lines, the electrification of most of elementary schools and rural health centers may not be realized by means of on-grid electrification. Under such a situation, it has been confirmed that the Project envisaging the electrification of elementary schools and rural health centers by independent power generating systems operated with renewable energy is quite consistent with the policies set out at the respective level of administration such as the national government and the provincial government.

2.3.5 Relationship between On-Grid and Off-Grid Electrification Programs

(1) Present Situation of On-Grid Electrification in Nampula Province

Under the planning stage is the capacity expansion of the existing power transmission line constructed in the 1980’s along the length of the Nacala Corridor. The transmission line traverses the central part of Nampula Province from east to west and links the Cahora Bassa Hydropower Plant to the Nacala Port, the most important commercial port in the northern region. The purpose of this transmission line is to supply sufficient power to the Nacala Port and the surrounding industrial area which is considered as a growth pole in the country’s northern economic region.

It is expected that large-scale agricultural development will take place in the areas along and in the middle of this grid and such areas will become large power demand generators. However, unless economic development along the Nacala Corridor is realized, the incomes of population residing along this corridor in the western and central areas of Nampula Province will not increase. It is, therefore, assumed that the time when they will benefit from the on-grid electrification is still far beyond expectation.

(2) On-Grid Electrification Plan in Nampula Province

The plan of on-grid electrification in Mozambique is to extend the grid to all 128 district headquarters (DH) by 2014 and to the Administrative Post (AP) which is the administrative center at the district level. Then the program is planned to be expanded to power users at the community level as the final target after 2015 throughout the country in a step-wise program. The on-grid electrification to 97 DHs in 2010 and 107 DHs by 2012 has been completed. However, as of 2012, the on-grid electrification is still limited to the urban area and the perimeter of urban area where the population density is high, and the facilities of the DH and its surrounding households or commercial facilities. The schedule of the on-grid electrification plan at the community level as the final step of on-grid electrification in Nampula Province has not been prepared yet.

It is predicted that the short-term schedule of community level on-grid electrification at the project target area will continue to be unclear until the result of long-term economic development project appear. Under such unstable and unclear circumstances of the on-grid electrification project, off-grid electrification which utilizes renewable energy (installation of solar power system, etc.), and which can be implemented in the short term for elementary schools and health centers, is considered as compliant with the national policy.

In view of human resource development that would form a foundation of economic development along the Nacala Corridor in Nacala Province which is the center of both the Nacala Corridor and the Northern Region, the off-grid electrification for primary schools and health centers is judged to be realized, at least, to the same level of such plan being implemented for the other two provinces composing the Northern Region.

2.4 Outline of Education and Health Sectors at the National and Provincial Levels

2.4.1 Education Sector

(1) General

For over 500 years until 1975, Mozambique was a colony of Portugal. The education system of 1983 has been the first system established by the Mozambicans since the beginning of history of Mozambique. The development of the education sector has always been the priority area of the government.

During the colonial period, most Mozambicans did not have a chance to receive formal education except those in rural areas where missionaries set up schools. Even after the achievement of independence as the civil war continued for 17 years, again the Mozambicans lost the chance to receive formal education. This means that adults of over 30 have not received basic education, especially, in the rural areas.

The Government of Mozambique has made a great effort to build primary schools as the priority development issue. The total number of educational facilities throughout the country was around 9,670 units (most of them are primary school having 2 or 3 class rooms) in 2004 and reached to around 20,000 units in 2010. Nevertheless, the number of classrooms has not met the number of students demanding education, so that most of the classrooms are used for two shifts in rural areas, or three shifts especially in urban and peri-urban areas.

In some of the areas observed through the field survey and according to reports, the number of teachers does not match with the number of students. Observed were several cases where one teacher conducts two classes at the same time. Teachers of primary schools are not limited to residents of villages but often deployed from the urban areas. Therefore, the provision of staff-houses for teachers is necessary for most of the primary schools in the rural areas. As such it has been confirmed that the power needs of primary schools and health centers should include such needs associated with the provision of staff-houses for teachers, doctors, nurses, and the like.

(2) Comparison of Basic Indicator of Education Sectors between National and Nampula Province

Table 2.4.1 shows the basic indicators of the education sectors nationwide, Nampula Province and Maputo City (illiteracy, enrolment ratio, etc.)

Table 2.4.1 Basic Indicators of Education Sector Nationwide and in Nampula Province

Change of Basic Indicators of Education Sector

Area	Muzambique as a Whole				Nampula Province				Maputo City			
Year	1997	2007	2011	CAGR(%)	1997	2007	2011	CAGR(%)	1997	2007	2011	CAGR(%)
Total Population	16.7	20.6	23.1	2.19%	3.1	4.1	4.5	2.52%	1.0	1.1	1.2	1.28%
Share of Male	47.9	48.1	48.2	0.0%	47.9	49.3	49.4	0.2%	49.0	48.7	48.3	-0.1%
Share of Female	52.1	51.9	51.8	0.0%	52.1	50.7	50.6	-0.2%	51.0	51.3	51.7	0.1%
Share of Age 1 - 14	44.5	48.9	45.3	0.1%	44.6	47.9	44.5	0.0%	40.5	38.1	34.8	-1.0%
Share of Age 15-59	50.9	46.6	50.1	-0.1%	51.3	48.0	51.0	0.0%	56.5	60.3	61.2	0.5%
Shrea of Age Above 60	4.6	4.6	4.7	0.1%	4.1	4.1	4.5	0.6%	3.0	3.6	4.1	2.1%
Share of Urban Population in	29.2	30.4	31.0	0.4%	25.0	28.6	30.2	1.3%	100.0	100.0	100.0	0.0%
Shrea of Rural Population	70.8	69.6	69.0	-0.2%	75.0	71.4	69.6	-0.5%	0.0	0.0	0.0	0.0%
Illiterary Rate	60.5	50.3		-1.7%	71.7	62.3		-1.3%	15.0	9.8		-3.8%
Illiterary Rate (Male, %)	44.6	34.5		-2.3%	56.7	46.5		-1.8%	7.1	4.4		-4.3%
Illiteracy Rate (Female %)	74.1	64.1		-1.3%	85.9	77.4		-0.9%	22.6	14.8		-3.8%
Total Attendance												
Primary School Grade-1	66.8	107.3		4.4%	47.5	91.9		6.2%	132.8	131.5		-0.1%
Primary School Grade-2		80.1				81.1				148.5		
Secondary School Grad	6.9	41.6		17.7%	3.9	27.4		19.4%	25.6	114.0		14.1%
Secondary School Grade-2		18.2				12.5				58.4		
Higher Education	0.3	2.3		20.3%	0.0	1.1			3.4	14.2		13.9%
Electrification Ratio	6.0	10.0		6.5%	3.0	6.0		4.2%	38.1	63.0		4.7%

a. The number of total population is adjusted taking into consideration of [illegible]

Source: JICA Study Team based on statistical data obtained from Provincial Government of Nampula

As shown in this table, the average illiteracy rate nationwide in 2007 is 50.3% while that of Nampula Province is 62.3%. The average annual change of illiteracy rate in Nampula Province is thus less than 1.3% in the past 15 years. The rate has certainly decreased, but the annual rate of change is lower than that of the national average as well. Since the illiteracy rate in Maputo City is 9.8%, the same rate for the rural areas is considered as extremely high. The attendance rate in Nampula Province is lower than the national average as well. These indicators suggest that substantial effort has to be made to increase the quality of education in Nampula Province.

(3) Necessity of Night Classes

The PARPA which is the key national strategy states that literacy and basic education for adults are the most important development goals in the educational development program. Most of such literacy education (called Alphabetization) to the adults is conducted in most cases by utilizing the rooms of primary schools during the evening hours (17:30H–22:00H).

It has been confirmed through the field survey that the demand for literacy and basic education for adults is quite high. In primary or secondary schools in the rural areas that have not been electrified, night classes cannot be held because there is no light available, so that a number of adults participate in the normal classes for elementary pupils which causes the congestion of classrooms. It is, therefore, presumed that if there is proper lighting in classrooms, the number of adults in night classes would surely increase.

(4) Necessity of Audio-Visual Education

The provision of television and DVD sets is incorporated into the purchasing plan of solar power generation system designed to be installed in primary schools and health centers under the Belgium Government's finance. Since not only the primary schools in Nampula Province but all such schools in rural areas are located very far from the district center or trunk road at dozens of kilometers, and the number of teachers is also limited, it has been recognized that distance education is very much needed to increase the quality of education in such areas.

Under such circumstances, the audio-visual education using television sets has been considered as one of the effective tools to increase the learning effect and the quality of education especially in primary schools, particularly, when the number of teachers is not sufficient. Since the use of television and DVD to conduct the audio-visual education and distance education is considered as a possible tool to increase the quality of education, the power demand of such equipment is likewise considered as an important need.

It has been recognized that the introduction of proper TV education program is effective on learning especially in developing countries where the number of teachers is not sufficient and educational facilities are scattered in remote rural areas. The electrification of schools is thought to be necessary to increase the effect of learning with the introduction of TV education programs in the ordinary curriculum.

However, a set of proper learning materials (TV programs) has to be prepared and such programs can be copied to compact discs (CDs) for distribution to schools. It will then become possible for students to receive the benefit of audio-visual education with the proper guidance of their teachers. The most proper learning material can be produced locally by the Mozambicans themselves; however, the audio-visual education materials prepared in the national language, Portuguese, may be available only with the assistance of an international education institution such as UNESCO or the Government of Brazil and/or the Government of Portugal, under a bilateral technical cooperation program. It may also be possible to obtain such technical assistance from the Government of Japan.

The improvement of quality of teachers in itself is indispensable to develop the education sector and upgrade the quality of education. The Government of Mozambique regards the fostering of teachers as one of the most important development issues in the education sector. It has been making efforts to accelerate the construction of elementary schools, provide free education, increase the budget for education, etc. In order to address this important issue, the Government of Mozambique has been trying to rectify the situation by improving the teachers' training program, increasing the budget for the salary of teachers, providing long distance education for non-licensed teachers, etc. Under such a situation, it is important to make use of the TV and DVD available for the distance education of teachers in remote rural areas throughout the country.

Such efforts have resulted in the increase of enrolment in elementary schools to around five million in 2009 from two million in 1998 at the average annual growth rate of 9.5%. The number of teachers has likewise increased to 73,384 in 2009 from 34,869 in 1998 at the average annual growth rate of 7.7%. Therefore, the ratio of one teacher to pupils has reduced from 57:1 in 1998 to 68:1 in 2009.

2.4.2 Health Sector

(1) General

Despite having one of the world's highest economic growth rates, i.e., the average annual growth rate has been 8% for more than 15 years, nearly 70% of Mozambique's population lives in extreme poverty, and access to health and education services is limited. The United Nation's Human Development Index (2010) had ranked Mozambique as 165th out of 169 countries in terms of human development.

Much of the health infrastructure was destroyed during the long civil war and less than 50% of the population currently lives within 5 km of fixed health services. The country also has a severe shortage of trained professionals, particularly, in the health sector. The majority of health sector expenditures are financed by external sources. The national HIV prevalence rate is 13.6% (2007), placing Mozambique among the 10 most affected countries.

In children under 5 years of age, the major causes of morbidity and mortality are malaria, diarrheal disease, acute respiratory diseases and malnutrition. The next greatest killers of children are measles (due to degradation in immunization services) and AIDS. In adults, although malaria is still an important cause of morbidity, the major causes of mortality are tuberculoses and AIDS. The total fertility rate of 5.5 births per woman is not as high as some African countries and has been gradually decreasing in the past 15 years.

Prenatal and safe delivery services are poor and maternal mortality is a crisis, estimated at 408 maternal deaths per 100,000 live births. Progress in establishing a rural primary health care network and management system is limited by various factors, including high rates of infectious disease and malnutrition; growing prevalence of HIV/AIDS; inadequate access to potable water; limited number of trained health personnel; and decreasing funds for basic health care delivery annually. The services for child survival and disease assistance is increasing immunization coverage and preventing and treating major vaccine preventable diseases. One of the reasons of increased immunization is because of increased number of refrigerators that are operated by either electricity or gas to store vaccines. Overall, however, the health status of the Mozambican population is lower than average for African countries and far below international standards.

Table 2.4.2 shows the basic indicators of the health sector nationwide, Nampula Province and Maputo City. As this table shows, the average life expectation in Nampula Province has increased at 2.1% annually in the past 15 years. A decrease of mortality rate at minus 3.4% annually may attribute to such an increase. However, the average ratio of natal death is 1.14 times higher than the national average and it is 1.6 times higher than the average in Maputo City where the health facilities and services are comparatively well provided. These indicate that the expansion of relevant facilities and improvement of service quality are much needed. This improvement surely includes electrification improvement.

Table 2.4.2 Change and Comparison of Basic Indicator of Health Sector Nationwide and in Nampula Province (1997-2011)

Change of Basic Indicators of National and Nampula Province (Health Sector)

Area	Mozambique as a Whole				Nampula Province				Maputo City			
Year	1997	2007	2011	CAGR(%)	1997	2007	2011	CAGR(%)	1997	2007	2011	CAGR(%)
Total Population (million)	18.7	20.6	23.1	2.19%	3.1	4.1	4.5	2.52%	1.0	1.1	1.2	1.29%
Share of Age 1 - 14	44.5	46.9	45.3	0.1%	44.0	47.0	44.5	0.0%	40.6	38.1	34.8	-1.0%
Share of Age 15 - 59	50.9	48.6	50.1	0.1%	51.3	48.0	51.0	0.0%	56.5	60.3	61.2	0.5%
Share of Age More than 60	4.6	4.6	4.7	0.1%	4.1	4.1	4.5	0.6%	3.0	3.6	4.1	2.1%
Mortality Rate	143.0	93.6	86.2	-3.7%	154.0	90.2	91.0	-3.4%	78.7	61.8	55.8	-2.3%
Combined Special	5.9	5.7	5.6	-0.3%	7.0	6.8	5.6	-1.5%	4.2	3.0	2.7	-3.0%
Average Life Expectancy	42.3	50.9	52.4	1.4%	39.9	53.7	54.5	2.1%	58.3	56.2	57.5	-0.1%
Average Life Expectancy (Male)	40.6	48.6	50.4	1.5%	39.4	52.0	53.5	2.1%	55.1	53.2	54.3	-0.1%
Average Life Expectancy (Female)	44.0	52.9	54.4	1.4%	40.5	54.7	55.4	2.1%	61.8	59.1	60.6	-0.1%
Rate of Natal Death (in 100,000)		600.1				689.8				384.1		
Average Head per Household	4.1	4.4		0.6%	3.7	4.0		0.7%	5.3	4.9		-0.7%
Ratio of Electrification	5.0	16.0		6.5%	3.9	6.0		4.2%	38.1	63.8		4.7%
Ratio of Potable Water Facility												
In house	2.4	1.9		-2.1%	0.9	0.7		-2.3%	22.1	18.0		-2.0%
Out of house	9.1	8.2		2.7%	5.7	6.7		0.8%	26.9	39.1		3.5%
Spring	5.0	10.4		3.0%	4.7	8.6		6.7%	28.6	33.9		2.1%
Manual Wells	56.5	14.1		-13.2%	75.1	77.9		0.3%	23.9	3.8		-15.4%
Motor Driven Wells		46.9				55.7				5.6		
River, lake, pond	17.0	17.3		0.2%	13.4	19.8		3.6%		0.0		
Rainfall		0.6				0.0				0.0		
Others	1.2	0.8		-3.8%	0.1	0.2		6.5%	0.6	1.0		6.5%

Source: JICA Study Team based on statistical data obtained from Provincial Government of Nampula

(2) Health Facilities

Table 2.4.3 shows the total number of health facilities nationwide and in Nampula Province. Since the total population of Nampula Province accounts for around 20% of the total national population, it can be judged that the number of rural hospitals and health centers are provided in sufficient number. However, the share of health centers is only 14%. Thus, further expansion of the number of health centers is essentially required.

Table 2.4.3 **Number of Health Facilities Nationwide and in Nampula Province (2008)**

Case	Central and Provincial Hospital	Provincial Hospital	Health Center	Health Post	Sub-total of Health Center and Post	Grand Total
Nation as a whole	11	40	999	261	1,260	1,311
Nampula Province	1	8	136	55	191	200
Maputo Province	0	2	66	32	98	100
Maputo City	2	3	29	2	31	36
Nation as a whole	100%	100%	100%	100%	100%	100%
Nampula Province	9%	20%	14%	21%	15%	15%
Maputo Province	0%	5%	7%	12%	8%	8%
Maputo City	18%	8%	3%	1%	2%	3%

Source: Ministry of Health, National Planning and Cooperation Department

(3) Organization of the Ministry of Health

Figure 2.4.1 shows the organizational chart of the Ministry of Health. The Department of Maintenance under the Administration and Management Directorate is mandated to supervise the maintenance department of each provincial government.

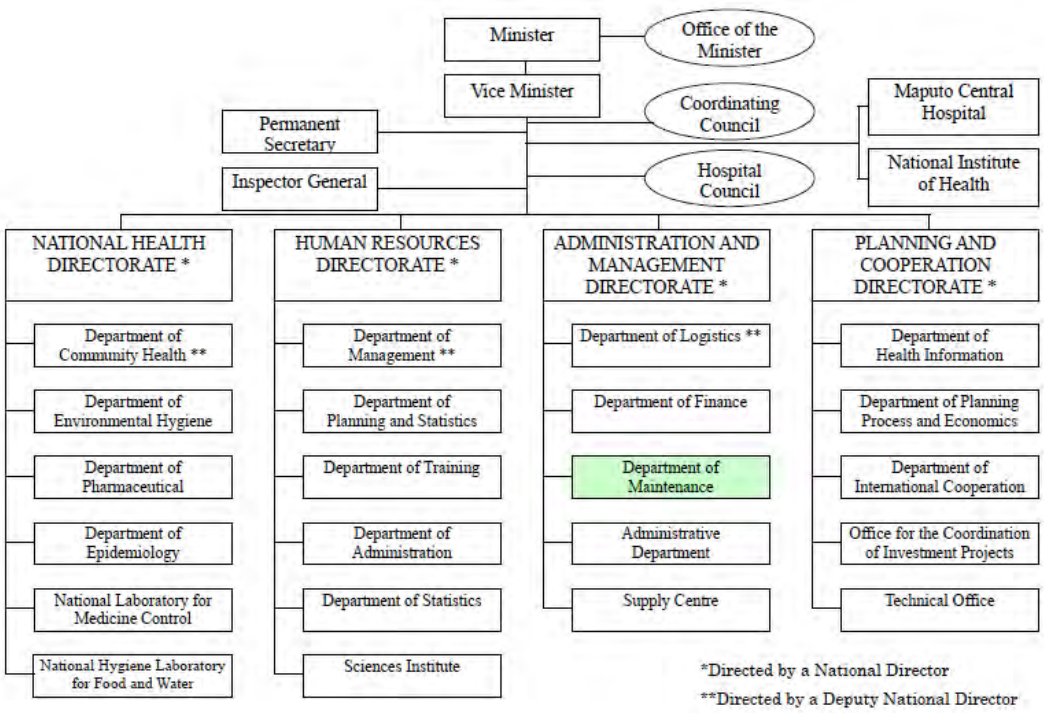


Figure 2.4.1 Organizational Chart of the Ministry of Health

2.5 Basic Information about Primary Schools and Health Centers

2.5.1 Educational Facilities in Nampula Province

The total number of schools in Nampula Province is 2,458, of which 114 are secondary schools. The number of students is around 930,000 for primary schools and around 50,000 for secondary schools. Table 2.5.1 shows the number of educational facilities and the number of students by type of facility.

Around 20% of the total number of schools conducts night classes and education for adults and the expansion of such classes are planned. The needs of basic education for adults are quite high; however, the lack of classrooms equipped with lighting systems hinders the realization of such expansion plan. It has been reported that a large number of adults participate in classes for children, causing the congestion of classrooms. It has also been confirmed that the provision of lighting system to conduct night classes are demanded strongly in the education sector in general and in rural areas in particular. The distribution of schools by district in Nampula Province is as shown in Table 2.5.2.

Table 2.5.1 Number of Educational Facilities and Students in Nampula Province (as of 2011 and planned for 2012)

Schools in Nampula

		Schools		Total Number of Students								
		2011	2012	2011			2012			Change (%)		
				Male	Female	Male and Female	Male	Female	Male and Female	Male	Female	Male and Female
General School Course		2,902	2,786	479,999	577,714	1,057,713	508,620	610,994	1,119,614	6.0%	5.8%	5.9%
Primary School 1st grade		1,846	1,962	376,580	427,466	804,146	392,963	445,827	838,790	4.3%	4.3%	4.3%
Primary School 2nd grade	Total	610	798	55,166	74,956	130,122	59,705	81,096	140,801	8.2%	8.2%	8.2%
	day shift	546	721	51,208	70,543	121,751	54,771	75,427	130,198	7.0%	6.9%	6.9%
	night shift	64	77	3,958	4,413	8,371	4,934	5,669	10,603	24.7%	28.5%	26.7%
Secondary School 1st grade	Total	108	110	37,594	56,669	94,263	43,386	63,297	106,683	15.4%	11.7%	13.2%
	day shift	71	73	28,286	43,329	71,615	32,216	49,571	81,787	13.9%	14.4%	14.2%
	night shift	37	37	9,308	13,340	22,648	11,170	13,726	24,896	20.0%	2.9%	9.9%
Secondary School 2nd grade	Total	60	60	10,559	18,623	29,182	12,566	20,774	33,340	19.0%	11.6%	14.2%
	day shift	32	32	5,691	10,529	16,220	6,608	12,244	18,852	16.1%	16.3%	16.2%
	night shift	28	28	4,868	8,094	12,962	5,958	8,530	14,488	22.4%	5.4%	11.8%
Teachers Training				263	710	973	449	529	978	70.7%	-25.5%	0.5%
IFP 7th grade +1				0	0	0	0	0	0	0.0%	0.0%	0.0%
IFP 10th grade +2	Total	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%
	day shift	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%
	night shift	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%
	Total	2	2	263	419	682	313	369	682	19.0%	-11.9%	0.0%
	day shift	2	2	263	419	682	313	369	682	19.0%	-11.9%	0.0%
	night shift	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%
ADPP		2	2	0	296	296	136	160	296	0.0%	-45.9%	0.0%
Technical Learning				764	2,058	2,822	988	2,253	3,241	29.3%	9.5%	14.8%
Elementary		0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%
Basic	Total	5	6	550	1,288	1,838	696	1,410	2,106	25.5%	9.5%	14.6%
	day shift	4	5	496	1,019	1,515	639	1,141	1,780	28.8%	12.0%	17.5%
	night shift	1	1	54	269	323	57	269	326	5.6%	0.0%	0.9%
Medium	Total	3	3	214	770	984	292	843	1,135	36.4%	9.5%	15.3%
	day shift	2	2	142	566	708	214	626	840	50.7%	10.6%	18.6%
	night shift	1	1	72	204	276	78	217	295	8.3%	6.4%	6.9%
Literate Education for Adults				63,813	32,643	96,456	92,841	62,297	155,138	45.5%	90.8%	60.8%
1st / 2nd		138	369	49,524	21,849	71,373	70,782	44,345	115,127	42.9%	103.0%	61.3%
3rd				14,289	10,794	25,083	22,059	17,952	40,011	54.4%	66.3%	59.5%
Education for Professionals		1	1	24	36	60	0	60	60	0.0%	66.7%	66.7%
Basic		1	1	24	36	60	0	60	60	0.0%	66.7%	66.7%
Medium		0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%

Source: JICA Study Team prepared based on the statistical data obtained from the Provincial Government of Nampula

Table 2.5.2 Number of Schools by District (Nampula Province)

Nampula Province - Primary and Secondary Schools by District (2011)

	District	Primary School 1st Grade	Primary School 2nd Grade			Total Primary Schools	Secondary School 1st Grade	Secondary School 2nd Grade	Total Secondary School	Total Schools
			Day	Night	Subtotal	Primary Total				
	Total in Province	1,846	546	66	612	2,458	73	41	114	2,572
	NDC Influence Areas	1,185	364	51	415	1,600	52	30	82	1,682
1	Nacala Port City	37	28	12	40	77	4	2	6	83
2	Nacala Velha	56	14	1	15	71	2	1	3	74
3	Memba	122	29	1	30	152	4	1	5	157
4	Mossuril	78	26	0	26	104	2	2	4	108
5	Ilha de Moçambique	14	7	4	11	25	2	2	4	29
6	Monapo	123	28	5	33	156	3	1	4	160
7	Muecate	76	19	1	20	96	2	1	3	99
8	Meconta	90	35	3	38	128	3	2	5	133
9	Nampula City	46	39	17	56	102	12	10	22	124
10	Nampula Rapale	115	35	1	36	151	3	2	5	156
11	Mecuburi	100	17	0	17	117	3	1	4	121
12	Muriupula	114	28	1	29	143	3	1	4	147
13	Ribaue	108	25	4	29	137	4	2	6	143
14	Malema	106	34	1	35	141	5	2	7	148
	Area Out of Influence Area	661	182	15	197	858	18	11	32	43
15	Erati-Namapa	128	26	4	30	158	2	1	1	159
16	Nacarroa	63	18	0	18	81	0	0	4	85
17	Lalaua	56	23	0	23	79	2	0	2	81
18	Mogovolas	130	30	3	33	163	3	3	6	169
19	Moginqual	80	15	1	16	96	3	1	4	100
20	Angoche	89	40	2	42	131	4	3	7	138
21	Moma	115	30	5	35	150	4	3	8	158

Source: JICA Study Team based on the data obtained from Health Department of Nampula Provincial Government

2.5.2 Health Facilities in Nampula Province

The total number of health centers in Nampula Province is 209. Table 2.5.3 shows the number of health centers and patients in Nampula Province. The total number of health centers that are electrified is 122 so that the rate of electrification is 58%. Most of the power sources of these facilities are of the solar power system and around 50 locations have been electrified by FUNAE. The total number of districts located within the direct influence area of the Nacala Corridor is 11 and the total number of health centers in such districts is 142. Out of the total number of health centers, 82 or 57.8% have been electrified and 60 or 42.2% have not been electrified. Thirty (30) sites among these 60 non-electrified sites have been studied through the field survey conducted in this study.

Table 2.5.3 Health Centers by District in Nampula Province

Nampula Province - Rural Health Center by District (2011)

	District	HC with Power	HC without Power	Total HC	Coverage of Power	HC with Water	HC without Water	Total HC	Coverage of Water
	Total in Province	**122**	**87**	**209**	**58%**	**100**	**109**	**209**	**48%**
	NDC Influence Areas	**82**	**60**	**142**	**58%**	**65**	**77**	**142**	**46%**
1	Nacala Port City	10	2	12	83%	7	5	12	58%
2	Nacala Velha	5	1	6	83%	2	4	6	33%
3	Memba	1	12	13	8%	3	10	13	23%
4	Mossuril	5	4	9	56%	4	5	9	44%
5	Ilha de Mozambique	4	1	5	80%	3	2	5	60%
6	Monapo	7	8	15	47%	5	10	15	33%
7	Muecate	4	5	9	44%	5	4	9	56%
8	Meconta	6	1	7	86%	4	3	7	67%
9	Nampula City	15	0	15	100%	12	3	15	80%
10	Nampula Rapale	5	10	15	33%	4	11	15	27%
11	Mecuburi	9	4	13	69%	4	9	13	31%
12	Murrupula	2	4	6	33%	3	3	6	50%
13	Ribaue	5	4	9	56%	5	4	9	56%
14	Malema	4	4	8	50%	4	4	8	50%
	Area Out of Influence Area	**40**	**27**	**67**	**60%**	**35**	**32**	**67**	**52%**
15	Erati-Namapa	5	4	9	56%	8	1	9	89%
16	Nacaroa	4	2	6	67%	2	4	6	33%
17	Lalaua	3	2	5	60%	3	2	5	60%
18	Mogovolas	6	1	7	86%	1	6	7	14%
19	Moginqual	4	4	8	50%	4	4	8	50%
20	Angoche	6	11	17	35%	10	7	17	59%
21	Moma	12	3	15	80%	7	8	15	47%

Source: DPS/DPPC/SIS

Legend:

HC means Health Center

Source: JICA Study Team based on the data obtained from Health Department, Nampula Provincial Government

One of the important roles of health centers is immunization against diseases. Since the vaccines needed for immunization must be stored in refrigerators, the provision of power source for refrigerators is indispensable for the proper operation of health centers. It has been confirmed that power is needed for the operation of vaccine refrigerators. In addition, the lighting system for delivery and emergency operations is also indispensable during nighttime.

It is possible to run a refrigerator without electricity but by gas. However, one gas cylinder will last for a maximum of only 7 days, so that frequent purchase of gas cylinders is needed. Such gas cylinders are available only in Nampula City and transportation cost is so high that health centers cannot afford to purchase them continuously. Besides, such operation is quite inconvenient.

The number of health centers equipped with water supply system that includes groundwater well is 100 and accounts for 48% of the total health centers.

2.5.3 Number of Primary Schools and Health Centers by District in Nampula Province

Figure 2.5.1 presents the number of primary schools and health centers in Nampula Province by district.

Primary Schools (2,456 sites)	Health Centers (209 sites)

Figure 2.5.1 Number of Primary Schools and Health Centers by District in Nampula Province

Source: JICA Study Team

The red line across Nampula Province from east to west is the alignment of the Nacala Transport Corridor, which is considered as the core infrastructure along the Nacala Development Corridor comprised of port, roads and railway. The road rehabilitation and expansion project along the Nacala Corridor is underway. The number of districts in this corridor's direct influence area is 11.

The total number of primary schools located within these 11 districts is 1,600 (or 1,682 including secondary schools) and the number of health centers is 142. If by geographical division, the number of primary schools and health centers in the coastal area is 567 and 65, respectively. The figures for the inland area are 1,033 and 77, respectively.

2.5.4 Rationale of Electrification for Primary Schools and Health Centers in Nampula Province

Around 80% of the total population of Nampula comprises subsistence rural farmers who live below the poverty line; however, as they are to be the foundation of economic development, the Government has exerted great effort to improve the livelihood of rural populations. The most important actions that will drive such an important issue are better primary education, increased adult literacy, training of teachers, improved health services (i.e., expansion of preventive care such as the supply of vaccines and promotion of births in health centers, etc.).

To carry out such actions, the most important infrastructure is the power supply facilities. On-gird electrification is only available to administrative facilities, as well as commercial and industrial enterprises that can pay electric bills, so that households are not covered yet. This will be the situation until such time that households receiving the fruits of rural economic development can afford to pay electric bills. Even though primary schools and health centers are public facilities, the local government still cannot allocate funds to pay the electric bills because of substantially limited budgets.

Under such a situation, the provision of PV systems or PV+Wind hybrid systems, of which the energy source is nature (sunlight and wind), to primary schools and health centers is believed to contribute in upgrading livelihoods in the rural areas.

2.6 Relationship between the Project and the Nacala Development Corridor Project

2.6.1 Profile of the Nacala Development Corridor

The governments of Mozambique, Malawi and Zambia, together with the private sector, have identified the Nacala Development Corridor (NDC) as a regional priority. The area covered by the NDC includes Nacala Port, the area bordering the Nacala railway lines to Entre Lagos and Cuamba–Lichinga railway lines, and Lake Niassa. There are 10.7 million inhabitants along the corridor and the 3.3 million on the Mozambican side represents around 61.5% of the total population of Nampula, Niassa and the northern part of Zambezia province. A Joint Ministerial Committee made up of public and private sector representatives has been created to drive infrastructure development to facilitate resource sector activities in the area, as shown in Figure 2.6.1.

The needed transport infrastructure supporting the Nacala Development Corridor comprises 1,033 km of road works; two one-stop border posts, one between Mozambique and Malawi, and the other between Malawi and Zambia; railway rehabilitation (780 km); railway construction (120 km); port development composed of the improvement of the existing port and the development of another (potentially 20 million metric tons per annum); industrial development in the hinterland of the new port including special economic zones (SEZs), and associated infrastructure. Figure 2.6.2 illustrates the conceptual development plan of the Nacala Port.

Within the territory of Mozambique, several large-scale mining projects have been under study, exploration, or implementation such as Memba (iron ore), Lalaula (iron ore), Moma (titanium, limonite, retile), Lichinga (coal), and Moatize (coal) projects. The Moatize Coal Mine located in Tete Province is being developed by the giant Brazilian mining company Rio Dose. The planned coal output is 15 million tons, 9 million tons of which are to be supplied to a coal-fired thermal power plant (1,500 MW) and the rests are to be exported.

Figure 2.6.1 Nacala Corridor Infrastructure Development Activity Map

Figure 2.6.2 New Nacala Port Development Project

Source: Globe Metal and Mining, January 5, 2012 ASX Media Announcement

In addition to these mining projects, large-scale agriculture development along the NDC is being studied to produce several kinds of grains, such as corn, maize, and soybeans, in big volumes. Therefore, a considerably large-scale bulk cargo handling berth should be provided at the New Nacala Port.

Due to the size of the NDC project, the roadwork has been phased, as follows:

Phase I: Upgrading of the Nampula–Cuamba Road (348 km) in Mozambique and the Lilongwe Bypass (13 km) in Malawi.

Phase II: Road rehabilitation of the Luangwa–Chipata–Mwami border (360 km) in Zambia.

Phase III: Road upgrading of the Cuamba–Mandimba Road (160 km) in Mozambique; rehabilitation of the Mangochi–Liwonde Road (70 km) and the Liwonde–Nsipe Road (82 km) in Malawi; and construction of two one-stop border points/axle load control facilities, one between Zambia and Malawi, and the other between Malawi and Mozambique.

In June 2009, the World Bank approved Phase I for the Malawi side and it is now being implemented. The African Development Bank and the Export and Import Bank of Korea together with JICA approved the loan for the road widening and upgrading project for the section of Nampula–Cuamba on the Mozambique side in 2010. The road works is ongoing at present.

2.6.2 Objectives and Rationale of the Nacala Development Corridor Project

The objectives of the Nacala Development Corridor Project are:

(1) To provide Malawi, Zambia, and the interior of Mozambique transport linkage (road and railway) to Nacala Port and improve transport services by reducing transport and delay costs at border crossings; and

(2) To improve accessibility to markets and social services by the communities within the influence zone and contribute to poverty reduction.

The development and upgrading of the transport infrastructure of the Nacala corridor falls within the Southern African Development Community's (SADC) priority projects which have been included in the NEPAD-STAP program. The project is designed to promote regional economic and socio-economic integration and to develop synergy between national and regional interventions taking into account cross-cutting issues with a view to reducing poverty and sustaining growth.

The strategy of the New Partnership for Africa's Development (NEPAD) evolve around the development of regional infrastructure to foster regional integration and competitiveness to allow economies of scale through the development of joint facilities and pooling of resources to overcome the limitations of small markets to reduce poverty and sustain growth. The NEPAD transport sector interventions, among others, target trade corridors without borders and barriers to reduce delays and costs at border crossings, inland terminals, and road checks, especially, the corridors serving landlocked countries. A total of 17 transport corridors mainly running in the east–west direction have been identified to drive development in their zones of influence. The Nacala Corridor is one of the transport corridors identified to unlock the development potential of the hinterland of Nacala Port in Mozambique, Malawi, and Zambia.

The Nacala Corridor comprises the road sections starting from Nacala Port in the coast of Mozambique and running westward through Nampula, Cuamba to Mandimba at the border with Malawi and continuing in Malawi through Mangochi, Liwonde, Lilongwe, and Mchinji at the border with Zambia to Chipata. The corridor continues to Lusaka in Zambia through Sinda, Petande, Nyamba, Kachole, and Rufunsa. The entire road section in Mozambique, Malawi, and Zambia, is designated as Route 20 of the SADC Regional Trunk Road Network (RTRN). Route 20 continues west up to the border with Angola and ends at the port in Lobito. The entire corridor from Nacala Port to Lusaka covers a distance of over 1,700 km.

2.6.3 Renewable Energy Utilization Project along the Nacala Development Corridor Project

The Nacala Development Corridor is a large-scale development project in Nampula Province, which is in northern Mozambique where economic development is slow and lags behind the rapid pace in the south. This project aims to provide transport and economic infrastructures to enhance the economic development particularly of the northern area of Nampula Province based on its economic potential.

However, most of this area has not yet been electrified although several high-voltage transmission lines traverse the area especially along the Nacala Corridor. The economic activity in this area is not significant and agriculture, which is the area's major economic driver, is still based on traditional subsistence farming. Thus, most of the population living along this corridor is poor. The literacy rate of farmers or most of the population is quite low. It is predicted that the farmers and the rest of the population residing along this corridor would be the major beneficiaries of economic development which is expected to take place along the corridor and that opportunities for increased incomes through job generation are high. However, it is anticipated that the benefits to be received by people with low literacy rates would be substantially limited.

Under such circumstances, it is imperative to strengthen the foundation that will enable the majority of the population, farmers especially, to participate in economic activities by providing electricity to a number of primary schools and health centers along this corridor to satisfy the basic needs of the people in this area. The electrification of primary schools and health centers, which is the focal point of this study, is considered as quite important from such a viewpoint. Moreover, the consistency between the project, which envisages the electrification of these public facilities, and the Nacala Development Corridor Project has been confirmed as quite high and closely related to each other.

2.7 Renewable Energy Utilization Projects

2.7.1 International Cooperation on Renewable Energy Utilization Projects

FUNAE is the core institution that has been implementing the policy of national electrification and renewable energy utilization to date. FUNAE has been undertaking the following projects with various international agencies.

1.	The World Bank	Rural Electrification and Access Project (ERAP) and the Energy Development and Access Project (EDAP) for the installation of solar power systems in primary schools and health centers (USD98 million)
2.	Belgian Government	Belgium Development Agency (BTC) for the installation of solar power systems in primary schools and health centers (USD30 million)
3.	Portuguese Government	Small-scale village electrification project (5kW)
4.	Norwegian Government	Assessment of renewable energy resources throughout the country (USD0.6 million)
5.	Indian Government	Technical and financial assistance on the manufacturing of photovoltaic cells in Mozambique (USD13 million)
6.	Korean Government	Financial facility for village electrification by means of medium-sized solar power generation plant in Niassa Province (USD41 million)

2.7.2 Off-Grid Electrification Projects in Mozambique Using Renewable Energy

(1) Off-Grid Electrification Projects of FUNAE

In Mozambique, the government institution mandated to promote off-grid electrification using renewable energy is FUNAE. Table 2.3.2 lists the projects implemented by FUNAE in the period 2005–2011 and their plan for 2012–2014. Most of the projects involve the provision of independent photovoltaic power systems. As shown in this table, the total number of independent photovoltaic power systems installed up to 2012 is 300 units. It is expected that this number will reach around 1,350 units (4.5 times larger than that of the total number installed so far) in the coming years.

(2) Standardization of Photovoltaic Power Systems

Table 2.7.1 summarizes the number of solar power systems for primary schools and health centers by province, which is planned to be implemented soon under the loan from the Belgian Government as mentioned above.

Table 2.7.1 Profile of Solar Power System Installation Project Financed by Belgian Government Loan Funds

Public Facility	Code	Min. Wp	Manica	Sofala	Zambezia-1	Zambezia-2	Total
			Area-1	Area-2	Area-3	Area-4	
Primary School (II)	CR3AC	1,000	7	23	15	16	61
Primary School (I))	CR2AC	800	18	57	35	24	134
Health Center (L)	HC-I	450	0	2	37	8	47
Health Post	HC-II	320	0	18	13	1	32
Staff House	SH	190	23	106	101	44	274
Administration Office	PA	400	10	29	26	12	77
Vaccine Ref. Store	VAC	300	0	20	50	9	79
Total			58	255	277	114	704
Note: Primary school – 195 schools; Health Center – 80 locations							

Source: JICA Study Team, based on Technical Specifications

Table 2.7.2 shows the specifications of the solar power systems expected to be provided to primary schools and health centers under the school and health center electrification project being implemented with the financial assistance of the Belgian Government. The systems mentioned in the table are substantially better than those used in the electrification of 100 schools and 100 health centers done in 2005. The design power output and battery capacity have been increased and are deemed proper and appropriate.

However, the specifications shown in the table are just the minimum standards and may not fully meet the technical requirements of the solar insulation data obtained for project areas and for project facilities. To illustrate, the battery is planned to be recharged during periodic maintenance, through the use of small diesel generators, although such lack of battery capacity may not cause system malfunction.

Table 2.7.2 Minimum Standard for Solar Power Systems of Primary Schools and Health Centers

System	Code	Daily Load Wh/day	Solar Module W_P	Battery $Ah@C_{20}$ x V	Charge Controller	Inverter VA
1	CR3AC	3,400	1,000	700 x 24V	55A	1,300
2	CR2AC	2,700	800	590 x 24V	45A	1,000
3	HC-I	1,500	450	300 x 24V	25A	500
4	HC-II	1,100	320	220 x 24V	20A	400
5	SH	650	190	260 x 12V	25A	300
6	PA	1,400	400	250 x 24V	25A	500
7	VAC	1,000	300	300 x 24V	25A	-

Note:
1. CR3AC: AC power source for primary school composing 3 class rooms
2. CR2AC: AC power source for primary school composing 2 class rooms
3. HC-I: Health Center designed to receive internal and out patient
4. HC-II: Health Center designed mainly for consultation but with birth facilities
5. SH: Staff House (House for teacher in case of primary school)
6. PA: Administration office
7. VAC: Refrigerator for storing vaccine and medicines

Source: Excerpt from the Technical Specifications prepared for purchase of solar power system with the financial assistance of Belgium Government.

The number of primary schools and health centers being provided with solar power systems under the Belgian Government loan in Niassa Province, Sofala Province, and Zambezia Province are 195 and 79, respectively, as shown in Table 2.3.2. As the size and scale of primary schools and health centers are mostly standard throughout the country, this indicated specification for the solar power systems may be accepted as the national standard when replicating the project elsewhere in the country.

2.8 Selection Criteria and Prioritization of Schools and Health Centers at the Candidate Sites for the Nampula Electrification Project

The following criteria were considered in the selection of primary schools and health centers which will benefit from the Nampula Electrification Project:

(1) Population density (in relation to the number of students who need lighting);
(2) Distance from trunk roads (in relation to ease of maintenance and supervision of operation);
(3) Distance from district centers (in relation to ease of maintenance and supervision of operation); and
(4) Off-grid electrification completed and possibility of on-grid electrification in coming years.

There are 2,572 educational facilities (of which 2,458 are primary schools) and 209 health centers in Nampula Province. The number of primary schools and health centers electrified are 50 and 122, respectively. This means that the total number of primary schools and health centers that need electrification is 2,408 and 87 units, respectively. It is recommended to electrify these units using solar power systems in phases to match the technical capacity of the implementing agency in terms of maintenance service provision and project management, as well as financial capacity.

Access roads in the project area are earth roads in bad condition even if they are just a few kilometers away from trunk roads. It has been confirmed that such a condition takes considerable transport cost and time. In some cases, access becomes even more difficult because some bridges get washed away or there are no rigid bridges that can carry the weight of even the small trucks carrying half its capacity. In this point of view, accessibility constitutes one of the important criteria.

Based on the data obtained from field surveys executed by FUNAE to profile the candidate primary schools and health centers along the Nacala Corridor, it was found that the average distance of primary schools from district centers is around 36 km, which requires a 3-hour drive. Almost 85% of the surveyed schools are located 2-60 km from district centers. On the other hand, the average distance of health centers from district centers is around 35 km which also requires a 3-hour drive. Almost 95% of the surveyed centers are located 8-60 km from district centers. Therefore, the sites to be selected will be within a 50-km range from the district centers or 5 hours drive away so that it could be possible to make one round trip in a day. These sites could be selected for the first development phase. On the other hand, the most distant candidate primary school is 85 km and 65 km for the health center. In this case, the time required for trips would exceed more than 6 hours; thus it might be difficult to get to the site and back to the base in a day. However, if the needed time for maintenance work is considered, some of the surveyed sites may be located beyond the maximum distance for a one day trip.

The power transmission grid runs along the trunk road of Nampula Province. Therefore, it is assumed that candidate project sites located along the trunk road will be electrified soon. However, even if electrification will be done as on-grid electrification, independent power generation systems are still needed. Since the power supply will not be stable while payment of electric bills will be on schedule, elimination of candidate sites where on-grid electrification is assumed to happen in the coming years was omitted.

Since primary schools and health centers are public facilities, either national or provincial government budget should be arranged in paying electric bills. However, the appropriation of funds for such expenditure or recurrent cost is not easy because of the limited budget overall. In the case of the provision of solar power generating system, of which fuel is the renewable energy, if the facilities are constructed with international financial assistance and with a development budget, the continuous payment of expenses, such as electric charges, will not be necessary in the future, so that no budget appropriation will be required except to cover the expenditure incurred for maintaining the power generating systems. Therefore, even if the sites for off-grid power generating systems utilizing renewable energy are close to the grid and will be connected to it in the near future, it is still better to consider such sites as candidates for off-grid electrification.

Some of the sites surveyed during the course of this preparatory study were eliminated as candidate project sites in accordance with the criteria set out below:

(1) Number of project beneficiaries: The number of students of primary school is to be more than 300.
(2) Distance of access from trunk road: Access to the site is to be relatively easy.
(3) Distance from district center: Site is to be within 60 km from district center.
(4) Possibility of on-grid type electrification: Site is to be located more than 8 km away from the district center.

Table 2.8.1 shows the number of candidate sites selected in accordance with the above criteria.

Table 2.8.1 Number of Selected Project Sites for the Nampula Electrification Project

Elementary Schools

Criteria		Students	Distance of Access		
	All	>300	<75km	<60km	<40km
Site	70	62	51	45	37
Coastal	19	16	13	12	11
Memba	3	2	1	1	1
Nacala-Velha	9	7	6	6	5
Nacala Porto	1	1	1	1	1
Mossuril	2	2	2	2	2
Angoche	1	1	1	1	1
Moma	3	3	2	1	1
Central	29	28	25	22	17
Meconta	3	3	3	3	1
Mecubun	7	6	4	4	4
Monapo	7	7	6	5	3
Mogovolas	1	1	1	1	1
Muecate	4	4	4	4	4
Murapula	2	2	2	2	1
Rapale	5	5	5	3	3
Western Inland	22	18	13	11	9
Malema	12	9	10	9	8
Ribaue	10	9	3	2	1
Total	70	62	51	45	37
GRAND TOTAL	100		77	70	52

Health Centers

Criteria		Distance of Access		
	All	<75km	<60km	<40km
Site	30	26	25	15
Coastal	5	6	6	2
Memba	1	2	2	0
Nacala-Velha	1	1	1	1
Nacala Porto	1	1	1	1
Mossuril	-	-	-	-
Angoche	1	1	1	0
Moma	1	1	1	0
Central	19	18	17	12
Maconta	-	-	-	-
Mecubri	3	2	2	2
Monapo	6	5	6	4
Mogovolas	1	1	1	1
Muecate	4	4	4	2
Murapula	1	1	0	0
Rapale	4	4	4	3
Western Inland	6	2	2	1
Malema	3	1	1	0
Ribaue	3	1	1	1
Total	30	25	25	15

Source: JICA Study Team

As shown in the table above, the number of candidate primary schools is 37 and that of health centers is 15. Thus the total number of candidate project sites is 52, which is almost half of the total number of candidate sites surveyed.

CHAPTER 3. Confirmation of Management and Maintenance System

3.1 Ministry of Energy and FUNAE

3.1.1 Types of Electric Power Supply

The types of electric power supply system at the national level are categorized into three; namely, the national transmission grid system (on-grid electrification), the mini-grid system (off-grid electrification), and the independent system (off-grid electrification). Electrification by connecting users to the national grid is undertaken by the (EDM) under the authority of the Ministry of Energy, while electrification through mini-grid systems is undertaken by the provincial governments under the authority of the Ministry of Energy and other relevant administrative divisions at the district level.

Planning, designing, installation, and quality management are the responsibility of the energy division of provincial governments. Most of these systems are managed by the administrative office of districts, and power is supplied to administrative institutions and commercial facilities. Private households can use the electricity supplied by mini-grid systems; however, the number of such power users is quite limited because most households cannot afford to pay electric bills. Access to systems with sizes below those of mini-grid systems or power supply to public institutions, such as schools and health centers, are undertaken by the education division or health division at the provincial level. These systems are categorized as independent systems.

3.1.2 Ministry of Energy

The Ministry of Mineral Resources and Energy was reorganized into two ministries in 2005; namely, the Ministry of Mineral Resources (MREM) and the Ministry of Energy (ME). According to the energy policy of the Government of Mozambique, MREM is mandated with the management of the upstream sector and the ME is mandated with the management of the downstream sector. MREM manages the production of natural gas and the ME manages the downstream side such as the marketing and distribution of electricity and energy. Figure 3.1.1 presents the organizational chart of the Ministry of Energy.

3.1.3 FUNAE

In 1997, the Government of Mozambique established FUNAE based on Decree 24/97 to solve the country's energy problems especially in the rural areas. FUNAE is responsible for promoting and realizing off-grid electrification projects, specifically, to: (1) develop and utilize various forms of low-cost energy; and (2) promote and use sustainable power sources. FUNAE undertakes the financing or provides guarantees to off-grid electrification projects that are deemed financially feasible and compliant with its objectives.

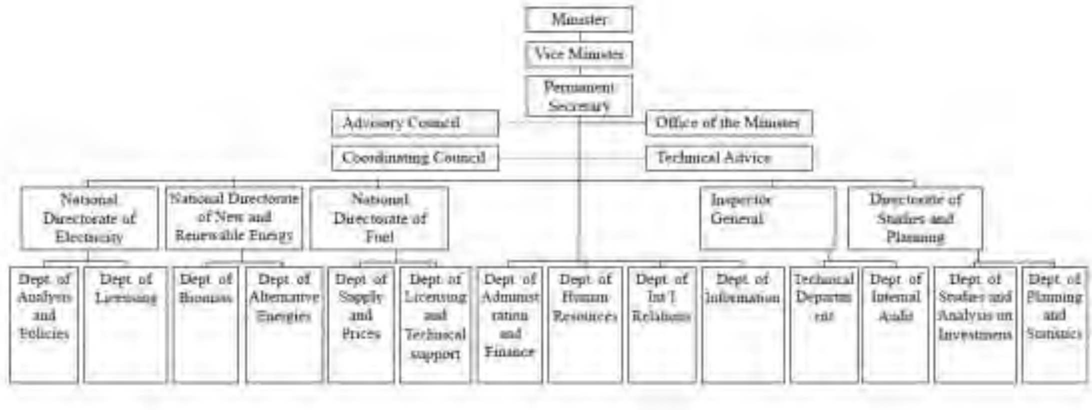
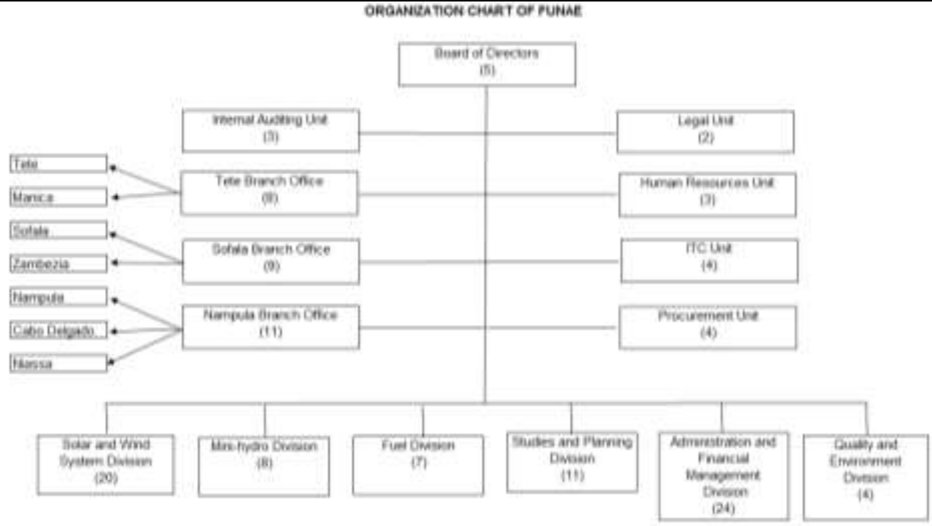


Figure 3.1.1 Organizational Chart of the Ministry of Energy

Figure 3.1.2 presents the organizational chart of FUNAE. The agency currently has 123 staff, 28 of whom are deployed in three regional offices, i.e., the Northern Region Delegation, the Central Region Delegation, and the Southern Region Delegation.

The total number of solar power systems currently installed in primary schools and health centers planned, installed, and managed by FUNAE is around 300 units. This number is expected to increase 5.5 folds, or about 1,650 units by 2015. This will require an increase in FUNAE personnel of about 680.

However, the plan is to contract private companies which will maintain the solar power systems. The tender documents and the general conditions prepared for the procurement of goods and services required to install around 700 units of solar power systems with financial assistance of Belgium Government state clearly that the contractor for the installation of systems will be responsible for maintaining the systems for up to two years after their official turnover to FUNAE and for training FUNAE technicians during the same period (see details in Appendix A1-4).



Board of Directors	5
Internal Audit Unit	3
Legal Unit	2
Procurement Unit	4
Human Resource Unit	3
ITC Unit	4
Solar and Wind Div	20
Mini-hydro Div	8
Fuel Div	7
Studies and Planning Div	11
Admini and Finance Div	24
Environment Div	4
Subtotal in Headquaters	95
Tete Branch	8
Sofala Branch	9
Nampula Branch	11
Subtotal in Branch Office	28
TOTAL	123

Admini and Management	21	22%
Finance and Accounting	24	25%
Planning	11	12%
Engineering	39	41%
Subtotal in Headquators	95	100%
Branch Office	28	

( ) shows the number of staff

Figure 3.1.2 Organizational Chart of FUNAE

3.2 Role of Agencies Responsible for Electrification

The Ministry of Energy is responsible for the formulation of the electrification policy and its implementation. There are three public entities under the Ministry of Energy, such as the EDM, which are responsible for on-grid electrification that includes power generation, transmission, and power charge collection.

Energy development and electrification utilizing renewable energy are under the responsibility of the Renewable Energy Division of the Ministry of Energy. However, rural electrification through mini-grids and village electrification through independent power generating systems, or the so-called off-grid electrification, are undertaken by FUNAE.

Thus, the Ministry of Energy is exclusively responsible for the formulation of energy policies and the supervision of all agencies responsible for its implementation, while the Renewable Energy Division is responsible for policy formulation on renewable energy and the supervision of all agencies responsible for policy implementation. FUNAE prepares renewable energy utilization plans and coordinates with other institutions and agencies to implement the projects. Further, FUNAE is responsible for supervising the tendering process and maintenance management of installed electrification facilities.

The organizations directly responsible for implementing projects are the divisions under the implementation agencies such as the Ministry of Education and the Ministry of Health. However, FUNAE is responsible for the design of facilities, management of tendering, project supervision, systems inspection after turnover, and maintenance management during the warranty period.

3.3 Maintenance System

A proper maintenance system composed of daily, quarterly, and annual maintenance activities is inevitable to extend the useful life of solar power systems in general and power generation systems up to their maximum lifespan of 20 years in particular (see details in Appendix-1). Daily inspection is to be undertaken by a committee organized by villagers where the power facility is installed. In emergency cases, the committee is to inform FUNAE's regional office about the matter. During the warranty period, FUNAE is to contact the representative of the contractor and after the warranty period is over, FUNAE is to contact the private company contracted for maintenance works. Annual inspection of the systems is to be conducted jointly by engineers of FUNAE and the private company contracted by FUNAE to maintain the facilities. This private company is to carry out the necessary works to remedy the systems' problems, if and when such work is deemed necessary.

Although the independent photovoltaic power system project referred to as the 100 primary schools and 100 health center projects has been completed as planned, some of the facilities have been found to be improperly operated because of the employment of improper design philosophy, circuit design, and method of system purchase. Furthermore, maintenance works were totally vested in FUNAE, which is not realistic.

The conventional skills and knowledge of engineers in Mozambique about maintenance work is not sufficient to maintain the solar power systems properly. Engineers (operators) should be familiar with batteries, inverters, converters, etc., and should obtain new knowledge and skills in troubleshooting them. However, it is not easy to learn these matters and acquire relevant skills in a limited time, unless the trainee has sufficient opportunity for on-the-job-training. It seems that the demand for maintenance of the solar power systems exceeds current maintenance capacities.

Facilities whose warranties have expired should be maintained properly by the operators themselves; namely, the owners of primary schools (Ministry of Education) and health centers (Ministry of Health), through their local offices. Divisions established under the ministries should supervise the maintenance work undertaken by the maintenance division of each provincial government.

Neither the concerned department for maintenance of facilities in the Ministry of Education nor Ministry of Health has their own engineers or technicians having the skill level meeting with the requirement for maintenance of modern and updated electronic equipment such as solar power system. Therefore, both ministries are considering to contract the services of private firms specialized on the maintenance of electronic facilities or photovoltaic power generating systems.

A key point in the conduct of proper maintenance management is the execution of daily and periodic inspection. For a telecommunication system, it is very necessary to manage such routine and day-to-day maintenance operations, especially, if such works are to be carried out in remote areas.

Therefore, mobile phone recharging stations should also be provided in primary schools and health centers planned to be electrified. In addition to this, training in and supervision over the use of equipment, daily inspection of equipment, and maintenance of facilities are to be carried out properly in each site in each village where primary schools and health centers are located.

The government agency exclusively mandated to promote the utilization of renewable energy in Mozambique is FUNAE. As presented in Figure 3.1.2, FUNAE divides the country into three regions; namely, the Northern Region, the Central Region and the Southern Region, for its management and administration as well as the deployment to its regional branch offices in the center of each region. In the Northern Region, the Regional Delegation for the Northern Region was established in Nampula City, the capital of Nampula Province. This regional office looks after two other provinces; namely, Cabo Delgado Province and Niassa Province. Its four (4) office staff consists of the regional office manager, electrical engineer, legal officer, and the coordinator. In January 2012, a new office was completed. Although it started operation, the number of working rooms is only four (4). Thus it is difficult to accommodate more staff in the future, even though over 600 units of PV generating systems are planned to be installed throughout these three provinces in the coming years. Under such a situation, it is unavoidable to depend totally on private contractors for both installation under the contract with the Ministry of Education and the Ministry of Health and the maintenance of equipment and facilities under a contract with specialized private companies to maintain electronic equipment.

FUNAE has organized and supervised the facility maintenance committee in each village to conduct easy inspection and maintenance operation at the village level. Nevertheless, the level of such maintenance is limited only to very simple and easy maintenance works such as the replacement of light bulbs and adding water to batteries; therefore, it is quite difficult to deal with substantial problems caused by excessive power charges and discharge of batteries and electronic equipment. The inspection, maintenance, and repair that require skilled engineers and technicians are the responsibility of private service companies specializing in the maintenance of electronic equipment and facility. During the time of this study, the private service company for each region was already selected and the contracts with relevant ministries were almost concluded.

At the same time, FUNAE recognizes the necessity to increase the number of their staff to supervise these private service companies undertaking the maintenance of power-generating equipment and facilities. It also acknowledges the need to manage its own staff and to keep competent electrical engineers within the agency itself.

CHAPTER 4. Weather Data Simulation

4.1 Methodology of Weather Data Simulation

The weather data analysis in Nampula Province is as presented below and in succeeding pages.

(1) Current Weather Data in Nampula Province

Weather observations for temperature, wind speed, wind direction, insolation, etc., are done in three locations in Nampula: Angoche which is along the coastal area, Nampula in the central part and capital city, and Lumbo in the southern coastal area. Weather observations are done continuously for 24 hours, but the observation period per day in other areas is limited to one hour and done at fixed schedules, such as 5:00 a.m., 12:00 noon, and 9:00 p.m.

Insolation data used for the analysis of solar power generation is insufficient. Twenty-four hour data is available only from the weather observation site in Nampula. Moreover, local data is deemed unusable for this study.

(2) Weather Simulation Based on Weather Data

Table 4.1.1 shows the weather simulation data based on weather models and data obtained by satellites. This data was used to reproduce weather conditions along the Nacala Corridor and its surrounding areas through a 5km mesh that show daily insolation amounts and hourly wind speeds based on a 2004 weather data.

Table 4.1.1 Outline of Weather Simulation

Items	Particulars
Objective Area	Area: LON S 14°～15°30’; LAT E 37°～41° Measuring Unit: 5km mesh
Name of Weather Model	WRF Model (Weather Research and Forecasting Model)
Data Used	Weather Data: NCEP-FNL (NCEP) Sea Surface Water Temperature: RTG-SST Land Use, Geological Data USGS
Objective Year	2004 (This year is considered as a standard year and was selected to avoid extraordinary years such as the year affected by El Niño and La Niña.)
Items Analyzed	Daily insolation (W/m^2) per one hour Wind speed (m/s) per one hour as 10m high from ground level Temperature (°C) per one hour as reference data

Source: JICA Study Team

4.2 Results of Weather Simulation

(1) Season

The average annual precipitation in Nampula (elevation, 416 masl) which is located at the central part of Nampula Province is around 860mm. Figure 4.2.1 shows that precipitation and temperatures are high in November and April. On the other hand, the level of precipitation goes down between May and October and temperatures become relatively lower. The former condition is categorized as wet season while the latter as the dry season.

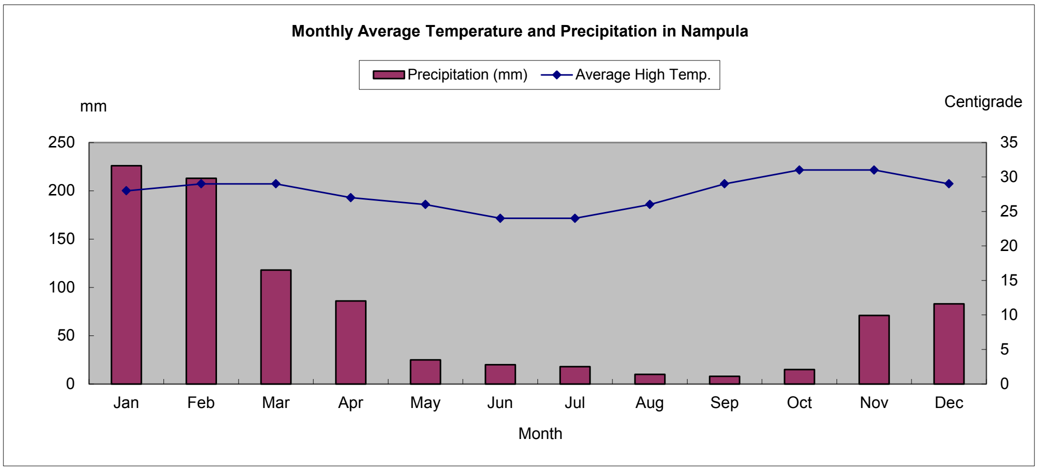


Figure 4.2.1 Monthly Precipitation and Average Maximum Temperature in Nampula

(2) Geological Features of Nampula Province

Figure 4.2.2 reflects the flat geological feature of Nampula Province which has a gradually rising elevation as the land moves inward from the coastal areas to the hinterland. The average elevation in the innermost part is around 500m, thus the average gradation from the coast to the hinterland is around 1%.

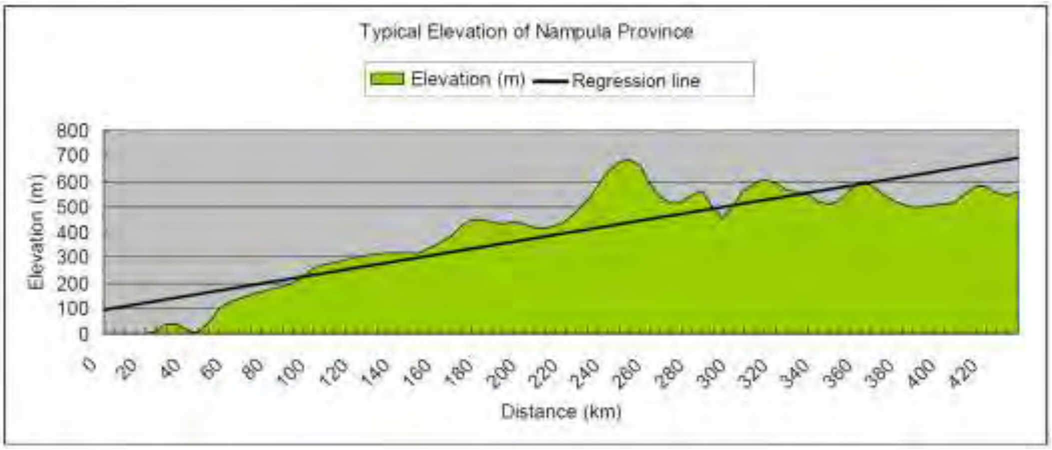


Figure 4.2.2 Elevation of Nampula Province

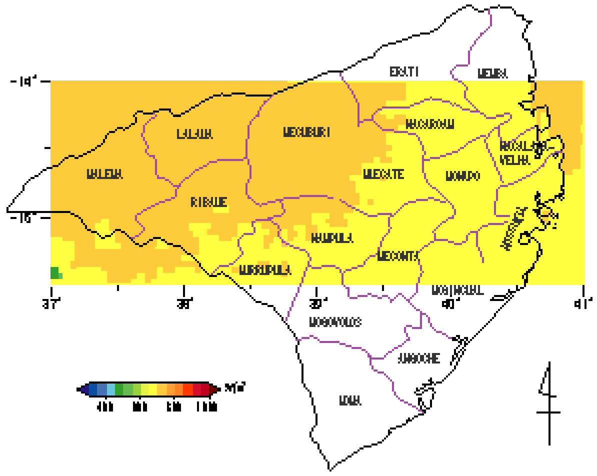
(3) Daily Insolation Amount

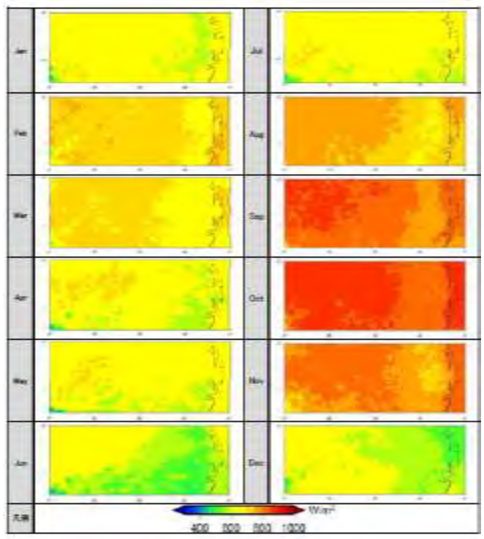
Figure 4.2.3 shows the geographical distribution of the annual average insolation relative to W/m^2. There are low mountains that lie northwest of Nampula Province and insolation amounts increase gradually from north to west as a result of this geographical feature.

Figure 4.2.4 shows the monthly average insolation. The insolation amount from August to October, or during the dry season, is higher than that from November to April.

Throughout the year the sun rises at around 5:00–6:00 a.m. and sets around 5:00–6:00 p.m. Although there is a time difference by season, the difference in sunshine hours is marginal.

Insolation becomes highest around 12:00 noon. Among other months, the level of insolation fluctuation is highest in January.





Note: Monthly average shows the average amount of daily insolation from 9:00 a.m. to 3:00 p.m.

Figure 4.2.3 Geographical Distribution of Annual Insolation Amounts	Figure 4.2.4 Average Monthly Insolation Amounts

Source: JICA Study Team based on weather simulation data

(4) Distribution by Hour

Figure 4.2.5 shows the data sorted by one mesh for five days each in January, April, July, and October in Nacala Velha (Coastal Area), Mecuburi (Central Area) and Malema (Western Area). Although there were some differences in the data between sunrise and sunset (the sun rises between 5-6 a.m. and sets between 17–18 p.m.), these were marginal. Insolation volume was highest at around 12:00 noon. In January, or the cold season, when the weather conditions usually are not stable, daily insolation fluctuations are quite high.

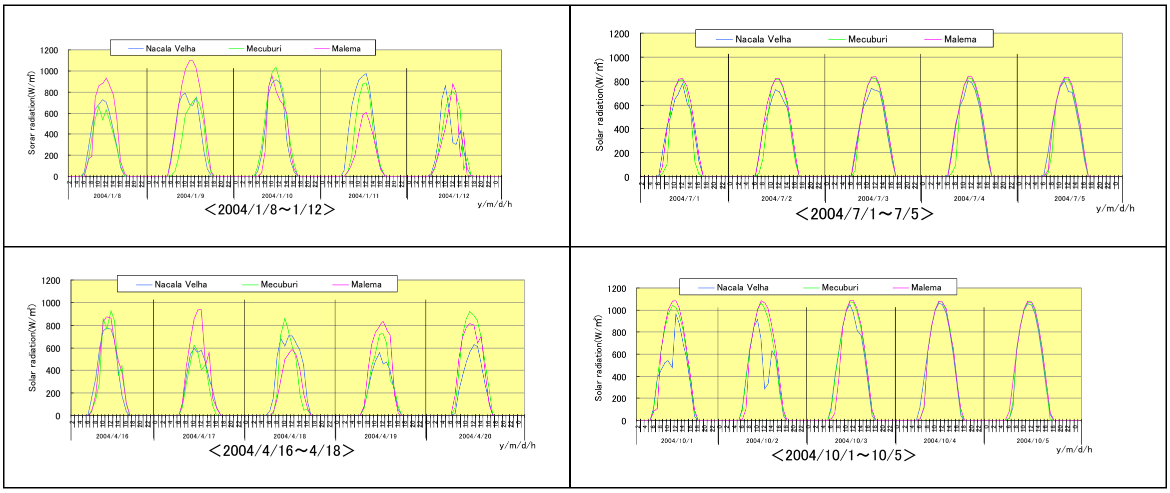


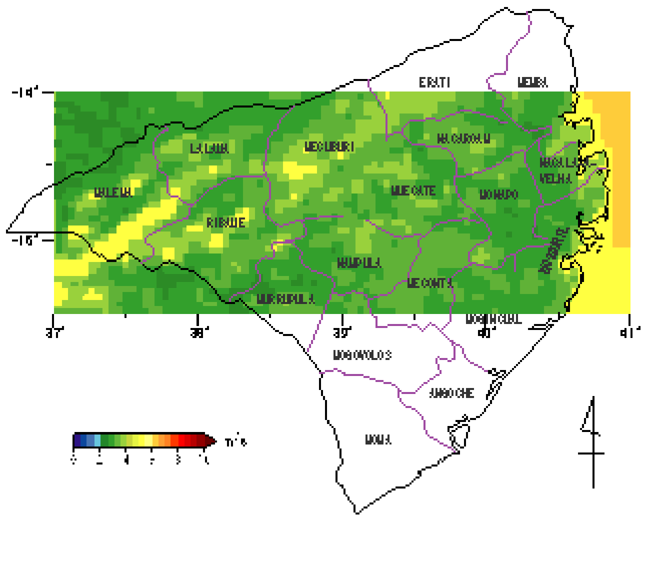
Figure 4.2.5 Daily Fluctuation of Insolation at the Four Representative Locations in Nampula Province

(5) Wind Speed

Figure 4.2.6 shows the geographical distribution of annual average wind speed (m/s). Low mountains lie from north to west of Nampula Province, and wind speeds gradually increase from north to west as a result of the geographical feature. Wind speeds along the coast facing the Indian Ocean tend to be high.

Figure 4.2.7 shows the geographical distribution of the monthly average wind speeds. As the distribution map shows, average wind speeds during the dry season, or from May to October average 4–6 m/s. On the other hand the winds clocks at 3 m/s during the wet season, which is from November to April. At any location, peak wind speeds were recorded twice a year during May and September.

In view of the province's geography, the monthly average wind speeds in the coastal areas were around 5 m/s, throughout the year. However, the central area had an average of 3–4 m/s. In Malema, wind speeds were higher from March and July than in the coastal or central areas.



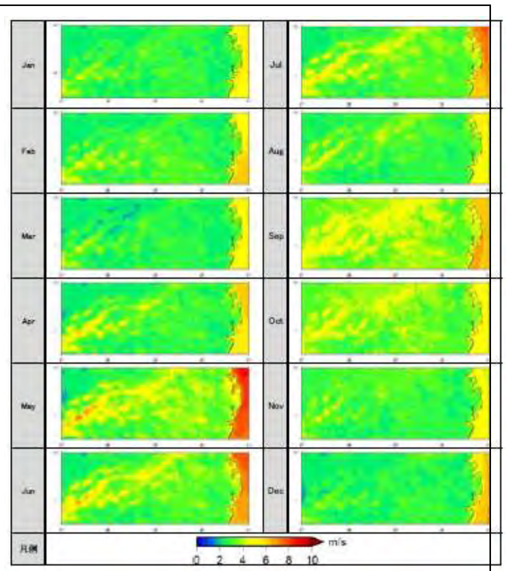


Figure 4.2.6 Geographical Distribution of Annual Average Wind Speed	Figure 4.2.7 Monthly Average Wind Speed

Source: JICA Study Team based on the results of weather simulation.

In the daily wind fluctuations, wind speeds are commonly weak during nighttime and they peak around noon. This trend is quite evident especially in the Nacala-Velha or the coastal areas.

Figure 4.2.6 shows that the average wind speeds that exceed 4 m/s (identified by the yellow color) are limited to the coastal area and parts of the west. This means that wind power generation is possible in these areas. The examination of wind power generation systems, evaluation, studies on output and battery storage capacity, etc., have been carried out based on the results of the weather simulation, as described above.

(a) Seasonal Distribution

Figure 4.2.8 shows the distribution graph of the monthly average wind speeds. Figure 4.2.7 shows the monthly average wind speeds in Nacala, Velha, Mecuburi, Malema and Memba.

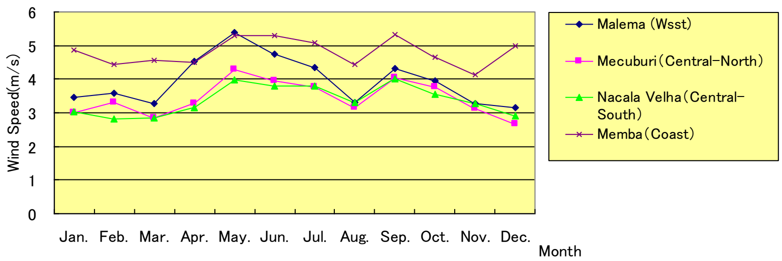


Figure 4.2.8 Monthly Average Wind Speed at the Four Representative Locations in Nampula Province

In all the locations, the highest average monthly wind speeds were recorded in May and September. Around 5 m/s winds blow throughout the year along the coastline. The average wind speed is 3-4 m/s in the central and coastal areas. Malema has the highest wind speed fluctuations between March and July and it is stronger than in the coastal and central areas.

(b) Distribution by Hour

Figure 4.2.9 shows the sorted data by 1 mesh for 5 days each in January, April, July and October in Nacala Velha (Coastal Area), Mecuburi (Central Area) and Malema (Western Area). The wind speeds were low during the night and were highest during noon time. Nacala Velha and the coastal areas are typical of this case.

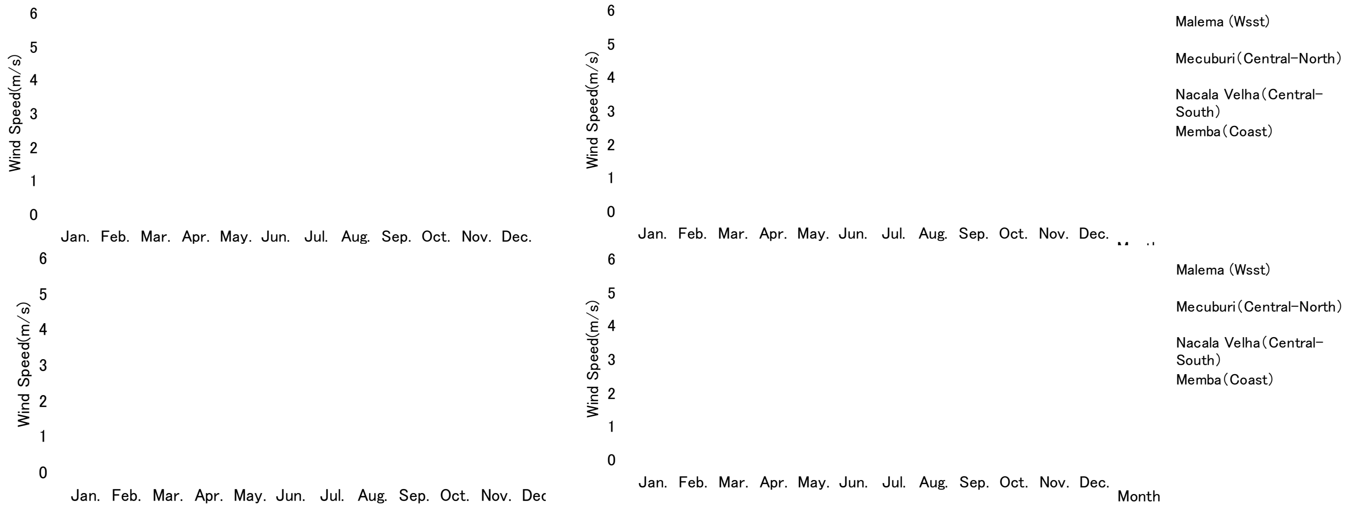


Figure 4.2.9 Changes of Wind Speed in a Day at the Four Representative Locations in Nampula Province

(c) Zoning by Weather Conditions

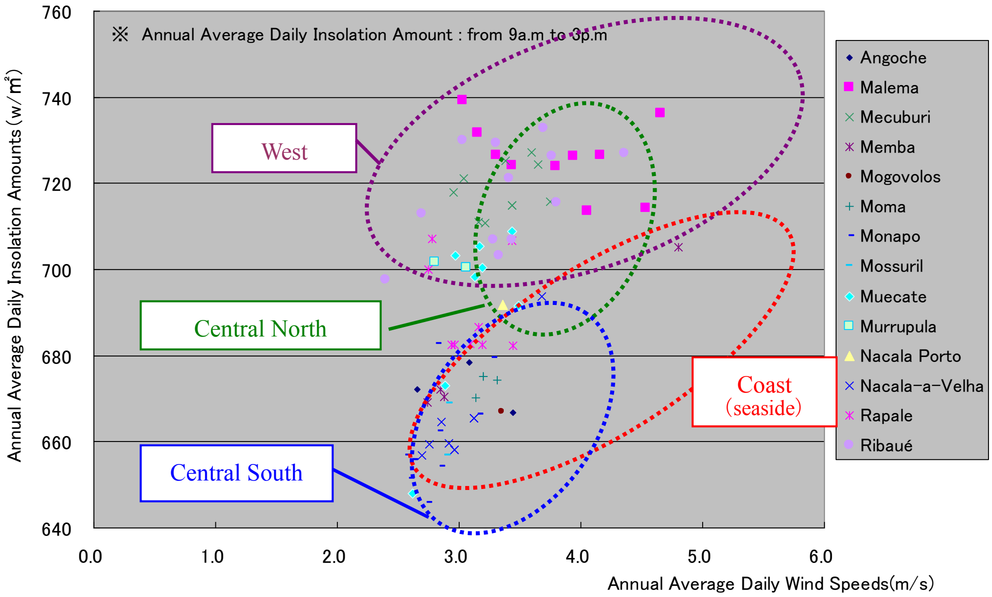
In terms of size and type of system, in the introduction of renewable energy utilizing power generating systems, the ideal system should adapt to local weather conditions. The examination concerning the selection of type and determination of size of systems, especially those that met each weather condition, was carried out either by clustering weather conditions, geographical distribution, or zoning. Figure 4.2.10 shows the data sorted by average annual daily insolation amounts and wind speeds.

As shown in the figure, insolation amounts and wind speeds were grouped into four zones; namely, coastal area in the east, central north area, central south area, and western area. The administrative boundaries of these areas were taken into consideration as well. Table 4.2.1 tabulates the character of each zone and group of districts.

Table 4.2.1　Characteristics of Insolation and Wind Speed in Districts and Weather Zones

Zone	Characteristics of Insolation and Wind Speed	District
Coastal Zone (East)	Both insolation amounts and wind speeds are lowest in Nampula province but the wind speeds are high along the coastline.	Memba, Nacala-Velha, Mossuril Mogincual, Angoche
Central South Zone	Both insolation and wind speeds are low in Nampula province.	Monapo, Meconta, Nampula, Meruli, Mogovolas, Mona
Central North Zone	Insolation is relatively strong. Wind speeds are average in Nampula province.	Erati, Muecate, Mecuburi
Western Zone	Insolation amounts are high and wind speeds are high by area. Wind speed changes substantially due to the complex nature and geological features.	Lalaua, Ribaue, Malema

Data on the average insolation amounts and wind speeds in a year is shown in Figure 4.2.10 and when they are also grouped as geological clusters, as shown in Figure 4.2.11, which also shows the weather zones in Nampula Province.



Annual Average Wind Speeds (m/s)

Figure 4.2.10　Zoning by Annual Average Daily Insolation Amount and Wind Speed

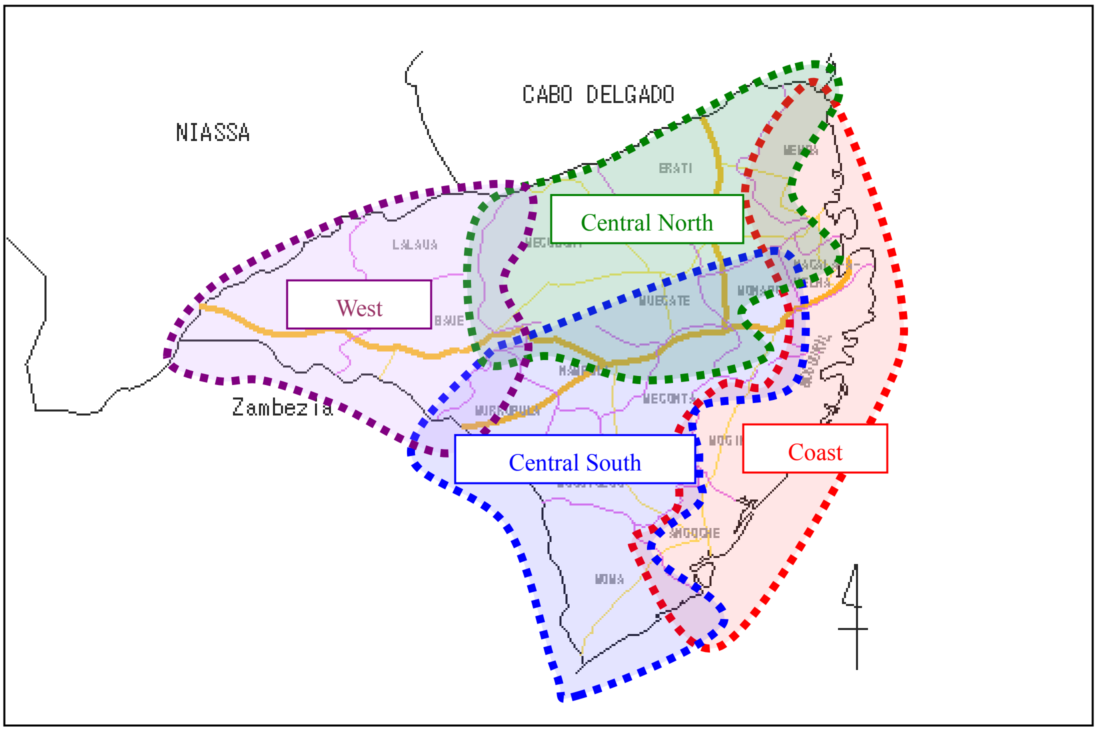


Figure 4.2.11　Conceptual Zoning of Weather Condition

If this conceptual weather zone is applied, the solar and wind hybrid generation system can be recommended for Memba, Nacala-Velha, Mossuril, Mogincual, Angoche in the Coast Zone and Malema, Ribaue and Lalaua in the West Zone. For the Central North and Central South Zones the solar power system can be recommended.

(d) Field Survey to Verify the Result of Weather Simulation

Results of the weather simulation confirm the thesis that the method is almost accurate especially in light of the statistics and comparisons even if there was partial availability of existing data. In addition, weather speeds were measured through actual 24-hour weather speed measuring operations in the representative locations in the Coastal and West zones. Table 4.2.2 is a summary of the results of this survey.

Figure 4.2.12 and Figure 4.2.13 illustrates the hourly recorded wind speeds measured at Mozambique Island and Cuamba, respectively. It shows that the peak wind speed happens during the period between 2 pm and 4 pm with speeds reaching 3-6 m/s which are sufficient for the power generation by wind force. As such the result of field survey verifies the results of weather simulation.

Table 4.2.2 Outline of Field Survey on Wind Speed

Location	Date and Time
Mozambique Island	Date and Time：3rd February 2012 from 16:36 for 24 hours. Remarks: Wind speeds were measured to confirm that wind conditions along the coast are appropriate for wind power generation.
Cuamba	Date and Time：9th February 2012 from 16:54 for 24 hours. Remarks: Wind speeds were measured to confirm that wind conditions in the westernmost or inland part of Nampula Province is relatively good. Since there was no available location to install the wind velocity measurement instrument safely for 24 hours, the wind velocity field measurement was carried out at the neighboring province close to the western end of Nampula Province.

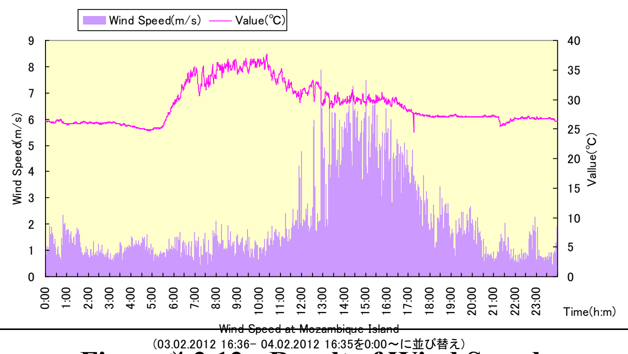


Figure 4.2.12 Result of Wind Speed Measurement (Mozambique Island)

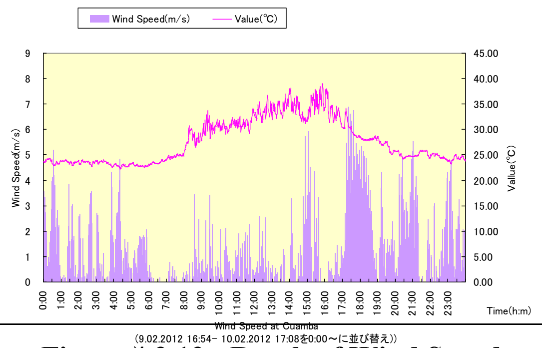


Figure 4.2.13 Result of Wind Speed Measurement (Cuamba)

CHAPTER 5. Present Operational Condition of Existing Solar Power System

5.1 Operational and Maintenance Condition of Solar Power System

In the number of units installed by FUNAE alone, the number of solar power generation units under operation is more than 300 units. These units have been installed starting in 2005 under the World Bank's‟ electrification program for primary schools and health centers. Several existing solar power generation systems were examined in the conduct of this study.

Consequently, various problems have been identified in relation to system design. For instance, some systems were designed without taking proper consideration of the coordinative procedures and protection requirements for specific parts and components. Sometimes, different components were simply combined, such as rated solar panel, controller, batter, inverter, etc. In other instances, protection was set up only for the overloading of inverters but there was no protection at the breaker-equipped outlets. These oversights resulted in breakdowns and malfunctions, such as when sudden high loads caused the breakdown of inverters. (An example was the breakdown of an inverter due to the use of iron.) Such equipment mishaps and damages can be avoided by the tripping of a breaker. In another case a total system was suspended due to the lack of minor spare parts, or due to a simple breakage of one single part of the entire system. These examples show that the design of the system itself was not properly done. Poor and sloppy design work is one of the causes that make maintenance difficult.

It was observed that power generation efficiency would decrease below the expected levels due to the degrading power generating efficiency of the solar panel itself. Battery performances were measured below their rated values, or the values stated in their catalogues. Although in general battery performance depreciates before their prescribe lifetime, one of the causes of battery performance dissipation is due to the purchase of lesser quality parts which in itself is linked to budget constraints.

However, ideal or superb maintenance regimes may not be realistic in the new technology of renewable energy systems, but it is worth noting that the system managed by FUNAE is, so far, operating. There were several cases where complete systems were abandoned completely due to malfunctioning batteries (i.e., solar power units installed by NGOs, religious groups, etc.). It is acknowledged that what is lacking is the number of engineers or technicians with sufficient knowledge and skills in the maintenance of renewable energy systems.

Some breakdowns were due to breakage and damaged components as a result of excessive loads. This form of breakdown is a manifestation that the proper understanding, appreciation, and utilization of the uses of solar power systems have not been properly imparted to consumers. This solidifies the assumption that knowledge and information on the proper usage of electrical equipment and electric system relative to solar power systems has not been sufficient for both end users and providers. In industrialized countries the service providers can be easily accessed and professional troubleshooters can immediately be obtained during breakdowns, but in countries or areas where no such immediate services is available, users themselves should be very careful in the operation and maintenance of such systems.

5.2 Operation Efficiency

The operational efficiency of the solar power system that will be installed in the primary schools and health centers should be assured because there is no other efficient way to obtain electric power in the villages where the primary schools and health centers are located. One of the factors for its high operating efficiency is that solar power systems do not require recurrent costs. For instance, the major reason why diesel power generators does not operate for the long term, or are abandoned, and the fact that the number of consumers connected to on-grid power systems are limited only to institutional organizations, commercial facilities and some wealthy households is because they are the only ones that can afford to pay the electric bills. Nevertheless, lowering electric bills cannot solve this problem because majority of rural villagers live below the poverty line and it would be unwise to distribute power as a form of subsistence economy.

5.3 Purchase Methods

The tendering for the construction of power generating system utilizing renewable energy by FUNAE, including the purchase of materials and equipment needed for village electrification, as well as the needed services, were carried out in strict compliance with transparent purchasing guidelines set by international funding agencies. The implementation of solar power generation systems with financial assistance from the Belgium Government is currently in progress. The general conditions of tender documents stipulate that the contactor is responsible for the basic design, detailed design, purchase of material and equipment, installation of equipment, handover, quality assurance and a two-year warranty following the handover. The contractor is thus obliged to stock a sufficient number and volume of spare parts and components. (See details in Appendix 4)

Such contract or purchase conditions, wherein the contractor is forced to prepare for potential risks, pushes up the costs a bit. However, relative high costs cannot be avoided if the total system will break down due to lack of care and maintenance by the contractor.

5.4 Preparation of Funds Needed for Spare Parts and Battery Replacements

Common Spare Parts: Spare parts for the solar power project should be selected on the assumption that they will be used for a two-year period. They should also be purchased at the same time as the main body is purchased and be within 10% of the initial capital investment costs. The purchase of such parts should be done in a single sitting and through a considerable volume; otherwise, an annual budget appropriation will be needed if purchases are done on a piecemeal basis. Common parts such as fuses, small lamps, wires, etc., can be purchased on a per item basis in domestic markets. However, a number of major parts, such as inverters or breakers cannot be purchased locally. This means that purchasing these major parts should be timed with the purchase of the major body of the system and that they should be purchased as recommended spare parts.

Batteries: The cost of battery accounts for almost 35–60% of the total cost of either a photovoltaic power generation system or a solar powered or wind hybrid powered generation system. The batteries need to be replaced after a number of years. Expected battery life differs by type of battery. Table 5.4.1 shows battery life by type, model, and manufacturer. The type of battery selected for the project is the Valve Regulated Lead-Acid Battery (Seal type) which has a cycle usage.

Table 5.4.1 Comparative Performance of Battery Models

Product	Expected Life Time	Number of Cycles	Depth of Discharge	Cost (JPY/kWh)	Water Supplement
A	5 years	2000	30%	200,000	None
B	3 years	1200	30%	70,000	None
C	5 years	2000	70%	150,000	None
D	3 years	1200	30%	45,000	None
A = Model SLM of Furukawa Battery Co., Ltd.; B = Model EB of Furukawa Battery Co., Ltd.; C = Model SLE of GS Yuasa Corporation; D = Model Eagle Pitcher of NISCO Co., Ltd.					

Source: JICA Study Team

Taking annual degradation into account, replacement batteries cannot be purchased at the time of system installation. Replacement batteries should be purchased after several years through a large lot and using government budget. One recommendation is the saving of 1/5 or 1/7 of the needed annual battery replacement costs in the budget for construction or repair of schools and health centers. However, such form of budget saving may be difficult if it is not legislated and the budget is limited.

The plan is that the budget for the replacement batteries should be shouldered by the relevant government ministry such as the Ministry of Education, for the batteries of the solar power system to be installed at primary schools; and the Ministry of Health, for the systems to be installed at the health centers throughout the project area. Since FUNAE is the leading government agency in the promotion and utilization of renewable energy in Mozambique, it has been making efforts to seek funding from international donors for the maintenance of facilities to be installed and other corresponding funding requirements, such as replacement batteries, etc.

5.5 Possibility of Enlisting the Project as a CDM Project

The project envisions the practical use of solar power as an alternative energy source as against fossil fuel, and aims to reduce greenhouse gas (GHG) emissions especially CO2 which will be made possible through the CDM. The applicable methodology approved by UNFCCC is the AMS-.A (Electricity Generation by User), which is applicable in the renewable energy utilization project whose power output is less than 15MW and which will reduce around five t-CO2 per year.

The possible volume of CO2 reduction was estimated through the formula following the AMS-I.A guideline and through the assumption that a solar power system will be installed in primary schools that have three classrooms and two staff houses, as follows:

$$BEco_2y = EBLy * EFco_2$$

Where; BEco2y Annual baseline emission in t-CO_2

EBLy Annual baseline energy in kWh

EFco2 CO_2 emission factor in t-CO_2/kWh

The applicable default value, on the assumption that the system will replace the diesel fueled power generation system, is 0.8kg CO2e/kWh. Assuming that the number of units required by the project is 100 and the emission trade unit value is US$25/t-CO2/y the annual emission trade value would be USD2,500 as shown in Table 5.5.1.

Table 5.5.1 Estimates of Annual Emission Trade Values

Power Consumption Volumes	Number of Operation Days	Emission Reduction Volumes (t-CO2)	Annual Emission Reduction Volumes
kWh/d	Days	Kg/kWh	t-CO2/y
5.5	350	0.8	1.54
Number of Units	**Trade Value**	**Annual Revenue**	**10-year Accumulation**
Unit	US$/t-CO2	USD/y	USD
100	25	2,500	25,000

Source: JICA Study Team

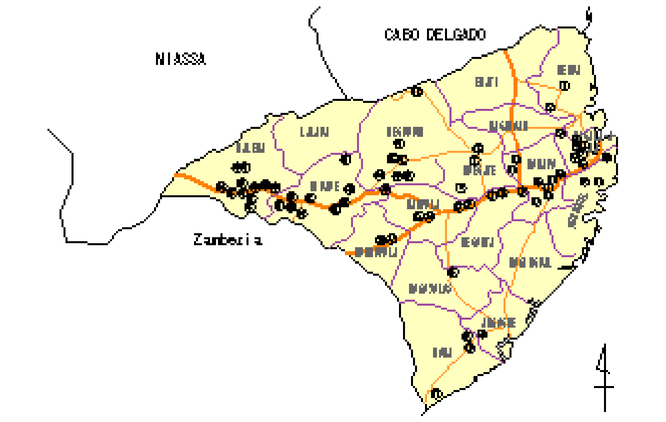
Estimated annual revenues will not be large enough to allow the purchase of replacement batteries. However, the amount that can be collected can be used in the purchase of small spare parts necessary for maintenance especially those that can be bought from local markets.

CHAPTER 6.　Field Survey Results

6.1　Results of Survey in Candidate Sites

In collaboration with FUNAE, 101 candidate primary schools and health centers (see Figure 6.1.1) were surveyed to obtain basic data and their actual power requirements.

Candidate Primary Schools (70)	Candidate Health Centers (31)



List of Schools

No	Schools	No	Schools	No	Schools	No	Schools
1	ESG1 de Mazua	19	EPC de Muapula	37	EPC de Cazuzo		
2	EPC de Cava	20	EPC de Namagula	38	EPC de Umuato		
3	EP1 de Macupe	21	EPC de Namaluco	39	EPC de Mecuasse		
4	EPC de Vida-Nova	22	EPC de Lapa	40	EPC de Ratane		
5	EPC de Munlatala	23	ESG1 de Lmala	41	EPC de Colemela		
6	EPC de Nahavara	24	EPC de Chipacane	42	EPC de 1 Maio		
7	EPC de Patone	25	EPC de Mucheleque	43	EPC de Mathayra	55	EPC de Mepuhi
8	EPC de Zangane	26	EPC De Catipa	44	EPC de Roeque	56	EGS1 de Niosse
9	ESG1 de GerGer	27	EPC de Nassuruma	45	EPC de Niessa	57	EPC de Muralelo
10	EPC de Mahelene	28	EPC de Mecutamala	46	ESG de Riane	58	ESH de Muralelo
11	EP1 de Shinhote	29	EPC de Maganha	47	EPC de Minuco	59	E. Familiar Rural de Nataleia
12	EPC de Namarral	30	EPC de Ivate	48	EPC de Inchua	60	ESG1 de Chihulo
13	EPC de Murromone	31	EPC de Nacololo	49	EP1 de Impauane	61	EPC de Chihulu
14	EP1 de Muelege	32	EPC de Muezia	50	EPC de Naipa	62	EPC Nampurro
15	EPC de Napala	33	EPC de Mulapane	51	EPC de Metotia	63	EPC 19 Outubro
16	EPC de Micolene	34	EPC de Natoa	52	EPC de Nacuacuali	64	EPC de Canhunha
17	EPC de Mucujua	35	EPC de Nathepo	53	Escola Familiar Agro-Técnica	65	EPC de Nacololo
18	EPC de Natete	36	EPC de Captpa	54	EPC de Nanrele	66	EPC Metacusse

List of Health center

No	Health Center	No	Health Center	No	Health Center
1	Baixo Pinda	11	CS de Nacopa	21	P.S. de Muleheia
2	C.S. de Caleia	12	C.S. Napala	22	P.S. Umuato
3	mahelene	13	C.s. de Chereque	23	C.S de Popue
4	Covo-Ger-Ger	14	C.S Namahia	24	CS de Momane
5	C.S. Chihire	15	C.s. Kavula	25	CS de Unidade de Moçambique
6	P.S. de Napala	16	CS de Mecutamala	26	CS de Chica
7	Miserapane	17	CS de Briganha	27	CS de Mecuasse
8	C.s. de Mucujua	18	P.S. Saua-Saua	28	CS de Riane
9	C.S. Natete	19	P.S. Mucova	29	CS de Murripa
10	C.S. Muatuca	20	C.S. Mutolo	30	CS de Murralelo
				31	CS Nataleia

Figure 6.1.1　Location Map of Candidate Sites

Source: JICA Study Team compiled the data obtained from the site profiling survey.

(1)　Results of Survey on Primary Schools

Seventy candidates mainly from primary schools were surveyed, as shown in Table 6.1.1. The average number of classrooms was around five. School buildings that had three classrooms comprised the largest group. The average number of staff houses per primary school was less than one with many other schools having no staff houses. All primary schools surveyed currently run two shifts with no night classes. The holding of evening classes in the primary schools will be made possible when the schools are electrified.

Table 6.1.1 Profile of Candidate Primary Schools

Classification	No.	Average Size of Facility per School			No. of Pupils				Average No. of Teachers
		Average No. of Rooms	Average No. of Admin. Rooms	Average No. of Staff House	Average No. of Rooms			Average No. of Admin. Rooms	
					First Shift	Second Shift	Total		
EPC	57	4.9	2.5	0.6	434	208	684	138	11.8
EP1	4	3.8	2.0	0.5	292	92	271	102	7.3
ESG	3	7.3	3.0	0.3	172	98	367	36	12.0
ESG1	4	6.0	2.3	0.3	-	-	207	71	10.8
E.F R	1	2.0	4.0	0.0	-	-	0	37	6.0
Escola Familiar Agro-Técnica	1	3.0	6.0	0.0	-	-	735	13	6.0
Total	70	5.0	2.6	0.5	397	185	626	124	11.4

Legend: EPC: Primary School (1st – 7th grade); EP1: Primary School (5th – 7th grade); EPG: Secondary School (8th – 12th grade);
EPG1: Secondary School (8th – 10th grade); Escola Familiar Agro-Technica: Agriculture Technical School

Source: JICA Study Team compiled the data collected by FUNAE

(2) Results of Survey on Health Centers

Candidate health centers were mainly of the CS-II Type, which is smaller than the CS-I. The survey was carried out in 31 sites, as shown in Table 6.1.2. The average number of rooms in the CS-II Type is five, including a consultation room, delivery room, and a laboratory. Around 60 consultations per day and around 30 deliveries per month are done in the health centers. Some CS types (with facility for maternal delivery) have staff houses, while most PS types (without facility for maternal delivery) have no staff houses.

Table 6.1.2 Profile of Candidate Health Centers

Classification	No. of Sites	Average per Facility				
		Average No. of Rooms	Average No. of Staff Houses	Average No. of Rooms	No. of Consultations per day	Average No. of Rooms
CS I	2	14.0	1.5	4.5	135.0	80.0
CS II	19	5.0	1.1	2.1	57.9	36.8
PS II	10	3.6	0.1	2.7	58.9	30.6
Total	31	5.1	0.8	2.4	63.3	31.3

Legend: I and II indicate size of facility (I>II); CS: With delivery room; PS: Without delivery room.

Source: JICA Study Team compiled the data collected by FUNAE.

6.2 Estimation of Power Needs by Project Site

The power needs of each project site were estimated based on the results of the survey conducted by FUNAE, as well as through field observations conducted by the Study Team, which included reviews of relevant documents and reports. Below is a summary of the field survey results.

6.2.1 Expected Electric Appliances

Between January 18, 2012 to February 10, 2012, as part of the preparatory study and to create site profiles, FUNAE carried out several interview surveys in the 70 primary schools and 30 health centers. The results allowed a better reading of the average size of primary schools as well as the power requirements of health centers. Table 6.2.1 shows the types of electric appliances and their power requirements. The use and purpose of these electric appliances are summarized in Table 6.2.2.

Table 6.2.1 Electric Appliances Needed at Project Sites and their Power Requirements

(Unit: Watt)

Lighting System (LED)	Mobile Phone Battery Charger	Vaccine Refrigerator	Computer	Television	DVD Player
6	10	1,100	100	50	30

Source: JICA Study Team

Table 6.2.2 Electric Appliance Usage

Electric Appliance	Primary School	Health Center	Staff House
Lighting System (LED)	Night class, office work, external lighting, etc.	Consultation, medical care, operation, delivery, office work, etc.	Night activities, office work
Mobile Phone Battery Charger	Telecommunication, revenue collection, etc.	Telecommunication, revenue collection, etc.	-
Vaccine Refrigerator	-	Vaccine and medicine, storage.	-
Computer	School administration, learning, IT lessons, etc.	Administration, registration, records, etc.	Recording, studying, office work etc.
Television	Audio-visual education	-	Audio-visual education, lessons for teachers and doctors, etc.
DVD	Audio-visual education	-	Audio-visual education, lessons for teachers and doctors, etc.

Source: JICA Study Team based on the results of the survey of candidate sites and standards.

Since the surveyed candidate primary schools and health centers have yet to be electrified, none of the above-listed electrical appliances exist. Quality of education is expected to substantially improve when power becomes available to the primary schools.

6.2.2 Justification of Necessity for Electrical Appliances

(1) Lighting Apparatus

A lighting system is indispensable for the holding of evening classes. Reports have shown that many primary schools had adults in their day classes, contributing to classroom congestion and affecting the quality of education for children.

The installation of a lighting system not only allows the holding of night classes but it also allows the ability of the health centers to handle pregnant mothers that give birth at night, thus improving the quality of health services and helping decrease mortality rates among babies and mothers. This means that a proper lighting system is a basic component of the project and integral part in improving the services of primary schools and the health centers. Perimeter lighting is also needed to ensure the safety of people visiting primary schools and the health centers at night.

(2) Mobile Phone Battery Chargers

At present, the mode of communication between primary schools and the outside world is primarily done through physical means - by people and transport. However, if the primary schools can be equipped with battery chargers for mobile phones, the mode of communication will be faster and instantaneous because it would allow anyone in the school to make a cell phone call to outside environs. This will not only address the communication needs of school administrations but will also help in the communication needs of the village where a primary school is located. The communication system will not only help in the vitalization of the communities where the schools are but more significantly, it will make the maintenance of the solar power generation units easier through the possibility of instantaneous contacts with engineers and supervisors outside the communes. If the use of a mobile phone or the charging of cell phone batteries by residents and villagers in the primary school becomes regular it could be possible for the school administration to collect charges from users. The collected charges can be gathered to help in the maintenance budget and the purchase of some parts such as the replacement of damaged parts, lighting apparatus, etc. This scheme underscores the importance of having battery chargers for mobile phones in the schools.

(3) Lighting System for Staff Houses

Most of the teachers working in the rural primary schools have studied or come from urban areas and only a few are actual residents in the villages where the primary schools and health centers are located. However, several teachers do reside in the project village with their family members. To a large extent the quality of education depends on the quality of teachers and their level of motivation. The clear assumption is that the quality of education will increase as the living environment for teachers improve.

(4) Health Centers Equipped with Refrigerators

One of the most important equipment in a health center is a refrigerator because it stores vaccines, medicines and other important medical accouterment. The availability of a refrigerator means better storage of medicines and medical paraphernalia. This amounts to better survival rates and a decline in mortality rates in rural villages through such aspects as the vaccination of newly born babies, the immunization of children and adults against common diseases, and medical assistance for injuries and mishaps. The role of electrification in the improvement of health care in the rural areas is so indispensable that without it mortality rates would be high.

(5) Computers

School administration and the quality of learning can be improved through the use of computers. This can be done through better administrative procedures and the improvement of learning for children through information technology thereby helping minimize the digital divide that has been apparent in the rural areas.

(6) Audio-Visual Equipment (Television and DVD Players)

The quality of education depends on both learning materials and the quality of teachers. Properly designed learning materials and learning modules using audio-visual equipment helps improve the quality of learning. This is especially true when the number of well-trained teachers is inadequate and such visual aids help fill up this deficiency. However, audio-visual education using educational TV programs will not be effective unless teachers properly guide students. Teachers handling this type of learning do not have to be qualified teachers but merely trained in the use of educational TV programs in classroom settings.

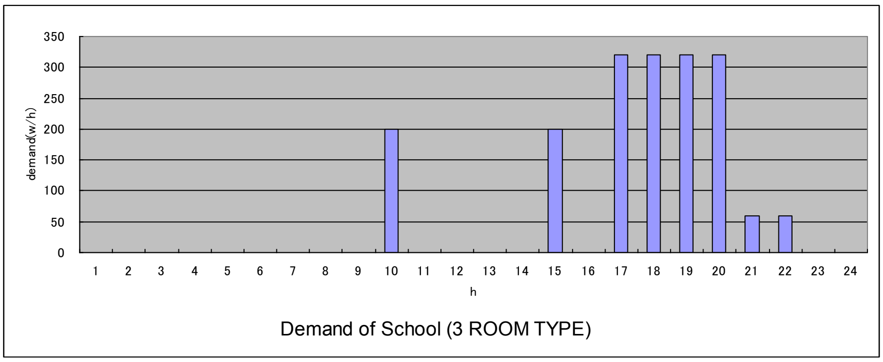
Audio-visual learning materials, such as educational TV programs, can be copied in a CD format. These CDs can then be distributed in the schools and used in accordance with the program designed for audio-visual education. The language used for such learning materials should be Portuguese so that they can be produced locally or obtained from Portugal and/or Brazil as these countries have produced a number of such educational TV program for distance education.

Nonetheless, the overarching goal that will help improve the quality of education is the provision of electric power to the non-electrified primary schools. The provision of power source, connectors, television sets; DVDs, etc., are mere add-ons in the overall benefits of the project. A mere requisite is that distance education and learning using TV and radio can now commence in many rural villages in Mozambique.

6.2.3 Daily Power Loads

Daily power loads are estimated by multiplying the required power of each equipment with the hours of their operation needed per day and when the estimated power needs of each equipment is totaled. Figure 6.2.1 illustrates the power need by hour.

Average daily loads were estimated based on the results of the profiling of each candidate site and the determination of the standard size of each facility, as shown in Table 6.2.3. As the power needs of a school is shifts on the night classes an increase in the number of rooms will not substantially affect the total power needs of the school. This assumption is similar to the equation of the power needs for the health centers. Although the numbers of rooms might increase, or the number of lighting apparatus will multiply, this will not affect much the total power needs of the health center.



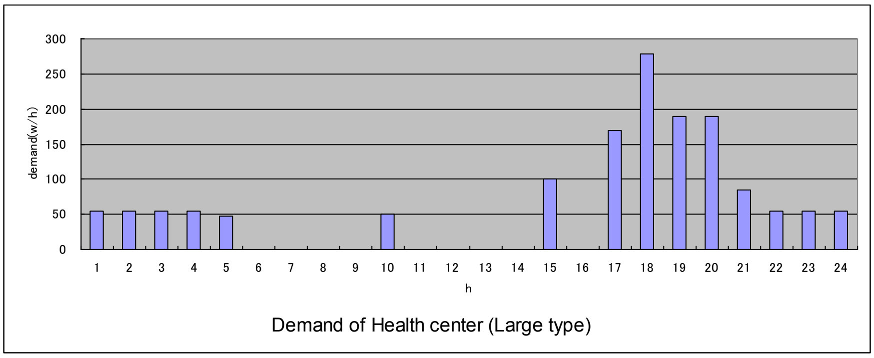


Figure 6.2.1 Power Needs per Hour per Day (Health Center, Primary School)

Table 6.2.3 summarizes the average daily loads by type of facility, which was estimated by multiplying the average required power of each electric apparatus and its estimated hourly use.

Table 6.2.3 Average Daily Load Estimated by Type of Facility

Site	Type	Daily Load (kWh/d)	Remarks
School-1	3CR＋2AO＋1SH	1.8	Standard-sized primary school
School-2	5CR＋2AO＋1SH	1.9	Average-size candidate sites
School-3	8CR＋3AO＋1SH	2.6	Large-sized primary school or secondary school
CS-1	6RM（1ER＋1DR＋1AO＋1LAB＋1BR＋1WR）＋2SH	1.5	Standard-sized health center
CS-2	10RM（2ER＋1DR＋1AO＋1LAB＋4BR＋1WR）＋2SH	2.1	Large-sized health center
Refrigerator for Vaccine Storage	1 unit	1.1	

Legend: CR (Classroom), AO (Administration Office), SH (Staff House), RM (Room), ER (Examination Room), DR (Delivery Room), LAB (Laboratory), BR (Bed Room), WR (Waiting Room).

Note: The power needs was estimated assuming that 2 rooms will be used for night classes disregarding the total number of class rooms.

Source: JICA Study Team based on the compiled data collected by FUNAE

6.3 Confirmation of Candidate Project Sites

6.3.1 Requirement of Land Space

Primary schools and health centers are often located in the central part or front part of villages with populations that range from 500 to 2,000. All the sites directly observed by the Study Team in the field survey had sufficient space of around 20-40m^2 either adjacent to the school or health center, or within 30m from either a school building or health center. The result of the site profiling and site selection by FUNAE showed that all the candidate sites had an ample land area that could be used to install a power generating unit. However, it was also noted that in some candidate sites the school buildings where surrounded by trees with thick foliage and with heights that ranged from five to six meters. It was assumed that wind speeds in these sites may not be sufficient especially during weak wind seasons.

6.3.2 Security and Preventive Measures Against Theft

The Study Team also took note that some primary and secondary school sites had their solar panels stolen. According to the experience of FUNAE the instances of theft was more common in the northern area. However, all solar panels stolen were installed on a simple steel frame and fixed by simple bolts and nuts. They were also installed just a meter above the ground, as shown in the photos below.

Missing solar panels of health center near Manapo District were stolen.

A complete set of solar panels installed in the secondary school was stolen in Mecuburi District. Currently, power is supplied by a small diesel power generator set.

To counter theft and vandalism on the solar power systems, FUNAE advises villagers to organize a solar panel security committee. It likewise encourages villagers to be the custodian and protectors of the solar generating system to protect the system from theft and vandalism.

The measures proposed to prevent theft and vandalism of the solar panels are the following:

- Most of the panels that were stolen were installed not in plain sight but were hidden from view, such as in corner areas, had their view obstructed by structures, or they were placed in areas where their visibility was low. Panels should be located in plain view of villagers, passersby, or the neighborhood.
- In most cases theft occurred during nighttime. Therefore, the solar panels should be placed in a well-lighted area and one that is lighted through an external lighting apparatus. The lighting of the panel and the system should already be considered in the initial stage of project design.
- Most of the stolen solar panels had heights that were lower than the height of an ordinary person. The solar panels should be installed higher than the height of an average person.
- Most of the stolen panels were fixed to their frames through normal bolt and nuts. The fixing of the panels should be done using special bolts and nuts, i.e., using hexagonal bolts which make dismantling difficult.

6.3.3 Possibility of Executing Daily Maintenance

(1) Daily Maintenance

The possibility of conducting daily inspections or regular maintenance work on the solar power systems is obviated by the fact that all the candidate primary schools and health centers are located several kilometers away from a trunk road. The road condition accessing from a trunk road to these locations are often very bad and rough. Under these circumstances, inspection and simple maintenance work should be preferably done by somebody in the candidate village or commune itself.

The persons who would have the responsibility of maintenance should be selected by the committee charged with the operation and maintenance organized by each village or commune. It should be noted, however, that in the rural areas the number of such qualified persons who are capable of conducting inspections and maintenance, or even those that can undertake plain inspections or a simple repair work, is quite limited.

As discussed in the preceding section, the illiteracy rate of the adult population in the rural villages is more than 68%. Therefore, the technical manual for maintenance works should be prepared not only in Portuguese, which is the primary language in Mozambique, but also in the local language or dialect used in the specific village. The persons selected by the village to conduct inspection and repair should take the maintenance lessons provided by FUNAE.

Such minute care may form the basis in the establishment of the daily maintenance procedure in each village. However, if possible, qualified and competent technicians should periodically tour all villages that have been installed with solar power systems to train or educate the necessary personnel and people in the villages especially in the regional branch office of FUNAE. Budget appropriations to cover personnel expenses and direct expenditures, such as transport costs, etc., are quite necessary for FUNAE management.

(2) Institutional Setup of Maintenance System

At present, both number of technical personnel (quantity) and level of skills (quality) are considered as insufficient within the organization designated to carry out the inspection and maintenance of power generating facilities in FUNAE. Therefore, the maintenance of facilities is vested substantially to the owner of the facilities, which are the Ministry of Education for the facilities installed at primary schools and the Ministry of Health for the facilities installed at rural health centers, respectively. Both owners of facilities have let private entities responsible for the maintenance of facilities under service contracts. However, it is imperative that FUNAE itself organize properly the technical and management personnel who are capable to undertake the role of managing and controlling such service contracts with the private entities.

The skills and management capability of the Ministry of Education and the Ministry of Health for the maintenance of power generating facilities are lacking as well. The cost requirement to conduct proper maintenance of solar power generating facilities is considerably high and thus very necessary to carefully study and confirm the organizational structure, institutional setup, methods of maintenance, preparedness, technical and managerial levels of relevant ministries, FUNAE and private entities for maintenance services.

The cost for the maintenance services to be undertaken by the supplier (contractor) of power generating facilities has not been estimated at the time of this study since the number of project sites and units to be installed were unknown. The cost for the execution of the project and the total life cost comparison among different power generating systems can be estimated more accurately when the number and location of project sites are specified. Such cost should then be included in the budget for the project.

6.3.4 Present Condition of the Solar Power and Wind Power Systems

(1) Solar Power Generation System

As shown in Table 2.3.2, the total number of installed solar power system (average rated output is 1.0kW) in Nampula Province is almost 300 units. During the course of the field survey the Study Team observed a number of solar power facilities installed in Nampula Province and found various facilities installed by organizations other than FUNAE are left idle because of complete discharge of battery, improper maintenance of battery, and broken or stolen solar panels. Although the Study Team did not observe any substantial problem on the existing solar power generating facility managed by FUNAE, several minor problems were observed such as breakage of lighting apparatus, etc., which hinder the optimum use of the solar power generating system.

(2) Wind Power Generation System

The introduction of wind power generation system in Mozambique has lagged behind the introduction of solar power generating system. FUNAE has been carrying out a resource evaluation study for wind power generation and had installed some wind velocity measurement equipment (installed on pole 10m high from ground level with data logger) at Tofinho in Inhambane Province. The result of wind condition survey suggests that there are several potential locations for a wind power generation system.

It was learned that the 300kW wind power generation project of the South African power company ESCOM is likely to be commissioned. The power generated by this wind power generation system is designed to be supplied to the grid; however, it could not be confirmed on whether it had become operational.

There is no power generating system in the Northern Region (Nampula, Cabo Delgado and Niassa provinces) at present. As discussed in the preceding sections, there exists a potential area for wind power generation along the coastal area of Nampula Province; however, it is determined that only a small-sized wind power generating system that will start power generation at only at just a 3 m/s wind velocity is possible and not a large capacity wind power generating system, so that it may not be recommendable. In addition, it was noted that FUNAE has neither the experience of formulating a plan nor installation as well as maintenance of wind power generation systems yet.

6.3.5 Conditions of Access Road to Candidate Sites

The geographical location of candidate sites for the project and the subject sites for field survey are shown in Figure 6.1.1. The map shows that many of these sites are located at some distance away from the trunk road. Access to most of these sites is mostly through earth roads, which are rough and sometimes run across streams and dry river beds. Even the trunk roads that are just a few kilometers away from a site are in very poor condition.. In addition, many bridge crossings are dangerous and some bridges have been partly washed away by floods. Ordinary vehicles and not four-wheel drive will find it very difficult to reach the candidate sites. This constraint on accessibility not only makes the transport of materials and facility components to the sites very difficult during the construction stages but will likewise prove to be difficult for regular site visit of engineers and technicians for the maintenance of the systems and their facilities.

Conditions of Access Road to Candidate Project Sites

The result of the site profiling survey carried out during the study period by FUNAE shows that an average distance of an Administration Center, or District, to a candidate site is 34 km for primary schools, and 32 km for the health centers. The needed transport time is between three to four hours depending on road conditions. However, the survey showed that return trips could be made within a day.

The means to transport equipment and components to the sites through rough and dilapidated access roads should be studied sufficiently when the construction plan is prepared. The use of heavy trucks is not also advisable due to the type and condition of the roads. This transport constraints will require the dismantling of equipment or components to make them lighter and so that they can be transported by half-trucks or four-wheel drive vehicles. The dismantling of parts should consider having the weights of individual parts or components lesser than the maximum weight that can be handled by a worker so that their lifting by a crew member will be possible. This means that most of the equipment, or their parts and materials, should be designed as compact as possible.

The result of cost-efficiency comparison among various power generating systems such as solar power, wind power, solar/wind hybrid power, and diesel engine driven power that satisfy the power needs shows that the least cost solution is the diesel power. However, this result is purely based on mathematic calculation of cost and effect. When the cost incurred for transporting fuel necessary for operation of diesel power generator through such a very poor road the cost effectiveness will sharply decrease. An appropriation of budget for continuous payment to purchase the diesel fuel is also considered as difficult.

CHAPTER 7. Comparison of Applicable Electrification Technologies

7.1 Comparison of Technical Options

The following four electrification technologies utilizing renewable energy were identified and their comparative analysis were conducted based on the weather conditions and the geography along the Nacala Corridor, which traverses, from east to west, the central part of the Nampula Province. The identified applicable electrification technologies were: 1) solar power system, 2) wind power system, 3) solar and wind power hybrid system, 4) Jatropha bio-diesel system, 5) solar power and Jatropha bio-diesel hybrid system, and 6) diesel power system. The comparative analysis included a SWOT assessment. (See Appendix A1-7.3)

7.2 Appropriate Technology of Renewable Energy Utilization

7.2.1 Examination of Appropriate Renewable Energy Technologies

Most of the appropriate technology that adopted an independent type power generation system especially those that met the requirements of the primary schools and health centers in Nampula province based on the weather data obtained through this study were properly examined. The result of such examination is summarized below. (See details in Appendix 3)

<Photovoltaic Power System>

- The study showed that it is possible to receive constant solar insolation throughout the year in Nampula Province. However, solar insolation decreases from April to June and from December to January in parts of the coastal area and in the inner western area. If proper power is to be obtained during these low periods of insolation, the system designed for such periods becomes excessive during periods of high insolation. It is judged that the central part of Nampula Province is suitable for the installation of solar power systems throughout the year.
- The size of the systems meeting the power demands, for both the primary schools and health centers, are as shown in Table 7.2.1.
- Battery size is determined to be the minimum size in maintaining balance at more than 80% under normal operations.
- It is assumed that standard-sized primary schools have three or five classrooms and those they require a solar power system with a 1.8kW capacity. In the case of large-sized schools with an average of eight classrooms the required solar capacity would be at least 2.6kW.
- The health center (excluding system for vaccine refrigeration) and those with six rooms require a solar power system with a 2.6kW capacity. Those that have ten rooms require a system with a 3.2kW capacity.

- For a center with a vaccine refrigerator the most appropriate configuration is a solar power system with a 0.8kW capacity or a battery capacity of 7.2kWh. This system ensures continued operation for more than 5 days without recharging.

<Wind Power>

- Table 7.2.1 shows the appropriate size of wind power system by region to meet with the power demand of primary school and rural health center in Nampula Province.
- As the power output demand at each site does not exceed 1.0kW, the wind power system evaluated is limited to a small-sized wind power system (1kW – 50kW)
- Small wind turbines commonly generate power from wind speed level of 3m/s. The appropriate area for wind power generation is an area where the wind blows constantly at more than 3m/s.
- The wind in the central part of Nampula Province (Nampula, Mecuburi, and Meconta) is generally weak throughout the year, and the period where wind speeds exceed 3m/s is relatively short and thus makes it difficult to obtain sufficient power to meet demand in the area. This makes the central part of Nampula Province not suitable for a wind power project.
- However, its western area, such as Malema, is buffeted by strong winds during certain seasons that could provide substantial annual power generation. The downside in this area is that it has substantial fluctuations that go on for weeks especially during the rainy season. A remedy in this regard would be enlarging the size of batteries. However, this tack will not be cost effective and realistic.
- The coastline is buffeted by strong winds throughout the year which provides an opportunity to introduce wind power generation units in the area. The size of system necessary to meet the power demands of the primary schools and health centers are shown in Table 7.2.1.
- It has been ascertained that the power demands for the primary schools can be met by a wind power generation system with a 1.0–5.0 kW capacity and a battery capacity of 30-60kWh. However, the cost for this system is quite high around JPY9 to18 million.
- Since wind conditions differ by geography and climatic conditions it is important to carry out field surveys that include the measurement of wind speeds, and other variables. It should be noted that system performance likewise depends in the feature of the site where the wind turbine is installed.
- Social and environmental factors will likewise be taken into consideration in the design of the system, such as noise, recycling of batteries, etc.
- Estimates of the power output in the study were based on wind speed data gathered ten meters from the ground. Some of the primary school and rural health centers have five-meter high trees in their vicinities. These trees commonly provide shade to students, patients and workers. Thus, it was considered that the wind turbines should have an average height of around 7–10 meters from the ground to obviate the adverse effects of the trees on the winds and the wind's effect on the turbines. The detailed design of the wind power system should

carefully take into account the height of the wind turbines vis-a-vis the physical condition of the site and all wind-obstructing objects in the site. It is preferable to carry out wind condition survey at selected location(s) by wind velocity measuring equipment for a long period (6 months to 12 months). <See Appendix-A4, Wind Measurement Method>

- In case that the wind power generation system is operated by wind power alone, the location where the average monthly wind velocity is less than 5 m/s at the lowest month is considered as not appropriate.

<Solar Power and Wind Hybrid Power System>

- A solar and wind hybrid power system can be set up in the coastal region and the inner western region because the wind speeds in these areas are relatively strong.
- Table 7.2.2 shows the required size of the system for primary schools and health centers.
- Since the wind speeds in the coastal area is more constant than in Malema, or in the inner western region, the required size of a solar system can be smaller (Coastal Region: 0.4kW–1.0kW, Western Region: 0.8–1.4kW), only half this size is needed in the case of solar power system alone.
- The cost of the solar power and hybrid wind power system is lower than the cost of solar power alone. The merit of adapting a hybrid solar and wind power system is that it increases the stability of system. It likewise reduces the required area for solar power system and minimizes the size of batteries.
- The most appropriate type of wind turbine for the solar power and small wind hybrid power system is a vertical and a gyro-mill wind vane type. The advantage of this type of wind turbine is that it makes it possible to receive wind from any direction and its power generation efficiency is high because the lifting force generated by the vanes is turned into a revolving force.
- The case that the solar/wind hybrid power generation system location is where the average monthly wind velocity is less than 3.5 m/s at the lowest month is considered as not appropriate.

7.2.2 Consideration of Batteries

Since power generation through renewable technology depends on natural energy, its generated power is basically not stable and fluctuates. This shows the indispensability of power batteries to the system because they provide power at any given time following the generation. However, the cost of batteries is considerably high taking up 35–60% of the total capital costs.

In other words, the most important factor in the design of an appropriate renewable energy system is how to determine the most effective storing capacity and how to prolong the life of a battery. For example, it is needed to foresee the tolerance of a battery's storage capacity to ensure that power supply continues in the wind power generator even during days when wind speeds are weak or when the sun is not shining brightly for the solar power generators.

Battery sizes were determined by studying weather fluctuations throughout the year and on fluctuations within a day based on collected data from the weather data simulation. It is assumed that the maximum number of days in a year wherein a battery's capacity will decrease by more than 80% is less than 30 days, less than 5 days for a capacity decrease of more than 50%, and 5 days for a decrease of not less than 30%.

7.2.3 Examination and Selection of Battery Type

The application of valve regulated lead-acid battery for cycle use was examined and selected for the independent solar power system and the solar power and wind hybrid system taking into consideration its long expected life for around 5 years at least requirement of maintenance.

At present, there are no proper facilities and industrial waste recycling operators to treat used lead-acid batteries and their lead and acid waste. The waste treatment of batteries has been vested to private companies in South Africa. However, the environmental load of waste treatment for large-size batteries in a large volume is quite high. (For example, the weight of one lead-acid type battery planned to be installed in a 1.0kW solar power system is around 500kg. Since the number of solar power system totals 100 units, the total weight of batteries to be treated will be around five tons.) On the other hand, the waste treatment for a stationary type lithium battery is relatively easier. This makes the lithium battery superior than a lead-acid battery. Due to its advantages and longer life span, the use of lithium batteries has been promoted in Japan although their use is not yet common in developing countries. However, even though it has been considered that the use of lithium batteries has various merits that can be applied in the project, its application in the project has been relegated to a mere reference. The utilization of renewable energy and widespread of use of solar power all over the world, the production output of stationary type batteries in the solar power system has rapidly increased and their relative research and development has progressed dynamically. Consequently, with the improving technology the lifespan of batteries will become longer and the inherent costs of maintaining and operating such batteries will become cheaper in the years to come.

Taking the factors mentioned above, it has been considered that the use of a lead-acid battery with a life span of at least five years is recommended for the project. Battery life however may differ depending on operating conditions. A careful examination of the most effective type of battery in the realization of the project is thus imperative.

7.2.4 Appropriate Size of Power Generation System

The appropriate sizes of power generating system were examined taking into account the conditions of radiation, wind conditions, type of power generating system, scale of system, power demand, etc., by region, type of power generation system and facility as shown in Table 7.2.1.

Table 7.2.1 Power Demand by Facility and Required Size of System by Type of Power Generation Method

Area	Facility / Method of Power Generation	Unit	School-1	School-3	Health Center-1	Health Center-2
	Power Demand	kWh/Day	1.8	2.6	1.5	2.1
Coastal Region	Photovoltaic Power Alone					
	Solar Power System	kW	1.0	1.0	1.0	1.2
	Battery	kWh	7.2	9.6	7.2	7.2
	Solar Power and Wind Hybrid System					
	Solar Power	kW	0.2	0.2	0.2	0.2
	Wind	kW	1.0	1.0	1.0	1.0
	Battery	kWh	4.8	7.2	4.8	4.8
	Wind Power Alone					
	Wind	kW	1.0	1.0	1.0	1.0
	Battery	kWh	9.6	14.4	9.6	12.0
Inner Western Region	Photovoltaic Power Alone					
	Solar Power System	kW	1.0	1.4	1.0	1.2
	Battery	kWh	7.2	9.6	7.2	7.2
	Solar Power and Wind Hybrid System					
	Solar Power	kW	0.4	0.6	0.4	0.4
	Wind	kW	1.0	1.0	1.0	1.0
	Battery	kWh	9.6	12.0	7.2	9.6
	Wind Power Alone					
	Wind	kW	3.0	3.0	3.0	3.0
	Battery	kWh	16.8	24.0	14.4	19.2

Source: JICA Study Team

7.2.5 Comparison of Total Lifetime Costs

The evaluation of total life cost by type of power generation system; namely, [Option-1] Solar Power System with Lead-Acid Battery; [Option-2] Solar Power and Small Wind Hybrid System with Lead-Acid Battery; and [Option-3] Wind Power System with Lead-Acid Battery, was carried out. Cost comparisons were conducted using six kinds of assumptions, as shown below. The analysis referenced the performance of standard products available in Japan.

1. Project Life: 20 years
2. Initial cost of solar power generating system per 1kW: JPY 500,000.
3. Initial cost of wind power generating system per 1kW: JPY 1,500,000.
4. Cost of stationary type lead-acid battery per 1kWh: JPY 150,000.
5. Period of battery replacement: 5 years or 3 times in a project life
6. Replacement of major components for controller: 10 years (1 time in a project life)
7. Annual spare parts cost (% of the body cost): For solar power system, 1% For wind power system, 2%
8. Annual maintenance cost: Approximately USD1,000 per site

The unit cost of a kW power generating system and the kWh battery cost were referred to the averaged unit cost that was publicly issued in several promotional materials prepared and issued by the Japan Small Wind Turbines Association and several Japanese battery manufacturers. (See Appendix A3 for details)

Table 7.2.2 shows the result of comparison on the initial capital cost and Table 7.2.3 shows the result of comparison on the total life cost by region and power generating system, respectively. (See Appendix A4 for details)

Table 7.2.2 Comparison of Initial Capital Cost of Power Generating Systems

Area	Facility / Power Generating System	School-1	School-3	Health Center-1	Health Center-2
	Power Demand (kWh/day)	1.8	2.6	1.5	2.1
Coastal Region	Solar Power Alone	1.00	1.00	1.00	1.00
	Solar Power and Wind Hybrid	0.96	0.94	0.96	0.94
	Wind Alone	1.54	1.60	1.54	1.81
Inner Western Region	Solar Power	1.00	1.00	1.00	1.00
	Solar Power and Wind Hybrid	1.59	1.44	1.29	1.56
	Wind Alone	3.10	2.99	2.79	1.81

Note: System costs were estimated based on the averaged unit cost that include the cost of installation and maintenance. The ocean freight from Japan to Mozambique, inland transportation cost, and cost of the works needed in Mozambique such as installation cost, construction cost of battery room, etc., are not included. Cost estimates of these works will be needed at a later stage.

Source: JICA Study Team

Table 7.2.3 Comparison of Total Lifetime Cost of Power Generation Systems

Area	Facility / Power Generating System	School-1	School-3	Health Center-1	Health Center-2
	Power Demand (kWh/day)	1.8	2.6	1.5	2.1
Coastal Region	Solar Power Alone	1.00	1.00	1.00	1.00
	Solar Power and Wind Hybrid	0.92	0.92	0.92	0.91
	Wind Alone	1.44	1.53	1.44	1.69
Inner Western Region	Solar Power	1.00	1.00	1.00	1.00
	Solar Power and Wind Hybrid	1.48	1.37	1.21	1.46
	Wind Alone	2.65	2.67	2.38	2.88

Note: System costs were estimated based on the averaged unit cost that include the cost of installation and maintenance. The ocean freight from Japan to Mozambique, inland transportation cost, and cost of the works needed in Mozambique such as installation cost, construction cost of battery room, etc., are not included. Cost estimates of these works will be needed at a later stage.

Source: JICA Study Team

As shown in the tables above, the total lifetime cost of solar power and wind hybrid systems is lower than that of a solar power system for sites located in the Coastal Region where the wind condition is considered suitable for the operation of wind power generation system. On the other hand, a solar power generating system is considered as more superior than the other systems and thus considered as the solar power generating system appropriate in most of the areas (central part and inner western regions) in Nampula Province. More accurate comparison of power generating systems by region can be made when the cost of systems become available with the confirmation of ocean freight, inland transportation cost, construction cost for battery house, total construction cost, installation cost, total maintenance cost, etc., and when the wind conditions are confirmed and the number of sites and units of equipment are determined.

7.2.6 Integrated Evaluation of Renewable Energy Utilization Technologies

(1) Solar Power System and Wind Power Generation System

The comparison of total lifetime costs of independent types off-grid power generation utilizing renewable energy for primary schools and health centers in Nampula Province reveals that cost-effectiveness of the solar power and wind hybrid system is a bit higher compared to the solar power systems in the Coastal Regions where wind condition is appropriate for the use of small-sized wind power generation systems.

It should be noted that the solar power and wind hybrid power generation system is a relatively new technology not only in the project area but in Mozambique as a whole. It was ascertained that the most appropriate technology utilizing renewable energy in most parts of the project area where solar insolation is high is the solar power system. In fact the solar system has a record of having almost 300 installed units throughout Mozambique.

However, solar power and wind hybrid systems would be appropriate in the coastal districts such as Memba, Nacala Velha, Mossuril, Ilha de Mozambique, Mogincual and Angoche, and the districts located deep in the western area, such as Malema and Ribaue, where the monthly average insolation are low specially in December–January and in June–July. This is because wind conditions are constant and suitable for power generation. The coastal districts have a total of 570 primary schools and 65 health centers. The western region has a total of 291 primary schools and 21 health centers. These numbers show that the introduction of solar power and wind hybrid systems in these areas is well worth considering.

7.3 Sustainable Maintenance System

In order to maintain the solar power facilities in excellent working condition, maintenance personnel should have more advanced knowledge and skill. There are technical experts and engineers in Mozambique with certain levels of technical skill and knowledge in the installation and repair of general electric appliances but their number is quite limited. In addition, electrical engineers assigned to administrative offices obtained their basic knowledge either by secondary education or by attending lectures or short-term trainings. The number of human resources who are practically engaged in employment related to electric technologies utilizing knowledge and techniques they have learned is quite limited. It would also be difficult for the public sector to employ technical experts and engineers with sufficient experience and skill since the talented and experienced ones choose to be employed in the private sector due to the competitive salaries.

For FUNAE as the agency promoting these projects, it is most appropriate to put importance on personnel assignment and to assign to the private sector aspects such as the design, installation, and construction of facilities as well as the responsibility of maintaining these facilities. FUNAE should focus on contract management and in monitoring of the private sector. If FUNAE itself should be directly responsible in the maintenance of the facilities, it has to provide appropriate maintenance for all projects totaling approximately 2,000. This will mean that FUNAE has to increase its personnel to around 680; a number which is six times bigger than its current staff complement. However, just to increase the number of staffs of FUNAE is both inefficient and impossible in reality.

Although no substantial deficiency was found during the field survey of the Study Team to observe the existing solar power generating facilities under the management of FUNAE, it was found that some facilities are damaged because of improper use (use of electric iron – excessively high power load) and not efficiently used because minor problems have not been solved (broken lighting apparatus – lamp – were not replaced). These problems could have been avoided if sufficient training and guidance on the operation and maintenance of facilities were executed prior to the start of their operation.

It was found that the highest efficiency in view of function and economy can be attained by use of solar and wind hybrid power generation system at several locations under certain conditions suitable for use of such system. However, the technologies associated with the solar and wind hybrid power generation system are a bit new to Mozambique, so that training and orientation of local engineers and technicians on the operation and maintenance of solar and wind hybrid power generation system is necessary. Under such a situation, the institutional and organizational setup of the maintenance system among FUNAE as the agency responsible for the promotion and management of renewable energy utilization, in general, the Ministry of Education and the Ministry of Health as the owner of power generation facilities, and private entities undertaking the maintenance services are to be studied carefully taking into account the respective roles, functions and budgetary appropriation for the maintenance of the power generation systems.

Taking all the above into account, it is suggested that FUNAE should concentrate further, not only on fostering the level of technical skills but also reinforcement of the skills on planning, contract management, utilization of information technologies for administration, etc. It is judged that the technical assistance for FUNAE in the field of management techniques is important as well.

CHAPTER 8. Expected Project Effects and Life Cycle Cost Analysis

8.1 Project Effects

Since the number of primary schools selected for electrification is 70, this would have a multiplier effect and would mean a future increase in the number of adults enrolling in evening literacy classes. The number could swell from 2,000 to 3,000 assuming that the number of participants is 40 per classroom and two rooms will be especially reserved for adult classes.

Qualitatively expressed, other project effects are as follows:

Primary Schools:

(1) Classrooms will be equipped with lighting facilities and thus making the holding of evening classes possible. This will increase the number of students and lead to the improvement of the quality of education, since the number of students per teacher will decrease.

(2) Classrooms will be equipped with lighting facilities making the holding of evening classes possible and allowing adults to receive basic education, such as on literacy, agricultural technology, and so on. This will improve the productivity of communities as a whole, and increase income opportunities for local residents.

(3) TV/DVDs can now be played in classrooms making it possible to provide classes with audio-visual equipment. This will improve the quality of education and learning. In addition, this mode of learning can help close the gap in the student and teacher ratio in rural public schools.

(4) Staff rooms and offices can be equipped with lighting and computers thereby improving efficiency of employees and the administration of the schools.

(5) The living condition of teachers will improve and, accordingly the quality of education will likewise improve.

(6) Some elementary schools have boarding houses especially for girls. If the boarding houses will be equipped with lighting facilities, the students will be able to study at night, thus improving learning and the quality of education.

(7) The availability of power will make the charging of mobile phones possible. This will improve communication between schools, administrative offices, as well as between family members.

(8) The availability of lighting at night will improve public safety and assure the safety of teachers, workers, and students.

(9) Nighttime community meetings in classrooms can be made possible. This will strengthen the organizational power of communities and contribute to improving the living standards of the communities as a whole.

Health Centers

(1) The storing of vital medicines and important vaccines in refrigerators will be made possible. This will help decrease mortality rates in the villages and offset the cost of operating the refrigerators.

(2) The storing of medicine in refrigerators will be made possible thereby promoting preventive health care such as the vaccination of children. This will decrease infant mortality rate in the rural areas as well as the illness frequency rate and improve health conditions in rural communities.

(3) The charging of mobile phone batteries will be made possible. Thus improving communication between staff, hospitals and administrative offices in case of emergencies in the communities.

(4) With the health centers equipped with lighting, the provision of urgent medical care at night will be possible.

(5) Medical care and child delivery during nighttime will become easy and decrease the maternal mortality and infant mortality rates.

(6) Services will improve and the trust of the communities in the health centers will increase. Furthermore, it will increase the number of pregnant women who will visit the health centers for consultations and deliveries thereby improving maternal care.

(7) The number of cases of infant vaccination will increase while the number of infant mortality rates will decrease.

(8) The living conditions of doctors and nurses will improve thereby improving the quality of medical care as well.

(9) The provision of lighting in the health centers will improve the safety of the staff and personnel assigned to night duties.

(10) The securing of safe drinking water will become easier.

(11) The provision of computers in the health centers will improve administrative efficiency and the overall medical services of the centers.

General Matters:

(1) Although this project aims to provide electrification for primary schools and health centers along the Nacala Corridor, the project will bring forth further development effects, such as fulfillment of basic human needs which is the project's short-term agenda, the promotion of human resources development which is a basic foundation of economic development, as well as the improvement of the quantity and quality of education, which is its long-term perspective.

(2) Promotion of carbon credit trade through CDM.

8.2 Cost Effectiveness

Due to the difficulty in estimating the effects of the project in a quantitative way, the evaluation of appropriate technology by means of comparing both the initial capital investment cost and the total lifetime cost of various technological options was utilized. The results of these evaluations are shown in Table 7.2.2 and Table 7.2.3, respectively. The figures in these tables indicate that the Solar and Wind hybrid power generation system is more cost-effective among the various technologies at the sites in the Coastal Region where wind conditions are appropriate for the operation of a wind power system. In some regions where wind conditions are not suitable for the wind power system, like the Central Region and the Inner Western Region, which have a relatively constant and stable insolation, the cost effectiveness of solar power system is the highest among other options.

CHAPTER 9. Recommendations

9.1 Recommendations on Appropriate Technology

Based on the weather data (insolation data, wind speeds, etc.) that have been collected and analyzed in this study, the appropriate off-grid power renewable energy technology for the primary schools and health centers in Nampula Province is the Solar Power Generating System. On the other hand, for the selected sites in the provinces of Memba, Nacala-Velha, Moussril, Ilha de Mozambique, Mogincual, and Angoche, which are along the coast, the appropriate technology would be the Solar and Wind Hybrid Power Generation System equipped with a long life (i.e., five-year) lead-acid battery unit. In fact, the lifespan of a solar and wind hybrid system can be extended to ten years if its capacitor is used to store the power generated by wind turbine and a long life lead-acid battery for power generated by solar power system. Its number of replacement batteries can also be minimized to further reduce the total life costs of the system. However, since these technologies are quite new to Mozambique they will require further studies and performance assessments, especially on the matter of effective technical transfer.

9.2 Technical Recommendations on Power Generating System

(1) Design Philosophy to Realize a Trouble-Free System

Based on observations and the examination of existing solar power generating facilities and power generation efficiency, the easy and simple circuit design of the system has led to excessive discharges and frequent charging of batteries. These two were the common causes of system breakdown.

Under an acute shortage of skilled engineers and technicians, the design should take into consideration all possible problems and malfunctions so that maintenance procedures will become easier. Although the cost will increase because of this measure, it will eventually lessen expenses that will be incurred from the constant replacement of parts, increases in maintenance personnel, decreases in operational efficiency, etc. The examples of protective circuit designs taking into consideration such foreseeable problems are as shown in Figure 9.2.1 and Figure 9.2.2.

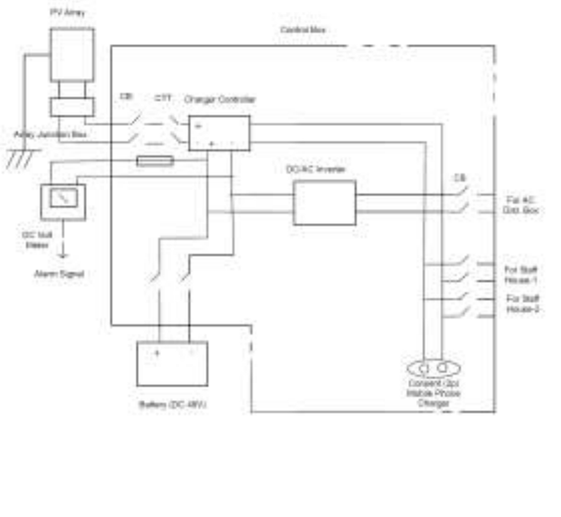


Figure 9.2.1 Example of Circuit Diagram for Solar Power System

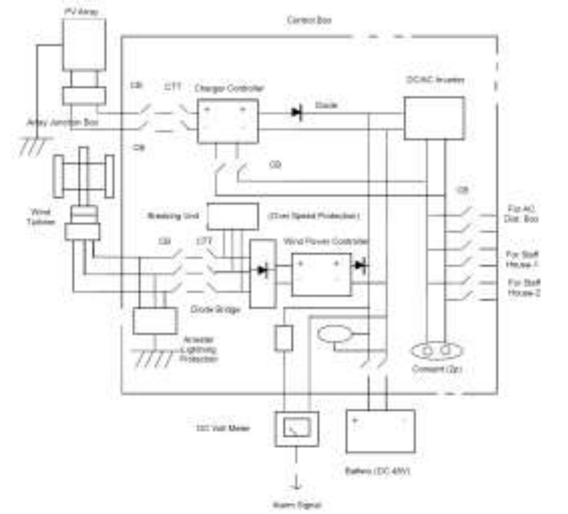


Figure 9.2.2 Example of Circuit Diagram for Solar and Wind Hybrid Power System

Source: JICA Study Team

(2) Preventive Measures against Solar Panel Theft

All solar panels that have been stolen or damaged were installed near ground level, or one or one-and-a-half meter from the ground. To avoid theft, solar panels should be installed at heights of more than two meters, or above the height of an ordinary person. Solar panels should also be installed within 30m from the building where the power will be used, and not on rooftops to avoid damage due to high temperatures, wind gusts, etc. The panels should also face north.

The photos below, showing the solar panels at the service stations of FUNAE, illustrates the proper way of installing solar panels. Special bolts and nuts should also be used in fixing the panels into support frames to make their removal more difficult.

(3) Location of Battery Room

In primary schools, the battery of solar power system is located mostly in administration offices; while in health centers; they are placed inside the room closest to where the refrigerators are located. Battery capacities have been examined carefully in this study to optimize system efficiency including the results of weather simulations. This exercise has led to an increase in battery size compared with the previous design. Therefore, it is recommended that batteries be placed in a battery room that is well ventilated and with sufficient space for maintenance work, and not inside schools or health centers. This storing method is similar to what FUNAE did in the solar power systems at their service stations.

	
FUNAE's Rural Service Station under Construction	**Solar Panel and Battery Room**
	
Supporting Frame of the Solar Panel	**Inside the Battery Room**

Source: JICA Study Team (Photos taken in Mecuburi)

9.3 Recommendations on Renewable Energy Utilization

(1) Reduction of Power Demand by Introduction of Power Conservation Technologies

Electrical apparatus such as lighting equipment and some appliances should be set at the same time as the main independent power generation system, or the mini-grid system. In such a case, cost reduction and increased application can be realized by lowering the standards of the power generation system and reducing the capacities of the batteries.

Power conservation technology is one of the technologies that Japan has been in the forefront. If consideration on the hardware side (selection of energy conservation equipment) and software side (enhanced consciousness about energy saving, energy saving mode selection for personnel computers and other equipment) will be specified in the tender conditions, the chance of Japanese companies bidding in such tender will likely increase.

(2) Other Usage of Solar Energy

The study has showed that Mozambique has a very stable source of solar energy. The usage of solar energy can be expanded not only for the electrification of primary schools and health centers but for other power users as well. For instance, solar power can be utilized to run irrigation pumps, for charging batteries used in farm tilling, operation of farm processing equipment, farm product production, the cultivation of cash crops, etc. It can even be used in the purification of drinking water.

An extensive study on water purification through solar power can also be pursued. Boiling water using solar power is one of the most energy efficiency methods. Water can easily be boiled to around 70°C with the use of solar water heaters. Boiled water can be used for sterilization of medical equipment and tools, especially those that are used in the delivery of babies in the health centers. The use of boiled water in cooking will also reduce the utilization of firewood leading to the minimization of deforestation and reduction of CO_2 emissions.

(3) Expansion of System to Meet Increased Demands

As the economy of Mozambique rapidly develops, its power demand will likewise increase substantially. The composition of the solar power generating system planned in this study did not take into consideration future demands but worked on the proposed minimum requirement of the project.

Expansion of the system can be recommended in order to meet future demand. For solar power generating systems, batteries can merely be added or expanded to address growing demand. However, when the time to expand or add comes, the systems or parts that should be employed should come from the same manufacturers, with the exact specifications, size including expert advice from the proper engineers or technicians.

(4) Necessity of Technical Training

It will not be appropriate to entrust electrical maintenance to a private service company in the conduct of proper and necessary maintenance. The recommendation is that FUNAE itself should organize several groups of engineers and technicians to handle the promotion and maintenance of the renewable energy systems. What will be needed is technical collaboration that will include advices on management, organizational and technical matters. Furthermore, when the solar and wind power systems are introduced, a proper design for each facility at each site is needed per region. The recommendation is to carry out Training-of-Trainers and On-the-Job Training throughout the design works that would be carried out in the field.

(5) Assessment of Village Electrification through Jatropha Bio-Fuel

The objective of Jatropha cultivation is to produce bio-fuel from Jatropha seeds that would supply energy to the village thereby increasing ‟farmer’s‟ incomes and reducing dependence on imported fuel. Although several Jatropha cultivation projects have been done on an experimental basis in Mozambique, the realistic use of Jatropha seeds has not progressed satisfactorily due to the dormant domestic market for Jatropha straight oil. If straight oil from Jatropha seeds will be directly used as fuel to run diesel generators in the villages, Jatropha farmers and villagers will be able to reap the benefits of electrification through such cultivation. Since this model has not yet been practiced in Mozambique, the recommendation is to carry out an experimental project in a small village where village electrification through Jatropha straight oil can be modeled.

Although such a village will be selected by related agencies and organizations, it can be suggested that the village should be as close as possible to the IIAM Agricultural Experimental Farm located in Monapo, which is an important facility for agricultural experiments in Nampula Province. The Jatropha research can be conducted in Manapo and the result of this pilot cultivation can be utilized and tested in the model village. The success of the model Jatropha electrification village can be replicated to other villages spread along the Nacala Corridor.

9.4 Remarks on Execution of Cooperation on Renewable Energy Utilization Project along the Nacala Corridor

At the start of the electrification project based on solar power systems and solar and wind hybrid systems for primary schools and health centers in the Nacala Corridor, the following concerns should be carefully noted:

(1) Maintenance and Management

The cost of maintenance for the first two years after the handover to the users as a warranty period is free and the contractor will be responsible for the delivery of the operating systems and for the proper maintenance. Beyond the warranty period, the owner is to conclude a contract with a private company specializing in maintenance services. Commonly, maintenance costs would be within a 5% to 8% range of the total initial investment cost or body cost. Assuming that the lifespan of a power generating equipment is 20 years, the costliest part of the system would be the battery. Battery cost accounts for around 35% to 60% depending on the size and type of system and they are replaced at least twice in 20 years. The budget for battery replacement could also be reserved every year for five years. In case the cooperation will be executed, this point must first be confirmed with the project-implementing agency. If the project will be executed through a BTS, a similar agreement should be concluded prior to project execution.

(2) Optimum Utilization of Primary School and their Management

For the electrification project in the primary schools, the deployment program of teachers should be part of the inputs. The student to teacher ratio has increased in the past years with students far outnumbering the number of teachers whose ranks do not increase in parallel with increase in student population. The Ministry of Education is taking various measures to address the issues of shortage of teachers by emphasizing training of non-licensed teachers, the return of retired teachers, providing various teachers'‽incentives, and other measures. Particular attention should be drawn on the arrangement of teachers who will handle night classes for adults.

(3) Demarcation of Undertaking with Other Donors

In Mozambique, several donor countries and international financial institutions, such as the World Bank, the Belgium Government, the Korean Government and the Indian Government have extended various types of cooperation for renewable energy projects, especially, for primary schools and health centers. Although Nampula Province has seen no overlapping of donor projects, such project duplication among other donors should be carefully examined.

APPENDICES

Appendix-A1 Project Related Information

Appendix-A2 Comparison of Total Lifetime Costs by Type of Power Generation System

Appendix-A3 Profile of Candidates Sites

Appendix-A4 Method of Wind Condition Analysis

APPENDIX-1

PROJECT RELATED INFORMATION

Table of Contents

Chapter 1 Profile of Mozambique

1.1 Characteristics of Mozambique

1.1.1 Geography

Mozambique is located in southern Africa and bordered by the Mozambique Channel and the Indian Ocean in the east; Malawi, Zambia, and Zimbabwe in the west; Tanzania in the north; and South Africa as well as Swaziland in the southwest. Mozambique is considered as an important route connecting the land-locked countries of Malawi, Zambia, and Zimbabwe with commercial ports along Mozambique's coast facing the Indian Ocean. The country's total land area is 799,380 km^2, 13,000 km^2 of which covers an inland water surface.

1.1.2 Climate and Natural Resources

The country has a tropical and subtropical climate. Its terrain is mostly coastal lowlands with central uplands, high plateaus in the northwest, and mountains in the west. Natural energy resources, such as potential hydraulic power, coal, natural gas, etc., are abundant and considerable deposits of rare metals, such as titanium, tantalum, and graphite, have been known to exist. However, mineral development or exploitation is still underway except for hydraulic power development along the Zambezi River. The area of arable land is limited to 5.4% of the total land area and irrigated land is a mere 1,180 km^2.

1.1.3 History

Almost five centuries as a Portuguese colony came to a close with independence on 25 June 1975. Large-scale migration, economic dependence on South Africa, a severe drought, and a prolonged civil war hindered the country's development until the mid-1990s. The ruling Front for the Liberation of Mozambique (Frelimo) party formally abandoned Marxism in 1989, and a new constitution the following year provided for multiparty elections and a free market economy. A UN-negotiated peace agreement between Frelimo and rebel Mozambique National Resistance (Renamo) forces ended the fighting in 1992. Since then the country's economic development has progressed despite several political changes to date.

1.1.4 Administrative Division

Mozambique is divided into 11 provinces for administration purposes, i.e., Cabo Delgado, Niassa, Nampula, Tete, Zambezia, Manica, Sofara, Inhambane, Gaza, Maputo, and Maputo City.

1.1.5 Demography

According to the National Statistics Institute, the total population of Mozambique in 2010 is about 22.95 million. The age group of 0–14 accounts for 45.9% of the total population, 15–64 age bracket accounts for 51.1%, and those more than 65 years old account for 3%. As such, the young population is quite large. The annual average population growth rate is relatively high at 2.44% (30^{th} in world rankings). The urban population accounts for around 38% of the total population as of 2011 and it grows at around 4% per year. Maternal mortality rate is 550 deaths per 100,000 live births (2008), while infant mortality rate is 78.95 deaths per 1,000 live births (13^{th} in world rankings). Both are considered very high. The average life expectancy is 51.78.

1.1.6 Urbanization

The population in the capital city Maputo is around 1.20 million, with 1.0 million in its peri-urban area. The populations in other major cities are around 0.75 million in Matra, 0.30 million in Beira, 0.25 million in Nampula, Lichinga (0.06) and Inhambane (0.05), respectively. The total urban population, therefore, accounts for around 15% of the total population. It includes those in regional cities which is around 38%. The government targets the provision of electricity from the power grid to the central part of cities throughout the country by 2015. However, with an urban population increasing at an average 4% per year due to in-migration from rural areas, the provision of infrastructure in urban areas has not coped with the increased demand. Although the capital city of Maputo has been electrified through a connection with the trunk power grid, charcoal remains an energy source for majority of the urban population and it causes urban air pollution.

1.2 Economic Outlook of Mozambique

1.2.1 Economic Conditions

Independent in 1975, Mozambique was one of the world's poorest countries. Socialist mismanagement and a brutal civil war from 1977 to 1992 exacerbated the situation. In 1987, the government embarked on a series of macro-economic reforms designed to stabilize the economy. These steps, combined with donor assistance and with political stability since the multi-party elections in 1994, have led to dramatic improvements in the country's growth rate. Fiscal reforms, including the introduction of value-added tax and reform of the customs service, have improved the government's revenue collection. In spite of these gains, Mozambique remains dependent upon foreign assistance for more than half of its annual budget, and the majority of the population remains below the poverty line. Subsistence agriculture continues to employ the vast majority of the country's work force, while smallholder agricultural productivity and productivity growth remain weak.

A substantial trade imbalance persists although the opening of the Mozal aluminum smelter, the country's largest foreign investment project to date, has increased export earnings. At the end of 2007, and after years of negotiations, the government took over Portugal's majority share of the Cahora Bassa Hydroelectricity (HCB) company, a dam which was not transferred to Mozambique when it gained independence because of the ensuing civil war and unpaid debts. More electrical power capacity is needed for additional investment projects in titanium extraction and processing and garment manufacturing that could further close the import–export gap. Mozambique grew at an average annual rate of 9% in the decade up to 2007, one of Africa's strongest performers.

However, heavy reliance on aluminum, which accounts for about one-third of exports, has subjected the economy to volatile international prices. The sharp decline in aluminum prices during the global economic crisis lowered GDP growth by several percentage points. Despite an 8.3% GDP growth in 2010, the increasing cost of living prompted citizens to riot in September 2010, after fuel, water, electricity, and bread price increases were announced. In an attempt to contain the cost of living, the government implemented subsidies, decreased taxes, and tariffs, and instituted other financial measures.

1.2.2 Economic Growth

Mozambique's economy was devastated by decades of conflict. Its high growth rate over the last decade started from a very low base and has been greatly dependent on capital-intensive investment by the private sector, as well as on the strong South African economy. Neither of these influences has favored smaller businesses, or the central and northern regions, raising concerns about the distribution of wealth. Problems with governance—corruption, legislation, and revenue collection in particular—have also inhibited economic development. To alleviate this, the government has initiated widespread reforms, particularly in banking, the management of public finance, and the collection of customs dues.

Agriculture employs 83% of the population and until recently accounted for 80% of exports. Minerals make up an increasing share of exports, and recent investment in Mozambique's mineral and gas deposits may increase their contribution to the economy.

The Mozambican economy also benefits from the transit of goods to and from the African interior. Investment in infrastructure for the Beira, Nacala, and Maputo corridors, which respectively link Zimbabwe, Malawi, and South Africa's Gauteng province to the Indian Ocean, has increased in recent years.

In 2010, the GDP of Mozambique was around USD20.3 billion and the GDP per capita was USD440 (201st in world rankings of 213 countries). Table-A1.1.1 shows the changes in the country's GDP and population for 11 years from 2000 to 2010. The average annual economic growth registered during this period was 7.5% which is stable and remarkable. The average annual population growth in the same period was around 2.3% and the rate of population growth has been declining gradually.

Table-A1.1.1 Changes in GDP, Population and GDP per Capita (2000-2010)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AAGR
GDP (Current) in US$ billion	4.223	4.198	4.223	4.331	4.490	5.185	6.107	6.662	7.436	8.565	9.976	
GDP (Constant) in US$ billion	4.017	4.552	4.789	5.084	5.542	6.014	6.738	7.123	7.530	7.629	8.236	
GDP Growth Rate per Annum (%)		13.3	5.2	6.2	9.0	8.5	12.0	5.7	5.7	1.3	8.0	7.5
Population ('000)	18,249	18,268	18,746	19,259	19,783	20,310	20,834	21,353	21,869	22,382	22,890	
Population Growth Rate (%)		0.1	2.6	2.7	2.7	2.7	2.6	2.5	2.4	2.3	2.3	2.3
GDP per Capita in US$	231	230	225	225	227	255	293	312	340	383	436	
Growth Rate of GDP per Capita (%)		-0.7	-2.0	0.2	0.9	12.5	14.8	6.4	9.0	12.5	13.9	6.7
Note: GDP in constant price at 2000												

Note: Compiled by the Study Team based on The World Bank, Indexomni, etc.

1.2.3 Economic Structure

In 2010, the primary economic sector (agriculture), the secondary economic sector (industry), and the tertiary economic sector (services) accounted for 29.0%, 26.6%, and 44.4% of the total GDP, respectively. The total number of labor force in the same year was around 990,000. The respective shares of agriculture, industry, and services in the total labor force were 81%, 6%, and 13%. Therefore, the GDP per laborer in agriculture, industry, and service sector is estimated at USD163, USD1,777, and USD1,631, respectively.

As shown in these figures, the productivity of agricultural labor is a mere 10% of that of industrial labor, most of whom are urban residents. Agricultural labor, comprising a major part of the population and residing in rural areas, falls below the poverty level and depend on subsistence economy. Meanwhile, the unemployment ratio in the country is around 27% and the poor accounts for almost 71% of the total population, both of which are considered quite high.

1.2.4 Major Products

The major agricultural products of Mozambique are cassava and maize. The major agricultural products for export are shrimp, cashew nuts, wood, sugar, copra, and cotton. The major industrial products for export are aluminum and natural gas, as well as electric power from the hydropower station of Cahora Bassa.

Chapter 2 Energy Sector

2.1 Energy Resources

1) Hydropower

The potential hydropower generation capacity of Mozambique is enormous, at an estimated 12,500MW (annual power output: 60,000GWh). This huge hydropower generation capacity is due to the world's largest artificial lake in terms of surface area called the Kariba Lake located at the upper Zambezi River in Zimbabwe.

2) Natural Gas

Mozambique is endowed with a huge natural gas deposit. Natural gas was discovered on land in Pande and Temane in Inhambane province and Buzi in Sofara province. The proven gas deposit is estimated at 3.5 TCF. Since 2002, the natural gas produced in Pande has been transported to Gauteng province in South Africa through a 865-km gas pipe line (340 km in South Africa).

2) Coal

There are several huge coal deposits in Moatize and Minjova in Mozambique's Tete province, as well as in Senagoe, Muchanha, and Vuzi. The total deposit is estimated at around 3 billion tons. Coal exploitation and production started in 1940 to satisfy both local and international demand. Although the operation of these coal mines has been suspended because of the civil war, the reopening of these mines is underway. Vale de Rio Dose of Brazil won the exploitation rights.

2.2 Overview of the Energy Sector

In 2009, the total primary energy supply (TPES) of Mozambique was 408.9 Petajoules (PJ) and a compound growth rate of 17.8% over a five-year period. Biomass meets 78% of the country's energy needs, followed by hydropower (14%), and oil products (7%). The use of coal and gas is marginal and accounts for about 1% of the TPES. Mozambique is a producer of natural gas but most of the production is exported. The country is also a net exporter of electricity. All the oil products used are imported and their cost accounts for 15% of country's imports (USD581 million), making Mozambique vulnerable to increases in the prices of oil products. Figure-A1.2.1 shows the share of energy supply by source in the country in 2009.

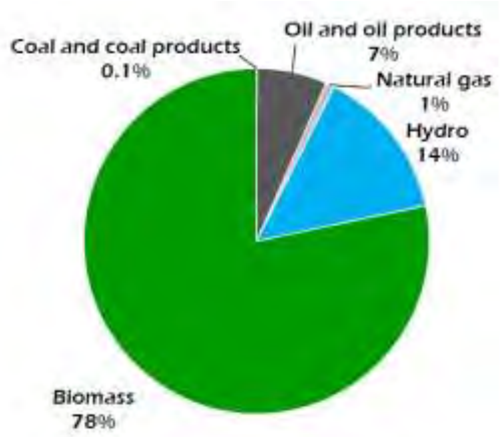
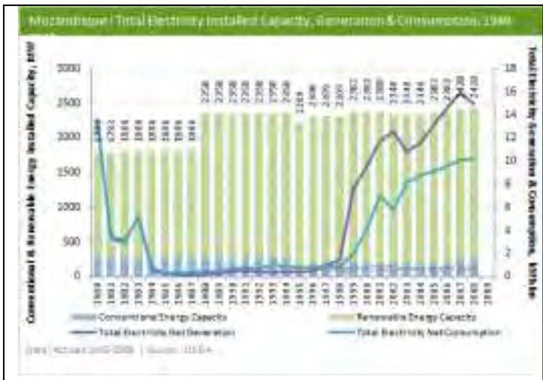


Figure-A1.2.1 Share of Energy Sources in 2009

In 2008, Mozambique's total electricity capacity was 2,428MW, 249MW of which was conventional thermal energy. Total renewable energy capacity accounted for 89.74% of this total installed capacity base, while renewable energy sources excluding hydropower accounted for almost 0%. In the same year, total electricity generation was 14.98 billion kWh with the largest source being hydropower (99.92% of total net generation). Figure-2.3.2 illustrates the changes in the total electricity installed capacity and consumption, as well as the installed capacity of conventional energy and its generation/capacity ratio.

	
Total Installed Capacity and Consumption	Installed Capacity of Conventional Power Generation Facilities and Net Generation

Source: EIA 2009

Figure-A1.2.2 Changes in Total Electricity Installed Capacity and Consumption, and Installed Capacity of Conventional Energy and its Net Generation

2.3 Energy Sector Development Strategy

The Government of Mozambique approved the Energy Management Strategy for the Energy Sector (2008-2012) which established policy guidelines and relevant measures for the energy sector based on the following principles:

- Increased sustainable access to electricity and liquid fuel;
- Sustainable utilization of wood fuel;
- Promotion of new and renewable sources of energy;
- Diversification of energy matrix;
- Joint planning and integration of energy initiatives with development plans and programs of the other sectors;
- Sustainable development and environmental protection;
- Tariff reflecting real costs and incorporation of mitigation measures to protect the environment;
- Promotion of the productive use of energy and integration of system and tools in the approach to energy supply;
- Institutional coordination and consultation with relevant stakeholders for better development of the energy sector;
- Active participation in international cooperation forums including the Southern African Development Community (SADC); and
- Efficient use of energy.

These principles are fundamental to the development of the energy sector and were established with the aim of developing the country's vast energy resources which have the capacity to satisfy most of the country's needs. These resources include hydropower and power generated from natural gas, coal, biomass, solar energy, and wind. According to the Mozambique Energy Management Strategy for the Energy Sector (2008-2012), the country is endowed with a considerable hydropower potential, which has been broadly estimated at 12,500 MW, with a corresponding annual energy generation potential of 60,000 GWh.

Approximately 500 MW of electricity generated from natural gas plus 5,000 MW from coal may be added to this potential. Yet, despite this significant potential a rapid shift from biomass to electricity use cannot be expected, because Mozambique is a vast country, with a majority of the population living in rural communities dispersed throughout its provinces. At present, only 13.2% of the population has access to electricity. Energy solution must take this reality into consideration and adapt to it by combining an intensification of electrification in those areas served by the national electricity grid with the adoption of hybrid solutions, in particular for remote areas, using available and sustainable biomass (wood fuel, bio-fuel, and biogas), solar, wind, and hydro power.

2.4 Poverty Reduction Policy of the Energy Sector

Mozambique suffers from the consequences of improper utilization of natural resources, which are distributed highly unevenly around the country, thereby resulting in an extremely low access to sustainable energy. This situation is partly due to the high cost of extending networks to, and increasing the number of connections in, remote and relatively low-demand areas using conventional technologies and design standards.

2.5 National Energy Sector Development and Access Program (NEDAP)

The government recognizes that adequate access to energy resources and services is a key driver of growth and poverty alleviation. The Plan for the Reduction of Absolute Poverty II (PARPA II) identifies the provision of energy services to rural schools, administrative posts, and hospitals as a priority project. Within the context of PARPA II and of the strategic investment priorities for the power sector, the Government of Mozambique prepared a comprehensive five-year development program (with an estimated budget of USD230 million) called "National Energy Sector Development and Access Program (NEDAP). In line with the strategy defined in NEDAP, the World Bank has assisted the government in the implementation of a program called Energy Development and Access Project (EDAP) which was formulated based on the Energy Reform and Access Program (ERAP) as the lead investment project in NEDAP.

The Rural and Renewable Energy Component of EDAP aims at increasing and accelerating a decentralized access to modern energy services by supporting micro and small investments in renewable energy production and distribution systems, PV and other renewable energy technologies in rural and peri-urban areas, including the installation of 500 solar PV systems in rural schools and health centers and electrification of 30 villages using renewable energy technologies This component was implemented by FUNAE. The first PV installation project implemented by FUNAE is known as the "100 Schools 100 Health Centers Project."

Access to energy is a precondition for economic development and social progress in Mozambique, especially in the rural and peri-urban areas. The government has affirmed in PARPA II the critical role of the energy sector in reducing poverty. The importance of the energy sector is also emphasized in the World Bank's 2008–11 Country Partnership Strategy (CPS), which identifies adequate access to energy resources and services as a key driver of economic growth and poverty alleviation. The CPS prioritizes especially the provision of energy services to rural schools, administrative posts, and hospitals/clinics. At the moment, energy-related goals set in PARPA II are being turned into strategies such as the Off-grid and Renewable Energy Strategy, Generation and Transmission Master Plan, North–South (Backbone) Transmission Least-Cost Study, and National Bio-fuels Strategy.

2.6 Energy Use by Households

According to the Ministry of Energy, at the household level, energy is mainly used for cooking and lighting. The principal energy source for the majority of Mozambicans is biomass, particularly wood fuel. Biomass coming from an estimated 30.6 million hectares of forests (wood fuel and charcoal) represents 80% of the energy consumed by households. Within rural communities, this accounts for nearly all the energy consumed. Charcoal production and use are widespread in small urban settlements and district capitals, and around larger towns and cities.

Only around 10.5% of households have access to electricity, with over half of them situated in Maputo and its surrounding areas. All the provincial capitals and most of the municipal areas are also supplied with electricity. Most of these urban centers are connected to the main national electrical grid, which is owned and operated by the Mozambican power utility EDM.

Nevertheless, the on-grid connection in most districts in each province is still limited to only the administrative posts, commercial facilities, and a few residences who can afford to pay electricity bills. Therefore, on-grid connection to households even 1 km away from the administrative posts has not been made possible and this situation will likely remain up to 2030. Since majority of households in rural areas survive on subsistence economy, their incomes are quite limited and will not allow them to pay their electric bills.

Chapter 3 Education and Health Sectors

3.1 Background of the Education Sector

The National System of Education (SNE) was introduced in 1983. It is the first system designed by Mozambicans themselves after independence. Before 1975, the country's education system consisted of missionary schools, public schools, and private schools. Missionary schools catered for the "natives," mainly in rural areas. Public schools, which catered for the common Portuguese and *assimilados*. were located mainly in urban areas. Private schools (mostly church owned) were mainly for the well-off Portuguese and assimilados. One of the characteristics of the pre-independence education system was that it was very selective and this has been retained by the post-independence education system. The SNE comprises five subsystems, namely general education, adult education, technical/vocational education, teacher training, and higher education. The education system is organized into three levels, namely, primary, secondary, and higher education. The description of each education level is shown below.

1) Pre-elementary education

Pre-school education is provided in crèches and kindergartens, usually under the Ministry of Health or private institutions. This education is not compulsory and is beyond the means of the majority of Mozambicans. As a result, only a small percentage of the target age group participates in formal pre-school education. Pre-school children are 3–5 years old and their population is around 2.0 million.

2) Elementary education

In Mozambique primary education is free and compulsory. It is subdivided into two levels, namely, the lower primary which consists of five years of schooling (Grades 1 to 5) and upper primary which comprises two years (Grades 6 and 7). The official age of entry into school is 6 years. Usually, primary schools operate in two shifts. Because of the shortage of schools at this level, some primary schools operate three shifts. The morning shift starts normally from 07:00 and end at 12:10. The afternoon shift starts from 12:15 and ends at 18:10. The night shift starts from 18:15 and ends at 10:40. Each subject lasts for 45 minutes.

The number of subjects is 10 and they include Portuguese, English, history, mathematics, and gymnasium. Although the majority of students taking the night shift is 18–21 years old, a considerable number of adults, who did not go to school when they were young, attend this shift. The illiteracy rate in Mozambique is around 60%. Under such a situation, adult education has drawn attention. The night shift is provided for those adults using the primary school buildings. After seven years of primary education, the pupils have a choice of enrolling for general secondary education, lower primary teacher training colleges, basic technical and vocational schools, or secondary education for adults. The total population of students 6 to 12 years old is around 4 million. The rate of enrollment is 76.6%, with boys at 80.3% and girls at 72.9%.

3) Secondary education

General secondary education is divided into two stages. The first stage, junior secondary, comprises three years (Grades 8 to 10). The second stage, senior secondary (also known as pre-university), comprises two years (Grades 11 and 12). Both levels of education are offered on the same premises. Although the total population of the age group 13 to 17 years is around 2.4 million, enrolment is very low, at 7.6% national average (males 7.8%, females 6.1%). Even in the capital city of Maputo, it is only 31.5%.

4) Higher education

Public and private universities, higher institutes, schools of higher education, and academies provide higher education to those who have completed Grade 12. As a result of the stiff competition for limited places at this level, all students have to sit for an entry examination. The number of students who undergo this level of education is quite limited.

5) Management and Administration of Education

In Mozambique, the Ministry of Education headquarters assumes overall responsibility for the administration of all education institutions in the country. The minister, vice-minister, and permanent secretary sit at the apex of the education ministry, which comprises 10 national directorates namely:

- The National Directorate for Finance and Administration;
- The National Directorate for Basic Education;
- The National Directorate for Technical and Vocational Education;
- The National Directorate for Secondary Education;
- The National Directorate for Adult Education;
- The National Directorate for Human Resources Development;
- The National Directorate for Teacher Training;
- The National Directorate for Pedagogic Support Resources;
- The Inspectorate, and
- The National Directorate for Planning.

There is a Provincial Directorate of Education for each of Mozambique's 11 provinces, and this directorate falls under the command of a provincial director. Below the Provincial Directorate there is the District Directorate headed by a district director. There are 146 districts in Mozambique. Below the District Directorate there is the school which is headed by a school director. Curriculum development for general education (primary, secondary, and pre-university) and teacher training (basic and intermediate) are carried out by the National Institute for Educational Development (INDE).

Table-A1.3.1 shows the number of public and primary educational facilities under the management of the Ministry of Education at the national level and in Nampula province.

Table-A1.3.1 Number of Educational Facilities for Primary Education

System	Noon Class				Night Class		
	Lower Primary	Upper Primary	Lower Secondary	Upper Secondary	Upper Primary	Lower Secondary	Upper Secondary
Mozambique	8,373	1,116	140	30	254	125	30
Nampula Province	1,431	136	14	5	31	12	3

Source: Ministry of Education

3.2 Policies on Literacy and Education for All

Literacy and basic education are governed by various legal instruments and development policies. The most outstanding instruments are the:

- Constitution of the Republic of Mozambique which stipulates that every citizen has a right to education (Article 88) and that education constitutes a means of achieving national unity, eradicating illiteracy, mastering science and technology, and providing citizens with moral and civil values (Article 113);

- the government's 2000–2004 programme, which provided for a wide-ranging and realistic prelaunch of literacy and aimed to cut rates by 10%;
- Law No. 6/92, which modernized the National Education System (SNE), bringing it in line with the new economic and political model enshrined in the 1990 Constitution;
- the 2001–2005 Action Plan for the Reduction of Absolute Poverty (PARPA), which defined literacy and adult education as primary goals in the education program;
- the National Strategy for Adult Literacy and Education and for Non-Formal Education (AEA/ENF), designed mainly to eradicate illiteracy in the country; and
- the new Government Programme (2005–2009) reaffirming the 10% poverty reduction goal.

All these standard-setting and political documents reflect the combined will of the government and society to ensure that literacy plays an ever-increasing role in poverty reduction and in the development of the country. This is very much in keeping with the international commitments undertaken in the Jomtien, Dakar, and other declarations. Literacy is regarded, on the one hand, as the acquisition of the basic notions of reading, writing, and numeracy and, on the other hand, as a process that stimulates participation in social, political, and economic activities and lays the foundation for continuing education.

The concept also reflects a form of functional literacy that is an integral part of local development. The concept of continuing education contained in this definition calls to mind the lifelong learning approach, a prerequisite for human development and for taking up the future challenges of a globalized economy and meeting the individual and collective demands of a constantly changing labor market. That approach is addressed in the draft Strategic Education Plan which suggests direct links between cutting illiteracy rates, sustainable development, and poverty reduction. Everyone agrees that poverty is not just a matter of education. However, education must be the preferred instrument in effecting both political and economic restructuring

3.3 State of Literacy in Mozambique

Nearly 18% of the world's population is illiterate; of this number approximately 64% are women. In sub-Saharan Africa, the percentage of illiterates is about 38%, 61% of whom are women. The world illiteracy rate among young people (15–24 years old) is 12%; 23% of the people in the sub-Saharan region, 59% of whom are women, can neither read nor write. Mozambique has rates higher than the average for the sub-Saharan region. According to data recently published by the National Institute of Statistics (Instituto Nacional de Estadística), the average rate of illiteracy among adults nationwide is about 53.6%; it is higher in rural areas (65.7%) than in urban districts (30.3%) and more marked among women (68%) than men (37.7%). In a country as large and diverse as Mozambique, regional variations are to be expected; for instance, rates range from 15.1% in Maputo province (in the south of the country) to 68.4% in Cabo Delgado province (in the north). The figures for young people are alarming, with rates of up to 37.9% in the 15 to 19 years age cohort (48% among young women) and 50.7% in the 20 to 29 years age cohort (61% among young women).

Furthermore, in 2001 there were 558 adult literacy and basic education units in the country. By 2004, the number had risen substantially and it was estimated that there were then a total of 5,000. After 2005, the number of schools that provides classes for adult education aiming at eradication of illiteracy might have increased in parallel with the expansion of electrification of primary schools, in particular by the installation of stand-alone solar power generation systems for primary schools in rural areas. As most of the adult persons work in the noon time and engaged mainly with farming and the primary school rooms are used for primary education for the pupils, classes for adult education (literacy education) are commonly held after ordinary classes end for the day or in the night. In this viewpoint, the electrification of schools plays an important role in strengthening the literacy education for illiterate adults.

Chapter 4 Electric Power Development Policy

4.1 Demand and Supply of Electricity

The categories of electric power demand in Mozambique can be classified into four as follows:

1. Local residential and business market (low voltage consumers);
2. Mozambican industrial market which is served by both Electrocidade de Mozambique (EDM) and Mozambique Transmission Company or MoTraCo (middle and high voltage consumers);
3. Southern African market and Southern African Power Pool (SAPP); and
4. Off-grid power demand handled by FUNAE.

The major players in the supply of electricity in Mozambique are EDM, Hidroelectrica de Cahora Bassa (HCB), and MoTraCo.

- *EDM*, which is the national power utility, is wholly owned by the government. It participates in all parts of the electricity supply chain, including some generation, although it is not the primary generator in the country; transmission; distribution; and consumer connection, supply and billing.
- *HCB* manages and operates the Cahora Bassa hydroelectric power stations and their associated transmission networks that supply power to SAPP. The installed capacity of 2,075 MW at the Cahora Bassa dam makes this the primary electricity source for both Mozambique and southern Africa as a whole.
- *MoTraCo* is the third major supplier of electricity in Mozambique and is a joint venture company formed by the state power companies in Mozambique, South Africa, and Swaziland to transmit power from South Africa to the Maputo-based Mozambique Aluminum Smelter (Mozal) plant. The company manages transmission lines in these three countries and was created in 1998 through an equity debt arrangement worth USD120 million.

4.2 Energy Management Policy of Mozambique

In 1997, Mozambique established the national power policy. The major objectives of this policy are to:

In addition to the overarching need to develop Mozambique's extensive energy resources (hydro, coal, gas, and biomass) for both regional and domestic consumption, the main challenges in the power sector in the country are as follows:

(a) Ensuring that affordable electricity supply is available to meet the rapidly growing domestic demand. In the near term, this will involve the continued extension of the grid with a focus on loss reduction and intensification of the grid in;

(b) Reaching the vast areas of the country beyond the EDM grid. The Government of Mozambique is committed to supporting decentralized electrification of rural schools and clinics and to increase access to modern energy services to villages and rural enterprises through solar photo-voltaic systems, mini-hydro schemes, modern biomass energy, and other renewable energy technologies (RETs);

(c) Ensuring that power shortages do not become a constraint to economic growth.
The proposed generation and transmission mega-projects will address sufficiency and security of supply for the medium to long term;

(d) Government capacity to negotiate and manage the new generation developments.

With up to five mega-power generation projects and a transmission backbone project at various stages of preparation, there is urgent need for increased specialized institutional capacity for this type of complex transactions at the Ministry of Energy, Ministry of Finance, and EDM; and,

(e) Institutional strengthening and capacity development at the main sector institutions (ME, EDM, FUNAE, and CNELEC) in order to improve their performance, governance, and effectiveness.

4.3 Rate of Electrification

The electrification has been expanding gradually by supplying power from the grid of the EDM in urban areas such as the capital city Maputo and provincial centers as well as residences located in peri-urban areas. Most of the rural areas located far from the major grid depend largely on independent /off-grid power supply systems such as small diesel power generators, mini-hydro, etc. Table-2.1 shows the rate of electrification by province.

As shown in **Table-A1.4.1**, the national average rate of electrification is around 12% of the total population; for Maputo, it was 46.5%. The average rate of electrification is calculated at 7% if the households electrified in Maputo and its peri-urban areas or the southern region is excluded. In rural areas in the central and northern regions, electrification is substantially low at a mere 2%. It is hard to imagine that electrification will progress if population density is quite low and power demand is substantially dispersed through vast areas. Under such conditions, rural residents can only access modern electric services through independent, self-standing, off-grid type of power sources that are not connected to the national grid.

However, a national electrification program is indispensable and it may be composed of a power development plan and a power investment plan for the mid- and long-term periods. It is evident that a huge investment will be needed to implement the program. In addition, it is certain that considerable time will be needed to create a power demand that will meet the expanded power generation and transmission capacity to be proposed. Therefore, off-grid power plants will be the way to go in implementing rural electrification for the foreseeable future.

Table-A1.4.1 Rate of Electrification by Province (2007)

Province		Population	Population Electrified	Rate of Electrification (%)
1	Maputo	2,358,815	1,097,013	46.5
2	Gaza	1,219,013	188,947	15.5
3	Inhambane	1,267,035	92,494	7.3
4	Manica	1,418,927	109,257	7.7
5	Sofala	1,654,163	205,116	12.4
6	Tete	1,832,339	109,940	6.0
7	Zambezi	3,892,854	182,964	4.7
8	Nampula	4,076,642	322,055	7.9
9	Niassa	1,178,117	77,756	6.6
10	Cabo Delgado	1,632,800	83,273	5.1
Total		20,530,705	2,468,815	12.0

Source: Study Team based on statistics of the Ministry of Energy, Renewable Energy Plan (2009)

Nevertheless, the most important factor that will hinder the expansion of access to electricity in Mozambique is the astonishingly low level of people's incomes. The consumer is compelled to balance between purchasing power or energy, on one hand, and other expenditure for living or survival, on the other hand. Both for the expansion of the national grid service and the mini-grid service, the major detrimental cause of low electrification ratios is that users or consumers cannot afford electricity services. In rural areas, users of electricity generated by diesel power generators on mini-grid systems are limited to business establishments, local administrative offices, health centers, and schools.

4.4 Power Supply System

The national energy supply in Mozambique falls into three distinct categories: the national grid, mini-grids, and independent systems. The responsibility for the national grid rests with the EDM power utility under the supervision of the MoE. Mini-grids are the responsibility of the MoE through the provincial directorates and/or donor-specific initiatives. Management is undertaken privately, typically led by the relevant district administrations.

The provincial directorates of energy are responsible for the design, installation, and quality management of the mini-grid systems. These systems are typically found at district headquarters level and feed commercial centers and local services. Households are eligible to sign up, but few do so due to affordability constraints. Below the mini-grid level, the responsibility for electricity access or energy services to institutional facilities to enable them to provide essential services falls on individual ministries (e.g., health, education). These comprise the independent systems.

4.4.1 On-grid Power Demand and Electrification Approach

Current electrification access rates are about 12% for the country, with the vast majority of these connections located in urban and peri-urban areas. The EDM is primarily involved in grid-based transmission and distribution, levy collection and, to a lesser extent, power generation. At present, its involvement in power generation is confined to five hydropower sites and numerous off-grid and backup generators it operates in regional capitals. EDM tariffs are unified and rural electrification activities are cross-subsidized.

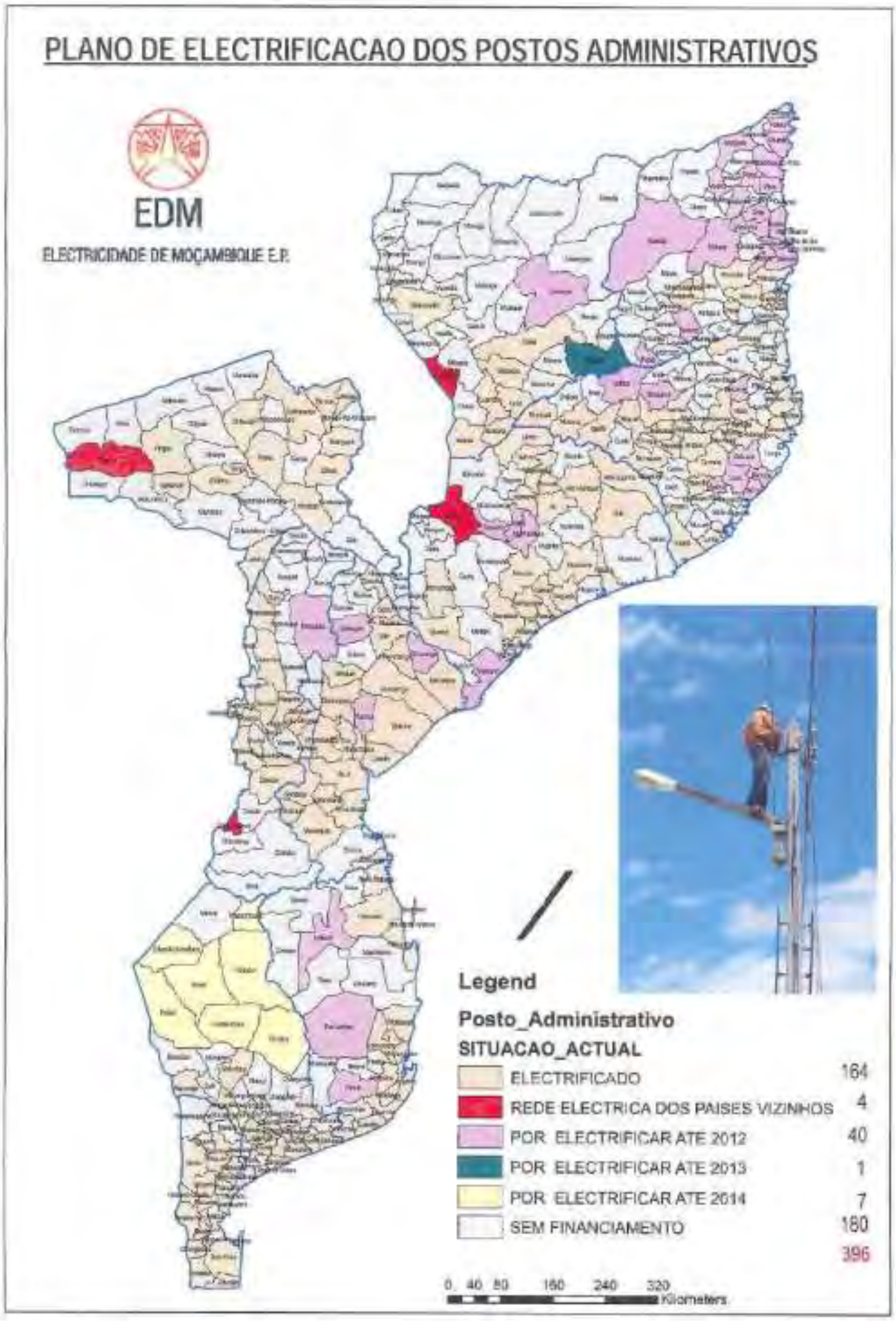
The EDM has one of the most ambitious rural electrification roll-out programs in Africa. Over the past three years, it has aggressively expanded its electrification network by over 260,000 connections. An estimated 100,000 connections were made in 2008 at an estimated cost of USD800 per connection. Grid-based rural electrification in Mozambique is mainly funded by grants and soft loans. About USD80 million was spent on rural and peri-urban electrification activities in 2008. About USD60 million of this came from the Swedish International Development Cooperation Agency (SIDA,) the Norwegian Agency for Development Cooperation (NORAD), the Danish International Development Agency (DANIDA), the World Bank, and the African Development Bank. So far, all regional capitals are connected to the national grid.

Figure-A1.4.1 shows the location of power-generating plants of various types and high-voltage transmission networks. **Figure-A1.4.2** illustrates the areas where administrative offices are connected to the transmission grid owned and managed by the EDM. As shown in **Figure-A1.4.2** all the administrative offices of the 396 districts will be connected to the power grid system in 2012.

Nevertheless, areas connected to the trunk power grid are limited to those where the administrative posts, commercial facilities, and a limited number of residents are located. A few kilometers outside these areas and in more remote areas, there are no electricity services at all.

Source: EDM

Figure-A1.4.1 Locations of Power Generation Plants and Transmission Networks



Source: EDM

Figure-A1.4.2 On-grid Electrification Program for District Administrative Offices

4.4.2 Off-grid Electricity Demand and Electrification Approach

More than 80% of Mozambique's population is not connected to the grid, and this is due to inadequate basic infrastructure, lack of investment, lack of market network, and huge cost of installing an energy grid, among other factors. The large majority of people rely on traditional wood and charcoal biomass resources for all their energy needs. They have little access to conventional electricity or modern fuels. In fact, they pay much more per kWh of energy for the little electricity they get than those in urban areas who have access. To solve the special problem of off-grid energy demand, the government set up FUNAE in 1997, mandating it to tackle the unique problems faced by rural populations. FUNAE is responsible for off-grid energy and electrification efforts.

4.4.3 Power Generation Plans

The devastating effects of the long war, approximately three decades, left the country's infrastructure damaged and chronically underdeveloped. The electrification rate is one of the lowest in the continent (15%). Lack of direct transmission lines from the Cahora Bassa hydroelectric dam, Hidroelectrica de Cahora Bassa (HCB), to Maputo and the southern region of the country is one of the indications of the lack of infrastructure. Electricity produced by HCB is routed to South Africa by the South African state-owned company Eskom and then imported back to Maputo. Of late, Mozambique is able to attract foreign direct investments owing to its stable and improving political environment. The country's total installed capacity in April 2009 was 2,308 MW with generation source dominated by the significant hydro capacity from Cahora Bassa dam on Zambezi River with a capacity of 2,075 MW.

Electricity is provided by a parastatal company, EDM, which has a monopoly over distribution. However, plans are in place to unbundle the company into generation, transmission, and distribution. The EDM has insignificant power generation capacity apart from a backup coal-powered station in Maputo and a few small hydroelectric stations with a total capacity of 233 MW. Domestic electricity consumption is expected to increase by 11% per annum until 2015 driven by rural electrification and the expected boom in the agricultural and manufacturing sectors. The energy-intensive industrial consumption was expected to reach 1,700 MW by 2010. To respond to the expected demand, the country plans to increase power generation capacity by 6,442 MW through a combination of hydroelectric, gas, and coal-fired power stations. The investment cost of these projects is estimated to be approximately USD5 billion.

Rural electrification plans, which are estimated to require an investment of approximately USD400 million, include the building of the Cahora Bassa North Bank, which can add as much as 550 MW of power to the national grid. In addition, the Moatize coal mine is ramping up exploration of coal of which about two-thirds of output is metallurgical coal for the global steel industry and the rest is thermal coal for use in a 1,000 MW power plant. Mphanda Nkuwa is another hydropower project which involves the construction of a 1,400 MW plant on the Zambezi River. Moreover, there are a number of gas fields that have the potential to be used for gas-to-power projects. Sasol and Anadarko have exploration activities in Mozambique. Sasol currently exports Mozambique natural gas via pipeline to its facility in South Africa, which is used for the production of synthetic fuel, chemical products, and power at its Secunda plant.

Table-A1.4.2 shows the plans under preparation and ongoing construction of power-generating facilities.

Table-A1.4.2 Power Generating Plant Construction Plans

Name of Project	Type	Capacity	Remarks
Cahora Bassa North Bank	Expansion of hydropower plant	850–1,200 MW	F/S completed
Mphanda Nkuwa	Hydropower Plant	1,300 MW(Phase-1) 1,300 MW (Phase-2)	By Camargo Correia of Brazil
Boroma	Hydropower Plant	400 MW	
Lupata	Hydropower Plant	650 MW	
Massingir	Hydropower Plant	40 MW	EDM
Lurio	Hydropower Plant	120 MW	
Mjawa	Hydropower Plant	25 MW	
Malema	Hydropower Plant	60 MW	
Moatize	Coal-fired Thermal Power Plant	1,500 MW	
Temane	Gas Combined Cycle Power Plant	300–400 MW	Branching gas from Sasol gas pipeline
Total		6,600–7,000 MW	

Source: Hankins (2009), Vatenfall (2008)
Note: The estimated total cost for the construction of power plants at Cahora Bassa North, Mphanda Nkuwa, and Moatize is USD1.7 billion.

4.4.4 Power Output of EDM

The total power generating capacity of power generation units owned and operated by the EDM in 2010 was a mere 240 MW (hydropower=109 MW, diesel power and thermal power stations combined=130 MW). Of this figure, the total power generation capacity of 136MW is generated by superannuated power generating facilities (hydropower=61 MW, thermal power=75 MW) and the replacement of these superannuated units is needed at present. The total power consumption in 2005 was 1,707 GWh and the peak demand was 284.6 MW. As the share of power supply from Cahora Bassa hydropower plant by Mozambique is 300 MW (around 1,775 MW is for the demand of South Africa, Zimbabwe, and Malawi), it substantially exceeds the total demand of Mozambique. However, since transmission and distribution lines have been lacking, the electricity is used only by major urban areas.

The bulk of electricity supplied to major urban areas is transmitted through trunk power grids. Electricity in central areas of cities is supplied by mini-grids whose power generators are diesel-powered. The cost of power source development, power connection to the trunk grid, as well as operation and maintenance shouldered by power consumers in provincial centers and in rural areas where power demand is quite low is relatively higher than that of urban consumers. In these areas, revenue from the consumers does not exceed the cost of power supply. Most of the power consumers are categorized as domestic customers and they do not consume power for economic activities but for lighting and daily activities. The number of large power consumers is limited, but power consumers in major cities subsidize the cost of power in low-consumption areas.

4.4.5 Power Transmission Line Projects

Mozambique has been exporting the electricity generated by the Cahora Bassa hydroelectric facility located in Songo in Tete province to South Africa and to Zimbabwe. The additional power being produced near Cahora Bassa and by Moatize from coal-fired thermal power stations, etc. is expected to reach 6,000 MW in total. It is evident that such a new electric power generated has to be transmitted to major power demand areas in Mozambique, namely, Maputo and its surrounding industrial areas or the southern region as a whole, as well as the central region which has Nacala as the center; thus the construction of new transmission lines is necessary. At present, two major power transmission line construction projects are being prepared with an estimated budget of USD1.7 billion. The lines will carry a maximum of 2,650 MW and 1,100 MW, respectively. Priority should be given to the construction of the direct current line from a new substation in Cataxa in Tete province to the substation in Maputo.

1) Tete–Maputo Transmission Line Project

The feasibility study on the power transmission line project has been completed and international financial institutions, such as the World Bank, and a number of donor countries have proposed financial assistance. This new transmission line project is called Tete–Maputo Transmission Line Project or backbone transmission line. The link from Tete to Maputo will have two high tension lines, the first with 800 kV of direct current and the second with 400 kV of alternating current. The line will traverse the provinces of Tete, Sofala, Gaza, Inhambane, Maputo, and Manica, requiring about 8,000 pylons. The total budget of this project is estimated at more than USD1.7 billion. According to the World Bank, the line is expected to expand electrification in Mozambique from 13% to 20% of the population. The preparation of the final project feasibility report including EIA has been ongoing. If the necessary funding will be completed in time, construction is due to take place between 2014 and 2017.

2) Tete–Nacala Transmission Line Project

At present, the high tension transmission line of 500 kV links the Cahora Bassa hydropower station in Tete to Nacala via Nampula in the central region. It is necessary to construct another line parallel to it to enhance the economic development of the central and northern regions. The estimated cost of this new transmission line is at USD1.7 billion as well.

4.4.6 Transmission Lines of EDM

The power transmission system of the EDM is composed of the systems for the northern, central and southern regions. In the northern region, a 220-kV high-tension line links Songo substation in Tete and Nampula (around 1,000 km) and a 110-kV line links Nampula and Nacala (around 300 km). Another 220-kV transmission line links Tete and Chibata of the central region. In the central region there exist 110-kV transmission lines linking hydropower stations at Chicamba and Mavuji and the power demand area along the Beira–Manica corridor. In the southern region, there exist 110-kV transmission lines that link Xai-xai and Maputo, Chokwe and Inhambane. Another 275-km transmission line links Maputo and Komatipoort of South Africa operated by Eskom.

4.5 Rural Electrification Policy

4.5.1 Rural Electrification in the African Continent

In any country the construction of electric grids to distribute power in rural areas is an infrastructure assignment carrying huge expenses, not less so in most African countries where existing infrastructure is rudimentary. In Africa and elsewhere, rural electrification has largely been the responsibility of the public sector, which in the African context generally implies a large influence from donors. In comparison with industrial countries, rural electrification in Africa has been progressing at a slow pace.

The large distances and low incomes make distribution expensive and rural customers financially unattractive to private sector investors. Expenses associated with vast distances could be met by decentralized grids in lieu of a full grid coverage. Such off-grid approaches for supplying electricity in remote areas are frequently powered by diesel generators which are dependent on fuel transport for operation and generate a comparatively higher running cost. An alternative to diesel-powered off-grids are available renewable energy sources.

In sub-Saharan Africa the potential of renewable energy sources is high. In particular, micro hydropower and solar photovoltaic (PV) systems have been utilized. Due to the low population density and geographical distances, these sources are often the least-cost alternative, and financing instruments like the Clean Development Mechanism can become an important driver for renewable energy sources in Mozambique.

4.5.2 Rural Electrification in Mozambique

In Mozambique electricity generation is heavily dominated by the 2,075 MW hydropower station Cahora Bassa, situated in the northwestern part of the country. Cahora Bassa, a few smaller hydropower stations, and a backup coal power station supply electricity to the national grid. The lion's share of electricity from Cahora Bassa is exported to neighboring countries but transmission lines reach the largest cities and some towns. Since the country is stretching over enormous distances, transmission losses are significant and the power supply becomes fragile in the outskirts of the grid. Numerous diesel generators have been allocated to supply smaller and remote districts.

Mozambique has endured a long-lasting civil war which ended in 1992. Since then, efforts in grid extension have been significant; still the renewable energy level was below 2% in 2007. The EDM is the governmental utility responsible for electrification (generation, transmission, and distribution) in Mozambique, but a restructure is considered. The EDM buys most of its distributed electricity from the

Cahora Bassa dam at low costs which somewhat complicates competition and the introduction of other energy sources. The private sector, however, is free to contribute. The EDM carries out renewable energy by extending the national grid and the tariff is regulated by the Ministry of Energy. Another public institution is FUNAE, founded in 1997 and strongly supported by donors. In practice it is responsible for rural off-grid electrification mainly using diesel generators and solar PV systems.

Chapter 5 Utilization of Renewable Energy

5.1 Renewable Energy Sources in Mozambique

As tabulated in Table-A1.5.1 the major and important renewable energy sources of Mozambique are solar, wind, mini-hydropower, biomass, geothermal, etc. The present primary energy consumption of Mozambique is dominated by traditional bio-energy such as wood fuel, charcoal, and agricultural waste. The major energy used in rural areas for night lighting at public facilities, such as health centers and schools, are candles or kerosene lamps. However, since 2005 the introduction of photovoltaic cells for elementary schools and health centers started.

Table-A1.5.1 Major Renewable Energy Sources in Mozambique

Sources	Resource Availability	Remarks
Solar	High Insulation:4.5-7.0 kWh/m^2/day Assuming average insulation of 5.2kWh/m2/day, 1.49 million GWh of annual radiation is incident on the total land surface of Mozambique	Estimated around 1 MW PV system has been installed (Source: FUNAE)
Wind	Wind resources along the coast. Average >6 m/s in some areas.	Resource map of wind speed is needed.
Small-scale Hydro up to 10 MW	Potential hydropower generation capacity is more than 1,000 MW.	Around 60 potential locations have been identified.
Biomass	Several hundred MWs using various fuel sources. Bagasse (433,000 MT/year) can be used.	In Maputo and Sofala, 5 sugar mills are under operation.
Geothermal	Possible resources but no studies carried out yet in Tete, Manica, and Niassa provinces. More than 25 MW.	Realistic plans and resource assessment are needed.

Source: JICA Study Team

5.1.1 Small-scale Hydropower

The Ministry of Energy estimates that over 60 potential micro and mini-hydro power projects with potentials of up to 1,000 MW exist in Mozambique. The central part of the country (Manica province) has the best potential resources. Table-A1.5.2 provides a summary of the priority government projects.

Table-A1.5.2 Priority Small Hydropower Projects

Identified Location	Installed Capacity (kW)	River	Distance to Nearest Village	District, Province
Mbahu	2,000	Lucheringo	30	Lichinga, Niassa
Majaua	1,000	Majaua	10	Milange, Zambezia
Kazula	30	Kazula	12	Chiuta, Tete
Maue	280	Maue	1	Angonia, Tete
Mavonde	30	Nhamukwarara	3	Manica, Manica
Rotanda	30	Rotanda	1.5	Sussundenga, Manica
Sembezia	30	Bonde	2	Sembezia, Manica
Honde	75	Musambizi	4	Barue, Manica
Choa	20	Nhamutsawa	2.5	Barue, Manica

The production of renewable energy in 2005 was estimated at about 300,000 TJ, with an average annual growth of 2%. Almost all of this is traditional biomass for domestic consumption. About 90% of renewable production consists of fuel wood. However, over the last few years new renewable technologies, such as solar power technology, are being introduced, accounting for about 12,000 TJ in 2005, which was about 3% of total renewable energy production. In most provinces the vast majority of the population uses fuel wood for cooking.

In the bigger cities, people use mainly charcoal for cooking, as is most notably reflected in the data for the provinces of Sofala (Beira City) and Maputo (Maputo City). In Maputo City about 25% of the population uses other energy sources for cooking, mainly liquid petroleum gas (LPG). In most provinces the majority of the population uses kerosene for lighting, followed by fuel wood. Other energy source for lighting is electricity and, as such, reflects the electrification pattern of the country, with Maputo City having by far the highest electricity consumption.

5.2 Implementing Agency to Promote Utilization of Renewable Energy

5.2.1 Establishment of FUNAE

More than 80% of Mozambique's population is not connected to the grid, and this is due to the inadequate basic infrastructure, lack of investment, lack of market network and huge cost of installing an energy grid, among other factors. The large majority of people rely on traditional wood and charcoal biomass resources for all of their energy needs. Members of this group have little access to conventional electricity or modern fuels. In fact, they pay much more per kWh of energy for the little electricity they get than those who have access in urban areas.

To solve the special problem of off-grid energy demand, the government set up FUNAE in 1997, mandating it to tackle the unique problems faced by rural populations. FUNAE is responsible for off-grid energy and electrification efforts. FUNAE's organizational objectives are:

- to develop, produce, and use different forms of low-cost power; and
- to promote rational and sustainable management and conservation of power resources.

FUNAE provides financial aid and guarantees for economically and financially viable projects that are in harmony with its objectives. Its off-grid activities include:

- the provision of financial assistance/guarantees and loans to enterprises that have as their objective the production and dissemination of production techniques, distribution and conservation of power in its diverse forms;
- the provision of financial assistance for the installation of power production equipment or the distribution of power;
- acquiring, financing or supplying financial guarantees for the purchase of equipment and machinery destined for the production and distribution of power, with particular focus on the use of new and renewable power sources;
- the promotion of distribution networks for petroleum products in rural areas;
- the provision of financial assistance to transport petroleum products to rural areas;
- the provision of support and consulting services and technical assistance for rural energy projects;
- financing of the preparation of studies and investigative papers on technologies for the production, distribution, and conservation of power products or renewable power, including their publication; and

- the promotion of the development and planting of forests for biomass production.

With support from the government and various donors, such as the European Union, NORAD, DANIDA, the World Bank/Global Environmental Facility and others, FUNAE has managed the installation of PV systems, development of micro hydro projects, installation of wind pumps, and promotion of fuel-efficient stoves in the country. However, given FUNAE's small size and modest budget and the huge size of the off-grid population in the country, the impact of its work is relatively small.

A recent review of energy programs in Mozambique put it this way: FUNAE has a huge task—in scope and in scale—in rural energy. Despite being a young, eight-year-old organization, FUNAE is involved in:

- all forms of energy supply: traditional and modern fuels, decentralized grid, stand-alone energy systems;
- all forms of uses: household energy, productive use promotion, energy savings;
- all forms of finance: loans, subsidized loans, subsidies, guarantees;
- all forms of investments: project preparation, project implementation, project rehabilitation.
- Whether any such relatively inexperienced institution is capable of handling such a range of activities effectively is doubtful. (Source: Energy Security in Mozambique)

5.2.2 The Experience of FUNAE and its Plan

The first project undertaken by FUNAE was in 1997 to install diesel generators for village electrification through independent, mini-grid systems (off-grid system) in rural areas in general and in remote villages in particular. **Table-A1.5.3** shows the record of installation of diesel-power-based village electrification since 2001 to date.

The renewable energy utilization project undertaken by FUNAE started from 2005 under the Electricity Rural Development Project (ERDP) formulated and financially assisted by the World Bank to install self-standing PV system to 100 schools and 100 health centers during the period 2005–2011 or in the past seven years. Table-A1.5.4 shows FUNAE's record of installing PV systems at elementary schools and health centers in rural areas, as well as its ongoing projects and plans up to 2015.

Table-A1.5.3 Village Electrification by FUNAE using Diesel Power Generators

Year	Project	Number of Beneficiaries	Installed Capacity	Average Number of Beneficiaries per Project	Average Capacity
	Nos.	People	kW	People	kW
2001	4	19,845	63.80	4,961	16.0
2002	0	0	0.00	0	-
2003	1	1,325	400.00	1,325	400.0
2004	0	0	0.00	0	-
2005	5	25,017	308.00	5,003	61.6
2006	7	25,371	256.00	3,624	36.6
2007	4	9,018	156.80	2,255	39.2
2008	13	251,818	1,333.60	19,371	102.6
2009	19	90,663	1,844.00	4,772	97.1
2010	10	91,448	1,026.40	9,145	102.6
Total	63	514,505	5,388.60	8,167	85.5

Source: FUNAE

Table-A1.5.4 PV Projects and Plans of FUNAE

Off-grid Electrification Project of FUNAE

	Total	Northern Region		Central Region					Southern Region			Implementation Period	
		Cabo Delgado	Niassa	Nampula	Tete	Zambezia	Manica	Sofala	Inhambane	Gaza	Maputo	From	To
Installed Unit													
School	150	8	8	50	8	50	6	6	6	8	3		
World Bank-ERAP	150	8	8	50	8	50	5	8	6	8	3	2005	2011
Health Center	150	3	28	50	18	50	0	1	0	0	0		
World Bank-ERAP	150	3	28	50	18	50		1				2005	2011
Total	300	11	36	100	26	100	5	7	6	8	3		
On-going and Planned													
School	795	175	175	50	100	90	75	80	50	0	0		
World Bank-EDAP	250	75	75				50		50			2012	2014
World Bank-New	300	100	100		100							2013	2015
Belgium	195					90	25	80				2012	2014
Japan	50			50								?	?
Health Center	771	167	175	50	100	59	50	70	50	50	0		
World Bank-ERAP	100							50		50		2005	2011
World Bank-EDAP	242	67	75				50		50			2012	2014
World Bank-New	300	100	100		100								
Belgium	79					59		20					
Japan	50			50									
Total	1,566	342	350	100	200	149	125	150	100	50	0		
Total Up To 2015													
School	945	183	183	100	108	140	80	86	56	8	3		
World Bank	700	183	183	50	108	50	55	6	56	8	3		
Belgium	195					90	25	80					
Japan	50			50									
Health Center	921	170	203	100	118	109	50	71	50	50	0		
World Bank	792	170	203	50	118	50	50	51	50	50	0		
Belgium	79					59		20					
Japan	50			50									
Sub-total	1,866	353	386	200	226	249	130	157	106	58	3		
Administration Post	77	0	0	0	0	38	10	29	0	0	0		
Belgium	77					38	10	29					
Sub-total	77	0	0	0	0	38	10	29	0	0	0		
Grand Total	1,943	353	386	200	226	287	140	186	106	58	3		

Village Electrification

	Total	Northern Region		Central Region					Southern Region			Implementation Period	
		Cabo Delgado	Niassa	Nampula	Tete	Zambezia	Manica	Sofala	Inhambane	Gaza	Maputo	From	To
Executed Project													
Project	75	1	1	6	1	0	0	5	31	21	9	2000	2011
Mozambique Goverment	75	1	1	6	1			5	31	21	9		
On-going Project													
Project	84	11	17	6	5	14	6	4	15	5	1	2011	2014
World Bank-EDAP	30	10	10						10				
EU	4	1	1	2									
Portgal	50		6	4	5	14	6	4	5	5	1		
Total Up to 2014													
Project	159	12	18	12	6	14	6	9	46	26	10		
World Bank	30	10	10	0	0	0	0	0	10	0	0		
Mozambique Governmnt	75	1	1	6	1	0	0	5	31	21	9		
EU	4	1	1	2	0	0	0	0	0	0	0		
Portgal	50	0	6	4	5	14	6	4	5	5	1		

Note

1 Mini-grid PV system in Niassa: 550kW at Mavago, 400kW at Muembe, 350kW at Mecula.
Total Project Cost is estimated at US$41 million of which US$35 million is the project loan provided by the Korean Exim Bank. Tendering in 2012.

As shown in the table above, 300 units of self-standing PV systems of average 1.2kW in total has been installed in all provinces throughout the country in the past 7 years or between 2005 and 2011. It is planned to install at once 1,550 units of PV system of similar output by 2014 or in coming 3 years. The financial arrangement for the installation of 1,450 units has been already secured from the Government of Belgium and the World Bank.

Therefore, by the end of 2015, around 1,860 elementary schools and health centers in total throughout Mozambique will be electrified by use of self-standing PV system. Furthermore; FUNAE has been executing the village electrification by mini-grid system. The number of villages electrified by independent mini-grid system by FUNAE has reached to 75 villages in the past 11 years or between 2000 and 2011. From 2012 to 2015 or in the coming four years, around 84 villages is planned to be electrified by the installation of PV system. The total number of village electrified by independent mini-grid PV system will reach to 150. The scale of project being undertaken by FUNAE in coming few years will be around 5 times larger than the project scale executed in the past 7 years.

5.2.3 Organizational Chart of FUNAE

As of February 2012, the total number of staff of FUNAE, including board members, is 123. Its Maputo headquarters is staffed by 95 persons, and a total of 28 are assigned to run its three branches in the northern region (Nampula), central region (Beira), and southern region (Maputo). **Figure-A1.5.1** illustrates the current organizational chart of FUNAE.

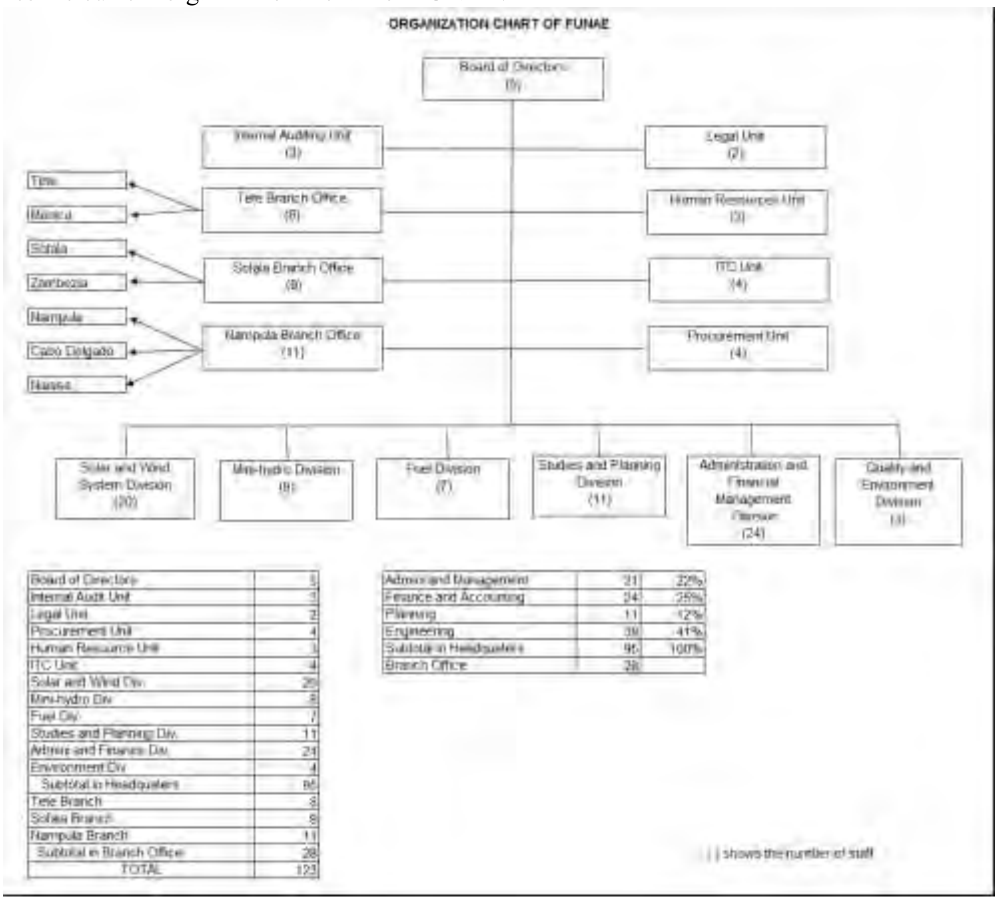


Figure-A1.5.1 Organizational Chart of FUNAE

Chapter 6 Comparison of Adaptable Electrification Technologies

6.1 Comparison of Applicable Technologies

With regard to the applicable technologies, the comparison were conducted by SWOT analysis for the following technologies; 1) solar power system, 2) wind power system, 3) solar and wind power hybrid system, 4) Jatropha bio-diesel system, 5) solar power and Jatropha bio-diesel hybrid system and 6) diesel power system. According to the result of the analysis, the most appropriate technology among the applicable technologies along the Nacala Corridor is 1). The second suitable is the hybrid system of 1) and 4). However, it is assumed that it takes time to organize farmers for the production of Jatropha fuel. As the weather condition differs from place to place, the third suitable technology can be 3) in limited coastal areas where the wind blows relatively constantly.

1) Solar Power System

Strengths	Weaknesses
● Environmentally friendly as fossil fuel is not used ● No operational cost required as fossil fuel is not used ● Possible to be utilized in remote areas as it is a power plant independent from transmission lines ● Very easy to maintain PV panels themselves (wiping surfaces) ● Decline over time of power generation efficiency is small if PV panels are of good quality. ● Possibility to exert a scale merit in terms of maintenance system as PV panels whose power reduction by temperature rise of panel surfaces is reduced (20% reduction under approximately 60 degree Celsius) have been already introduced in Mozambique.	● Decrease of electricity volume generated in cloudy weather as its energy source is sunlight. ● Batteries are necessary for night and cloudy time as its energy source is sunlight. ● The initial cost is higher than power generation facilities by fossil fuels (3 to 8 times) ● Certain area of land is necessary for installation (Example: 25m^2 for 5kW) as it requires approximately 5 m^2 per 1kW. ● Necessary to assume a point of time when electricity generated becomes smallest in examination of the facility scale in order to achieve sustainable supply of electricity. Thus, it is necessary to size up facility scale or battery volume in areas where the fluctuation of the amount of solar isolation is big. ● Average household which are categorized as low-income population cannot be benefited as the cost for power generation is high.
Opportunities	**Threats**
● Possibility of widespread application is high in areas where sunlight is obtained constantly as it does not require operational cost. ● Possibility to generate industries and employment opportunities in the area of maintenance as donors such as the World Bank, EU countries, and Korea promote the introduction of solar power system in Mozambique.	● Easy to lose power generation ability without sufficient maintenance skills. It is difficult to quickly replace or repair solar power system in case of damages and thefts of panels as solar power system is one of the new energy technologies ● Easy to lose its function and cause serious troubles in power generation if maintenance is not provided by technicians with expert knowledge for various kinds of electric equipments composing of the system (battery, invator, controller, wiring and so on).

2) Wind Power System

Strengths	Weaknesses
● Environmentally friendly as fossil fuel is not used ● No operational cost required as fossil fuel is not used ● Possible to generate electricity day and night as long as wind blows steadily. ● Possible to be utilized in remote areas as it is a power plant independent from transmission lines ● Area necessary for installation is smaller than solar power system. ● Easy to understand the mechanism of "power generation" and to appeal to people as the rotation of blades can be seen directly.	● Sufficient amount of electricity can be generated only in areas where wind blows at a certain speed (5m/s) for a certain period (at least 5 hours per day) as it requires wind power as its energy resources. ● The initial cost is higher than power generation facilities by fossil fuels (5 to 10 times) depending on the wind conditions. ● It makes wind noise (high-speed rotation at a wind speed over 10m/s) and motor nose
Opportunities	**Threats**
● Possibility of widespread application is high in areas where wind	● Easy to lose power generation ability without sufficient

power can be obtained constantly as it does not require operational cost. ● In terms of the total volume of electricity generated, wind power is the second widely used in the world among renewable energy resources following hydropower. However, it requires the condition that wind blows stably (5 to 6 m/s) for long time for example in coastal areas in case of Mozambique. ● Adaptation of large-scale wind power generation is on process as the maintenance cost of small-scale wind power generation is relatively high per kW.	maintenance skills as wind power system is one of the new energy technologies. ● Possibility to lose its function by lighting damages if windmills are installed high above the land surface in order to gain wind speed. ● Maintenance cost can be quite high if the number of facilities installed is not sufficient as installation cases are quite few in Mozambique and the future prospect is not sure.

3) Solar Power and Wind Power Hybrid System

Strengths	Weaknesses
● Environmentally friendly as fossil fuel is not used ● No operational cost required as fossil fuel is not used ● Possible to be utilized in remote areas as it is a power plant independent from transmission lines ● Possible to store a certain volume of electricity by ● There are cases where it is possible to store the certain volume of electricity if solar and wind powers complement each other. ● Possible to reduce the volume of batteries by power generation by wind power system at night	● The initial cost is high as it combines two types of renewable energy facilities. It costs 5 to 10 times higher than power generation facilities by fossil fuels. ● More difficult to install and maintain systems as it gets more complicated. ● Maintenance costs can increase as two different power generation systems are combined. ● Average household which are categorized as low-income population cannot be benefited as the cost for power generation is high.
Opportunities	**Threats**
● Possibility of widespread application as it does not require operation cost in cases where an appropriate system is developed according to the amount of solar isolation and the characteristics of wind in areas concerned.	● Power generating function can be easily lost without appropriate maintenance skills as the both power generating technologies of solar and wind are of new energy technology. ● Difficult to maintain facilities in cases where there are no technical staffs who can handle various kinds of technologies as this system combines two different technologies.

4) Jatropha bio-fuel system

Strengths	Weaknesses
● Environmentally friendly as fossil fuel is not used ● Conventional diesel engines can be utilized in Jatropha caltivation areas if Jatropha oil can be produced in its cultivation areas. ● Jatoropha can be cultivated without manure or fertilizer even in dry areas as long as there is a precipitation of more than 600mm. ● Jatropha cultivation can be a stable source of cash income for farmers if it is decided to use certain amount of Jatropha seeds in public facilities such as schools and health centers every year and to purchase the seeds from farmers in the areas concerned. ● It can contribute to the cost reduction of the whole system as this system is suitable for hybrid with solar power and wind power.	● The full-scale Jatropha cultivation has not been proven as it is sill in the pilot stage in Mozambique. ● To spread Jatropha cultivation at community level takes time as it is not commonly practiced.
Opportunities	**Threats**
● In areas where grid electrification is not feasible from the aspects of financial arrangements, the demand for electricity and paying capacity, Jatropha farmers themselves can become uses of electricity if Jatropha is cultivated at community level and its oil is utilized as fuel for diesel generator and this enables farmers to obtain electricity without paying cost. Thus, this system can be widely adapted at small-scale community level if a system is applied where farmers can cultivate Jatropha with little cost. ● The amount of production increases if the cultivation and trade	● Power cannot be generated as expected if the production amount of Jatropha oil falls below estimation and the designated amount of Jatropha oil for fuel cannot be produced. ● It is highly likely for the system to be established if it deviates from the principle of local production for local consumption as it is not suitable for large-scale projects such as plantation. ● The use of Jatropha bio-diesel is prohibited if any health risk of phorbol ester contained in Jatropha

of Jatropha starts. If the amount of Jatropha seeds increases, it becomes possible to sell the seeds on regular bases from farmers to oil refineries. This partly transforms subsistence agriculture into agriculture which generates cash income.	bio-diesel is scientifically proven.

5) Solar power and Jatropha Bio-diesel Hybrid System

Strengths	Weaknesses
● Environmentally friendly as fossil fuel is not used ● No operational cost required as fossil fuel is not used ● Possible to be utilized in remote areas as it is a power plant independent from transmission lines ● In cases where certain amount of solar isolation cannot be obtained, it is possible to charge batteries by small diesel power generation by using Jatropha bio-fuel. In this way, it is sometimes possible to store a certain volume of electricity at all times. ● It is not necessary to invest money in land development as Jatropha is cultivated as a hedge around cultivation areas. ● All the investment farmers have to put is labor as nursery trees necessary for the first time are distributed by traders of contract farming who buy Jatropha seeds. ● It is small and cheap since diesel engines for Jatropha bio-fuel are ordinary engines which do not require any special improvement and supplements for solar power generation. ● Installation cost is low. It is not necessary to size up PV panels according to a season of low solar isolation as it has supplemental power.	● It takes time to ensure support and participation of farmers who cultivate Jatropha in villages concerned as Jatropha cultivation is not yet common in Mozambique, ● 6000m hedge of Jatropha is necessary in order to operate a diesel engine of 5kW for 60 days annually. This requires participation of 300 farmers but it takes time to organize the farmers.
Opportunities	**Threats**
● As Jatropha can be used as a supplement of solar power, Jatropha cultivation can become common in Mozambique which has abundant land suitable for Jatropha cultivation, ● It may generate cash income for farmers even though the amount of Jatropha seeds necessary for solar power facilities is small. ● If the number of farmers who enjoy cash income, Jatropha cultivation may become widely used all over the country. This may form a big market and Jatropha can be used as a fuel for transportation,	● Power cannot be generated as expected if the production amount of Jatropha oil falls below estimation and the designated amount of Jatropha oil for fuel cannot be produced. ● It is highly likely for the system to be established if it deviates from the principle of local production for local consumption as it is not suitable for large-scale projects such as plantation. ● The use of Jatropha bio-diesel is prohibited if any health risk of phorbol ester contained in Jatropha bio-diesel is scientifically proven.

6) Diesel Power System

Strengths	Weaknesses
● The initial cost is distinctly low compared to solar power system and wind power system. ● Project cost estimated by life cycle cost analysis is about half of solar power system even based on the current fuel price. ● Maintenance is technically easy as the maintenance of diesel power system is common.	● It affects the global environment as it is a fossil fuel. ● Transportation cost is extremely high if it is used in remote areas. ● In order to continue power generation sustainably, it is necessary to purchase fuels regularly.
Opportunities	**Threats**
● As the initial cost is quite low, it can be widely used if there is no problem of fuel cost. ● As its maintenance is relatively easy, it can become common.	● In order to generate electricity sustainably, it is necessary to supply a certain amount of fuel and it costs continuously. If budget is not smoothly secured and implemented, its operation will be suspended and it cannot generate electricily. ● It negatively affects the global environment by increasing the emission of carbon dioxide.

Chapter 7 Maintenance and Sustainability of Options

7.1 Maintenance for Solar Power Facilities

Appropriate maintenance is necessary for solar power system to be used in a good condition until its expected life (20 years). Especially, it is important to monitor the systems as follows.

1) General Maintenance

It is essential to conduct daily maintenance and regular maintenance in order for solar power system to operate sustainably for long period of time. General items of maintenance are shown below.

(1) Daily Maintenance

Daily maintenance should be conducted once a month mainly by observation as per items shown in Table-A1.7.1.

Table-A1.7.1 Items and Points to Consider for Daily Maintenance

Parts	Items		Points to Consider
Solar Panel	Observation	a) dirt and damage of surfaces such as glass	No serious dirt or damage
		b) corrosion and rust of cradles	No corrosion or rust
		c) damage to outside wiring (connection cables)	No damage on connecting cables
Junction Terminal Box (Conduit Box)	Observation	a) corrosion and damages of boxes	No corrosion or rust
		b) damage to outside wiring(connection cables)	No damage on connecting cables
Power Conditioners	Observation	a) corrosion and damages of boxes	No corrosion or rust of boxes and no exposure of live parts
		b) damage to outside wiring(connection cables)	No damage on wiring connected to power conditioners
		c) ventilation（air vents、ventilation filters and so on）	Air vents are open Ventilation filters (if any) are not clogged.
		d) abnormal noise and odor, smoke and overheating	No abnormal noise, vibration, odor nor overheating during operation
		e) unusual indication of displays	No error messages nor lamp signals on displays
		f) power generating condition	No error messages about power generating conditions on display

(2) Regular Maintenance

Regular maintenance should be conducted twice a year by an expert on the items shown in the Table A-1.7.2.

Table-A1.7.2 Items and Points to Consider for Regular Maintenance

Parts	Items		Points to Consider
Solar Panels	Observation, direct touch	Connection with earth wires and backlash of joining terminal	Connected firmly to earth wires. No backlash of screws
Junction Terminal Box （Conduit Box）	Observation, direct touch	a) corrosion and damage on boxes	No corrosion or damage
		b)damage on outside wiring and backlash of joining terminal	Nothing wrong with wiring No backlash of screws
		c) connection with earth wires and backlash of joining terminal	Nothing wrong with earth wires No backlash of screws
	Measurement and testing	a)insulation resistance	＜Solar Batteries－Earth Wire＞ More than 0.2MΩ Measured voltage DC500V （measured for each circuit） ＜Output terminal－Ground＞ More than 1MΩ Measured voltage DC500V
		b)open circuit voltage	Specified voltage Correct polar character
Power Conditioners	Observation, direct touch	a) corrosion and damage on boxes	No corrosion or damage
		b) damage on outside wiring and backlash of joining terminal	Nothing wrong with wiring No backlash of screws
		c) damage on earth wire and backlash of joining terminal	Nothing wrong with earth wires No backlash of screws
		d) ventilation（air vents、ventilation filters and so on）	Air vents are open Ventilation filters (if any) are not clogged.
		e) abnormal noise, vibration and odor during operation	No abnormal noise, vibration and odor during operation
	Measurement and testing	a) insulation resistance (power conditioner input and output terminal – ground)	More than 1MΩ Measured voltage DC500V
		b) operation check of display (indication on display, generating electricity）	Nothing wrong with display condition and power generating condition
Others Switch for Solar Power System	Observation, direct touch	a) backlash of joining terminal of switch for solar power system	No backlash of screws
	Measurement	a) insulation resistance	More than 1MΩ Measured voltage DC500V

Comparison of Total Lifetime Costs by Type of Power Generation System

(Photovoltaic Power System, Solar and Small-scale Wind Hybrid System, Wind Power System)

The following data sources compared the total lifetime costs of power generating units:

1. Cost of Power Generating Units

Photovoltaic Power System: The average unit cost of the system per kW is at JYE 500,000, this is indicated in the presentation document referred to as "Present Situation of Renewable Energy in Our Country, Data-7"prepared by the Agency for the Natural Resources and Energy, Ministry of Economy, Trade and Industry of Japan issued on March 6, 2012.

Small-scale Wind Power Generating System: The average unit cost of system per kW is at JYE 1,500,000. This is indicated in the promotion material referred to as "Approach to Power Purchase Systems for Renewable Energy at Fixed Prices of Small-scale Power Generating business society in Japan" prepared by the Japan Small Wind Turbines Association issued on March 19, 2012.

2. Batteries

The type of battery selected for the project is a valve-regulated lead-acid battery, which has a longer battery life and with lesser frequent maintenance. The major lead-acid battery manufacturers in Japan are The Furukawa Battery Co,, Ltd., GS Yuasa Corporation, Nisco Co., Ltd., etc. The catalogue of GS Yuasa for a similar type of battery shows that the maximum life of this battery is seven years. However, this lifespan has been pegged at five years taking into account the weather conditions in the project site. The average unit cost per kWh of this type of battery is JYE 150,000, which is also an average for different manufacturers.

3. Spare Parts

The annual cost of spare parts for a photovoltaic system, wind power system, and PV+Wind hybrid system are respectively assumed to be 1.00%, 2.00% and 1.75% of the cost of the respective power generating system. It is assumed that the cost for spare parts on the 10^{th} year from its commissioning is five-times higher than a normal year since major parts and components will have to be replaced.

4. Cost for Maintenance Workers

Annual maintenance costs were estimated based on following assumptions: The necessary number of skilled workers and unskilled labors are 1 and 2 respectively for the maintenance of the system once a month at each site. The labor cost is estimated at US$ 500 per year per site. The duration of maintenance per one site is assumed to be one day as well. Thus the transportation cost of the labor incurred for a maintenance work per site per day is assumed to be at USD500 which is an average rent cost of one 4WD half-truck suitable for transporting persons and machinery needed for maintenance work. Accordingly the total annual costs required for the maintenance of system per one site is estimated at USD1,000 or JPY80,000.

5. Cost Comparison Methods

The method of the total life cost comparison in net present value was carried out based on the presumption that the project life is 20 years and the discount rate used for the computation of the NPV is set at 12%. Such cost is comparable with the cost of photovoltaic system at 1.00 and other power generating system. (See computation table of subsequent page)

6. Summary of Cost Comparison

The summary of cost comparison in total life cost by power generation system and by region is as shown in Table-1.

Table-1 Summary of Cost Comparison (Total Life Cost)

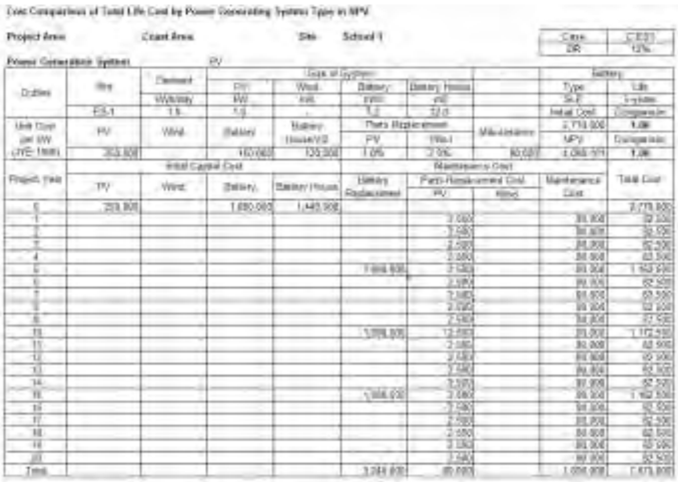
Area	Facility / Power Generation System	School-1	School-3	Health Center-1	Health Center-2
	Power Demand (kWh/Day)	1.8	2.6	1.5	2.1
Coastal Area	Photovoltaic Cell (PV)	1.00	1.00	1.00	1.00
	PV+Wind Hybrid	0.92	0.92	0.92	0.91
	Wind	1.44	1.53	1.44	1.69
Inland Western Area	Photovoltaic Cell (PV)	1.00	1.00	1.00	1.00
	PV+Wind Hybrid	1.48	1.37	1.21	1.46
	Wind	2.65	2.67	2.38	2.88

Note: The total life cost of Solar Power Generation System (Photovoltaic Cell – PV) is set as 1.

Source: JICA Study Team

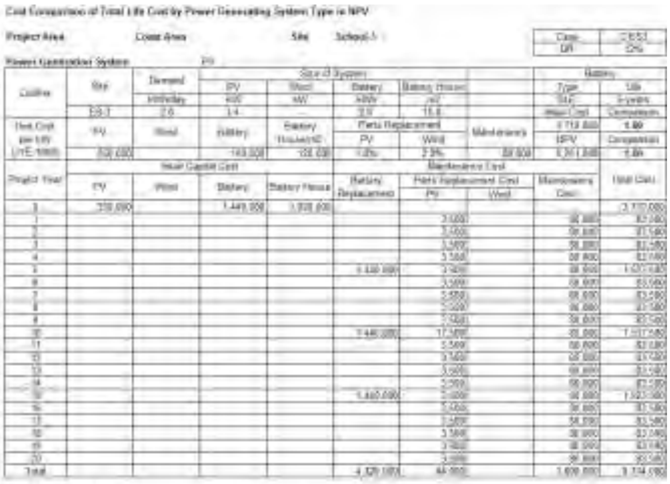
(1) Cost Comparison of Total Life Cost by Power Generating System in NPV

Coastal Region – Primary School


Cost Comparison of Total Life Cost by Power Generating System Type in NPV

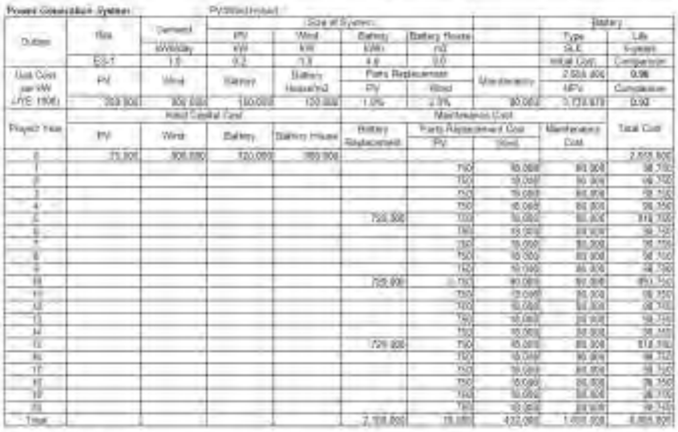
Project Area Coast Area Site School 1

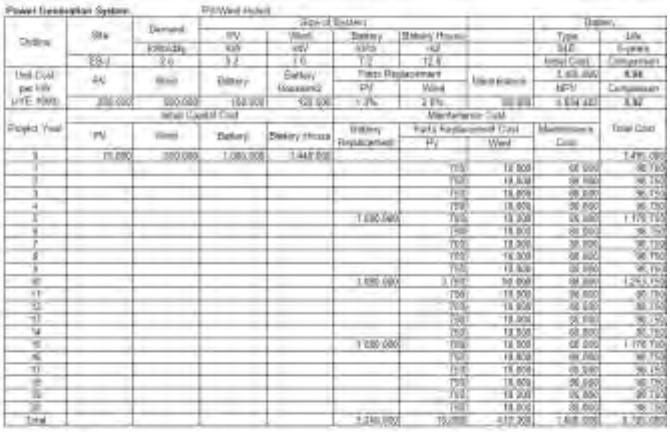
Power Generation System PV

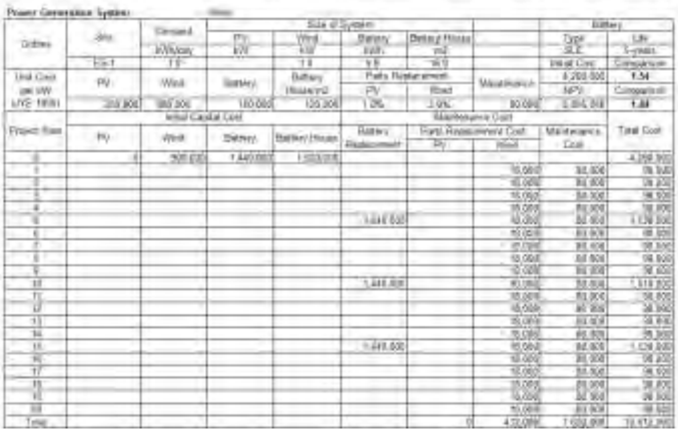

Cost Comparison of Total Life Cost by Power Generating System Type in NPV

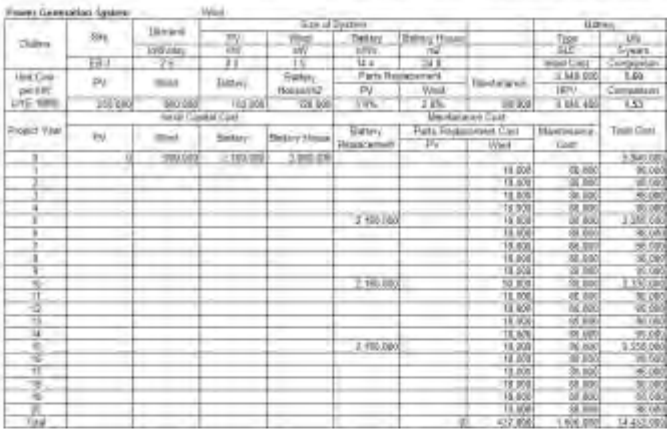
Project Area Coast Area Site School 1

Power Generation System PV


Power Generation System PV/Wind Hybrid

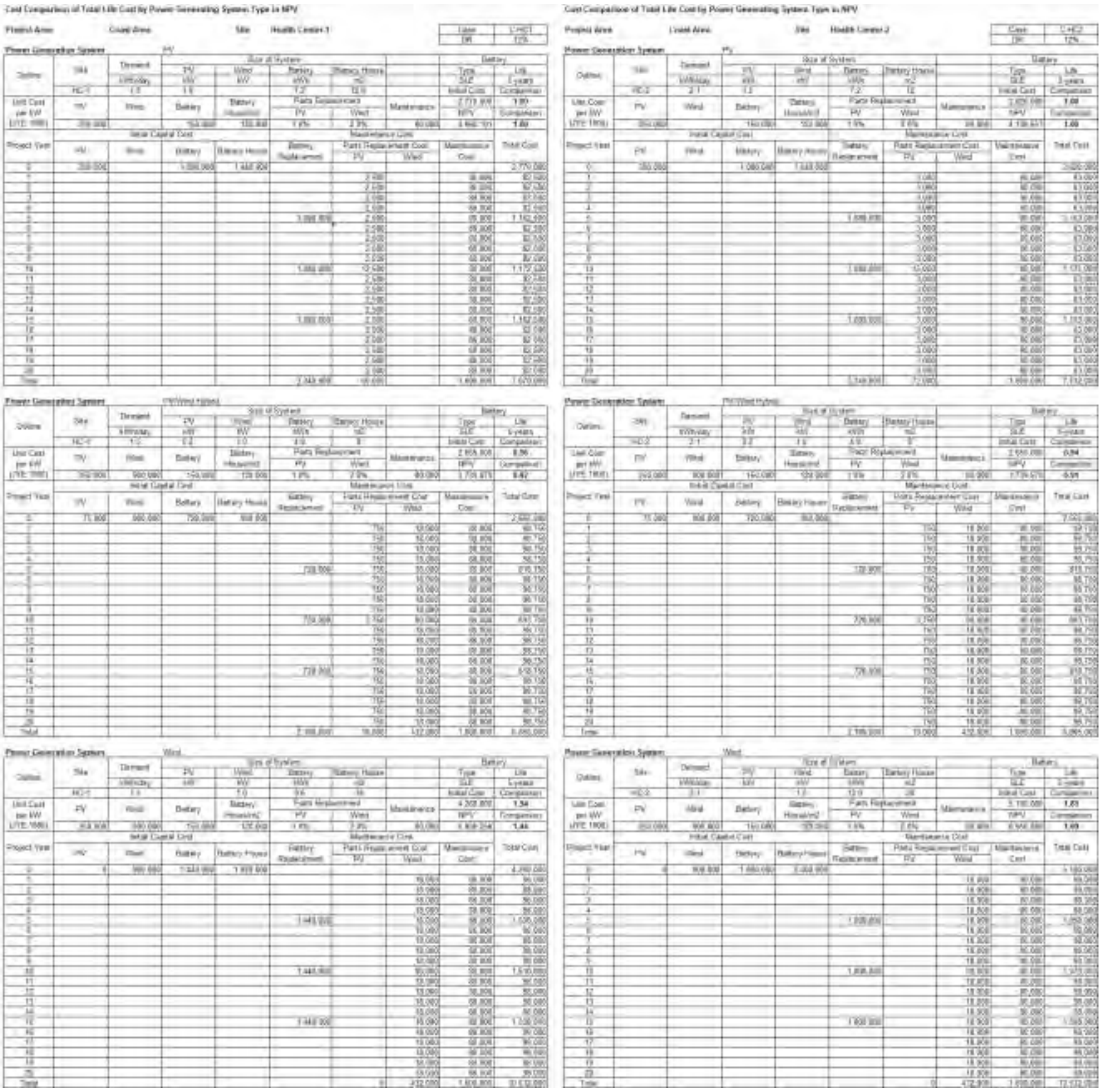

Power Generation System PV/Wind Hybrid


Power Generation System Wind


Power Generation System Wind

(2) Cost Comparison of Total Life Cost by Power Generating System in NPV

Coastal Region – Health Center



Cost Comparison of Total Life Cost by Power Generating System Type in NPV

Project Area: Coast Area — Site: Health Center 1 — Case: CHC1 — DR: 12%

Power Generation System: PV

Power Generation System: PV/Wind Hybrid

Power Generation System: Wind

Cost Comparison of Total Life Cost by Power Generating System Type in NPV

Project Area: Coast Area — Site: Health Center 2 — Case: CHC2 — DR: 12%

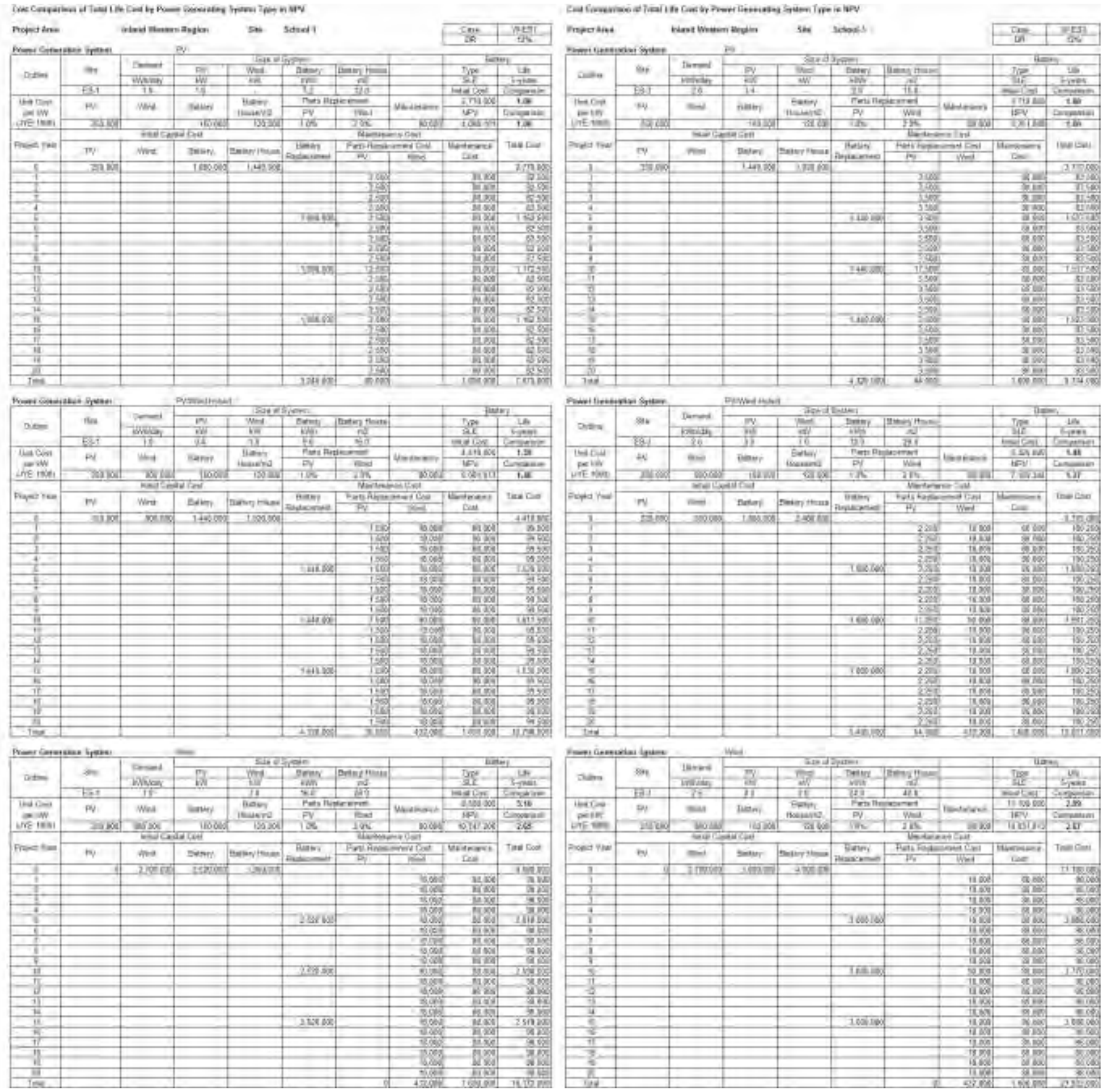
Power Generation System: PV

Power Generation System: PV/Wind Hybrid

Power Generation System: Wind

(3) Cost Comparison of Total Life Cost by Power Generating System in NPV

Inner Western Region – Elementary School


Cost Comparison of Total Life Cost by Power Generating System Type in NPV

Project Area: Inland Western Region — Site: School 1 — Case: WEST1 — DR: 12%

Power Generation System: PV

Power Generation System: PV/Wind Hybrid

Power Generation System: Wind

Cost Comparison of Total Life Cost by Power Generating System Type in NPV

Project Area: Inland Western Region — Site: School 1 — Case: WEST3 — DR: 12%

Power Generation System: PV

Power Generation System: PV/Wind Hybrid

Power Generation System: Wind

(4) Cost Comparison of Total Life Cost by Power Generating System in NPV

Inner Western Region – Health Center

Cost Comparison of Total Life Cost by Power Generating System Type in NPV

Project Area: Inner Western Region — Site: Health Center 1 / Health Center 2

Power Generation Systems: PV; PV/Wind Hybrid; Wind

Project Year	PV	Wind	Battery	Battery House	Battery Replacement	Parts Replacement Cost PV	Parts Replacement Cost Wind	Maintenance Cost	Total Cost
0	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]
1–20					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX-A3

Profile of Candidates Sites

Primary Schools

#	DISTRICT	INFRAESTRUCTURE	COORDINATES	NR. OF DIVISIONS		Staff house	Nr. of Students					Nr. Of teachers	DISTANCE FROM VILAGE (Km)	WATER PUMP
				Classroom	Adm. Sector		Male	Female	Total	First Shift	Second Shift			
1	RAPALE	EPC Natoa	S: 15°13,469' E: 039°07,339'	6	6	0	673	500	1173	818	352	23	17	1
		EPC Mulapane	S: 15°04,772' E: 039°28,397'	4	2	0	412	378	790	614	176	25	24	1
		EPC Muecia	S: 15°06,073' E: 036°31,740'	5	3	0	276	272	548	548	0	16	31	1
		EPC Namaita	S: 15°15,184' E: 039°57,853'	6	3	1	506	378	884	778	106	17	65	0
		EPC Nathapo	E: 15°15,187' E: 038°87,853'	4	3	1	476	408	884	778	106	17	65	0
2	NACALA-A-VELHA	EP1 Macape	S: 14°28,766' E: 040°31,902'	4	2	1	181	148	329	233	96	4	–	0
		EPC Vida Nova	S: 14°27,614' E: 040°31,190'	3	2	1	182	123	305	305	0	10	18	1
		EPC Muene	S: 14°24,598' E: 040°29,693'	10	4	6	468	357	825	598	227	16	15	1
		EP1 Vila	S: 14°33,222' E: 040°34,243'	3	2	0	158	99	254	167	87	6	6	1
		EPC Muntatala	S: 14°28,728' E: 040°28,568'	3	2	0	184	146	330	160	105	6	22	0
		EPC Patone	S: 14°38,562' E: 040°26,468'	3	2	1	192	145	337	–	–	7	22	1
		EPC Zangane	S: 14°39,111' E: 040°22,100'	3	3	1	195	120	315	315	0	5	30	1
		EPC Nahavara	S: 14°44,234' E: 040°27,317'	4	2	1	319	232	551	297	244	1	60	0
		ESG Ger-Ger	S: 14°26,864' E: 040°21,857'	8	4	0	166	24	190	105	85	14	40	0
3	MUECATE	EPC Namaluco	S: 14°51,773' E: 040°17,622'	4	0	0	281	222	591	248	343	7	9	0
		EPC Chipacane	S: 14°56,616' E: 039°24,546'	9	4	0	320	380	700	–	–	16	27	0
		EPC Lapa	S: 14°38,917' E:039°35,509'	4	2	0	204	224	428	300	128	8	29	0
		ESG Imala	S: 14°35,210' E: 039°34,038'	8	2	1	253	95	348	238	110	16	35	0
4	MONAPO	EPC Micolene	S: 14°53,834' E: 040°10,880'	8	4	4	295	223	518	–	–	9	–	0
		EPC Murromone	S: 14°46,728' E: 040°22,961'	3	3	0	352	295	647	400	247	10	24	0
		EP1 Mualege	S: 14°49,674' E: 040°23,428'	5	3	1	275	275	525	425	100	11	20	0
		EPC Murajue	S: 15°08,818' E: 040°02,603'	7	3	2	252	227	479	329	150	8	50	1
		EPC Napata	S: 14°58,921' E: 04°015,808'	9	3	0	450	300	750	450	300	6	3	1
		EPC Muapula	S: 14°38,131' E: 039°54,064'	5	3	3	435	303	738	419	319	11	75	1
		EPC Naree	S: 14°44,174' E: 039°55,039'	13	5	4	–	–	1300	–	–	20	60	1
5	MURRUPULA	EPC Umuato	S: 15°25,306' E: 038°3	9	4	0	393	356	749	432	314	15	55	0
		EPC Cazuza	S: 15°22,267' E: 038°	7	5	1	341	352	693	460	233	13	22	1
6	NACALA PORTO	EPC Nahalene	S: 14° 38,539' E: 040°47,071'	4	3	0	268	330	598	429	169	12	22	0
7	MOSSURIL	EPC Namamal	S: 14°49,298' E: 040°30,347'	6	3	0	269	253	522	268	254	9	28	1
		EP1 Sinhote	S: 14°46,840' E: 040°40,463'	3	2	0	179	246	425	342	83	8	33	0
8	MEMBA	EPC Namatapa	S: 14°07,367' E: 040°38,199'	3	2	0	383	242	525	–	–	7	–	0
		ESG Mazua	S: 14°00,707' E: 040°20,853'	6	3	0	150	102	252	–	–	7	–	0
		EPC Cava	S: 14°10,624' E: 040°15,719'	3	4	0	518	336	854	353	501	12	35	0

#	DISTRICT	INFRAESTRUCTURE	COORDINATES	NR. OF DIVISIONS		Staff house	Nr. of Students					Nr. of teachers	DISTANCE FROM VILAGE (Km)	WATER PUMP
				Classroom	Adm. Sector		Male	Female	Total	First Shift	Second Shift			
9	MECONTA	EPC Nassurume	S: 14° 59,791' E: 039°44,551'	3	2	1	375	354	729	319	410	16	50	0
		EPC Cerpa	S: 14° 37,990' E: 039°47,573'	8	2	0	220	209	429	279	150	14	60	0
		EPC Muchalegue	S: 14° 54,539' E: 040°02,262'	4	2	0	252	211	463	320	143	10	20	0
10	Malema	EPC Murralelo	S: 15° 02' 25.7" E: 37° 30' 47.8"	5	2	1	359	347	703	—	—	10	22	1
		EPC de Nomela	S: 14° 56' 5.85" E: 37° 13' 19.6"	5	2	0	550	540	1.01	—	—	9	35	1
		EPC Canhunha	S: 14° 58' 01 1.5" E: 37° 20.7"	7	3	0	556	206	762	—	—	17	3	1
		EPC 19 Outubro	S: 14° 56' 49.3" E: 37° 35' 16.6"	5	3	0	470	386	856	—	—	20	2	1
		EPC Namparo	S: 14° 53' 31.8" E: 37° 45' 02.3"	3	2	0	357	346	703	—	—	16	71	1
		E.F.R. de Naiaweia	S: 14° 52' 11.3" E: 37° 20 56.1"	2	4	0	22	51	74	—	—	5	20	1
		EPC de Mepuhi	S: 14° 53' 31.8" E: 37° 45' 02.3"	9	2	1	425	275	700	—	—	11	41	2
		EPC de Chimuo	S: 14° 41' 13.8" E: 37° 27' 20.0"	4	2	0	80	82	169	—	—	7	10	1
		EPC Metacusse	S: 14° 54 31.2" E: 37° 0 49'25.2"	4	2	4	147	375	523	—	—	11	58	1
		ESG1 de Murralelo	S: 15° 02' 25.7" E: 37° 30' 47.7"	5	2	0	228	146	374	—	—	10	22	1
		EPC Nioce	S: 14° 58' 17.5" E: 37° 39' 20.80"	5	3	0	115	300	415	—	—	15	35	1
		ESG1 de Nioce	S:14° 55'17.5" E:37° 39'20.80"	5	2	0	223	112	335	—	—	10	30	0
11	Ribaue	ESG1 de Ribaue	S: 15° 00' 48.5" E: 37° 49' 21.0"	10	3	0	402	298	700	—	—	11	12	0
		ESG1 de Riwega	S: 15° 10' 30.0" E: 38° 0.5' 29.7"	4	2	1	142	159	301	—	—	8	63	1
		EPC Mecuasse	S: 14° 47' 38.9" E: 38° 28' 0.8"	3	2	0	283	286	569	—	—	12	63	0
		EPC de Ratane	S:15° 03' 36.7" E: 38° 24' 12.5"	5	2	0	368	538	894	—	—	18	—	0
		EPC de Colomela	S: 14° 42' 0.79' E: 38° 24' 0.02"	3	2	0	522	364	886	—	—	11	—	1
		EPC de Mexico	S: 15° 06' 42.9" E: 37° 43' 31.2"	2	2	0	503	349	852	—	—	11	—	0
		EPC de Tanhoia	S: 14° 42' 0,79' E: 38° 24' 0.02"	—	—	0	—	—	—	—	—	11	—	1
		EPC de Mathanya	S: 14° 58' 29.2" E: 38° 09' 20.5"	4	2	0	427	386	783	—	—	8	—	0
		EPC de Nacosa	S: 14° 58' 25.6" E: 37° 52' 44.4"	3	2	0	468	602	1000	—	—	10	48	0
		EPC 1° de Maio	S:14° 3.4 41.0" E: 38° 17' 10.1"	3	2	0	423	450	873	—	—	11	—	1
12	Mecubúri	Escola Familiar Agro-Técnica	S:14° 41' 01.3" E: 38° 52' 59.2"	3	6	0	18	20	38	—	—	8	2	0
		EPC de Naipa	S: 14° 49' 06.5" E: 38° 57' 55.9"	6	2	0	623	841	1464	—	—	21	—	0
		EPC Impamane	S: 14° 52' 06.5" E: 39° 00' 37.0"	4	2	0	142	200	342	—	—	9	—	1
		EPC de Metálá	S:14° 52' 06.5" E: 39° 00' 37.0"	4	2	0	330	287	617	—	—	16	20	3
		EPC de Inchua	S: 14° 29' 11.1" E: 38° 54' 20.3"	2	3	0	356	125	481	—	—	13	78	0
		EPC Nacuacuali	S: 14° 41' 03.8" E: 38° 54' 03.7"	5	2	0	435	513	948	—	—	15	5	1
		EPC de Nanrose	S: 14° 48' 18.3" E: 38° 44' 44.9"	2	2	0	356	444	800	—	—	12	25	0
13	Moma	EPC de Ivati	S: 16° 16' 18.2" E: 39° 33' 20.8"	6	3	0	423	312	735	—	—	8	50	0
		EPC de Maganha	S: 16° 20' 48.0" E: 39° 36' 0.8"	6	2	0	210	284	494	—	—	9	63	1
		EPC de Nacololo	S: 16° 42' 48.0" E: 39° 42' 27.3"	5	2	0	320	216	536	—	—	8	42	0
14	Angoche	EPC Namaguda	E: 16° 12' 21.2" S: 39° 37' 46.1"	3	2	0	558	969	1017	—	—	10	48	1
15	Mogovolas	EPC Mecuasse	S: 15° 40' 41.6" E: 39° 29' 26.2"	8	2	0	423	383	806	—	—	14	20	1

Health Center

#	DISTRICT	INFRAESTRUTURE	COORDINATES	TIPO DE CENTRO	DIVISIONS	STAFF HOUSE	HEALTH STAFF	DISTANCE FROM VILLAGE (Km)	CONSULTATIONS BY DAY	BIRTHS BY MONTH	EQUIPMENTS: FREEZER: GAS	EQUIPMENTS: FREEZER: PETROLEUM	EQUIPMENTS: FREEZER: SPV	EQUIPMENTS: MICROSCOPE	EQUIPMENTS: STERILIZER	WATER PUMP
1	MUECATE	CS Chenequa	S: 14°21,568' E: 039°31,030'	II	7	0	2	57	40	80	1				1	0
		CS Kavala	E: 14°54,208' E: 039°19,414'	II	4	1	2	47	70	55	1				1	0
		PS Napala	S: 14°48,948' E: 039°47, 321'	II	6	1	3	27	50	40	1				1	0
		CS Namaria	S: 14°34,930' E: 039°22,601'	II	5	0	2	43	40	25	1				1	0
2	MONAPO	CS Netia	S: 14°44,253' E: 039°56,262'	I	23	2	7	40	150	100	1			1	1	1
		CS Mueruca	E: 14°39,588' E: 039°50,387'	II	6	2	2	42	50	80	1				1	1
		CS Chinsi	S: 14°33,173' E: 040°17,632'	II	6	2	2	55	60	30	1				1	0
		PS Napala	S: 14°58,821' E: 040°15,808'	II	2	0	1	8	60	0					1	0
		CS Mucupa	S: 15°08,710' E: 040°32,688'	II	8	1	2	50	50	30	1				1	1
		CS Mesenjama	E: 14°58,901' E: 040°10,830'	II	3	2	1	12	75	30			1			0
3	RAPALE	CS Mutolo	S: 15°22,504' E: 039°32,090'	II	7	2	1	15	30	0	1					1
		PS Mucova	S: 14°55,998' E: 039°16,786'	II	4	0	1	29	70	0	1				1	0
		PS Seua-Seua	S: 14°58,862' E: 039°20,704'	II	2	0	1	46	40	0	1				1	0
		PS Mulehwa	S: 15°13,828' E: 039°50,452'	II	4	0	1	14	50	0	1					0
4	NACALA-A-VELHA	CS Ger Ger	S: 14°26,864' E: 040°21,857'	II	6	2	4	40	65	33	1				1	1
5	MEMBA	CS Baixo Pinda	S: 14°12,704' E: 040°42,700'	II	3	1	2	80	20	65		1			1	1
		CS Calesa	E: 14°07,388' E: 040°51,190'	II	3	0	2	55	75	22	1				1	0
6	MORRUPULA	PS Muuto	S: 15°26,262' E: 039°47,810'	II	3	0	1	65	100	0						0
7	NACALA PORTO	CS Naheteno	S: 14°36,092' E: 040°40,898'	II	8	1	1	22	50	90	1		1			1
8	MALEMA	C.S. de Nataleia	S 14º 52' 11.3" E: 37º29'58.1"	II	5	1	3	–	30	16	1				1	1
		C.S. de Murrasso	S: 15º 01' 43.0" E: 37º 30' 52.7"	II	4	1	2	–	60	0	1			0	0	0
		P.S. de Murripa	S: 14º 53' 8.3" E: 37º 46' 10.8"	II	4	0	2	47	–	30						0
9	Ribaue	C.S Mecuasse	S: 14º 47' 46.1" E:38º 22' 10.0"	II	5	1	2	30	70	15	1				1	0
		P.Saúde de Riane	S: 15º 00' 46.1" E: 37º 43' 21.0"	II	4	0	3	–	60	10	1				1	0
		C.S Chica	S: 14º 52' 11.3" E: 37º 29'58.1"	II	4	2	2	–	60	50	1				1	0
10	Mecoburi	C.S. de Momane	S: 14º 38'55.9" E:38º 47'42.3"	I	5	1	2	16	120	60	1				1	1
		P.Saúde de Popue	S: 14º 31' 15.5" E: 38º 53' 44.8"	II	4	–	6	–	45	10	1				1	1
		P.Saúde Unidade Moç	S: 14º 55' 36.2" E: 38º 38' 48.8"	II	3	0	35	14	55	20	1				1	1
11	Muma	C.S de Singuima	S: 15º 42' 60.0" E: 39º 19' 00.2"	II	4	1	4	47	35	60	1				1	1
12	Angoche	C.S de Nacopa	S:15º 59' 42.8" E: 39º 41' 15.1"	II	3	0	3	40	60	36	1				1	0
13	Mogovolas	C.S Mecutamala	S: 15º 40' 41.6" E:39º 20' 25.2"	II	8	0	4	20	60	50	1				1	0

APPENDIX-A4

Method of Wind Condition Analysis

The wind conditions of the area or site where the solar / wind hybrid power generating facilities planned to be installed shall be carried out for evaluation and determination of their design prior to the implementation of the project in accordance with the method stated below.

Period of Observation : 6 months – 12 months (continuously)
Cycle of Measurement : 10 seconds per cycle
Measurement Items : 1. Average wind speed
2. Maximum instantaneous wind speed
3. Most direction of wind frequency

Contents of Analysis : 1. Average Monthly Wind Speed
2. Time variation of wind speed
3. Relative frequency

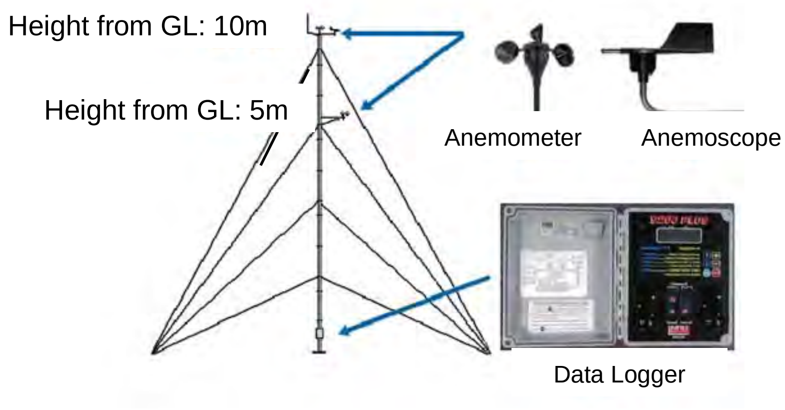
Height of Measuring Point: 5 meters and 10 meters from the ground level
Measuring Equipment : The particulars of measuring equipment shall comply the following conditions.

Measuring Equipment and Tools		Particulars
Sensor	Anemometer	Cup type, Observation width: 1～60 m/s, Resolution：Less than 0.5 m/s
	Anemoscope	Vane type, Activation speed: Less than 5 m/s、 Resolution: Less than 10 degree
Recorder		Data logger
Measuring Tower	Tower	Pole type
	Anchor	Anchor shall have a sufficient strength to support a tower.
	Wire	Supporting wire shall have a sufficient strength to support the tower.
Power		Battery or solar panel with battery

Measuring Point: The measuring point shall be the point(s) selected that represents the characters of wind conditions thereof.
(The data obtained by the satellite climatic data simulation can be utilized for the selection of locations suitable for execution of wind condition observation and analysis.)

Number of Locations : The number of locations for measuring wind conditions shall be determined as much as possible taking into account the number of facilities planned to be installed, geographical scope of candidate area, geological features, etc. The best location for observation is the location where subject facility is planned to be located.

Typical Feature of Measuring Equipment and Their Installation:



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