No.

Japan International Cooperation Agency

Preparatory Survey for
Renewable Energy Promotion Program in Africa
— Public Facility Electrification —

Final Report

November 2009

Nippon Koei Co., Ltd.

Proact International Inc.

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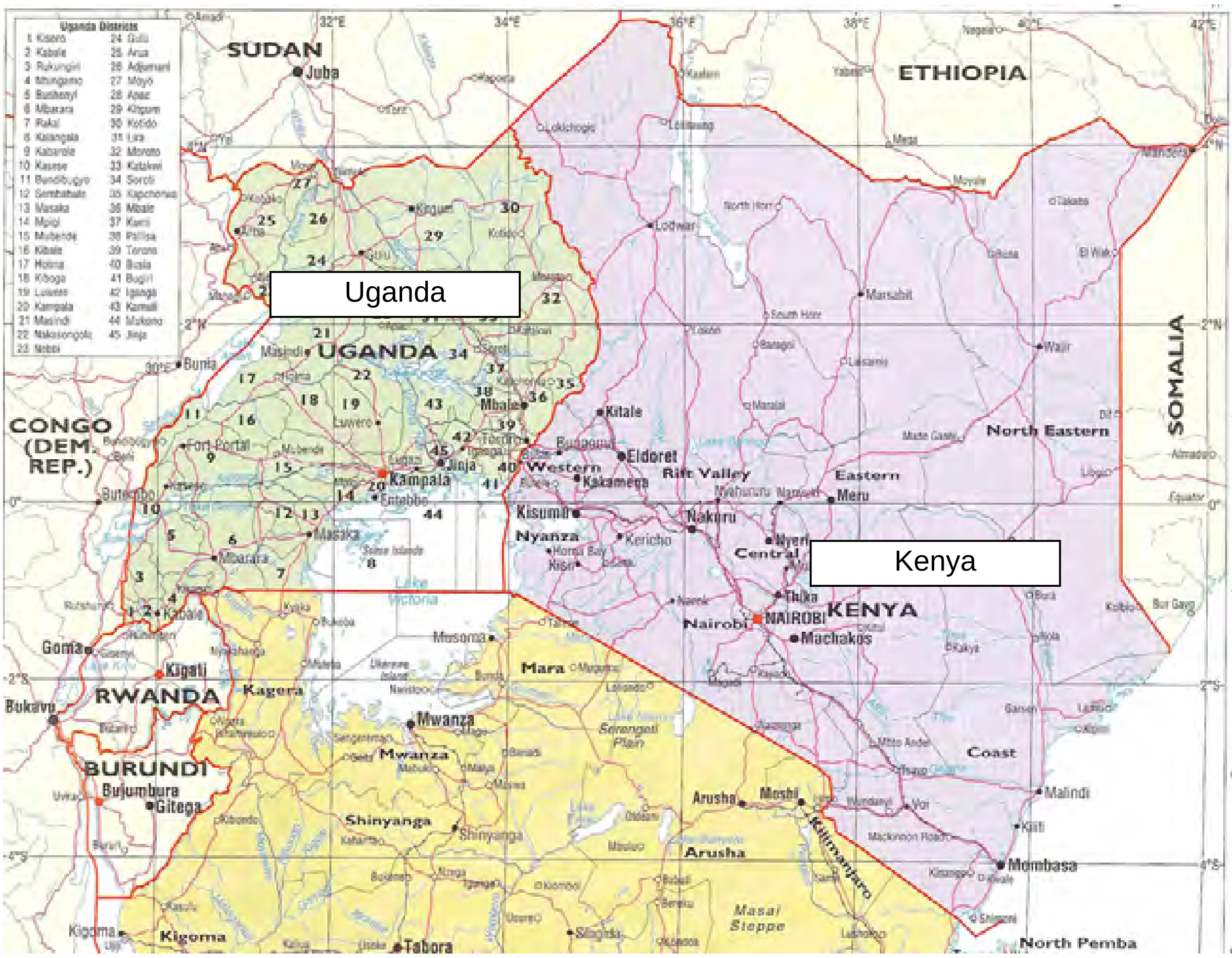
Location Map



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Abbreviation

CBO	Community Based Organization
CDF	Constituency Development Fund
CREEC	Centre for Research in Energy and Energy Conservation
CSS	Community Solar System
DWD	Department of Water Development
ERT	Energy for Rural Transformation
GNI	Gross National Income
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
IFC	International Finance Cooperation
IREMP	Indicative Rural Electrification Master Plan
JICA	Japan International Cooperation Agency
KenGen	Kenya Electricity Generating Co. Ltd.
KPLC	Kenya Power and Lighting Co. Ltd.
Ksh	Kenya Shilling
LED	Light Emitting Diode
MEMD	Ministry of Energy and Mineral Development
MoE	Ministry of Energy
MoES	Ministry of Education and Sports
MoMS	Ministry of Medical Service
MoPHS	Ministry of Public Health and Sanitation
NFE	Non Formal Education
NGO	Non-Governmental Organization
ODA	Official Development Assistance
PSDC	Private Sector Development Centre
PV	Photovoltaic
REA	Rural Electrification Agency
REA	Rural Electrification Authority
REF	Rural Electrification Fund
REM	Rural Electrification Master Plan
RESP	Rural Electrification Strategy and Plan
SHS	Solar Home System
TICAD	Tokyo International Conference on African Development
UBoS	Uganda Bureau of Statistics
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
US$	US$ Dollar
Ush	Uganda Shilling
VCR	Video Cassette Recorder

Exchange Rates (as of April 2009)

- US$ 1 = JPY 97.29
- Ksh 1 = JPY 1.258
- US$ 1 = Ksh 77.34
- Ush 1 = JPY 0.046
- US$ 1 = Ush 2,115

Electrical Terminology

・ V (Volt)	Unit of voltage
・ kV (kilovolt)	1,000 volts
・ W (Watt)	Unit of active power
・ kW (kilowatt)	1,000 watts
・ MW (Megawatt)	1,000 kW
・ Wh (Watt-hour)	Unit of energy
・ kWh (kilowatt-hour)	1,000 Wh
・ MWh (Megawatt-hour)	1,000 kWh
・ Wp (Watt-peak)	Unit of PV output[1]
・ kWp (kirowatt-peak)	1,000 Wp
・ MWp (Megawatt-peak)	1,000 kWp

[1] Maximum watt of PV module DC output under standard conditions of 1,000 W/m^2 intensity, 25 °C ambient temperature and a spectrum that relates to sunlight that has passed through the atmosphere (AM or Air Mass 1.5).

Chapter 1 Introduction

1.1 Background

(1) Assistance in Africa

Africa is now getting the attention of the world as an economic development region following the Asian region. Investments to developing natural resources are increasing and the African economy can grab the opportunity to take off from long-term stagnation because of shortage of natural resources.

On the other hand, there are a lot of problems and issues to be resolved in Africa. African countries are the first countries to get impacts from food price hike and climate change. They set poverty reduction as a long-range goal. However, they are also requested to respond to climate change. Thus, they are expected to accomplish the development with minimum CO_2 emission and environmental impact.

Under such condition, the Government of Japan announced its policy to promote strong assistance to African countries. In the Tokyo International Conference on African Development (TICAD) IV held last May 2008, the Government of Japan announced initiative package for development in Africa including commitment to increase the Japanese Official Development Assistance (ODA) and make it double within five years.

The Government of Japan also announced its policies like support to promoting renewable energy through “Cool Earth Partnership” as countermeasure against global climate change.

(2) Assistance to promote renewable energy

The Japan International Cooperation Agency (JICA) has learnt a lesson that “condition improvement for popularization and promotion in business basis” is important to familiarization with renewable energy. A study[2] held in Kenya and Uganda for four months from July 2008 showed the necessity of condition improvement for popularization and promotion in business basis as well as promoting electrification of public facilities in rural area such as schools and health facilities.

JICA conducted this study to gather basic information to formulate new projects and to confirm the appropriateness of the model of battery charging equipment attached to a public facility. This equipment is proposed in a previous study held in 2008. JICA also considers how to arrange environment to substantiate the contents of the proposal and realize the dissemination of the proposal.

1.2 Objectives of the Study

The Preparatory Survey for Renewable Energy Promotion Program in Africa, hereinafter referred to as “the Study” was conducted in Kenya and Uganda. This Study aims to examine the model plan of photovoltaic (PV) system proposed for accelerating its dissemination in

[2] Dissemination of renewable energy into rural communities : study on photovoltaic and small-hydro projects in East Africa, JICA, 2008

non-electrified areas of Africa. The proposed system is to be built to provide electricity to local schools, health posts and other public facilities. It is also intended to enable community people to charge their mobile phones and batteries.

Based on the results of interview survey conducted in remote areas of the two countries, the basic design, cost estimates and management scheme of the model plan are studied. Moreover, relevant information on potential areas and sites are collected. Consequently, an appropriate cooperation scheme for the proposed model plan is formulated.

1.3 Study Team

The study team consists of the following three experts:

- Mr. Katsuhiko OTAKI: Team Leader / Public Facility Electrification Expert
- Mr. Deepak Bahadur BISTA: PV (Photovoltaic) Power Generation Expert
- Mr. Ryosuke OGAWA: Village Social Survey Expert

1.4 Record of Major Activities

The overall schedule of the Study is shown below.

	2009/4	2009/5	2009/6	2009/7	2009/8	2009/9	2009/10	2009/11
Site Survey	Kenya	Kenya / Uganda	Uganda					
Report					* Draft Final Report			* Final Report

Scopes of the Study are shown below.

- Examine the current situation of rural electrification, public facility in rural areas and electrification plan in the future
- Study the non-electrified areas in rural areas and the public facilities in said areas
- Research on other donors' activities related to rural electrification
- Conduct village social survey on electrification needs and facility management at the potential areas (managers of facility and ordinary villager)
- Undertake basic design and project cost estimates of hybrid PV generation system
- Study the management scheme of hybrid PV generation system for public facilities
- Review the basis for selection of potential areas for electrification project

Chapter 2 Current Situation of Rural Electrification

2.1 Rural Electrification Policy and Achievement

2.1.1 Rural Electrification Policy and Achievement of the Government of Kenya

2.1.1.1 Rural Electrification Policy of Kenya

In Kenya, rural electrification was done under the Ministry of Energy (MoE). The Rural Electrification Authority (REA) was established in 2007, and at present, carries out full-scale operation of projects since early 2009.

It was found that 63% of the population in Kenya is covered by a power grid. However, the electrification ratio on household basis in the rural areas is determined to be only 10%[3,4]. The difference in ratios is due to the expensive fees required for grid connection in areas with an available power grid.

The Government of Kenya is targeting to improve the coverage rate from 63% to 100%. It also intends to improve the electrification ratio for public facilities, e.g. trading centres, schools, health facilities, public water supply facilities and administrative offices, to 100% by 2012. Ultimately, its aim is to provide the people with power benefits by 2030[5].

The draft final Rural Electrification Master (REM) Plan, which was under preparation since 2007, was submitted in May 2009. It shows a 10-year plan from 2009 to 2018 and a detailed action plan for five years from 2009 to 2013 (the first half of the 10-year plan). According to the action plan, the target by 2013 is to improve the rural electrification ratio, including off-grid, from the present 10% to 22%.

In Kenya, it is now possible to extend the grid and provide electricity to rural villages because of the improved trunk transmission network. However, there are still many households that could not connect to the grid even in areas with available power grids, due to shortage of power caused by delayed power source development, and expensive connection fees. For these reasons, the necessity for off-grid electrification by photovoltaic (PV) or mini hydropower remains high.

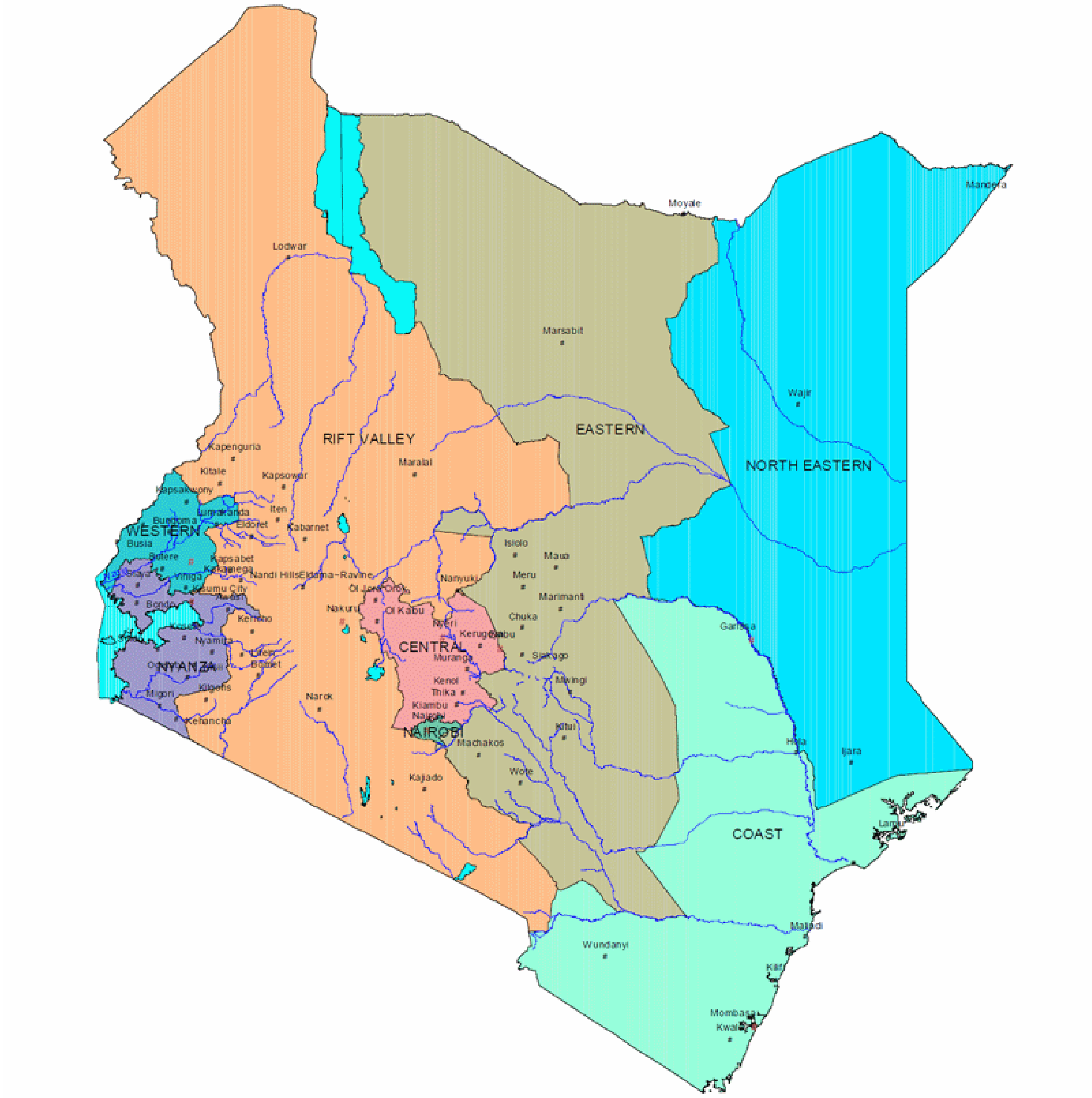
2.1.1.2 Administrative Units in Kenya and Electrification Ratio in Rural Areas

Administrative units in Kenya consists of eight provinces (Central, Coast, Eastern, Nairobi, North Eastern, Nyanza, Rift Valley and Western), with 254 districts. Division, location, sub-location and village are the lower level units.

About 210 constituencies are also used as units for development plans, such as the rural electrification plan, since Constituency Development Fund (CDF) is distributed for rural development, which includes building schools and health facilities. Previously, the borders for districts and constituencies are different. A district is used to be divided into several

3 Rural Electrification Authority Strategic Plan 2008-2012 / Contents Coverage of 10% is includes 450,000 grid users of grid and 300,000 PV users of PV.
4 Rural Electrification Authority Strategic Plan 2008-2012 / Sub-location is regarded to be covered if the sub-locationit has a transmission line of 11 kV or 33 kV.
5 Rural Electrification Authority Strategic Plan 2008-2012

constituencies while a constituency was divided into several districts. Presently, there are no districts divided into constituencies. However some large constituencies are still divided into districts since the latter increased in number in July 2009.



Source: Kenya Facts and Figures 2006, Central Bureau of Statistics

Figure 2.1.1-1 Administrative Unit (Province) in Kenya

The area where electrification ratio is low is almost the same as that identified by the Ministry of Foreign Affairs (MoFA) of Japan, which released a security alert (Levels 2 to 3 of 4), especially for the northern part of Kenya. The REM plan, drafted when the Study Team visited Kenya, is a plan on grid extension and proposes that 331 public facilities be electrified off-grid. Among said facilities, only 19 facilities (5.74%) are located outside of the area covered under the security alert level.

Apart from the selection of 331 facilities, REA is now selecting 250 public facilities using its selection criteria. It plans to seek Japanese assistance for the electrification of some of these 250 selected facilities. REA commented that a number of the 331 facilities may be chosen as part of the 250 selected facilities. Considering the current grid network and distribution of the 331 facilities, only a few were considered for the cooperation proposed by this project under JICA.

Table 2.1.1-1 Province-wise Electrification Ratio of Public Facilities in Kenya

Province	Electrified (No.)	Non-electrified (No.)	Unknown (No.)	Total (No.)	Electrified (%)
North Eastern	73	324	0	397	18.39
Eastern	1,603	2,616	54	4,219	37.99
Rift Valley	1,768	2,266	329	4,034	43.83
Coast	467	605	19	1,072	43.56
Nyanza	1,537	1,955	52	3,492	44.01
Western	1,064	734	33	1,798	59.18
Central	2,282	1,282	19	3,564	64.03
Total	8,794	9,782	506	18,576	47.34

Source: Rural Electrification Master Plan Draft Final Report, March 2009

2.1.2 Rural Electrification Policy and Achievement of the Government of Uganda

2.1.2.1 Rural Electrification Policy of Uganda

In Uganda, grid and off-grid rural electrification are regulated as the government's responsibility in the Electricity Act published in 1999. The Rural Electrification Fund (REF) was established in 2001 as financial support to rural electrification projects. The REA, meanwhile was established in 2003 to manage the rural electrification projects using the REF. Fund sources of REF include a levy of 5% on transmission bulk purchases of electricity from generation stations, money appropriated by parliament, and funds from donors.

The Rural Electrification Strategy and Plan (RESP) prepared in 2001 is a framework plan based on the Electricity Act 1999. This is intended for big policy targets like correcting imbalance between the urban and the rural areas, increasing opportunity of income generation, and effective utilization of existing renewable energy resources. RESP shows that the government provides necessary subsidy for rural electrification projects using the REF.

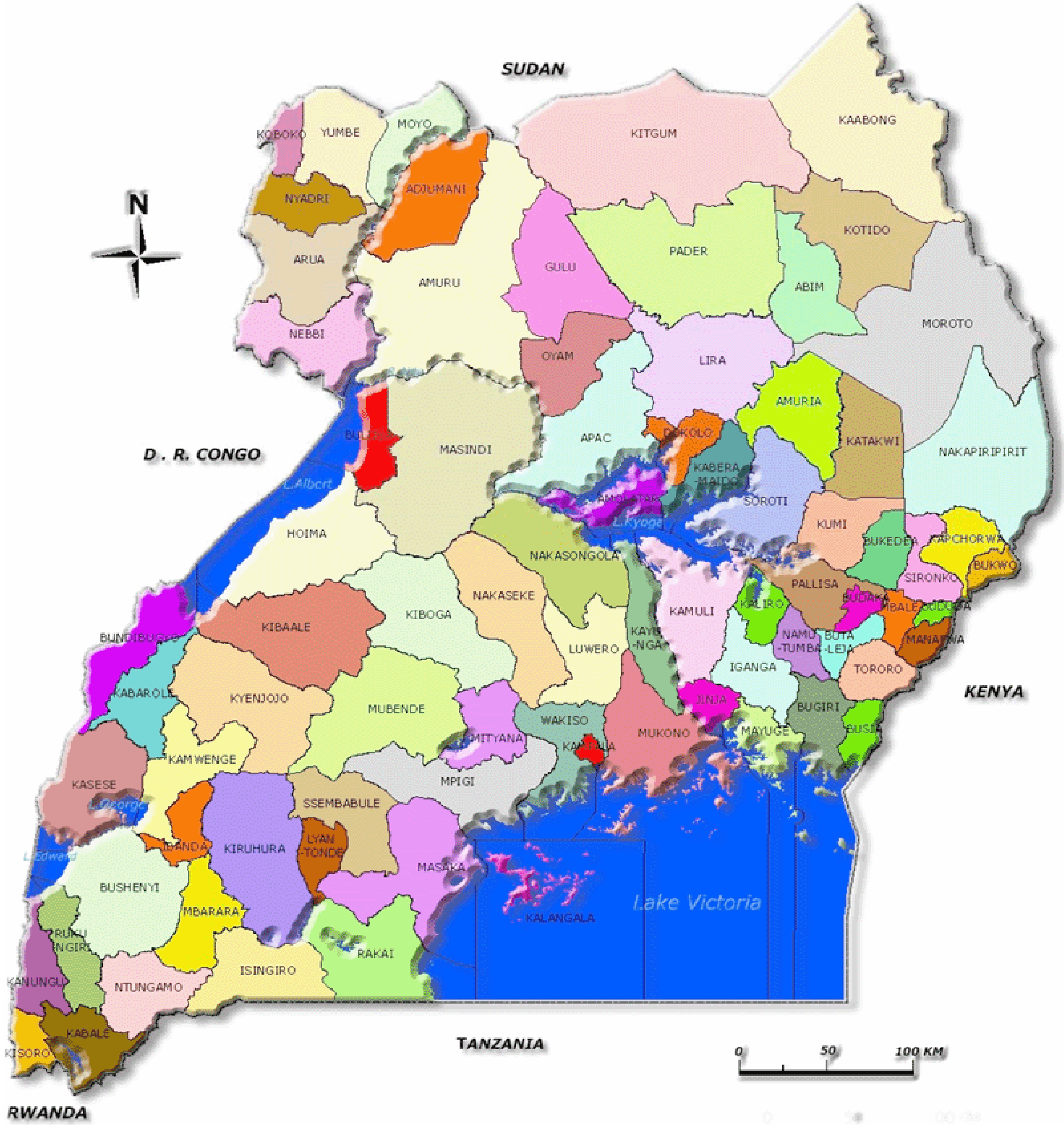
In Uganda, the electrification ratio on household basis is considered at 10% in the national level. However, it is determined to cover only 3% of the rural areas[6].

At present, the method to promote various electrification projects through the initiatives of private sector is adopted for rural electrification. The Government of Uganda is targeting to improve the ratio in rural areas to 10%, through investments from the private sector for three kinds of projects, namely 1) extension of the power grid of the Uganda Electricity Board (UEB) through investments from the private sector, 2) electrification by mini-grid generated from diesel generators or renewable energy, and 3) electrification by PV system.

2.1.2.2 Administrative Units in Uganda and Electrification Ratio in Rural Areas

Administrative units in Uganda consist of 80 districts and lower-level units, e.g. counties, sub-counties, parishes and villages.

[6] Indicative Rural Electrification Master Plan Report, January 2009



Source: Statistical Abstract 2009, UBoS

Figure 2.1.2-1 Administrative Unit (District) in Uganda

In Uganda, MoFA of Japan released a security alert (Level 2 to 3 of 4) for quite a lot of areas mainly in the northern part.

Considering that the rural electrification ratio in Uganda is lower than that in Kenya, there is a decent number of non-electrified public facilities in rural areas which is not covered under the security alert of Japan's MoFA. Although several projects on rural electrification and public facilities electrification are in progress through the Energy for Rural Transformation (ERT) of World Bank and Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ or German Society for Technical Co-operation), many areas and facilities are not electrified. Study Team members met with designated officials and explained that the Japanese side has many options for the target districts through cooperation under this JICA project.

2.2 Rural Electrification Project by Other Donors

2.2.1 Rural Electrification Project by Other Donors in Kenya

The Community Power Centre (Energy Kiosk) program by UNIDO is a notable project in Kenya. The project installs off-grid power generation systems like PV, mini-hydro, biomass and wind power in non-electrified villages and verifies the possibility of energy supply by renewable energy. Also, the project aims to improve the living standard by developing local industry and providing charging services to mobile phones and lanterns. The program has already started demonstration projects in a lot of sites in Kenya. The concept of the project by UNIDO is similar to this project. It is, therefore, imperative to analyze in detail the contents and results of this project, and to consider the possibility of complementing each together.

Energy Kiosk supported by UNIDO

Rechargeable lantern sold at Energy Kiosk

Photographs by JICA Study Team

Figure 2.2.1-1 Energy Kiosk supported by UNIDO (Photo)

2.2.2 Rural Electrification Project by Other Donors in Uganda

The largest rural electrification project in Uganda is ERT by the World Bank. The program aims to promote the rural electrification and development of information and communication technology sector. It is being implemented under corroboration with REA with the target of achieving 10% rural electrification ratio of RESP in electrification sector. The program implements and supports various kinds of projects related to energy development and utilization like power source development, grid extension and off-grid electrification including public facility electrification. A report shows 2,120 PV systems with a total capacity of 1.22 MWp were installed in ERT phase I (ERT 1) which was completed in February 28th 2009[7].

The IREMP which was completed in 2009 is being prepared as part of ERT. The household electrification ratio being considered in IREMP is 10% in the national level. However, the current situation is only 3% in the rural areas of Uganda. The IREMP shows specific drafts of rural electrification projects aimed at reducing the project cost to minimum considering factors like extension plan of transmission lines, population and geological conditions, and financial sources for the projects.

The distribution and installation of PV system to schools, health facilities and water supply

7 Project Appraisal Document No. 47183-UG, the World Bank, May 2009

facilities have been conceived in ERT phase II (ERT 2) which started in July 2009. A total of 2,054 PV systems with a combined capacity of 1.50 MWp will be installed in ERT 2[8].

The present rural electrification ratio in Uganda is crucially low while ERT covers only 10% of the public facilities needed to be electrified by the PV system. Thus, the hope of rural electrification and public facility electrification in REA is by JICA and other donors.

2.3 Situation in Non-electrified Villages

The Study Team conducted field surveys to understand the latest situation in non-electrified villages, apart from referring to report documents on rural electrification project and existing projects such as the Energy Kiosk by UNIDO in Kenya and ERT by World Bank in Uganda. The Study Team surveyed not only villages, but also the current situation of public facilities. Details of the field surveys are shown in **Appendix I**.

2.3.1 Electrification Ratio

As mentioned in Sections 2.1.1.1 and 2.1.2.1, the electrification ratio in rural areas is approximately 10% in Kenya and 3% in Uganda.

There are many households which could not connect to the power grid even if the grid reaches their village. This is because the installation cost for connection is too costly and unaffordable. There are several people who prefer a PV system since payment for grid connection is expensive and unreliable due to frequent black outs.

2.3.2 Form of Villages

Generally, it seems that trading centres are developed along the main roads of the villages visited by the Study Team in Kenya and Uganda. In some of the small villages, however, there are no trading centres although some small shops are scattered. A trading centre is an area where mainly small shops are gathered. Usually, a number of households near the trading centre consists a village.

The sizes of villages vary. There are 4,735,943 households and 2,870 trading centres in the rural areas of Uganda[9]. Based on the data, the number of households per trading centre is 1,650. According to the same data, 40% of trading centres have less than 100 households while 70% consist of less than 400 households. Only a few villages are larger than the average. Therefore, about 200 or 300 households per village is a reasonable coverage for the tentative design of a battery charging facility. However, it is necessary to survey the actual village size before designing each facility.

In Kenya, there are 6,695,986[10] households and 9,453[11] trading centres, excluding Nairobi. Based on these data, there are 708 households per trading centre. It seems that a few villages are

[8] Project Appraisal Document No. 47183-UG, the World Bank, May 2009
[9] Indicative Rural Electrification Master Plan Report, January 2009
[10] Calculated by consideiring5.1, which a is national average household size of 5.1 (Kenya Integrated Household Budget Survey 2005/06) and 34,149,527, which is the projected population except excluding the Nairobi area (Kenya National Bureau of Statistics).
[11] Rural Electrification Master Plan, Draft Final Report, March 2009

larger than the average size. Hence, it is reasonable to assume 200 or 300 households per village, similar to that in Uganda.

Generally, the trading centre in a non-electrified village is considered smaller than that in the electrified village. However, it should be considered that a battery charging facility in a non-electrified village will serve not only said village but also its neighboring villages.

2.3.3 Life and Income of Villagers

Main source of income in the villages is agriculture and most of the farmers raise livestock. Based on the survey conducted by the Study Team, most livestock raising is not large scale and mainly for domestic consumption. Fishery is also an important activity in villages near the Victoria Lake and its neighboring islands.

Income is fully dependent on the crops. Therefore, it is impossible to fix an average income per month or per year within the limited interview durations. The Study Team obtained comments from villagers such as “Decreased income due to fewer crops”, “Sales of livestock are not attractive because of decreasing market price” and “Income fully depends on the volume of catch.”

Gross National Income (GNI) per capita is US$ 680 in Kenya and US$ 340 in Uganda[12]. Average income per household is estimated to be US$ 280 in Kenya or US$ 140 in Uganda for an assumed five households. The average income in rural areas is lower than that in urban areas. Actual data shows that the average income of households per month is Ush 306,278 in urban area, Ush 142,778 in rural area, and Ush 170,891 as the national average[13].

In this survey, the Study Team focused to grasp the current expenditure for energy, and current problems and energy demands/needs in the future.

2.4 Energy Demand in Non-Electrified Villages

Energy demand including demand alternated by electricity in the future is charging mobile phones, lights and radios in rural areas.

2.4.1 Mobile Phones

Presently, those in non-electrified villages go to other villages and pay for the charging of their mobile phones. These can be regarded as among the major electrification needs. There are 4.1 million mobile subscribers in Kenya and 5,163,414 in Uganda[14]. However, according to newspapers, these phone users have increased to 15.9 million in Kenya[15] and 8.2 million in Uganda[16].

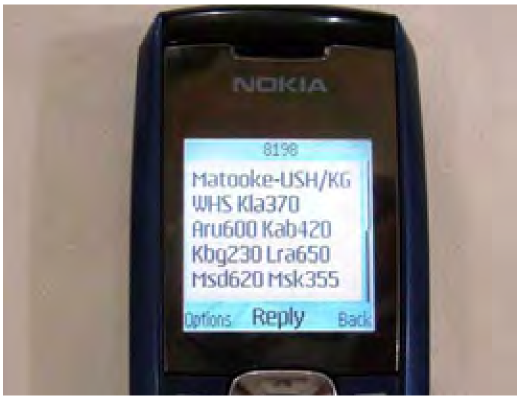
Based on the numbers of subscribers as of end of 2008 and numbers of households in both

[12] World Bank, 2007
[13] Uganda National Household Survey 2005/2006, Uganda Bureau of Statistics
[14] Statistical Abstract 2008, Kenya National Bureau of Statistics and Statistical Abstract 2008, Uganda Bureau of Statistics
[15] Cellular News, April 9th, 2009
[16] News Vision, January 29th, 2009

countries, household penetration ratios of mobile phones are 218.1%[17] in Kenya and 157.7%[18] in Uganda, which include those in the urban areas. Although this cannot be directly regarded as the mobile penetration ratio in the rural areas[19], it can be concluded that mobile phone use is now popular in the rural areas[20] since the Study Team found that most adults have mobile phones and that a lot of prepaid card dealers exist in non-electrified villages. Furthermore, it was observed that there are mobile charging businesses in many rural areas.

The fee for charging per mobile phone is generally Ksh 20 in Kenya, and Ush 500 in Uganda. Frequency of charging is generally every three days.

M-PESA (Money Transfer Service) Agent



Agricultural Markets Information

Photographs by JICA Study Team

Figure 2.4.1-1 Services Available for Mobile Phones (Photo)

2.4.2 Rechargeable Lighting Devices

Based on the field survey, it seems that there are only a few users of rechargeable lighting devices in rural areas. It was also found that rechargeable lanterns and torches are available at ordinary general shops, suppliers of PV equipment, or supermarkets. Moreover, most households that have cash income consume four or five liters of kerosene everyday for lighting.

Based on the above, it can be considered that there are needs for rechargeable devices. However, merits of these devices, especially rechargeable LED lantern, are not widely known.

Electrification needs for lighting are slightly smaller than those required for charging mobile although none responded to the query regarding energy consumption for lighting. Lighting needs, however, vary according to area, tribe and income level, and unlike for mobile phones, it is common for all people.

Needs for mobile charging are rapidly becoming common electrification requirements.

[17] Calculated by as 37,183,924, projected population in 2007 (Statistical Abstract 2008, Kenya National Bureau of Statistics) and 5.1, average household size (Kenya Integrated Household Budget Survey 2005/06)
[18] Calculated by as 5,200,000, number of household (Uganda National Household Survey 2005/2006, Uganda Bureau of Statistics)
[19] Generally, people in rural areas are less income than in urban area and facing difficulty to charge mobile. Additionally some of rural area is out of service area., therefore it can be considered that penetration ration of mobile phone in rural area is lower than one in urban area even there is alternative demand of fixed telephone in rural area.
[20] It is so difficult to determine the exact number of subscribers or penetration ratio considering prepaid account is popular and no ID card is required to avail SIM cards.

Meanwhile, lighting needs are supplied through kerosene or other conventional means. Hence, electricity is not indispensable and benefits of lighting devices are not widely known. Therefore, needs for lighting appear not so significant. However, such needs using electricity should be considered because villagers currently consume expensive kerosene daily and electric lights are expected to cause more benefits against kerosene lighting.

Electric lighting is essential considering benefits such as reasonable price, brighter outputs, less possibility of fire, no smoke produced, less CO_2 emission, and others.

Kerosene candle

Kerosene lantern

Rechargeable torch (240 V AC)

Rechargeable LED lantern

Photographs by JICA Study Team

Figure 2.4.2-1 Lighting Devices (Photo)

For example, a kerosene lamp is sold at Ksh 300 to Ksh 400. It was noted that more than Ksh 300 in Kenya is spent to purchase four to five liters of kerosene. In case sufficient illumination is not obtained, two or more lamps are used. At the same time, rechargeable LED lanterns made in China are sold at Ksh 1,200. Its unstable quality should be considered, however the cost of a rechargeable lantern is recovered after half a year if the charging fee is Ksh 50 and frequency of charging is twice a month[21].

Use of LED lantern could be promoted if its benefits are disseminated, its quality is improved

[21] Generally, charging fee for mobile phone is Ksh 20 in Kenya. Ksh 50 was assumed as charging fee for rechargeable LED lantern considering that the capacity of the battery of a mobile phone is 2.8 Wh to 4 Wh (700 mAh to 1 Ah, 4 V), while that of LED lanterns is 24 Wh (4 Ah, 6V). Based on these proportions, the charging fee for LED lanterns is less than 6 or 10 times. LED lanterns can work for 50 hours after charging. Therefore it needs to be charged twice a month for 2 or 3 hours use per day, based on the result of the interview survey.

and stabilized, it becomes more available in rural areas, and the capacity for charging is extended[22].

2.4.3 Automobile Battery

Based on site visits conducted, automobile batteries in Kenya, which are charged at places with grid connection, are not being used as power source for private houses or shops.

Meanwhile, in some places in Uganda, the Study Team observed that automobile batteries are utilized for various purposes. They are used to supply power for private houses or as charging device. It is noted however that their use is less popular than those in the South East Asian countries where televisions are commonly used. Charging fee of automobile battery ranges from Ush 1,000 to 4,000 in Uganda, depending on the capacity of the battery.

Battery charging shop in Uganda

Inside the charging shop

Photographs by JICA Study Team

Figure 2.4.3-1 Car Battery Charging (Photo)

[22] As mentioned above, battery in lanterns has more capacity than that for mobile phones. Existing charging shops have only a few PV panels and the capacity of charging is limited, therefore, the existing shops cannot provide enough services to meet the future demand of lantern charging.

Chapter 3 Current Situation of Public Facilities and Electrification Plan

3.1 Management, Configuration and Location of Public Facilities

3.1.1 Current Situation of Related Sectors in Kenya

3.1.1.1 Medical and Health System in Kenya

Medical and health facilities in Kenya consist of national, provincial and district hospitals, health centres, and dispensaries. The hospitals are under the Ministry of Medical Service, while the health centres and dispensaries are under the Ministry of Public Health.

There are 6,194 medical and health facilities. About 51% of these are public and 49% are private, as founded by the Faith Based Organization (FBO). Most of these facilities are classified as dispensaries[23]. About 52% of the population has access to medical and health facilities within five km[24].

Provincial hospitals or higher level facilities are well-equipped similar to general hospitals in Japan. In district hospitals, the number of medical specialists is not enough although doctors (medical officers), who graduated from a 6-year course, are assigned to these facilities. According to government policy, at least one health centre shall be established per division, with the district acting as the administration unit. Meanwhile, it also states that a dispensary shall be established per location and administered under a division.

A clinical officer who graduated from a 4-year course and several nurses are assigned in health centres, where simple surgeries are performed. At the dispensaries, meanwhile, mainly medical care, dispensing of prescribed drugs and promoting of health or sanitary knowledge are carried out by a few nurses and other staff.

Dispensary (comparatively large)

Dispensary (comparatively small)

Photographs by JICA Study Team

Figure 3.1.1-1 Health Facility in Kenya (Photo)

3.1.1.2 Education System in Kenya

The education system in Kenya is managed by its Ministry of Education. Its schooling

[23] There are 4,767 medical or health facilities in 2004 in 2004. Among them, 562 hospitals, 691 health centers and 3,514 dispensaries as of 2004 according to Health Management Information System”(Ministry of Health, 2005).
[24] VISION 2030 First Medium Term Plan 2008-2012”

standards adopt the 8-4 system. People study in primary schools (Standard 1 to 8) for eight years and in secondary schools (Form 1 to 4) for four years. There are 26,104 primary schools and 6,485 secondary schools in Kenya as of 2007[25]. (Among these, 8,041 are private primary schools and 2,240 are private secondary schools[26].)

Primary school

Secondary school with PV system

Photographs by JICA Study Team

Figure 3.1.1-2 School in Kenya (Photo)

Parents can decide whether to enroll their children in either public or private primary schools. They may also allow their children to travel to school from their houses or stay in boarding schools. However, it is expensive to send children to private or boarding schools. In cases where the capacity of the school is exceeded, the government regulates the number of enrollees.

Transferees after enrolling are also common. Usually, night prep classes are held for Standard 6 students or above. However there are no night prep classes in schools without lighting facilities. Because of this, some students transfer to schools with electricity before reaching Standard 6. The main purpose for transferring is to prepare for KCPE[27], where an important examination is taken at the end of Standard 8, before being accepted in secondary schools.

Enrollment to secondary schools is decided based on the result of KCPE and the students' desire to continue their education. Since national or provincial public schools are sufficiently equipped and have excellent teachers, more students enroll in these schools where a good result of KCPE is required. On the other hand, district or lower level public schools do not have satisfactory facilities, and thus, parents who can afford it send their children to private schools. Enrollment ratio in secondary schools is around 40 to 50%[28]. This however varies according to region. Some students enroll in technical training institutes after graduating from primary school.

[25] "Statistical Abstract 2008" (Kenya National Bureau of Statistics)
[26] Ministry of Education
[27] Kenya Certification of Primary Education
[28] Comparing the number of students of Standard 8 in last year and Form 1 in this year based on "Statistical Abstract 2008" (Kenya National Bureau of Statistics)

3.1.2 Current Situation of Related Sectors in Uganda

3.1.2.1 Medical and Health Systems in Uganda

Medical and health systems in Uganda are managed by its Ministry of Health. Medical and health facilities consist of national referral hospitals, district hospitals (one facility per 500,000 population), health centre IV (county level, one facility per 100,000 population), health centre III (sub-county level, one facility per 20,000 population), health centre II (parish level, one facility per 5,000 population) and health centre I (village level, 1 facility per 1,000 population)[29]. There are 3,237 facilities[30] except for health centre I. These consist of 114 hospitals, 160 health centres IV, 955 health centres III and 2,008 health centres II. Health centre I does not have its own building.

Number of staff depends on the facility. According to the standard requirements, health centres IVs have medical officers who graduated from a 6-year course, while health centres III have clinical officers who graduated from a 4-year course. Nurses, midwives and security guards are also assigned for said facilities.

Most health centres are electrified with PV system in off-gird areas. Health centres III and II are electrified with small-scale PV system mainly for lighting purposes while LPG supplies power to refrigerators for storing vaccines. Health centres IV meanwhile have large scale PV system. At some of these health centres, refrigerators are operated by the PV system.

Health Centre III

Health Centre II

Photographs by JICA Study Team

Figure 3.1.2-1 Health Facility in Uganda (Photo)

3.1.2.2 Education System in Uganda

The education system in Uganda is managed by its Ministry of Education and Sports. It adopts the 7-4-2 school system. Students study in primary school (Primary 1 to 7) for seven years, O-level (Ordinary) secondary school course (Senior 1 to 4) for four years and A-level (Advanced) secondary school course (Senior 5 to 6) for two years. There are 14,728 primary schools and 2,644 secondary schools in Uganda as of 2007[31]. Some secondary schools offer

29 Health Sector Strategic Plan II 2005/06 - 2009/2010, Ministry of Health
30 Statistical Abstract 2008, Uganda Bureau of Statistics
31 Statistical Abstract 2008, Uganda Bureau of Statistics

only O-level courses. Enrollment ratio in secondary schools is around 59%[32]. Most primary schools are established as public schools, however, almost half of the secondary schools are private schools[33].

After graduating from primary school or O-level secondary course, some of students enroll in technical institutes. Conditions for enrolling in technical institutes vary for each institute.


Secondary school


Dormitory of a Secondary School

Photographs by JICA Study Team

Figure 3.1.2-2 Schools in Uganda (Photo)

3.2 Condition of Non-electrified Public Facilities

The Study Team determined the current situation of non-electrified public facilities through documents related to the rural electrification plan, existing project reports (particularly the Energy Kiosk in Kenya by UNIDO and ERT in Uganda by World Bank), and field surveys. During the field survey, the Study Team focused on verifying the current status of villages especially with regards to energy consumption and expenditures. The details of the survey results are shown in **Appendix I**.

District hospitals or high-level facilities are mostly electrified. However some district hospitals were just upgraded from being dispensaries in 2007, when the number of districts increased. Thus, such district hospitals were not yet electrified.

More than half of the health centres and dispensaries are not electrified[34]. Some health facilities are electrified by PV systems or diesel generators, through the support of donors' activities. However many of said facilities could not utilize the generated electricity at present due to the failure of the system or cost of buying fuel. Similar to health facilities, most education facilities are not electrified in the rural areas[35].

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[32] Comparing the number of students of Primary 7 in 2006 and Senior 1 in 2007 based on "Statistical Abstract 2008" (Uganda Bureau of Statistics)

[33] "Annual School Census 2007" shows 2,029 of 14,728 primary schools (13.8%) and 1,282 of 2,644 secondary schools (48.5%) are privately owned.

[34] Electrification status of 3,008 medical or health facilities, except in Nairobi Province, is available and among these, 1,507 facilities are not electrified according to "Rural Electrification Master Plan Draft Final Report" (March 2009).

[35] Electrification status of 6,115 educational facilities, except in Nairobi Province, is available and among these, 3,364 facilities are not electrified according to "Rural Electrification Master Plan Draft Final Report" (March 2009). Electrified ratio of primary school seems to be lower than one of secondary school, because there are more primary schools in rural area.

About 1% of health centres IV, 34% of health centres III and 65% of health centres II are not electrified[36]. Moreover, some of the existing PV systems are not functioning well due to system failure and insufficient capacity to meet the demands. About 54% of the secondary schools, 82% of the primary schools, including pre- and post-primary schools, are located in "deep rural" areas. Only 27.0% of secondary schools and 4.6% of primary schools are connected to a grid at present, while 22.5% secondary schools and 47.1% primary schools remain as off-grid (more than 1km from grid), even after completion of electrification based on the "Indicative Rural Electrification Master Plan".

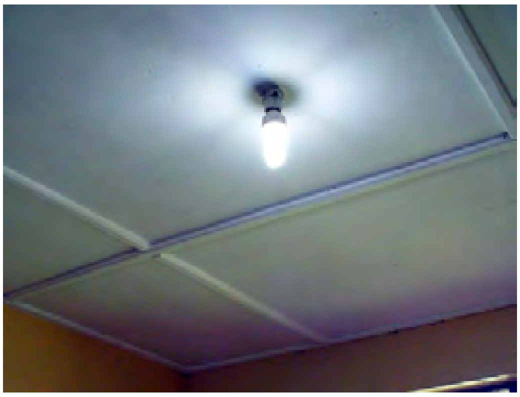
3.3 Electrification Needs of Public Facilities in Rural Areas

3.3.1 Electrification Needs of Health Facilities

Dispensaries and health centres in Kenya, and health centres IV/III/II in Uganda are considered as the target public facilities for the project. Doctors graduating from six-year course are not assigned to these facilities except health centre IV in Uganda. Clinical officers who completed a four-year course and other staff are assigned at health centres in Kenya and health centres III in Uganda. These facilities provide medical/health services including simple surgeries. Dispensaries in Kenya and health centres II in Uganda offer services like medical care, dispensing of prescribed drugs, and dissemination of health or sanitary information by nurses and other staffs.

In such health facilities above, there are needs for power supply for refrigeration of vaccines and blood supplies. Deliveries carried out at night time or emergency services and security also require lighting. There are also electrification needs for television, VCR and DVD players to present programs to promote health knowledge.

Refrigerator powered by LPG or 12 V DC



Bulb inside consultation room powered by PV

Photographs by JICA Study Team

Figure 3.3.1-1 Electrification Needs at Health Facilities (Photo)

At present, small PV systems cover such demands at some facilities. Other facilities meanwhile either have no or less capacity PV systems to supply the demand for refrigerators (presently operated by LPG) and lighting (presently through kerosene or flash torch). Some facilities

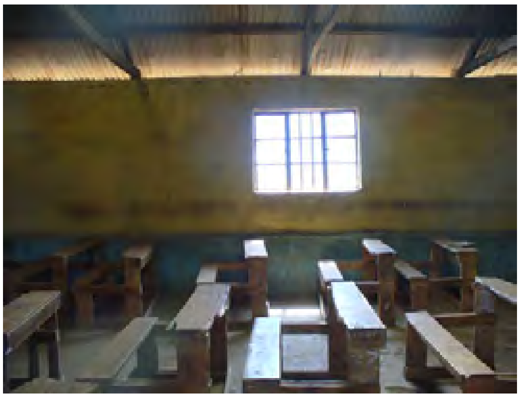
[36] "Indicative Rural Electrification Master Plan Report" (Ministry of Energy and Mineral Development, January 2009) shows only 10% of health centers (IV/III/II) are grid connected including mini-grid, 37% of health centers are standalone electrification including PV system and 53% of health centers are not electrified.

utilize gasoline/diesel generators to cover such demands.

The required capacity of PV systems fully depends on the size of each facility, therefore, estimation for each facility is necessary. The expected load and design options are discussed in Section 4.4.2.

3.3.2 Electrification Needs at Educational Facilities

Primary and secondary schools are considered as the target public facilities for the project. There are needs for power supply for computers and printers in staff's offices and computer training rooms. Lighting is likewise found necessary for staff's offices and classrooms. Televisions are also required in dining rooms of students' dormitories and lighting is needed for night prep classes at primary and secondary schools.



Classroom

Bulb at ceiling of classroom

Inside of dormitory

Computer classroom of secondary school

Photographs by JICA Study Team

Figure 3.3.2-1 Electrification Needs at School (Photo)

Some schools respond to such needs by procuring PV systems, kerosene lamps or flash torches. However, there are still more schools that have no computer training rooms and night prep classes due to unavailable electricity. Accordingly, it is not appropriate to estimate the required PV system capacity considering the existing facilities/equipments. Hence, the estimation should consider facilities/equipments to be used in the near future. Enough capacity of PV systems will bring various benefits not only by providing power to facilities/equipment but also for students traveling to schools from their homes. They will also no longer transfer to boarding schools if night prep classes will be offered in electrified schools. Moreover, excellent teachers will then be willing to be employed in said schools if electricity becomes available to the villages.

Required capacity of PV system fully depends on the size of each facility, therefore, estimation for each facility is necessary. Expected load and design options are discussed in Section 4.4.1. Based on the field survey, it should be considered that CRT (Braun tube) type is more common than the liquid crystal display (LCD) type in rural areas, in case power load for computers is required.

3.3.3 Electrification Needs for Water Pumping

Relatively large-scale water wells are considered as among the target public facilities for the project, considering the many existing water wells. Particularly, electrification of water well equipped with non-operational diesel generators due to failure or high fuel cost will be cost-effective since the pump installed to the well can be utilized as it is.

Compared to electrification of other public facilities, operation of water wells by power is advantageous because these do not require batteries. Pumping can be stopped when power is not available at night or when the weather is bad. In Kenya, people usually pay fees[37] to avail of water. The current fee collection scheme is already working well. Therefore, it is beneficial at this point if charging services would include operation of the water wells. Meanwhile, people in Uganda usually get water from public wells without payment. Thus, the situation on payment schemes in Kenya and Uganda are not identical.

As with the other facilities, the required capacity of PV systems for water wells fully depends on the size of each facility therefore, estimation for each facility will be based on the required water quantity and depth of well. The method of calculation is discussed in Section 4.4.4.

Tube-well by hand pumping

Tube-well by PV pumping operated by Grundfos

Photographs by JICA Study Team

Figure 3.3.3-1 Water Supply Facility (Tube-well) (Photo)

3.3.4 Electrification Needs of Trading Centres

A trading centre is an area with many/several small shops/enterprises. Each building in said area usually belongs to a private entity. It should be noted therefore that there are different needs for electrification. Thus, it is not practical to install some of the buildings with special requirements.

[37] Generally, the price is Ksh 2 for one jerrican (around 20 liters) according to the interview survey. Water well is usually managed by the community and the income from water fees is used for the maintenance of the well facilities like pumps.

Presently, business activities like mobile phone charging services, barber shops using electrical shavers, and video halls are operating even in non-electrified rural areas. These establishments acquire electricity for their businesses using PV systems, gasoline generators or automobile batteries charged at grid-connected areas.


A trading centre area in Kenya


A trading centre area in Uganda


Outside of a mobile charging shop (Kenya)


Inside of a mobile charging shop (Kenya)


Inside of a mobile charging shop (Uganda) (1)


Inside of a mobile charging shop (Uganda) (2)

Photographs by JICA Study Team

Figure 3.3.4-1 Trading Centre and Mobile Charging Shop (Photo)

Installation cost of a PV system, generator or automobile battery is not cheap. Business owners therefore acquired the means through their own funds or from bank loans. Therefore, the necessity for considering a trading centre as a target facility is lower than the necessity for the other public facilities discussed above.

At the same time, other public buildings in the trading centre area can be considered as target facilities if there are no potential places for the installation of a community battery charging system. This is proposed in the Study taking into account the convenience of village people.

3.3.5 Location and Utilization of Public Facilities

Based on site visits conducted, health facilities are located near the centre of villages. Educational facilities, on the other hand, are sometimes located away from the village centres, mainly due to land acquisition issues. However this keeps students focused on their study while at boarding schools. Water wells, meanwhile, are sometimes not located at the centre of villages but at locations easily accessible to people.

Health facilities are used not only for providing medical treatment services but also for promoting health/sanitary knowledge. Meanwhile, educational facilities are intended not only for conducting usual classes for students but also for carrying out non-formal education (NFE) for adults.

3.3.6 Expected Use of Electrified Public Facilities

It is expected that the method of utilization of public facilities discussed above will not change after electrification. However, some changes will occur due to utilization of televisions and VCRs, and the extended operational hours of lighting for security purposes.

Additional effects are also expected from having excellent teachers/officers who will then be willing to work for longer hours, and from students realizing that transferring to other schools is no longer necessary.

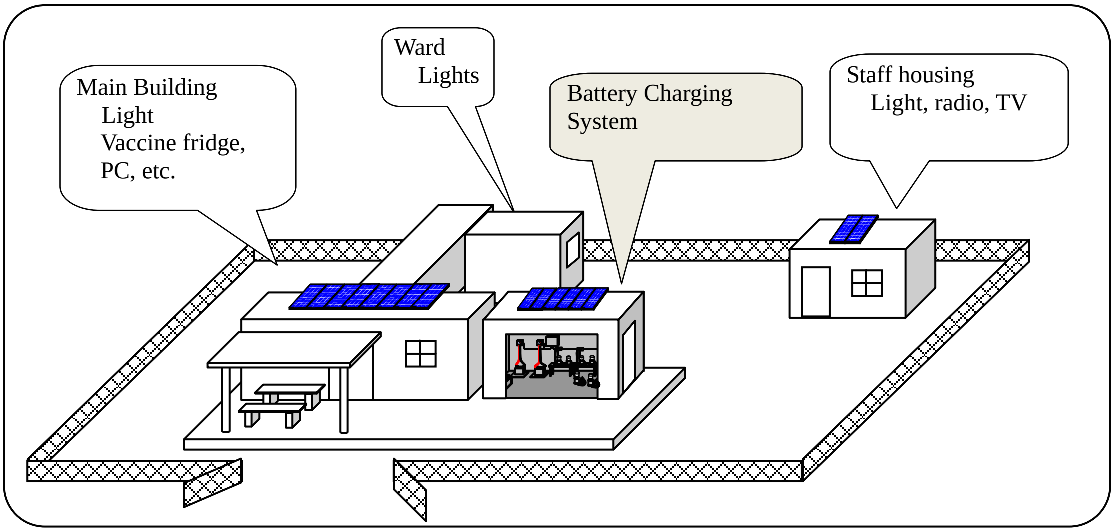
3.4 Electrification Plan for Public Facilities in Remote Areas

3.4.1 Proposal of Combined PV System - Community Solar System

Many donors and NGOs have been building PV systems at public facilities, schools and health centres in remote rural areas. In this study, JICA is exploring a new idea of combining a PV institutional system and a battery charging system that is open to community people of Kenya and Uganda. This hybrid system is named Community Solar System (CSS). (See **Figure 3.4.1-1** and **Figure 3.4.1-2**.)

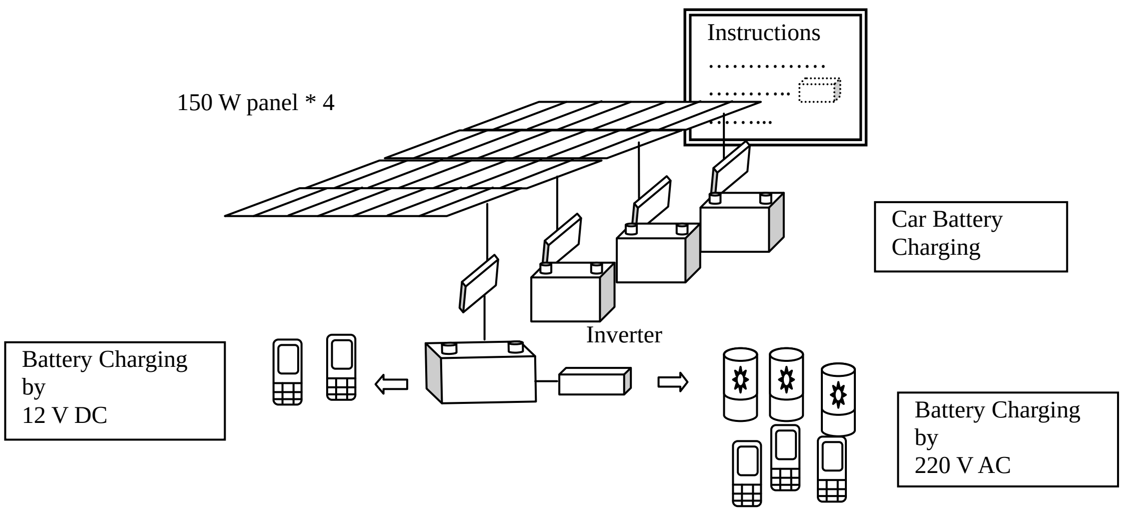
It is clear that the objective of developing PV institutional systems is to improve social services, education, health care, water supply, etc. which are being provided by the local public facilities. In addition, the development of PV battery charging facilities with PV institutional systems to provide mobile phone charging service to community people for immediate benefits of their daily life is conceived to be feasible. Furthermore, these battery charging facilities will promote the change of rural lighting from conventional kerosene lamps to rechargeable lamps that use fluorescent tubes or LEDs, which is viewed as a promising scenario for poverty eradication in un-electrified areas.

The battery charging facility can be developed independently. However, the CSS is expected to work more effectively because of synergy effects between PV institutional system and battery charging system. This approach is quite different from the conventional approach of distributing Solar Home Systems (SHSs) into remote un-electrified communities. However, it does not reject SHS which is useful but a little more expensive. Rather, it will pave the way for the dissemination of SHS. If kerosene lamps are replaced with rechargeable lamps, the rural household economy will not be affected by surging fuel prices. Also, the rural people will become free from risks of fire and health hazards caused by smoke. Furthermore, carbon dioxide emissions will be reduced. Thus, the dissemination of energy efficient and long-lasting LED into the rural areas together with battery charging facilities would share the same goal with the Lighting Africa Project that is supported by the World Bank and IFC. Japan, being the front runner in PV panels, LEDs and rechargeable batteries, is expected to play a leading role in pioneering the initiative of deploying CSSs in remote un-electrified areas of developing countries.



Prepared by JICA Study Team

Figure 3.4.1-1 Concept of Community Solar System (in case of Health Centre)



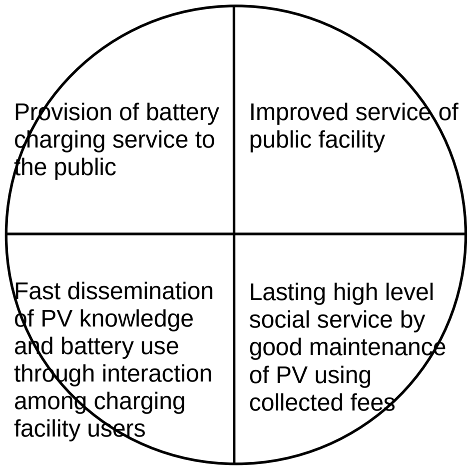
Prepared by JICA Study Team

Figure 3.4.1-2 Conceptual Design of Battery Charging System

This project is conceived to realize the following benefits:

- Public facilities are improved through the use of electricity for lighting, vaccine refrigeration, office equipment, etc.;
- Local people can easily charge their mobile phones, rechargeable lamps, car batteries in their respective community;
- Provision of high level social services will continue through secured funds for PV system maintenance collected from charging service fees; and
- Many battery charging system users will interact with each other and, thereby, acquire knowledge about PV which, in turn, will help in PV market expansion.

Many villagers exchange and share information about rechargeable lamps and other equipment when they come to the battery charging facility. For example, a rechargeable LED lantern, which is not known in remote areas, can spread quickly if such information exchange mechanism exists. Thus, the battery charging facility should be recognized to work not only for income generation but also for market development.



Prepared by JICA Study Team

Figure 3.4.1-3 Effects of Community Solar System

Chapter 4 PV System Sizing

4.1 Installed Model Systems

4.1.1 Installed Model Systems in Kenya

In the past, there was no definite policy on renewable energy in Kenya, even during the very early stage where commercial markets already exist in the country. The PV system was first introduced by NGOs such as those belonging to religious groups, international organizations and others. However, there were no records regarding said system being commercially purchased or installed in the country. In 2005, the Ministry of Energy (MoE) planned to install the PV system at health centres and schools in off-grid areas. For this, the representative of each constituency submits a proposal from which the MoE selected the site to survey for installation. **Table 4.1.1-1** summarizes the past installation of PV systems in public facilities by region.

Table 4.1.1-1 System Installed by MoE

Fiscal Year	Region	Facilities
2005/2006	North Eastern	Secondary schools
2006/2007	Rift Valley, North Eastern, Eastern and Coast	Secondary schools
2007/2008	Rift Valley, North Eastern and Eastern	Secondary schools, Boarding Primary schools, Dispensary
2008/2009 (To March end)	North Eastern and Eastern	Dispensary, Health Center, Primary school, District Hospital, Sub-District Hospitals
2008/2009 (On Going project)	Rift Valley and Eastern	Dispensary, Health Center, Primary and Secondary schools
2008/2009 (To Start)	Rift Valley, Eastern and Coast	Boarding Primary and Secondary schools, Dispensary and National park

Prepared by JICA Study Team based on data from MoE

Initially, boarding schools and health facilities in the Eastern、North Eastern and Rift Valley were selected for the installation of the system. Up to the beginning of the fiscal year 2008/2009, MoE initiated the installation of the system. Subsequently, during the later half of same fiscal year, REA, after its establishment, took the responsibility for selecting the sites, system sizing, procurement, and installation supervision. In May 24th, 2009 REA issued the first tender related to the installation of the system. Based on the information from REA, the site selection will be carried out in accordance with the Rural Electrification Master plan from onward, ward site selection will now be carried out in accordance with the Rural Electrification Master plan. REA consequently selects and surveys facilities at places where grid extension is not planned. **Table 4.1.1-2** summarizes the range of PV system capacity installed in public facilities up to March 2009.

Table 4.1.1-2 Average Installed Capacity of Public Facilities up to March 2009

Facilities	Installed PV Capacity	Average
Primary School	2.4 kWp - 5.06 kWp	3.73 kWp
Secondary School	1.14 kWp - 6.3 kWp	3.32 kWp
High School	1.3 kWp - 11.68 kWp	6.49 kWp
Dispensary	0.55 kWp - 0.77 kWp	0.66 kWp
Health Centre	1.3 kWp - 3.08 kWp	2.19 kWp
Sub-District Hospital	1.5 kWp - 3.3 kWp	2.4 kWp
District Hospital	1.5 kWp - 3.3 kWp	2.4 kWp

Source: MoE and REA

The generated power is mainly used for lighting, and PV module and related component of the system are installed at each building within the same facility as individual power source based on specific requirement. Prior to tendering, the size of the PV system is determined based on a detailed survey of load demands, load types, utilization pattern, size of rooms, and other related data. From the above table, it is understood that the capacity of each system differs depending on the size and power requirement of each facility. In boarding schools, administration block supplies power to the principal and vice-principal’s office, related administration office, staff room, classrooms, library, laboratory, computers, and security office. The dormitory normally has separate buildings for boys and girls, where power is used for room and security lighting purposes. At the dinning hall and kitchen, the generated power is supplied to lights and television. At the staff’s quarters, power is provided for the lights and audio-visual equipment. Lights in classrooms are mainly switched on during evening preparatory class from 7 PM to 9 PM. Television at the dining hall is used at lunch/dinner or during free time and holidays. Even at primary schools where there are no dormitories, children from grade 6 to 8 of that locality come to school to attend evening classes. However, most of these schools do not have enough lights and uses kerosene lamp or small PV panel donated by a donor agency, NGO, religious group and others. This is deemed insufficient for study purposes.

In the case of health centres, the smallest building consists of four to five rooms. The Olgulului Health Centre has two buildings where PV system installation work is in progress. Its house wiring system is almost completed while the PV, battery and related components are not yet installed. It was observed that in one of the buildings, two 20 W fluorescent lights each are installed for its registration/waiting room, two treatment rooms, medicine distribution room and storeroom. Meanwhile, only one 20 W fluorescent light is installed at its other rooms such as the general storeroom. At its other building, five 20 W fluorescent lights and two 20 W fluorescent lights are installed in the delivery room and staff room, respectively. For security purposes, the outside of both its buildings are provided with six 20 W fluorescent lights.

Almost all health centres have small LPG-generated refrigerators for storing vaccines. Unfortunately, due to distribution/management problems, said units are no longer functioning in some of the health centres. The distributed vaccination refrigerators have a rated capacity of 85 W, which can also be operated by connecting to the power grid or with a 12 V DC system. The PV system distributed in past and by REA, having capacity below 0.77 kWp is not thought to support refrigerator unit.

At present, with the help of international donor agencies, NGOs and public participation, the health centres are adding more facilities for treatment, child care, delivery and other services. The power demands at these places are therefore expected to increase.

Vaccination refrigerator (85 W)

Plug for 12 V DC connection

Source: JICA Study Team

Figure 4.1.1-1 Vaccine Refrigerator (Photo)

The cost of MoE's installed system is summarized in **Table 4.1.1-3** below. The costs shown exclude transportation and installation expenses. According to REA, the transportation and installation costs amount to 20 to 25% of the total system cost.

Table 4.1.1-3 Cost of Installed System by MoE

Fiscal Year (F/Y)	Total Budget (Ksh)	Installed Number (No.)	Total Installed Capacity (kWp)
2005/2006	51,262,682.00	16	39.53
2006/2007	170,381,288.62	40	158.16
2007/2008	181,962,301.47	40	158.51
2008/2009	60,888,534.00	38	46.97
2008/2009	97,940,943.00	**On-Going**	
2008/2009	**To Start**		
Total	562,435,749.09	134	403.17
Average	112,487,149.82	34	100.79

Exchange rate: USD 1.0 = Ksh.79.29, Ksh.1.0 = JPY 1.285
Source: MoE

The system installed by MoE at public facilities varies according to the requirement of each building, and is thus provided as a separate individual unit. The system voltage at DC side is 12 V, which is converted to AC for power supply. If the system capacity is bigger than what the single charge controller or inverter can handle, the number of required components is increased to meet the capacity of the system and load demand. The day of autonomy taken is three days for system sizing of the capacity of a battery bank with allowable maximum discharge of 20%.

In Kenya, there is a system called community power centre installed by UNIDO, which utilizes the combination of renewable power generation system as a hybrid system. Electricity is generated by combining the power from either small hydro, PV, straight vegetable oil, bio-gas or wind energy, depending on the available energy at each project site. **Table 4.1.1-4** below summarizes mainly the PV system-related projects of UNIDO.

At the community power centre project developed by UNIDO, mobile charging, LED lamp charging and sales, internet services, and computer class facilities are available. The tariff collected from the services provided is used for the operation and maintenance of the system.

Table 4.1.1-4 System Capacity and Project Sites of UNIDO

No.	Name of site	Location	Type of system	Capacity	Commission	Note
1	Kibae Hybrid	Keruguya town on Mukengeria River, Kirinyaga District	Hydro & Solar PV hybrid	2 kW & 0.5 kWp	2008	The first Pilot project.
2	Mesocho	Keera River, Kisii District	Hydro to Solar PV	0.5 - 1 kWp		Due to reduction of water flow planned to change the power source to solar
3	Siaya	Siaya District	Straight Vegetable oil & Solar PV	10kW & 2 kWp	2009	Joint project between UNIDO/UNDP
4	Bungoma (Changara)	Past Malakisi town, Teso District	Straight Vegetable oil & Solar PV	10kW & 2 kWp	2009	Joint project between UNIDO/UNDP
5	Ngong	Kajiado District	Solar PV & Wind	3kWp & 5kW	Planned to begin in May 2009	Toprovide power to local Masaai Village school, hospital and trading center

Source: UNIDO

4.1.2 Past Records of Model System Installation in Uganda

In Uganda, through the cooperation of World Bank, the ERT program is developed and applied since August 2008. It is intended for Ministry of Education and Sports (MoES) installation of PV systems at schools in rural off-grid areas. To establish the system, the open tender method is applied. In order to participate in the installation of the system, REA requirements must be followed. **Table 4.1.2-1** summarizes the installed system through the first batch of ERT program.

Table 4.1.2-1 Installed Capacity and Cost of First Batch of ERT Program at Schools

No.	District	No. of Schools	Total Capacity (Wp)	Total Cost (EUR)
1	Apac	14	7,050.00	135,897.50
2	Arua	15	9,750.00	171,912.90
3	Bushenyi	20	12,975.00	243,960.50
4	Kamuli	14	5,925.00	112,094.70
5	Kasese	14	4,575.00	93,649.00
6	Kibaale	12	6,075.00	111,495.90
7	Luwero	8	1,725.00	38,864.50
8	Mbale	12	4,200.00	82,630.20
9	Mubende	12	4,125.00	89,481.20
10	Pallisa	8	2,475.00	55,158.60
Total		129	58,875.00	1,135,145.00

Source: REA

The PV systems for rural health centers are also installed through ERT program. Under the program, 632 health facilities in 20 districts were surveyed from March to June 2004. It defined the required capacity of the system for each particular unit within the same facility. To determine the capacity of each unit within the same facility, the number of patients, covered area, and location of the facility are also considered. From this, the capacity of the systems is chosen to match the requirements depending on specific conditions and location of the facility, regardless of the similarity in the overall size of the buildings. For example, four types of system were installed for the outpatient ward, three types for the maternity ward, and two types each for the general ward, operation theater, and laboratory. Moreover, the system required for staff also depends on the position held. Hence, the requirements for eight types of systems are developed. **Table 4.1.2-2** summarizes the average PV system cost of most institutional packages.

Table 4.1.2-2 Average Capacity and Cost of PV System of Institutional Packages

Purpose	Application for	Capacity (Wp)	Cost (US$/Wp)
Lighting	Staff quarter (Health worker/Doctor)	Above 100 Wp	13.00
	Medical Ward	Above 750 Wp	15.00
HC IV	Medical, Theatre & Lab equipment	Above 1,280 Wp	21.85
HC III	Medical & Lab equipment	Above 650 Wp	20.00

Source: Collected information by JICA study team

In Uganda, the Directorate of Water Development (DWD) is responsible for supplying drinking water. **Table 4.1.2-3** summarizes the population of each region with access to water.

Table 4.1.2-3 Access to Quality Drinking Water by Region

Region	Population (no.)	Access to Water (%)
West Nile	2,104,404	63.5
Northern	2,524,173	51.2
Western	2,956,490	66.8
South Western	3,789,621	65.1
Buganda (Central)	5,395,832	58.2
Eastern	6,695,698	56.4
Karamoja (North Eastern)	1,202,850	40.5

Source: DWD

From the above table, it is understood that even though DWD aimed to supply 65% of the population with a quality drinking water in 2005, this has not been met to date. Presently, DWD raised its target to 75%, hoping to achieve its goal up to year 2015. Until now, DWD already utilized possible surface water resources for gravity feed rural water schemes. Therefore, in order for it to establish its projects, it would need power source to pump up and supply water. From the survey of DWD, in order to pump up 1 m^3 of water in the rural area with a 40 to 80 meter head, around 0.3 to 0.67 kWh/m^3 of energy is required.

With the cooperation of World Bank, DWD issued the tender for 17 PV water pumping systems in 2006 and installed said system within the period of November 2007 to April 2008. **Table 4.1.2-4** below summarizes the installed 17 water pumping systems.

Table 4.1.2-4 PV Water Pumping System Established by World Bank

Region	Site	District	Installed Capacity (Wp)
West Nile	Nyapea	Nebbi	23,400
	Nyadri	Maracha	8,640
	Delo	Yumbe	18,000
	Morudu	Yumbe	18,000
	Laropi	Moyo	8,640
	Pekelle	Adjumani	8,640
	Ciforo	Adjumani	8,640
Western	Kagadi	Hoima	4,440
	Nyakabara I	Kyenjojo	13,320
	Nyakabara II	Kyenjojo	4,440
	Rwebosongo	Bundibugyo	8,880
	Muhoro RGC	Kibaale	8,640
South Western	Mahyolo	Kamwenge	12,960
Buganda (Central)	Kalangala	Kalangala	13,320
Eastern	Katakwi	Katakwi	8,880
Karamoja (North Easten)	Nakiperimolu	Kotido	8,880
	Matany	Moroto	8,880
Total Installed Capacity (Wp)			186,600

Source: DWD

4.2 Design of Off-grid PV System and Design Tool

4.2.1 Process of Off-grid PV System Design

Unlike grid-connected PV systems, off-grid PV systems are closed systems that store electricity generated by PV in batteries and use it when necessary for lights and other appliances. Therefore, the first step of the system design is to estimate the daily electricity loads. Then, the necessary capacity of PV modules (solar array) and batteries (battery bank) can be calculated.

It is important that in case of closed system without back-up, the designed generating and storage capacity should have a relatively large margin. Hence, the system should have enough redundancy and can cope with unexpected situations such as surges in electricity demand or long cloudy days, to provide stable electricity supply. The Community Solar System that will be built in remote areas of developing countries also needs to have large redundancy, taking into account the risk of poor maintenance.

An example of a daily load estimation format is shown in **Figure 4.2.1-1**. The system designer needs to be careful about overestimation because the staff of targeted public facilities tends to express their desires, not fair thoughts, on the number of electrical appliances and their usage. If the designer uses these figures in the load estimation, the capacity of PV system may be much larger than what is actually needed and the load factor will remain pretty low. This often leads to criticisms by outside people. To avoid these problems, it is recommended to use the average, and not the maximum figures, on the number of appliances and hours of usage. Unlike grid-connected generators, it is possible to use more-than-average electricity in case of off-grid PV system, because it has batteries that have the capacity to store electricity more than average use. Generation systems such as diesel generators usually have no electricity storage, and need to have their capacity more than the maximum demand.

Load Analysis

AC Load

Load Description	Qty	Power Rating (W)	Operating Time (hrs/day)	Energy Consumption (Wh/day)
*****	x	xx	xxx	(Qty * W * hrs/day)
Sub total				a

DC Load

Load Description	Qty	Voltage (V)	Battery Capacity (Ah)	Rate of Discharge (%/day)	Energy Consumption (Wh/day)
*****	x	xx	xxx	xxx	(Qty * V *Ah* %/day)
Sub total					b

Average Daily DC Energy Consumption	a+b	Wh/day

Prepared by JICA Study Team

Figure 4.2.1-1 An Example of Load Calculation Sheet

The size of solar array depends on the solar radiation of the construction site. Therefore, it is necessary to obtain the solar radiation data before system design. The capacity of the battery bank varies depending on the length of period (days of autonomy) in which power supply continues even when PV power generation is impossible due to long cloudy and rainy days or system failure. If the days of autonomy are lengthy, the system stability improves. However, battery replacement costs will also go up. Thus, it is impractical to set the days of autonomy very long.

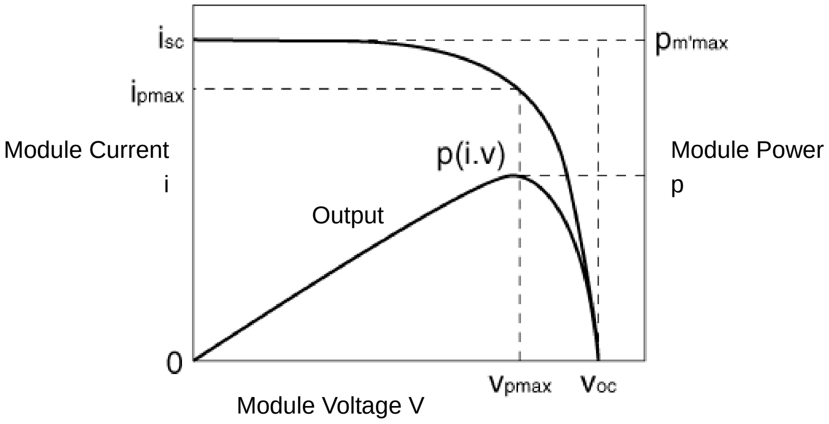
Based on the daily load estimation data, the capacity of solar array and battery bank is calculated. The necessary data and formulas are as follows.

> Necessary data to calculate the capacity of solar array
> - Daily load
> - Sunshine (Equivalent sunshine hours)[38] (In principle, minimum monthly figure should be adopted)
> - Loss factors in power generation by PV[39]
>
> Solar array capacity (W)
> = Daily load(Wh) / Equivalent sunshine hours (h) / Loss factors

Here, it is important to note that the rated capacity of PV module is the maximum value of the power output (P_{max}) under the condition of solar radiation being 1,000 W/m^2. At the point of P_{max}, the module voltage and current are defined as the maximum power voltage (V_{pmax}) and

[38] The unit "kWh/m^2/day" is referred to as the "equivalent sunshine hour".
[39] Many factors, including deterioration of battery, module temperature, direction, etc., are combined

maximum power current (I_{pmax}), respectively. (See **Figure 4.2.1-2**) Usually, PV modules with V_{pmax} of around 18 V are used with 12 V batteries. However, the module voltage goes down to 13 - 14 V when connected with 12 V batteries, and the module power output is also lower than P_{max}. Taking this point into account, it is necessary to use larger capacity modules than those calculated by the above formula.



Prepared by JICA Study Team

Figure 4.2.1-2 Electrical Characteristics of Solar Module

Therefore, as shown below, a more accurate value of the necessary solar array capacity can be obtained by calculating the necessary current of solar array and multiplying the value by V_{pmax} of the solar module to be procured[40].

Solar array capacity (W)
= Necessary solar array current (A) x Maximum power voltage (V)
= (Daily load(Wh) / Battery voltage (V) / Equivalent sunshine hours (h) / Efficiency) x Maximum power voltage (V)

Data necessary to calculate the capacity of battery bank
- Daily load
- Days of battery autonomy
- Battery voltage[41]
- Depth of discharge allowed
- Charge/discharge loss of battery, Inverter loss

Battery bank capacity (Ah)
= Daily load (Wh) x Days of autonomy / Battery voltage (V) / Depth of discharge (DOD) / Efficiency

In addition, a battery charging facility is to be established for the community people. The battery charging facility is planned to provide services to the following three types of rechargeable batteries:

(1) Mobile phones (Recharge with 240 V AC adaptors)
(2) Rechargeable lamps (same as above)
(3) Automotive batteries (Direct connection with PV modules)

For (1) and (2), it is recommended to have a battery bank and inverter to provide charging

40 Current of PV module remains almost constant when the voltage is lower than the maximum power voltage.
41 It is standard to use 12 V batteries, however, 24 V batteries are used to lower the value of current in case of large PV systems.

services even on rainy days or at night time. On the other hand, for (3), it is only possible to recharge automotive batteries by using the power from PV modules.

The final consideration is that the total capacity of the solar array and battery bank is determined as multiples of the capacities of the selected PV module and battery.

4.2.2. Design Tool

When implementing this scenario or building the Community Solar System, the system design is conducted by applying the process indicated above. Daily loads are to be calculated using the actual data of targeted public facilities. However, the size, layout and electricity demand of these facilities varies a lot depending on regional conditions, both in Kenya and Uganda. Therefore, it is difficult to show a standard design. Rather, it is more effective to develop a versatile "design tool" that can automatically calculate the necessary size of PV modules, inverters and batteries using the value of estimated loads and meteorological data. The tool can be used not only in Kenya and Uganda, but also in many other developing countries. The design tool requires the following:

Input data

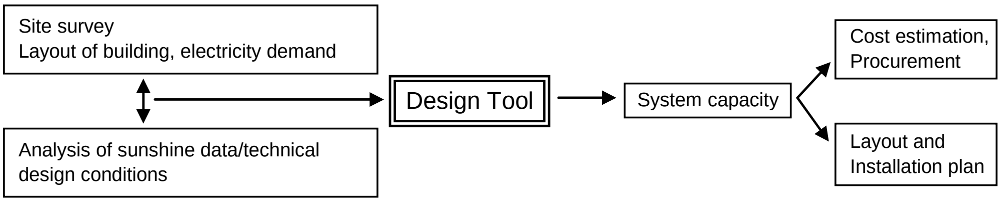
(1) Conditions of public facility
- Type, number and area of rooms and associated facilities
- Desired electrical appliances, their wattages and estimated hours of use

(2) Estimated usage of battery charging facility
- Estimated number of users for mobile phone charging
- Estimated number of users for other battery charging

(3) Meteorological conditions
- Sunshine data (Equivalent hours of sunshine)

(4) Technical conditions
- Days of battery autonomy
- Depth of discharge
- Generation loss factors, charge/discharge loss factors
- System voltage, Battery voltage

A work flow diagram of the design tool based on the above-mentioned concept is shown in the figure below and an example of a design tool is presented in the next page.



Prepared by JICA Study Team

Figure 4.2.2-1 Workflow of PV System Design

Demand Estimation

AC Load		a	Wh/day
DC Load		b	Wh/day
Average Daily DC Energy Consumption		a+b	Wh/day

PV Array Sizing

Average Daily DC Energy Consumption	c	a+b	Wh/day
DC System Voltage	d	Normally 12V or 24V	V
Insolation	e	insolation data (xxx Wh/m^2) divided by 1,000W/m^2	hrs
Efficiency	f	Combination factor of charge/discharge loss, temperature, etc	%
Required Maximum Current	g	c/d/e/f	A
Rated Maximum Voltage	h	around 18V in case of 12V system	V
Module Rated Maximum Power	i	g*h	W
Selected Size of Module	j		W
Number of Modules	k	round-up of i/j	
Actual Rated Array Capacity	l	j*k	W

Battery Bank Sizing

Average Daily DC Energy Consumption	c	a+b	Wh/day
DC System Voltage	d	Normally 12V or 24V	V
Days of Autonomy	m	Normally 3 days but depends on site conditions	days
Allowable Depth of Discharge	n		%
Efficiency	o	Combination factor of discharge loss, inverter loss, etc	%
Battery Bank Rated Capacity	p	c/d*m/n/o	Ah
Selected Size of Battery	q		Ah
Number of Batteries	r	round-up of p/q	
Actual Rated Battery Bank Capacity	s	q*r	Ah

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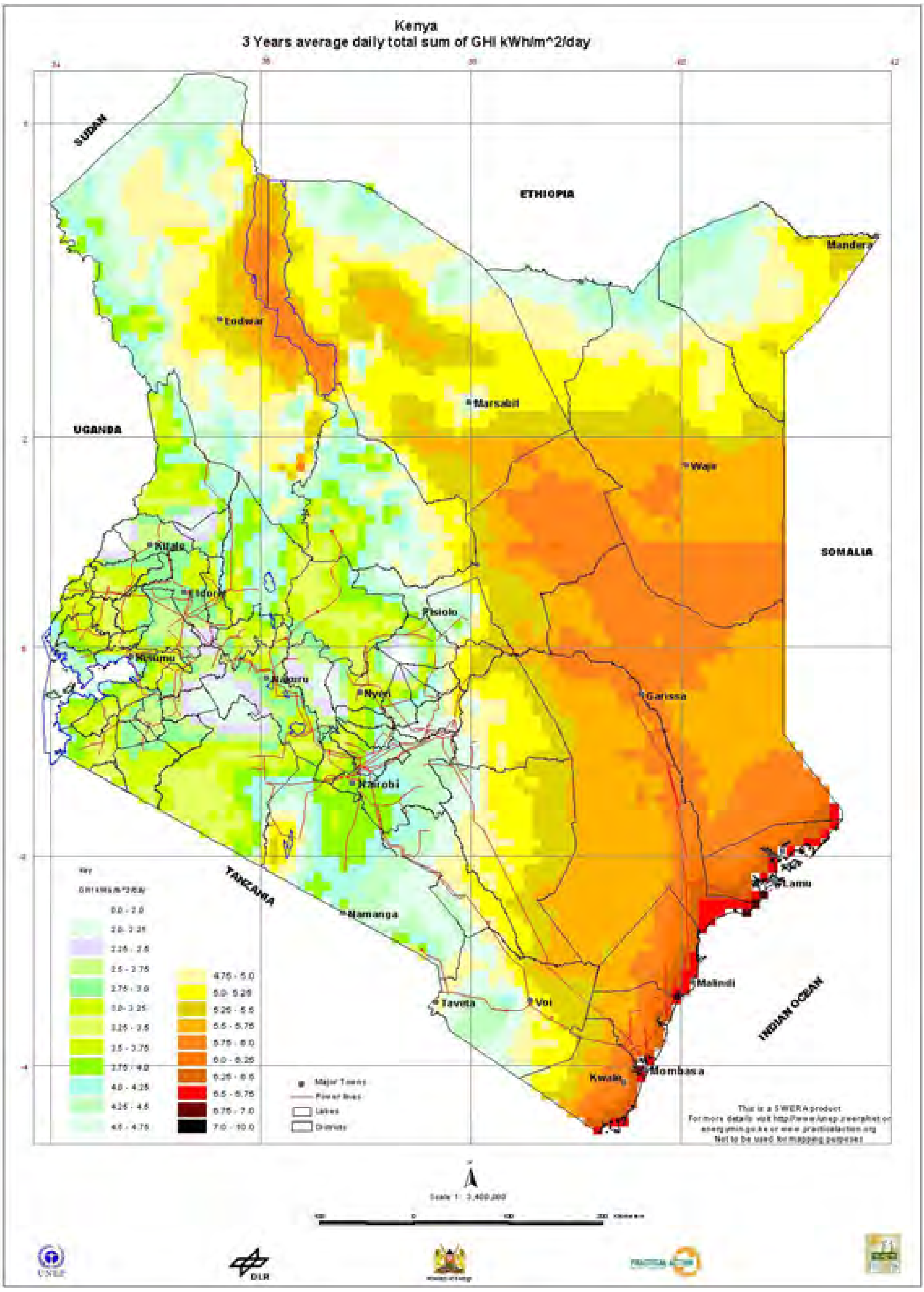
Figure 4.2.2-2 An Example of Design Tool

4.3 Basic Condition for System Design

4.3.1 Solar Insolation

Based on collected information from MoE, **Table 4.3.1-1** shows the annual average horizontal solar insolation of Kenya within a three-year period (2000 to 2002).



Source: MoE

Figure 4.3.1-1 Annual Average Horizontal Solar Insolation Map from 2000 to 2002, Kenya

The national annual average horizontal solar insolation of Kenya is between 4 to 6 kWh/m^2/day (i.e., from 4 to 6 hours of solar insolation). For system sizing, an average value of 5 kWh/m^2/day (5 hours of solar insolation) is adopted. The eastern and some part of the northwest regions have more than 5 kWh/m^2/day. In the north towards the Ethiopia border, northwest towards the Sudan border area, and to the west and south Tanzanian borders, the solar insolation value is less than 4 kWh/m^2/day. The details of the solar insolation map from 2000 to 2002 are shown in **Figure II.1-1** to **Figure II.1-3** of **Appendix II**.

In Uganda, the national annual average horizontal solar insolation is between 4.4 to 5.5 kWh/m^2/day and a system sizing value of 5.0 kWh/m^2/day is adopted, except for the southwest and mountain regions where the adopted value is 4.0 kWh/m^2/day.

During the study period, it was not possible to obtain the numeric data from both countries. Therefore, data from NASA were used to understand and compare the solar insolation. According to said data from the NASA home page, an average of 22 years (1983 to 2004) is recorded by the satellite which includes all environmental occurrences within the period. It is noted that both Kenya and Uganda crosses the equator. Consequently, the data in the north and south hemispheres shall be arranged separately to calculate average solar insolation of related regions and to see any other major features that need to be considered during the actual installation.

In the case of Kenya, **Table 4.3.1-1** and **Table 4.3.1-2** shows the values from the north and south hemispheres, respectively. Meanwhile, **Table 4.3.1-3** shows the monthly average horizontal solar insolation, and **Figure 4.3.1-2** presents the graph of average data.

From the table showing the data for the northern part of Kenya, it appears that the monthly average through out the year is above 5 kWh/m^2/day, even if the monthly averages from April to August and October to December are smaller than that of the northern hemisphere, . Furthermore, even during the rainy season in June, the monthly average value is almost same as the annual average and does not exhibit significant differences throughout the year. This means that the PV system can generate power at the same level throughout the year in these areas. The southern hemisphere’s monthly average values meanwhile are lower than the annual average value of 5 kWh/m^2/day during certain months. Its seasonal variation is higher than that of the northern hemisphere.

Table 4.3.1-1 Ave./Min./Max. Solar Insolation of Northern Hemisphere, Kenya (kWh/m^2/day)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation
Average	6.26	6.69	6.39	5.76	5.69	5.38	5.39	5.79	6.37	5.84	5.43	5.79	5.89	819
Minimum	5.27	5.76	5.75	5.18	5.19	4.63	4.79	5.27	5.71	5.27	4.63	5.08	5.21	(m)
Maximum	6.94	7.51	7.04	6.25	6.16	5.87	5.96	6.30	6.90	6.33	5.90	6.41	6.46	

Source : NASA (http://eosweb.larc.nasa.gov/)

Table 4.3.1-2 Ave./Min./Max. Solar Insolation of Southern Hemisphere, Kenya (kWh/m^2/day)

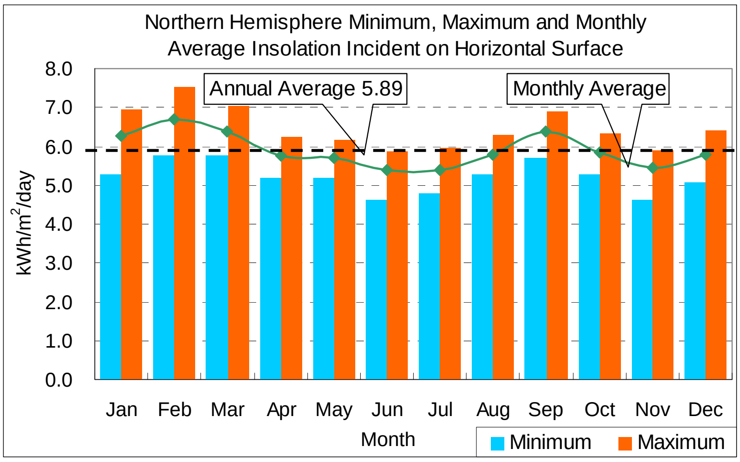
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation
Average	5.98	6.44	6.20	5.63	5.13	4.83	4.89	5.24	5.93	5.92	5.51	5.67	5.61	820
Minimum	5.03	5.51	5.67	5.07	4.54	4.29	4.46	4.66	5.31	5.24	4.81	5.09	4.97	(m)
Maximum	6.67	7.25	6.70	6.11	5.69	5.36	5.48	5.84	6.49	6.48	6.02	6.22	6.19	

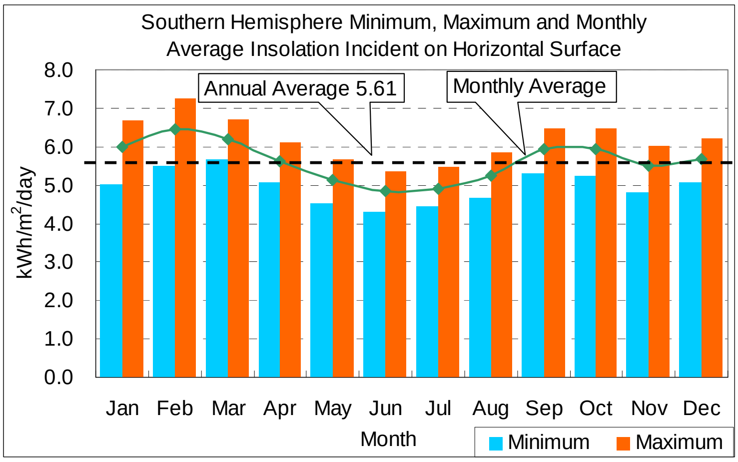
Source : NASA (http://eosweb.larc.nasa.gov/)

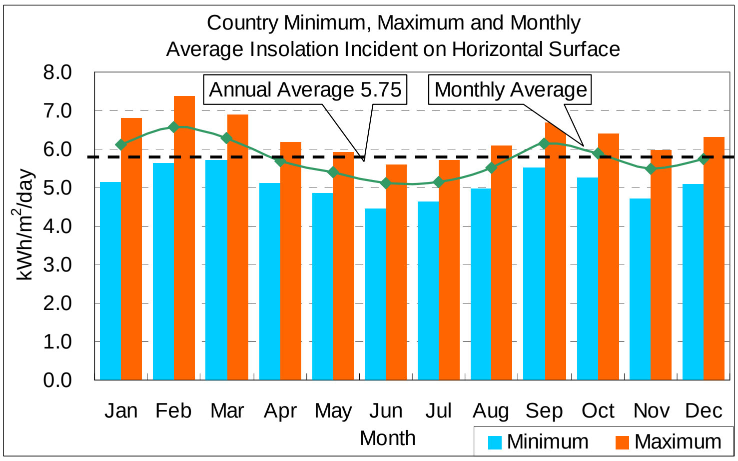
Table 4.3.1-3 National Ave./Min./Max. Horizontal Solar Insolation, Kenya (kWh/m^2/day)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation
Average	6.12	6.56	6.30	5.70	5.41	5.11	5.14	5.51	6.15	5.88	5.47	5.73	5.75	819
Minimum	5.15	5.64	5.71	5.13	4.87	4.46	4.62	4.97	5.51	5.26	4.72	5.09	5.09	(m)
Maximum	6.81	7.38	6.87	6.18	5.92	5.61	5.72	6.07	6.70	6.40	5.96	6.32	6.33	

Source : NASA (http://eosweb.larc.nasa.gov/)







Source: NASA satellite data / arranged by JICA Study Team

Figure 4.3.1-2 Annual Average Horizontal Solar Insolation (Average of 1983-2004), Kenya

In the case of Uganda, **Table 4.3.1-4** and **Table 4.3.1-5** present the data for the northern and southern hemispheres, respectively. **Table 4.3.1-6** shows the 22-year average data of monthly horizontal solar insolation of the whole country and **Figure 4.3.1-3** presents the graph of average data.

In the part of Uganda which lies at the northern hemisphere, the monthly average value is slightly lower than the annual average, in the months from May to August and October to November. This is regardless of the fact that the value throughout the year is greater than 5 kWh/m^2/day, except in July. Meanwhile, in the part that lies at the southern hemisphere, the values are slightly lesser than the 5 kWh/m^2/day during most of the months. By comparing the annual average data, it was realized that the northern hemisphere values are around 10% higher than those of the southern hemisphere.

Table 4.3.1-4 Ave./Min./Max. Solar Insolation of Northern Hemisphere, Uganda (kWh/m^2/day)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation
Average	5.97	6.23	5.91	5.53	5.36	5.06	4.97	5.22	5.68	5.37	5.30	5.64	5.51	1,163
Minimum	5.47	5.30	5.38	5.10	4.95	4.50	4.58	4.83	5.15	4.90	4.49	5.06	4.98	(m)
Maximum	6.61	7.14	6.58	5.95	5.79	5.54	5.52	5.64	6.29	5.92	5.79	6.14	6.08	

Source : NASA (http://eosweb.larc.nasa.gov/)

Table 4.3.1-5 Ave./Min./Max. Solar Insolation of Southern Hemisphere, Uganda (kWh/m^2/day)

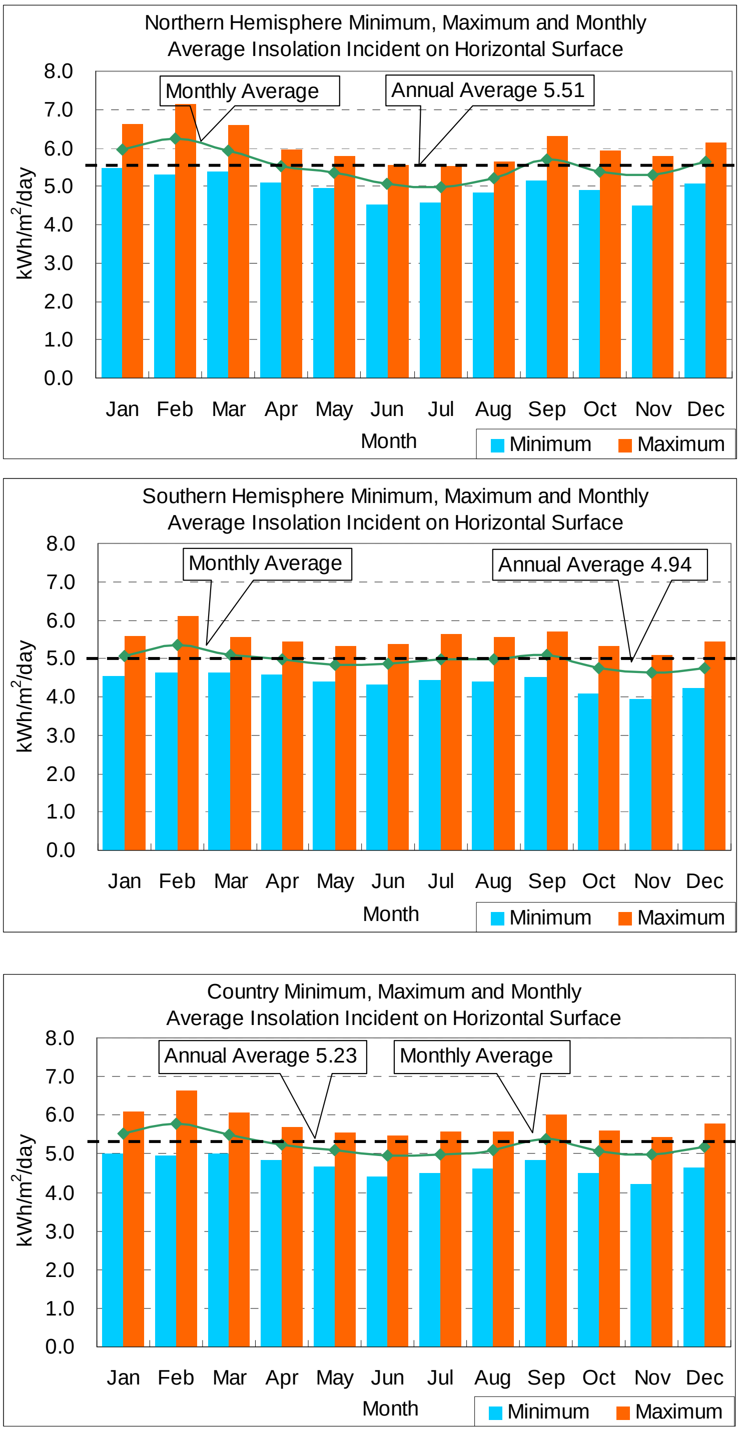
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation
Average	5.06	5.35	5.09	4.97	4.85	4.86	4.99	4.98	5.09	4.73	4.63	4.73	4.94	1,569
Minimum	4.55	4.63	4.64	4.59	4.41	4.31	4.43	4.40	4.52	4.07	3.94	4.22	4.39	(m)
Maximum	5.59	6.11	5.55	5.43	5.32	5.39	5.65	5.55	5.71	5.31	5.10	5.43	5.51	

Source : NASA (http://eosweb.larc.nasa.gov/)

Table 4.3.1-6 National Ave./Min./Max. Horizontal Solar Insolation, Uganda (kWh/m^2/day)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation
Average	5.51	5.79	5.50	5.25	5.10	4.96	4.98	5.10	5.39	5.05	4.97	5.19	5.23	1,366
Minimum	5.01	4.96	5.01	4.84	4.68	4.41	4.51	4.62	4.83	4.49	4.22	4.64	4.69	(m)
Maximum	6.10	6.62	6.07	5.69	5.56	5.47	5.58	5.59	6.00	5.61	5.44	5.79	5.79	

Source : NASA (http://eosweb.larc.nasa.gov/)



Source: NASA satellite data / arranged by JICA Study Team

Figure 4.3.1-3 Annual Average Horizontal Solar Insolation (Average of 1983-2004), Uganda

In both Kenya and Uganda where seasonal variation occurs, there are some months where the insolation value is less than 5 kWh/m^2/day. Nevertheless, for system sizing purposes, the average value of 5 kWh/m^2/day (5 hour of solar insolation) is adopted.

In actual practice, the nearest data of project site should be applied to obtain more accurate results. The 22-year monthly average data by each degree of longitude and latitude, downloaded from NASA's website, are summarized in **Table II.2-1** to **Table II.2-6** of **Appendix II**.

4.3.2 Days of Autonomy (No-sun Days)

In the PV system, it is a fact that power generation is not usually possible at night and during bad weather days. Thus, the need to supply power shall be as per demand basis. It is therefore required to consider days without sun and power storage, for smooth system operation. For a lighting system, power storage is considered for three days in general. In Kenya, the practice is to consider no sun for three to four days, as also adopted by REA. The same practice is also considered in Uganda.

Table 4.3.2-1 and **Table 4.3.2-2** below summarize the 22-year monthly average no-sun days data for Kenya and Uganda, respectively, which were downloaded from the NASA website.

Table 4.3.2-1 Average No-sun Days (Average of 1983-2004), Kenya

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average of North	4.85	3.83	3.04	3.02	2.74	4.23	3.40	2.84	3.17	3.00	4.35	3.71	3.52
Average of South	4.92	4.17	2.55	2.92	3.94	2.97	2.59	3.57	2.97	3.77	3.69	3.06	3.43
Country Average	4.88	4.00	2.79	2.97	3.34	3.60	3.00	3.20	3.07	3.38	4.02	3.38	3.47

Source : NASA (http://eosweb.larc.nasa.gov/)

Table 4.3.2-2 Average No-sun Days (Average of 1983-2004), Uganda

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average of North	2.89	4.60	3.15	2.59	2.68	3.56	2.74	2.54	3.06	3.08	4.97	3.54	3.28
Average of South	3.16	4.19	2.86	2.52	2.84	3.39	3.24	3.04	3.44	3.72	4.65	3.30	3.36
Country Average	3.03	4.43	3.06	2.55	2.71	3.52	2.90	2.75	3.13	3.33	4.87	3.49	3.31

Source : NASA (http://eosweb.larc.nasa.gov/)

From the above table, the annual average no-sun days in Kenya is 3.4, and 3.3 in Uganda. The no-sun day is the number of days possible to occur in a month, which is not a continuous daily occurrence. This means there is very little chance of having continuous 3.4 or 3.3 no-sun days, as mentioned. Furthermore, in normal practice, while calculating the required capacity of storage battery, said values are raised to adjust market availability. This will provide more capacity than that actually required. Therefore for system sizing, three no-sun days is adopted to calculate the capacity of a storage battery. In an actual system installation, the nearest data at the project site should be applied to obtain more accurate results. The 22 years monthly average data by each degree longitude and latitude is summarized in **Table II.3-1** and **Table II.3-2** of attached **Appendix II**.

4.3.3 Other Conditions

System Voltage

The present system voltage in Kenya is 12 V DC. In case of Uganda, 24 V DC is applied to health centres and 12 V DC to schools. In both countries, AC power supply system is 240 V, 50 Hz.

To maintain the standards in this plan, the present adopted system voltage is also adopted for system sizing.

Storage Battery

In Kenya, open-type large capacity vehicle battery manufactured within the country is used in most cases. These are improved type of battery for PV system, which have a short life and require several replacements for a long span to obtain smooth and reliable system operation. In the case of Uganda, considering transportation and maintenance, the sealed type of storage battery is generally used. Depending on maintenance methods, utilization pattern and conditions of storage battery life varies system by system.

If storage battery is not replaced during the system utilization spans due to the financial constraints or other reasons, the PV system could not be used even though no other particular problem exists apart from the battery. It is noted that these types of car batteries are not suitable for long series and parallel connections, which eventually affect the life of whole battery bank. For reference, maximum depth of discharge and life of used storage batteries for PV system are summarized in below **Table 4.3.3-1**.

Table 4.3.3-1 Type of Battery and Its Life Span

Type of Battery	Max. depth of discharge	Life
12 V Car battery (open type)	30%	2-3 years
Improved 12 V car battery for PV use (open type)(made in Kenya)	50%	3-4 years
12 V solar battery (sealed type)	50%	4-5 years
12 V, 6 V (small capacity) or 2 V deep cycle battery (sealed type)	70%	Around 7 years
2 V deep cycle battery (open type)	80%	Around 8 years
(For Reference) Large type capacitor (If used up to half of rated voltage, 4 V to 2 V)	75%	15-20 years

The battery life is based on maximum 20% discharge in a day.

Prepared by JICA Study Team

Lighting Load

LED lamps are drawing attention recently as the lighting of the new generation because of their high energy efficiency and long life. Research and development of LED lamp is continuing, and its commercial application, as flashlights or automotive lamps, has already started. It is expected that many different types of LED lights, for both corporate and individual use, will come into the market soon. In Japan, many LED lights have already been introduced.

It is advantageous to use LED lights with PV systems. Due to their high price, LED lamps are not widely used at the moment. However, with efficient LED, PV systems can be smaller in size if compared with the case of using traditional fluorescent lamps. The savings in the PV system development cost may offset the cost of LED lamps. For the case of rechargeable lamps, smaller size batteries can be used with LED, or the charging intervals can be longer if same size batteries are used.

Furthermore, fluorescent lamps need to be replaced when they expire. Since replacement lamps are difficult to buy in remote areas, this decreases the sustainability of the PV system. In contrast, LED lamps have very long life and replacement will be no longer necessary, which will dramatically improve the PV system's sustainability. With such advantages, it is important to endeavor using LED lamps with the PV systems in remote areas.

In this report, two cases of system sizing are described:

- **Case I**: The presently installed related components in public facilities are adopted as a system. The PV modules are either made in Europe, U.S., India or China, however, the price in the local markets is expensive because of the small sizes of procurement lots. Batteries made in local or neighboring countries are adopted and the depth of discharge of the battery is assumed to be 50%.
- **Case II**: Equipment is the same as that adopted in Case I, however, lighting loads are not assumed to be fluorescent light, which is commonly used in Kenya and Uganda, but LED lamps which are energy-saving and long life. Hence, the system size is downsized for reference. Lighting loads in Case II is estimated to be 70% of those in Case I.

Table 4.3.3-2 summarizes the system sizing parameters to calculate the system capacity.

Table 4.3.3-2 System Sizing Parameters

Item	Value	Unit	Remark
Average solar insolation hour	5	hour	Possible insolation to have at earth surface converted to hourly basis (1,000 W/m^2×5 h/day=5 kWh/m^2/day)
Days of autonomy (No-sun day)	3	day	Possible occurrences of no-Sun days
PV module efficiency	80	%	Lifetime eff. and power reduction due to temp. rises and dirt's
Inverter efficiency	90	%	Conversion eff. of inverter (DC to AC) (may vary by manufacturer)
Charge controller efficiency	95	%	To protect from over charge and discharge (may vary by manufacturer)
Battery efficiency	90	%	Charge discharge loss and self discharge
Max of depth of discharge (DOD)	50	%	Max. possible discharge (of improved car and sealed type battery)
DC system voltage (School, Health center & Charging facility in Kenya)	12	V	Supply voltage is AC 240 V, 50 Hz
DC system voltage (Health center in Uganda)	24	V	
DC system voltage (School & Charging facility in Uganda)	12	V	
PV module voltage	17	V	Depends upon type of module selected (at standard conditions)

Prepared by JICA Study Team

4.4 System Design Plan

In off-grid areas of both countries, there are individuals venturing into mobile charging business by installing small PV modules. Due to the low capacity of the PV module, only limited number of mobiles can be charged per day. Besides the PV systems, charging stations for car batteries and rechargeable lamps also exist. For charging batteries and lamps, the owner needs to travel to the nearest possible charging station and pay extra fees apart from the charging services. For local people, it is financially difficult to purchase a system like SHS, since its initial cost is high. Thus, considering the less costly fuel and transportation expenses, there are people willing to buy LED lamps and other equipment if charging stations exist in the nearby area.

Thus, if additional power supply is provided apart from the system installed at public facilities (that can also serve as charging facility for mobiles, rechargeable lamps, car batteries and others), local people will realize the convenience. Otherwise, there is also a need to consider establishing individual charging service stations.

Besides the system sizing parameters, there are also other factors which affect the size of the system and its smooth operation. Public facilities such as schools and health centres have different purposes, and their requirement, utilization pattern and size of facility need to be considered to meet their demands. For this, system sizing is done by assuming the average demand and utilization pattern. Besides the required capacity for public facilities, the required system capacity for charging facility is calculated. In case the public facilities and charging facility can be installed at the same site, the system size of the charging facility is added to that of the public facilities.

If LED lamps are used, it will then be possible to reduce the capacity of PV and storage batteries, which will also directly affect the cost of the total system. There are no definite plans to provide access to LED lamps for local people at present, although it will be possible to utilize LED lamps in case Japan implements equipment supply. System sizing is therefore basically carried out with the assumption that the light loads are fluorescent lamps, which are commonly used in Kenya and Uganda. However, system sizing adopting LED lamps is also undertaken for reference.

4.4.1 PV System for School

4.4.1.1 School of Kenya

The MoE of Kenya is providing PV system for primary and secondary boarding schools and the size and number of classrooms differs from school to school. Each facility is surveyed in detail to decide the system capacity and, through open tender, selected a company or group to install the system. The DC system voltage is 12V. If the required capacity is larger than the single charge controller can handle, the number of charge controller is increased to match the system performance. The power supply system is 50Hz, 240V AC.

In actual practice, the total load, the position of building within the facility, the average solar insolation of that area, and other factors must be considered to decide the size of the system. During the first stage of planning, the information collected at the sites by the study team, the present installations of MoE, and the installations of MoE through REA are considered as references to decide the average system capacity of schools. The assumed loads are summarized in **Table 4.4.1-1**.

Table 4.4.1-1 Assumed Loads of Secondary School (Kenya)

Subject	Load (W)	Qty.	Load sub-total (W)	Use (h/day)	Daily load (Wh/day)	Remark
For main building			**1,440**		**3,700**	**Sub-total**
Class room	120	4	480	3	1,440	(20 W x 6 lamps) x 4 room
Laboratory	20	2	40	3	120	20 W x 2 lamps
Principal office	20	1	20	1	20	20 W x 1 lamp
Vic-principal office	20	1	20	1	20	20 W x 1 lamp
Staff office	20	2	40	1	40	20 W x 2 lamps
Administration office	20	1	20	1	20	20 W x 1 lamp
Library	20	2	40	3	120	20 W x 2 lamps
Entrance hall & corridor	10	4	40	3	120	10 W x 4 lamps
Computer for office work (including printer)	350	2	700	2	1,400	Normally running hour is short, it is also use to prepare question papers and printing
Security lights	10	4	40	10	400	Outdoor lights
For dormitory			**160**		**960**	**Sub-total**
Boys dormitory	10	4	40	2	80	10 W x 4 lamps (around 90 student)
Girls dormitory	10	4	40	2	80	10 W x 4 lamps (around 90 student)
Security lights	10	8	80	10	800	Outdoor lights for 2 buildings
For dining hall and kitchen			**310**		**1,210**	**Sub-total**
Kitchen	20	3	60	3	180	Including preparation & cleaning
Dinning hall	20	3	60	3	180	Including cleaning
Security lights	10	4	40	10	400	Out door lights
TV (holidays and free hours)	150	1	150	3	450	At dining hall
For staff quarter			**130**		**340**	**Sub-total**
Bed room	10	2	20	2	40	2 bed rooms
Living room	10	1	10	2	20	Common use
Kitchen	10	1	10	2	20	Common use
TV/Radio	80	1	80	3	240	Common use
Entrance	10	1	10	2	20	10 W x 1 lamp

Prepared by JICA Study Team

Light loads are for night preparation classes and the TV at dining hall is assumed to be used by students during free time and holidays. The two families in the staff quarter are assumed to use a common kitchen and the TV and radio are assumed to be used at night and holiday. From the assumed loads and utilization pattern, the total load is calculated and summarized in **Table 4.4.1-2** below.

Table 4.4.1-2 Assumed Daily Load of School (Kenya)

Subject	Daily load (Wh)	Remark
For main building	3,700	4 classes, office, admin., lab., library, security and 2 computers
For dormitory	960	2 separate dormitories for boys and girls
For dining hall and kitchen	1,210	Power included preparation, cleaning and TV
For staff quarter	340	2 bed rooms, common living and kitchen and TV/radio
Total	6,210	

Prepared by JICA Study Team

Case I

In this case, the equipment and components used are those applied at present packages in Kenya. The capacity of the system is calculated assuming the system sizing parameters summarized in **Table 4.3.3-2**. The result is shown in **Table 4.4.1-3** below.

Table 4.4.1-3 System Capacity, Size and Number of Components for School (Kenya, Case I)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,704	Wp	And above
Battery (12V, @20hr) with base/box	1	1,900	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	1,000	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	221	Wp	And above
Battery (12V, @20hr) with base/box	2	300	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	15	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	558	Wp	And above
Battery (12V, @20hr) with base/box	1	700	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	500	W	Capacity of each
Charge controller (12 V DC)	1	40	Amp	Capacity of each
For staff quarter				
PV module	1	157	Wp	And above
Battery (12V, @20hr) with base/box	1	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	10	Amp	Capacity of each

Prepared by JICA Study Team

The total PV capacity and battery capacity are computed as follows:

$$\text{Daily load of DC side (Wh)} = \text{Daily DC load (Wh)} + \frac{\text{Daily AC load (Wh)}}{\text{Inverter efficiency (\%)}}$$

PV capacity (Wp) =

$$\frac{\text{Daily DC load (Wh)} \times \text{PV module voltage (V)}}{\text{DC system voltage (V)} \times \text{PV module efficiency (\%)} \times \text{Charge controller efficiency (\%)} \times \text{Battery efficiency (\%)} \times \text{Average solar insolation hours (hr/day)}}$$

Battery capacity (Ah) =

$$\frac{\text{Daily load of DC side (Wh)} \times \text{No-sun day (day)} \div \text{DC system voltage (V)}}{\text{Charge controller efficiency (\%)} \times \text{Battery efficiency (\%)} \times \text{Max of depth of discharge (\%)} \times \text{Battery rate factor}}$$

Here, the charging losses of battery and charge controller are covered by PV during power generation hours and the numerical values below decimal point are rounded up for calculation.

The capacity of the battery is 72 hours (for 3 no-sun days) excluding battery correction factor. Normally, the rated battery capacity is indicated at either 10 or 20 hours rate (hr). To select the battery, it is imperative to understand the battery capacity either at calculated hour or at rated capacity indicated by the manufacturer. Therefore, the calculated capacity is changed to rated capacity for better understanding. Battery factor differs depending upon type and manufacturer; therefore, it is required to adopt the exact value at the time of installation. For simplicity, the average battery rate factor of 1.3 is applied to understand the capacity at 20 hours rate and rounded up to adjust to market availability.

Case II

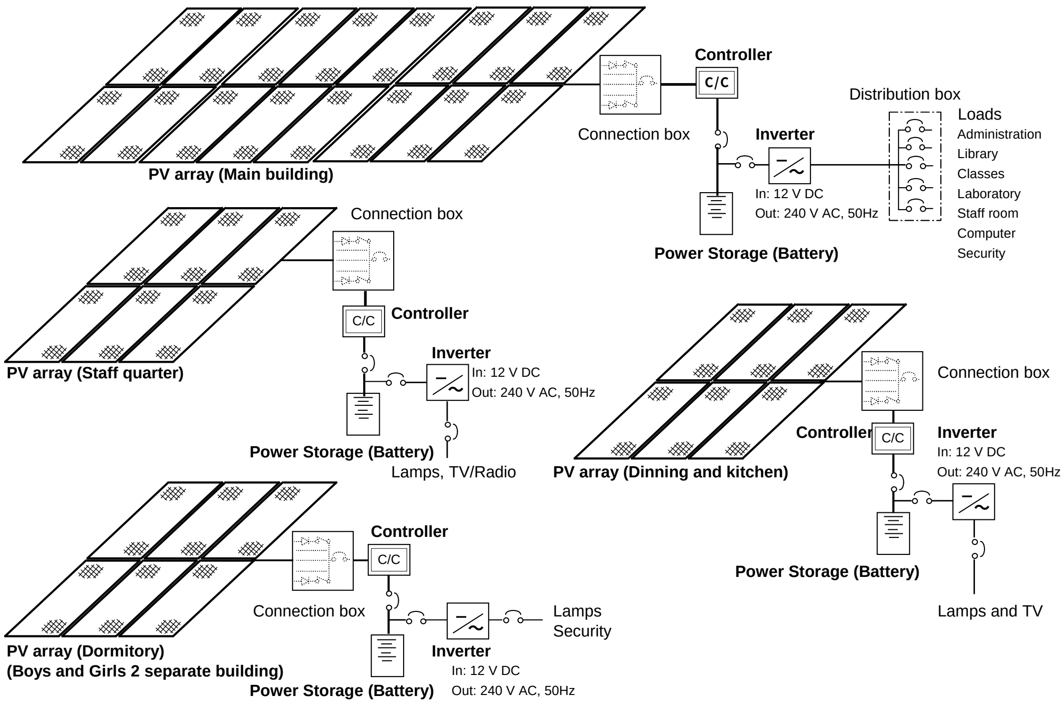
In this case, the lighting loads are assumed to be from LED lamps, which are energy-saving and have long life and system size is downsized. Lighting loads in Case II is estimated at 70% of the lighting load in Case I. **Table 4.4.1-4** summarizes the system capacity applying the system sizing parameters shown at **Table 4.3.3-2**.

Table 4.4.1-4 System Capacity, Size and Number of Components for School (Kenya, Case II)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,386	Wp	And above
Battery (12V, @20hr) with base/box	1	1,600	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	1,250	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	155	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	453	Wp	And above
Battery (12V, @20hr) with base/box	1	500	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	30	Amp	Capacity of each
For staff quarter				
PV module	1	143	Wp	And above
Battery (12V, @20hr) with base/box	1	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	10	Amp	Capacity of each

Prepared by JICA Study Team

The PV system sketch of the school facility is shown in **Figure 4.4.1-1** below.



Prepared by JICA Study Team

Figure 4.4.1-1 PV System Sketch of School, Kenya

4.4.1.2 School of Uganda

In Uganda, the MoES installed PV systems at secondary schools under the ERT program. The number and size of classrooms differs from school to school. Therefore, detailed survey is done and through open tender, the supplier is selected to install the system. The system voltage is 12 V DC. If the required size is larger than the single equipment can handle, the number of equipment like charge controller and inverter is also increased to match the requirement. The power supply to the loads is 240 V AC, 50 Hz.

The requirement of each facility, solar insolation and other parameters are considered to decide on the size of the system. The size of the system is calculated by taking the average of existing installed systems, the information collected at sites and the actual installations done through ERT program. The assumed loads of the school facilities are summarized in **Table 4.4.1-5**.

Table 4.4.1-5 Assumed Loads of Secondary School (Uganda)

Subject	Load (W)	Qty.	Load sub-total (W)	Use (h/day)	Daily load (Wh/day)	Remark
For main building			**1,680**		**4,420**	**Sub-total**
Class room	120	6	720	3	2,160	(20 W x 6 lamps) x 6 room
Laboratory	20	2	40	3	120	20 W x 2 lamps
Principal office	20	1	20	1	20	20 W x 1 lamp
Vic-principal office	20	1	20	1	20	20 W x 1 lamp
Staff office	20	2	40	1	40	20 W x 2 lamps
Administration office	20	1	20	1	20	20 W x 1 lamp
Library	20	2	40	3	120	20 W x 2 lamps
Entrance hall & corridor	10	4	40	3	120	10 W x 4 lamps
Computer for office work (including printer)	350	2	700	2	1,400	Normally running hour is short, it is also use to prepare question papers and printing
Security lights around building	10	4	40	10	400	Outdoor lights
For dormitory			**200**		**1,040**	**Sub-total**
Boys dormitory	30	2	60	2	120	(10 W x 3 lamps) x 2 bed rooms
Girls dormitory	30	2	60	2	120	(10 W x 3 lamps) x 2 bed rooms
Security lights	10	8	80	10	800	Outdoor lights for 2 buildings
For dining hall and kitchen			**310**		**1,210**	**Sub-total**
Kitchen	20	3	60	3	180	Including preparation & cleaning
Dinning hall	20	3	60	3	180	Including cleaning
Security lights	10	4	40	10	400	Outdoor lights
TV (holidays and free hours)	150	1	150	3	450	At dining hall
For staff quarter			**260**		**680**	**Sub-total**
Bed room	20	2	40	2	80	(10 W x 2 lamp) x 2 buildings
Living room	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
Kitchen	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
TV/Radio	80	2	160	3	480	80 W x 2 buildings
Entrance	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings

Prepared by JICA Study Team

The TV at dining hall for students is used during free time and holidays. The light loads at schools are used mostly at evening preparatory classes. The two staff quarters are shared by two families each having two bedrooms and common living room and kitchen. The radio and TV set are used at night and holidays. By the type of loads and hours of uses, the daily load is calculated and summarized in **Table 4.4.1-6**.

Table 4.4.1-6 Assumed Daily Load of School (Uganda)

Subject	Daily load (Wh)	Remark
For main building	4,420	6 classes, office, admin., lab., library, security and 2 computers
For dormitory	1,040	2 separate dormitories with 2 rooms each for boys and girls
For dining hall and kitchen	1,210	Power included preparation, cleaning and TV
For staff quarter	680	2 buildings (2 bed rooms, kitchen and TV/radio for each building)
Total	7,350	

Prepared by JICA Study Team

Case I

Table 4.4.1-7 summarizes the system capacity, size and number of components calculated using system parameters given in **Table 4.3.3-2**.

Table 4.4.1-7 System Capacity, Size and Number of Components for School (Uganda, Case I)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	2,035	Wp	And above
Battery (12V, @20hr) with base/box	1	2,300	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	1,000	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	240	Wp	And above
Battery (12V, @20hr) with base/box	2	300	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	15	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	558	Wp	And above
Battery (12V, @20hr) with base/box	1	700	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	500	W	Capacity of each
Charge controller (12 V DC)	1	40	Amp	Capacity of each
For staff quarter				
PV module	2	157	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

Case II

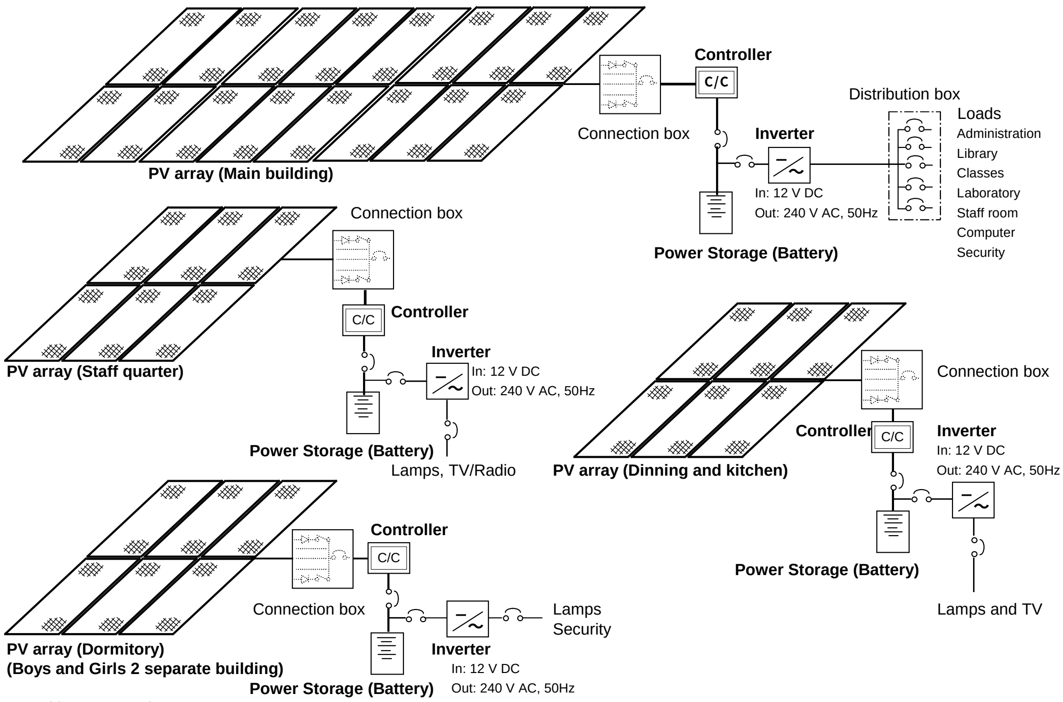
Table 4.4.1-8 summarizes the system capacity applying the system sizing parameters shown at **Table 4.3.3-2**.

Table 4.4.1-8 System Capacity, Size and Number of Components for School (Uganda, Case II)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,618	Wp	And above
Battery (12V, @20hr) with base/box	1	1,800	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	1,000	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	168	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	453	Wp	And above
Battery (12V, @20hr) with base/box	1	500	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	30	Amp	Capacity of each
For staff quarter				
PV module	2	143	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

The PV system sketch of the school facility is shown in **Figure 4.4.1-2**.



Prepared by JICA Study Team

Figure 4.4.1-2 PV System Sketch of School, Uganda

4.4.2 PV System for Health Facility

4.4.2.1 Health Facility of Kenya

In the rural area of Kenya, the health centre and dispensary is made up of 4 to 5 rooms which consist of treatment rooms, medicine supply and store room, general store room and so on. The larger health centre has delivery room and rest room after delivery. In some cases, with the participation of local people utilizing CDF (Constituency Development Fund) or religious group or NGO or international donor agency, additional rooms like treatment room, separate male and female treatment rooms, maternity ward also included in the process of construction.

The majority of health facilities have small refrigerator to store vaccines which runs by LPG. Unfortunately, there are cases the refrigerator is not functioning due to delivery problem of LPG. With the cooperation of NGO or religious group, some health facilities have small PV system installed for lighting purposes, but due to low capacity it is not enough to supply power as per requirement.

As in case of schools, it is necessary to understand the solar insolation of the site, the type of loads and utilization pattern, position of the buildings of same facility and other parameters to design the system. The information collected by the study team, the existing systems installed under the scheme of MoE, and the future system installation plans of REA are considered to obtain the required load of an average health centre for the whole country. The assumed loads are summarized in **Table 4.4.2-1**.

Table 4.4.2-1 Assumed Loads of Health Facility (Kenya)

Subject	Load (W)	Qty.	Load sub-total (W)	Use (h/day)	Daily load (Wh/day)	Remark
For main building			**880**		**2,920**	**Sub-total**
Waiting room	20	1	20	2	40	20 W x 1 lamp
Examination room	20	2	40	2	80	20 W x 2 lamps
Treatment room	20	2	40	2	80	20 W x 2 lamps
Office	20	1	20	2	40	20 W x 1 lamp
Medicine distribution and store	20	2	40	2	80	20 W x 2 lamps
Emergency operation room	20	5	100	2	200	20 W x 5 lamps
Maternity ward	60	3	180	3	540	(20 W x 3 lamps) x 2 rooms
Store room	10	1	10	1	10	10 W x 1 lamps
TV for information (with DVD/VCR)	350	1	350	3	1,050	Health information to public
Security lights	10	8	80	10	800	Outdoor lights
For refrigerator			**85**		**2,040**	**Sub-total**
Small vaccine refrigerator (12V DC)	85	1	85	24	2,040	Once cooled, low consumption
For staff quarter			**260**		**520**	**Sub-total**
Bed room	20	2	40	2	80	(10 W x 2 lamp) x 2 buildings
Living room	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
Kitchen	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
TV/Radio	80	2	160	2	320	80 W x 2 buildings
Entrance	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings

Prepared by JICA Study Team

Based on the above table, the daily load is calculated and summarized in **Table 4.4.2-2**. Normally, the health centres in rural areas have two staff quarters, therefore the system for each quarter is taken separately.

Table 4.4.2-2 Assumed Daily Load of Health Centre (Kenya)

Subject	Daily load (Wh)	Remark
For main building	2,920	4 medical room, administration, medicine store, operation, TV and security
For refrigerator	2,040	85W x 24hr. (consume around 1.9kW/24hr for cooling only)
For staff quarter	520	2 buildings (2 bed rooms, kitchen and TV/radio for each building)
Total	5,480	

Prepared by JICA Study Team

In rural health facilities, the local people (especially women) gather there to get information on nutrition, illness and treatment, delivery and child care and so on from medical missions. Considering these facts, a TV can be added and installed at the waiting area which can relay appropriate medical information repeatedly and will gain large influence on people. The assumed operating time of the TV set is three hours a day.

Likewise, the power of the small LPG-powered vaccination refrigerator is also considered to be supplied by PV system. The WHO recommends five days of autonomy for vaccine refrigerator at health centres. The PV system for the refrigerator will be built separately to avoid power draw out from other users which may cause power interruption and damage to stored vaccines. The team considered to apply only three days of autonomy to calculate the battery capacity for the refrigerator since the refrigerator consumes less power once it is cooled and the LPG can be used as back-up power source during no-sun days. The calculated capacity of the battery bank is rounded up to suit to market availability.

Case I

In this case, the present adopted components and the system parameters mentioned in **Table 4.3.3-2** are considered in the computation of the system capacity. The results are summarized in **Table 4.4.2-3**. The method of system sizing is the same as in school.

Table 4.4.2-3 System Capacity, Size and Number of Components for Health Facility (Kenya, Case I)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,345	Wp	And above
Battery (12V, @20hr) with base/box	1	1,500	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	1,000	W	Capacity of each
Charge controller (12 V DC)	2	40	Amp	Capacity of each
For refrigerator				
PV module	1	846	Wp	And above
Battery (12V, @20hr) with base/box	1	1,000	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	N/A	N/A	W	Capacity of each
Charge controller (12 V DC)	1	60	Amp	Capacity of each
For staff quarter				
PV module	2	120	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

Case II

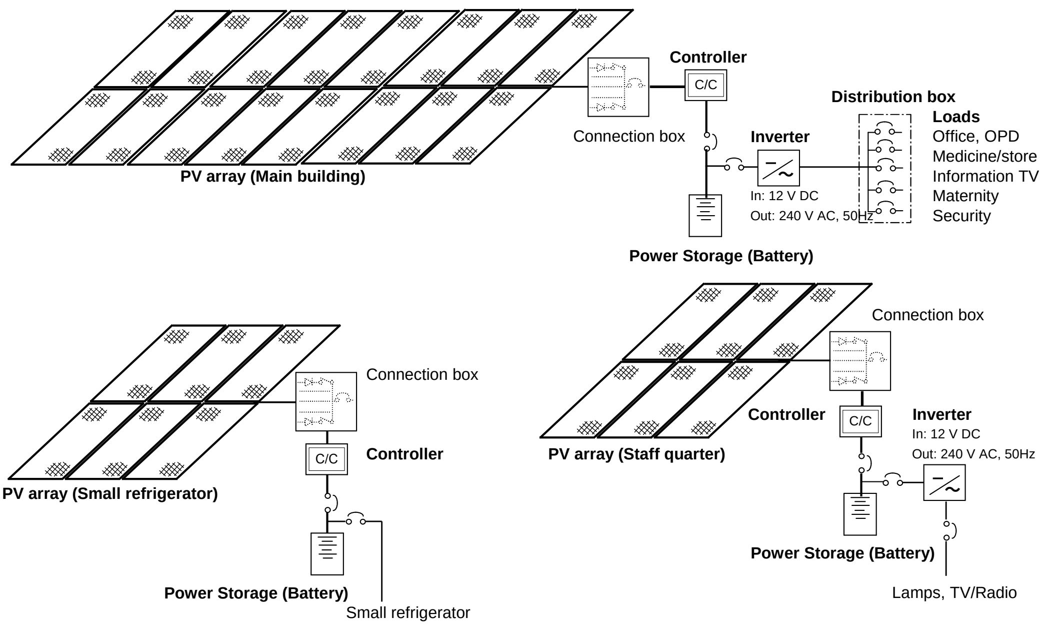
Table 4.4.2-4 summarizes the system capacity applying the system sizing parameters shown at **Table 4.3.3-2**.

Table 4.4.2-4 System Capacity, Size and Number of Component for Health Facility (Kenya, Case II)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,087	Wp	And above
Battery (12V, @20hr) with base/box	1	1,200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	800	W	Capacity of each
Charge controller (12 V DC)	2	40	Amp	Capacity of each
For refrigerator				
PV module	1	846	Wp	And above
Battery (12V, @20hr) with base/box	1	1,000	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	N/A	N/A	W	Capacity of each
Charge controller (12 V DC)	1	60	Amp	Capacity of each
For staff quarter				
PV module	2	107	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

The PV system sketch of health centre is shown in **Figure 4.4.2-1** below.



Prepared by JICA Study Team

Figure 4.4.2-1 PV System Sketch of Health Facility, Kenya

4.4.2.2 Health Centre of Uganda

In Uganda, the component of ERT program for rural health centres where grid extension is not available is considered to support all existing facilities of district HC II to IV. The ERT program is considering installing PV systems to several districts in different stages by phase of programs. Furthermore, even if the facility is already connected by grid it is recommended to install PV system to large facilities standing as hub to surrounding facilities and locality considering the fact that the grid power supply is unstable. This is to supply power mainly to refrigerators for vaccinations and preserving bloods.

There are small PV systems donated by NGO and religious group which are mainly for lighting but insufficient to supply the required power.

The solar insolation of the locality, the type of loads and their utilization pattern are the factors considered in developing the system. The ERT program is adopted as the base for power supply by PV system categorized depending upon requirement. The study team also carried the system calculation based on the same categorization. For load calculation of Case II, 100% of the load in wards and 40% in the staff quarters are assumed as lighting load. The required power for each facility is summarized in **Table 4.4.2-5**.

Table 4.4.2-5 Assumed Loads of Health Facility (Uganda)

	AC Loads (Wh/day)								
	HC IV			HC III			HC II		
Wards	Except light	Light	Total	Except light	Light	Total	Except light	Light	Total
OPD	0	628	628	0	580	580	0	475	475
Maternity	0	922	922	0	732	732	0	436	436
General	0	941	941	0	660	660	0	390	390
Operation	0	1,700	1,700	0	900	900	N/A	N/A	N/A
Laboratory	0	172	172	0	80	80	N/A	N/A	N/A
Administration	0	882	882	0	626	626	0	240	240
Staff quarter	Except light	Light	Total	Except light	Light	Total	Except light	Light	Total
Senior medical officer	576	384	960	576	384	960	282	188	470
Doctor	474	316	790	N/A	N/A	N/A	N/A	N/A	N/A
Clinical officer	282	188	470	282	188	470	N/A	N/A	N/A
Nurse 2	588	392	980	588	392	980	588	392	980
Nurse 1B	450	300	750	N/A	N/A	N/A	N/A	N/A	N/A
Nurse 1A	258	172	430	258	172	430	258	172	430
Nurse	150	100	250	150	100	250	150	100	250
Other loads									
Refrigerator small (12V DC)			2,040			2,040			2,040
Refrigerator medium			4,800			4,800			N/A
Information TV (with DVD/VCR)			1,050			1,050			1,050

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In rural health facilities, the local people (especially women) gather there to get information on nutrition, illness and treatment, delivery and child care and so on from medical missions. Considering these facts, a TV can be added and installed at the waiting area which can relay appropriate medical information repeatedly and will gain large influence on people. The assumed operating time of the TV set is three hours a day.

Even a small HC in a rural area is using a small vaccine refrigerator powered by LPG but due to management and distribution problem of LPG the refrigerator is unusable in most of the time. To avoid this kind of problem, the study team considered to supply power to these units by PV system. Depending on the size and location of HC III and IV, a small or medium type refrigerator is used. The PV system for the refrigerator will be built separately from other systems to avoid power draw out from other uses, which may cause power interruption and damage to stored medicine. The WHO recommends five days of autonomy for vaccine refrigerator. The team considered to apply only three days of autonomy to calculate the battery capacity for the refrigerator since the refrigerator consumes less power once it is cooled and the LPG can be used as back-up power source during no-sun days. The calculated capacity of the battery bank is rounded up to suit to market availability.

The system voltage of the present ERT program for HC is 24 V DC. The team also adopted the same system voltage in calculating the system capacity to avoid confusion.

Case I

In this case, the assumed component of the system is considered to be same with the current supply power for HC in Uganda. Using the system sizing parameters described in **Table 4.3.3-2** and the required capacity of PV, the size and number of components are calculated and summarized in **Table 4.4.2-6**.

Table 4.4.2-6 System Capacity, Size and Number of Component for Health Facility (Uganda, Case I)

Subject	PV module (Wp)	Inverter (W)	C/C (Amp.)	Battery (Ah)	Remark
HC IV					
					Total of PV module: 8,094 Wp
Wards					
OPD	290	800	10	200	12V battery*2 capacity @20hr
Maternity	425	600	15	300	12V battery*2 capacity @20hr
General	434	600	15	300	12V battery*2 capacity @20hr
Operation	783	1,000	30	500	12V battery*2 capacity @20hr
Laboratory	80	200	10	100	12V battery*2 capacity @20hr
Administration	406	600	15	300	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	442	600	15	300	12V battery*2 capacity @20hr
Doctor	364	500	15	200	12V battery*2 capacity @20hr
Clinical officer	217	300	10	200	12V battery*2 capacity @20hr
Nurse 2	452	500	15	300	12V battery*2 capacity @20hr
Nurse 1B	346	300	10	200	12V battery*2 capacity @20hr
Nurse 1A	199	200	10	200	12V battery*2 capacity @20hr
Nurse	116	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC III					
					Total of PV module: 6,618 Wp
Wards					
OPD	268	600	10	200	12V battery*2 capacity @20hr
Maternity	338	500	10	200	12V battery*2 capacity @20hr
General	305	300	10	200	12V battery*2 capacity @20hr
Operation	415	500	15	300	12V battery*2 capacity @20hr
Laboratory	37	300	10	100	12V battery*2 capacity @20hr
Administration	289	200	10	200	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	442	600	15	300	12V battery*2 capacity @20hr
Clinical officer	217	300	10	200	12V battery*2 capacity @20hr
Nurse 2	452	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	199	200	10	200	12V battery*2 capacity @20hr
Nurse	116	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC II					
					Total of PV module: 3,025 Wp
Wards					
OPD	219	600	10	200	12V battery*2 capacity @20hr
Maternity	201	500	10	200	12V battery*2 capacity @20hr
General	180	300	10	100	12V battery*2 capacity @20hr
Administration	111	200	10	100	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	217	600	10	200	12V battery*2 capacity @20hr
Nurse 2	452	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	199	200	10	200	12V battery*2 capacity @20hr
Nurse	116	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy

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Case II

Table 4.4.2-7 summarizes the system capacity applying the system sizing parameters shown at

Table 4.3.3-2.

Table 4.4.2-7 System Capacity, Size and Number of Component for Health Facility (Uganda, Case II)

Subject	PV module (Wp)	Inverter (W)	C/C (Amp.)	Battery (Ah)	Remark
HC IV					
					Total of PV module: 7,116 Wp
Wards					
OPD	203	800	10	200	12V battery*2 capacity @20hr
Maternity	298	600	10	200	12V battery*2 capacity @20hr
General	304	600	10	200	12V battery*2 capacity @20hr
Operation	549	1,000	20	300	12V battery*2 capacity @20hr
Laboratory	56	200	10	100	12V battery*2 capacity @20hr
Administration	285	600	10	200	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	389	600	15	300	12V battery*2 capacity @20hr
Doctor	321	500	10	200	12V battery*2 capacity @20hr
Clinical officer	191	300	10	200	12V battery*2 capacity @20hr
Nurse 2	398	500	15	300	12V battery*2 capacity @20hr
Nurse 1B	305	300	10	200	12V battery*2 capacity @20hr
Nurse 1A	175	200	10	100	12V battery*2 capacity @20hr
Nurse	102	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC III					
					Total of PV module: 5,951 Wp
Wards					
OPD	188	600	10	200	12V battery*2 capacity @20hr
Maternity	236	500	10	200	12V battery*2 capacity @20hr
General	213	300	10	200	12V battery*2 capacity @20hr
Operation	290	500	10	200	12V battery*2 capacity @20hr
Laboratory	27	300	10	100	12V battery*2 capacity @20hr
Administration	202	200	10	200	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	389	600	15	300	12V battery*2 capacity @20hr
Clinical officer	191	300	10	200	12V battery*2 capacity @20hr
Nurse 2	398	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	175	200	10	100	12V battery*2 capacity @20hr
Nurse	102	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC II					
					Total of PV module: 2,694 Wp
Wards					
OPD	153	600	10	100	12V battery*2 capacity @20hr
Maternity	141	500	10	100	12V battery*2 capacity @20hr
General	126	300	10	100	12V battery*2 capacity @20hr
Administration	78	200	10	100	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	191	600	10	200	12V battery*2 capacity @20hr
Nurse 2	398	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	175	200	10	100	12V battery*2 capacity @20hr
Nurse	102	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy

Prepared by JICA Study Team

The PV system sketch of health facility is shown in **Figure 4.4.2-2** below.

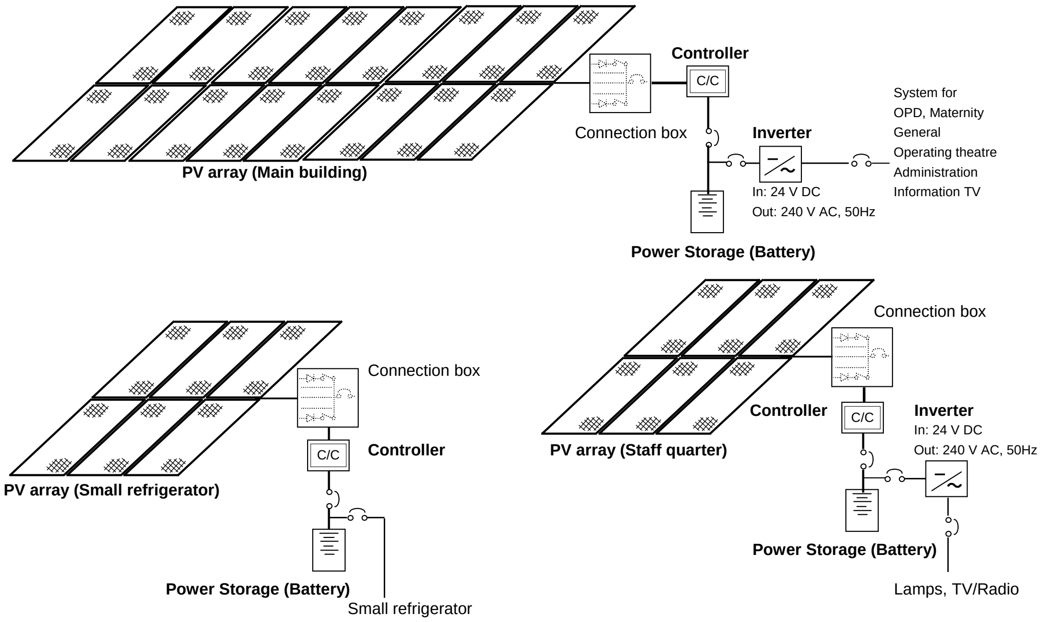

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Figure 4.4.2-2 PV System Sketch of Health Facility, Uganda

4.4.3 Charging System

In rural areas, grid extension is not viable due to reasons like lack of power for supply, financial shortage, scattered households, low demand and so on. With these reasons, some of the individuals in those areas are installing small PV systems to provide mobile charging services. It is not possible to cover all the demands by these small PV charging service centres considering the increasing demand for charging mainly for mobiles.

Due to the scarcity of these charging facilities, the local people need to travel to the nearest possible charging station which directly affects their financing ability and time. If charging service facility is made available within the local area, it can be assumed that it will definitely be utilized by the local people in that area.

Similarly, the charging facility can be used for charging rechargeable lights to replace the use of kerosene lamps for lighting thereby reducing health hazard, possibility of fire and expense due to purchase of kerosene. Furthermore, some well-to-do families can charge large capacity batteries that can be used to power multiple lightings, TV, radio and other appliances. It is therefore more economical to put up a PV system like SHS where large number of households will be able to participate in this concept.

The charging system is considered to be installed together with the system for public facilities like schools and health centres. But if the public facilities are not easily accessible and the demand is high for the charging system, it will be installed individually at the most convenient location. In this case, the system sizing is done separately.

The size of the system depends on the capacity and the number of rechargeable lights, storage battery and so on. In general, the boarding schools and health centres are situated at the village centre or at convenient locations accessible to surrounding villages. The village where public facilities exist is larger than the other surrounding villages. Based on the result of the survey, it is decided to charge around 100 mobile phones in a day. And if the charging system is developed, it can be assumed that there will be families willing to charge their rechargeable lamps, battery for power supply and so on in the future. Therefore, the system also considered to charge rechargeable lamps and large capacity batteries. The assumed component, number and approximate load size are summarized in **Table 4.4.3-1**.

Table 4.4.3-1 Assumed Loads and Numbers to be Charged in a Day

Subject	Qty. (/day)	Voltage (V)	Capacity (Ah)	Daily load (Wh/day)	Remark
For mobile phone and lantern				**1,051**	**Sub-total**
Mobile phone (700 mAh @70% discharge, 4 V)	100	4	0.49	280	300 nos. (100% of 300HH), charging every 3 days (100 nos./day), AC adapter efficiency (70%) is considered.
Rechargable lantern (4 Ah @50% discharge, 6V)	45	6	2.00	771	225 nos. (75% of 300HH), charging every 5 days (45 nos./day), converting efficiency from AC to DC (70%) is considered.
For car battery as storage				**1,260**	**Sub-total**
Car battery (70 Ah @30% discharge, 12 V)	5	12	21.00	1,260	25 nos. (8% of 300HH), charging every 5 days (5 nos./day)

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In practice, the days of autonomy for PV lighting system is three days but in charging system there is no such case considered because the batteries of individual owners can be used for many days with one charging and each individual owner can manipulate the charging days of discharged batteries and vary the day of charging for each battery. If the system is designed with storage battery, the cost of the system will be higher which will directly reflect at the charging service tariff.

Mobile phones and rechargeable lamps have small batteries that need regular charging. For convenience, it is considered that mobile phones and rechargeable lamps can be charged even in a bad weather day. Therefore, one day of no-sun day is considered in the system for mobile and small rechargeable lamps.

The charging of large capacity batteries will be by DC system only and having battery bank for bad weather day charging is not considered because the system will require large battery bank which is not practical for charging station. Since the utilization pattern of large capacity battery will differ from each household the required time for charging and the amount of power will vary for each battery. Therefore, fixed charging service fee is not recommendable. To have impartial service, it is recommended to install a current meter which can measure the total amount of current supplied to each individual battery and the charging service fee will be according to this. If the local people will understand that even when the charging interval increases the charging amount will not increase, then the timing of charging of individual batteries can be adjusted more conveniently and will also help to extend the battery life to some extent.

Mobile phones need to be charged completely within a short time frame. Since solar insolation varies every second, small battery is considered. Also, the local people will purchase rechargeable lamps according to their choice or financial level. Therefore, there will be a variety of rechargeable lamps to be charged at the same time. To cope to this situation, it is considered having both AC and DC charging systems. But since the number is not possible to predict, it is assumed that charging of both mobile phones and rechargeable lamps will be by AC system.

The priority location for the charging system is at public facilities and at public facilities with excess power available to maximize the utilization of the system.

To develop the charging stations in both Kenya and Uganda, the charging of locally available batteries and the system-sizing parameters mentioned at **Table 4.3.3-2** are considered. The result of system sizing is summarized in **Table 4.4.3-2**. The battery for 1-day autonomy is considered for charging of mobile phones and rechargeable lamps.

Table 4.4.3-2 System Capacity, Size and Number of Components for Charging Station

Subject	Qty.	Capacity	Unit	Remark
PV module	1	1,009	Wp	And above
Battery (12V, @20hr) with base/box	1	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	30	Amp	Capacity of each
Charge controller (12 V DC) with Ah Meter	5	10	Amp	Capacity of each

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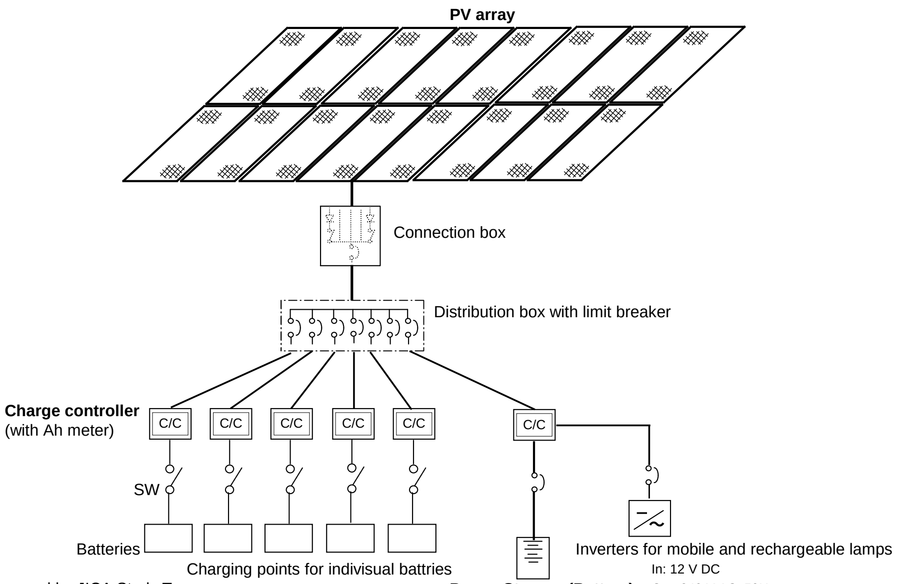
The PV system sketch of the charging system is shown in **Figure 4.4.3-1** below.



Prepared by JICA Study Team

Figure 4.4.3-1 PV System Sketch of Charging System

4.4.4 System Sizing for PV Water Pumping System

In rural areas, the drinking water system for human and cattle consists of surface water, spring water, hand pumps and diesel generator water pumps. In off-grid areas, there are diesel water pumping systems installed through the participation of local residents facing problems on operation and maintenance. Due to financial difficulties in rural areas, especially in purchasing oil and maintenance, diesel generator systems are not working smoothly. This causes the problem in obtaining water during the dry season.

In Kenya, a service charge of Ksh 2 per jerrycan (20 liters) is collected for the operation and maintenance of the diesel generator water pumping system. In some cases when the collected amount is not enough, the local residents provide additional contribution for maintenance.

In this kind of water pumping system, it is possible to install a PV system instead of the diesel generator for pumping and distribution. The latter system does not require battery to store power, making it more convenient to perform operation and maintenance. In actual practice, PV system needs to pump up required volume of water during day-hours, which means it needs to pump larger volume in a day and a larger storage tank. This system will also require carrying out of detailed study of tube-well.
The size of the PV water pumping system is determined by the total pumping head and volume of water required in a day. Generally, the type of PV system differs depending on the requirement for water volume and pumping head. Therefore, said system consists of two types based on water volume requirement.

Low Volume Water Requirement

Variable speed pump/motor is used in most cases of low volume of daily water requirement. The capacity required is derived according to the available solar insolation. In this type of system, the maximum pumping head is 100 m average to possibly pump a daily water volume of around 10 m^3. This type of pump/motor can go up to 120 m deep. If the total pumping head is lower, it would be possible to obtain a higher volume of water with same system. The average diameter of deep tube-well submersible pumps for this system is around 4 inches. Therefore, its inner diameter should be more than 4 inches to fit the required installation for the pump/motor.

The required capacity of PV can be calculated using the equation below.

- $$\mathrm{Re}quired\_PV\_Capacity\_(Wp) = \frac{H \times Q}{Ph \times Fm \times Ft \times O}$$

Where,

- H: Total head (m)
- Q: Required volume of water in a day (m^3/day)
- Ph: Solar Insolation hour of the site
- Fm: Efficiency of power supply unit (Efficiency depends up on the manufacturer)
- Ft: PV module efficiency (Lifetime efficiency and power reduction by temperature and dirt)
- O: Efficiency of pump/motor

For example, if the total pumping head is 100 m and the required water volume in a day is 10 m^3, the required PV capacity is computed as:

- $$\mathrm{Re}quired\_PV\_Capacity(Wp) = \frac{100 \times 10}{5 \times 0.9 \times 0.8 \times 0.3} = 926(Wp)$$

At the time of actual installation, the pump/motor should be adjusted as per manufacturer's requirements. Therefore, the capacity of the PV system will depend on the system selected.

The above calculation method can be used for inductant pump/motor. If the requirement for water volume is larger than what a single pump/motor can pump, additional unit of such equipment would be necessary. For this, riser pipe needs to be separated inside the tube well or additional riser pipe should be provided separately. Consequently, the inner diameter of the tube–well should be larger while increasing the PV capacity with the provision of related components.

Large Volume of Water Requirement (using deep tube-well)

Small pump/motor could not be used if the requirement for water volume is large or there are needs to pump water from high pumping head. In this case, a larger size of pump/motor is necessary. However, no inductant pump/motor is available to meet the requirements. Most large size pump/motor operates at a rated capacity and are run using AC power supply either from power grid or diesel generator. To enable to use such unit using a PV system, it is vital to understand the characteristics of its power generation system to ensure compatibility.

For example, to run a 15 kW AC pump/motor considering all losses and conversion factors, a PV capacity of 23 kWp or more is required. However, it is uncommon to continuously obtain 1 kW/m^2 of solar insolation on the earth surface. Moreover, due to the fluctuation of the solar insolation the system might hardly be operational. Considering this, an additional 20 to 30% more PV capacity is necessary. To ensure continuous operation of such pump/motor, the average solar insolation needed is 700 to 800 W/m^2. If the solar insolation goes below this value, it may not be able to drive the pump/motor even if the PV system generates power.

To avoid such technical problem, operation of more than one pump/motor in the same tube well could still be executed even at low insolation level. Moreover, when enough power is available to drive large pump/motor it can be switched to generate larger capacity with the same PV capacity. By running the pump/motor based on the insolation level, the required water volume is obtained. However, for this type of installation, the inner diameter of tube-well should be larger to meet the system requirements.

In 1995, NEDO (Japan) installed this type of PV system in Nepal for demonstration purposes. At present, the system is still running. The outline of the system is as follows:

- PV system capacity: 40 kWp
- Large size pump/motor rated capacity: 15 kW, 200 V, 50 Hz (3-phase)
- Depth of installation of large P/M: 90.4 m
- Medium size pump/motor rated capacity: 11 kW/15 kW, 200 V・50/60 Hz (3-phase)
- Depth of installation of medium size P/M: 133.02 m
- Pumped water volume in a day: 120 m^3/day (rainy season) to 270 m^3/day (dry season)

In the morning and evening, medium sized pump/motor runs considering the following system operation pattern:

- During the day when the insolation level is just enough, only the large sized pump/motor runs
- If the insolation level is higher, both pump/motors are expected to be operational.
- This implies that the pump/motor runs according to the available solar insolation with auto system.

Figure 4.4.4-1 below shows the overview of system

PV array (40kWp)

PV sub-array and connection box

Control panel and inverter

Deep tube-well

Source: NEDO (Japan) - NAST (Nepal) demonstration project

Figure 4.4.4-1 Deep Tube-well PV Water Pumping System (Photo)

Chapter 5 Criteria for Selecting Target Areas and Public Facilities

5.1 Criteria for Selecting Target Areas

The target areas of Community Solar System (CSS) are un-electrified areas without electricity grids. There may be some cases that electrified communities want to install CSSs because of unstable electricity supply. However, the use of uninterrupted power supply systems would be more economical and recommended in such cases. In Kenya, the REA stated that PV systems would be used even after grid electrification because electricity supply in remote areas is not stable.

In addition, most rural households are low income and cannot afford grid connection because of high connection charge. Therefore, it is expected that CSS will still be used by many rural people even after grid electrification. In high income areas, many households with grid connection might allow their neighbors to charge their mobile phones, and hence CSS users might decrease. However, when use of rechargeable lanterns, which require long hours for recharging, spread in the local communities, the use of CSS will be in high demand again.

Based on the above-mentioned understanding, even those communities having grid electricity plan but with no confirmed timetable are eligible for CSS development. The communities that have both social and economic functions (core communities) would be given high priority. In this scenario, it is planned to provide PV systems to the public facilities and PV battery charging facilities in the core communities to improve their public services.

In Kenya, electricity grids have been extended considerably to cover more than half of the country. Therefore, the communities and public facilities suitable for CSS are limited. At the moment, the REA of Kenya is formulating a master plan of rural electrification and the selection of around 250 public facilities targeted for off-grid electrification until the year 2013 will be completed by June 2009. Hence, it is recommended that JICA selects the candidate sites of CSS from the REA list of public facilities.

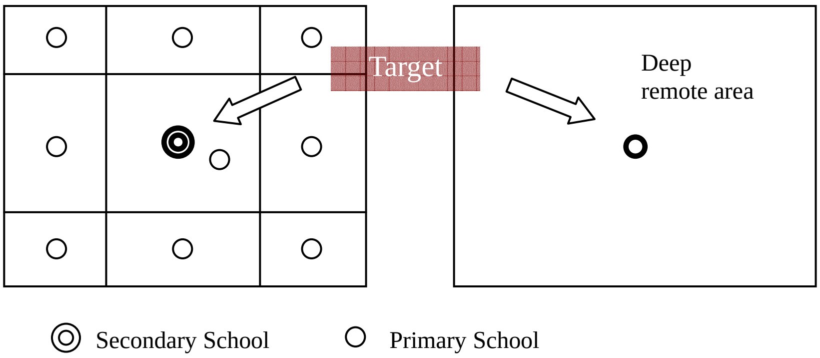
On the other hand, Uganda has low rural electrification rate and, therefore, has many public facilities suitable for CSS development. Its grid extension has not been going well as planned and off-grid electrification of public facilities by PV is regarded as an important component of rural electrification. Many donors, including the World Bank, have been implementing PV electrification of public facilities but the number of completed sites to date is still limited. Many public facilities are left without electricity. Hence, JICA can find the candidate sites of CSS by coordinating with REA, the World Bank and other donors to find the list of public facilities that have no plan of electrification.

There are some areas in both Kenya and Uganda where JICA sets restrictions on entering due to security reasons. However, the rural electrification rate in those areas is generally low and, therefore, the need for PV electrification of public facilities is high. Thus, it is recommended that JICA pursues appropriate measures to undertake PV electrification activities even in the restricted areas while considering the security conditions of the target sites.

The Rural Electrification Authority (REA) of Kenya and Rural Electrification Agency (REA) of Uganda are the appropriate organizations to work with as counterparts in the project's implementation. There are ministries responsible for schools and health centres in both countries, but those ministries would not pay attention to battery charging. The REA, on the other hand, has strong interest in rural electrification and battery charging.

5.2 Selection of Target Facilities

High priority public facilities suitable for CSS are Secondary Schools and upper level Health Centres ("Health Centre" in Kenya and "Health Centre III" in Uganda) in un-electrified areas. Isolated Primary Schools located deep in remote areas or large boarding Primary Schools, which can be viewed as important central schools in remote areas, would be also eligible for CSS. Similarly, isolated Health Centres servicing large areas would also be eligible.



Prepared by JICA Study Team

Figure 5.2-1 Concept of Area Density and Target Facility

In general, these facilities will provide public services to many local people and will be located at sites accessible by car. Therefore, battery charging facilities, if combined with PV electrification facilities at public facilities, can be easily accessible. In the premises of public facilities, the battery charging facility that deals with many customers every day should be properly located so as not to disturb the main activities of the public facilities. For example, in case of schools, battery charging facilities should be located away from classrooms so as not to make any nuisance.

In principle, if there is a Secondary School and a Health Centre in the same un-electrified community, a CSS with combined PV institutional system and battery charging system should be installed at both sites in order to secure income for system maintenance. However, if running two battery charging facilities might be troublesome, it will be better to install one battery charging facility at one of the public facilities and set up a mechanism to manage the income by the community. The community is responsible for providing the necessary funds for maintenance to each public facility.

5.3 Water Supply Facility

Water supply facilities, such as wells, pumps and storage tanks, are often located far from the centre of the community. Therefore, it is not practical to install a battery charging facility in such remote location and it would be better to build a PV water supply system alone. Usually, the water users are supposed to pay some fees, so securing funds for the PV system maintenance would not be difficult. Furthermore, the PV pumping system does not require batteries, which is an advantage in terms of maintenance. Of course, a PV battery charging facility can also be built if the water supply facility is located near the community centre.

Chapter 6 Demand Estimation and Financial Analysis of Combined PV System

6.1 Demand Estimation

An estimate of the demand for battery charging in a rural community is shown in **Table 6.1-1**. The PV system to be developed under this scenario will be located in core communities in the vicinity. Therefore, battery charging users will come from neighboring communities. In Kenya and Uganda, the size of core communities is relatively large. In many cases, there are 200 to 300 households. Mobile phones are widely used even in remote areas. It is fair to estimate that every household has one mobile phone. In the future, each individual will own one mobile phone. According to the field studies conducted in this survey, mobile phone charging is conducted every three days or twice a week on the average. It takes only two to three hours to recharge a mobile phone and therefore the users of battery charging facility will come in a dispersed way in the morning, daytime or evening during the day.

On the other hand, rechargeable lamps have just started entering the rural market. Rechargeable lamps made in China and India can be found even in remote areas. Some donors and the REA of Uganda have expressed strong interest in rechargeable lamps. Their design and battery capacity vary a lot. Among them, the rechargeable lamps that are intended to replace the kerosene lamps are equipped with a 6 V - 4 Ah lead-acid battery. The UNIDO of Kenya is developing its own model that has the same size battery. Although it is difficult to estimate the typical pattern of battery charging in case of rechargeable lamps, it can be assumed that such battery will last for about five days and need about eight hours for recharging. Thus, the users of battery charging facility will come in the morning and pick up batteries in the evening.

Furthermore, some people will use large-size automotive batteries so they can use many lamps and watch TV at the same time, which is common in Asia but rare in Africa. Such practice will spread over time among high income families as rural people accumulate knowledge on PV. Automotive battery also needs more than eight hours for recharging and requires the same pattern of charging service as rechargeable lamps.

Table 6.1-1 Estimated Number of Battery Charging Customers

Item	Estimation
Mobile phone charging	Number of owners 300, Interval every 3 days, Number of users 100/day
Rechargeable lantern charging	Number of owners 225, Interval every 5 days, Number of users 45/day
Automotive battery charging	Number of owners 25, Interval every 5 days, Number of users 5/day

Prepared by JICA Study Team

6.2 Financial Analysis

The estimated revenue of battery charging facility is shown in **Table 6.2-1**. This study revealed that the common rate of phone recharging fee is around US$ 0.25 in both Kenya and Uganda. However, data of lamp recharging fee was not easily obtained because of limited number of rechargeable lamps used in remote areas. It is estimated that the fee will be fixed at around US$ 0.50, which would be proportional to the rate of mobile phone charging fee. In case of automotive battery charging, recharging fee falls in the range from US$ 0.50 to US$ 2.00 in Uganda. Compared with phone charging, the amount of energy used for recharging is more than

100 times. Therefore, it could go up very high. However, it is assumed that rural people can only afford around US$ 1.00. For this reason, automotive battery charging is not an attractive investment.

The number of users is based on the demand estimate mentioned earlier. It is recommended that extra number of users be taken into account when designing the battery charging facility. At the early stage, revenues will be generated only from phone charging. However, use of rechargeable lamps and automotive batteries will increase over time. Furthermore, charging service providers might be able to boost their revenue by retailing rechargeable lamps and replacement batteries.

Table 6.2-1 Estimated Revenue from Battery Charging

Item	Estimation	Monthly revenue
Mobile phone	Number of owners 300, 10 charging/month, Fee US$ 0.25	US$ 750
Rechargeable lantern	Number of owners 225, 6 charging/month, Fee US$ 0.50	US$ 675
Automotive battery	Number of owners 25, 6 charging/month, Fee US$ 1.00	US$ 150
Total		US$ 1,575

Prepared by JICA Study Team

On the other hand, the associated costs include operators' salary (around $50 per month for one person), rewards for committee members, spare parts such as clips and cables, and replacement costs of charge controllers and batteries. In addition, the maintenance costs of institutional PV system should be taken into account. The aggregate costs, however, will be smaller than the expected revenue and the surplus would reach a significant amount, and the management of cash surplus must be worked out carefully. Bank deposit is recommended, but use of mobile phone as a tool for fund transfer, which is common in remote areas, might be also possible. If demand for battery charging increases more than originally planned, it will be possible to invest in additional PV units by using the retained funds.

Chapter 7 Management of Combined PV System

7.1 Basic Concept of Management

For the PV institutional system, no special work for operation is necessary. Only regular maintenance of batteries and replacement of old components are required. In principle, these practices have been successfully conducted in many sites and therefore, can be transferred to new sites in Africa. However, PV users or operators do not usually have good understanding about these maintenance activities. This is attributed to the limited information on PV operation and maintenance in rural areas, insufficient instruction and guidance at the time of PV installation, and failing to remember information guidance learned from the past. Another problem is the shortage of funds for battery replacement, which is a common situation for public facilities. The facilities with PV systems need to secure funds for maintenance.

Therefore, it is important to prepare maintenance manuals and provide well-designed training (preferably hands-on) for the public facilities where PV systems are installed. In addition, maintenance support by installers, provision of warranty, and information service through mobile phone will support the public facilities. It is realized that the wide use of mobile phones even in remote areas facilitate communication with PV dealers. Information on troubleshooting and spare parts obtained conveniently and promptly is vital for PV dissemination.

On the other hand, a battery charging system that initially targets mobile phone users and is subject to plans for extension of services to other battery charging customers requires a special arrangement (management scheme) for operation as part of the business. Many users will visit and use the charging system daily. Users bring in their phones and other equipment for recharging and pay for the service. In schools, students are allowed in the morning to charge their lamps brought from their homes. (In this case, special arrangement is necessary during vacation seasons.)

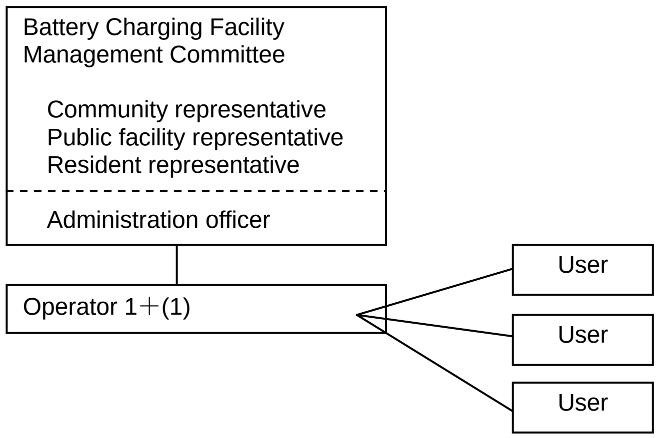
The required works such as dealing with customers, fee collection, record keeping, accounting, etc. would be time-consuming and labor-intensive. The staffs of public facility are busy in carrying out their assignments and therefore cannot conduct these additional tasks. Thus, establishing a good management system with newly-hired operators is the key to the success of the battery charging system. Battery charging is important for the community just like water supply and therefore should be run properly every day. Moreover, the revenue should be managed properly and used for PV system maintenance. For these reasons, it would be appropriate that the battery charging system is owned and operated by the community. This idea should be explained well to the community and public facility at the initial stage of PV system development.

7.2 Management Organization

When the community owns a solar system, the suitable management organization would not be a private business entity. In order to serve the community and to use the revenue for its benefits, a neutral committee consisting of representatives from community, public facility and residents would be appropriate. It was confirmed that a community organization running facilities of common interest has been a traditional system, and many such local committees are working in Kenya and Uganda. For example, it is common practice to organize a committee for managing water supply system and collect fees from users in remote areas. Furthermore, community-based committees, often called facility management committees, are organized to support public facilities such as schools and health centers on behalf of the government.

In the past, the central and local governments were fully involved in the management of local public facilities. However, as a result of education, social stabilization and local autonomy, community people can presently organize and manage these public facilities. Thus, it is feasible to develop a committee that could manage Community Solar Systems in rural areas of Kenya and Uganda.

In summary, the targeted community should establish a dedicated organization (committee) and use the proceeds for the benefits of community people. In addition, JICA should assist in developing such organization and provide appropriate training to the committee members during construction. A concept of an appropriate management organization is shown below.



Prepared by JICA Study Team

Figure 7.2-1 A Concept of Management Structure for Battery Charging Facility

The basic tasks necessary for the management of battery charging system are as follows:

Operator

There should at least be one full-time operator who is supposed to conduct the following tasks.

- Checking of user and set up of battery charging
- Checking the status of battery charging
- Fee collection and keeping records
- Daily system maintenance
- Dealing with claims

These tasks are the same as in the case of private battery charging stations. It is recommended to have a substitute operator to cope with the situation when the designated operator is not available.

Management Body - Committee

The committee, which is independent from the public facility, has the authority to manage the PV system and is supposed to undertake the following tasks:

- Management of revenue (cash) and expenditure (salary, maintenance costs)
- Auditing accounts
- Keeping accounting records
- Arrangement of expenditure for public facility

It is necessary to secure enough funds for PV system maintenance, which is one of the objectives to develop a community solar system. Representatives from the public facility should join the committee.

The management scheme is basically the same as the management for water supply described above, which is common in Africa. The community that will be granted with a community solar system can perform its operation and maintenance if detailed guidance and intensive training are provided before commissioning.

7.3 Relationship with Existing Battery Charging Providers

There are situations where some villagers are already operating small PV battery charging stations at the communities where community solar systems are planned. In such cases, the impacts on existing charging services should be carefully examined. Community solar system is designed as a public system to serve the people and hence, making profits is not a priority. Therefore, it is recommended to avoid causing negative impacts on the existing battery charging stations. Most existing battery charging services are small-scale and use the minimum size of PV system. Hence, the number of users is limited. If the charging fee of the community solar system is set at the same level as the existing charging stations, they can also serve other customers who live far from the community solar system since the charging services required is the same.

Based on this understanding, it is more important to acquire new customers of PV battery charging inside and outside the community than to make arrangements with existing battery charging operators. It will be possible to design the scope of charging services, paying attention to the existing battery charging stations and promote a mutually beneficial situation. In addition, community solar systems can recharge large batteries used for rechargeable lamps, which is very difficult for existing small battery stations. Sales of rechargeable lamps (lanterns) in rural areas would grow quickly if battery charging services are accessible. Thus, it would be feasible to have a community solar system focusing on customers with large-size batteries.

7.4 Organizational Development at the Early Stage

The proposed battery charging system can be built using standard PV components. Local technicians in Kenya and Uganda can design, install and maintain the PV systems using their technology and skills. Therefore, technology transfer from Japan is not strongly required. On the other hand, the management of battery charging system discussed earlier is very important in achieving the objectives of a community solar system. However, the community people can hardly develop an appropriate scheme without assistance. JICA is therefore proposed to be responsible for the development of management scheme as well as the system development. During the process of planning to construction, a series of meetings will be held to discuss the development plan of a community solar system. During such meetings, guidance must be given to the community regarding the organizational development for managing the community solar system. These activities are to be conducted by consultants that have extensive experience in business development as soft component of project.

The battery charging service is a new type of community business that can potentially generate big income from the beginning. If the assistance in organization development is only provided at the time of system development, it is unlikely that the community management system becomes effective. It is recommended therefore that monitoring activities should be continued for several years after the consulting services by JICA, to reinforce the management structure.

In Uganda, UNDP established 11 Private Sector Development Centers (PSDCs) in 1998. PSDC provides services mainly to small and medium enterprises. However, other organizations including local communities, local governments, NGOs, CBOs and microfinance institutions are also covered. PSDC provides a variety of consulting services for business support, community development, organizational development assistance, and ICT.

It would be feasible to utilize PSDC to follow up the JICA project on community solar system and develop a promising business model for community-based PV battery charging. In this case, it would be appropriate that PSDC signs a service contract with the communities where JICA has granted a community solar system, and provides consulting services until the battery charging services become stable. In return, PSDC can receive consulting fees from the income generated from battery charging services.

7.5 Business Model for PV System Dissemination

Rechargeable lamps and other electrical products that need PV electricity will be widely used after the installation of the community solar system. Thus, the system works to lead the PV business development in remote areas as well as to provide battery charging services to remote villagers. When the community solar systems are developed in remote areas and battery charging has become part of the villagers’ lives, it is expected that PV market expansion will naturally progress based on the following mechanism:

1) First Stage - Mobile Phone Charging

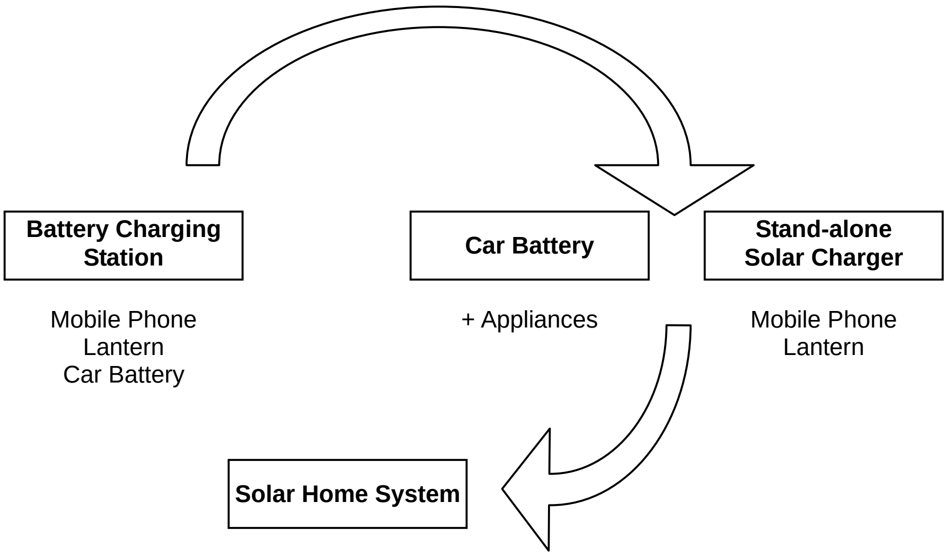
It is evident that there is a strong need for mobile phone charging services in remote communities. With community solar system, PV battery charging will spread in the community. The PV system can generate good income, which will encourage the owner of the community solar system to learn the proper use and maintenance of the PV system. The system will be sustainable and continue to provide battery charging service to the community people. In order to make this battery charging business grow, providing necessary financial and technical support is indispensable.

2) Second Stage - Introduction of other products with batteries

The villagers accumulate knowledge on PV application, and become interested in using electrical products that work with rechargeable batteries. They would try to use rechargeable LED lanterns that are starting to enter the local markets. High income families may go for automotive batteries and inverters. PV dealers will increase their sales taking advantage of these trends. Many organizations have recognized these possibilities. The “Lighting Africa” project of IFC is a good example of an initiative going in the same direction. The more they use PV technology and rechargeable batteries in their daily lives, the more they learn about PV and batteries. Frequent use of the PV system for battery charging will spread knowledge of its benefits, and hence, rural people will gain confidence in the PV system. Although they were already aware of such system before, they will further gain confidence in the utilization of PV with the community solar system, which is fundamentally different. They would accumulate skills for battery use and maintenance. Thus, many villagers will be educated to properly use and maintain PV systems, and become potential customers of such systems.

3) Third Stage - Sales increase of high-end PV products

By using mobile phones and rechargeable lamps, many villagers become confident on PV and gain good knowledge for the sustainable use of PV. At this stage, many rural people will start developing ideas on how to use PV to improve their lives and consider purchasing PV accessories. Some high income families will buy upscale PV systems such as self-rechargeable solar lamps or solar home systems (SHS). PV dealers can increase their sales and are motivated to provide better service to cater to the increasing number of PV customers and expand such market. The favorable business cycle will emerge and evolve over time.



Prepared by JICA Study Team

Figure 7.5-1 Stages of PV Dissemination in Rural Communities

The business model elaborated above is different from the ordinary model that places emphasis on financial aspects and pursues the dissemination of SHS from the beginning. The new model also focuses on the flow of knowledge and information for the users, not only in monetary terms. This is regarded as an important factor in making a decision for buying unfamiliar products, and to promote their sustainable use. The users are the main players deserving more focus than the sellers in the market, since the former makes the final decision on the purchase. The proposed concept of community solar system is backed by this new business model.

7.6 Human Resource for the Business Model

The above-mentioned business model starts with a PV battery charging system in un-electrified community. The installation of such PV systems will be carried out by grass-rooted private investments as well as donor projects. It is important to support entrepreneurs who will challenge the battery charging business. In most cases, their background might be merchandising, not agriculture. They are expected to start with a small battery charging business and gradually expand it by getting more customers, which is an ideal situation. In order to support such initiatives, financial support needs to be considered first. However, a small PV system that is designed for phone charging only requires a PV module of 20 to 40W and an investment of several hundred dollars, which is in the same range of other local business investments. Thus, financing needs for the investment will be effectively dealt with by local small financial institutions.

Sensitization on such new business and provision of information on PV dealers and PV system operation are more important than financial support. In particular, it would be very effective that the central government undertakes pilot projects and publicizes their outputs, which will strongly draw attention of the public. The government may consider tying up with mobile phone companies to work together for the promotion of PV battery charging.

Also, it is very important to educate potential users to develop new customers of PV battery charging and to stabilize the new venture within a short period. So far, user training has been conducted primarily by PV installers, which usually ends in inadequate results in remote areas. PV dealers cannot spend enough time and money for the customers who live in long distance. As a result, knowledge transfer to remote users is insufficient and PV systems cannot be operated in a sustainable way. PV systems are, in general, easy to use for a long time once the users get a certain level of knowledge on system maintenance. Information on the necessary tips of PV system maintenance can be obtained from various sources. The important issue is how to transfer the information to remote villagers. Education at vocational schools as well as official publicity campaigns would be effective. Furthermore, it is recommended to give training to those who are interested in PV battery charging business in their communities and to make them understand the basics of PV system. With such efforts, an effective information dissemination mechanism will be created in remote areas, in which the trainees will work as information providers and spread the knowledge about PV to other villagers. Thus, in order to facilitate the business model, continuous information dissemination to remote areas would be the prime objective of ODA programs.

Chapter 8 Recommendations

Human society must tackle world-scale problems such as global warming and fossil fuel depletion, which are expected to become serious in the middle of this century. Application of PV is a core technology for both advanced economies and developing countries in dealing with and addressing such problems. A ten-year plan will be needed to effectively promote PV systems all over the world. At the moment, commercial application of PV is only possible in advanced countries. In contrast, developing countries need assistance from advanced countries to disseminate PV systems. Japan, a frontrunner in PV development, is determined to develop a clear vision and take the necessary measures for PV development on a global scale.

1) Definition of Community Solar System in ODA Program and Start of Pilot Project

The concept of community solar system that integrates battery charging system with PV institutional system in public facilities is not yet recognized as a promising scheme to promote PV utilization in developing countries. However, UNIDO in Kenya has already started a project based on the same concept, the Energy Kiosk. This would lead to similar undertakings of other donors. There is no technical difficulty in developing community solar systems, and the concept is easy to understand. Moreover, the required investment is relatively not substantial. Thus, many public and private organizations can undertake aid projects to build community solar systems. The concept contributes to the development of local communities and in the mitigation of global warming, thus, it should draw more attention and be clearly defined in the ODA program. Japan, having an edge in PV and LED technology, is expected to lead other counties in realizing the concept.

Based on this understanding, it is expected that JICA will conduct more in depth studies of the said concept and its effectiveness, and integrate it into Japan’s ODA program. Wasting time for mulling this idea should be avoided. Early implementation of pilot projects is recommended to assess its feasibility, sustainability and replicability.

2) Support for New Business Model to Disseminate PV

As outlined in Section 7.5, the business model to accelerate PV development starts with a small battery charging business. The necessary investment for the venture is expected to be minimal and affordable, and therefore, local entrepreneurs who are interested in such business will emerge if funds are made available locally. Once it starts, the small business will soon generate good income from the existing strong demand for mobile phone charging and the growing need for rechargeable lamps. It is important to take necessary measures to promote these ventures in remote areas.

In addition to the development of a local credit scheme, training is needed to be provided to local people who are interested in PV business, regarding the issues on PV technology, procurement and installation, and ways of providing battery charging services. Use of media such as newspapers and distribution of posters will be also effective. It is apparent that implementation of pilot projects using ODA funds have positive impacts to many people.

Furthermore, integrating PV into the school curriculum, in vocational schools for instance, will be effective to ensure the supply of human resources for this business in the long term.

On the user side, the plan on gaining consumers' confidence in new products that work with rechargeable batteries is important. In particular, some rechargeable lamps, at the early stage of its dissemination in the market, are poor in quality and therefore may cause problems. Users will then be disappointed and this could hamper progress of the PV business. Hence, the development of an appropriate quality certification scheme should be considered. In addition, application of LED technology to lighting equipment is recommended to improve sustainability. Measures to promote LED, such as the exemption of import duties on LED lamps, should be considered. As for SHS, which is the ultimate goal of PV business, it is recommended from a long-term viewpoint, to reduce the system cost with the improvement of PV panel procurement and also to develop a consumer finance program when the potential users are already well aware of the benefits of SHS.

3) Human Resource Development in Japan

There is little demand for stand-alone PV systems in Japan, and therefore human resources that can work to develop them will remain very limited due to the lack of hands-on opportunities in the country. When JICA leads the role in building PV systems in developing countries, the bottleneck is the shortage of Japanese consultants who have experience in off-grid PV systems. Hence, JICA may have difficulty in hiring experienced consultants. Training of human resources for the fields of study, which is only feasible in developing countries, should be intentionally planned and conducted by JICA. Otherwise, human resources for such subjects cannot increase and new ODA projects could not proceed well as planned. Such training can be conducted only by JICA on a long-term basis, which private companies in Japan have no interest in undertaking. Thus, JICA strategically needs to consider how to develop domestic human resources for community solar system projects in cooperation with energy industries and NGOs.

Application of small PV systems in remote areas is a community-oriented grassroots type project, and involvement of the people is indispensable. It is easy for everyone to learn the technology and raise a capital for small PV systems. Therefore, NGOs and volunteers working in Africa are expected to be more intensively involved in the projects for developing PV systems, which will augment JICA's programs. In order to foster the involvement of NGOs and volunteers, JICA needs to build a good relationship with them and provide basic knowledge on PV development and maintenance to facilitate their participation.

4) International Collaboration

The international society needs to tackle the global warming issue and hence, international collaboration will be extremely important. There are many international organizations and aid agencies involved in the projects for global warming mitigation and poverty reduction. For example, UNIDO in Kenya is implementing a project similar to community solar system, and as confirmed in this study, it is willing to collaborate with JICA.

It has become a major ODA concern to help African countries, whose demand for energy will grow in the future, in terms of development of renewable energy and achieving the improvement of living standards. The responsibilities of aid organizations are enormous. The international society is keen on this matter and pays attention to the activities of aid organizations. Thus, JICA needs to build strong relationships with other international organizations and coordinate its programs with them. In many ODA projects, however, collaboration with other donors is not straightforward because each organization has its own objectives, timetables and practices. Therefore, it is recommended for JICA to expedite international collaboration more intensively, starting with information exchange with other donors, and to adopt an approach to work out effective ways of cooperation on a per project basis.

Appendix I Result of Non-Electrified Village and Public Facilities

Chapter 1 Field Surveys and Site Visits in Kenya

1.1 Schedule of Field Surveys and Site Visits in Kenya

The Study Team conducted field surveys and site visits for a duration of ten days, as follows:

- April 18 (Friday): Site Visit to UNIDO Energy Kiosk (I)
- April 21 (Tuesday): Site Visit to UNIDO Energy Kiosk (II)
- April 22 (Wednesday) to April 25 (Saturday): Field Survey (I)
- April 30 (Thursday) to May 2 (Saturday):Field Survey (II)
- May 5 (Tuesday): Site Visit to the Grundfos Solar Pumping

The Study Team selected the target areas of field survey with due consideration to security aspects, low ratio of grid-connection in the vicinity, accessibility of the place within one day from Nairobi (considering short study period) and places with different characteristics determined during the first/second surveys.

Some villages selected were based on the proximity to the existing/planned grid and distribution of public facilities according to the data from MoE and REA. Security situation and road conditions were considered prior to finalization of the trip schedule. The Study Team conducted field survey of the current situation of public facilities and interview survey to village people. They surveyed the current situation of water wells and trading centres located near the villages.

1.2 Result of Field Surveys and Site Visits in Kenya

1.2.1 Site Visit to UNIDO Energy Kiosk (I)

1.2.1.1 Kibae Energy Kiosk

The Study Team visited the Kibae Energy Kiosk on April 18, 2009. The facility is located at 4 km east of Kerugoya town in Kirinyaga district, 150 km from Nairobi. It is located at latitude of 0° 28’ 27’’ south, longitude 37° 17’ 40’’ east and at altitude 1,581 m above sea level. Relevant information/data obtained during the visit are as follows:

- Kibae village has 1,000 households that benefit from the centre. About 300 of these households reside near the community power centre. The centre provides electricity using PV system and pico-hydro power generator. The centre is mainly operated by the “Kibae Self Help Group”, which has 132 members. Each of them pays a monthly membership fee of Ksh 100. The centre was opened in January 2008.
- The centre provides charging services for mobile phones, LED lanterns and automobile batteries. Furthermore, it offers computer training, internet connection, television and video hall services at its social hall, which is attached to the building. It also has facilities for manufacturing soap and juice.
- The centre offers charging services at Ksh 5 for mobile phones and Ksh 10 for LED lanterns. It is noted that the charging rates of the centre are cheaper that its nearby competitors.
- People can purchase a LED lantern for ten installment payments of Ksh 200. UNIDO

provides 100 LED lanterns to the centre. Half of these lanterns are donated to schools while the remaining are provided to the villagers. The lantern can work for 30 hours after 8 hours of charging. Considering the average use of 3-4 hours per day, charging will be required once a week.

- Several LED lanterns were returned because of the reduction of users who gets power from power distribution lines which are 3 km from the centre.
- The centre has three computers which the villagers can use for a rental fee of Ksh 1 per minute. Internet connection is also available with an additional payment of Ksh 0.5 per minute. These computers are connected to the internet through Safari.com, using USB broadband adapter.

1.2.1.2 Kamahuha Energy Kiosk

The Study Team also visited the Kamahuba Energy Kiosk on April 18, 2009, after visiting Kibae Energy Kiosk. It is located at latitude of 0° 50’ 51’’ south, longitude 37° 11’ 16’’ east and at an altitude of 1,353 m above sea level. Relevant information/data observed during the visit are as follows:

- Banana harvests in this region are sold to buyers from Nairobi. Previously, the yield was 30 tons/month. This is presently reduced to around 10 tons/month.
- There is no available irrigation water, which is essential for the people.
- The facility generates power through biogas using banana wastes like banana cane. It presently provides biogas to schools for cooking purposes.
- The facility was built using the Ksh 3,000,000 received from UNIDO and Ksh 750,000 from the community. UNIDO later spent an additional Ksh 300,000 for the improvement of the facility. The facility has a 10-kW diesel generator and a 10-kW gasoline generator. The generators will be used for other purposes in the near future.
- Power distribution line installed six months ago is 8 km away from the village. Hence, the village located at the kiosk is now connected to the power grid.

1.2.2 Site Visit to UNIDO Energy Kiosk (II)

1.2.2.1 Oloosho Oiborr Village (Potential Site for Energy Kiosk)

The Study Team visited Oloosho Oiborr Village on April 21, 2009. It is located at latitude 1° 24’ 45’’ south, longitude 36° 36’ 09’’ east and at an altitude of 1,767 m above sea level. The location is considered as potential site for a hybrid system of wind and solar power generation system. Animal husbandry and agriculture are the main economic activities in the region. Other relevant information/data obtained are as follows:

- Primary school, dispensary and community centre required electricity. Villagers have demanded electricity for cooling milk and charging of their mobile phones.
- People pay Ksh 2 for a jerrican at the water well. Additionally, animal keepers pay Ksh 500 every month for livestock water. About 2,000 households are using the water well and generally consume 100 liter/day of water. There is a plan to install wind power equipment

made in China funded by Australian Embassy.

- People mainly use kerosene lamps for lighting. They buy kerosene at Ksh 80 per liter. According to the interview of one villager, he said that he consumes 15 liters per month for all three rooms in his house. Mobile phone charging service is available at Ngong Town, which is 13 km away from the village. The charging fee for mobile phone is Ksh 20 per unit. Frequency of charging is every 2 or 3 days. Usually they go to the town by *matatu* (shared-taxi) which costs Ksh 140 round trip. Without such vehicle, they need to walk to the town for two or three hours particularly in daytime.
- The Oloosho Oiborr dispensary has 12 rooms including a consulting room, general ward and store room. The number is greater than that in Kenya. The dispensary had 1 or 1.5 kWp of PV panel, which was stolen. Refrigerator is run by LPG, which costs Ksh 2,800 per cylinder and lasts for 84 days. One clinical officer, one nurse and one security guard are assigned in the dispensary, which receives 600 to 1,200 patients per month. The number increases in June to August because of malaria and colds cases.
- The Oloosho Oiborr primary school has a nursery and standard 1-8 classes. The school conducts health class for the villagers during Wednesday and Friday afternoons (after the classes of lower grade pupils). It has nine teachers and classes are held from 8 am to 5 pm. Teachers are eager to conduct night classes if electricity is available. There is a small PV panel on the roof which does not work due to system failure. All students commute from the school to their residences (maximum 10 km away from the school).

After the school visit, the Study Team visited the wind power station of KenGen on Ngong Hill, which is located at latitude 1° 23’ 27’’ south, longitude 36° 38’ 15’’ east and at altitude 2,357 m above sea level. The operation of the station started in 1993. It has two units of 200 kW generators at present. Installation work for six units of 850 kW is on-going near the station. The Study Team was informed that considerable power generation is expected in November to January due to strong winds.

1.2.2.2 Mbuuni Energy Kiosk

The Study Team visited the Mbuuni Energy Kiosk on April 21, 2009, after visiting Oloosho Oiborr village. It is located at latitude 1° 29’ 26’’ south, longitude 37° 21’ 32’’ east and at an altitude of 1,385 m above sea level. It is 10 km west from Machakos town. Relevant information/data obtained during the visit are as follows:

- The kiosk has processing equipment for sunflower seed grown by a local women’s group and the equipment installation is supported by UNIDO. They intend to process jatropha and sunflower seed in other areas in the future.
- Sunflower grows naturally in the area, while maize, banana and beans are grown around the area.
- Sunflower oil is sold at Ksh 120 per liter. Since the oil has not been certified by the Kenyan Bureau of Standard, this has not been sold outside the village.
- About 0.6 liter of sunflower oil is produced from 1 kg of sunflower seed. Four liters of sunflower oil is consumed at an ordinary household monthly.

- UNIDO does not support salary payments for the staff of the facility. This is covered by the sales of sunflower oil.

1.2.3 Field Survey (I)

1.2.3.1 Moigutuo Village

The Study Team visited Moigutuo Village on April 23, 2009. It is located at latitude 0° 46’ 36’’ north, longitude 35° 48’ 32’’ east and at altitude 1,745 m above sea level. It is 40 km north of Kabarnet town in Baringo district, and 300 km from Nairobi. Its major economic activities are agriculture and livestock for domestic consumption.

- The area has a population of 12,000. It has 12 primary schools with 72 teachers, however the schools do not offer secondary education. After the community built two classrooms using their own funds, the government decided to provide support for building two additional classrooms.
- The dispensary in the village is funded by the district. However, it is very small with only two rooms, including two staff quarters. Presently, it has no staff and the community is recruiting new ones.
- Almost all the teachers have PV system in their residences, which they use to provide power for lighting, mobile phone charging and television. There are also around 100 households that have PV system in the area.
- Households without PV system use kerosene, candle or flash torch with dry cell batteries for lighting. It was reported that 60% of the household have mobile phones. Water is usually available for free at the river located 2 km from village. However, during the dry season, people go to other places, 5-6 km from the village, to collect water. People are aware about the KPLC grid extension plan.

1.2.3.2 Chemolingot Village

The Study Team visited Chemolingot Village on April 24, 2009. It is located at latitude 0° 59’ 6’’ north, longitude 35° 58’ 20’’ east and at an altitude of 895 m above sea level. It is about 65 km north of Marigat town in Baringo district, accessible through national road B4, and 300 km from Nairobi. The remaining 35 km road after Loruk village is unpaved.

- Power distribution line was installed in this village through political intervention. However no cable is still connected to the buildings.

1.2.3.3 Tangulbei Village

The team visited Tangulbei Village on April 24, 2009, after visiting Chemolingot Village. It is located at latitude 0° 48’ 1’’ north, longitude 36° 17’ 3’’ east and at an altitude of 1,200 m above sea level. It is 30 km west of Lurok in Baringo district. This is the biggest and central village of Tangulbei division. Its health centre receives patients from other villages located 40 km away. Major economic activities are agriculture and livestock for domestic consumption. Other observed information/data are as follows:

- Health centre and secondary school are located 2-3 km away from the village centre. However, water well is located at the centre of the village. Many villagers gathered near the water walls during the early hours of the evening, while the Study Team was conducting the site visit.
- Few households have PV system while others use kerosene for lighting. There are two mobile phone charging shops and most of the villagers frequent one of them. According to one shop owner, he started his business after receiving requests from many villagers and has not experience stiff competition with the other charging shop. The shop utilizes PV system for charging mobile phones. The owner brings home the PV panels every evening to keep it from being stolen.

1.2.3.4 Salabani Secondary School

The Study Team visited Salabani Secondary School on April 25, 2009. It is located at latitude 0° 32’ 40’’ north, longitude 36° 2’ 37’’ east and at altitude 989 m above sea level. It is about 15 km north of Marigat in Baringo district. Other information/data gathered are as follows:

- The school received the PV system in 2008 from MoE. It consists 16 units of 70 Wp panels and some other panels donated by a French NGO. The school uses the generated electricity for lighting its facilities including the dormitory, 21 inches colored television, mobile phone charging for teachers/staff and security lighting. There are no problems at present and it is working in good condition. The school also received a manual from the vendor of the system.
- The school has two buildings. One of these buildings, which has 14 panels installed, consist of the head teacher’s room, office, faculty room and some classrooms. The other building meanwhile, which has two panels installed, consist mainly of class rooms. Furthermore, there are other two buildings provided as dormitory.
- The school has 120 students. The male-female ratio is 50-50 and all students are boarding in the school.

1.2.4 Field Survey (II)

1.2.4.1 Olgulului Village

The Study Team visited the Olgulului Village on April 30, 2009. It is located at latitude 2° 35’ 51’’ south, longitude 36° 59’ 25’’ east and at altitude 1,191 m above sea level. It is 30 km south-west from Namanga, one of the important border towns to Tanzania in Kajiado district. The lands in the village are mostly owned by Maasai’s community whose main economic activity is animal husbandry. At the village, no trading centre exists and a few public facility and residences are scattered. The following are recorded information during the site visit.

- Adults own mobile phones and penetration ratio is around 80%. Mobile phones are mainly used for calling rather than SMS. It was reported that these are charged at Ksh 40 in the village.
- Since the village is located near the border to Tanzania, the mobile phones can be connected to Vodacom, (one of the Tanzanian networks) and not by Safaricom (Kenyan network).

Actually, while at the site, the Study Team member received SMS from Vodacom, which said, “Kalibu! Vodacom welcomes you to Tanzania, the land of Mt.Kilimanjaro!”. Subscribers of Safaricom can make calls via Vodacom’s network. However, the cost is four times that of Safaricom’s network.

- Installation work for the PV system started two weeks ago at the health centre with some of the cablings installed. The PV panel was not installed yet. A staff expects that sterilization using heat from kerosene can be replaced by electricity after PV system installation. Water from water walls contains too much salt so they sterilize equipment once a week to avoid damaging the sterilizing machine. The building used as staff quarter will be utilized for maternity services after installation of PV system. Although this is a malaria endemic area, no microscopes are available for examination of malaria virus.
- The health centre covers 30 km^2 and accommodates 15 to 20 patients per day. There are about 10 to 15 deliveries per month in the village. Massai people however prefer to deliver at their homes rather than at the hospital. Thus, only four babies per month are delivered in its health centre. In case of night deliveries, flash torches and kerosene lamps are used for lighting.
- People installed 5 km of water pipe from the water well. Elephants however kept on damaging the pipes as they are sensitive to the smell of water. Hence, people gave up in repairing the pipe. Presently, people obtain water from wells in private lands with the permission of the land owner.
- The primary school in the village has 360 students. Previously, the school operates a diesel generator. At present, PV system is installed by the NGO, African Medical Research Foundation, in 2008. Due to this, the school can hold night preparatory classes for Standards 6 to 8, from 7:30 pm to 9:30 pm.
- Water well is located at around 3 km from the health centre and primary school. It is located at latitude of 2° 36’ 24’’ south, longitude 36° 59’ 52’’ east and altitude 1,164 m above sea level. They operate a diesel generator and collect Ksh 10 per cattle and Ksh 5 per sheep and goat every month to cover fuel cost. Water for personal use is free of charge.
- There is a shop providing barber services at Ksh 30, shaving at Ksh 20 and mobile phone charging at Ksh 30. A private house of a school teacher has PV system for television and DVD player. He also offers mobile phone charging services to villagers.

1.2.4.2 A.I.C. Samaria Mission

The Study Team visited A.I.C. Samaria Mission on May 1, 2009. It is located at latitude 2° 31’ 3’’ south, longitude 36° 57’ 22’’ east and altitude 1,234 m above sea level. It is 30 km west of Namanga, a border town to Tanzania in Kajiado district, and 200 km from Nairobi. It is a Korean missionary facility and consists of a church, primary school, dispensary and water well. It seems that there are no private houses nearby. The following are other information regarding the site:

- It has 110 acres of land.
- The primary school has 250 students in standard 1 to 8, who are all boarding. The missionary plans to establish a secondary school soon, hence, higher electricity

consumption is expected after its establishment.

- The dispensary is supported by the district hospital in supplying medicines.
- The missionary presently operates a 10-kW diesel generator manufactured in 2004. It consumes four drums of fuels (800 liters) every month. It is usually operated for four hours per day. However it is sometimes operated for 12 hours per day during the dry season since more quantity of pumped water is required.

1.2.4.3 Lengism Village

The Study Team visited Lengism Village on May 1, 2009. It is located at latitude 2° 23’ 51’’ south, longitude 37° 12’ 53’’ east and at altitude 1,176 m above sea level. It is inhabited by Maasai’s community and located 20 km north of Namanga gate of the Amboseli National Park. There are several shops at the central village while the Lengism primary school is 1 km from said location. Maasai has usually big families. The village has 160 households with 560 to 575 population including those residing in small houses. Other collected information are as follows:

- A shop providing charging services has a PV system (purchased in Nairobi), 21-inch color television and lighting for bar. Charging fee for mobile phones is Ksh 20 and it has around 12 customers per day. It is also possible to charge rechargeable lantern for Ksh 30. .
- The village chief charges his mobile three times a week and has three extra batteries.
- The Lengism primary school has 560 students and offers standard 1 to 8 classes. It has a windmill to pump up water at a place slightly far from the school. Beside the school land is a missionary dispensary, which is not similar to the visited A.I.C. Samaria Mission. Said dispensary promised to offer medical services for Ksh 30 only. However, they are presently charging Ksh 100. Thus, the relationship between the missionary and community is very bad.
- The water well is sited 5 km from the village. (It is located at latitude 2° 24’ 01’’ south, longitude 37° 09’ 57’’ east and altitude 1,198 m above sea level) Water contains little salt. Although the well is equipped with a diesel generator, water could not be pumped due to its low underground level. The tank, weighing approximately 3 tons, is almost empty. Half of the installation cost is donated by 24 families from the village and the other half is funded by an NGO. Villagers pay Ksh 10 per month per cattle, at the end of every month. There is no charge for sheep, goat and personal usage.

1.2.4.4 A Primary School (on the route)

The team visited the site of the primary school on May 1, 2009. It is located at latitude 2° 22’ 52’’ south, longitude 37° 05’ 41’’ east and altitude 1,217 m above sea level. It is also a Maasai’s community and is 15 km north of Lengism village. Few residences were found around the school but no shops exist. Other surveyed information is as follows:

- People charge their mobile phones at a shop located 72 km from the village. They hitch in order to reach the town. Most of the villagers have mobile phones. Some have spare batteries, considering the difficulty to reach the town to avail of charging services.
- The monthly fee per head for drinking water of livestock is Ksh 10 in the rainy season and

Ksh 20 in the dry season.

1.2.4.5 Mailwa Village

The Study Team visited Mailwa Village on May 1, 2009. It is located at latitude 2° 19’ 44’’ south, longitude 36° 57’ 46’’ east and altitude 1,319 m above sea level. It is inhabited by Maasai’s community and located 40 km west of Lengism village. More than a dozen shops were observed along the road. Other observations are as follows:

- There are two shops involved in the mobile phone charging business.
- The dispensary in the village has six rooms, including an out-patient consulting room, medicine store and maternity room.

1.2.4.6 Ilpartimaro Village

The Study Team visited Ilpartimaro Village on May 2, 2009. It is located at latitude 2° 16’ 03’’ south, longitude 36° 44’ 06’’ east and at an altitude of 1,497 m above sea level. The following are other surveyed information:

- The primary school in the village has four buildings and conducts eight classes from standard 1 to 8. One of the buildings has a PV system where night preparatory classes are held from 7:00 pm to 9:00 pm. The voltage of its PV system is 12 V and installation work is efficient.
- Around 70% of households have mobile phones.

1.2.4.7 Meto Village

The Study Team visited the place on May 2, 2009. It is located 30 km south west of Ilpartimaro village and 300 m from the border to Tanzania. There is a mountain path to the Tanzanian side. It has a population of about 6,700. Other surveyed information/data are as follows:

- Dispensary in the village is located at latitude 2° 24’ 39’’ south, longitude 36° 32’ 58’’ east and at an altitude of 1,694 m above sea level. The NGO, AMREF, installed the PV system to the dispensary. However, the system capacity is small and can be used for lighting purposes only. Previously, refrigerators were run using LPG,. however, these refrigerators are not being used at present, as no LPG is supplied from the district offices. Since lighting is not enough for performing surgery at night, dry battery flash torches are utilized. The dispensary receives around 30 patients per day and some are from Tanzania. The staff expects that PV system can supply energy to the refrigerators and lights for the microscope, maternity ward and operation room. A staff is using one of the rooms in the dispensary and opens it in case of emergency. It is not allowed to use the PV system for mobile phone charging, as promised to the NGO which installed said system.
- This village is out of the service coverage for mobile phone networks. Users go on top of the hills near the village to access signals. However, only a few villagers own mobile phones. Fee for charging mobile phones is Ksh 40. Usually, they communicate with others outside the village using a 2-line wireless telecom installed at the dispensary and primary school.

- Kerosene can be purchased at Kajiado or Namanga, which are located 80 km from the village. It is also available at the village. However, it costs Ksh 40 for 300 mL, which is almost double the price at petrol stations along the national highway.
- Before a secondary school was established in the village, the nearest existing one was 100 km away.
- There exists a polytechnic school, which offers courses such as craftsmanship, secretarial, agriculture and mechanical. It is temporarily closed at present since it is constructing its new building. Students can enroll for a term of two and a half years after graduating from primary school. There are no courses that require high consumption of electricity.
- The primary school in the village is located at latitude 2° 24' 38'' south, longitude 36° 33' 18'' east and altitude 1,668 m above sea level. The school has 600 students and 13 teachers in standard 1 to 8. There are two streams from standard 1 to 4 due to the large number of students. The school has only two staff's quarters while other teachers stay at a rented private house. It also has a PV system and each classroom has three 10 W fluorescent lights.
- Staff's quarters are equipped with PV system, television, radio and light.
- Water is supplied from the Tanzanian side through a water pipeline.

1.2.5 Site Visit to Grundfos Solar Pumping

1.2.5.1 Musingini Village (Pilot Site for Grundfos Water Pumping System)

The Study Team visited Musingini Village on May 5, 2009. It is located at latitude 1° 01' 40'' south, longitude 37° 35' 42'' east and altitude 1,170 m above sea level.

- The water well has been manually operated since 2005. In March 2009, Grundfos, a famous pump system manufacturer, installed a PV pumping system with the water well in the village as a pilot site. The system applied a unique technology of Grundfos for pumping and variable speed motor.
- The unique characteristic of the facility is that Grundfos assumes responsibility for the maintenance and provides fee collection system (payment by M-PESA[42] and charging by token[43]). The operation itself is done by the community, and a warden is paid by the community (Ksh 3,000 per month).
- The previous cost for water is Ksh 1 for a jerry can when the well used to be pumped manually. Its cost has now increased to Ksh 2. In the dry season, the well serves more than 100 customers per day, because of big demands of water for livestock. Some customers carry four drums (800 liters) of water at a time using a small dolly pulled by cattle or

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42 M-PESA is a money transfer system using mobile phone provided by Safaricom, which is largest mobile phone carrier in Kenya. A user can send money anytime as long as there is balance by operation of mobile phone and user can deposit cash as balance at agent after registration. Recipient can receive cash at agent of Safaricom so M-PESA is quite common as a money transfer method especially in the rural areas without a bank. In other areas likewise, some people use M-PESA to avoid carrying large amounts of money. All the required programs are already installed on the SIM for Safaricom, therefore the subscriber of Safaricom can use the system after registration and can deposit money through the Safaricom agent. PESA means "Cash" in Kiswahili.

43 The balance is managed through a membership ID recorded on the token at Grundfos side. After the user holds the token over the terminal, water is dispensed and the balance is deducted based on the quantity of water that the user gets. Terminal and server in Grundfos communicate through Safaricom mobile network. The token was distributed to the community when the system was installed at the water well.

bicycle.

- System installation cost was Ksh 3 million which are all paid by Grundfos, which is also responsible for the maintenance. At the same time, community pays Ksh 600 (water sales of 300 jerry cans) per day to Grundfos.
- The community suffers from losses during rainy season since water sales is quite low. However these losses are completely recovered during the dry season. The profit becomes the income of the community. The warden need not manage the account while Grundfos presents its data of sales and profit on a monthly basis.

1.2.5.2 Musingini Primary School

The team visited Musingini Primary School on May 5, 2009. It is located at latitude 1° 01' 32'' south, longitude 37° 35' 55'' east and at an altitude of 1,175 m above sea level.

- The school has 322 students and nine classes from nursery to Standard 8.
- There is no electricity supply, and hence, there are no night preparatory classes.

1.2.5.3 Musingini Secondary School

The team visited Musingini Secondary School on May 5, 2009. It is located at latitude 1° 01' 28'' south, longitude 37° 35' 51'' east and at an altitude of 1,180 m above sea level. The following are other surveyed information:

- The school was established in 2007.
- Faculty and students are hopeful that the science room and laboratory will be electrified.

Chapter 2 Field Surveys and Site Visits in Uganda

2.1 Schedule of Field Surveys and Site Visits in Uganda

The Study Team conducted field surveys and site visits for a duration of ten days, as follows:

- May 20 (Wednesday) to May 23 (Saturday): Field Survey (I)
- May 27 (Wednesday): Field Survey (II)
- May 28 (Thursday) to May 30 (Saturday): Site Visit to CREEC[44] PV System Installation Pilot Site Visit (I) and Field Survey (III)
- June 3 (Wednesday): Site Visit to CREEC PV System Installation Pilot Site (II)
- June 7 (Sunday): Site Visit to NIDA[45] Charging Business

The Study Team selected the target areas of field survey with due consideration to accessibility of the place within one day from Kampala (considering the short study period) and expediting visits to various places with different characteristics.

Some villages were selected based on their proximity to the existing/planned grid and distribution of public facilities according to the data from REA. Security situation and road conditions were considered prior to finalization of the trip schedule. The Study Team conducted field survey of the current situation of public facilities and interview survey to villagers. They surveyed the current situation of water wells and trading centre located near the villages.

2.2 Results of Field Surveys and Site Visits in Uganda

2.2.1 Field Survey (I)

2.2.1.1 Solar Equipment Supplier (Solar Power Agency (U) Ltd.)

The team visited the Solar Equipment Supplier on May 20, 2009. It is located along Republic Street, the main street of Mbale City. The following are relevant information surveyed:

- The shop provides PV panels, inverters, bulbs, installation works and after service supports.
- Some of the electrified households also use PV system because power from the grid is unstable (frequent black outs occur) and it is expensive. A family owner pays Ush 150,000 every month for using television, washing machine and lighting. The owner said that one household pays about Ush 50,000 every month to have power for only five bulbs.
- The shop offers an original loan scheme for customers. The scheme involves 50% initial deposit and 50% installment payments for 3 month without interest. The owner said that the risk for the shop is not so high since it will uninstall the PV panels if payment is not given as agreed. It is difficult to use bank loans due to high interest rates and cumbersome procedures.
- The knowledge of village people about the PV system is limited.

[44] Centre for Research in Energy and Energy Conservation, under the Faculty of Technology, Makerere University, Uganda
[45] Nkoola Institutional Development Associates, Ltd.

2.2.1.2 Namawanga Health Centre II

The Study Team visited Namawanga Health Centre II on May 21, 2009. It is located in Bukinde sub-county, Mbale district. It is located at latitude 0° 52’ 29’’ north, longitude 34° 11’ 40’’ east and altitude 1,240 m above sea level. Other surveyed information/data are as follows:

- The health centre has a total of ten staff, including a nurse, midwife and a nurse assistant
- PV system was installed in 2006 by the Ugandan government project, “Solar for Africa”.
- Only two out of its eight bulbs are working since it has no budget to buy replacements.
- The system used to work for longer hours. Presently, it is only sufficient for four hours per day.
- Power distribution lines were installed near the health centre during the presidential and national parliament elections in 2006. However, there is no power supply as of date.
- Refrigerator for vaccines is run using LPG.
- Some staffs have mobile phones and take them for charging to a trading centre 3 km away. Charging fee is Ush 500. One of staff reported that she charges her mobile phone every four days. It was also reported that almost all households have a mobile phone.

2.2.1.3 Lwangoli Health Centre III

The team visited Lwangoli Health Centre III on May 21, 2009. It is located in Busoba sub-county, Mbale district. It is located at latitude 0° 57’ 54’’ north, longitude 34° 08’ 45’’ east and at an altitude of 1,142 m above sea level. Surveyed information/data are as follows:

- The health centre has a total of 11 staff.
- Power distribution line was set up near the health centre in 2006. Some houses near the centre got connected. However, the health centre itself did not avail of the connection due to lack of budget from the district and there are no plans yet to connect.
- PV system was installed in 2006. The system consists of one panel, two batteries and ten bulbs, of which only five are in working condition. These five bulbs are working well from 6 pm to 7 am. Kerosene lamp is hardly used at the health centre.
- Security light was stolen. It seems that this will be sold to other places.
- Refrigerator for vaccines is run by LPG. It can work for one month using one cylinder. It is, however, troublesome to bring old cylinders to the district office for replacements.
- Only two out of the eight existing bulbs are working due to lack of budget to buy replacements.
- Staff’s mobile phones are charged at a trading centre located 11 km away from the health centre. Charging fee is Ush 500.
- A household using four bulbs and a radio spend Ush 30,000 for grid electricity.

2.2.1.4 Sira Health Centre III

The Study Team visited Sira Health Centre III on May 21, 2009. The centre is in Bungokho sub-county, Mbale district. It is located at latitude 0° 59’ 49’’ north, longitude 34° 08’ 32’’ east and at altitude 1,152 m above sea level. Surveyed information/data are as follows:

- The centre has a total of 13 staff.
- The health centre provides only prescriptions, but not medicines. Patients have to buy the prescribed medicine at a drug store.
- It receives 80 to 100 patients every day and half of these came for malaria treatment during the time that it provided medicines. Presently, it receives only 10 to 20 patients per day. It offers services to 600 residents of six villages.
- PV system was installed in 2006. The system consists of two panels, two batteries and nine bulbs, although only four are in working condition. The PV system previously did not work due to a short circuit of lines near the charge controller, but is now temporarily working.
- Kerosene lamps are used if lighting is not enough. Kerosene is available at Mbale town, 13 km away from the health centre and costs Ush 1,700 per liter. Round trip transportation cost to the town is Ush 4,000. Staff members charge their mobile phones at Mbale town for Ush 500. More than half of the staff own mobile phones.
- Refrigerator for vaccines is run using LPG. The refrigerator was donated by UNICEF.
- Villagers can get water at a well near the village.
- The main lighting source of villagers is from kerosene lamps. A staff of the health centre spends Ush 9,000 per month for the kerosene.

2.2.1.5 St. Clare Girl's High School

The team visited St. Clare Girl's High School on May 21, 2009. It is located in Budaka Township, Budaka district. It is located at latitude 1° 00' 46'' north, longitude 33° 56' 50'' east and at an altitude of 1,128 m above sea level. Surveyed information/data are as follows:

- This boarding school offers O level (Senior 1-4) and A level (Senior 5-6) classes. It has 250 students and tuition fee for one term (3 months) is Ush 260,000.
- The school is connected to the grid. However, power is not reliable as it once experienced black out for two weeks. Because of this, the school installed a PV system with two batteries (100 Ah each) and an inverter (600 W).
- There are nine staff's quarters and each has one 12 V DC bulb. A television and a DVD player are provided at the head teacher's quarter. There are two bulbs (2 of 10 W) in each classroom and dormitory.
- There is a computer classroom. There is a plan to supply power to more than 60 computers using the PV system.

2.2.1.6 St. Clare Girl's Day and Boarding Primary School

The team visited St. Clare Girl's Day and Boarding Primary School on May 21, 2009. It is located at latitude 1° 00' 24'' north, longitude 33° 57' 17'' east and at altitude 1,135 m above sea level. Other collected information/data are as follows:

- The school has 1,020 students in primary 1 to 7. It has a maximum of three streams per grade with 50 to 60 students per class. School tuition fee for a term (3 months) is Ush 250,000 for primary 1 to 4 and Ush 270,000 for primary 5 to 7.
- Capacity of power supplied from the grid is not enough with long duration black outs

sometimes occurring. Additionally, the grid electricity cost of Ush 200,000 per month is so expensive.

- The school installed a PV system in March 2009 for lighting purposes. The system has two batteries (2 of 100 Ah) and eight bulbs. The lights are used from 7 pm to midnight for night preparatory class, and from 5 am to 6 am for morning preparatory class. Electricity is also used during leisure hours at the dormitory. The school employed a technician to manage the PV system.
- There are 25 computers in the school.

2.2.1.7 St. Anthony Boys Primary School

The team visited St. Anthony Boys Primary School on May 21, 2009. It is a missionary school located at latitude 1° 00’ 33’’ north, longitude 33° 57’ 15’’ east and altitude 1,135 m above sea level. Other collected information/data are as follows:

- No staff was available when the team visited the school. Therefore, the vendor who installed the PV system explained the system briefly to the Study Team.
- The system was installed in March 2009 and consists of 130 Wp panel, 200 Ah battery and 12 bulbs. Television and radio are also used at the school.

2.2.1.8 St. Paul Secondary School

The Study Team visited St. Paul Secondary School on May 22, 2009. It is located in Kabelekeke village, Pallisa district. It is located at latitude 1° 11’ 07’’ north, longitude 33° 55’ 33’’ east and at an altitude of 1,138 m above sea level. Related surveyed information/data are as follows:

- St. Paul Secondary School is a day and boarding school offering three classes from Senior 1 to 3. It plans to offer Senior 4 from next year. The school has 197 students, including 70 females. Almost all the students reside locally. Its tuition fee for a term (3 months) is Ush 120,000 for boarding students and Ush 30,000 for day students.
- The school has 12 teachers and six other staff.
- It is not connected to the power grid but has electricity through a solar PV system with 85 Wp panel, three 100 Ah batteries, and a regulator that has options for operating radios and charging mobile phones. It was installed in March 2009 using the proprietor’s own funds. A 33 kV transmission line crosses the land of the school.
- Power is provided for nine bulbs, a black and white television, a radio, charging mobile phones of staff, and its neighborhood (the school was established through the support of its neighborhood). Ten mobiles are charged per day.
- Charge controller has outlets for 3V/6V/9V/12V/USB (5V) DC. Mobile phones are charged using 6V DC.
- The school has solar lamps with their own specific panels.
- Lights are on from 7 pm to 6 am in only one block. There are plans to install another system at another block and the main gate.
- The people near the school use kerosene lamps to light their homes. Cost of kerosene is Ush

2,500 per liter, bought from a trading centre which is 200 meters away from the school

- The major source of income for the surrounding population is agriculture.
- Apart from the traditional subjects, the school also offers courses on weaving, tailoring, poultry raising and home economics.

2.2.1.9 Jonathan Memorial College

The team visited Jonathan Memorial College on May 22, 2009. The college is located in Kasiebai village, Butebo sub-county, Pallisa district. It is located at latitude 1° 13’ 55’’ north, longitude 33° 55’ 02’’ east and at an altitude of 1,071 m above sea level.

- This mixed day and boarding secondary school is owned by Hon. Steven Mallinga, Uganda’s Minister of Health. It was established in February 2009 with Senior 1 to 3 and 5. It has 219 students, including 127 boarders. Tuition fee per term (3 months) is Ush 242,000 for boarders and Ush 112,000 for day students.
- The school is not connected to a power grid but utilizes solar system with four 100 Ah batteries, and three panels. There are also plans to install seven more systems and separate system to supply power to a 3,000-liter water pump
- The system is used to light nine bulbs, provide power to computers, printer, radio, television, and for charging mobile phones. No sophisticated gadgets are used during the rainy season
- The system in the boys’ section had been tampered and was provided with a temporary reconnection.
- The school also has six rechargeable lamps for emergency use.
- People in the village informed that around 60% of households own mobile phones.
- Mobile phone charging is available at the residence of the founder.
- The nearest trading centre, 3 km away from the school, is connected to the grid.

2.2.1.10 Residence of the Health Minister (Hon. Steven Mallinga)

The team visited the residence of the Health Minister on May 22, 2009. It is located at latitude 1° 14’ 06’’ north, longitude 33° 55’ 09’’ east and at an altitude of 1,078 m above sea level.

- It has a powerful PV system consisting of 12 batteries of 200 Ah each, about 20 panels of around 85 Wp and triple light inverters. The year of the PV system installation is 1998.
- It is used to light the entire home, provide power for the television, radio, computer and printer, flat iron, refrigerator and charge mobile phones and lamps.
- There is a separate PV system used to charge mobile phones for the surrounding communities, at no fee. Around 15 people per day visit the place to charge mobile phones.

2.2.1.11 Butebo Health Centre IV

The team visited Butebo Health Centre IV on May 22, 2009. It is located in Butebo sub-county, Pallisa district. It is located at latitude 1° 11’ 56’’ north, longitude 33° 55’ 10’’ east and at altitude 1,124 m above sea level. The following are the obtained information regarding the centre:

- The health centre is connected to the grid but since it was unstable, a PV system with 15 panels was installed in two phases, in 2002 and in January 2009. The old panels are used to supply power for the refrigerator for storing blood while the new system was intended to light 20 bulbs from 7 pm to 7 am. The security lights are connected to the power grid.
- It receives about 180 out-patients per day from four parishes. It gets reference cases from all the small health centres and immunizes about 120 children per day.
- The vaccination refrigerator operates using a 3.5-kg gas cylinder donated by UNEPI.
- It has one big generator which was brought in with a fault and two small ones used to supply power sockets when there is no power from the grid.
- The health centre is manned by 26 staff, who use kerosene lamps bought from the trading centre. Kerosene costs Ush 2,100 to 2,200 per liter.
- Lowest monthly salary of health centre staff is Ush 190,000. No information was provided to the team with regards to the highest salary.

2.2.1.12 Kagumu Health Centre III

The team visited Kagumu Health Centre III on May 22, 2009. It is within the trading centre of Kagumu sub-county, Pallisa district. It is located at latitude of 1° 06’ 11’’ north, longitude 33° 51’ 49’’ east and at altitude 1,100 m above sea level. The health centre is managed by a Community Based Organization (CBO) called Kagumu Development Organization (KADO) with 612 members and 36 groups covering four sub-counties. The CBO is supported by a poverty action fund, from commissions earned by linking farmers to markets, members’ subscription fees and donor’s funds through proposal writing. The following are related surveyed information:

- The health centre is funded by the district and KADO. It receives about 50 to 60 patients a day and is manned by six staff.
- It is 8 km from the grid line but utilizes a solar system for power, consisting of three panels, two sealed batteries and two inverters, of which one was faulty. The system is used to supply power to 12 bulbs from 7 pm to 6 am, a computer with a 17 inch CRT monitor, ink jet printer and charging mobile phones for staff. Since the capacity is limited, other lights are turned off and start-up the generator before using the computer and printer.
- Extra bulb is kept as immediate replacement, if needed.
- There is no refrigerator for storing vaccines. They need to go by bicycle twice a week (Tuesday and Saturday) to health centre IV, which is 8 km away, to receive vaccine. The CBO has plans to acquire another system to supply power to a vaccination refrigerator.
- It uses kerosene and rechargeable lamps to supplement the solar lights.
- The surrounding communities charge mobile phones from the nearby trading centres and MTN (the largest mobile carrier in Uganda) mast which is about 50 meters from the health centre.
- About 80% of households are into farming.
- People would be willing to invest in a PV system since hydro power is expensive (Ush 6 million to extend the grid power from a distance of 300 m). However, they are not informed

or aware of PV system.

2.2.1.13 Phone Charging Service Shop, Bulange

The Study Team visited a phone charging service shop at Bulange on May 22, 2009. It is situated in the trading centre of Bulange sub-county, Namutumba district. It lies at latitude 0° 44' 10'' north, longitude 33° 41' 58'' east and is at an altitude of 1,087 m above sea level. The village is located 10 km from grid end.

- The owner started the business in 2007. It is open from 7 am to 10 pm, and accommodates about 30 clients a day. Charging fee is Ush 500 per phone and now serving a community of about 3,000 people. Sales of air time (prepaid card for mobile) are supplemental income for the owner.
- The shop utilizes solar system for power, which consist of 65 Wp panel, two batteries and an inverter.
- The concept of the business was learnt from Iganga town. A PV system is now used for charging mobiles, lighting two bulbs and provide power to television and radio. It was also used to charge lamps. The business competitors are those who utilize generators.
- The owner initiated the same business in Bunambutye.
- There is a plan to expand the system to supply power for refrigerators for soft drinks, and video hall.
- The owner is building a house from the proceeds of the business and intends to transfer house after completion. The money previously saved in a bank has been spent for the owner's housing project. The total investment value of said house is Ksh 3 million.

2.2.1.14. A SHS User House

The Study Team visited a SHS User House on May 23, 2009. It is located at latitude 1° 07' 46'' north, longitude 34° 09' 04'' east and at altitude 1,141 m above sea level. Its location is 3 km away from the grid end.

- It is powered by a solar system which was installed in May 2008 at a cost of Ush 1.9 million. The system comprises of a battery, one panel (85 Wp) and an inverter. The system is used for lighting six bulbs and charging mobile phones. The system has never experienced any problem apart from one of the bulbs which blew out.
- The solar systems were procured by paying 50% of the total cost while the remaining amount through three monthly installment payments with no interest. (Usually installment payment requires 1.5% to 2.5% interest rate per month.)
- The idea for installing the solar system was taken from radio advertisements, promotional campaigns from the suppliers and from an owner of the same system in Nakaloke Trading Centre.
- The households' source of income is cattle business and crop cultivation like cassava, maize, *matoke* (banana), potato and beans.
- Many villagers are interested in acquiring the solar systems but lack the initial capital.
- Most of the villagers use kerosene lamps and candles which are harmful to health.

- Water is obtained 0.5 km away from a water spring.

2.2.2 Field Survey (II)

2.2.2.1 Battery Charging Service Shop, Kiyindi

The Study Team visited a battery charging service shop in Kiyindi on May 27, 2009. It is located 90 km east from Kampala at latitude of 0° 16' 42'' north, longitude 33° 08' 52'' east and at an altitude of 1,145 m above sea level. It is one of landing sites to Buvuma Island in Mukono district. Other collected information/data are as follows:

- Charging fee depends on the capacity, i.e., Ush 1,000 (10 Ah), Ush 2,500 (50 Ah to 75 Ah), Ush 3,000 (100 Ah to 120 Ah) and Ush 4,000 (200 Ah). Duration for charging is 12 hours.
- The shop caters to around 10 to 20 customers per day. They are mainly from Buvuma Island and own batteries for domestic use.
- The shop charges batteries by connecting to the power grid and pays Ush 120,000160,000 to the power company (UMEME).
- The owner invested Ush 2.5 Million for the shop.
- Batteries are connected in series. Therefore charging operation could not start if the number of batteries connected is not enough. (For this purpose, the owner connects his extra batteries.)

2.2.2.2 Phone Charging Service Shop, Kyanama Landing Site

The Study Team visited a phone charging service shop in Kyanama landing site on May 27, 2009. It takes 1 hr 20 min from Kiyindi to reach the site. It is located at latitude 0° 14' 08'' north, longitude 33° 14' 33'' east and at altitude 1,129 m above sea level. It is in Busamizi sub-county, Mukono district. The village has 200 households and major economic activities include fishery, timber production and farming. Other related surveyed information/data are as follows:

- The owner has a PV system with a panel of 80 Wp and a battery of 100 Ah. Said system was bought for Ush 1,230,000 in 2007, from Sebagala and Sons, Limited in Kampala, through the help of a relative.
- The system is used to light two bulbs, and for charging mobile phones. It was also used to supply power to a television until the power has weakened.
- The system charges about five to ten phones per day for Ush 500.
- There are other charging services at a video hall and barber shop, which are using generators or batteries charged at Kiyindi.
- In the village, major lighting source is kerosene lamp. Kerosene costs Ush 2,300 per liter. Most villagers prefer to buy 100 to 300 mL for one- or two-day consumption. Usage hour of the lamp is limited, i.e., 7 pm to 8:30 pm.
- People informed that around 30% of adults in the village own mobile phones
- The team was asked by the villagers regarding where the PV system components could be purchased, and how it can be installed.

2.2.2.3 Kitamilo Health Centre IV

The Study Team visited Kitamilo Health Centre IV on May 27, 2009. It takes 1 hr 50 min from Kiyindi to reach the site. It is located at latitude 0° 11’ 48’’ north, longitude 33° 16’ 22’’ east and at an altitude of 1,150 m above sea level. Its location is in Nailambi sub-county, Mukono district. Surveyed data are as follows:

- It uses a PV system for lighting, charging phones and supplying power to two vaccination refrigerators. The system was installed in 2007 by the district. The centre also has rechargeable AC lamps which are charged from the grid at the main land. In case of shortage of such lamps, kerosene lamps are used as alternative. Apart from this, there is another PV system for the maternity ward.
- The staff residence uses kerosene and rechargeable lamps.
- The people close to the health centre charge mobile phones at a nearby church, for a fee of Ush 500 per phone.
- There are six health centres III and eight health centres II in the island. However this is the only categorized health centre IV in the area. It receives 30 to 100 patients per day from the entire island. In case of emergency, speed boats owned by the health centre is available. However fuel cost (20 liters for one way) is paid by the patient. For ordinary boat, the fare is Ush 6,000 one way.
- Kerosene is sold at Ush 2,600/liter in the island.

2.2.2.4 Nailambi Sub-county Headquarters

The Study Team visited Nailambi sub-county headquarters on May 27, 2009. The site takes 15 min to reach from Kitamilo. It is located at latitude 0° 10’ 13’’ north, longitude 33° 17’ 31’’ east and at altitude 1,193 m above sea level. Surveyed data are as follows:

- The intention for visiting the place was mainly to inquire where to find Busabala Village on Buvuma Island. It was learnt that said village is off Entebbe Road and not on Buvuma Island.
- The chief of the sub-county explained that there are only a few who own PV systems in the island. He also never heard about the pilot project of PV system by Makerere University.
- The chief has a PV system in his residence.
- He informed the team that residents close to the headquarters charge their mobile phones at a nearby church, for a fee of Ush 500 per phone.

2.2.3 Visit to the CREEC PV System Installation Pilot Site (I) and Field Survey (III)

2.2.3.1 Busabala Village

The Study Team visited Busabala Village on May 28, 2009. It takes 1 hr from Kampala to reach the village. It is located at latitude 0° 12’ 31’’ north, longitude 32° 37’ 11’’ east and at an altitude of 1,139 m above sea level. It is in Makindye Sabagabo Sub-county, Wakiso district. This is one of the pilot sites for PV system installation by CREEC. Other information/data are as follows:

- The village chief purchased a PV system in 2006, consisting of two panels, a battery of 100 Ah and five lamps, from an Austrian firm Elwin. It costs Ush 687,000 paid in small monthly installments for over a year. Firstly, it was recommended that he install the system to the church. However, he requested it to be installed in the office and store of the Department of Fishery, which is used as village office and store for the community. Three out of the five lamps he received blew out. The loan was paid using the earnings from the phone charging services. At the time of the site visit to the village, he had already paid the loan. He still has an extra profit of Ush 100,000 which will be used for community services.
- He also received one small solar phone charging system, donated by Makerere Research Team in May 2008.
- He charges two to three phones per day for Ush 200-300 each.
- This village has a population of 400. Among these, about 150 own mobile phones. The main sources of income in the village are fishing, farming and retail shops.
- The systems are not used to supply power for security lights.
- Rechargeable lamps are used for lighting. Other villagers use local kerosene candles and buy the kerosene from a petrol station for 2,300 per liter. The grid is 7 km away from the village.
- The village chief believes that he can accommodate more clients if he has a bigger system.
- Water for human consumption and livestock is obtained from the lake.
- There were those selling fish during the site visit. Ice for cooling fishes is bought from Kampala.

2.2.3.2 Bukakata Sub-county Office

The Study Team visited Bukakata Sub-county Office on May 28, 2009. It is located at latitude 0° 17’ 10’’ south, longitude 32° 0’ 42’’ east and at altitude 1,140 m above sea level. It is situated in Masaka district. A power distribution line project, funded through Japanese grant aid, has been implemented along the road from Masaka to Bukakata. The total population of the sub-county is 13,000, while that in Kabasese village is 7,000. Surveyed information/data are as follows:

- Although the headquarters is near a power line donated by Government of Japan, it had not been connected yet to the hydro power system. The power line is intended to supply power to a fish factory at the landing site. The office does not know when it will be connected to the grid.
- The office has a PV system, which was provided by the Uganda Bureau of Statistics (UBoS) in April 2007 to operate computers. Encoded data will be stored on USB flash memory, and then sent to Masaka.
- The staff members have mobile phones which they charge at Luvule, 30 km away from the headquarters, for a cost of Ush 500. Transportation cost to Luvule is Ush 3,000 one way. Those who own batteries travel to Masaka or Luvule for charging at a total cost of Ush 5,000.
- About 80% of the villagers have mobile phones.

- There is a charging service centre nearby but only known costumers can avail of the services.
- Villagers obtain water from the lake, which is one km away. There are water wells nearby, about one to two km away. However, its water quality is not reliable.
- The nearest health centre IV, Kiyumba, is 35 km away from Bukakata. Bukakata Health Centre III, which is located next to the office, does not have a PV system.
- The main economic activities are fishing, lumbering, and selling charcoal.
- The fishing business is getting better because the fishermen have been educated on proper fishing methods and encouraged to save earnings in banks.
- There are only two houses with PV systems. Most of the villagers use kerosene lamps. Kerosene is available for Ush 2,500/liter. The lamps can work for three hours using 200 mL of kerosene.

2.2.3.3 Phone Charging Shop, Kabasese Village

The Study Team visited a phone charging shop in Kabesese Village on May 28, 2009. The village is in Bukakata sub-county office, Masaka district. Other surveyed information/data are as follows:

- The PV system available consists of one panel, a battery and an inverter.
- The owner uses the system to charge people’s phones for Ush 500.
- About 16 phones are charged in a day.

2.2.3.4 Byakabanda Health Centre III

The Study Team visited Byakabanda Health Centre III on May 29, 2009. Information/data collected are as follows:

- The health centre is not connected to a solar or hydro power system
- Kerosene lamps are used for cases handled at night.
- Staff members charge phones at Rakai town for Ush 500, plus transportation cost of Ush 1000 one way.
- LPG is used to run the vaccine refrigerator.

2.2.3.5 Kibaale Secondary School

The Study Team visited Kibaale Secondary School on May 29, 2009. It is located at latitude 0° 46’ 57’’ south, longitude 31° 20’ 37’’ east and at an altitude of 1,227 m above sea level. It is situated in Kyalurangira sub-county, Rakai district. Relevant data are as follows:

- This day school has a hostel to accommodate those who are far from the area. It offers Senior 1 to 4 classes with 403 students. Some grades are divided into two streams with six classes. It has 16 teachers and 10 support staff. The school rents houses in the trading centre as accommodation for the teachers and staff.
- The school got connected to a PV system in September 2006 from MoE, through funding from GTZ. It consists of three 200 Ah batteries, inverter and six panels. The parents of

students paid for the cost of wiring and bulbs.

- The system is used to light 14 bulbs and phone charging. The system was designed to light 45 bulbs, but since it weakened, it could not light even just 14 bulbs overnight. The suppliers have failed to respond to their complaints about the system and there are no technicians nearby who can provide help. The system was badly wired and there is nobody with the right technical skills to look after it.
- They used the PV system to power a television but this has stopped since the power weakened. It was observed that whenever a television was switched on, the lights go off.
- There is a plan to offer computer courses and hire a teacher. No computers however are available.
- People near the school go the trading centre to have their phones charged for Ush 500 per phone.
- The staff members use kerosene lamps, candles and even phones for lighting purposes. Kerosene is bought from the trading centre at Ush 2,100 per liter

2.2.3.6 Kibaale Health Centre II

The Study Team visited Kibaale Health Centre II on May 29, 2009. It is located at latitude 0° 46’ 42’’ south, longitude 31° 20’ 40’’ east and at altitude 1,217 m above sea level. It is in Kyalurangira sub-county, Rakai district.

- The health centre receives 50-60 patients a day and the most reported case is malaria (50% of the cases). Others are flu and wounds. It also receives 25-30 expecting women per day.
- There is no PV system and there are no known plans related to extending the power to the health centre. The health centre uses kerosene lamps at night using 0.5 liters kerosene a day, which is bought from the trading centre. The centre has two lamps and torches.
- It has a vaccination refrigerator powered by LPG.
- There are five staffs that use kerosene lamps at their homes.
- The staff charges their phones at Rakai town once a week, for a fee of Ush 500 per phone.

2.2.3.7 Buyamba Secondary School

The Study Team visited Buyamba Secondary School on May 29, 2009. It is located at latitude of 0° 39’ 24’’ south, longitude 31° 23’ 30’’ east and at a altitude of 1,286 m above sea level. It is in Dwanilo sub-county, Rakai district. Other surveyed information are as follows:

- This day school has a hostel for those who are far from the school. It offers O level classes only from Senior 1 to 4, with a population of 360 students. Senior 3 has two streams. It has 16 teachers and 6 support staff.
- The school has a PV system installed ten years ago, which was donated by a church and comprises 1 battery of 200 Ah, 2 panels of 30 Wp. The system is only used for lighting six bulbs but has weakened.
- The staff stopped charging mobile phone using PV system since it weakened. They instead go the trading centre, about 2 km from the school, to avail of the charging services at Ush 500 per phone.

- The hostels use kerosene lamps and consume a liter of kerosene when solar power is available and two to three liters when solar power is weak. Kerosene is bought from the trading centre at a cost of Ush 2,000. Teachers also use kerosene lamps at their homes.
- The first battery got a fault while another was purchased in October 2008.
- The main economic activity of the residents near the school is agriculture (coffee, *matoke*, beans, maize, and animal husbandry (cows and goats).
- Most adults own mobile phones according to interviews. There are around ten shops engaged in phone charging business.
- A diesel generator is available for pumping up water at latitude 0° 39’ 08’’ south, longitude 31° 23’ 01’’ east and at a altitude of 1,243 m above sea level. However, it has already failed and is no longer working. Villagers therefore get water from the river.

2.2.3.8 Phone Charging Service Shops, Buyamba

A trading centre is located at latitude of 0° 39’ 19’’ south and longitude 31° 23’ 15’’ east. On May 29, 2009, the Study Team visited two barber shops doing charging business in said trading centre. Observed information/data are as follows:

- One of the shops has a solar system comprised of one 100 Ah battery, two panels and an inverter, which cost Ush 2.5 million in total. The owner utilizes it for services such as haircutting, charging phones and lighting 2 bulbs. He charges 40 phones per day and most of his customers are those who visit the shop for haircut.
- Another shop acquired a PV system in 2007. Said system is used for services such as haircutting, charging phones and lighting. The owner also has a generator which he uses to power a video set. He intends to expand his business to include secretarial services. However, the required capital is still insufficient.
- According to local staff hired by the Study Team, the cost per haircut is Ush 1,000 and the frequency for availing said service is once a week.

2.2.3.9 Solar Equipments Supplier (Naco Solar Ltd.)

The Study Team visited Naco Solar Ltd. on May 30, 2009. It is located at latitude of 0° 20’ 29’’ south and longitude 31° 44’ 16’’ east. Its facility is in a trading centre in Masaka. Other information regarding the supplier is as follows:

- The shop sells a set of solar home system including 50 Wp PV panel, 40 Ah battery, inverter and six bulbs, for Ush 1.3 Million, excluding transportation and installation costs. It also sells other panels, batteries, bulbs and other related items bought from Ultra Solar in Kampala.
- The owner is a graduate of secondary school and worked under engineer of Shell Foundation, Holland in 2006. It was during that time she learnt about the PV system.

2.2.3.10 Kawanda Secondary School (China-Uganda Friendship School)

The Study Team visited Kawanda Secondary School on May 30, 2009. It is located at latitude 0° 2’ 22’’ south, longitude 31° 29’ 38’’ east and at an altitude of 1,231 m above sea level. It is in

Lugusulu sub-county, Sembabule district. A friend of the local staff hired by the Study Team in Sembable informed that there is a school built under a Japanese support, Said school was actually found to be constructed through the supported of China. Other information is as follows:

- The school has four new blocks. Two of which consist a class room (3 class room/block), one consist of a library, computer class room and laboratory, and one is administrative block. The blocks are provided with large window, which is completely different from other ordinary schools in Uganda. There are no computers in its computer class room. New blocks are not used at the time of inspection.
- There are 12 fluorescent lamps, assumed to be 20W, for each classroom. However the grid is 8 km away from the school and there is no schedule yet as to when it will be extended to the school. A staff said that a diesel generator will be installed. There are, however, doubts on sustainability especially for fuel supply and cost.

2.2.3.11 Ntuusi Health Centre IV

The Study Team visited the Ntuusi Health Centre IV on May 30, 2009. It is located at latitude 0° 03' 06'' north, longitude 31° 12' 55'' east and at a altitude of 1,303 m above sea level. It is in Bogelo Village, Lwemiyaga sub-county, Sembabule district, and is 1.5 km from a trading centre. Surveyed information/data are as follows:

- The centre has two PV systems, one of which is intended to supply power to a vaccination refrigerator and consist of two batteries and five panels. The other system is for lighting three bulbs only. The former is no longer operational since early this year. The centre also uses kerosene for lighting and sterilizing medical equipments. They consume two liters of kerosene at a cost of Ush 2,600 per liter.
- The centre's staff members include one officer-in-charge, a clinical officer, a nursing officer, registered midwife, a registered nurse, an enrolled midwife, a nursing assistant, a guard, a vaccinator and three compound cleaners. It has a total of four blocks, i.e., office and out patients block, general ward, maternity ward and surgery block.
- Only eight out of the 12 staff stay at the health centre.
- The staff quarters are not connected to the PV system. They also use kerosene lamps for lighting.
- The centre covers a population of 36,842. The centre receives 50 to 60 patients per day and the most common disease is malaria, followed by HIV, diarrhea and cough. Patients with complex cases are referred to Masaka Hospital, which is about 63 km away from the health centre.
- All staff members who have mobile phones take their units for charging at Ntuusi trading centre, 1.5 km away from the centre.
- The surrounding population gets income from cattle business and growing crops such as beans, *matoke*, cassava, sweet potatoes and maize.
- The centre has two water tanks which stores and supplies rain water.

2.2.3.12 Smarthill Primary School, Ntuusi

The Study Team visited Smarthill Primary School in Ntuusi on May 30, 2009. It is located at latitude 0° 02’ 41’’ north, longitude 31° 12’ 32’’ east and at an altitude of 1,270 m above sea level. It is in Lwemiyaga sub-county, Sembabule district. Other information/data about the school are as follows:

- The private school is a mixed day and boarding school with seven classes (Primary 1 to 7). About 50% of the pupils come from Ntuusi while the rest are from other surrounding areas and districts. The school has 16 staff members serving a population of 540 pupils.
- Almost all its staff members and 85% of adults in the village have mobile phones.
- The school acquired a PV system in 2005 using the proprietor’s funds. It comprised of five batteries, five panels and an inverter. It is mainly intended to provide power for lighting and charging phones. The system had already weakened. Consequently, the staff charge their phones for Ush 500 per phone, at the trading centre, just walking distance away from the school.
- The staff staying at the school premises use kerosene lamp for lighting.
- The school has no technical person to manage the solar system.
- The school gets water from Kakinga, which is 10 km away from the school.

2.2.3.13 Phone Charging Service Shop, Ntuusi

The Study Team visited a phone charging service shop in Ntuusi on May 30, 2009. It is located at latitude 0° 02’ 51’’ north, longitude 31° 12’ 29’’ east and at a altitude of 1,274 m above sea level. Obtained information related to the shop are as follows:

- The centre uses a battery and inverter to charge phones and lighting. The centre charges its battery at Sembabule town.
- The centre charges about 20 phones per day at Ush 500 per phone. It also sells airtime and offer calling services at Ush 200 per call.
- It is open from 7 am to 10 pm.
- The owner complained about customers who avail service on credit, and goes to other charging centres without paying.

2.2.3.14 A SHS User’s House

The Study Team visited a SHS user’s place on May 30, 2009. It is a residence of a relative of the local staff hired by the Study Team. The owner of the residence has a large stock farm and stays there on weekends only. He stays in Kampala during weekdays. It is located at latitude 0° 02’ 22’’ north and longitude 31° 14’ 38’’ east.

- He has two PV systems bought at Kampala and installed by him. One was acquired 12 years ago while the other was just recently. He has four batteries of 100 Ah, four panels, an inverter of 300 VA and a generator which supplies power to a television and DVD player.

2.2.4 Visit to the CREEC PV System Installation Pilot Site (II)

2.2.4.1 Namulonge Village

The Study Team visited Namulonge Village on June 3, 2009. It is located at latitude 0° 31’ 01’’ north, longitude 32° 36’ 58’’ east and at an altitude of 1,152 m above sea level. The village was one of the pilot sites for the PV system installation project of CREEC, under Makerere University. The team visited and talked to the local coordinator of the project. The following data were gathered:

- The PV system was installed in 2006 and 20 households availed of the services. Each household paid Ush 20,000 as registration fee and chose either 12 Ah system for Ush 100,000 or 7 Ah system for Ush 70,000. Installment payment for six months, excluding registration fee, is permitted. The price of the system was affordable for most villagers.
- The project provided one PV panel, a battery, two bulbs, radio and charger for mobile phones. No charge controller was installed. Replacement bulb was the responsibility of each household.
- At first, the system was working well. A resident gave up using said system after it failed functioning in 2008. The coordinator said that it was because of rats that destroyed the components. (The team attempted to perform rewiring and successfully restored the connection) Other participants of the project are also facing the same problem.
- The coordinator received a 10 Wp PV panel from CREEC as recompense for the failure of the system. She previously used the panel in a relative’s residence. However, it is not working presently since the battery has expired.
- The coordinator spends one liter of kerosene, a half liter of which is for the lights to control warm temperature for her poultry breeding. , The other half liter is for lighting for personal use. The Study Team explained that the light using PV system is usually not suitable for warming poultry.
- She uses firewood for cooking. Charcoals, however, are used in the evening because it is safer to handle in the dark.

2.2.5 Site Visit to NIDA Charging Business

2.2.5.1 Saazy Village

The Study Team visited Saazy Village on June 7, 2009. It is located at latitude 0° 05’ 54’’ north, longitude 32° 35’ 59’’ east and at an altitude of 1,167 m above sea level. The village has 170 households and located opposite to Entebbe International Airport of Victoria Lake. Other relevant information/data regarding the village are as follows:

- NIDA is doing the charging business as a completely private business. It did not obtain support from any donors. Initially, NIDA implemented this project at three villages, including Saazy. At each village NIDA serves 100 households as client. NIDA started the business at two villages in 2008 and at another village in 2009.
- In Saazy village, NIDA start its business in 2008. Its clients, including 100 out of the 170

households, rented CCFL[46] lanterns which are not for sale. Deposit for rental is Ush 20,000 and installment payment of the amount is possible.

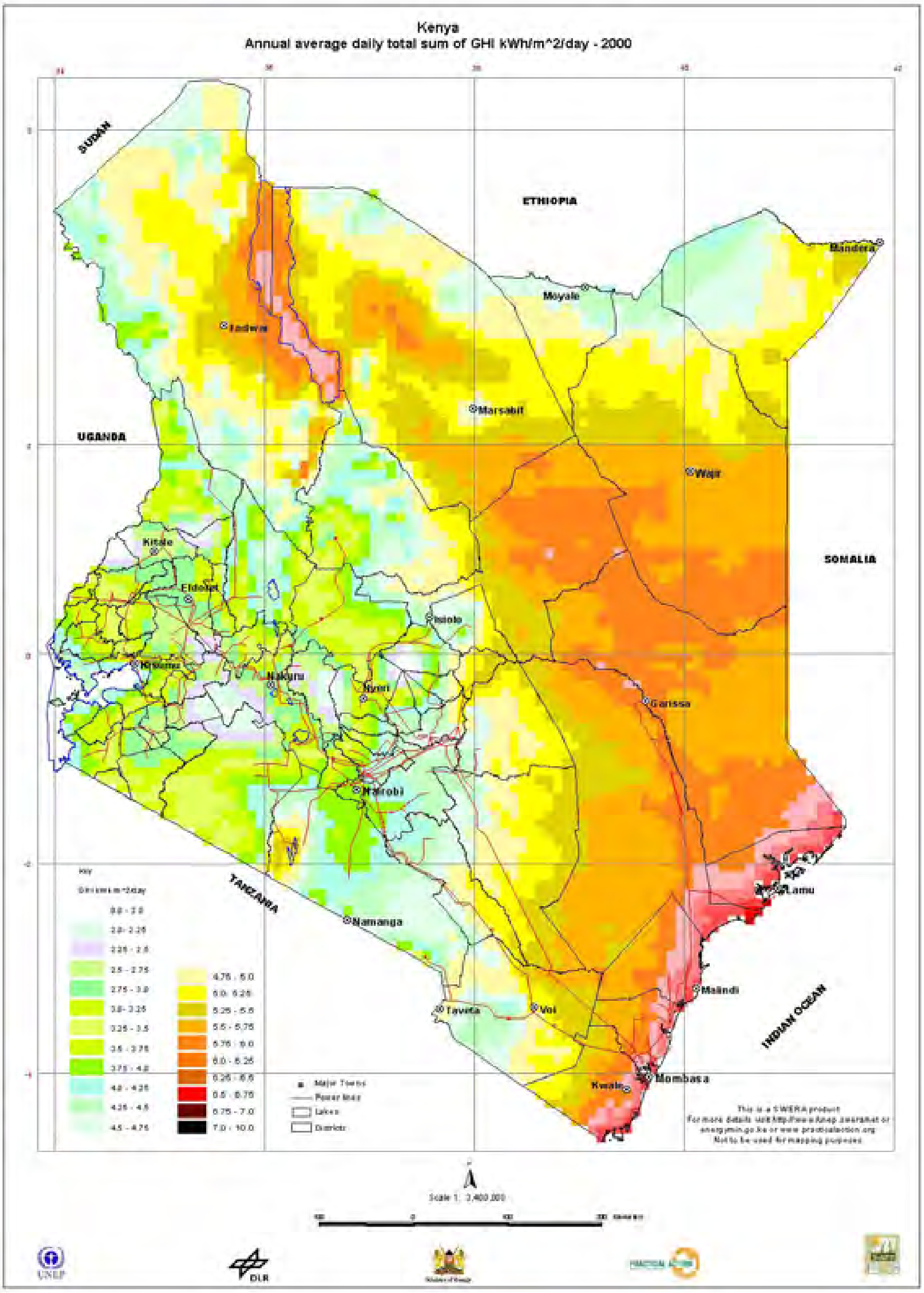
- Charging fee at the charging station is Ush 1,000. After charging, users pay the warden. The warden receives 10% of the fee and deposits the rest to a designated bank account of NIDA.
- The lantern is designed for recharging after five days or ten hours usage. It is also designed against over-discharge after certain duration of discharging. These design criteria are intended to secure the user's income and for protection of battery against over-discharge. The lantern has a function to indicate the remaining usable time, determined by counting the LED blinks.
- Processing using a unique terminal is required before/after charging of the lantern. Therefore, the lantern cannot be brought to other places for charging. The unique terminal can record the history of charging on SD card, and the data can be transferred to a computer via USB device.
- The lantern has an output terminal that functions as cigarette lighter and can supply power to other equipment like mobile phone chargers or small LCD television.
- It requires one to two hours to charge. The charging centre consist of two 120 Wp and a charge controller. It can charge a maximum of eight lanterns simultaneously. The centre usually charges around 30 to 40 lanterns per day. During the site visit, there were 42 lanterns in said centre. According to a NIDA official, the system is designed with some allowance when subjected to bad weather.
- The original cost of the lantern is Ush 200,000. NIDA will not request the client to pay the whole cost if the lantern was accidentally broken as it is covered by insurance. At present, clients handle the lantern carefully and NIDA has never claimed for any insurance. Parts of the lantern are imported, but it is assembled in Uganda.
- The total system cost is US$ 4,000, excluding the lanterns. Lanterns are the most expensive component of the system.
- NIDA is now accepting requests from other villages. It has already accepted 1,808 clients in 11 villages. NIDA hopes to start the project in other villages as soon as possible, if enough capital funds are available.

The Study Team interviewed a client at the charging centre. The client informed that its cost is the same as that for kerosene lamp, except for the initial deposit. He expressed satisfaction in using the chargeable lantern as it provides more illumination without smoke. He also informed that he can charge his mobile by using the system, without going to other charging shops 5 km away from the village.

[46] Cold Cathode Fluorescent Lamp is used backlight of LCD screen. Its feature is high brightness comparing to energy consumption.

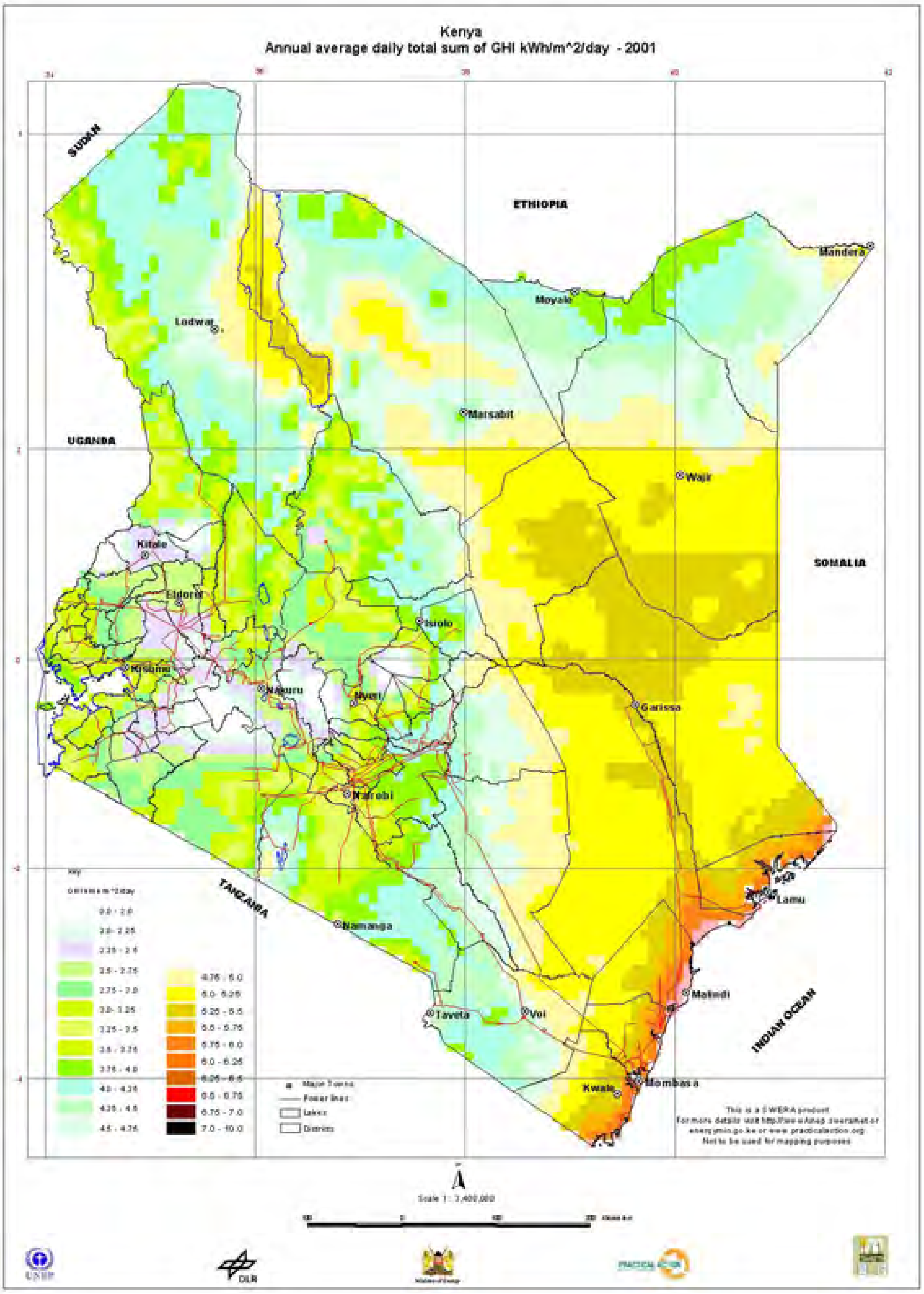
Appendix II Solar Insolation Data Map

II.1 Solar Insolation Map



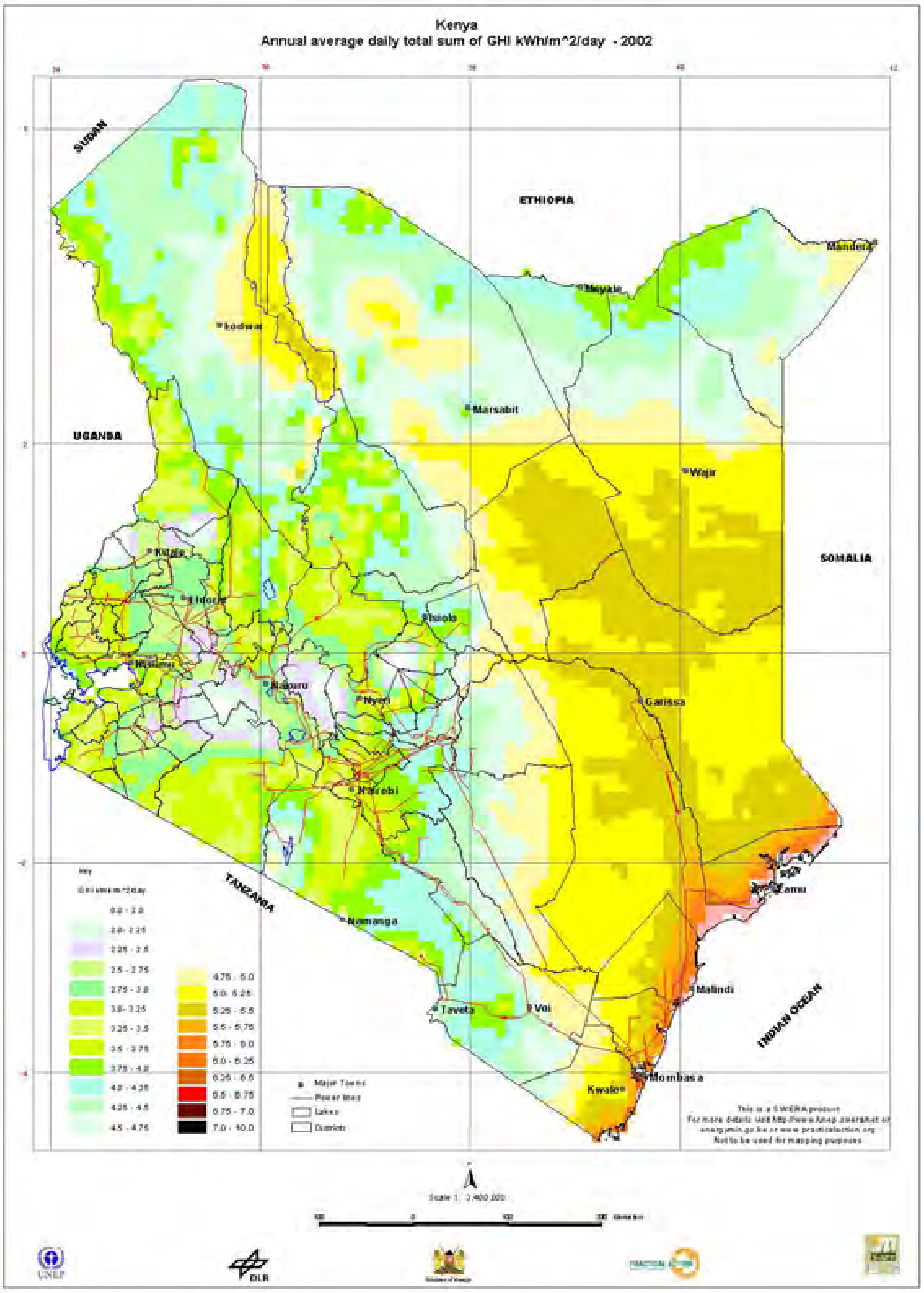
Source: MoE

Figure II.1-1 Average Solar Insolation Map of Kenya (Year 2000)



Source: MoE

Figure II.1-2 Average Solar Insolation Map of Kenya (Year 2001)



Source: MoE

Figure II.1-3 Average Solar Insolation Map of Kenya (Year 2002)

II.2 Solar Insolation Data

Table II.2-1 Monthly Average Horizontal Solar Insolation Data of Kenya (Avg. of 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation (m)
Lat 4 to 5 / Lon 34 to 35	6.07	6.34	5.94	5.44	5.53	5.37	5.33	5.63	6.22	5.66	5.42	5.72	5.71	575
Lat 4 to 5 / Lon 35 to 36	6.16	6.51	6.17	5.64	5.71	5.65	5.66	6.02	6.47	5.80	5.55	5.89	5.93	654
Lat 4 to 5 / Lon 36 to 37	6.16	6.49	6.29	5.79	5.74	5.65	5.70	6.09	6.35	5.80	5.66	5.93	5.96	604
Lat 4 to 5 / Lon 37 to 38	6.27	6.58	6.35	5.72	5.68	5.46	5.45	5.89	6.19	5.58	5.55	5.96	5.88	1,104
Lat 4 to 5 / Lon 40 to 41	6.52	6.95	6.41	5.37	5.09	4.22	4.16	4.73	5.51	4.95	5.22	5.95	5.41	887
Lat 3 to 4 / Lon 34 to 35	6.12	6.44	6.13	5.54	5.53	5.31	5.24	5.65	6.30	5.79	5.49	5.82	5.77	1,096
Lat 3 to 4 / Lon 35 to 36	6.18	6.58	6.39	5.80	5.79	5.66	5.71	6.17	6.62	6.06	5.68	5.87	6.03	586
Lat 3 to 4 / Lon 36 to 37	6.37	6.72	6.60	6.06	5.99	5.84	5.97	6.38	6.76	6.19	5.87	6.11	6.23	526
Lat 3 to 4 / Lon 37 to 38	6.49	6.90	6.74	6.01	6.05	5.88	6.09	6.46	6.97	6.24	5.86	6.15	6.31	645
Lat 3 to 4 / Lon 38 to 39	6.39	6.85	6.49	5.60	5.47	5.24	5.37	5.78	6.26	5.65	5.41	5.90	5.86	835
Lat 3 to 4 / Lon 39 to 40	6.40	6.81	6.34	5.23	4.91	4.32	4.32	4.82	5.48	4.97	5.08	5.79	5.36	902
Lat 3 to 4 / Lon 40 to 41	6.52	6.98	6.41	5.19	4.95	4.26	4.23	4.76	5.58	4.84	4.87	5.77	5.35	636
Lat 3 to 4 / Lon 41 to 42	6.54	6.98	6.57	5.46	5.25	4.68	4.65	5.15	5.82	5.09	5.05	5.88	5.58	419
Lat 2 to 3 / Lon 34 to 35	6.23	6.56	6.30	5.80	5.65	5.47	5.44	5.86	6.44	6.02	5.72	6.01	5.95	1,242
Lat 2 to 3 / Lon 35 to 36	6.23	6.67	6.44	5.94	5.84	5.57	5.55	6.00	6.59	6.17	5.71	5.93	6.04	803
Lat 2 to 3 / Lon 36 to 37	6.18	6.54	6.49	6.10	5.96	5.70	5.80	6.21	6.71	6.26	5.66	5.78	6.11	674
Lat 2 to 3 / Lon 37 to 38	6.13	6.62	6.49	5.96	5.84	5.55	5.86	6.20	6.79	6.14	5.54	5.67	6.06	562
Lat 2 to 3 / Lon 38 to 39	6.23	6.73	6.39	5.66	5.89	5.64	5.80	6.18	6.68	5.99	5.27	5.58	5.99	511
Lat 2 to 3 / Lon 39 to 40	6.30	6.73	6.12	5.28	5.30	4.98	4.98	5.35	5.95	5.29	4.84	5.43	5.53	434
Lat 2 to 3 / Lon 40 to 41	6.41	6.80	6.23	5.30	5.12	4.59	4.55	4.97	5.67	5.01	4.78	5.56	5.41	411
Lat 1 to 2 / Lon 34 to 35	6.15	6.51	6.31	5.93	5.69	5.53	5.43	5.79	6.34	6.02	5.69	5.93	5.93	1,515
Lat 1 to 2 / Lon 35 to 36	6.20	6.67	6.44	5.94	5.76	5.38	5.21	5.55	6.34	5.97	5.54	5.88	5.90	1,436
Lat 1 to 2 / Lon 36 to 37	6.49	6.98	6.68	6.20	6.20	5.94	5.89	6.26	6.90	6.29	5.65	6.05	6.28	1,179
Lat 1 to 2 / Lon 37 to 38	6.30	6.85	6.58	6.02	5.99	5.68	5.72	6.11	6.83	6.21	5.47	5.74	6.12	912
Lat 1 to 2 / Lon 38 to 39	6.07	6.67	6.39	5.89	6.00	5.78	5.89	6.27	6.84	6.28	5.39	5.46	6.07	361
Lat 1 to 2 / Lon 39 to 40	6.02	6.44	6.11	5.68	5.87	5.58	5.63	5.97	6.39	5.88	5.12	5.30	5.82	261
Lat 1 to 2 / Lon 40 to 41	6.11	6.51	6.17	5.62	5.46	5.01	5.03	5.38	5.87	5.48	5.08	5.43	5.59	194
Lat 0 to 1 / Lon 34 to 35	6.24	6.58	6.39	5.86	5.60	5.39	5.25	5.60	6.14	5.97	5.70	6.02	5.89	1,465
Lat 0 to 1 / Lon 35 to 36	6.24	6.71	6.59	5.94	5.68	5.33	5.09	5.33	6.19	5.97	5.62	6.05	5.89	1,848
Lat 0 to 1 / Lon 36 to 37	6.48	7.00	6.73	6.16	6.11	5.82	5.66	6.00	6.78	6.22	5.58	5.99	6.20	1,694
Lat 0 to 1 / Lon 37 to 38	6.47	7.05	6.71	6.18	6.07	5.75	5.72	6.08	6.86	6.24	5.45	5.86	6.19	1,327
Lat 0 to 1 / Lon 38 to 39	6.07	6.69	6.45	6.00	6.12	5.72	5.86	6.25	6.86	6.36	5.39	5.48	6.10	504
Lat 0 to 1 / Lon 39 to 40	5.78	6.22	6.15	5.90	5.90	5.60	5.70	6.04	6.50	6.17	5.39	5.34	5.88	225
North Avg.	**6.26**	**6.69**	**6.39**	**5.76**	**5.69**	**5.38**	**5.39**	**5.79**	**6.37**	**5.84**	**5.43**	**5.79**	**5.89**	**819**
Lat 0 to -1 / Lon 34 to 35	6.42	6.78	6.64	6.20	6.03	5.86	5.81	6.26	6.53	6.21	5.99	6.28	6.24	1,346
Lat 0 to -1 / Lon 35 to 36	6.19	6.68	6.46	5.74	5.50	5.36	5.24	5.58	6.08	5.79	5.42	5.90	5.82	2,151
Lat 0 to -1 / Lon 36 to 37	6.21	6.72	6.43	5.66	5.61	5.32	5.16	5.48	6.19	5.70	5.14	5.74	5.77	2,287
Lat 0 to -1 / Lon 37 to 38	6.06	6.69	6.25	5.52	5.24	4.76	4.66	4.91	5.81	5.50	4.88	5.46	5.47	1,502
Lat 0 to -1 / Lon 38 to 39	5.90	6.58	6.27	5.87	5.56	4.91	4.90	5.24	6.22	6.13	5.31	5.43	5.68	558
Lat 0 to -1 / Lon 39 to 40	5.53	6.05	6.02	5.76	5.48	5.09	5.24	5.57	6.15	6.07	5.36	5.25	5.62	221
Lat 0 to -1 / Lon 40 to 41	5.69	6.13	6.03	5.74	5.31	4.92	5.03	5.33	5.77	5.79	5.48	5.38	5.54	130
Lat -1 to -2 / Lon 34 to 35	6.12	6.51	6.42	5.98	5.83	5.76	5.74	6.06	6.37	6.26	5.80	5.95	6.06	1,449
Lat -1 to -2 / Lon 35 to 36	6.10	6.58	6.49	5.95	5.69	5.53	5.48	5.81	6.30	6.08	5.60	5.82	5.94	1,886
Lat -1 to -2 / Lon 36 to 37	6.42	6.86	6.66	5.83	5.36	5.11	5.23	5.55	6.37	6.13	5.59	6.06	5.92	1,490
Lat -1 to -2 / Lon 37 to 38	6.41	6.94	6.41	5.58	4.95	4.37	4.26	4.55	5.72	5.77	5.23	5.81	5.49	1,332
Lat -1 to -2 / Lon 38 to 39	5.83	6.46	6.14	5.68	5.18	4.58	4.61	4.94	5.87	5.96	5.31	5.49	5.49	630
Lat -1 to -2 / Lon 39 to 40	5.44	5.94	5.98	5.69	5.16	4.76	4.84	5.13	5.77	5.93	5.44	5.32	5.44	180
Lat -1 to -2 / Lon 40 to 41	5.54	5.94	5.92	5.61	5.03	4.68	4.80	5.15	5.62	5.71	5.51	5.39	5.40	68
Lat -1 to -2 / Lon 41 to 42	5.69	6.13	6.02	5.41	4.84	4.58	4.87	5.28	5.65	5.64	5.35	5.36	5.39	17
Lat -2 to -3 / Lon 36 to 37	6.42	6.84	6.51	5.82	5.38	5.27	5.47	5.79	6.43	6.28	5.69	5.97	5.98	1,285
Lat -2 to -3 / Lon 37 to 38	6.29	6.77	6.32	5.55	4.91	4.50	4.54	4.86	5.88	5.99	5.50	5.77	5.56	1,256
Lat -2 to -3 / Lon 38 to 39	5.98	6.52	6.17	5.66	5.01	4.55	4.59	4.94	5.86	6.05	5.48	5.62	5.53	554
Lat -2 to -3 / Lon 39 to 40	5.55	6.02	6.00	5.67	4.99	4.68	4.75	5.01	5.68	5.90	5.56	5.44	5.43	173
Lat -2 to -3 / Lon 40 to 41	5.55	5.96	5.95	5.47	4.79	4.57	4.72	5.16	5.70	5.80	5.54	5.41	5.38	24
Lat -3 to -4 / Lon 37 to 38	6.20	6.55	6.02	5.24	4.55	4.26	4.44	4.88	5.79	5.98	5.58	5.74	5.43	1,198
Lat -3 to -4 / Lon 38 to 39	6.18	6.57	6.04	5.32	4.59	4.32	4.37	4.70	5.58	5.85	5.57	5.79	5.39	695
Lat -3 to -4 / Lon 39 to 40	5.71	6.20	5.95	5.43	4.75	4.55	4.61	4.87	5.51	5.76	5.55	5.54	5.36	188
Lat -3 to -4 / Lon 40 to 41	6.24	6.57	6.51	5.60	4.80	4.75	4.91	5.63	6.30	6.40	6.27	6.15	5.83	1
Lat -4 to -5 / Lon 38 to 39	6.08	6.43	5.92	5.15	4.32	4.16	4.28	4.63	5.46	5.75	5.65	5.73	5.29	632
Lat -4 to -5 / Lon 39 to 40	5.80	6.07	5.70	5.15	4.58	4.49	4.58	4.86	5.46	5.56	5.55	5.63	5.28	54
South Avg	**5.98**	**6.44**	**6.20**	**5.63**	**5.13**	**4.83**	**4.89**	**5.24**	**5.93**	**5.92**	**5.51**	**5.67**	**5.61**	**820**
Country Avg.	**6.12**	**6.56**	**6.30**	**5.70**	**5.41**	**5.11**	**5.14**	**5.51**	**6.15**	**5.88**	**5.47**	**5.73**	**5.75**	**819**

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)

Table II.2-2 Monthly Minimum Average Horizontal Solar Insolation Data of Kenya (Avg. of 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Lat 4 to 5 / Lon 34 to 35	5.34	5.14	5.23	4.84	5.09	4.35	4.74	5.24	5.35	5.26	4.39	4.86	4.99
Lat 4 to 5 / Lon 35 to 36	5.36	5.53	5.43	5.08	5.20	4.63	5.09	5.54	5.63	5.39	4.50	4.89	5.19
Lat 4 to 5 / Lon 36 to 37	5.54	5.52	5.54	5.15	5.28	4.86	5.07	5.54	5.72	5.34	4.87	5.10	5.29
Lat 4 to 5 / Lon 37 to 38	5.45	5.40	5.52	5.15	5.06	4.75	4.91	5.42	5.57	5.19	4.66	4.89	5.16
Lat 4 to 5 / Lon 40 to 41	5.22	5.84	5.64	4.99	4.48	3.38	3.33	4.02	5.12	4.36	4.70	5.00	4.67
Lat 3 to 4 / Lon 34 to 35	5.45	5.35	5.27	4.99	5.09	4.35	4.56	5.20	5.48	5.38	4.67	5.12	5.08
Lat 3 to 4 / Lon 35 to 36	5.44	5.72	5.69	4.99	5.15	4.53	4.85	5.80	5.83	5.70	4.66	4.99	5.28
Lat 3 to 4 / Lon 36 to 37	5.54	5.85	6.07	5.27	5.39	5.08	5.25	5.87	6.22	5.82	4.81	5.44	5.55
Lat 3 to 4 / Lon 37 to 38	5.45	5.80	6.13	5.41	5.32	5.29	5.36	6.01	6.27	5.55	4.86	5.29	5.56
Lat 3 to 4 / Lon 38 to 39	5.30	5.62	5.78	5.15	4.76	4.61	4.67	5.14	5.76	4.92	4.76	4.96	5.12
Lat 3 to 4 / Lon 39 to 40	5.06	5.65	5.64	4.76	4.27	3.76	3.63	4.10	5.04	4.27	4.57	4.92	4.64
Lat 3 to 4 / Lon 40 to 41	5.15	5.86	5.32	4.72	4.46	3.62	3.64	4.14	5.08	4.40	4.43	4.90	4.64
Lat 3 to 4 / Lon 41 to 42	5.23	6.35	5.78	5.02	4.83	3.93	4.09	4.58	5.24	4.68	4.44	5.06	4.94
Lat 2 to 3 / Lon 34 to 35	5.67	5.51	5.61	5.10	5.20	4.65	4.95	5.45	5.86	5.60	4.92	5.47	5.33
Lat 2 to 3 / Lon 35 to 36	5.48	5.80	5.80	5.17	5.26	4.51	4.88	5.58	5.93	5.55	4.68	5.34	5.33
Lat 2 to 3 / Lon 36 to 37	5.44	5.69	6.04	5.43	5.66	5.02	5.34	5.78	6.24	5.76	4.87	5.26	5.54
Lat 2 to 3 / Lon 37 to 38	5.03	5.63	6.10	5.42	5.37	5.11	5.22	5.70	6.11	5.46	4.65	4.88	5.39
Lat 2 to 3 / Lon 38 to 39	4.98	5.86	5.75	5.04	5.48	5.13	5.16	5.75	6.15	5.09	4.58	4.97	5.33
Lat 2 to 3 / Lon 39 to 40	4.91	5.79	5.32	4.65	4.88	4.48	4.33	4.65	5.47	4.81	4.40	4.72	4.87
Lat 2 to 3 / Lon 40 to 41	5.00	6.05	5.36	4.77	4.66	3.81	3.82	4.42	5.27	4.56	4.30	4.89	4.74
Lat 1 to 2 / Lon 34 to 35	5.41	5.53	5.93	5.40	5.29	4.81	5.05	5.38	5.64	5.24	4.44	5.34	5.29
Lat 1 to 2 / Lon 35 to 36	5.27	5.80	5.80	5.23	5.13	4.25	4.74	5.16	5.52	5.37	4.43	5.35	5.17
Lat 1 to 2 / Lon 36 to 37	5.45	6.14	6.15	5.58	5.58	4.87	5.12	5.76	6.07	5.60	4.58	5.51	5.53
Lat 1 to 2 / Lon 37 to 38	4.98	6.03	6.19	5.36	5.45	4.83	5.09	5.50	6.01	5.53	4.54	4.88	5.36
Lat 1 to 2 / Lon 38 to 39	5.16	5.80	5.94	5.12	5.64	5.20	5.30	5.83	6.16	5.65	4.74	5.02	5.46
Lat 1 to 2 / Lon 39 to 40	5.18	5.73	5.62	5.06	5.58	5.08	5.12	5.43	6.01	5.35	4.76	4.77	5.31
Lat 1 to 2 / Lon 40 to 41	5.13	5.92	5.68	5.34	5.24	4.51	4.43	5.06	5.46	5.10	4.57	4.89	5.11
Lat 0 to 1 / Lon 34 to 35	5.68	5.53	5.81	5.39	5.21	4.74	4.88	5.38	5.28	5.55	4.79	5.42	5.30
Lat 0 to 1 / Lon 35 to 36	5.43	5.84	5.87	5.17	5.11	4.58	4.73	4.80	5.20	5.49	4.50	5.38	5.17
Lat 0 to 1 / Lon 36 to 37	5.25	6.09	6.06	5.61	5.50	4.95	5.15	5.34	5.83	5.54	4.63	5.33	5.44
Lat 0 to 1 / Lon 37 to 38	5.18	6.35	6.11	5.62	5.34	4.89	5.15	5.35	5.76	5.49	4.52	5.10	5.40
Lat 0 to 1 / Lon 38 to 39	4.73	6.02	6.00	5.46	5.63	4.92	5.10	5.63	5.97	5.41	4.58	4.93	5.36
Lat 0 to 1 / Lon 39 to 40	5.09	5.35	5.72	5.55	5.61	5.15	5.30	5.44	6.18	5.49	4.96	4.91	5.39
North Avg.	**5.27**	**5.76**	**5.75**	**5.18**	**5.19**	**4.63**	**4.79**	**5.27**	**5.71**	**5.27**	**4.63**	**5.08**	**5.21**
Lat 0 to -1 / Lon 34 to 35	5.71	5.83	5.84	5.58	5.55	5.10	5.23	5.82	6.01	5.65	5.21	5.84	5.61
Lat 0 to -1 / Lon 35 to 36	5.26	5.81	5.75	5.22	5.17	4.61	4.82	5.19	5.65	5.38	4.44	5.07	5.20
Lat 0 to -1 / Lon 36 to 37	4.72	5.98	5.85	5.04	4.99	4.36	4.70	4.93	5.01	5.19	4.21	4.99	5.00
Lat 0 to -1 / Lon 37 to 38	4.79	5.75	5.56	5.02	4.61	3.86	3.87	4.12	4.88	4.95	4.20	4.70	4.69
Lat 0 to -1 / Lon 38 to 39	5.02	5.72	5.83	5.22	5.12	4.03	4.36	4.45	5.22	5.21	4.67	4.72	4.97
Lat 0 to -1 / Lon 39 to 40	4.87	5.26	5.60	5.18	5.04	4.68	4.82	5.07	5.66	5.46	4.88	4.78	5.11
Lat 0 to -1 / Lon 40 to 41	5.12	5.46	5.67	4.99	4.89	4.58	4.68	4.96	5.31	5.33	4.93	5.06	5.08
Lat -1 to -2 / Lon 34 to 35	5.14	5.47	5.71	5.44	5.19	5.07	5.17	5.45	5.92	5.82	4.99	5.06	5.37
Lat -1 to -2 / Lon 35 to 36	5.12	5.66	5.91	5.41	4.95	4.81	5.10	5.40	5.73	5.53	4.93	5.12	5.31
Lat -1 to -2 / Lon 36 to 37	5.33	5.56	5.79	5.25	4.61	4.45	4.60	4.88	5.35	5.64	4.86	5.58	5.16
Lat -1 to -2 / Lon 37 to 38	5.13	5.83	5.70	5.02	4.26	3.67	3.58	3.73	5.03	5.14	4.60	5.11	4.73
Lat -1 to -2 / Lon 38 to 39	4.90	5.62	5.65	5.28	4.56	3.98	4.10	4.30	5.22	5.19	4.78	4.94	4.88
Lat -1 to -2 / Lon 39 to 40	4.95	5.29	5.56	5.12	4.70	4.43	4.55	4.72	5.31	5.28	5.00	4.73	4.97
Lat -1 to -2 / Lon 40 to 41	4.99	5.41	5.51	5.11	4.43	4.31	4.51	4.79	5.11	5.08	4.90	5.07	4.93
Lat -1 to -2 / Lon 41 to 42	4.50	5.64	5.72	4.92	4.31	4.17	4.58	4.96	5.20	5.02	4.55	4.88	4.87
Lat -2 to -3 / Lon 36 to 37	5.20	5.61	5.92	5.41	4.79	4.74	4.92	5.15	5.79	5.84	5.01	5.25	5.30
Lat -2 to -3 / Lon 37 to 38	4.97	5.75	5.81	5.11	4.17	3.92	4.04	3.94	5.12	5.51	4.84	5.14	4.86
Lat -2 to -3 / Lon 38 to 39	4.84	5.61	5.80	5.26	4.46	4.05	4.22	4.35	5.22	5.26	4.93	5.00	4.92
Lat -2 to -3 / Lon 39 to 40	5.05	5.54	5.64	5.10	4.39	4.40	4.51	4.61	5.40	5.13	4.84	5.00	4.97
Lat -2 to -3 / Lon 40 to 41	4.77	5.54	5.65	5.03	4.36	4.11	4.39	4.75	5.36	4.76	4.76	5.03	4.88
Lat -3 to -4 / Lon 37 to 38	4.90	5.04	5.54	4.87	3.87	3.75	4.00	4.25	5.10	5.20	4.91	4.99	4.70
Lat -3 to -4 / Lon 38 to 39	4.88	5.26	5.50	4.95	4.04	4.06	4.02	4.04	4.91	4.97	4.85	5.27	4.73
Lat -3 to -4 / Lon 39 to 40	5.14	5.52	5.59	4.94	4.13	4.28	4.38	4.43	5.23	4.90	4.88	5.10	4.88
Lat -3 to -4 / Lon 40 to 41	5.12	5.65	5.60	4.65	4.03	4.23	4.57	4.67	5.67	5.25	5.14	5.54	5.01
Lat -4 to -5 / Lon 38 to 39	5.11	4.76	5.45	4.27	3.67	3.87	3.94	4.07	4.91	5.00	4.92	5.27	4.60
Lat -4 to -5 / Lon 39 to 40	5.16	4.80	5.30	4.43	3.89	4.13	4.26	4.13	4.70	4.56	4.94	5.07	4.61
South Avg.	**5.03**	**5.51**	**5.67**	**5.07**	**4.54**	**4.29**	**4.46**	**4.66**	**5.31**	**5.24**	**4.81**	**5.09**	**4.97**
Country Avg	**5.15**	**5.64**	**5.71**	**5.13**	**4.87**	**4.46**	**4.62**	**4.97**	**5.51**	**5.26**	**4.72**	**5.09**	**5.09**

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)

Table II.2-3 Monthly Maximum Average Horizontal Solar Insolation Data of Kenya (Avg. of 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Lat 4 to 5 / Lon 34 to 35	6.68	7.29	6.71	5.93	6.08	5.85	5.97	6.25	7.15	6.51	5.96	6.23	6.39
Lat 4 to 5 / Lon 35 to 36	6.84	7.42	7.03	6.09	6.28	6.16	6.40	6.50	7.25	6.44	5.94	6.48	6.57
Lat 4 to 5 / Lon 36 to 37	6.84	7.46	6.98	6.31	6.31	6.05	6.27	6.52	6.99	6.21	6.06	6.58	6.55
Lat 4 to 5 / Lon 37 to 38	6.96	7.57	7.11	6.12	6.02	5.79	6.00	6.54	6.69	6.03	5.94	6.44	6.43
Lat 4 to 5 / Lon 40 to 41	7.17	7.78	7.18	5.80	5.70	4.81	5.03	5.63	5.90	5.45	5.79	6.55	6.07
Lat 3 to 4 / Lon 34 to 35	6.79	7.41	6.93	5.98	5.97	5.73	5.82	6.16	7.12	6.60	6.04	6.40	6.41
Lat 3 to 4 / Lon 35 to 36	6.86	7.44	7.09	6.32	6.31	6.11	6.45	6.54	7.22	6.61	6.19	6.52	6.64
Lat 3 to 4 / Lon 36 to 37	7.13	7.59	7.33	6.73	6.65	6.48	6.63	6.76	7.37	6.69	6.34	6.72	6.87
Lat 3 to 4 / Lon 37 to 38	7.14	7.73	7.48	6.67	6.53	6.35	6.58	6.91	7.46	6.68	6.27	6.77	6.88
Lat 3 to 4 / Lon 38 to 39	7.16	7.74	7.14	6.10	5.85	5.71	6.12	6.36	6.70	6.27	5.90	6.67	6.48
Lat 3 to 4 / Lon 39 to 40	7.04	7.70	7.10	5.70	5.40	5.10	4.97	5.93	5.86	5.37	5.49	6.43	6.01
Lat 3 to 4 / Lon 40 to 41	7.04	7.75	7.31	5.71	5.35	4.90	4.91	5.62	5.97	5.23	5.31	6.46	5.96
Lat 3 to 4 / Lon 41 to 42	7.06	7.68	7.29	5.73	5.67	5.29	5.16	5.67	6.29	5.40	5.40	6.70	6.11
Lat 2 to 3 / Lon 34 to 35	6.92	7.35	7.06	6.21	6.10	5.85	5.98	6.33	6.96	6.50	6.23	6.61	6.51
Lat 2 to 3 / Lon 35 to 36	7.04	7.40	7.02	6.47	6.37	6.07	6.05	6.42	6.99	6.54	6.05	6.52	6.58
Lat 2 to 3 / Lon 36 to 37	6.98	7.39	7.01	6.65	6.44	6.21	6.26	6.83	7.25	6.64	6.06	6.36	6.67
Lat 2 to 3 / Lon 37 to 38	6.99	7.48	7.07	6.44	6.31	5.88	6.56	6.51	7.27	6.51	6.09	6.52	6.64
Lat 2 to 3 / Lon 38 to 39	6.98	7.54	7.03	6.28	6.36	6.03	6.38	6.67	7.21	6.59	5.59	6.19	6.57
Lat 2 to 3 / Lon 39 to 40	6.93	7.47	6.79	5.54	5.67	5.48	5.58	6.10	6.37	5.77	5.47	6.19	6.11
Lat 2 to 3 / Lon 40 to 41	6.99	7.62	7.23	5.62	5.48	5.14	5.14	5.62	6.07	5.61	5.35	6.39	6.02
Lat 1 to 2 / Lon 34 to 35	6.95	7.29	6.94	6.29	6.15	6.03	5.92	6.14	6.78	6.32	6.09	6.40	6.44
Lat 1 to 2 / Lon 35 to 36	7.07	7.60	7.08	6.47	6.34	5.81	5.78	5.94	6.97	6.33	6.09	6.59	6.51
Lat 1 to 2 / Lon 36 to 37	7.27	7.75	7.28	6.70	6.76	6.36	6.54	6.70	7.38	6.73	6.05	6.66	6.85
Lat 1 to 2 / Lon 37 to 38	6.99	7.74	7.17	6.56	6.47	6.25	6.12	6.60	7.24	6.52	5.96	6.31	6.66
Lat 1 to 2 / Lon 38 to 39	6.74	7.54	6.77	6.42	6.48	6.13	6.24	6.58	7.32	6.85	5.88	5.90	6.57
Lat 1 to 2 / Lon 39 to 40	6.44	7.15	6.48	6.13	6.16	5.91	5.91	6.27	6.71	6.29	5.63	5.88	6.25
Lat 1 to 2 / Lon 40 to 41	6.60	7.10	6.66	5.84	5.73	5.46	5.63	5.97	6.22	6.03	5.59	5.97	6.07
Lat 0 to 1 / Lon 34 to 35	6.99	7.37	6.97	6.50	5.94	5.93	5.72	5.99	7.00	6.57	6.16	6.50	6.47
Lat 0 to 1 / Lon 35 to 36	7.11	7.65	7.18	6.53	6.13	5.92	5.50	5.76	7.12	6.63	6.41	6.66	6.55
Lat 0 to 1 / Lon 36 to 37	7.19	7.70	7.20	6.65	6.60	6.34	6.34	6.54	7.39	6.66	6.03	6.71	6.78
Lat 0 to 1 / Lon 37 to 38	7.18	7.90	7.25	6.80	6.68	6.38	6.41	6.63	7.34	6.74	5.94	6.50	6.81
Lat 0 to 1 / Lon 38 to 39	6.62	7.49	6.84	6.66	6.67	6.18	6.39	6.56	7.20	6.93	5.71	6.14	6.62
Lat 0 to 1 / Lon 39 to 40	6.47	6.90	6.58	6.25	6.20	5.99	5.99	6.46	6.96	6.54	5.77	5.66	6.31
North Avg.	**6.94**	**7.51**	**7.04**	**6.25**	**6.16**	**5.87**	**5.96**	**6.30**	**6.90**	**6.33**	**5.90**	**6.41**	**6.46**
Lat 0 to -1 / Lon 34 to 35	7.25	7.46	7.30	6.76	6.39	6.50	6.57	6.76	7.05	6.58	6.53	6.78	6.83
Lat 0 to -1 / Lon 35 to 36	6.93	7.48	7.11	6.14	6.05	6.00	5.82	5.91	6.69	6.48	6.02	6.55	6.43
Lat 0 to -1 / Lon 36 to 37	6.96	7.39	7.14	6.11	6.23	5.91	5.68	6.03	6.81	6.27	5.71	6.20	6.37
Lat 0 to -1 / Lon 37 to 38	6.79	7.63	6.81	6.02	5.92	5.52	5.45	5.55	6.57	6.16	5.32	6.06	6.15
Lat 0 to -1 / Lon 38 to 39	6.49	7.44	6.71	6.22	6.12	5.60	5.54	5.82	6.78	6.62	5.68	5.81	6.23
Lat 0 to -1 / Lon 39 to 40	6.25	6.96	6.32	6.11	5.92	5.45	5.66	5.90	6.64	6.43	5.84	5.57	6.09
Lat 0 to -1 / Lon 40 to 41	6.37	7.05	6.39	6.08	5.68	5.31	5.48	5.70	6.35	6.43	5.92	5.60	6.03
Lat -1 to -2 / Lon 34 to 35	6.85	7.10	6.87	6.52	6.35	6.34	6.31	6.54	6.82	6.70	6.38	6.66	6.62
Lat -1 to -2 / Lon 35 to 36	6.89	7.50	7.07	6.49	6.37	6.03	6.08	6.33	6.99	6.51	6.22	6.52	6.58
Lat -1 to -2 / Lon 36 to 37	7.32	7.68	7.19	6.47	6.11	5.77	6.17	6.38	7.01	6.74	5.87	7.03	6.65
Lat -1 to -2 / Lon 37 to 38	7.24	7.84	7.05	6.08	5.49	5.07	5.33	5.55	6.41	6.29	5.81	6.45	6.22
Lat -1 to -2 / Lon 38 to 39	6.30	7.36	6.63	6.02	5.59	5.36	5.44	5.78	6.40	6.56	5.73	5.98	6.10
Lat -1 to -2 / Lon 39 to 40	6.09	6.77	6.46	5.97	5.57	5.28	5.18	5.64	6.12	6.46	5.88	5.75	5.93
Lat -1 to -2 / Lon 40 to 41	6.04	6.65	6.45	5.95	5.53	5.01	5.14	5.67	6.13	6.40	6.06	5.77	5.90
Lat -1 to -2 / Lon 41 to 42	6.09	6.56	6.38	5.68	5.32	4.99	5.26	5.81	6.27	6.26	5.89	5.74	5.85
Lat -2 to -3 / Lon 36 to 37	7.06	7.46	7.10	6.40	5.81	5.74	6.24	6.60	7.07	6.85	6.20	6.63	6.60
Lat -2 to -3 / Lon 37 to 38	7.04	7.58	6.89	6.05	5.45	5.09	5.49	5.73	6.59	6.47	6.16	6.46	6.25
Lat -2 to -3 / Lon 38 to 39	6.58	7.56	6.60	5.94	5.46	5.19	5.51	5.78	6.39	6.59	5.92	6.07	6.13
Lat -2 to -3 / Lon 39 to 40	6.16	6.80	6.54	6.18	5.49	4.96	5.13	5.46	6.13	6.37	6.00	6.04	5.94
Lat -2 to -3 / Lon 40 to 41	5.88	6.62	6.31	5.80	5.41	4.89	5.05	5.62	6.16	6.32	5.93	5.95	5.83
Lat -3 to -4 / Lon 37 to 38	7.44	7.66	6.56	5.87	5.19	4.77	5.15	5.71	6.43	6.76	6.25	6.49	6.19
Lat -3 to -4 / Lon 38 to 39	7.05	7.69	6.52	5.75	5.09	4.75	4.98	5.50	6.14	6.44	6.13	6.43	6.04
Lat -3 to -4 / Lon 39 to 40	6.11	7.01	6.43	6.03	5.37	4.87	4.89	5.31	6.01	6.22	5.94	6.04	5.85
Lat -3 to -4 / Lon 40 to 41	6.86	7.16	7.03	6.38	5.81	5.32	5.40	6.19	6.68	7.04	6.77	6.77	6.45
Lat -4 to -5 / Lon 38 to 39	7.05	7.46	6.33	5.67	4.88	4.74	4.67	5.28	5.95	6.38	6.33	6.30	5.92
Lat -4 to -5 / Lon 39 to 40	6.44	6.74	6.10	6.18	5.36	4.80	4.81	5.35	6.22	6.23	5.99	6.14	5.86
South Avg.	**6.67**	**7.25**	**6.70**	**6.11**	**5.69**	**5.36**	**5.48**	**5.84**	**6.49**	**6.48**	**6.02**	**6.22**	**6.19**
Country Avg.	**6.81**	**7.38**	**6.87**	**6.18**	**5.92**	**5.61**	**5.72**	**6.07**	**6.70**	**6.40**	**5.96**	**6.32**	**6.33**

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)

Table II.2-4 Monthly Average Horizontal Solar Insolation Data of Uganda (Avg. of 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation (m)
Lat 3 to 4 / Lon 30 to 31	6.09	6.29	5.84	5.37	5.26	4.83	4.59	4.87	5.32	5.05	5.23	5.71	5.36	1,031
Lat 3 to 4 / Lon 31 to 32	6.19	6.39	5.99	5.66	5.51	4.97	4.69	4.95	5.56	5.40	5.47	5.81	5.54	822
Lat 3 to 4 / Lon 32 to 33	6.29	6.54	6.07	5.71	5.64	5.28	5.09	5.41	6.08	5.81	5.70	5.94	5.79	1,033
Lat 3 to 4 / Lon 33 to 34	6.05	6.29	5.91	5.48	5.54	5.33	5.19	5.50	6.12	5.65	5.44	5.74	5.68	1,161
Lat 3 to 4 / Lon 34 to 35	6.12	6.44	6.13	5.54	5.53	5.31	5.24	5.65	6.30	5.79	5.49	5.82	5.77	1,096
Lat 2 to 3 / Lon 30 to 31	5.99	6.10	5.64	5.09	5.04	4.63	4.51	4.65	5.01	4.75	4.92	5.48	5.14	1,417
Lat 2 to 3 / Lon 31 to 32	6.00	6.19	5.89	5.57	5.38	4.86	4.67	4.84	5.30	5.12	5.26	5.64	5.38	849
Lat 2 to 3 / Lon 32 to 33	6.18	6.44	6.10	5.71	5.45	5.08	5.03	5.31	5.92	5.64	5.58	5.89	5.68	1,441
Lat 2 to 3 / Lon 33 to 34	6.21	6.51	6.24	5.85	5.65	5.39	5.33	5.70	6.38	6.01	5.74	6.01	5.91	1,099
Lat 2 to 3 / Lon 34 to 35	6.23	6.56	6.30	5.80	5.65	5.47	5.44	5.86	6.44	6.02	5.72	6.01	5.95	1,242
Lat 1 to 2 / Lon 30 to 31	5.67	5.91	5.45	5.25	5.17	4.86	4.73	4.80	4.98	4.57	4.63	5.16	5.09	1,115
Lat 1 to 2 / Lon 31 to 32	5.72	5.96	5.68	5.45	5.19	4.90	4.90	4.97	5.22	4.82	4.97	5.35	5.25	993
Lat 1 to 2 / Lon 32 to 33	6.07	6.36	6.09	5.66	5.39	4.97	4.96	5.25	5.70	5.44	5.48	5.83	5.59	1,058
Lat 1 to 2 / Lon 33 to 34	6.22	6.56	6.36	5.99	5.72	5.39	5.29	5.67	6.22	6.01	5.83	6.07	5.94	1,060
Lat 1 to 2 / Lon 34 to 35	6.15	6.51	6.31	5.93	5.69	5.53	5.43	5.79	6.34	6.02	5.69	5.93	5.93	1,515
Lat 0 to 1 / Lon 29 to 30	5.53	5.82	5.41	5.18	5.04	4.70	4.63	4.73	5.13	4.82	4.80	5.05	5.06	1,245
Lat 0 to 1 / Lon 30 to 31	5.34	5.61	5.30	5.13	4.98	4.75	4.76	4.82	5.07	4.67	4.62	4.92	4.99	1,264
Lat 0 to 1 / Lon 31 to 32	5.57	5.79	5.53	5.20	5.00	4.88	4.91	4.99	5.15	4.80	4.78	5.18	5.14	1,233
Lat 0 to 1 / Lon 32 to 33	5.60	5.88	5.61	5.21	4.93	4.82	4.86	5.03	5.32	5.01	5.01	5.29	5.21	1,147
Lat 0 to 1 / Lon 33 to 34	5.81	6.13	5.97	5.48	5.16	5.00	4.96	5.27	5.67	5.48	5.34	5.59	5.48	1,127
Lat 0 to 1 / Lon 34 to 35	6.24	6.58	6.39	5.86	5.60	5.39	5.25	5.60	6.14	5.97	5.70	6.02	5.89	1,465
North Avg.	**5.97**	**6.23**	**5.91**	**5.53**	**5.36**	**5.06**	**4.97**	**5.22**	**5.68**	**5.37**	**5.30**	**5.64**	**5.51**	**1,163**
Lat 0 to -1 / Lon 29 to 30	5.08	5.37	5.07	5.01	4.88	4.70	4.69	4.72	5.01	4.71	4.63	4.76	4.88	1,351
Lat 0 to -1 / Lon 30 to 31	5.29	5.56	5.20	5.11	5.01	5.01	5.18	5.14	5.28	4.88	4.74	4.91	5.10	1,416
Lat 0 to -1 / Lon 31 to 32	5.08	5.41	5.18	4.99	4.84	4.94	5.05	5.01	5.11	4.71	4.63	4.74	4.97	1,257
Lat -1 to -2 / Lon 29 to 30	4.90	5.17	5.03	4.93	4.80	4.80	4.90	4.92	5.00	4.69	4.63	4.69	4.87	1,879
Lat -1 to -2 / Lon 30 to 31	4.93	5.22	4.97	4.83	4.71	4.83	5.14	5.09	5.07	4.68	4.54	4.57	4.87	1,940
South Avg	**5.06**	**5.35**	**5.09**	**4.97**	**4.85**	**4.86**	**4.99**	**4.98**	**5.09**	**4.73**	**4.63**	**4.73**	**4.94**	**1,569**
Country Avg.	**5.51**	**5.79**	**5.50**	**5.25**	**5.10**	**4.96**	**4.98**	**5.10**	**5.39**	**5.05**	**4.97**	**5.19**	**5.23**	**1,366**

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)

Table II.2-5 Monthly Minimum Average Horizontal Solar Insolation Data of Uganda (Avg. of 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Lat 3 to 4 / Lon 30 to 31	5.66	5.41	5.20	4.94	4.79	4.35	4.04	4.53	4.84	4.65	4.60	4.97	4.83
Lat 3 to 4 / Lon 31 to 32	5.69	5.43	5.39	5.26	4.85	4.52	4.17	4.60	4.89	4.70	4.70	5.05	4.94
Lat 3 to 4 / Lon 32 to 33	5.85	5.62	5.40	5.37	5.25	4.65	4.68	4.92	5.47	5.29	4.62	5.17	5.19
Lat 3 to 4 / Lon 33 to 34	5.57	5.09	5.20	4.99	5.04	4.53	4.77	5.01	5.63	5.20	4.62	5.11	5.06
Lat 3 to 4 / Lon 34 to 35	5.45	5.35	5.27	4.99	5.09	4.35	4.56	5.20	5.48	5.38	4.67	5.12	5.08
Lat 2 to 3 / Lon 30 to 31	6.65	7.02	6.37	5.50	5.44	5.00	5.01	5.07	5.66	5.42	5.41	6.03	5.71
Lat 2 to 3 / Lon 31 to 32	5.52	5.01	5.42	5.07	4.90	4.18	4.11	4.31	4.56	4.40	4.58	5.08	4.76
Lat 2 to 3 / Lon 32 to 33	5.69	5.35	5.55	5.37	5.07	4.47	4.68	4.78	5.27	4.96	4.58	5.12	5.07
Lat 2 to 3 / Lon 33 to 34	5.71	5.47	5.74	5.32	5.20	4.58	4.85	5.07	5.68	5.41	4.82	5.47	5.28
Lat 2 to 3 / Lon 34 to 35	5.67	5.51	5.61	5.10	5.20	4.65	4.95	5.45	5.86	5.60	4.92	5.47	5.33
Lat 1 to 2 / Lon 30 to 31	5.05	5.02	4.96	4.88	4.65	4.42	4.40	4.46	4.53	4.07	3.98	4.59	4.59
Lat 1 to 2 / Lon 31 to 32	5.32	4.77	5.00	5.07	4.77	4.31	4.46	4.52	4.80	4.29	4.22	4.76	4.69
Lat 1 to 2 / Lon 32 to 33	5.65	5.15	5.54	5.09	4.90	4.57	4.51	4.88	5.13	4.95	4.44	5.13	5.00
Lat 1 to 2 / Lon 33 to 34	5.72	5.51	5.98	5.51	5.26	4.80	5.03	5.10	5.47	5.53	4.55	5.46	5.33
Lat 1 to 2 / Lon 34 to 35	5.41	5.53	5.93	5.40	5.29	4.81	5.05	5.38	5.64	5.24	4.44	5.34	5.29
Lat 0 to 1 / Lon 29 to 30	4.81	5.12	4.65	4.66	4.69	4.14	4.31	4.26	4.72	4.29	3.98	4.49	4.51
Lat 0 to 1 / Lon 30 to 31	4.86	4.71	4.66	4.67	4.63	4.32	4.38	4.48	4.56	4.11	3.74	4.48	4.47
Lat 0 to 1 / Lon 31 to 32	5.01	4.86	4.98	4.84	4.60	4.39	4.57	4.59	4.69	4.42	4.16	4.45	4.63
Lat 0 to 1 / Lon 32 to 33	4.93	4.94	4.99	4.79	4.54	4.34	4.42	4.68	4.95	4.51	4.01	4.66	4.65
Lat 0 to 1 / Lon 33 to 34	5.05	4.84	5.31	4.88	4.54	4.45	4.41	4.85	5.05	4.99	4.49	4.98	4.82
Lat 0 to 1 / Lon 34 to 35	5.68	5.53	5.81	5.39	5.21	4.74	4.88	5.38	5.28	5.55	4.79	5.42	5.30
North Avg.	**5.47**	**5.30**	**5.38**	**5.10**	**4.95**	**4.50**	**4.58**	**4.83**	**5.15**	**4.90**	**4.49**	**5.06**	**4.98**
Lat 0 to -1 / Lon 29 to 30	4.57	4.67	4.66	4.61	4.54	4.23	4.08	4.25	4.26	4.19	3.98	4.47	4.38
Lat 0 to -1 / Lon 30 to 31	4.81	4.84	4.73	4.65	4.56	4.51	4.61	4.52	4.80	4.34	4.08	4.42	4.57
Lat 0 to -1 / Lon 31 to 32	4.57	4.54	4.56	4.64	4.40	4.30	4.55	4.66	4.80	4.00	3.84	4.03	4.41
Lat -1 to -2 / Lon 29 to 30	4.26	4.65	4.63	4.54	4.32	4.32	4.41	4.23	4.25	3.80	3.98	4.17	4.30
Lat -1 to -2 / Lon 30 to 31	4.54	4.44	4.62	4.49	4.24	4.20	4.52	4.33	4.46	4.02	3.81	4.02	4.31
South Avg.	**4.55**	**4.63**	**4.64**	**4.59**	**4.41**	**4.31**	**4.43**	**4.40**	**4.52**	**4.07**	**3.94**	**4.22**	**4.39**
Country Avg	**5.01**	**4.96**	**5.01**	**4.84**	**4.68**	**4.41**	**4.51**	**4.62**	**4.83**	**4.49**	**4.22**	**4.64**	**4.69**

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)

Table II.2-6 Monthly Maximum Average Horizontal Solar Insolation Data of Uganda (Avg. of 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Lat 3 to 4 / Lon 30 to 31	6.64	7.23	6.66	5.75	5.68	5.41	5.09	5.16	5.64	5.56	5.91	6.17	5.91
Lat 3 to 4 / Lon 31 to 32	6.81	7.35	6.77	6.17	6.06	5.52	5.21	5.45	6.28	5.99	6.07	6.16	6.15
Lat 3 to 4 / Lon 32 to 33	6.73	7.39	6.80	6.11	6.03	5.65	5.80	5.90	6.93	6.39	6.21	6.30	6.35
Lat 3 to 4 / Lon 33 to 34	6.47	7.17	6.62	5.92	5.87	5.81	5.81	5.94	6.67	6.22	5.93	6.14	6.21
Lat 3 to 4 / Lon 34 to 35	6.79	7.41	6.93	5.98	5.97	5.73	5.82	6.16	7.12	6.60	6.04	6.40	6.41
Lat 2 to 3 / Lon 30 to 31	6.71	7.20	6.43	5.50	5.39	5.19	4.96	4.93	5.36	5.46	5.41	6.03	5.71
Lat 2 to 3 / Lon 31 to 32	6.66	7.24	6.60	6.02	5.76	5.44	5.23	5.28	5.88	5.84	5.84	6.03	5.98
Lat 2 to 3 / Lon 32 to 33	6.67	7.34	6.77	5.94	6.00	5.54	5.48	5.79	6.75	6.26	6.03	6.24	6.23
Lat 2 to 3 / Lon 33 to 34	6.77	7.23	6.93	6.14	6.10	5.82	5.92	6.27	7.15	6.61	6.14	6.49	6.46
Lat 2 to 3 / Lon 34 to 35	6.92	7.35	7.06	6.21	6.10	5.85	5.98	6.33	6.96	6.50	6.23	6.61	6.51
Lat 1 to 2 / Lon 30 to 31	6.52	7.03	6.21	5.88	5.48	5.30	5.34	5.18	5.23	5.12	5.14	5.73	5.68
Lat 1 to 2 / Lon 31 to 32	6.23	6.85	6.42	5.78	5.55	5.49	5.59	5.47	5.79	5.35	5.42	5.89	5.82
Lat 1 to 2 / Lon 32 to 33	6.62	7.19	6.76	6.00	6.04	5.47	5.56	5.62	6.38	5.82	5.86	6.24	6.13
Lat 1 to 2 / Lon 33 to 34	6.90	7.35	6.81	6.41	6.18	5.71	5.77	6.07	6.97	6.49	6.18	6.56	6.45
Lat 1 to 2 / Lon 34 to 35	6.95	7.29	6.94	6.29	6.15	6.03	5.92	6.14	6.78	6.32	6.09	6.40	6.44
Lat 0 to 1 / Lon 29 to 30	6.30	6.75	5.95	5.70	5.64	5.26	5.09	5.11	5.59	5.35	5.23	5.76	5.65
Lat 0 to 1 / Lon 30 to 31	5.98	6.62	5.94	5.59	5.38	5.27	5.33	5.25	5.58	5.14	5.08	5.51	5.56
Lat 0 to 1 / Lon 31 to 32	6.18	6.66	6.19	5.56	5.40	5.37	5.45	5.34	5.72	5.23	5.35	5.85	5.69
Lat 0 to 1 / Lon 32 to 33	6.22	6.88	6.06	5.52	5.37	5.25	5.35	5.43	6.06	5.56	5.51	5.82	5.75
Lat 0 to 1 / Lon 33 to 34	6.80	7.11	6.45	5.92	5.57	5.40	5.41	5.59	6.29	5.92	5.77	6.04	6.02
Lat 0 to 1 / Lon 34 to 35	6.99	7.37	6.97	6.50	5.94	5.93	5.72	5.99	7.00	6.57	6.16	6.50	6.47
North Avg.	**6.61**	**7.14**	**6.58**	**5.95**	**5.79**	**5.54**	**5.52**	**5.64**	**6.29**	**5.92**	**5.79**	**6.14**	**6.08**
Lat 0 to -1 / Lon 29 to 30	5.64	6.18	5.42	5.61	5.22	5.08	5.16	5.38	5.51	5.32	5.14	5.24	5.41
Lat 0 to -1 / Lon 30 to 31	5.82	6.23	5.72	5.57	5.41	5.51	5.91	5.65	6.02	5.27	5.12	5.70	5.66
Lat 0 to -1 / Lon 31 to 32	5.64	6.49	5.85	5.34	5.28	5.63	5.81	5.41	5.67	5.28	5.14	5.64	5.60
Lat -1 to -2 / Lon 29 to 30	5.39	5.69	5.38	5.32	5.33	5.33	5.54	5.66	5.70	5.39	5.14	5.35	5.43
Lat -1 to -2 / Lon 30 to 31	5.47	5.95	5.37	5.31	5.37	5.41	5.86	5.65	5.63	5.29	4.95	5.26	5.46
South Avg.	**5.59**	**6.11**	**5.55**	**5.43**	**5.32**	**5.39**	**5.65**	**5.55**	**5.71**	**5.31**	**5.10**	**5.43**	**5.51**
Country Avg.	**6.10**	**6.62**	**6.07**	**5.69**	**5.56**	**5.47**	**5.58**	**5.59**	**6.00**	**5.61**	**5.44**	**5.79**	**5.79**

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)

II.3 Days of Autonomy (No-sun Days) Data

Table II.3-1 Monthly Average No-sun Days Data of Kenya (Avg. of year 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Lat 4 to 5 / Lon 34 to 35	3.72	5.21	3.60	3.25	2.35	5.81	3.48	2.25	4.05	2.13	5.59	4.71	3.85
Lat 4 to 5 / Lon 35 to 36	3.87	4.17	3.81	3.13	2.71	5.52	3.17	2.52	3.84	2.03	5.56	5.31	3.80
Lat 4 to 5 / Lon 36 to 37	3.01	4.27	3.64	3.16	2.59	4.08	3.37	2.69	2.92	2.35	4.34	4.23	3.39
Lat 4 to 5 / Lon 37 to 38	4.15	4.97	4.10	2.93	3.43	4.01	2.95	2.42	3.05	2.22	4.75	5.51	3.71
Lat 4 to 5 / Lon 40 to 41	6.08	4.47	3.67	1.95	3.59	5.97	6.11	4.71	2.01	3.82	2.98	4.94	4.19
Lat 3 to 4 / Lon 34 to 35	3.34	4.86	4.34	2.92	2.41	5.42	4.02	2.63	3.90	2.19	4.53	3.78	3.70
Lat 3 to 4 / Lon 35 to 36	3.66	3.53	3.54	4.34	3.31	6.04	4.50	2.00	3.71	1.89	5.54	4.64	3.89
Lat 3 to 4 / Lon 36 to 37	3.99	3.70	2.58	4.00	3.00	3.90	3.58	2.52	2.44	1.80	5.36	3.45	3.36
Lat 3 to 4 / Lon 37 to 38	5.01	4.38	2.66	3.04	3.58	2.85	3.86	2.25	2.96	3.27	5.17	4.43	3.62
Lat 3 to 4 / Lon 38 to 39	5.38	4.98	3.29	2.35	4.13	3.60	4.04	3.48	2.34	4.00	3.65	4.99	3.85
Lat 3 to 4 / Lon 39 to 40	6.53	4.76	3.42	2.75	4.10	4.02	4.80	4.50	2.51	4.24	2.89	4.71	4.10
Lat 3 to 4 / Lon 40 to 41	6.56	4.53	5.17	2.60	3.00	4.64	4.25	3.96	2.74	2.81	2.77	4.62	3.97
Lat 3 to 4 / Lon 41 to 42	6.16	2.48	3.86	2.41	2.42	4.93	3.66	3.31	3.14	2.43	3.49	4.27	3.55
Lat 2 to 3 / Lon 34 to 35	2.63	4.43	3.34	3.56	2.46	4.60	2.67	2.27	2.79	2.26	4.24	2.68	3.16
Lat 2 to 3 / Lon 35 to 36	3.73	3.65	2.98	4.04	3.23	5.60	3.63	2.11	3.14	3.21	5.51	3.18	3.67
Lat 2 to 3 / Lon 36 to 37	3.71	3.76	2.14	3.19	1.61	3.52	2.61	2.14	2.10	2.42	4.13	2.73	2.84
Lat 2 to 3 / Lon 37 to 38	5.71	4.27	2.00	2.71	2.54	2.54	3.43	2.45	2.91	3.48	4.71	4.20	3.41
Lat 2 to 3 / Lon 38 to 39	6.31	3.70	3.05	3.33	2.15	2.65	3.36	2.30	2.47	4.70	4.04	3.44	3.46
Lat 2 to 3 / Lon 39 to 40	6.79	3.86	3.95	3.46	2.33	2.95	3.92	3.88	2.52	2.93	2.66	4.05	3.61
Lat 2 to 3 / Lon 40 to 41	6.91	3.17	4.27	2.88	2.84	4.95	4.82	3.43	2.06	2.65	3.13	3.73	3.74
Lat 1 to 2 / Lon 34 to 35	3.83	4.30	1.71	2.83	2.17	3.96	2.22	2.03	3.17	4.01	6.53	3.24	3.33
Lat 1 to 2 / Lon 35 to 36	4.65	3.61	3.03	3.48	3.28	6.24	2.67	2.23	4.02	3.06	6.01	2.79	3.76
Lat 1 to 2 / Lon 36 to 37	4.96	3.28	2.59	2.85	3.10	5.35	4.00	2.42	3.65	3.49	5.84	2.86	3.70
Lat 1 to 2 / Lon 37 to 38	6.59	3.35	1.97	3.28	2.79	4.54	3.52	2.99	3.46	3.44	5.21	4.64	3.82
Lat 1 to 2 / Lon 38 to 39	4.80	3.61	2.23	3.97	1.75	3.01	3.05	2.12	3.07	3.20	3.72	2.55	3.09
Lat 1 to 2 / Lon 39 to 40	4.42	3.08	2.58	3.38	1.68	2.74	2.75	2.75	1.83	2.89	2.16	3.15	2.78
Lat 1 to 2 / Lon 40 to 41	4.92	2.62	2.56	1.44	1.36	3.11	3.57	1.78	2.14	2.26	3.07	2.96	2.65
Lat 0 to 1 / Lon 34 to 35	2.73	4.59	2.91	2.45	2.26	3.50	2.18	1.21	4.15	2.12	4.94	2.98	3.00
Lat 0 to 1 / Lon 35 to 36	3.97	3.75	3.29	4.04	3.11	4.33	2.12	3.08	4.79	2.49	5.92	3.48	3.70
Lat 0 to 1 / Lon 36 to 37	5.83	3.56	3.04	2.67	3.04	4.48	2.68	3.46	4.15	3.43	5.21	3.31	3.74
Lat 0 to 1 / Lon 37 to 38	6.18	2.89	2.67	2.81	3.72	4.53	3.25	3.72	4.72	3.67	5.00	4.17	3.94
Lat 0 to 1 / Lon 38 to 39	6.69	2.88	2.01	2.70	2.63	4.30	3.96	3.02	3.89	4.58	4.50	2.99	3.68
Lat 0 to 1 / Lon 39 to 40	3.59	3.78	2.11	1.67	1.47	2.51	2.17	3.02	1.47	3.41	2.50	2.61	2.53
Lat 0 to -1 / Lon 34 to 35	3.47	3.88	3.64	3.09	2.62	3.94	2.98	2.22	2.43	2.74	3.90	2.17	3.09
Lat 0 to -1 / Lon 35 to 36	4.65	3.56	3.40	2.61	1.91	4.14	2.60	2.11	2.07	2.08	5.31	4.20	3.22
Lat 0 to -1 / Lon 36 to 37	7.28	3.16	2.84	3.23	3.48	5.46	2.88	3.05	5.81	2.66	5.48	3.94	4.11
Lat 0 to -1 / Lon 37 to 38	6.65	3.93	3.37	2.66	3.84	5.66	5.18	4.86	4.85	3.15	4.18	4.20	4.38
Lat 0 to -1 / Lon 38 to 39	4.51	3.53	2.07	3.16	2.56	5.31	3.35	4.61	4.82	4.75	3.67	4.05	3.87
Lat 0 to -1 / Lon 39 to 40	3.86	3.74	2.16	2.91	2.37	2.47	2.54	2.78	2.34	3.16	2.79	2.65	2.81
Lat 0 to -1 / Lon 40 to 41	2.99	3.10	2.00	3.76	2.56	2.01	2.28	2.15	2.33	2.62	3.06	1.84	2.56
North Avg.	**4.85**	**3.83**	**3.04**	**3.02**	**2.74**	**4.23**	**3.40**	**2.84**	**3.17**	**3.00**	**4.35**	**3.71**	**3.52**
Lat -1 to -2 / Lon 34 to 35	4.86	4.51	3.28	2.75	3.34	3.64	3.18	3.17	2.11	2.22	4.08	4.74	3.49
Lat -1 to -2 / Lon 35 to 36	4.87	4.04	2.81	2.82	3.92	3.79	2.31	2.13	2.57	2.70	3.69	3.83	3.29
Lat -1 to -2 / Lon 36 to 37	5.16	5.26	4.00	2.93	4.39	3.75	3.61	3.63	4.89	2.62	3.81	2.35	3.87
Lat -1 to -2 / Lon 37 to 38	6.19	4.47	3.38	3.11	4.25	4.66	4.93	5.50	3.61	3.27	3.49	3.62	4.21
Lat -1 to -2 / Lon 38 to 39	5.05	3.68	2.52	2.05	3.83	3.93	3.29	3.95	3.21	3.90	2.99	3.21	3.47
Lat -1 to -2 / Lon 39 to 40	2.90	3.01	2.02	2.95	2.94	2.20	1.85	2.59	2.54	3.50	2.42	3.26	2.68
Lat -1 to -2 / Lon 40 to 41	3.02	2.54	2.19	2.83	3.57	2.30	1.74	2.22	2.82	3.47	3.15	1.84	2.64
Lat -1 to -2 / Lon 41 to 42	6.42	2.19	1.69	2.77	3.45	2.81	1.71	1.82	2.49	3.46	4.54	2.71	3.01
Lat -2 to -3 / Lon 36 to 37	5.84	5.03	2.71	2.21	3.45	2.96	3.23	3.42	2.93	2.32	3.63	3.58	3.44
Lat -2 to -3 / Lon 37 to 38	6.55	4.25	2.45	2.32	4.60	4.00	3.34	5.74	3.82	2.32	3.54	3.27	3.85
Lat -2 to -3 / Lon 38 to 39	5.75	3.95	1.80	2.12	3.51	3.23	2.36	3.63	3.27	3.94	2.95	3.47	3.33
Lat -2 to -3 / Lon 39 to 40	2.68	2.23	1.75	2.91	3.78	1.66	1.63	2.59	1.63	3.88	4.04	2.45	2.60
Lat -2 to -3 / Lon 40 to 41	4.24	1.92	1.56	2.46	2.65	2.88	2.10	2.40	1.84	5.45	4.33	2.23	2.84
Lat -3 to -4 / Lon 37 to 38	6.50	6.36	2.57	2.11	4.75	3.45	3.14	4.18	3.67	3.88	3.70	3.88	4.02
Lat -3 to -4 / Lon 38 to 39	6.37	5.66	2.87	2.19	3.84	1.73	2.41	4.48	3.70	4.76	3.77	2.73	3.71
Lat -3 to -4 / Lon 39 to 40	3.14	3.07	1.92	2.76	4.17	1.77	1.68	2.86	1.57	4.57	3.51	2.35	2.78
Lat -3 to -4 / Lon 40 to 41	5.46	3.92	4.23	5.08	5.03	3.15	2.20	5.12	2.85	5.57	5.45	3.02	4.26
Lat -4 to -5 / Lon 38 to 39	5.04	7.27	2.46	4.95	4.73	2.01	2.39	3.80	2.85	4.09	3.92	2.48	3.83
Lat -4 to -5 / Lon 39 to 40	3.47	5.90	2.17	4.25	4.60	2.53	2.03	4.65	4.06	5.68	3.18	3.08	3.80
South Avg.	**4.92**	**4.17**	**2.55**	**2.92**	**3.94**	**2.97**	**2.59**	**3.57**	**2.97**	**3.77**	**3.69**	**3.06**	**3.43**
Country Avg	**4.88**	**4.00**	**2.79**	**2.97**	**3.34**	**3.60**	**3.00**	**3.20**	**3.07**	**3.38**	**4.02**	**3.38**	**3.47**
Country Min.	2.63	1.92	1.56	1.44	1.36	1.66	1.63	1.21	1.47	1.80	2.16	1.84	2.53
Country Max.	7.28	7.27	5.17	5.08	5.03	6.24	6.11	5.74	5.81	5.68	6.53	5.51	4.38

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)

Table II.3-2 Monthly Average No-sun Days data of Uganda (Avg. of year 1983-2004)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Lat 3 to 4 / Lon 30 to 31	2.23	4.05	3.55	2.29	2.82	3.10	3.70	2.03	2.59	2.51	3.67	4.01	3.05
Lat 3 to 4 / Lon 31 to 32	2.40	4.20	3.20	2.12	3.76	2.83	3.50	2.31	3.45	4.13	4.16	4.05	3.34
Lat 3 to 4 / Lon 32 to 33	2.21	3.89	3.47	1.68	2.25	3.46	2.43	2.69	2.86	2.93	5.73	3.96	3.13
Lat 3 to 4 / Lon 33 to 34	2.40	5.25	3.82	2.73	2.90	4.44	2.56	2.76	2.45	2.63	4.46	3.34	3.31
Lat 3 to 4 / Lon 34 to 35	3.34	4.86	4.34	2.92	2.41	5.42	4.02	2.63	3.90	2.19	4.53	3.78	3.70
Lat 2 to 3 / Lon 30 to 31	3.51	3.94	3.46	3.52	4.12	2.85	2.88	2.80	2.86	3.39	5.30	4.92	3.63
Lat 2 to 3 / Lon 31 to 32	2.42	5.42	2.63	2.63	2.88	4.32	3.65	3.39	4.30	4.23	3.99	2.96	3.57
Lat 2 to 3 / Lon 32 to 33	2.40	4.82	2.69	1.83	2.21	3.66	2.28	3.03	3.34	3.73	5.53	4.00	3.29
Lat 2 to 3 / Lon 33 to 34	2.54	4.51	2.48	2.66	2.63	4.45	2.79	3.42	3.15	3.09	4.86	2.83	3.28
Lat 2 to 3 / Lon 34 to 35	2.63	4.43	3.34	3.56	2.46	4.60	2.67	2.27	2.79	2.26	4.24	2.68	3.16
Lat 1 to 2 / Lon 30 to 31	3.28	4.07	2.67	2.00	2.99	2.83	2.22	2.19	2.83	3.25	4.14	3.54	3.00
Lat 1 to 2 / Lon 31 to 32	2.11	5.54	3.65	2.20	2.32	3.73	2.78	2.74	2.29	3.53	4.58	3.53	3.25
Lat 1 to 2 / Lon 32 to 33	2.29	5.37	2.74	3.07	2.81	2.53	2.93	2.24	2.89	2.90	5.63	3.72	3.26
Lat 1 to 2 / Lon 33 to 34	2.49	4.43	1.94	2.45	2.43	3.39	1.69	3.06	3.47	2.47	6.48	3.06	3.11
Lat 1 to 2 / Lon 34 to 35	3.83	4.30	1.71	2.83	2.17	3.96	2.22	2.03	3.17	4.01	6.53	3.24	3.33
Lat 0 to 1 / Lon 29 to 30	3.92	3.41	4.29	2.89	2.02	3.51	2.27	3.08	2.45	3.34	5.06	3.43	3.31
Lat 0 to 1 / Lon 30 to 31	2.90	4.54	3.74	2.63	2.24	2.77	2.34	2.31	3.13	3.85	5.58	2.77	3.23
Lat 0 to 1 / Lon 31 to 32	3.17	4.54	3.08	2.19	2.41	3.12	2.27	2.60	2.67	2.38	3.95	4.48	3.07
Lat 0 to 1 / Lon 32 to 33	3.76	4.61	3.26	2.41	2.51	3.04	2.74	2.03	2.14	3.08	6.04	3.75	3.28
Lat 0 to 1 / Lon 33 to 34	4.10	5.80	3.27	3.33	3.78	3.24	3.43	2.52	3.43	2.71	4.94	3.38	3.66
Lat 0 to 1 / Lon 34 to 35	2.73	4.59	2.91	2.45	2.26	3.50	2.18	1.21	4.15	2.12	4.94	2.98	3.00
North Avg.	**2.89**	**4.60**	**3.15**	**2.59**	**2.68**	**3.56**	**2.74**	**2.54**	**3.06**	**3.08**	**4.97**	**3.54**	**3.28**
Lat 0 to -1 / Lon 29 to 30	3.05	3.54	2.50	2.51	2.02	3.06	3.96	3.21	4.36	3.29	4.34	1.82	3.14
Lat 0 to -1 / Lon 30 to 31	2.87	3.57	2.80	2.81	2.90	3.04	3.41	3.67	2.55	3.49	4.24	3.21	3.21
Lat 0 to -1 / Lon 31 to 32	3.11	4.39	3.71	2.04	2.75	3.76	3.13	2.22	1.93	4.80	4.98	4.51	3.44
Lat -1 to -2 / Lon 29 to 30	4.04	2.92	2.34	2.37	3.10	3.11	3.22	4.41	4.55	5.81	4.07	3.37	3.61
Lat -1 to -2 / Lon 30 to 31	2.51	4.13	2.18	2.04	3.22	3.85	3.85	4.56	3.49	4.43	4.75	3.59	3.55
South Avg.	**3.16**	**4.19**	**2.86**	**2.52**	**2.84**	**3.39**	**3.24**	**3.04**	**3.44**	**3.72**	**4.65**	**3.30**	**3.36**
Country Avg	**3.03**	**4.43**	**3.06**	**2.55**	**2.71**	**3.52**	**2.90**	**2.75**	**3.13**	**3.33**	**4.87**	**3.49**	**3.31**
Country Min.	2.11	2.92	1.71	1.68	2.02	2.53	1.69	1.21	1.93	2.12	3.67	1.82	3.00
Country Max.	4.10	5.80	4.34	3.56	4.12	5.42	4.02	4.56	4.55	5.81	6.53	4.92	3.70

Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Source: NASA (http://eosweb.larc.nasa.gov/)