No.

The Master Plan Study
on
Rural Electrification
Using
Renewable Energy Resources
in the
Northern Part of the Republic of Ghana

Final Report
(Technical Background Report)

May 2006

Japan International Cooperation Agency
Economic Development Department

ED
JR
06-070

Preface

In response to the request from the Government of the Republic of Ghana, the Government of Japan decided to conduct the Master Plan Study on Rural Electrification by Renewable Energy Resources in the Northern Part of the Republic of Ghana, and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent the Study Team, headed by Mr. Masayasu ISHIGURO of Nomura Research Institute, Ltd. and organized by Nomura Research Institute, Ltd. and Chubu Electric Power., Inc. to Ghana five times from February 2005 to May 2006.

The Study Team had a series of discussions with the officials concerned of the Government of the Republic of Ghana and Ministry of Energy, and conducted related field surveys. After returning to Japan, the Study Team conducted further studies and compiled the final results in this report.

I hope that this report will contribute to the promotion of the plan and to the enhancement of amity between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Ghana, Ministry of Energy for their close cooperation throughout the Study.

May 2006

Tadashi IZAWA
Vice President
Japan International Cooperation Agency

May 2006

Mr. Tadashi IZAWA
Vice President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We have concluded the Master Plan Study on Rural Electrification Using Renewable Energy Resources in the Northern Part of the Republic of Ghana, and hereby present the final report for Study.

The Study was implemented on the basis of a contract with the Japan International Cooperation Agency (JICA) by Nomura Research Institute, Ltd. and Chubu Electric Power Co., Inc. over a period of approximately 16 months, from February 2005 to May 2006.

The Study consisted of preparation of a Master Plan premised on establishment of a setup enabling promotion of off-grid electrification on a sustained basis utilizing photovoltaic (PV) power generation systems in the three northern regions of Ghana. Besides taking up problems that have affected past PV projects, the Study Team examined advisable approaches to rural electrification (RE) through both on-grid and off-grid programs, and identified tasks for the future in the institutional and organizational aspects as well. In parallel with this work, the Study Team made in-depth examinations and analyses in the technical aspect, on subjects such as procedure for forecasting demand in RE promotion, segmentation between on-grid and off-grid programs, postulation of electrification models, and establishment of technical standards. As the culmination of these operations, the Study Team made recommendations concerning the approach to RE through PV systems from a holistic standpoint.

We are convinced that the implementation of these recommendations will enable sustainable RE promotion in Ghana and, by extension, make a substantial contribution to social advancement in the northern regions.

We earnestly hope that the Ghanaian government will actively apply the technology and know-how transferred through the Study and implement the recommendations in this report on a priority basis.

We are deeply indebted to the concerned personnel of the JICA, the Ministry of Foreign Affairs, and Ministry of Economy, Trade and Industry for their support and advice. We are also grateful for the assistance and support received in the implementation of the Study from the Ghanaian government and other concerned Ghanaian institutions as well as the JICA office and the Japanese embassy in Ghana.

Very truly yours,

Masayasu ISHIGURO
Team Leader
The Master Plan Study on Rural Electrification
Using Renewable Energy Resources in the
Northern Part of the Republic of Ghana

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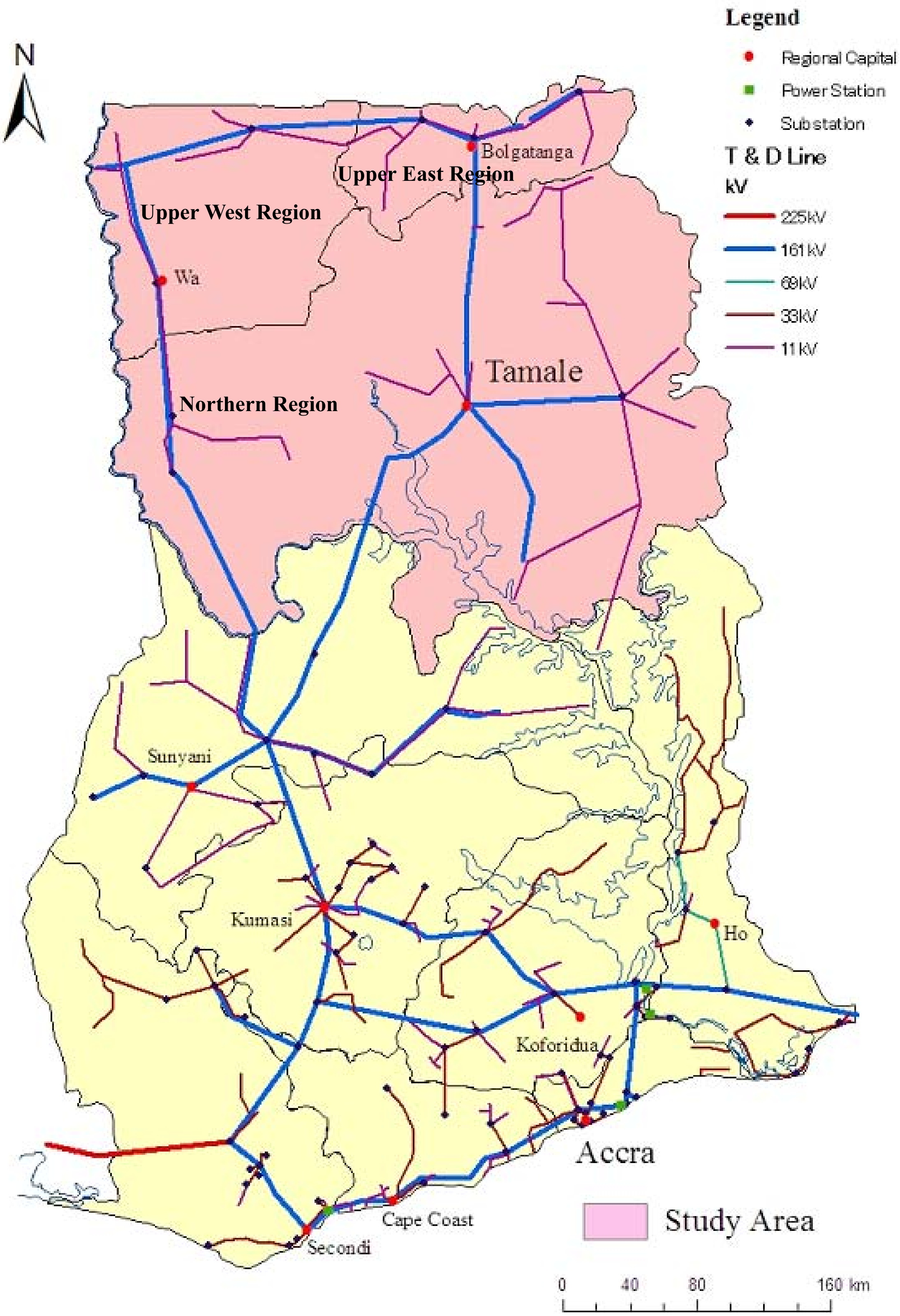
Acronyms

AAC	All Aluminum Conductor
AC	Alternating Current
BCS	Battery Charging Station
BOHS	Battery Operated Home Systems
CDM	Clean Development Mechanism
CEB	Benin Electricity Community
CIE	Compagnie Ivoirienne d' Electricite
DANIDA	Danish Agency for Development Assistance
DC	Direct Current
EC	Energy Commission
ECG	Electricity Company of Ghana
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ESCO	Energy Service Company
EU	European Union
FGD	Focus Discussion Group
FS	Feasibility Study
GDP	Gross Domestic Product
GEF	Global Environmental Facilities
GIS	Geographic Information System
GNPC	Ghana National Petroleum Corporation
GPRS	Ghana Poverty Reduction Strategy
GSB	Ghana Standards Board
HIPC	Highly Indebted Poor Country
ICT	Information and Communication Technology
IPP	Independent Power Producer
JI	Joint Implementation
JICA	Japan International Cooperation Agency
JSS	Junior Secondary School
KII	Key Informant Interview
KNUST	Kwame Nkhrumah University of Science and Technology
M/M	Minutes of Meeting
MLGRD	Ministry of Local Government and Rural Development
MME	Ministry of Mines and Energy
MOE	Ministry of Energy
MOEdu	Ministry of Education
MOH	Ministry of Health
MOI	Ministry of Industry
NED	Northern Electrification Department
NEDO	New Enwrgy and Industrial Technology Development Organization
NEF	National Electrification Fund
NEFB	National electrification Fund Board
NES	National Electrification Scheme

NGO	Non Governmental Organization
O&M	Operation and Maintenace
ODA	Official Development Assistant
OJT	On the Job Trainning
PURC	Public Utilities Regulatory Commission
PV	Photo Voltaic
RE	Rural Electrification
RESCO	Rural Energy Service Company
RESPRO	Renewable Energy Service Project
RET s	Renewable Energy Technologies
S/W	Scope of Works
SHEP	Self Help Electrification Programme
SHS	Solar Home System
SNEP	Strategic National Energy Plan
TAPCO	Takoradi Power Company
TICO	Takoradi International Company
TOR	Tema Oil Refinery
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
USAID	United States Agency for International Development
VRA	Volta River Authority
WB	World Bank



(Source) JICA Study Team

Figure: Transmission and Distribution Network in Ghana

Chapter 1 Introduction

1.1 Backgroud and objectives of the study

1.1.1 Particulars leading up to the study

The Republic of Ghana continues to have a serious problem of poverty in rural communities. The Ghana Poverty Reduction Strategy (GPRS) paper not only positions rural electrification (RE) projects as essential for improvement of the standard of living and eradication of poverty among residents of these communities, but also points out the need for installation of renewable energy systems.

The Ghana Ministry of Energy (MOE) is targeting electrification of all communities with at least 500 residents by 2020 as a final objective. To this end, it has formulated the National Electrification Scheme (NES) and the Self Help Electrification Project (SHEP, a NES component), and is promoting RE through extension of distribution lines. However, the power sector has fallen into financial difficulties due to factors such as the steep depreciation of the Ghana cedi and non-payment of power charges by large-scale customers. As a result, RE projects are not making much headway in rural communities. Specifically, the electrification rate in the rural areas centered in the northern part of the country is extremely low at an average 20%, as compared to corresponding rates of 30% nationwide and 60% in urban areas.

The northern savanna region, where poverty is concentrated, is characterized by a low population density and scattered distribution of communities and houses. These attributes present cost-related limits to electrification by extension of distribution lines. The region also offers a high and stable amount of insolation, and consequently has good possibilities for electrification by dispersed power sources utilizing photovoltaic (PV) and other renewable energy systems.

Under these circumstances, in June 2003, the Ghanaian government requested the Japanese government to conduct a developmental study for the purpose of formulating a master plan for RE over the medium and long terms utilizing renewable energy in the northern rural areas as well as examining approaches to a sustainable implementing setup. The Japan International Cooperation Agency (JICA) sent a project formation study team to Ghana in February 2004 and a preliminary study team there in October 2004. The latter team considered the particulars behind the request as well as Ghanaian wishes regarding the study, and confirmed its importance.

This study will be implemented in accordance with the Scope of Works (S/W) signed by the Ghana government and JICA on 12 November 2004 and the minutes of meetings (M/M) signed by the same two parties on 2 March and 6 October 2004.

1.1.2 Study objectives

(1) Formulation of a master plan for RE utilizing renewable energy in northern Ghana trough:

    1) Policy recommendations for RE utilizing renewable energy
    2) Plan for RE utilizing off-grid PV systems
    3) An action plan for sustained diffusion of off-grid renewable energy systems

(2) Transfer of technology for sustained implementation of RE utilizing renewable energy

1.1.3 Study regions

The study will cover the three regions in the northern part of the country, i.e., the Northern Region, Upper West Region, and Upper East Region.

1.1.4 Counterpart organization

The counterpart organization will be the Ghana Ministry of Energy (MOE).

1.2 Membership of the Study Team

Table 1.2.1 shows the membership of the JICA Study Team and their respective fields.

Table 1.2.1 Membership of the Study Team

No.	Name	Field
1	Masayasu ISHIGURO	Leader, rural electrification policy
2	Yasuhiro KAWAKAMI	Subleader, organizational and institutional issues for electrification using renewable energy resources
3	Hiroo YAMAGATA	Economic and financial analyses in the energy sector
4	Shigenobu HANDA	Village socioeconomic study
5	Masaru MIYAGI	Photovoltaic systems and other renewable energy technology
6	Toshiaki KIMURA	GIS/data bases
7	Keiji SHIRAKI	Distribution planning

1.3 Overall work and schedule

1.3.1 Overall work

The study consists of four stages.

Stage 1 (stage of target clarification)

The Study Team clarified the objective and framework of the study with the Ghanaian side through discussion of the Inception Report and the first workshop.

Stage 2 (stage of basic study and RE policy study)

This stage was devoted to information collection and analysis in the following areas.

- Collection and review of basic information in areas such as RE policy, power development plans, energy supply and demand, and renewable energy
- Commencement of the village socioeconomic study and reconsigned field study
- Study of comprehensive RE policy and the framework for off-grid PV RE

Stage 3 (stage of off-grid PV RE planning)

In this stage, the Study Team clarified specific strategies and guidelines for the autonomous and sustained spread of off-grid PV RE, and prepare a plan for the same, through the following work.

- Formulation of comprehensive RE policy and the framework for off-grid PV RE
- Establishment of criteria for selection of off-grid PV RE sites
- Clarification of prerequisites of the off-grid PV RE model and conditions related to sustained diffusion
- Clarification of the roles and responsibilities of the government, the RESPRO, and the private-sector PV industry, and formulation of strategy for promotion
- Formulation of off-grid PV RE strategy consistent with public service improvement

Stage 4 (stage of action plan formulation)

Stage 4 consists of formulation of an action plan for execution of the Master Plan (for RE in northern Ghana using renewable energy resources), i.e., a plan of action needed for achievement of the Master Plan agenda and resolution of problems surfacing in the process of execution. Figure 1.3.1 shows the overall flow of the study work.

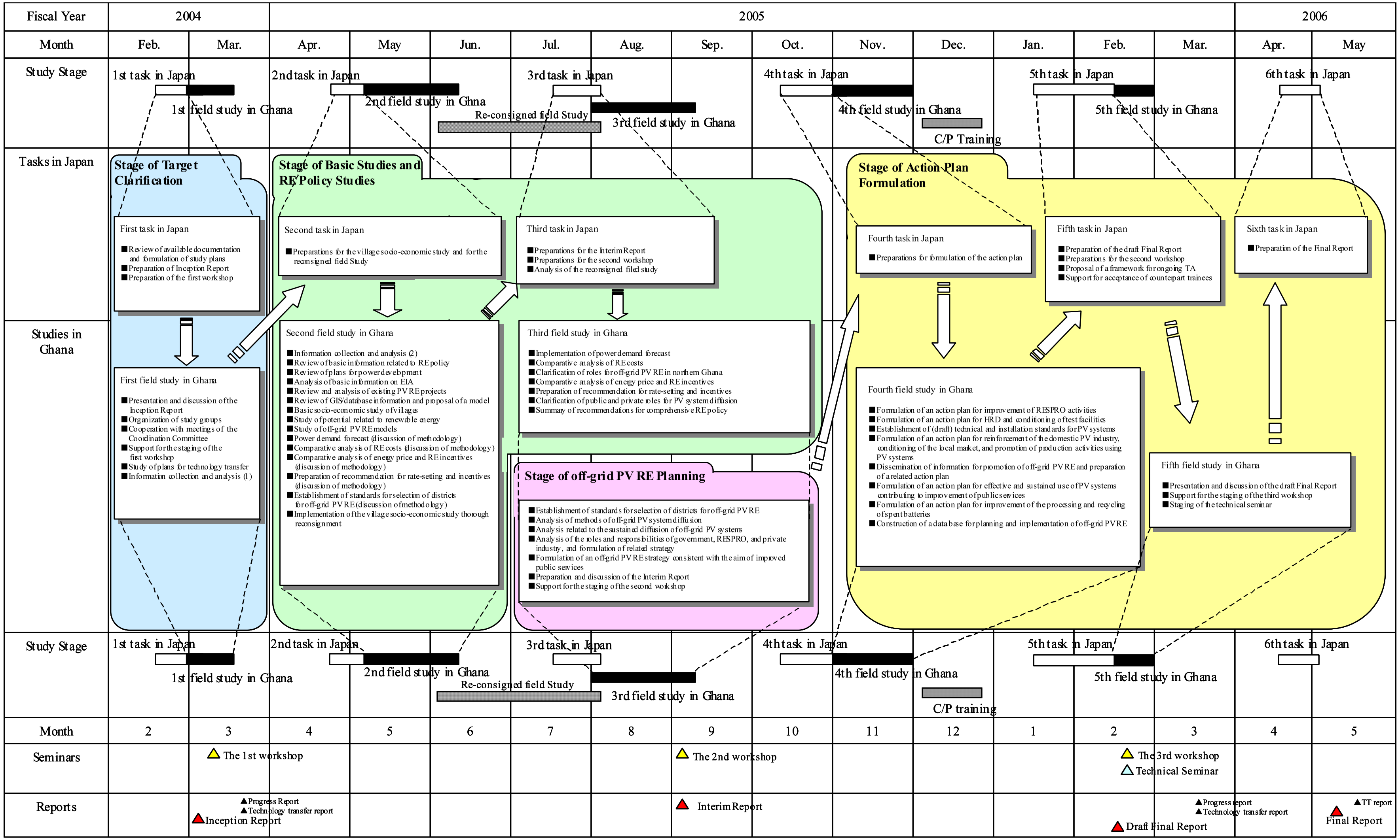
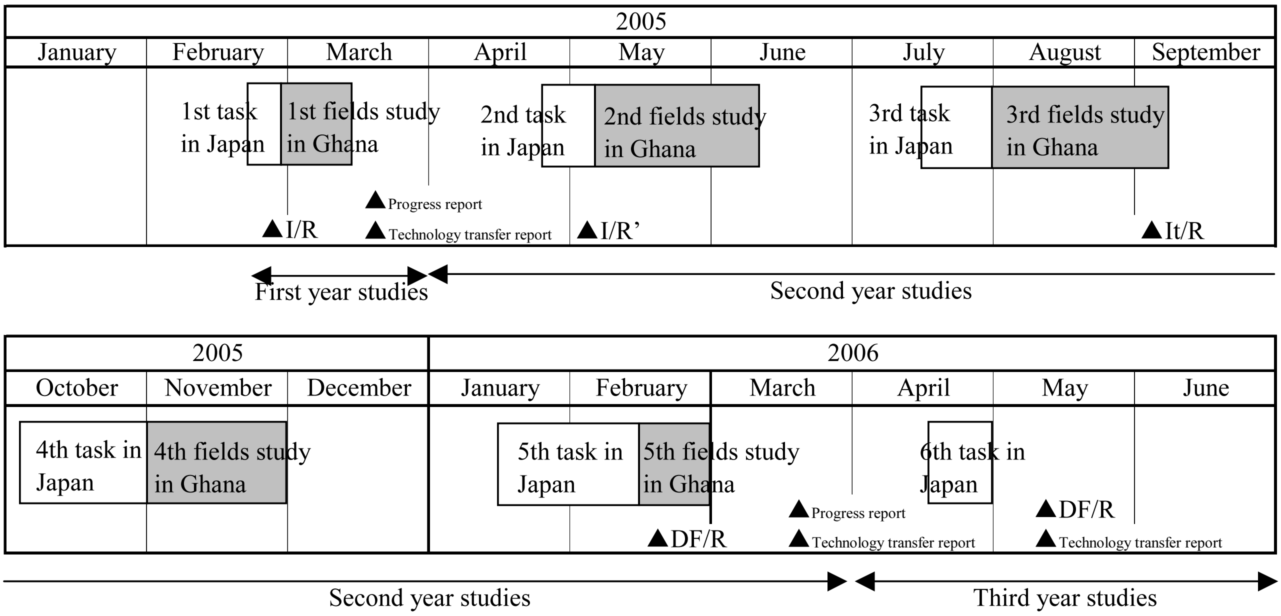


Figure 1.3.1 Overall flow of the study work

1.3.2 Overall schedule

This study was implemented over a period of about 16 months, from February 2005 to May 2006, and to include a total of five field studies in Ghana.

Figure 1.3.2 shows the overall schedule.



I/R: Inception Report	I/R': Revised Inception Report	It/R: Interim Report
DF/R: Draft Final Report	F/R: Final Report	

Figure 1.3.2 Overall schedule

1.4 Organization of study groups

This study is not aimed merely at the transfer of PV technology. There is a need for transfer of the diverse assortment of technology required for the formulation of the Master Plan. This assortment includes macro approaches in the aspects of policies and institutions, micro approaches with resident participation, approaches with citizen participation, and approaches reflecting concern for the local socioeconomic situation. As such, the study must be implemented in close coordination with the counterpart and other concerned institutions right from the start. The Study Team decided to establish study groups for effective transfer of practical technology through collaborative work and smooth execution of the study.

Table 1.4.1 presents the main activities of each group.

Table 1.4.1 Study groups and main activities

Study group name	Main subjects of study activities
RE Policy and Institution Group	・Conformance with electrification policy (on-grid & off-grid) ・Measures for RE promotion ・Measures to promote use of renewable energy for RE
Off-grid PV Electrification Organization and Institution Group	・Organization for project operation ・Tariff schemes and procedure for charge collection ・Procedures for use of PV systems rooted in district development
PV System Technology Group	・Technical and installation standards (technical studies) ・Materials and programs needed by the test center ・Training program for technicians
Economic & Financial Analysis/Demand Forecast Group	・Comparison with reasonable energy prices ・Techniques for economic and financial analysis of projects ・Techniques for demand forecasting (estimate) in prospective sites
Village Socioeconomic Study Group	・Techniques for data collection ・Techniques for village data analysis
GIS/Data Base Group	・Construction of a data base using the GIS for the collected data ・Techniques for updating the data base
Distribution Planning Group	・Confirmation of the on-grid RE plans ・Comparative study of RE costs

Chapter 2 Legislative framework of the power sector

2.1 Structure of the power sector

Ghana depends on electrical power for about 8% of its final energy consumption. The power source mix consists mainly of hydropower, with some import from the neighboring Cote d'Ivoire. More specifically, of the entire installed generation capacity of 1,652,000kW, hydropower accounts for 1,072,000kW, followed by thermal power at 550,000kW and an emergency-use diesel power generation system in Tema at 30,000kW.

According to the 2002 census report, some 43% of the population have access to electricity, and about 80% of the civil power supply is confined to the urban areas.

Besides the Ministry of Energy (MOE), which is the policy-making body which has jurisdiction over energy, the following five institutions are involved with the energy sector.

- Energy Commission (EC): advice, planning, regulation, and supervision related to energy policy
- Public Utilities Regulatory Commission (PURC): tariff regulation
- Volta River Authority: power generation and transmission
- Electricity Company of Ghana (ECG): distribution (southern regions)
- Northern Electrification Department (NED): distribution (northern regions)

2.1.1 EC

The Energy Commission (EC) was established in accordance with the Energy Commission Act of 1997 (Act 541). Its role lies in regulation and administration related to use of energy resources, and related policy coordination.

In particular, the EC offers recommendations regarding the development and use of domestic energy resources, advises the Minister of Energy in the policy aspect, and builds frameworks for energy industry regulation and supervision. The types of energy industry regulation include enterprise licensing, inspection, and supervision.

As other parts of its role, the EC also reviews national plans, constructs data bases needed for deciding policy for energy development, and encouragement of competition in the energy market.

The Minister of Energy is responsible to the EC, which has a membership of seven, consisting of the chairperson and six members.

2.1.2 PURC

The Public Utilities Regulatory Commission (PURC) was established in accordance with the Public Utilities Regulatory Commission Act of 1997 (Act 538). It is in engaged in the regulation and supervision of services provided by public utilities. At present, it regulates the power and water sectors, and is to regulate natural gas in the future.

The PURC has a membership of nine. Members are appointed by the president of the Republic. The main duties of the PURC are as follows.

- Establishment of guidelines for the setting of tariffs for services provided by public utilities
- Examination and approval of water tariffs and power tariffs
- Protection of the interests of consumers and enterprises
- Supervision of public utility services for assurance of observance of standards
- Encouragement of competition among public utilities
- Examination and arbitration of disputes between customers and public utilities
- Advice for public utilities

Act 538 invests the PURC with the authority to enact regulations. Thus far, it has enacted two regulations: the Public Utiliities Termination of Service Regulation 1999 (LI1651), which sets conditions for the termination of service provision, and the Public Utilities Complaints Procedure Regulation 1999 (LI1665), which stipulates procedures for the lodging of complaints by public utilities or customers.

2.1.3 VRA

At present, all hydropower generation is conducted on the responsibility of the Volta River Authority (VRA). The VRA was established in 1961 in accordance with the Volta River Development Act (Act 46), for development of the river system, use of the system to generate power, transmission, and wholesale power supply.

The VRA owns two hydropower stations at Aksombo and Kpong, and one thermal power station at Aboadze. The Aksombo power station is now undergoing improvement. When this improvement is finished, the generation capacity will be increased to 108,000kW and thereby raise the VRA's total output to 1.02 million kW.

The Aboadze thermal power station is divided between two companies: the Takoradi Power Company (TAPCO) and Takoradi International Company (TICO). TAPCO operates a 330,000kW combined-cycle generation facility. TICO is run as a joint venture of the VRA and the CMS in Michigan, United States of America. It used to operate two 110,000kW gas turbine generators that were modeled after the TAPCO station as a single cycle. In 2004, however, it switched to a combined-cycle operation, and the capacity was increased to 330,000kW.

As of 2004, Ghana had a total installed power generation capacity of 1,762,000kW (see Table 2.1.1).

Table 2.1.1 Power generation facility capacity in Ghana (as of 2004)

Power station	Facility capacity(MW)
Hydropower	1,072 (61%)
Aksombo hydropower	912
Kpong hydropower	160
Thermal power	690 (39%)
Aboadze thermal power	660
Tema diesel	30

(Source) VRA, MOE

In addition to these generation facilities, Ghana imports up to 250,000kW of power from Cote d'Ivoire to meet the domestic demand.

Until 1995, Ghana had a surplus supply capacity and exported power to the CIE in Cote d'Ivoire as well as to Togo and Benin. Thereafter, however, the supply capacity rapidly dropped with increase in demand and inappropriate extension of distribution lines. Now, on the contrary, it has concluded a contract with Cote d'Ivoire for import of a maximum of 250,000kW.

In June 2002, the VRA concluded a contract for export of power to SONABEL in Burkina Faso, and commenced this export that October.

In addition to its grid power, the VRA has installed over 4,000 PV systems with a combined capacity of about 1,000kW.

2.1.4 ECG

The Electricity Company of Ghana (ECG) was registered as a joint-stock company in October 1997, in accordance with the 1993 Company Act (Act 461) and the 1963 Companies Code. It succeeded the Electric Corporation of Ghana, which was established in 1967 by government ordinance (NLCD 125), and the government holds all of its stock.

The ECG purchases all of its power from the VRA in bulk, and is one of the distribution firms selling to final consumers. It is obligated to distribute and supply power in eight districts (Accra East, Accra West, Tema, Eastern, Central, Western, Ashanti, and Volta).

Since 1997, the amount of ECG power sales has increased at an annualized rate of 3.9%. In 2002, it came to 4.3 billion kWh. The number of customers, on the other hand, grew by a corresponding rate of 9.2% from 1999 to 2002, when it reached about 970,000. In other words, there was a rapid increase in the pool of small customers.

The ECG has a high rate of distribution loss; in 2002, the rate came to 26% as compared to the benchmark value of 18%. Much of this loss is caused by non-technical loss. The rate of charge collection is no higher than about 80%, much lower than the rate of 95% established by the PURC as a guideline. Improper meter reading accounts for about 50% of this loss, followed by meter bypassing at 25 %, direct connection from cables at 10%, charge errors at 5%, and unauthorized reconnection at 5% (according to the 2001 Annual Report).

Table 2.1.2 Energy purchase and sales, and system loss of the ECG

(Unit: GWh)

	1997	1998	1999	2000	2001	2002	Growth Rate (97 - 02)
Total Energy Purchases	3,386	3,118	3,846	3,989	4,175	4,326	5.0%
Total Energy Sales	2,647	2,417	2,828	3,086	3,080	3,200	3.9%
System Loss	739	701	1,019	903	1,095	1,127	-
System Loss Rate	21.8%	22.5%	26.5%	22.6%	26.2%	26.0%	-

(Source) ECG Annual Report

Table 2.1.3 Number of ECG customers

(Unit: customer units)

	1997	1998	1999	2000	2001	2002	Growth Rate (97 - 02)
Special load tariff	-	-	-	-	-	827	-
Non-special load tariff	-	-	-	-	-	936,299	-
Prepaid tariff	-	-	-	-	-	32,548	-
Total	-	-	744,005	832,593	893,880	969,674	9.2%

(Source) ECG Annual Report

2.1.5 NED

The Northern Electrification Department (NED) was established in 1987 as a subsidiary of the VRA. It took over the responsibility for distribution and supply to the northern regions (Brong Ahafo, Northern, Upper East, and Upper West) from the ECG.

There has been a rapid rise in the number of NED customers and power sales. The number of customers rose from 139,683 in 2002 to 174,144 in 2004, for an increase averaging 11.7% annually. Over the same period, the power sales increased from 265.4 to 324.5 million kWh for a corresponding increase rate of 10.6%. This increase in sales reflects that in the number of communities connected to the distribution lines under the NES and the SHEP.

Table 2.1.4 Status of NED projects

	2002	2003	2004	Growth Rate (02 - 04)
Total Energy Supplied (GWh)	383.0	423.9	480.3	12.0%
Total Energy Billed (GWh)	265.4	284.5	324.5	10.6%
Total Energy Accounted for (GWh)	271.4	292.4	336.0	11.3%
System Loss (%)	29.1%	31.4%	30.1%	-
Billed Revenue (bilion cedis)	128.9	203.1	259.7	-
Collected Revenue (billion cedis)	89.5	141.2	202.1	-
Collection Rate (%)	69%	70%	78%	-
Accounts Receivables (days)	77.1	132.5	200.8	-
Debtors Collection Period (days)	218.0	238.0	282.0	-
Customer Population	139,683	150,950	174,144	11.7%
Average Tariff (cedis/kWh)	486	714	797	-

(Source) NED Annual Report

The NED had a high (30.1%) rate of system loss in 2004. The following may be cited as causes of this high loss.

- Low-voltage feeders that extend for long distances and carry excessive load
- Excessive load on transformers
- Outdated distribution network
- Surreptitious use
- Inefficient meter reading and billing
- Business resources inappropriate for operation over the wide service area

The NED operates over an expansive and impoverished area that covers about 65% of the country. In many cases, the customer sites are scattered and receive lifeline tariffs. These adverse conditions drive up the investment and operating costs. Because of these issues, the NED's financial situation has worsened to an extreme degree, and it is receiving a lot of aid from the VRA for its operation.

2.2 Power sector policy

The MOE announced energy policy in 2002 and revised this policy in 2004. The government's power sector policy is set forth in the context of this larger policy.

2.2.1 Poverty reduction

Ghana's energy policy is closely linked to strategy for poverty reduction.

In 1999 Ghana suffered from a serious terms of trade shock, with prices for Ghana's main exports, gold and cocoa, falling and prices for oil imports rising. This, combined with a delay in adjusting fiscal and monetary policy, led to sharp depreciation of the exchange rate and rapid increase in inflation rate. Ghana faced difficult fiscal situation, and fiscal deficit reached an estimated 23% of gross domestic product (GDP).

In February 2002, Ghana reached its highly-indebted-poor-country (HIPC) decision point. Under the HIPIC initiative, it is implementing its macroeconomic reform agenda through the Ghana Poverty Reduction Strategy (GPRS). The GPRS provides a new vision of Ghana that emphasizes creation of wealth, improved governance, and reduced income and regional inequalities.

To this end, the government intends to maintain a stable macroeconomic environment with moderate infraction, improve infrastructure and market access, increase the availability and quality of basic health and education services, and strengthen protection mechanisms for the most vulnerable segments of society.

The government regards conditioning of the fundamental infrastructure as indispensable for the advancement of economic activities in rural areas. The power supply is particularly vital for assurance of means of telecommunication or heightening of the reliability of the same. This, in turn, is expected to assist expansion of local economies, creation of job opportunities, and increase in income levels.

2.2.2 Policy framework

The government has posted seven objectives as the framework of energy policy, and has clearly defined action to be taken toward each (see Table 2.2.1). The focal points for policy steps to be taken in the power sector are structural reform, rectification of power tariffs by adjustment to levels enabling retrieval of costs, promotion of electrification and economic development in rural areas, and expanded use of renewable energy such as solar power, wind power, and mini hydropower.

Table 2.2.1 Energy policy framework (excerpt of those parts related to the power sector)

Objective 1: Consolidate and improve existing energy supply system

- Secure private sector investment in partnership with the public sector for re-capitalization of the energy supply system.
- Ensure efficiency in the management of the existing energy supply system through the restructuring of the utilities and unbundling of electricity supply system and the deregulation of the petroleum sector. The restructuring of the Ghana National Petroleum Corporation (GNPC), ECG and the creation of the power transmission company will be completed.
- Ensure cost-recovery in energy supply through efficient pricing of all energy services. The utility companies, i.e., VRA, ECG and Tema Oil Refinery (TOR), all face very precarious financial position, which could lead to the complete breakdown of energy services delivery in the country. It is the intention of the Ministry of Energy to reverse this situation in order to ensure un-interrupted supply of energy to meet the requirement of the economy.

Objective 2: Increase access to high quality energy services

- The Ministry of Energy will continue to expand Government support for rural electrification from both grid extension and decentralized sources such as solar PV and mini-hydro.

- The Ministry of Energy, in line with the objectives of creating jobs, will initiate a vigorous program support for productive uses of electricity in the rural areas.
- There are some remote rural communities that cannot be connected to the grid in the next 5 to 10 years. Under the rural electrification program, the Ministry of Energy in partnership with the utility companies and the private sector will initiate a program to provide these communities with Solar PV systems.

Objective 3: Secure future energy supplies

- Diversify Ghana's energy supply sources by promoting the exploitation of alternative energy supply sources.
- The Ministry of Energy will promote the use of indigenous renewable energy such as wind energy, solar energy, small hydro as well as biomass energy.
- Promote end-use energy efficiency and conservation.
- The requisite legal and regulatory mechanisms will be put in place to facilitate the participation of Independent Power Producers (IPPs).

Objective 4: Stimulate economic development

- Export of energy: This is to be achieved through the sale of Ghanaian energy services to neighboring country markets. By this, the Ministry of Energy will pursue a strategy to expand electricity supply capacity in the country in order to become a net-exporter in the West African Power Pool. The Ministry of Energy also intends to expand petroleum product supply to neighboring countries by expanding the Tema Oil Refinery and, in the medium term, commission the building of a new and modern refinery.
- Enhance productive uses of electricity in rural areas: This activity will be pursued under the Rural Electrification Programme in collaboration with Ministry of Industries and Ministry of Local Government and Rural Development and is intended to ensure that electricity supplied to the rural communities is used to support agriculture and the establishment of small and medium scale businesses.
- Enhance government revenue generation: The Ministry of Energy will ensure that the energy sector will continue to provide a basis for the enhancement of government revenue through efficient taxes and levies on energy supply and consumption.
- Employment generation: This will be achieved through the expansion and operation of indigenous energy supply services such as electricity generation, electricity retailing and refining of crude oil.

Objective 5: Minimize environmental impacts of energy supply and consumption

- Promote the gradual increase of more environmentally friendly energy supply sources such as renewable energy (solar, wind and small hydro) in the energy mix of the country.
- Support and actively participate in international efforts and cooperation with international organizations that seek to ensure sustainable delivery of energy to mitigate climate change. The Ministry of Energy endorses the United Nations Joint Implementation (JI) and Clean Development Mechanism (CDM).

Objective 6: Strengthen institutional and human resource capacity and R & D in energy development

- Support institutional reforms in the energy sector in line with the provisions of Energy Commission (EC) Act 541 and Public Utility Regulatory Commission (PURC) Act 538.
- Strengthen existing regulatory agencies (Public Utility Regulatory Commission (PURC) and Energy Commission (EC)) to enhance the regulatory environment in the energy sector.

- Support the training of Ghanaians in all fields of energy development and management.
- Re-direct the use of the "Energy Fund" for the support of energy Research & Development activities.

Objective 7 - Special Concerns

- Renewable Energy Technologies (RETs)
    - Create a level playing field for renewable energy by removing all fiscal and market barriers.
    - Encourage utility companies to adopt renewable energy in their supply mix.
    - Institute a "RET-Friendly" pricing framework in competitive applications such as in electricity supply.
    - Provide Government funding support for non-grid connected renewable energy technologies for economic activities (such as agriculture) and social services (such as schools, health centers, provision of potable drinking water).
    - Support technological development and cost reduction through pilot demonstration projects and local manufacture of RETs .
- Power Sector Reform
    - The Energy Commission Act 541 and the Public Utility Commission (PURC) Act 538 passed in 1997 provide the legal framework for sweeping reforms in electric power generation, transmission, distribution and regulation in Ghana.
    - Under these Acts, the private sector is allowed to invest in and own electric power plants.
    - A publicly owned Transmission Utility Company (which has not yet been established) is to provide "open access" transmission services for all electric power generators to their prospective customers.
    - The private sector is being encouraged to invest in the distribution system in partnership with the Electricity Company of Ghana. Government is committed to the privatization of the distribution utilities to allow for strategic investors. The Ministry of Energy will finalize the process for the partial privatization of the distribution utilities.
    - Pricing of electricity has been vested in an independent regulatory body, the Public Utilities Regulatory Commission (PURC), established under PURC Act 538 1997. Government, as a matter of policy, will ensure that electricity prices reflect efficient economic costs of generation, transmission and distribution while making it "affordable" to the "poor" in society.
    - The existing regulatory environment will be strengthened in order to facilitate the entry into the power sector of IPPs in addition to ensuring improved performance of electric power utilities.

(Source) MOE

2.2.3 Structural reform

Structural reform is progressing in Ghana, as in other countries. Thus far, the investment required for the operation of electric utilities has depended on the national finances and international institutions. The government is trying to affect a shift from this setup in the direction of participation by private capital.

The following measures have been implemented for the purpose of structural reform to this end.

- Establishment of a new regulatory setup
- Instatement of the competitive mechanism into wholesale (bulk) power supply
- Privatization of existing government-owned power companies and assurance of private-sector participation
- Minimization of the governmental role and utilization of diverse social capabilities
- Input of diverse resources for cost-effective promotion of transmission and distribution projects under the NES

Thus far, two regulatory institutions (the EC and the PURC) have been established through legislative measures, and the regulatory environment consisting of enterprise licensing, formulation of technical standards, tariff approval, and protection of demand is gradually taking shape. Nevertheless, while the blueprint has been drawn for the fundamental structural reform resting on the functional unbundling and rebuilding of the existing utilities (VRA, ECG, and NED), the detailed timetable has not yet been set. (The plan calls for the unbundling of the VRA in terms of function (hydropower, thermal power, and transmission), and the consolidation of the ECG and the NED as distribution companies.)

2.2.4 Electrification financing

At present, a special tax (government levy) is imposed on sales of power and other energy. The revenue from this tax can be used for RE and the spread of PV systems.

There are two such funds: the Electrification Fund based on revenue from taxes on power charges in use by final consumers, and the Energy Fund based on revenues from petroleum product taxes. The former tax amounts to 1.7 cedi per kWh, and the latter, to 5 cedi per liter.

The objective of the Energy Fund is to promote use of oil-alternative energy, and disbursements are recognized for development and use of PV systems and other renewable energy technologies.

In scale, however, such disbursements are fairly limited. In 2002, for example, the ECG and the NED had combined sales of 3.465 billion kWh, and the revenue from taxes on these sales came to only about 5.9 billion cedi (about 650,000 dollars). In addition, the rate of charge collection is only about 80% at the ECG and 69% at the NED. As such, a significant portion of these taxes are not collected.

The tax revenues funding the Energy Fund, too, amount to approximately 7 billion cedi, and the disbursements that can be allotted for PV systems are naturally limited.

As this indicates, it would be financially difficult to fund electrification solely with tax revenues, and the current RE projects are drawing on the HIPC Fund.

2.2.5 Environmental concerns related to electrification and PV systems

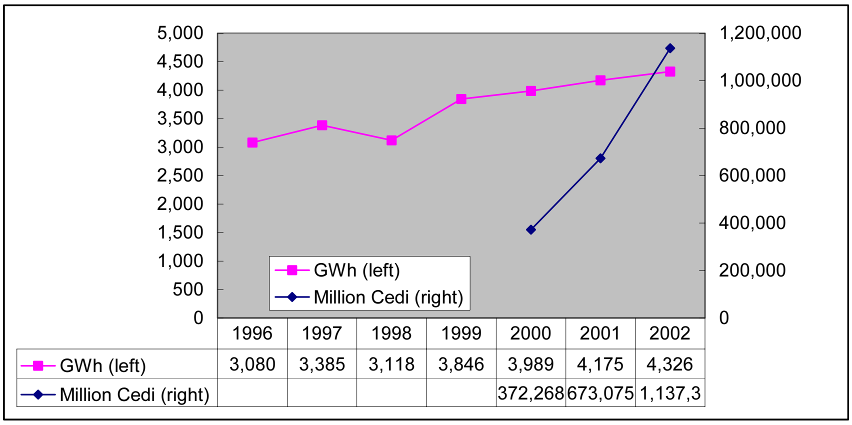
In Ghana, the Environmental Protection Agency (EPA) is in charge of regulations regarding environmental impact assessment (EIA). Projects requiring EIAs and the related procedures are stipulated by the Environmental Assessment Regulations 1999. In the power sector, EIAs are required for the construction of transmission lines, thermal power stations, dams, and hydropower stations. There is no particular requirement for PV systems. In the case of PV systems, the element with the most impact on the environment is the battery. Facilities processing and recycling spent batteries are subject to EIAs due to the risk of water pollution and soil contamination.

The EPA, the MOE, and the EC recognize the importance of properly disposing of and recycling spent batteries, and are discussing arrangements in preparation for the future spread of PV systems as a means of electrification. The provisional license currently issued to PV system dealers by the EC clearly stipulates the obligation for observance of EPA environmental regulations, and requires businesses to make reports on the occasion of battery disposal. At present, however, there are businesses disposing of car batteries, but disposal of exclusively PV system batteries is not organized as a business.

2.3 Energy prices, power tariff scheme, and market prices

2.3.1 Energy prices

As noted above, in Ghana, the power supply structure consists of ECG purchase and distribution of the power generated by the VRA and IPPs. In the northern regions that are covered by this study, the VRA-NED purchases power from the VRA and supplies it to customers. The power purchases by the VRA have steadily increased except for a dip due to the drought in 1998, and have expanded at an average annual rate of 5.8% over the years 1996 - 2002.



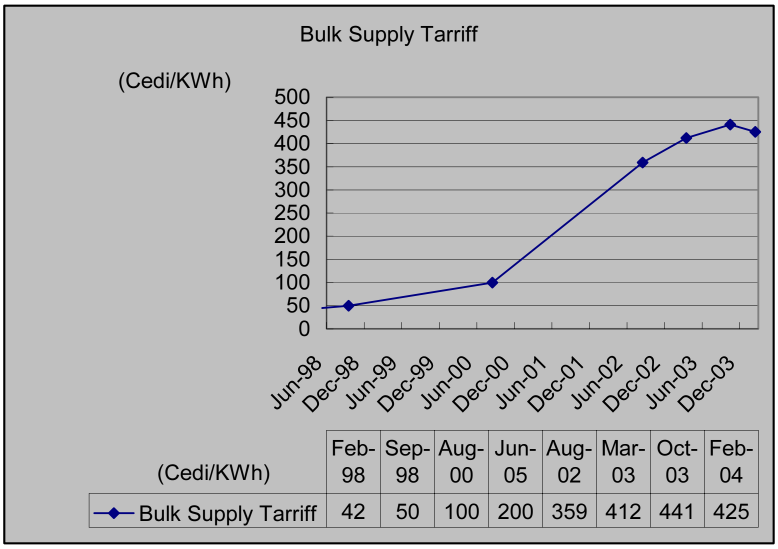
	1996	1997	1998	1999	2000	2001	2002
GWh (left)	3,080	3,385	3,118	3,846	3,989	4,175	4,326
Million Cedi (right)					372,268	673,075	1,137,3

(Source) ECG

Figure 2.3.1 ECG power purchase and cost (millions of cedi)

The power purchasing cost has also risen substantially. While the purchasing amount has increased by 4 - 5 % since 2000, the cost has basically doubled by the year. Per unit of power as well, the cost increased by 72% from 2000 to 2001 and 63% from 2001 to 2002. During this period, Ghana experienced an extremely high inflation rate of about 25%. Although some of this cost increase can be reflected in tariffs, the unit cost increase far outstrips the extent of tariff hikes.

The prices applied in bulk sales by the VRA and IPPs are regulated by the PURC. The wholesale price authorized by the PURC in 2004 was ten times as high as that in 1998.



(Cedi/KWh)	Feb-98	Sep-98	Aug-00	Jun-05	Aug-02	Mar-03	Oct-03	Feb-04
◆ Bulk Supply Tarriff	42	50	100	200	359	412	441	425

(Source) PURC

Figure 2.3.2 Trend of wholesale power tariffs

This increase derives largely from the change in the power source mix in Ghana. The mix, which consisted mostly of hydropower, is gradually coming to center around thermal power. In 2002-2003, each accounted for about half of the total. Because of this change, wholesale power tariffs must reflect the fluctuation of international fuel prices. With hydropower, there are no fuel costs, which kept the wholesale power tariff low. In contrast, in a situation of continual expenditures to purchase fuel, these costs must be properly reflected.

The following tariff adjustment formula was applied in 2002-2003 to reflect the fuel price fluctuation.

$$P = P_0 (a \text{ x } FP/FP_0 + ß \text{ x } CPI/CPI_0)$$

Here:

P:	Adjusted Variable Energy Price
P_0:	Base Thermal Variable Energy Price
FP:	Fuel Price
FP_0:	Base Fuel Price (US$2.2/bbl)
CPI:	United States CPI
CPI0:	2%
a:	0.89
ß:	0.11

$$BST = (X_1H_c+X_2P_2+X_3P_3) + nK) \text{ x ExchangeRate + Transmission Cost}$$

Here:

P2: simple-cycle generation cost calculated by the above equation

P3: combined-cycle generation cost calculated by the above equation
X1: hydropower generation rate
X2: simple-cycle generation rate
X3: combined-cycle generation rate
K: System Capacity Price
n: thermal power generation rate

For a time, prices were automatically adjusted in accordance with the above formula. It can be seen that all of the fuel cost (including exchange rate loss) can be transferred to the wholesale price. Although this formula is not applied now, a similar line of thought is presumably being applied in determination of wholesale prices.

2.3.2 Power tariff scheme

Table 2.3.1 shows the end-user power tariffs as of February 2004. The residential and non-residential tariffs are based on a progressive scheme. Households pay a sum of 19,080 cedi for supply of up to 50kWh a month and 583 cedi per kWh over that. For example, a household using 80kWh for one month would pay 36,570 cedi (19,080 + (80 - 50) x 530). Like the wholesale power tariffs, this scheme is determined by the PURC.

The wholesale power tariff set by the PURC is 425 cedi per kWh, and the transmission cost is 315 cedi per kWh. As such, even calculated in simple terms, the supply cost is 740 cedi per kWh. In contrast, the residential tariff is held to about 381 cedi per kWh, almost half as high, in the event of use of the entire 50kWh in the lowest rank (i.e., the lifeline tariff). This is on a very low level that does not even meet the wholesale price. Although the influence could be moderated slightly because the demand may not reach 50kWh in actuality, this low level has an enormous effect on the financial situation in the power sector. It may also be noted that, even in the next-highest rank, the tariff would not meet the supply cost.

Table 2.3.1 Power tariffs in May 2004

Residential		
	0-50kWh (lifeline)	19,080 Cedi/Month
	51-300kWh	583 Cedi/kWh/Month
	300+kWh	1,018 Cedi/kWh/Month
Non-Residential		
	0-300kWh	848 Cedi/kWh/Month
	300+kWh	1,039 Cedi/kWh/Month
	Service Charge	21,200 Cedi/Month
Special Load Tariff- Low Voltage		
	Max Demand	143,100 Cedi/kVA/month
	Energy Charge	403 Cedi/kWh
	Service Charge	63,600 Cedi/Month
Special Load Tariff- Low Voltage		
	Max Demand	97,520 Cedi/kVA/month
	Energy Charge	382 Cedi/kWh
	Service Charge	63,600 Cedi/Month
Special Load Tariff- High Voltage		
	Max Demand	89,040 Cedi/kVA/month
	Energy Charge	371 Cedi/kWh
	Service Charge	63,600 Cedi/Month

(Source) PURC

As indicated by the name, the lifeline tariff is a policy-based tariff aimed at social equality. It is set with consideration of factors such as the amount people are willing to pay and income levels. This makes it difficult to hike tariffs through simple transfer of costs, and resulted in the current situation.

In 1998, the lifeline tariff was 2,250 cedi per month. At the time, the wholesale power price was 50 cedi per kWh, and the lifeline tariff was set on a level basically on a par with the wholesale power price. As a result, the influence was comparatively small. While this tariff has been raised, the rise has not kept abreast of that in supply costs. Because household income levels are not high in Ghana, many households meet their needs with the lifeline tariff. The loss incurred by the ECG and the VRA-NED only increases as the number of customers in this rank rises.

Furthermore, this low tariff is often abused. One group interviewed in this study indicated that it cut its power charges by concluding contracts for four power connections and keeping use of each under the lifeline tariff quota even though it was a single customer. Coupled with the insufficient capabilities for customer management, such practices are putting power business into an extremely serious situation.

2.3.3 NED financial status

Based on the costs of power management and the tariff problem described above, this section views the financial status of the VRA-NED, which is currently in charge of electrifying the northern regions.

(1) Profit-loss statement

Because the NED had not completed its annual report for fiscal 2004 and financial data were not available even as of November 2005, this analysis is based on data up to and including 2003, which were available when it was executed. Table 2.3.2 presents the profit-loss statement for the NED.

Table 2.3.2 VRA-NED P/L calculation

(million Cedi)

Profit and Loss		
	2002	**2003**
Total Sales	123,614	195,205
Power Sales	120,000	191,053
Residential	59,896	104,600
Non-Residential	41,626	58,057
Low Voltage	9,228	13,397
High Voltage	9,250	14,999
Other	3,614	4,152
New Connection	1,498	1,241
Other	343	543
Interest	1,773	2,368
Operating Cost	127,426	216,590
Power Purchase	101,645	175,008
Salaries	15,686	25,393
Materials	290	1,185
Repairs&Maintenance	1,884	2,652
Other	7,921	12,352
Depreciation	129,017	158,802
Total Cost	256,443	375,392
Net Profit	-132,829	-180,187

(Source) VRE-NED

Sales increased substantially at an average annual rate of 58% from 2002 to 2003. On the gigaW-hour basis, on the other hand, the demand grew at an annualized rate of about 7 %. The sales revenue increase due to the tariff hike therefore had a big influence.

In spite of this, residential use occupied the biggest part of the sales. This part accounted for the majority of the sales increase. Over the period in question, the number of residential customers increased by about 13,000, almost all of whom are thought to be receiving the aforementioned lifeline tariff. The increase in the number of customers consequently had the effect of further squeezing the NED finances.

In the cost aspect, the biggest increase was recorded by power purchasing costs, which went up by 75%. These costs increased faster than sales. In terms of absolute numbers as well, the sales increase was virtually cancelled out by this increase in the purchasing cost.

Other costs, too, exhibited significant increases. Considering that the inflation rate is over 20%, however, the trend is virtually flat on the real basis; it is not the case that there was an explosive cost increase. As such, the figures should be interpreted as evidencing much effort to hold down costs.

At the NED, which has facilities and plants with a book value of close to 3 trillion cedi, the repair and maintenance cost appears to be very low at only 2.65 billion cedi, less than 0.1% as high. However, as seen in the balance sheet analysis, this total value of nearly 3 trillion cedi is an apparent magnitude resulting from repeated revaluation of assets along with inflationary accounting. For this reason, it could not be concluded that the cost level is too low.

This problem is further compounded by the extremely high level of transmission loss. The rate of transmission and distribution loss at the NED is over 30%. This is a problem at the ECG as well as the NED.

Eventually, the NED deficit expanded in 2002 and 2003, and reached 180.2 billion cedi at the end of 2003. This trend has continued for over five years. Behind this deficit lies the fact that the increase in the number of customers has been biggest in the residential division, where the structure is at a back spread, and from the inability to make a tariff revenue hike commensurate with the rise in power purchasing costs. In other words, the deficit is not a matter of NED capabilities; it is a structural problem, in that it derives from the structure of tariffs and costs. Unless improvements are made in this respect, there are no prospects for a turnaround in NED finances.

(2) Balance sheet

Table 2.3.3 shows the VRA-NED balance sheet. It should be noted that the figures do not match those of the NED Annual Report in some cases, because the table converted the latter using ordinary accounting methodology.

Total assets expanded from 2.5 trillion cedi to 2.9 million cedi. This increase is not due entirely to the addition of new facilities. A look at the figure for work in progress in 2002 reveals a sum of about 3.9 billion cedi, much lower than that of 1.4 trillion cedi for the increase in facility assets to 2003. The big increase in these assets resulted almost entirely from revaluation. Due to the high inflation, the NED revaluates its assets every year, and the revaluation is responsible for almost all of the increase.

Table 2.3.3 VRA-NED balance sheet

(million Cedi)

Balance Sheet	2002	2003
Fixed Asset	2,516,106	2,934,870
Property, Plant&Equipment	2,512,157	2,924,602
Work in Progress	3,949	10,268
Current Asset	135,113	229,609
Stocks	4,557	12,695
Power Debtor (account recievable)	91,874	152,698
less provision for bad debts	-1,837	-3,054
Other debtors	4,068	15,689
Short Term Investment	5,622	7,319
Cash etc.	30,829	44,262
Total Asset	2,651,219	3,164,479
Current Liability	157,540	402,588
Deposit for new connection	11,596	17,859
Levy/electricity find	2,777	3,383
trade creditor (Accounts payable)	160	161
Other	3,290	5,160
VRA Current Account	139,717	376,025
Equity	2,493,679	2,761,889
VRA Investment Account	326,354	203,578
Retained Earnings (income surplus)	-86,566	-203,677
Capital Surplus (asset reevaluation)	2,253,891	2,761,988
Total Equity and Liabilities	2,651,219	3,164,477

(Source) VRE-NED

Notable under the current asset heading is the accounts receivable item, which is indicated by the term "power debtor." It accounts for a remarkable 80% of the power sales in the profit and loss statement. Aside from the high level of transmission and distribution loss described above, there is a substantial delay in collection of payments for power actually distributed. The figure was 76% in 2002, and the situation consequently appears to be worsening. From this situation, it may be inferred that payment for almost all of the sales increase cannot actually be recovered, and that the increase is not helping to improve the cash balance.

Under the "current liability" heading, deposits for new connections occupy a fairly large amount. This indicates that some customers have not yet been connected although the NED has received connection deposits from them. Installation is therefore not keeping abreast with the applications. By far the largest item is the VRA current account, which shows that the operation is funded with short-term borrowings from the VRA.

The NED is a department of the VRA and therefore cannot receive financing from other institutions on its own. This is why an item equivalent to long-term borrowings is not on the balance sheet. Investment-type funds in particular are obtained from the VRA through its investment account. At present, however, the amount is basically offset by the retained earnings. In the equity category, what occupies the largest share and almost all of the righthand side of the balance sheet is capital surpluses, which is the cumulative total of book value increase due to asset revaluation. It derives from bookkeeping in inflation accounting as opposed to funds actually earned by the NED. This manipulation through inflation accounting is worsening the outlook for the NED balance sheet somewhat and requires caution.

(3) Cash flow

The figures for cash flow provide a basic picture of NED management. The cash balance indicates that almost all of the operating deficit is offset by depreciation. Nevertheless, accounts receivable are steadily increasing along with sales, and the figure for cash on hand is negative. This deficiency can be met with provision of short-term funds from the VRA current account.

New investment is held to a low level. Over the last few years, it has been in the range of 6.3 - 7.0 billion cedi, on the order of maintenance costs. It apparently has not gone beyond large-scale repair of certain facilities.

Financing activities depend on provision of funds from the VRA because there is no external borrowing. In 2003, the cash flow from financing was negative as a total of 122.8 billion cedi was taken out of the account.

On the bottom line, the NED is left with a certain amount of cash. As of the end of 2003, this cash on hand came to 51.58 billion cedi, or about one-third as much as the total cost. While this level may be termed sufficient, the NED has absolutely no reserve for a lot of new investment on its own resources, and will have all it can do to continue operating on the current level.

Table 2.3.4 VRA-NED cash flow

(million Cedi)

Cash Flow	2002	2003
Operating Profit	-132,829	-180,187
Adjustment		
Depreciation	129,017	158,802
Interest on Investment	-1,773	-2,368
Fixe asset sales proceeds	0	
Decrease/(Increase)in :		
Stocks	764	-8,138
Accounts recievable	-41,262	-71,227
(Decrease)/Increase in:		
accounts payable	5,536	8,740
VRA Current Account	62,549	236,308
Net CF from Operations	22,002	141,930
Cash Flow from Investment		
Interest	1,773	2,368
Purchase of plant	-2,953	-74
Work in Progress	-3,958	-6,319
Net Cash from Investment	-5,138	-4,025
Cash Flow from financing		
Investment from VRA	0	-122,776
Net CF from financing	0	-122,776
Change in Cash etc.	16,864	15,129
Opening Cash etc.	19,587	36,451
Closing Cash etc.	36,451	51,580

(Source) VRA-NED

2.3.4 ECG financial status

The ECG transmits and distributes power purchased from the NED. It is definitely not in a good financial position. Data for it are for the situation in fiscal 2003, because its financial statement for fiscal 2004 had not been completed either as of the end of calendar 2005.

For this study, the ECG has less of a direct connection than the VRA-NED, and the Study Team decided not to make an in-depth study of the various financial tables. However, it basically shares with the VRA-NED the situation of operating loss on a current basis, because it cannot hike tariffs high enough to compensate for the steep increase in the capital investment requirement related to the transmission system along with demand expansion.

As of the end of 2003, ECG customers numbered 1.09 million, up 12.7% from the end of 2002. Its power sales over the same period increased from 3,199 to 3,342 GWh, up only 4.4%. This low level of sales relative to the increase in the number of customers evidences the fast-paced expansion of small-volume customers.

Meanwhile, the ECG's aggregate assets rose by about 12%, from about 6.2 to 7.0 trillion cedi, indicating that capital investment was more or less commensurate with the power sales. However, even this level of investment may not have been fully sufficient, considering the dilapidation of existing facilities and the need for additional ones.

Although the increase in power sales was limited, sales revenue increased from 1.55 trillion cedi in 2002 to 2.27 cedi in 2003, up a remarkable 46%, due to the two tariff hikes made in 2003. Nevertheless, direct costs, which are occupied almost entirely by power purchasing from the NED, increased by an even higher margin, while sales management costs also rose as the operation expanded. As a result, the ECG recorded a net loss of 482.6 billion cedi. Net losses have continued to be recorded in every one of the last few years, and have become chronic in nature.

As for cash flow, loss is essentially offset by depreciation, and does not produce a funding shortage. Debts, however, are piling up, and make large-scale investment difficult. In response, in 2003, the ECG was released from its obligations for repayment of a total of 792.4 billion cedi in long-term debt and cumulative interest through governmental aid, in order to provide leverage for improvement of its finances. Even so, under the current circumstances of continuous deficit, it could fall into the same position sooner or later. As this indicates, it would be difficult for the ECG, too, to make extensive investment.

2.3.5 Operation and Maintenance (O&M) cost in RE

The O&M cost for solar systems is virtually negligible, as long as owners/users perform the minimum requisite cleaning. In reality, however, owners/users cannot be expected to perform even O&M work on this level, and the business side must do the minimum requisite checking. Some detailed data on the operation cost in electrification led by PV systems are available from the RESPRO, but long-term data have not been compiled due to problems in aspects such as the transfer of work accompanying a change of accountants. The RESPRO does not necessarily obtain highly reliable data itself because its scale is fluctuating.

At present, RESPRO does maintenance for some 2,000 SHS, at a fee of two dollars per month per system. The actual work is performed by a few engineers and staff. Their wages and operation cost are met by expenditures. Table 2.3.5 outlines RESPRO expenditures relative to its revenue.

Table 2.3.5 Balance of RESPRO revenue and expenditure

	Actual Cost/Income
Revenue	40,000,000
Salary	20,000,000
Daily Service Allowance	30,000,000
Equipment	5,000,000
Vehicle	20,000,000
Utility& Office Supply&Bank Charge	30,000,000
Tax etc.	15,000,000
Total Cost	120,000,000
Profit/(Loss)	-80,000,000

(Source) RESPRO

Table 2.3.5 shows averages figures for the few months for which data have been recorded. It can be seen that RESPRO is still running a deficit of from 80 to 100 million cedi per month. This situation is definitely not sustainable.

It might be added that the wages paid to RESPRO staff are very low, and that this is leading to a serious loss of personnel. Current wage levels at the power utilities are about three times as high. Although personnel expenses can be held down by measures such as employment of two or more novice workers instead of seasoned ones, personnel expenses should be double the current level at the least.

Under these circumstances, monthly fees for maintenance of the approximately 2,000 systems would have to come to about 200 million cedi (averaging 100,000 cedi per system) for the operation to break even. This would be equivalent to 10 dollars per month and 120 dollars per year, or about five times as much as at present. With the inclusion of a fee of about 300 dollars every five years for battery replacement, the requisite expense would be increased by about 5 dollars per month.

This level of cost is by no means conducive to the operation of economy of scale given the nature of RE, and SHS in particular. Although costs could be brought down somewhat through modification of the collection method and posting of personnel, it is thought that the monthly fee would have to be reduced to at least 11 or 12 dollars per month inclusive of battery replacement.

Chapter 3 RE program based on on-grid and off-grid electrification

3.1 On-grid electrification

3.1.1 NES and SHEP policy schemes

(1) NES

In parallel with its program of economic recovery initiated in 1989, the government of Ghana formulated the National Electrification Scheme (NES) for attainment of the goal of nationwide electricity supply over the 30-year period from 1990 to 2020. In the NES, the objectives of electrification are promotion of economic development and increase in the standard of living. The sources of the capital required for its promotion consist of grant and concessionary credit, taxes deriving from the National Electrification Fund, and allocations from the national treasury.

The Canadian government provided grant funding for the NES formulation, and the study for national power sector planning was executed with it. The study was made by the Canadian consultant firm Acres International. This culminated in the preparation of the National Electrification Master Plan consisting of six five-year plans and extending for the next 30 years. The Master Plan identified 4,221 communities with a population of at least 500 as sites eligible for electrification.

In the first phase of the NES, the subjects of electrification are all regional capitals and the communities located on the way to them. In subsequent phases, work is to begin with projects offering the best economic feasibility.

(2) SHEP

The Self Help Electrification Programme (SHEP) was prepared as a program to supplement the NES. The SHEP supports electrification in communities that are no further than 20km away from 33- or 11-kV distribution lines. The communities must purchase utility poles for low-voltage distribution lines. (At present, the burden of low-voltage distribution line purchase is also borne by the government. In the NED, residents pay 5,000 cedi on average as their burden of the cost for connection to the house and all of the cost of in-house wiring, according to an interview with NED personnel.) The aim of this approach was to attain system connection targets under the NES ahead of schedule.

In SHEP 1, which was implemented in 1990 - 1991, 50 communities were connected to the grid. In SHEP 2, which was implemented from 1992 to 1994, some 250 communities were connected to the grid.

A nationwide survey was conducted in 1993 and 1994, and identified 1,400 communities as subjects for SHEP 3. Because of the large scale, SHEP 3 was divided into three phases. The third phase was completed at the end of 2004.

As of December 2000, a total of 1,877 communities (including all district capitals) had been connected to the grid under the NES and SHEP projects.

In 2001, the government initiated SHEP 4. Applications were received from some 2,500 communities, and the government asked the ECG and VRA to make a feasibility study. The study estimated the cost of electrification of all 2,500 communities at about 350 million dollars. The first phase of SHEP 4 was conducted with materials left over from SHEP 3. As of the end of 2004, a total of 193 communities had been electrified.

The SHEP 4 is expected to be funded with soft loans and grant aid. At present, the only funding set is the 15 million dollars from the Export-Import Bank of India determined in 2004.

Table 3.1.1 Status of NES achievement as of December 2000

Project	Number of communities
NES	430
Other turnkey/bilateral aid projects	373
SHEP 1	100
SHEP 2	250
SHEP 3, Phase 1	280
SHEP 3, Phase 2	494
Total	1,877

(Source) MOE

Thanks to these electrification plans, the rate of household electrification nationwide, which was only about 15% in 1989, reached 43% in 2000. This is the highest rate of any African country in Sub-Sahara region.

The NES, however, is facing numerous problems. One particularly serious problem is the non-payment of charges for power in rural areas. This is making it even more difficult to obtain the income needed for investment to expand the power supply network.

3.1.2 Technical aspects of NES and SHEP

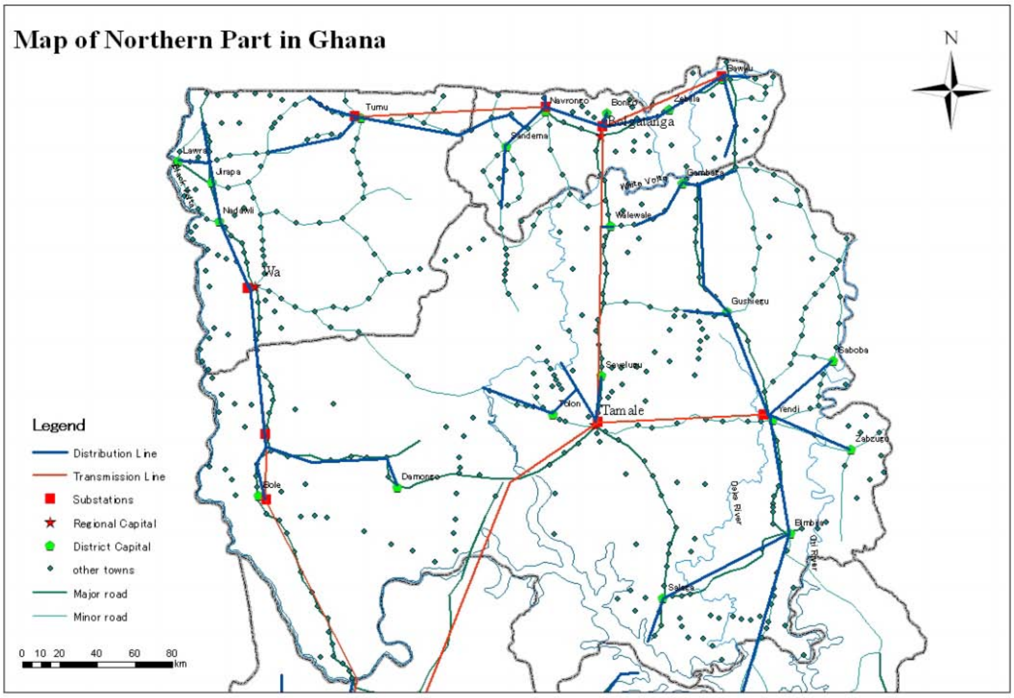
(1) Status of the distribution system

The distribution facilities in the northern part of Ghana are operated and managed by the regional offices for each of the three regions. These offices are located in Tamale, Bolgatanga, and Wa.

Note: In addition to the three northern regions, the NED also supplies power in Techiman and Suyani.

These facilities are composed almost entirely of 34.5kV and 11kV lines (the former being equivalent to 33 kV lines). The lines lead away from the substations in Tamale, Yendi, Bolgatanga, Wa, and Sawla, the major towns in each region. The voltage is 11kV in all places except Sawla, where it is 34.5kV. In some cases, distribution lines are extended directly from sub-transmission lines. This is the effective method for transmitting power to scattered rural cities. The sub-transmission lines have a voltage of 34.5kV. In one exceptional case, current with a voltage to ground of 20kV or 30kV is put through two aerial shield wires on the transmission line between Techiman and Bolgatanga, and the distribution lines are fed from them.

Figure 3.1.1 shows the transmission and distribution line systems in the northern regions.



(Source) Prepared by JICA Study Team based on NED data

Figure 3.1.1 Transmission and distribution line systems in the northern regions

(2) Technical standards for distribution facilities

Ghana has established technical standards (Electrical Power System Specifications) that are common to both the ECG and the NED. Facilities are constructed in accordance with these standards. Electrification based on these standards would presumably leave facilities that would not present any problems as regards safety or supply reliability.

Table 3.1.2 Main technical standards for distribution facilities

Item		Standard
Frequency		Voltage
Voltage	33kV	Rated voltage:33kV Peak voltage:36kV
	11kV	Rated voltage:11kV Peak voltage:12kV
	Low-voltage	Rated voltage:433/250V Peak voltage:438/253V Low-voltage:358/207V
Cable	High-voltage	All Aluminum Conductor(AAC) Standard sizes 33kV trunk :400mm^2、240mm^2、150mm^2 feeder:240mm^2、120mm^2、50mm^2 11kV trunk :265mm^2、150mm^2、120mm^2 feeder:120mm^2、50mm^2
Supporting structures	High-voltage	The standard structures are wooden poles or poles of galvanized steel pipe The standard height is 11 m, but 12- or 13-m poles are erected as necessary.
Design span		High-voltage: 100 m in the case of 11-m poles Low-voltage: 46 m

(Source) ECG and NED

(3) NED projects and SHEP

1) Status of project implementation

Table 3.1.3 outlines the projects that have been initiated by the NED recently.

Table 3.1.3 Project outline

Project outline	Site
Construction of one 2.5-MVA (33kV/11kV) substation	Ntroso
Installation of one 315-kVA (33kV/0.433kV) distribution transformer	Kenyasi
Installation of one 315-kVA (33kV/0.433kV) transformer for shield wire Installation of high-voltage line (5.2km)	Akomadan
Installation of two 200-kVA (34.5kV/0.433kV) distribution transformers Installation of one 200-kVA (11kV/0.433kV)distribution transformer	Tamale
Installation of eight 50-kVA (34.5kV/0.433kV) distribution transformers	Tamale Airport Junction etc.
Extension of 11.5-kV high-voltage distribution line Installation of one 315-kVA distribution transformer	Watech
Installation of one 25-kVA distribuition transformer (single-phase)	Kobedi

(Source) NED Annual Report

2) Status of SHEP implementation

Table 3.1.4 outlines the implementation of SHEP projects over the last few years at the NED.

Table 3.1.4 SHEP status

2004	Number of electrified households: 2,006 Initiation of distribution substation construction: 147(8,925kVA) Initiation of 34.5-kV distribution line construction: 976km
2003	Number of electrified communities: 26
2002	Number of electrified communities: 7

(Source) NED Annual Report

3) Tasks as viewed from the current status of distribution facilities

Distribution lines have been extended to the major communities by the electrification plans thus far, but some communities along the way have been unelectrified. These communities can be electrified at relatively low cost by installing transformers and extending low-voltage distribution lines. Because of the priority accorded to the will of the community in the SHEP projects, some of them may be left unelectrified. In the promotion of a national RE plan, there is consequently thought to be a need for early preparation of a master plan with consideration of such points and determination of electrification sequence and methods.

3.2 Off-grid PV electrification

3.2.1 Policies and schemes related to off-grid PV electrification

(1) Promotion of PV electrification by the government

The government of Ghana is pursuing off-grid electrification using renewable energy, and particularly PV systems, for areas that cannot be reached by the NES and SHEP programs for RE by extension of distribution lines for the next ten years.

The MOE and EC have been making organizational and institutional arrangements for off-grid PV systems, but there are problems in the technical and financial aspects, and there is not yet a setup for comprehensive promotion. Table 3.2.1 summarizes the provisions of the major laws and policies related to off-grid electrification.

Table 3.2.1 Policy and legislation related to off-grid electrification in Ghana

Related policy and legislation	Year	Summary of provisions
Energy Commission (EC) Act	1997	Collection for the Energy Fund from income from sales of petroleum products, electricity, and natural gas. This fund is to be used to promote the development and use of PV and other renewable energy systems.
Ghana Poverty Reduction Strategy (GPRS)	2002	Stimulation of production activities among the poor in rural areas through supply of power to them with renewable energy systems, (PV, wind power, biomass)
Energy Policy (draft)	2004	For electrification of rural communities, the MOE shall promote off-grid electrification based on PV and mini hydropower systems, as well as on-grid electrification. In cooperation with power utilities and private enterprises, the MOE shall initiate PV electrification programs for communities that would be difficult to electrify by extension of the grid.

(Source) Prepared by JICA Study Team from various documents

Funding for PV electrification may be obtained from the Energy Fund, but use of this fund is negligible, partly because the annual income is very low at only 7 billion cedi, and the input of public funds is limited. In sectors such as health care and education, PV projects are being promoted with independent donor funds. For such reasons, it appears that the MOE does not have a full grasp of all projects.

(2) Licensing scheme

The EC has instated a scheme of licensing for PV projects, and has already issued provisional licenses to the two companies DENG Engineering and Terra Solar. These provisional licenses are issued to enterprises that install PV systems and collect fees in the role of service providers. The scheme is not adapted to the diverse components of the PV system industry, such as outright system sales and sales of materials.

The scheme has not yet been solidly established, partly because of the lack of specific plans for environment-friendly disposal of spent batteries and technical standards. According to the EC, the main features of the provisional license scheme are as follows.

- The licensees must be qualified to engage in business in Ghana and satisfy the environment-related requirements of the EPA.

- The license is valid for two years and must be renewed thereafter.

- The licensee must pay the prescribed licensing fee.
- The licensee must determine service fees inclusive of a financial plan.
- The licensee must observe the technical standards in procurement and installation.
- The licensee must submit reports on disposal of batteries.
- The licensee must submit periodic reports on its activities.

(3) Technical standards, code of prctice, and end user manuals

To maintain PV equipment quality on a certain level as well as to provide businesses and consumers with proper technical information, it is indispensable to establish technical standards and a code of practice on the national level. The Ghana government is also aware of this. With the support of the Danish Agency for Development Assistance (DANIDA), the Ghana Solar Energy Society (GHASES) and the Ghana Standards Board (GSB) collaborated in the drafting of technical standards (i.e., Draft Standardized Requirements for the Application of PV Systems in Ghana). The EC has appropriated budget for the completion of the standards, but they have not yet been approved, and the work is consequently at a standstill.

At the first workshop held in March 2005, business representatives expressed apprehensions about a tightening of governmental regulations due to the instatement of technical standards. The participants eventually agreed to the idea after it was pointed out in discussions that the standards would not depart from the conventional perspectives of international standards (i.e., that there would not be double standards) and that the provision of correct knowledge to consumers in manuals would ultimately help the PV industry to grow.

Because the technical standards and code of practice have not yet been established, the specifications of the particular equipment and standards of the import source country are currently been applied on a provisional basis. At present, the EC is leading the drafting of technical standards and a code of practice targeted for completion at the end of 2005.

In the case of PV systems, users can extend the service life of their systems by carrying out proper maintenance such as cleaning panels, reading charge controllers, and maintaining batteries. At present, enterprises explain the use of systems to their customers in accordance with the manuals of their own preparation. The first workshop also produced a basic agreement among the participants on a certain degree of integration in preparation of these manuals.

(4) Study and training scheme, and equipment test center

In Ghana, there is no unified training for PV-related businesses on the national level; currently, university institutions and enterprises put together their own curricula for it. In addition, technical instruction is furnished by skilled engineers through on-the-job training (OJT).

However, there are strong needs for training at a national level and for a technical certification scheme in order to improve technical capabilities and provide incentives for acquiring official qualifications. Preparations are being made for establishment of a training scheme at Tamale Polytechnique, in the city of Tamale in northern Ghana. Table 3.2.2 profiles the PV system training currently being offered.

Table 3.2.2 Current training for PV engineers

Implementing entity	Term	Description
KNUST[1]	Two weeks	The KNUST provides training to technicians in response to an MOE request. It has not accepted any trainees over the last year. RESPRO technicians received this training. The KNUST offers classes on solar energy as part of its master's curriculum, and accepts students from other West African countries.
DENG	Two weeks	DENG Engineering provides training in the whole process of design and installation in line with the curriculum prepared by the Australian Institute for Sustainable Power (ISP). The text also covers mini hydropower and other types of renewable energy systems. The company plans to graduate about 100 technicians a year.

(Source) Prepared by the JICA Study Team based on interview findings.

Test centers for assurance of PV equipment quality are sited in the KNUST and DENG. Because they are not on a large scale, however, they generally apply the results of plant testing at the import source.

3.2.2 Review of past PV projects

To promote off-gride electrification in districts where it would be difficult to extend the distribution line under the SHEP, the government of Ghana executed pilot projects for off-grid PV electrification with the support of donors from the second half of the 1990s. This section profiles four major projects.

(1) Renewable Energy Service Project (RESPRO)

The official name of this project is "Renewable Energy-based Electricity for Rural, Social and Ecomonic Development in Ghana." Project expenditures for the first three years were met by 2.5 million dollars in grants from the Global Environmental Facility (GEF), 500,000 dollars from the government of Ghana (including PV equipment worth 300,000 dollars) and 1 million dollars in technical assistance funding from the National Renewable Energy Laboratory in the US Department of Energy.

The RESPRO was the largest single PV electrification project implemented in Ghana, and was undertaken in the East Mamprussi District in the Northern Region. It promoted electrification of over 13 communities based on the fee-for-service model.

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[1] Kwame Nkrumah University of Science and Technology

The objectives of the project were as follows.

- Deepening of understanding in the Ghanaian government of requisite level of technology in use of PV systems as stand-alone power sources and other factors involved in RE promotion, in the areas of equipment selection, cost, and O&M costs
- Demonstration of the technical, economic, and institutional feasibility of extensive installation of small PV systems to governmental authorities, the private sector, and aid institutions
- Paving of the way for approaches to renewable energy in the context of the RE activities currently being promoted to the MOE and power utilities
- Electrification of 13 unelectrified communities in remote areas
- Action as a catalyst for extensive use of PV technology

The idea underlying implementation of the project was the launch of power supply by PV systems with models enabling full retrieval of costs on the private-sector basis.

Initially, the plan included the aim of getting the utilities deeply involved in the project. At the time, however, the NED, which is in charge of the northern regions, was faced with a power crisis due to a drop in hydropower output because of drought, and did not exhibit much interest as it lacked the margin to support PV system projects.

The MOE consequently instituted a RESPRO unit to supervise the project and launched it in February 1999 without utility participation. The project installed about 1,400 PV systems (see Table 3.2.3).

Table 3.2.3 PV systems installed in the RESPRO

1. Household

District	Town	Total
Bolgatanga	Tengzuk	40
	Bolga	45
Bawku/East	Pusiga	45
Navrongo		192
Tamale		108
	Pishegu	40
E/Mamprusi	Nakpanduri	310
	Bunkpurugu	535
Upper West		34
Total		1,349

2. Non-Household

District	Church Mosque	Bar	Saloon	Shop	Office	School	Tailor	Fuel Shop	Total
Tamale		1		1					2
Kasena/Nankana		3							3
E/Mamprusi	6	8	1	7	1	1	1	2	27
E/Gonja	1			1					2
Gushegu/Karaga				3					3
Total	7	12	1	12	1	1	1	2	37

3. Public services

Street lights	13	Binde(4), Yunyoo (3), Tengzu (1)
Well pumps	1	Binde
Refrigerators for vaccine in clinics	3	Wantugu, Singa, Binde

(Source) New Energy, *Renewable Energy Service Project (RESPRO)—Socio-Economic Impact Assessment Study of Photovoltaic Electrification for Rural and Economic Development in Northern Ghana*, September 2002

The RESPRO owns the PV systems and collects fees for performance of maintenance services (fee-for-service model). In the case of residential supply, it received an initial installation cost of 10,000 cedi and monthly fee of 15,000 cedi for a 50W system, and corresponding sums of 15,000 and 25,000 cedi for a 100W system. Customers were obliged to pay a deposit equivalent to about six months of fees at the time of installation. Because the monthly fee is held down to the lifeline fee for on-grid service, the RESPRO cannot cover the cost of battery replacement, and there are plans for having this burden assumed by the customers.

The following lessons were learned through the RESPRO.

- The energy service companies (ESCOs) installing and operating PV systems have a high overhead.
- The RESPRO had a high operating cost because it was undertaken in a remote area.
- The government must determine definite policy to establish the PV market.
- Execution of PV programs requires a composite strategy.
- Wider spread of PV systems requires the construction of a policy framework accompanied by a proper funding mechanism.
- The involvement of utilities is needed to maximize the benefits of PV systems.
- There is a need to improve the fee-for-service business model, which is reaching its limits in use alone.

As a project promoted in this form with GEF funding, the RESPRO came to an end in 2002. The RESPRO unit was registered as an NGO corporation and is currently active as an installer and operator of PV facilities under the supervision of the MOE.

As of June 2005, the RESPRO was staffed with five technicians (two of whom are stationed in the Upper East Region), one accountant, and one warehouse employee.

(2) Danish National International Development Agency (DANIDA) Project

The official name of this project is "Development of Renewable Energy Resources in Ghana." It was conducted as a project of grant aid from the Government of Denmark, and part of the funding was allocated for the construction of energy service centers. A total of 14 such centers were constructed and installed with battery charge stations (BCS). Three of these centers were also equipped with solar telephone offices. In this project, it was decided to install BCS instead of solar home systems (SHS), which cost more, because of the low level of income among farmers as the beneficiaries.

In addition, rural banks provided loans to fund purchase of batteries and bulbs by beneficiaries.

The project was initiated in 1999 and operated centers for a period of two years between 2000 and 2002. In 2003, it was transferred to the EC, which transferred it to the regional assemblies in the following year (2004). Thereafter, the regional assemblies were required to issue an annual report to the EC on BCS operation and the financial status. The banks making loans to the beneficiaries were required to submit financial statements.

The project was therefore transferred to the EC after a two-year proving period, which revealed the following problems.

- Besides managing the collection of fees for use of the BCS on a daily basis, the personnel operating the BCS had to make the rounds of households to ascertain the repayment of loans made by the banks and collect them (this job was commissioned to the operators by the banks because it would cost too much for them to make visits to households to retrieve loans).
- The banks provided four-year loans and sought deposits as security from the loan recipients. The borrowers merely paid the security deposits and made almost no effort to repay loans.
- As the beneficiaries who received loans refused to repay them, repayments to banks fell into arrears. During the first three years, principal repayments were on the level of only about 10%.
- Even if banks sent officers to visit loan recipients in arrears to negotiate with them, the recipients merely refused to make repayments. The operators commissioned to collect repayments generally did not make a serious attempt to do so.

The following can be cited as prospective factors behind the decisive problems that occurred with retrieval of bank loans.

- Because the banks did not participate right from the stage of project formation, the residents did not regard them as project partners.

- The operator of the DANIDA Project did not clearly explain to the residents that the bank loans carried a 10% interest and 1% commission, and that, as the borrowers, they were obliged to repay these amounts.
- The banks, too, did not get a full explanation of the project from the project operator. As a result, the residents were under the impression that the facilities were constructed with grants, and did not realize that they had to repay the bank loans.
- The beneficiaries were dissatisfied that the batteries failed before the end of their service life. When bulbs were burned out, they assumed that the BCS operators would replace them and simply left them in the socket. Furthermore, the operators did not have a high level of skill. These circumstances also dampened inclinations for repayment among the loan recipients.
- The communities are bound by ties of blood, and operators could not take a tough stance when making rounds to collect loan repayments.
- Even if they succeeded in collecting repayments, operators sometimes ended up spending the money themselves instead of handing it to the banks.
- Some operators even bought their own SHS, stopped using the unreliable BCS, and connected the battery to the SHS. They asserted that they did not have to repay the loan because they were not using the BCS.
- The loan sum was too big for the poor farmers. For banks, visits to borrowers in remote areas to collect repayments entailed too much overhead.

As for the lessons, the project underscored the importance of seeing that participants have a clear understanding of its meaning and are given the necessary knowledge in use of batteries. Because many of the residents in the northern regions are poor, it is not easy to collect funds, and the project showed that a "soft" financing system could very well lead to failure.

(3) Ministry of Mines and Energy/Spain off-grid project

This project was launched in July 1998, in advance of the RESPRO and DANIDA projects. It consisted of installation work for the first two years and assurance by contractors for the last year. With financial assistance from the Spanish government, it installed a total of 2,196 PV systems with a combined output of 265kW in a total of ten communities. Systems were operated on the fee-for-service basis.

The purpose was to prove the utilization possibilities of PV systems and identify the prerequisites for incorporation of fee-for-service PV electrification into the NES.

The project cost was met by funding from the Spanish government split 50-50 between concessional loans and export credits. The implementing institutions were the Ghanaian Ministry of Mines and

Energy (the predecessor of the MOE) and the Spanish firm ISOFOTON S.A. (whose Ghanaian counterpart was Wilkins).

The project objectives were as follows.

- Supply of power to ten communities with dispersed PV systems
- Examination of issues in application of PV electrification based on the fee-for-service model
- Examination of the influence of concentrated installation of PV systems connected in a grid to government facilities
- Heightening of interest in PV systems and buildup of the needed human resources in educational institutions

Table 3.2.4 Systems installed in the Spanish project

PV System	Unit Capacity (Wp)	Number of Installation	Total Capacity (Wp)
Household use (A)	50	760	38,000
Household use (B)	100	1,163	116,300
Hospital	600	14	8,400
Street light	150	200	30,000
School/community	250	48	12,000
Water pump (tap water)	6,000	1	6,000
Water pump (irrigation)	1,200	1	1,200
Battery charging station	500	6	3,000
Centralized system	50,000	1	50,000
Total		2,194	264,900

(Source) Ahiataku-Togobo, Wisdom, *MME/Spain Offgrid Sola PV Rural Electrification Project*, Ministry of Mines and Energy, November 2000

The district assemblies strongly supported the implementation of the project, which covered communities that were at least 20km away from the existing grid. The project also stipulated instruction about PV systems for the beneficiary communities and satisfaction of the following conditions.

- Residents desiring installation must pay a sum of 70,000 cedi (about 16 dollars at the time) in initial costs through the district assembly within a prescribed time to cover the expense of connection and indoor wiring.
- At least 30% of the parties desiring installation in the community must receive SHS.
- The monthly payment is 2 dollars per system.

The project selected communities able to meet these conditions within a certain period. A community electrification committee (consisting of from three to six memberd including technicians) was established with the cooperation of the assembly president or community chief, and managed the facilities for the government. The committees were responsible for collection of monthly fees and performance of O&M, and were to submit a list of all paying parties along with the fees collected to the government. Parties failing to make payments for four months were informed that the system would be removed unless payments were made within one month. To maintain the committee, 20% of the fee revenue was paid to it as a commission.

A special account (the off-grid solar electrification account) was opened for management of all fee revenue. Over the period of January 1999 - June 2000, this account accumulated about 150 million cedi (about 30,000 dollars at the time).

The EC report entitled "Reconnaissance/Feasibility Studies for Solar PV Rural Electrification in Off-grid Communities in Ghana" pointed to the following items as problems in the project.

- Of the ten communities, eight were in a re-settlement area of VRA. Although they were reached by the grid after the PV systems had been installed, relocation of the PV systems was not taken into account. As a result, users ended up having both on- and off-grid systems regardless of their payment capabilities.
- While system ownership rights lay with the government, it was not possible to change batteries and other parts due to the shortage of funds collected through the project. In addition, community members sometimes neglected to return funds they collected to the government.
- Due to the fierce resistance mounted by users, it was, in effect, impossible to remove systems from non-paying users in a scheme under the direct jurisdiction of the government.
- To have the governmental staff directly perform system O&M and collect charges made their work load excessive and was not realistic.

Upon the conclusion of the project term, the entire project was transferred to the RESPRO.

(4) MOE electrification project in junior secondary schools (JSS)

In 2004, the MOE began using the HIPC fund to install lighting systems in some 200 junior secondary schools throughout the country. To eliminate interdistrict disparity, the project covered at least one or two candidate schools in each district as a general rule, and ultimately finalized selections through consultation with district leaders. The MOE procures the materials and consigns the installation work to the RESPRO. Completion of the project is targeted for 2005.

3.2.3 Summary of problem points in past PV projects

Besides conducting interviews with the MOE and the RESPRO to determine the current status of PV electrification projects, the Study Team carried out a field study in the areas shown in Table 3.2.5 to confirm the state of past projects.

Table 3.2.5 PV electrification sites in the field study

Region	District/community	Systems studied
Northern	Bunkpurugu Yunyoo／Bunkpurugu	・SHS (residential and public facilities) and BCS installed by the RESPRO
Upper West	Wechiau／Wechiau	・SHS (residential and public facilities) and BCS installed by the MOE with Spanish assistance
Upper West	Wa／Wa	・SHS (installed by the RESPRO) of a comparatively affluent home not electrified in the SHEP in the town of Wa[2]
Upper West	Lawra／Babile	・Sites reached by the grid fairly soon after the installation of PV systems by the RESPRO (at shops and households) ・SHS installed by the RESPRO at a junior secondary school
Northern	West Gonja／Busumu	・SHS at clinics and night schools installed in the DANIDA-New Energy project
Northern	Central Gonje／Sankpala	・BCS installed in the DANIDA project
Northern	Tolon Kumubungu／Wantulu	・SHS (for lighting, wireless equipment, and refrigerators) installed at a clinic by the Ministry of Health (MOH)

(Source) Prepared by JICA Study Team based on project reports and interview findings

The field study of these sites additionally confirmed the following organizational and institutional problems.

- In areas where the grid has been extended after PV electrification, some stores and households used both systems (PV systems for lighting and the grid for other equipment) or keep the PV systems for back-up. Users understand that the grid tariffs are commodity tariffs and are oriented toward use of the PV systems for use at a flat rate.
- In public facilities, users did not understand the system ownership and in many cases left systems out of order. In addition, users sometimes reported system failure to the district assembly or national agency outpost in the district, but generally did not get any action in return.
- Because many customers were petty farmers, they sometimes paid in lump sums when they had income instead paying regularly.
- For BCS, operators were selected by the community to manage systems and collect charges. For other systems, however, there was no such organized activity.
- In some areas, systems were not in operation due to the lack of supply spare material such as Direct Current (DC) lighting bulb.

Through the PV pilot projects executed with the support of donors beginning in the late 1990s, Ghana gained technical expertise and learned many lessons. Table 3.2.6 summarizes the problems identified in past projects in the aspects of planning, O&M, tariffs/payments, and customers.

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[2] In this home, indoor wires had been installed for grid service and there was assortment electrical products including a refrigerator, but a 300-W PV system was installed because of inability to pay the cost of 18 utility poles.

Table 3.2.6 Summary of problems with past PV projects

Project	Spain/MME	RESPRO	DANIDA
System	Solar home system (SHS)	Solar home system (SHS)	Battery charge station (BCS)
Project principal	National government and communities	Energy service company (ESCO)	Rural banks and communities
Business models	Fee for service	Fee for service	Financing for customers from rural banks
Plans	・The project selected areas where extension of the grid was expected as the electrification subjects.	・Attempts were made to select areas unlikely to be reached by the grid for the foreseeable future, but the grid service came sooner than expected and caused a problem of relocation.	・Problems arose because the project principal did not explain matters fully to the rural banks and customers in advance.
O&M	・The area was too wide for coverage by the governmental technicians, who consequently could not offer enough support.	・The RESPRO is providing technical support, but the operating costs are high because the work is directly managed.	・BCS operators perform maintenance but did not have the technical skills needed for problem-solving.
Rate setting and collection of charges	・The project failed financially because the tariffs were too low and charges often could not be collected. ・Communities did not return the collected charges to the government.	・Costs could not be retrieved because the tariffs were set on a par with the lifeline tariff (2 dollars). ・Operating costs were high because RESPRO personnel collected charges themselves.	・BCS operators collected charges, but could not take a tough attitude due to ties of blood. ・Operators sometimes pocketed the charges they collected.
Customers	・Customers did not allow systems to be removed even though they were not paying the charges.	・Many of the customers were poor farmers who did not have a steady income and paid in lump sums after being in arrears.	・Loans were made to residents with low income levels. ・Because of the lack of in-depth advance explanation, residents did not understand their repayment obligation.

(Source) JICA Study Team

3.2.4 Technical discussion for off-grid PV electrification

(1) Actual record of PV electrification in Ghana

1) Actual PV system installation

As of 2003, PV system installation in Ghana totaled 4,911 systems with a combined capacity of 1.0MW. Almost all of them were off-grid systems. Since 2004, the MOE has been promoting a project for electrification of junior secondary schools. Ultimately, it plans to install PV systems in some 1,100 schools nationwide. As this indicates, PV systems are effective means of RE in Ghana.

Table 3.2.7 shows the number of PV systems installed in Ghana, and Figure 3.2.1, photos of two systems.

Table 3.2.7 Number of PV systems installed in Ghana (as of 2003)

Application	No. of installation
Solar Home Systems	4,500
Water Pumping	80
Vaccine Refrigeration	210
Telecommunication(repeater stations)	63
Radio transceivers	34
Rural telephony	3
Battery charging stations	20
Grid connected (50kW)	1
Total Number of Installed Systems	**4,911**
Total Installed Capacity	**1.0MWp**

(Source) MOE *CHALLENGES OF SOLAR PV FOR REMOTE ELECTRIFICATION IN GHANA*

Clinic system (Busunu)

Battery Charging Station system (Wacheu)

(Photo) JICA Study Team

Figure 3.2.1 Cases of PV system installation

The specifications of the existing PV system equipment and materials vary with the project and with the installer or manufacturer; they have not yet been unified. For the purpose of example, Table 3.2.8 shows specifications from the junior secondary school, DANIDA, and MME/Spain projects. The lack of unified standards and specifications presents latent problems due to drawbacks in areas such as equipment compatibility and availability. The establishment of standards and specifications is therefore an urgent task.

Table 3.2.8 Examples of material specifications

Item	MOE/JSS		DANIDA	MME/Spain	
PV Module					
Cell type			Monocrystal	Monocrystal	
Peak power	50W	100W	50W	50W	100W
Peak power voltage	16.5-18.0V	16.5-18.0V			
Peak power current	2.92-3.22A	5.98-6.29V			
Short-circuit current	3.10-3.22A	6.53-6.87A	3.27A		
Open-circuit voltage	21-22V	21-22V	21.6V		
Warranty	15-20years	15-20years			
Charge controller					
Normal system voltage	12V	12V	12/24V		
Normal current rating	10A	20A	10A	8A	15A
Maximum input current	15A	25A	25%		
Input voltage range	12-25V	12-25V			
Warranty	5years	5years			
Battery					
Type	Flooded or Sealed	Flooded or Sealed	Flooded	Sealed gel	Sealed gel
Normal voltage	12V	12V	12V	12V	12V
Amp-hour capacity	80Ah-C_{10}	144Ah-C_{10}	60Ah-C_{20}	105Ah	144Ah
Deep cycle capacity	2500cycle at 50%	2500cycle at 50%			
Depth of discharge			50-60%		
Warranty	5years	5years			
DC/AC Inverter					
Rated Power	250W				
Surge power	600W				
Efficiency	92%				
Input current	22A				
Output voltage	230V				
Warranty	5years				

(Source) MOE *SECTION VI-TECHNIKCAL SPECIFICATIONS*
SUPORT FOR THE DEVEROPMENT AND MANEMENT OF RENEWABLE ENERGY IN GHANA PROJECT COMPLETION REPORT
MME, *SPAIN OFF-GRID SOLAR PV RURAL ELECTRIFICATION PROJECT*

2) PV enterprises in Ghana

The PV electrification project experience is cultivating the growth of many dependable PV enterprises within Ghana. Table 3.2.9 lists those recommended by the MOE.

Table 3.2.9 List of PV system companies

No.	Name	No.	Name
1	Wilkins Engineering Ltd.	5	DENG Engineering
2	SOLARCO Ltd.	6	Terra Solar
3	Gold River Solar Electric	7	WISE ENERGY
4	Solar Light Company	8	BEST Solar

(Source) MOE

The following is a profile of the major ones.

●Wilkins Engineering Ltd.

This company was founded in 1993 as an engineering consultant. It has been engaged in wiring, PV system installation, and supply of related equipment since 1996. It imports material from the Spanish company Isofoton. It has 28 full-time employees, 12 of whom are PV system technicians. It also has 60 part-time employees. For PV systems, its main achievements were installation of the 50kW grid-connected system in the MOE and of 300 systems in schools across the country.

●DENG Engineering

DENG Engineering launched business in water heaters in 1995 and commenced business in PV systems in 1998. It has about 50 employees, and maintains offices in Accra and Kumashi. It has agencies in Donkorkrom, Nkoranza, and Tamale. It has also obtained a service provider license from the EC. It began a comprehensive training course in the areas of system design, installation, and maintenance for PV technicians in April 2005. Over the last five years, it has sold about 2,000 SHS and 5,000 solar lanterns.

●Terra Solar

Established in 1998, Terra Solar obtained an EC license for service provision in 2004. It has three employees, and imports equipment mainly from the United States, Canada, and Belgium.

●BEST Solar

BEST Solar grew out of PV projects implemented under the NGO New Energy beginning in 1989, and was incorporated in 2002. It has seven employees, four of whom are PV technicians. It also acts as an agent for DENG Engineering in Tamale. It purchases equipment mainly from DENG, but buys seal batteries from WISE ENERGY. It installed PV systems in the RESPRO and DANIDA projects.

●WISE ENERGY

WISE ENERGY was established by the Dutch firm Stroomweak in 2001. It has 15 employees, three of whom are engineers. It imports equipment from Stroomweak. It handles SHS, street lights, pump systems, and back-up systems. Almost all of these products are standardized and sold in kits. Stroomweak has installed about 10,000 SHS of the type it handles in Mali.

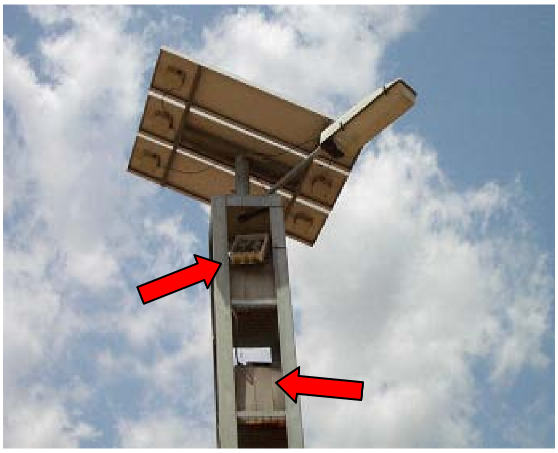
3) Problems with existing PV systems

In May 2005, the Study Team made a field study of PV systems installed in the northern regions. Many of the users clean the panels once a week and are otherwise skillfully operating the systems. Nevertheless, the following technical problems were observed in several cases. Some problems date from the time of installation, while others arose in the process of maintenance and operation by users.

Examples are shown in Figure 3.2.2 and Figure 3.2.3, and descriptions are provided in items a) - i).

(Photo) JICA Study Team

Figure 3.2.2 Distribution lines directly connected to batteries (bypass of the charge controller)



(Photo) JICA Study Team

Figure 3.2.3 Broken connection box and battery

a) Because the charge controller failed, the PV panel and battery were directly connected.
  - Battery damage and service life reduction due to overcharging and/or overdischarging

b) The battery is put out of action due to a lack of fluid, and the system does not operate.

c) The light is burnt out, but has not been replaced due to uncertainty about the party responsible for replacement.

d) There is a mismatch of system components, e.g., too small battery capacity difference of low-voltage guard operating values between the battery and inverter.
  - Poor system effficiency, equipment damage due to differences in respect of operating points.

e) Customers do not understand how to make routine checks, and do not know who to contact in the event of breakdown.
  - Induction of breakdown due to grime, etc.
  - Escalation into more serious trouble due to delayed detection of defects

f) The PV panel supports are not long enough, and makeshift extensions are attached to them.
  - Decrease in the strength of supporting parts.

g) Panels are not all headed in the right direction.
  - Decrease in generation efficiency.

h) Spent or broken batteries are simply discarded.
  - Soil contamination/water pollution due to the acid and lead contained in the batteries

i) Terminals are not used for connection of cable to the batteries. Terminals are exposed.
  - System shutdown and shorting when cables slip off
  - Shock due to contact with terminals

The technical causes of these problems include the difference of technical and installation standards depending on the project and manufacturer, shortage of technicians, lack of education for users about routine checking, lack of user manuals, and lack of basic knowledge about electricity and of PV system knowledge among users and technicians. As such, the key tasks for resolution of these problems are the establishment of uniform technical and installation standards, preparation of user manuals, user education and information provision, and training of specialized technicians.

(2) Off-grid PV system design conditions

1) Recommended design conditions

In PV system design, it is important to set appropriate values for design parameters, because the PV module output, battery capacity, and other factors differ depending on these values. Table 3.2.10 shows design parameters and values applied by the RESPRO and BEST Solar.

Table 3.2.10 Design parameters (RESPRO and BEST Solar)

Item	RESPRO	BEST Solar
Battery charging efficiency	-	90%
Cable loss	2%	-
Inverter efficiency	-	85%
PV Module manufacture tolerance	-	-3%
Design factor (dirt,temperature,e.t.c.)	-	95%
Peak sunshine hour	5	5.06
Days of autonomy	2	5
Depth of discharge (D.O.D)	80%	70%
Charge controller safety factor	1.3	-
Inverter safety factor	1.75	-

(Source) Interviews with the RESPRO and BEST Solar

The major difference between the two is the number of (continuous) days of autonomy (without solar radiation). Whereas BEST Solar applies one of five days, the RESPRO applies one of two. The RESPRO, however, also applies one of five in work under projects such as the UNDP/GEF and JSS projects. It presumably applies tighter design values for parameters such as autonomy in order to hold down the requisite facility investment, because it applies the fee-for-service model. A higher design tolerance would increase the system reliability but also compel a larger facility capacity and use of more costly products, and therefore drive up the system price. This would impose a heavier burden on the users and consequently impede the spread of PV systems. For this reason, it is also vital to apply tight parameter values to create minimum requisite systems. Table 3.2.11 shows some design parameter values that are recommended in light of these considerations

Table 3.2.11 Recommended design conditions (for off-grid PV systems)

Item	Parameter	Remark
Battery charging efficiency	80%	The ordinary value for lead acid batteries
Cable loss	5%	Wiring size should be decided so that voltage drop is less than 5%.
Inverter efficiency	85 to 90%	The ordinary value for inverters Application for AC systems (DC systems = 100%)
Design factor (dirt,temperature,e.t.c.)	90%	In consideration of decrease in generation efficiency due to panel grime and temperature, and equipment loss
Peak sunshine hour (Irradiation)	Minimum Monthly Average	Use the minimum monthly average of the local area. Refer to table 3.2.12
Days of autonomy	3 to 5	3 days in the case of ordinary facilities, 5 days in districts where poor irradiation conditions continue for many days (based on in-depth study of observation data), and 5 days for key facilities (e.g., vaccine refrigerators)

Depth of discharge (D.O.D)	70%	70% in the case of a deep cycle battery, 50% in the case of other batteries
Charge controller safety factor	-	Above the discharge voltage of the PV module Capacity above the maximum current, inclusive of the load start-up current, in the case of DC systems Should also have a tolerance of 20%
Inverter safety factor	-	Rated capacity higher than the total rated power consumption for the load Surge capacity higher than the load surge power。 Should also have a tolerance of 20%

(Source) JICA Study Team

Table 3.2.12 Monthly average irradiation (hours) in various areas

Month	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
Accra	4.66	5.21	5.26	5.67	5.42	4.61	4.19	4.53	5.12	5.62	5.51	4.93	5.06
Kumasi	4.82	5.31	5.31	5.37	4.71	4.03	4.04	3.78	3.99	4.71	5.00	4.55	4.63
Tamale	5.12	5.48	5.61	5.89	5.87	5.51	4.95	4.84	5.00	5.47	5.70	5.21	5.39
Yendi	5.16	5.46	5.56	5.86	5.92	5.42	5.04	4.63	4.96	5.62	5.67	5.17	5.37
Bole	5.42	5.82	5.76	5.80	5.71	5.09	4.65	4.49	4.83	5.54	5.52	5.25	5.32
Wa	5.46	5.81	5.80	5.86	5.87	5.61	5.14	4.94	5.13	5.64	5.65	5.38	5.52
Navrongo	5.39	5.4	5.78	5.96	5.93	5.72	5.34	5.10	5.32	5.68	5.62	4.82	5.51

(Source) Data provided by the EC

2) Example of system design based on the recommended parameter values

This section presents an example of SHS design based on the recommended parameter values. Table 3.2.13 shows the assumptions regarding power demand in this example, and assumes that it is installed in Tamale.

Table 3.2.13 Power demand

Item	W	Number	Used time	Wh	A	Using W
light	8	2	4	64	1.3	16
W&B TV	30	1	2	60	2.5	30
Radio	15	1	2	30	1.3	15
Total				154	5.1	61

(Source) Prepared by the JICA Study Team

a) Selection of PV modules

$$\text{Used current}\quad Iu = \frac{\text{Power consumption}}{\text{system voltage}} = \frac{154\text{Wh}}{12\text{V}} = 12.83\text{Ah}$$

$$\text{Requisited current}\quad In = \frac{\text{Used current}\quad Iu}{\text{battery efficiency x inverter efficiency x design factor}}$$

$$= \frac{12.83}{0.8 \times 1.0 \times 0.85} = 18.9\ \text{Ah}$$

$$\text{Requisited PV output}\quad W = \frac{\text{Requisited current}\ In \times \text{System Voltage V}}{\text{Sunshine hours h}} = \frac{18.9 \times 12}{4.84}$$

$$= 46.9 \quad \Rightarrow$$

Selection of a PV module with a maximum power of at least 46.9 Wp

b) Calculation of battery capacity

$$\text{Battery capacity} = \frac{\text{Use current}\quad Iu \times \text{Autonomy}}{\text{depth of discharge x inverter efficiency}}$$

$$= \frac{12.8 \times 3}{0.7 \times 1.0} = 55 \quad \Rightarrow$$

Selection of a deep cycle battery with a capacity of at least 55 Ah

c) Selection of charge controller

The charge controller must have a higher capacity than the PV short-circuit current. In the case of a DC system, the capacity has to be even higher because the load current flows through the charge controller. The maximum load current varies with the equipment, but is generally as follows:

Lights: rated current x 1 – 2, TV sets: rated current x 2.5 - 5

Motors: rated current x 5 - 10

If the TV set is taken as the maximum, the calculation would be as follows.

Maximum load current = maximum TV set current + rated light current + rated radio current

$$=(2.5\times 5)+1.3+1.3=15.1\ \text{A}$$

If the short-circuit current of the PV module selected was 3.45 A, then:

$3.45 < 15.1$ ⇨

A selection would be made of a charge controller that had a capacity of at least 15.1 A.

Chapter 4 Current village socioeconomic status

4.1 Objective of the village socioeconomic study

Electrification projects are not a matter of merely supplying electrical materials and equipment; they also require a determination of the circumstances among customers (including potential ones) as their users. It is vital to ascertain all sorts of socioeconomic circumstances with attention to the following questions.

1) Is electrification really necessary? (justification)

2) What are the proper choices for the type and scale of the electrification system? (efficacy)

3) What kind of impact will electrification have? (impact)

4) Are there any problems as regards payment for system use and the setup for O&M? (sustainability and spontaneous expansibility)

The main indicators in regard to the first question are the pattern of life in the subject district, the level of needs for electricity as compared to those for various other goods and services, and the level of various development and economic activities.

Concerning the second question, the distribution of housing, use of electrical products, and type of system preferred by the residents would be the main indicators for estimating the electrification method and power demand.

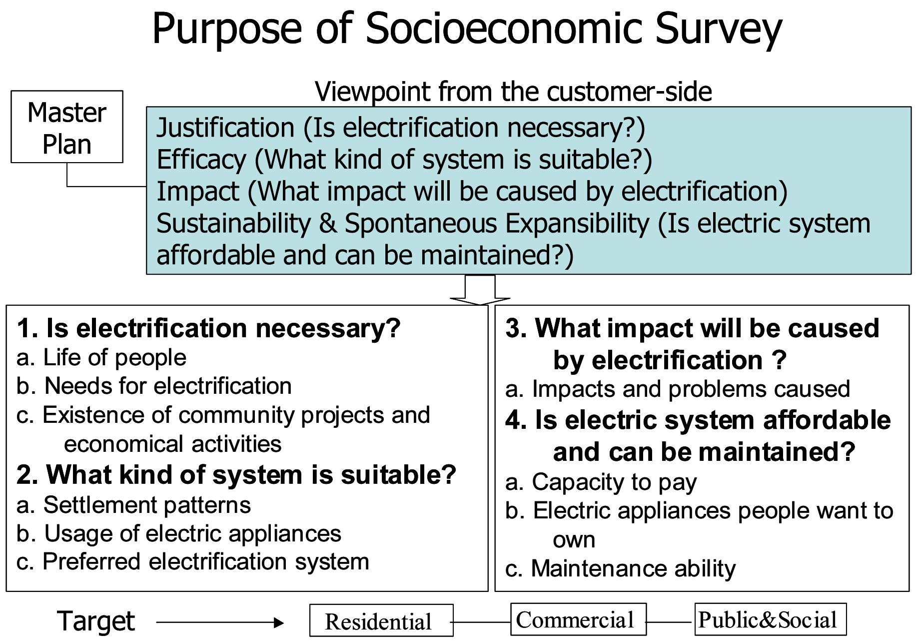
The key indicator for the third question would be the diversity of circumstances induced by electrification and the customer perception of them.

For the fourth question, the main indicators would be the amount of disposable income (based on energy-related expenditures), relationship between electrical products people want to buy and their disposable income, and the setup and capabilities for system O&M.

Objective data of this sort are of vital importance for estimation of power demand and establishment of standards for the selection of areas and for the business models in formulation of the RE master plan. They are also useful as material for judging relevance, effectiveness, and sustainability in discussion of electrification policies by governmental authorities. In this master plan study as well, the Study Team consequently collected and analyzed data concerning the socioeconomic status, and particularly that related to power and energy, among customers in the three northern regions.

This socioeconomic study was under constraints of both time and budget. In the interest of efficient collection and analysis of data, the Study Team decided to utilize secondary data including available statistical documents and various reports for general socioeconomic data on the area level. For detailed data on socioeconomic circumstances on the level of particular villages (especially as regards electrification and energy, for which there are few data in available documents), it decided to collect data through the field study of sample villages for analysis[3]. The Study Team therefore collected and analyzed both quantitative and qualitative data through these two investigative components, in order to achieve results that would assist formulation of the master plan for RE premised mainly on PV systems.

Figure 4.1.1 diagrams the concept of the village socioeconomic study.



(Source) JICA Study Team

Figure 4.1.1 Concept behind the village socioeconomic study

4.2 Procedure of the village socioeconomic study

4.2.1 Collection and analysis of secondary data

In Ghana, there have already been various studies portraying the socioeconomic status in villages, and they have served as the basis for the preparation of documentation and statistical data. The Study Team decided to make effective use of this material for more efficient execution of the socioeconomic study of village life. More specifically, the materials shown in Table 4.2.1 were used to ascertain and analyze the general socioeconomic situation in the three northern regions.

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[3] In available documentation, villages are termed "communities" or "localities."

Table 4.2.1 Survey of documentation on the village socioeconomic status

Document	Description	Remarks
District Medium Term Development Plan	General situation in each district and strategy for development	The chief edition is for the years 2002 - 2004, but there is also a 2001 - 2005 edition.
District Annual Development Plan 2005	General situation in each district and strategy for development	Although FY2005 has already begun, the Plan is still under preparation in many districts.
District Poverty Profiling and Mapping Report	General situation in each district and various data on poverty	Studies and reports are being prepared in the three northern regions with GTZ aid, but have not yet been completed in many districts.

(Source) JICA Study Team

4.2.2 Execution of the sample survey

The Study Team applied various techniques in implementing a sample survey with the objectives, subjects, and study items noted below.

Table 4.2.2 Sample survey objectives, subjects, and items

1. Questionnaire survey
• Objective: Collection of socioeconomic data, both quantitative and qualitative, related to electrification and energy from households, public facilities, and commercial facilities, using questionnaire forms. • Subjects: The survey was conducted with about 20 subjects in each community. The breakdown was generally 14 households, three public facilities, and three commercial facilities, but varied along with the number of public/commercial facilities in each community. Ordinarily, communities in rural areas take the form of "compounds" bringing together many households in a single site. However, the study took economically independent groups as the standard subjects instead of the compound. In the category of public facilities, the prospective survey subjects were mainly schools, health centers/clinics, water supply facilities, community centers, government facilities, mosques/churches, markets, automobile/bus stations, and institutions for management of outdoor lighting. In the category of commercial facilities, they were grocery stores, restaurants, lodging facilities, and household handicraft facilities as opposed to industrial plants and other large-scale facilities. * The sample households representing each community were selected at fixed distances from the starting point calculated in correspondence with the total number of households in each community. The public and commercial facilities were selected at random. • Survey items: Households 1) General household information (membership, house build, occupation of the head, etc. 2) Information on power/energy (knowledge concerning electrification, lighting fixtures and expense, use of electrical appliances, problems in power use and O&M, amount residents would be willing to pay, etc. 3) Other important information (income/expenditure, needed services) *The questions may differ depending on whether the community is electrified or unelectrified) Public/commercial facilities 1) Nature of business 2) Information on power/energy (lighting fixtures and expense, use of electrical appliances, problems in power use and O&M, amount residents would be willing to pay, etc.)

2. Focus group discussion

- Objective:
  Collection of more detailed qualitative data that would be hard to obtain through conventional survey methods such as documentation surveys and questionnaire surveys. Based on certain guidelines, adjustments (e.g., change of question sequence or content, and deletions/additions) were made in the course of the discussion for correspondence with the membership and situation. There were two particular aims: 1) to determine the actual community awareness, expectations, and needs regarding electrification; and 2) to gauge the level of community power consumption and O&M capabilities.

- Subjects:
  The discussion was held in only 30 (15 for electrified and 15 for un-electrified) of the 93 communities studied. Each group had a membership of about ten residents in various positions, including the communitie heads, community assembly members, representatives of women's groups, representatives of youth groups, teachers, religious leaders, representatives of water management committees, farmers, and merchants.

- Discussion items:
  1) General information (e.g., population, number of compounds, compound/facility density, activities on a typical day, presence/absence of public/commercial facilities, presence/absence of community organizations, presence/absence of community development projects, and requisite services)
  2) Information on power/energy (knowledge concerning electrification, problems in power use and O&M, reasons for lack of electricity, influence of electrification, amount residents would be willing to pay, etc.)

*The questions may differ depending on whether the community is electrified or unelectrified)

3. Interviews with key informants

- Objective:
  Collection of more detailed qualitative data that would be hard to obtain through conventional survey methods such as documentation surveys and questionnaire surveys. Based on certain guidelines, adjustments (e.g., change of question sequence or content, and deletions/additions) were made in the course of the discussion for correspondence with the membership and situation. Particular emphasis was placed on interviews with personnel concerned with facilities for education or health/medical care (Regional Offices in the Educaiton and Ghana Health Service), for which solar PV systems are anticipated to play an important role, to identify electrification problems and possibilities.

- Subjects:
  The interviews were held with personnel in the fields of education and health/medical care in 28 of the total 34 districts in the three northern regions.

- Discussion items:
  Electrification influence and problems in O&M (electrification facilities), electrification needs and possible O&M arrangements (unelectrified facilities), relationship with strategy in the fields of education and health/medical care, relationship with other development projects, etc.

(Source) JICA Study Team

The communities covered in the sample survey to represent the socioeconomic situation in the three northern regions were determined by the following procedure.

Step 1

The survey population consisted of 3,246 communities remaining after exclusion of communities with a population of no more than 250 from the total number of 6,585 communities (based on the fiscal 2000 census). (Communities with a population of no more than 250 were thought to be too small and so excluded from the sample survey.)

On this basis, the following equation was utilized to determine a total of 93 communities considered statistically significant.[4]

$$n = \frac{N}{\left(\frac{\varepsilon}{K(a)}\right)^2 \frac{N-1}{P(1-P)} + 1}$$

α =the probability (risk) of misestimation of the population characteristic value = ordinarily 5% = K (α) in this case = 1.96

ε =margin of plus-or-minus error in the sampling ratio; a figure of plus-or-minus 10% was adopted in this survey because one in excess of 10% makes it difficult to perform a comparative analysis with sufficient certainty.

n=the requisite number of samples

N=the size of the host population

P = population ratio; the share of the host population occupied by communities able to represent the socioeconomic status in the three northern regions. To prevent the number of samples from becoming too small, the Study Team applied one of 50% to maximize the P (1-P) value (0.5 x 0.5 = 0.25).

Step 2

Next, the Study Team decided to classify the subject communities as follows in order to represent as many regional characteristics as follows.

Unelectrified communities

- Communities that can be electrified only by off-grid PV systems (meaning those other than the communities that can be electrified by on-grid systems (SHEP) in the future)
- Communities that can be electrified by on-grid systems (SHEP) in the future (meaning communities that are currently covered by SHEP and those that could physically be electrified by extension of the grid if they so request)

Electrified communities

- Communities electrified by off-grid PV systems (in or before December 2001)
- Communities electrified by off-grid PV systems (in or after January 2002)
- Communities electrified by on-grid systems

Many off-grid PV projects were implemented in the late 1990s by other donors. As such, battery problems, which greatly affect the sustainability of off-grid PV systems, may possibly have surfaced in many communities so electrified by December 2001. The Study Team consequently decided to use the start of 2002 as a boundary in classification of communities electrified by PV systems.

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[4] Statistical techniques for matters such as determination of the number of samples made reference to various social surveys and documentation on statistical methods, and are not detailed here.

Furthermore, the Study Team excluded areas thought to present access problems, seeing that the field study was to be conducted in the rainy season.

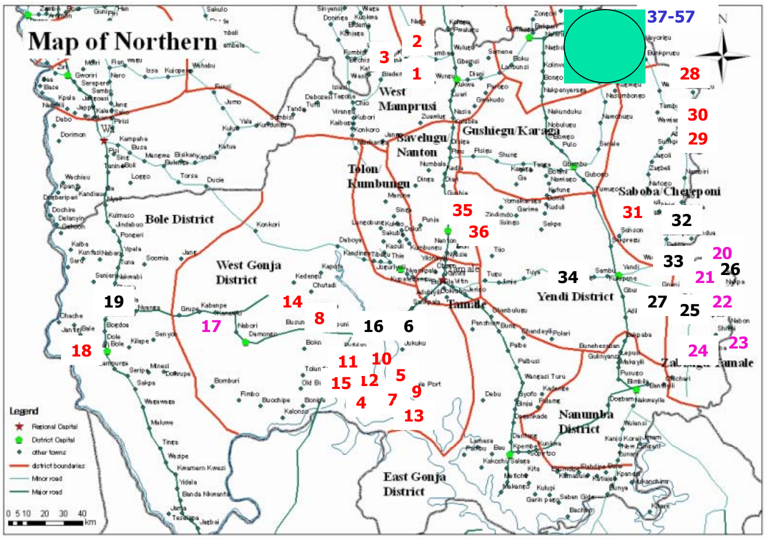
Step 3

The Study Team applied the broad classification noted above to the subject communities and then randomly sampled them to select the communities to be covered by the survey. As the culmination of this procedure it selected the communities noted below for the survey.

The samples numbered 93 in all. It was decided to determine the number in each class with consideration of differences in respect of the number of communities in the three northern regions and the small number of areas that have been electrified by off-grid PV systems since January 2002.

The following tables and figures show the communities covered in the sample survey.

Northern Region



Electrification Status	Number of Sample Communities
Communities that can be electrified only by off-grid PV systems	21
Communities that can be electrified by on-grid systems (SHEP) in the future	6
Communities electrified by off-grid PV systems (in or before December 2001)	21
Communities electrified by off-grid PV systems (in or after January 2002)	0
Communities electrified by on-grid systems	9
Total	57

(Source) JICA Study Team

Figure 4.2.1 Map of the Northern Region

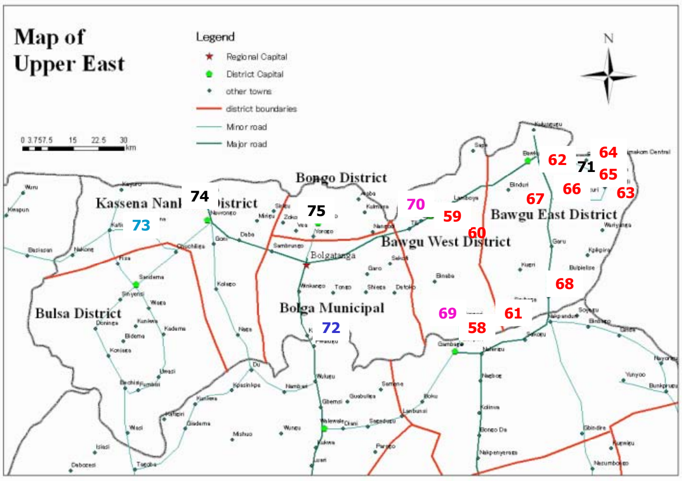
Table 4.2.3 Communities covered in the survey in the Northern Region

No.	Community	District	Electrification Status *1	Population *2
1	Bimbini	West Mamprusi	1	138
2	Duu	West Mamprusi	1	4,500
3	Kpasenkpe	West Mamprusi	1	14,200
4	Mpaha	Central Gonja	1	7,000
5	Kafulwurape	Central Gonja	1	465
6	Kusawgu	Central Gonja	5	484
7	Sheri	Central Gonja	1	1,978
8	Busunu	West Gonja	1	2,572
9	Bethlehem	West/Central Gonja	1	409
10	Butei	West/Central Gonja	1	495
11	Lampur	West/Central Gonja	1	261
12	Kokope	West/Central Gonja	1	585
13	Kakale	West/Central Gonja	1	350
14	Langatire	West/Central Gonja	1	326
15	Kpabuso	West/Central Gonja	1	1,443
16	Yapei	West/Central Gonja	5	6,524
17	Kananto	West/Central Gonja	2	506
18	Mandari	Bole	1	2,790
19	Sawla	Sawla	5	6,082
20	Yachadom	Zabzugu/Tatale	2	872

No.	Community	District	Electrification Status[*1]	Population[*2]
21	Nahuyili	Zabzugu/Tatale	2	1,616
22	Kulkpaligu	Zabzugu/Tatale	2	1,250
23	Sheini	Zabzugu/Tatale	2	980
24	Kandin	Zabzugu/Tatale	2	1,142
25	Zabzugu	Zabzugu/Tatale	5	12,370
26	Tatale	Zabzugu/Tatale	5	6,100
27	Sabare	Zabzugu/Tatale	5	1,078
28	Wenchiki	Saboba/Chereponi	1	1,131
29	Kpani	Saboba/Chereponi	1	957
30	Kudani	Saboba/Chereponi	1	549
31	Wapuli	Saboba/Chereponi	1	1,695
32	Saboba	Saboba/Chereponi	5	3,687
33	Demon	Saboba/Chereponi	5	1,022
34	Sang	Yendi	5	6,162
35	Tamaligu	Savelugu/Nanton	1	1,720
36	Bagurugu	Savelugu/Nanton	1	1664
37	Jilig No. 2	East Mamprusi	3	523
38	Jimbale	East Mamprusi	3	1,590
39	Nanjong No.2	East Mamprusi	3	1,793
40	Nanjong No. 1	East Mamprusi	3	1,909
41	Binde	East Mamprusi	3	1,759
42	Bunkpurugu	East Mamprusi	3	1,234
43	Boufouk	East Mamprusi	3	256
44	Bumbuna	East Mamprusi	3	2,778
45	Chintilong	East Mamprusi	3	924
46	Gbankoni	East Mamprusi	3	6,000
47	Gbedank	East Mamprusi	3	2,091
48	Gbetimopak	East Mamprusi	3	418
49	Jiling	East Mamprusi	3	520
50	Kambatiak	East Mamprusi	3	1,064
51	Kambogu	East Mamprusi	3	1,476
52	Kinkango	East Mamprusi	3	859
53	Kpenteng	East Mamprusi	3	528
54	Mangol	East Mamprusi	3	481
55	Navier	East Mamprusi	3	2,200
56	Pagnatik	East Mamprusi	3	700
57	Tatara	East Mamprusi	3	21

(Source) JICA Study Team

Upper-East Region



Electrification Status	Number of Sample Communities
Communities that can be electrified only by off-grid PV systems	11
Communities that can be electrified by on-grid systems (SHEP) in the future	2
Communities electrified by off-grid PV systems (in or before December 2001)	1
Communities electrified by off-grid PV systems (in or after January 2002)	1
Communities electrified by on-grid systems	3
Total	18

(Source) JICA Study Team

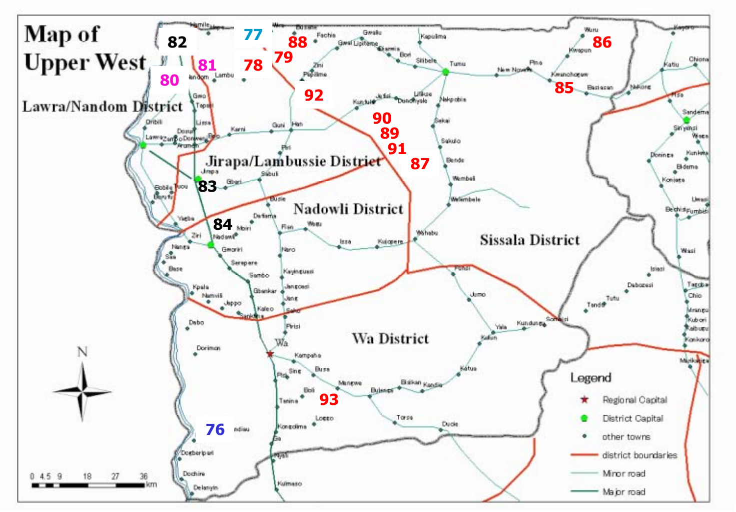
Figure 4.2.2 Map of the Upper East Region

Table 4.2.4 Communities covered in the survey in the Upper East Region

No.	Community	District	Electrification Status*1	Population*2
58	Zongoyire	Bawku West	1	588
59	Tanga Natinga	Bawku West	1	600
60	Goriga	Bawku West	1	1,198
61	Duri	Bawku East	1	2,000
62	Sarabogo	Bawku East	1	2,308
63	Poanaba	Bawku East	1	96
64	Kanjam	Bawku East	1	445
65	Vortkom	Bawku East	1	214
66	Bugri Natinga	Garu Tinpane	1	2,122
67	BasYonde central	Garu Tinpane	1	2,279
68	Sumaduri	Garu Tinpane	1	738
69	Apodabogo	Bawku West	2	1,247
70	Windnaba	Bawku West	2	3,000
71	Pusiga	Bawku West	5	6,823
72	Tenzuk	Talensi/Nabdam	3	847
73	Chiana	Kasena Nankana	4	2,890
74	Paga	Kasena Nankana	5	7,819
75	Bongo	Bongo	5	4,787

(Source) JICA Study Team

Upper-West Region



Electrification Status	Number of Sample Communities
Communities that can be electrified only by off-grid PV systems	11
Communities that can be electrified by on-grid systems (SHEP) in the future	2
Communities electrified by off-grid PV systems (in or before December 2001)	1
Communities electrified by off-grid PV systems (in or after January 2002)	1
Communities electrified by on-grid systems	3
Total	18

(Source) JICA Study Team

Figure 4.2.3 Map of the Upper West Region

Table 4.2.5 Communities covered in the survey in the Upper West Region

No.	Community	District	Electrification Status[*1]	Population[*2]
77	Wechau	Wa	3	13,341
78	Fielmo	Sissala	4	2,497
79	Kongo	Jirapa	1	223
80	Buo	Jirapa	1	2,100
81	Kogle	Jirapa	2	839
82	Ketuo	Jirapa	2	960
83	Kokoligo	Jirapa	5	1,500
84	Jirapa	Jirapa	5	8,060
85	Nadowli	Nadowli	5	3,882
86	Banu	Sissala	1	253
87	Wuru	Sissala	1	370
88	Bichemboi	Sissala	1	646
89	Puzene	Sissala	1	611
90	Dasima	Sissala	1	982
91	Duwie	Sissala	1	759
92	Gbelle	Sissala	1	229
93	Wasai	Sissala	1	325
94	Kulkpong	Sissala	1	1,455

*1Electrification Status is classified as follows;

1= Communities that can be electrified only by off-grid PV systems, 2 = Communities that can be electrified by on-grid systems (SHEP) in the future, 3= Communities electrified by off-grid PV systems (in or before December 2001), 4= Communities electrified by off-grid PV systems (in or after January 2002), 5= Communities electrified by on-grid systems

*2 Data on the number of population were acquired by the iterview in the sample survey. Therefore, communities with a population of no more than 250 were included in the sample survey, although Population Census 2000 indicated those communities as with a population of more than 250.

(Source) JICA Study Team

4.3 Results of analysis of the village socioeconomic study findings

The Study Team made an analysis of the various socioeconomic data from the documentation survey and sample survey from the perspectives noted above, i.e.: 1) is electrification really necessary? (propriety), 2) what are the proper choices for the type and scale of the electrification system? (efficacy), 3) what kind of impact will electrification have? (impact), and 4) are there any problems as regards payment for system use and the setup for O&M? (sustainability and independent extensibility).

The Study Team initially divided the unelectrified communities into two categories: those that could be electrified only by off-grid PV systems, and those that could be electrified by extension of the grid (SHEP) in the future. It also expected to analyze and survey the communities electrified by off-grid PV systems before and after 2002.

However, comparison revealed that there was not a lot of data difference between the categories of unelectrified communities and communities electrified by off-grid PV systems. As such, to facilitate comprehension of the results, it was decided to abolish the aforementioned categorization and apply a division of three categories for the account in this chapter: unelectrified communities, communities electrified by off-grid PV systems, and communities electrified by on-grid systems.

The sample survey was implemented from June to August of 2005. As noted above, it consisted of the questionnaire survey, focus group discussion (FGD), and key informant interview (KII). Table 4.3.1 shows the breakdown of the number of questionnaire survey respondents (residences, commercial facilities, and public facilities).

Table 4.3.1 Number of questionnaire survey respondents

Number of Subjects of Questionnaire Survey

	Residential Houses			Commercial Facilities			Public&Social Facilities		
Northen Region	843	UE-OFF	317	124	UE-OFF	28	66	UE-OFF	14
		UE-ON	92		UE-ON	11		UE-ON	7
		E-OFF (before	275		E-OFF (before	75		E-OFF (before	37
		E-OFF (after 2002)	29		E-OFF (after 2002)	0		E-OFF (after 2002)	0
		E-ON	130		E-ON	10		E-ON	8
Upper-East Region	267	UE-OFF	150	55	UE-OFF	37	40	UE-OFF	27
		UE-ON	30		UE-ON	4		UE-ON	3
		E-OFF (before	14		E-OFF (before	0		E-OFF (before	0
		E-OFF (after 2002)	31		E-OFF (after 2002)	4		E-OFF (after 2002)	2
		E-ON	42		E-ON	10		E-ON	8
Upper-West Region	308	UE-OFF	199	27	UE-OFF	13	24	UE-OFF	9
		UE-ON	35		UE-ON	1		UE-ON	4
		E-OFF (before	29		E-OFF (before	3		E-OFF (before	3
		E-OFF (after 2002)	0		E-OFF (after 2002)	2		E-OFF (after 2002)	3
		E-ON	45		E-ON	8		E-ON	5
Total	1418			206			130		

(Source) JICA Study Team

As shown in Table 4.3.2, the FGD was conducted with 30 communities.

Table 4.3.2 Communities covered by the focus group discussion (FGD)

Target Villages for FGD

No.	Village	Region	No.	Village	Region	No.	Village	Region
1	Bimbini	Northen	33	Demon	Northen	65	Vortkom	Upper East
6	Kusawgu	Northen	35	Tamaligu	Northen	71	Pusiga	Upper East
9	Bethlehem	Northen	38	Jimbale	Northen	74	Paga	Upper East
15	Kpabuso	Northen	41	Binde	Northen	75	Bongo	Upper East
16	Yapei	Northen	42	Bunkpurugu	Northen	76	Wechau	Upper West
17	Kananto	Northen	50	Kambatiak	Northen	77	Fielmuo	Upper West
24	Kandin	Northen	53	Kpenteng	Northen	78	Kongo	Upper West
26	Tatale	Northen	54	Mangol	Northen	79	Buo	Upper West
27	Sabare	Northen	60	Goriga	Upper East	80	Kogle	Upper West
28	Wenchiki	Northen	62	Sarabongo	Upper East	84	Nadowli	Upper West

(Source) JICA Study Team

The KII subjects were personnel in the regional offices of the MOEdu and MOH.

4.3.1 Is electrification really necessary? (justification)

While various electrical products make life more convenient for their users, unlike food and water, electricity is not a necessity; people can live without it. Consequently, even if plans are made for it, electrification may take time to spread if electrical products are not very important in the context of the prevailing pattern of life, needs for electricity are lower than those in other areas, or there is a low level of various developmental and economic activities requiring electricity. In such cases, it is inconceivable that all people will, or will be able to, use electricity unless the supply is free. Impoverished households would find it particularly hard to utilize power freely and continuously without some kind of aid. This section presents the results of data analysis with attention to justification.

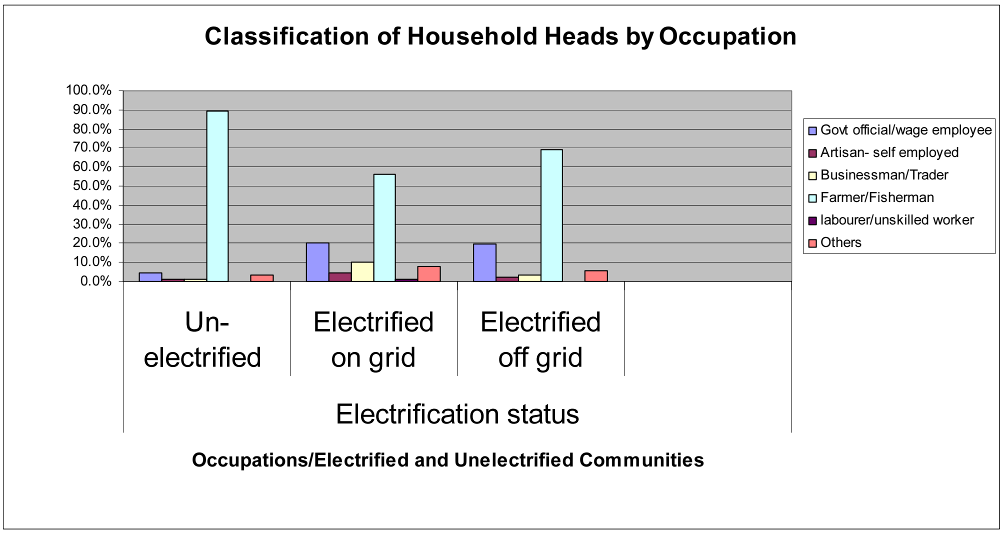
(1) Life situation of community residents

It is vital to make an analysis and decision as to whether people have a life pattern that really requires a supply of electricity, through examination of their daily life.

Ordinary households

In the questionnaire survey, about 89% of the respondents in unelectrified communities were farmers who grew crops for their own subsistence. The corresponding figures for communities electrified by off-grid PV systems and on-grid systems were about 70 and 57%, respectively. The main crops are peanuts, potatoes, cassava, corn, sorghum, grains, rice, and vegetables. The cash crops are shea nuts, cotton, cashews, and onions. The main types of livestock are sheep, goats, fowl, pigs, and cows. Farming depends on rainwater. The amount of production is generally low, and it is difficult to predict harvests. In many cases, it is consequently not easy for farmers even to produce their own food supply. Less than 1% utilize irrigation facilities.

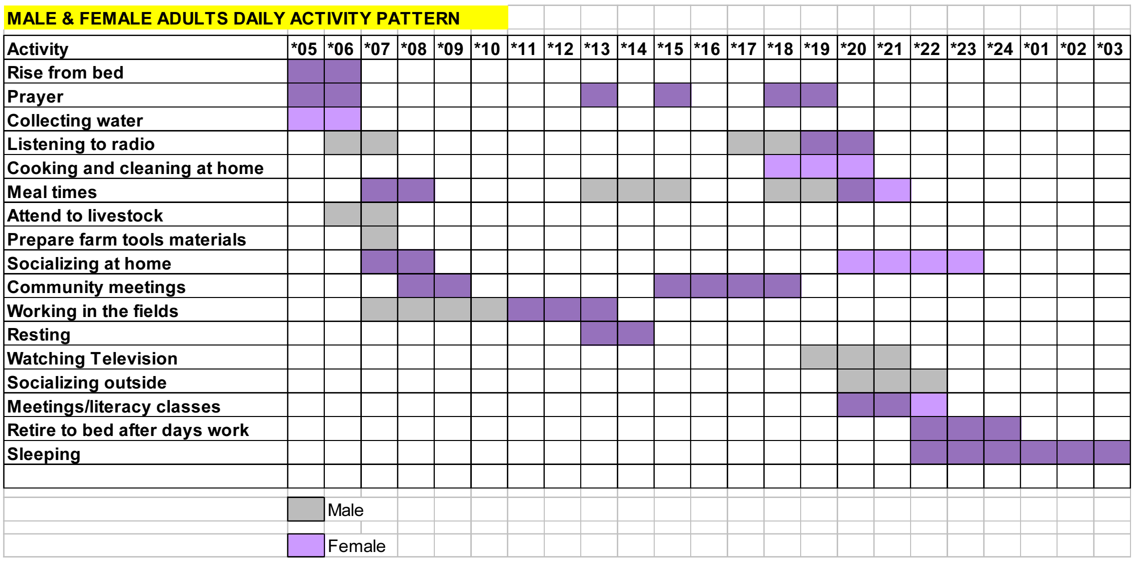
Some households are engaging in activities to improve their livelihood, such as running drinking bars or brewing pito, operating small general goods/drug stores, and extracting vegetable oil. Such economic activity is more common among electrified communities than among unelectrified ones. There are also some residents engaged in non-farming occupations, e.g., governmental employment (about 5% in unelectrified communities, 18% in communities electrified by off-grid PV systems, and 20% in communities electrified by on-grid systems), handicrafts (corresponding figures of about 1, 2, and 5%), and retail sales (corresponding figures of about 1, 3, and 10%). Figure 4.3.1 shows the main types of occupation in rural communities.



(Source) JICA Study Team

Figure 4.3.1 Main types of occupation in rural communities

The daily life pattern varies with the local tradition and religion. For this study, the Study Team attempted to ascertain the general activity pattern through FGD. Figure 4.3.2 shows the typical activity pattern in ordinary households (by adult men and women in rural communities) in the three northern regions.



MALE & FEMALE ADULTS DAILY ACTIVITY PATTERN

Activity	*05	*06	*07	*08	*09	*10	*11	*12	*13	*14	*15	*16	*17	*18	*19	*20	*21	*22	*23	*24	*01	*02	*03
Rise from bed	■	■																					
Prayer	■	■							■		■			■	■								
Collecting water	🟪	🟪																					
Listening to radio		▨	▨										▨	▨	■	■							
Cooking and cleaning at home														🟪	🟪	🟪							
Meal times			■	■					▨	▨	▨			▨	▨	■	🟪						
Attend to livestock		▨	▨																				
Prepare farm tools materials			▨																				
Socializing at home			■	■												🟪	🟪	🟪	🟪				
Community meetings				■	■						■	■	■	■									
Working in the fields			▨	▨	▨	▨	■	■	■														
Resting									■	■													
Watching Television															▨	▨	▨						
Socializing outside																▨	▨	▨					
Meetings/literacy classes																■	■	🟪					
Retire to bed after days work																		■	■	■			
Sleeping																		■	■	■	■	■	■

▨ Male

🟪 Female

(Source) JICA Study Team

Figure 4.3.2 Activity pattern in ordinary households

As compared to adult females, adult males in rural communities tend to be more active outside the home and compound. The main activities of adult females are housework-type chores (inside the home and compound) and socializing.

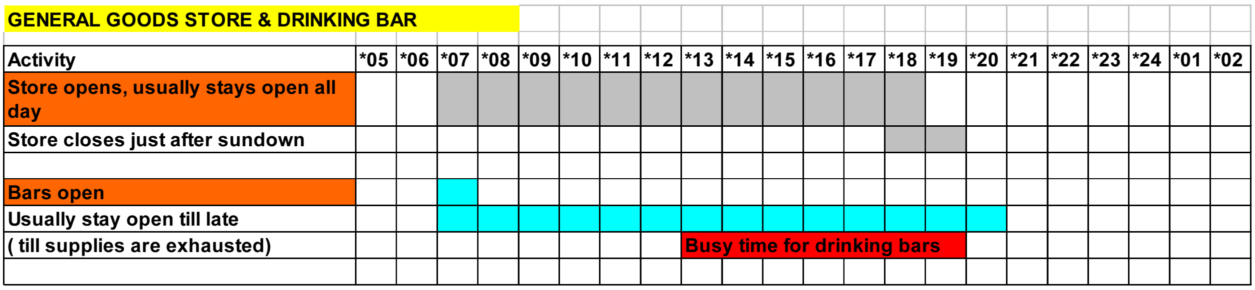
The best prospective times for use of electricity, and especially electric lights, are early morning and nighttime. The activities in question are prayer sessions for a few hours beginning at about 5:00 AM, cooking and cleaning at night, eating, and socializing. Power could also be used for listening to the radio and viewing TV, but people generally use battery-powered radios and few of them have TV sets. During the day, people are often at work in fields or other outside locations, and needs for power are low.

Considering this situation in ordinary households in rural communities in Ghana, there are thought to be needs for power for lighting about six hours in the morning and at night, and for entertainment (about six hours' worth of radio and three hours' worth of TV per day).

Nevertheless, the prevalence of people engaged in subsistence-level farming indicates that many people do not have significant cash and would find it hard to pay power tariffs on a both regular and continuous basis. At the same time, there are also some households whose members are engaged in economic activitis on a both regular and continuous basis, and some economically affluent households in the vicinity of urbanized districts. It would be easy for them to purchase electrical products, and they have rising needs for other products in addition to lights and TV sets.

Commercial facilities

Figure 4.3.3 shows the daily pattern of activity among commercial facilities in the three northern regions (applying particularly to small stores and bars in rural communities).



GENERAL GOODS STORE & DRINKING BAR

Activity	*05	*06	*07	*08	*09	*10	*11	*12	*13	*14	*15	*16	*17	*18	*19	*20	*21	*22	*23	*24	*01	*02
Store opens, usually stays open all day			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨								
Store closes just after sundown														▨	▨							
Bars open			🟦																			
Usually stay open till late			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦						
(till supplies are exhausted)									Busy time for drinking bars	🟥	🟥	🟥	🟥	🟥	🟥							

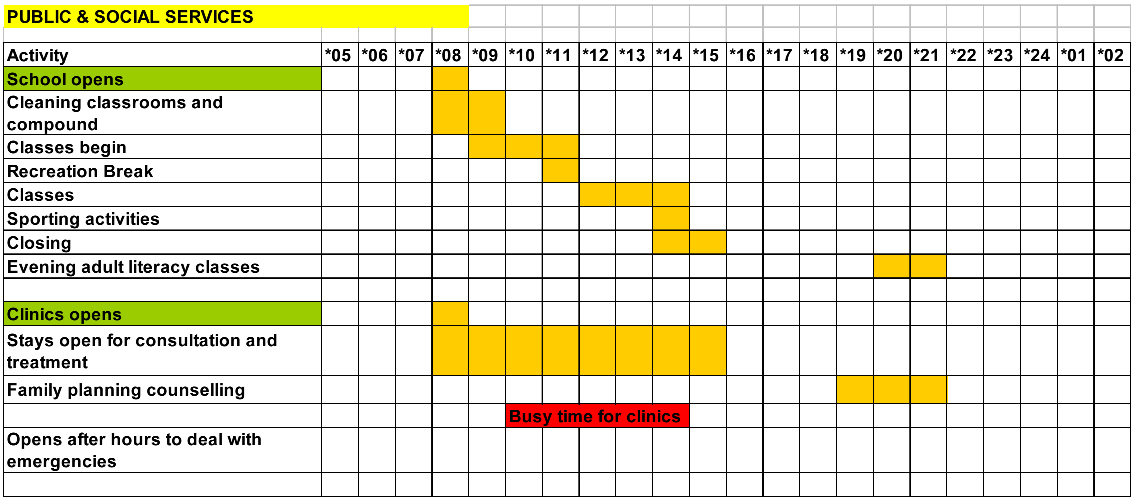
(Source) JICA Study Team

Figure 4.3.3 Activity pattern of commercial facilities

Small stores are generally open for 12 or 13 hours beginning about 7:00 AM. Although the field study found that some were open until late at night, it was enough to supply them with power for a few hours at night if use was confined to lighting (but not if it included refrigerators and fans). Bars have the same business hours as small stores, but usually are equipped with refrigerators and fans. As such, they tend to consume more power for uses other than lighting.

Public facilities

Figure 4.3.4 shows the daily pattern of activity among public facilities in the three northern regions (applying particularly to JSS and clinics).



PUBLIC & SOCIAL SERVICES

Activity	*05	*06	*07	*08	*09	*10	*11	*12	*13	*14	*15	*16	*17	*18	*19	*20	*21	*22	*23	*24	*01	*02
School opens				🟨																		
Cleaning classrooms and compound				🟨	🟨																	
Classes begin					🟨	🟨	🟨															
Recreation Break							🟨															
Classes								🟨	🟨	🟨												
Sporting activities										🟨												
Closing										🟨	🟨											
Evening adult literacy classes																🟨	🟨					
Clinics opens				🟨																		
Stays open for consultation and treatment				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨											
Family planning counselling															🟨	🟨	🟨					
						Busy time for clinics	🟥	🟥	🟥	🟥												
Opens after hours to deal with emergencies																						

(Source) JICA Study Team

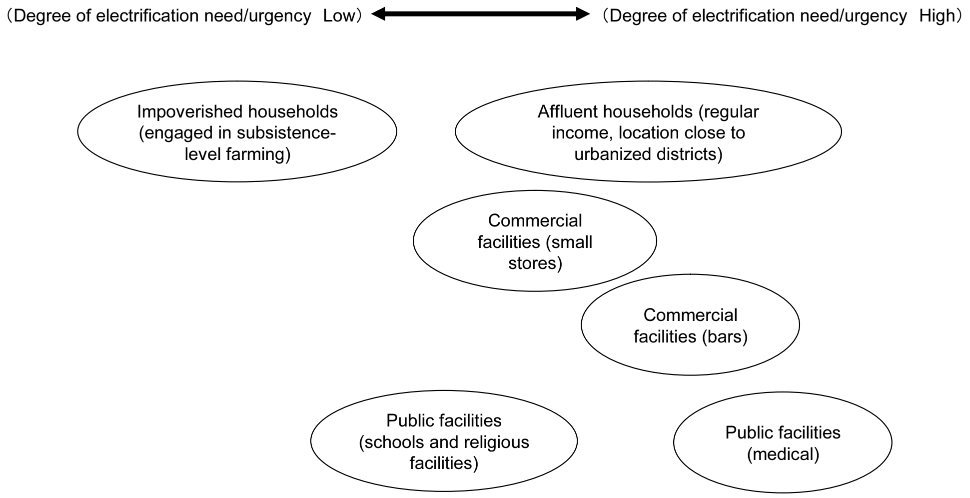
Figure 4.3.4 Activity pattern of public (educational and medical) facilities

JSSs are typically open from 8:00 AM to 3:00 PM. Although some are installed with electrical lighting, classes can be held with natural lighting from outside (through windows), and needs for the former are not very high. Teachers use radios to hear the news, but there are not strong needs for other electrical products. As such, needs for a supply of power in connection with formal schooling are low. In contrast, there are higher needs for electrical lighting for facilities that are used at night for study by students in higher grades or for adult literacy classes.

Like schools, clinics and other medical facilities are busiest around the middle of the day. For health reasons, however, it is not recommended for them to open their windows, and they therefore have stronger needs for electrical lighting even during the daytime. Naturally, electrical lighting is extremely important at night both for ordinary care and for coping with emergencies such as childbirth. They also have strong needs for electricity for applications such as storage of vaccine and blood, storage of bodies, and wireless communications with medical institutions on a higher level.

Religious facilities have higher needs for electricity during times of worship, but the duration of use of items such as lights, cassette players, microphones, and speakers is fairly short. The study found that they generally used kerosene lamps for lighting at night (this was the case among 67% of the responding facilities).

Figure 4.3.5 shows the degree of need for and urgency of electrification for each type of facility.



(Source) JICA Study Team

Figure 4.3.5 Need for electrification in each facility category

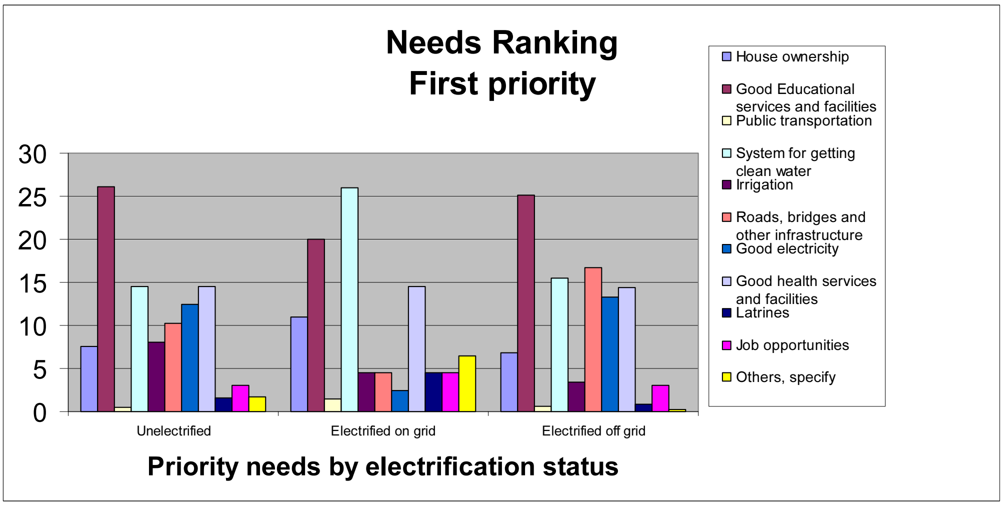
Ideally, a supply of electricity would be available to all people. In light of the current life and activity circumstances, however, it would be more practical to promote electrification beginning with the areas marked by the highest degrees of need and urgency. Ordinary households and impoverished homes in rural communities would find it especially difficult to use electricity on a continuous basis, to the point of paying the tariffs to do so. In contrast, electrification is more justified among more affluent households with a regular income, or households near urbanized districts that presumably have higher motivation for electrification because they know the convenience of a power supply and have experienced entertainment applying electrical products. In addition, the electrification of public facilities should be given a high priority because they exert a simultaneous impact on many users.

(2) Goods and services regarded as necessary at present

Life-enriching electricity is in the circle of various goods and services people want to have in the future, but the order of priority accorded to these goods and services varies with the type of household. When electricity has a lower priority than other items, it is possible that electrification will not spread in the case of unelectrified communities and that power consumption will fail to rise in that of electrified ones. For this reason, it is important to make full surveys and checks of actual needs for electricity in preparation of the master plan.

Ordinary households

Figure 4.3.6 shows the results of the ordering of priority of various goods and services in respect of need, obtained through the questionnaire survey and FGD in this study.



(Source) JICA Study Team

Figure 4.3.6 Ranking of electrification need

The top five responses as regards the goods and services most in need in unelectrified communities were as follows: 1) good educational services and facilities, 2) safe water, 3) good health services, 4) electricity, and 5) good public infrastructure (roads, bridges, etc.).

In communities already electrified by off-grid PV systems, on the other hand, the top five responses were: 1) safe water, 2) good educational services and facilities, 3) good health services, 4) home ownership, and 5) "others."

In communities electrified by on-grid systems, the top five responses were: 1) good educational services and facilities, 2) good public infrastructure (roads, bridges, etc.), 3) safe water, 4) good health services, and 5) electricity.

The respondents expressed strong needs for good educational services and facilities, safe water, and good health services regardless of the community electrification status. The same trend emerged from the FGD. This is because education, water, and health are basic human needs (BHN) indispensable for life. In addition, these needs are not satisfied in many districts of the three northern regions.

In contrast, although the needs for it are by no means weak, electricity is not perceived as a BHN on the level of education, water, and health services, because people can get along without it. Only when they live in circumstances assuring a supply of educational services, safe water, and health services do people begin to feel the need for electricity.

Conversely, as long as the major BHN apart from electrification are not satisfied, perceived needs for electricity remain low and work against diffusion. For this reason, the further development and spread of good educational services, safe water, and good health services must accompany the diffusion of electricity. It could also be observed that the positioning of electrification would probably rise by using it as a tool for the promotion of good educational services, safe water, and good health services.

Public facilities

Table 4.3.3 shows the current status of electrification of two major types of public facility (educational and medical) based on the results of the KII.

Table 4.3.3 Electrification of public facilities (educational and medical) in the three northern regions

Electrification Status of Educational & Health Facilities in the Northern Part																
SUMMARY-UER		**EDUCATIONAL FACILITIES**							**HEALTH FACILITIES**							
No.	**District**	**Pre/ Prim.**	**JSS**	**SSS**	**Voc**	**Trg Col.**	**Tertiary**	**Adult Lit.**	**CHPS**	**Clinic**	**Health Cen.**	**Hosp.**	**Dist. Hosp.**	**Reg. Hosp.**	**Nut. Cen.**	**Trg Inst.**
1	SUMMARY-NR	2013	354	37	3	3	2	3797	12	46	89	7	6	1	9	3
2	SUMMARY-UER	719	218	22	2	2	2	2015	17	48	26	0	2	1	3	4
3	SUMMARY-UWR	619	264	17	7	2	2	1858	30	5	50	5	3	1	?	2
	Total	*3351*	*836*	*76*	*12*	*7*	*6*	*7670*	*59*	*99*	*165*	*12*	*11*	*3*	*12*	*9*
	Electrified grid	455	211	74	12	7	6	455	8	22	54	12	11	3	10	9
	Electrified PV	2	144	1				1350	1	11	28					
	Unelectrified	2894	481	0	0	0	0	6320	50	66	83	0	0	0	2	0
	% Unelectrified	86%	58%	0%	0%	0%	0%	82%	85%	67%	50%	0%	0%	0%	17%	0%

(Source) JICA Study Team

Educational and medical facilities that require a high level of electrical products have almost all been electrified already. The reason is that these facilities are located in urbanized districts where there is a good supply of electricity, because they cannot fully function without it. A policy factor is also at work here: the MOE is promoting electrification for the diffusion of information and communication technology (ICT) on the district level. In contrast, the low-level educational and medical facilities sited in rural areas have not yet been electrified. Among them, electrification is justified.

The FGD as well as the KII underscored the need for electrification of the staff houses attached to educational and health facilities. Electrification was found to be important for the performance of various work within the housing (e.g., research of educational materials by teachers) and improvement of personnel motivation in posting from urbanized districts through the increase in convenience and comfort, and therefore is thought to have the requisite justification.

(3) Degree of development and economic activity

The degree of diverse development and economic activity in communities is another barometer of electrification justification. In other words, if communities have extensive development and economic activities requiring electricity, they presumably have higher electrification needs that would drive the diffusion of electricity.

The FGD enabled determination of the development and economic activities in communities. It was learned that various activities are being promoted by the community development committees, unit committees (involved in infrastructural conditioning), and self-help groups.

The main development activities were construction of waterworks, schools, and health facilities; installation of latrines; and construction of irrigation facilities. The main economic activities were shea butter production, grain banking, soap making, grain milling, and other food processing. In addition, groups offered literacy classes.

Judging from the need for electricity, the chief subjects of electrification in the context of development activities would be waterworks and irrigation facilities utilizing electric-powered well pumps. There are also strong needs for lighting and refrigerators in health facilities and lighting in the conduct of literacy classes. For such reasons, electricity could very possibly contribute to the quality of public facilities in communities.

In the context of economic activities, on the other hand, needs for electricity are lower because of extensive utilization of traditional manual methods. The sole conceivable exception is the utilization of electric-powered flour mills for grains, as evidenced by communities reached by the grid. However, such mills consume a lot of electricity and cannot be powered by off-grid PV systems.

As indicated by the above, electrification is thought to have a high justification in the case of public facilities in communities, but is not strongly needed for general economic activities at present. Although needs for electrical motive power clearly cannot be denied, they could not be met without large-capacity on-grid systems.

4.3.2 What are the proper choices for the type and scale of the electrification system? (efficacy)

If electrification is found to be justified, a study must be made of the proper type of system and scale both at present and into the future. In examination of the cost-effectiveness of on-grid and off-grid PV systems, the distribution of subject housing and facilities is one parameter. Likewise, the utilization of electrical products serves as an indicator for forecastting the size of the power demand both at present and into the future. Another parameter in system selection is the preferences of residents.

(1) Distribution of housing

While duration of sunshine is an important datum for assessing prospects for PV systems, from the socioeconomic standpoint, the distribution of housing is also a vital item. Housing distribution affects decisions on the method of electrification and planning for expansion of transmission and distribution facilities. For example, if many unelectrified houses are located far from the existing distribution lines, installation of stand-alone systems (such as solar PV systems) would probably be more effective, considering the cost of line extension and O&M. As this suggests, it is crucial to ascertain the distribution of houses and other facilities in each particular community. The three northern regions that are the subject of this report have a combined population of about 3.5 million and a population density averaging about 44 persons per square kilometer, lower than the national average of 79. On-site observation through the field studies showed that, in many communities, housing is concentrated in the central part and only sparsely scattered for a few kilometers around in other parts. There is a certain interregional difference in respect of density that was also confirmed in the FGD. Whereas about 80% of the housing is concentrated in the central part of the community, close to the home of the community head and the market, in the Northern Region, the corresponding figure for the Upper East and Upper West regions ranges from about 20 to 30%, with the remainder being scattered over a wide area. In this respect, stand-alone systems such as solar PV would be especially effective in the Upper East and Upper West regions.

(2) Use of electrical products

Ordinary households

The types of electrical product that people would or could buy after electrification and the demand for electricity associated with the hours of product use can be estimated by viewing the use of electrical products. Table 4.3.4 shows the rates of household diffusion (penetration) for various electrical products. Although electrical products are ordinarily not available for use in unelectrified communities, several households have small-scale generators of their own, and some possess electrical products that can be powered by battery.

Table 4.3.4 Use of electrical products

Appliance owned and in use	Unelectrified			Electrified off-grid			Electrified on grid		
	N	Penetration	Hours of use	N	Penetration	Hours of use	N	Penetration	Hours of use
Small colour tv	4	0%	5	5	1%	2.3	14	6%	3.42
Big colour tv	9	1%	2.9	9	2%	1.9	43	20%	3.95
Black and White tv	17	2%	2.2	23	6%	3.5	21	10%	3.41
VCR	11	1%	3.2	15	4%	2.4	30	14%	2.71
Radio	563	68%	5.9	225	60%	5	96	44%	4.52
Radio cassette player	401	49%	4.2	185	49%	3.7	123	57%	4.35
Small refrigerator	1	0%	6	3	1%	12	20	9%	16.2
Big Refrigerator	0	0%	0	2	1%	8	12	6%	15.09
Small freezer	0	0%	0	0	0%	0	6	3%	17.2
Big Freezer	0	0%	0	1	0%	24	5	2%	17
Cell phone charger	3	0%	24	0	0%	0	7	3%	17.14
Incadescent lights	3	0%	3	8	2%	8	107	49%	8.1
Flourescent lights	2	0%	7.5	60	16%	7.6	50	23%	8.8
Fan	7	1%	2.6	8	2%	2.8	55	25%	5.4
Flash light	453	55%	5.3	328	87%	3.4	91	42%	3.8
Sewing machine	1	0%	0	0	0%	0	1	0%	0
Electric iron	1	0%	0	4	1%	1	28	13%	1
Coil heater	0	0%	0	2	1%	1.2	19	9%	1.6
Table-top single burner cooker	0	0%	0	0	0%	0	0	0%	0
4 burner electric cooker	0	0%	0	0	0%	0	0	0%	0
Total No. of Respondents	823			378			217		

(Source) JICA Study Team

From Table 4.3.4, it can be seen that the top three electrical products in each electrification category are lights (including flashlights), radios, and cassette players (including those with a radio function).

Lights have obvious benefits and are the primary type of electrical product used by villagers. There is a deep need for flashlights in communities where many residents are active outside and many areas are dark at night due to the lack of outdoor lighting.

Radios are popular products because they are easy to carry around and provide all sorts of information and entertainment. In rural areas, they are generally powered by battery. Cassette players are also highly popular, partly because of their radio function but also because they match the general love of music and promote social communication through singing and dancing.

Once they decide to further pursue their objectives in use of radios and cassette players, people may be expected to consider purchase of TV sets. TV sets are highly popular as means of information and entertainment, and may be considered status symbols in rural districts. The widespread diffusion of TV sets, however, also requires broadcasting services (TV waves) with nationwide coverage.

The rate of electric fan ownership rises along with the level of electrification. Ghana's temperatures make fans suitable for purchase as electrical products. There would seem to be strong needs for refrigerators, but the diffusion rates for them are not very high. This appears to indicate that, in rural communities, people mainly produce their own food and do not have enough disposable income to readily purchase refrigerators.

The electric power demand can be estimated from the duration (hours per day) of use of these major electrical products.

Commercial facilities

The major types of electrical product used in small stores are lights, radios, cassette players (with a radio function), and fans. In terms of the daily average, these stores use lights for about 9 hours, radios and cassette players for about 6 hours, and fans for about 7 hours.

Public facilities

The major types of electrical product used in SSS are lights and radios. On the average, junior high schools use lights for 7.5 hours a day, and radios, for about 1 hour a day. High schools are already electrified by on-grid facilities. Besides lights and radios, some also have fans, TV sets, and refrigerators. In terms of the daily average, high schools use lights for 13 hours, cassette players with a radio function for about 4 hours, and fans for about 10 hours.

Heath centers use lights, refrigerators, fans, water pumps, and other products. The duration of light use is long (more than 10 hours per day on the average). As evidenced by refrigerators, the centers may also use electrical products that utilize other types of energy (e.g., gas and kerosene) in addition to electricity. They would like to use refrigerators for a longer duration, but generally limit their use to a few hours a day because of the high energy costs.

Religious facilities make use of lights, fans, radios, cassette players with a radio function, microphones, and speakers, each for 2 - 4 hours per day on the average.

(3) System preferences

Table 4.3.5 presents figures for the type of electrification system preferred by communitiers, based on the responses to the questionnaire survey.

Table 4.3.5 Electrification preferred by villagers

Preferred eledctrification system (%)

	On-grid	SHS	BCS	I don't know
Unelectrified	60.8	31.2	1.6	6.4
Electrified off-grid	92.5	5.2	0.7	1.5
Electrified on-grid	82.7	13.5	0.0	3.8

(Source) JICA Study Team

Although other data indicate a low degree of understanding of electrification systems, most respondents preferred on-grid systems because they felt that the tariffs for off-grid PV systems were high considering their low capacity. Many (about 55%) of the questionnaire survey respondents residing in communities electrified with off-grid PV systems indicated that service personnel were slow to respond to trouble with the systems.

The promotion of off-grid PV electrification therefore demands campaign to erase the impression that off-grid PV systems are inferior to on-grid systems.

4.3.3 What kind of impact will electrification have? (impact)

The perceived impact of electrification is a good indicator of its significance and a means of gleaning lessons of value to future electrification. Nevertheless, electrification is generally regarded as having positive effects for making life more comfortable; very few people deny its inherent value. This is because electricity does indeed benefit people provided that the O&M and supply are properly performed. In the category of public facilities, medical facilities gave the highest ratings of the positive impact of electricity for facilitating their work.

In light of the above considerations, the socioeconomic study questioned respondents about the negative impact of electrification and items of apprehension about it instead of its positive impact. Table 4.3.6 profiles the awareness of the respondents about the influence of electrification from the qualitative survey activities (KII, FGD, etc.).

Table 4.3.6 Negative effects of electrification and items of apprehension

Ordinary households

(Unelectrified communities)
- There is no access to the grid system.

(Communities electrified by off-grid PV systems)
- The supply is unstable.
- There is no access to the grid.
- The capacity is not sufficient for running mills.
- The number of homes electrified by off-grid PV systems in the community is still small.
- The systems are not suited for use to power refrigerators and TV sets.

(Communities electrified by on-grid systems)
- The number of homes electrified by on-grid systems in the community is still small.
- Power consumption results in a heavier monetary burden (because other energy costs do not decline even if electrical systems are used).
- Youth are going to entertainment facilities with electricity and seem to do little else but view TV and video programs. As a result, they spend less time at home and help out less in the home, and do less studying. This points to the risk of a decline in traditional community culture.
- There is more noise at night due to the increase in various activity made possible by the supply of electricity.

(Source) Prepared by the JICA Study Team based on FGD results

The perceived negative influences of and apprehensions about electrification in the case of commercial and public facilities are similar to those in the case of ordinary households. The main ones are system capacity and tariffs. In the case of public facilities, it is often unclear which party (national government, regional government, facility operator, or user) bears the responsibility for O&M. As such, it may take time to make arrangements for payment of tariffs and O&M.

4.3.4 Are there any problems as regards payment for system use and the setup for O&M? (sustainability and spontaneous expansibility)

Even if electrification is justified, electricity cannot be supplied free of charge. Therefore, the level of payment ability among customers (actual and latent) is a critical factor for the spontaneous spread of electrification.

With on-grid systems, O&M does not entail much time or trouble for customers, and is ordinarily performed by the provider (business) side. With off-grid PV systems, on the other hand, the provider may perform O&M, but the customer generally has to do a certain amount of work, e.g., clean the panels, control the daily amount of electricity use, and manage the battery. For this reason, the availability of a setup sufficient for O&M and elements needed for its skillful functioning is a key factor for spontaneous expansion of electrification systems among households and communities.

This section considers data related to the self-propelled spread of electrification.

(1) Payable tariff

Ordinary households

Data for the economic situation related to payment for on-grid electrification systems are important particularly for forecasting demand and estimating payable tariff rates in the preparation of master plans for electrification. Nevertheless, it would be extremely difficult to obtain suitable economic data within a short time, for the following reasons.

1) Residents do not have accurate records for their own income and expenditures.

2) Many residents are engaged in farming for their own subsistence and do not have a fixed regular income.

3) Residents do not want to let others know much about their economic situation, and there may be problems of credibility with their information.

In light of the above considerations, the Study Team decided to infer the payable electricity tariff rate from the payment situation for various energy (electricity, kerosene, candles, batteries, etc.) instead of data for general income and expenditure. (It should be added that, according to the monthly income data obtained from a questionnaire survey with, however, a small number of samples yielded figures of about 903,000, or 99.1 dollars, in districts electrified by on-grid systems and about 511,000 cedi, or 56.1 dollars, in unelectrified communities. As regards the rate of land and housing ownership, which is an indicator of income disparity, it may be noted that the figure approaches 90 % for individual and family (or compound) ownership taken together. In respect of ownership of land and housing, the situation in Ghana communities is therefore quite favorable.) It is also vital to compare the results of this last socioeconomic study with those of previous ones.

Table 4.3.7 shows data for expenditures for various types of energy obtained from the questionnaire survey.

Table 4.3.7 Energy expenditures by ordinary households

	Valid number	Avarage total energy cost		Running cost for PV		Available running cost
		Initial	Running	Cost	ratio	
Unelectrified households	986	120,000	59,000			14,000
PV electrified households	193	291,000	80,000	19,000	23.8%	
Grid electrified households	216	296,000	77,000			

(Source) JICA Study Team

The monthly household expenditures for lighting (including kerosene lamps and other non-electrical items) and use of electrical products averaged about 59,000 cedi (6.5 dollars) in unelectrified communities, 80,000 cedi (8.8 dollars) in communities electrified with off-grid PV systems, and 77,000 cedi (8.6 dollars) in communities electrified with on-grid systems.

Table 4.3.8 presents more detailed figures for monthly energy expenditures.

Table 4.3.8 Energy expenditures by ordinary households (detailed)

	Monthly avarage cost										
	Grid	Generator	Kerosene	Candle	Dry cell	SHS	BCS	Lantern	Others	Total	
Unelectrified households	0	0	37,617	166	20,712	0	0	0	572	120,124	59,067
PV electrified households	0	0	34,730	149	25,126	13,155	6,028	92	318	291,434	79,598
Grid electrified households	43,181	0	20,574	207	12,439	138	565	0	37	295,869	77,141

(Source) JICA Study Team

Even when households are electrified, they do not stop using kerosene or batteries. This is because: 1) the existing electrification system is not adapted to products that are carried around, and 2) there is parallel use of other energy due to considerations involving the tariffs for electricity.

At any rate, average monthly expenditures for kerosene, the main non-electrical energy, came to about 37,000 cedi (4.1 dollars) in unelectrified communities, 34,000 cedi (about 3.7 dollars) in communities electrified with off-grid PV systems, and 20,000 cedi (about 2.2 dollars) in communities electrified with on-grid systems. The corresponding figures for batteries were about 20,000 cedi (2.2 dollars), 25,000 cedi (2.7 dollars), and 12,000 cedi (1.3 dollars), respectively.

In light of the level of expenditures for various types of energy in unelectrified communities, and particularly for kerosene and batteries, the major non-electrical energies, the payable tariff level can be inferred as follows.

1) When electricity can replace kerosene and batteries for all applications: about 58,000 cedi (6.4 dollars)
2) When electrification can replace half of the current applications: about 29,000 cedi (3.2 dollars)
3) When electrification can replace one-fourth of the current applications: about 14,000 cedi (1.5 dollars)

Even if electricity becomes available, households are unlikely to stop all spending for kerosene and batteries. It may also be observed that electricity expenditures in communities electrified by PV systems currently account for only about one-fourth of their total energy expenditures (the average for SHS and BCS households taken together is about 19,000 cedi, or 2.1 dollars). As such, the monthly PV system tariff level that could be paid without undue strain would be the third, i.e., about 14,000 cedi (1.5 dollars).The Study Team also collected data on the amount people would be willing to pay on energy, as shown in Table 4.3.9.

Table 4.3.9 Amount ordinary households are willing to pay for electricity

	Willing to pay more		Willing to pay less	
	Number	Difference from present cost (average: cedis)	Number	Difference from present cost (average: cedis)
Unelectrified households	214	28,841	480	32,445
SHS electrified households	4	35000	11	34,077
BCS electrified households	11	21,818	49	58,893
Grid electrified households	17	20500	39	42,654

(Source) JICA Study Team

All households want to hold down their expenditures, and it is no surprise that the households wanting to reduce energy expenditures are more numerous than those willing to pay more. The notable point is the gap between the two. The ratio of the households willing to pay more to the those wanting to pay less is 30 to 70 among unelectrified households and households electrified by grid systems, but 26 to 74 among those electrified with SHS and 18 to 82 among those using BCS.

While energy expenditures include spending on energy other than electricity, these results imply that many customers are dissatisfied with PV system tariffs. The FGD in communities electrified with off-grid PV systems also revealed pronounced feelings of unfair treatment as compared to on-grid systems, which have a larger capacity and are eligible for official aid.

Commercial facilities

Table 4.3.10 shows monthly energy expenditures by various types of commercial facilities.

Table 4.3.10 Monthly energy expenditures by commercial facilities

		General goods/drug store	Restaurant /bar	Drinking bar/pito brewing	Bakery	Furniture/ carpentar	Handicraft	Tailor/ seamstress	Hair salon/barber shop	Repair shop	Grain milling	Veg. oil extraction	Guest house	(Reference) households
Un-electrified	Num. of facilities	23	1	26	2	3	2	21	6	5	34	4	10	986
	Avg. mont. proft.	1,205,882	1,250,000	997,619	1,000,000	2,875,000	1,250,000	681,818	750,000	450,000	751,250	350,000	–	–
	Avg. engy. cost	38,870	19,000	38,327	–	–	30,000	52,588	18,000	17,500	374,303	115,826	24,700	59,000
PV electrified	Num. of facilities	9	–	6	–	1	–	2	1	–	–	–	2	193
	Avg. mont. proft.	1,812,500	–	1,125,000	–	1,250,000	–	462,500	–	–	–	–	–	–
	Avg. engy. cost	44,556	–	72,667	–	56,000	–	25,000	15,000	–	–	–	57,500	80,000
On-grid electrified	Num. of facilities	4	1	3	–	2	–	3	4	2	2	–	1	216
	Avg. mont. proft.	600,000	500,000	3,750,000	–	–	–	250,000	625,000	1,000,000	625,000	–	–	–
	Avg. engy. cost	75,000	80,500	191,667	–	160,000	–	61,000	60,250	60,250	355,000	–	75,000	77,000

(Source) JICA Study Team

Among the commercial facilities, monthly energy expenditures by small stores, for which there were fairly many samples, averaged about 52,800 cedi (5.8 dollars) overall. The corresponding figures were about 38,000 cedi (4.2 dollars) in unelectrified communities, 44,000 cedi (4.8 dollars) in communities electrified by PV systems, and 75,000 cedi (8.2 dollars) in communities electrified by on-grid systems.

Monthly energy expenditures by drinking bars averaged about 108,000 cedi (11.1 dollars) overall. The corresponding figures were about 38,000 cedi (4.2 dollars) in unelectrified communities, 72,000 cedi (7.9 dollars) in communities electrified by PV systems, and 191,000 cedi (21 dollars) in communities electrified by grid systems.

Tailor shops made monthly energy expenditures averaging about 46,100 cedi (5.1 dollars) overall. The corresponding figures were about 52,000 cedi (5.7 dollars) in unelectrified communities, 25,000 cedi (2.7 dollars) in communities electrified by PV systems, and 61,000 cedi (6.7 dollars) in communities electrified by on-grid systems.

Public facilities

Among public facilities, monthly energy expenditures averaged about 11,500 cedi (1.3 dollars) on the junior secondary school level and 150,000 cedi (16.5 dollars) on the high school level. Religious facilities spent an average of 113,000 cedi (12.4 dollars) per month for use of electrical lights and small electrical products.

(2) Electrical products people want to buy

Electricity is used for all sorts of electrical product that make life more convenient. Data showing the kinds of product people want to buy can consequently serve as indicators of the degree of need for electricity and the advisable type of system.

Ordinary households

Table 4.3.11 lists the electrical products people want to buy, based on the results of the questionnaire survey.

Table 4.3.11 Electrical products people want to buy

Appliance want to own	Unelectrified		Electrified on grid		Electrifid off grid	
	N	Penetration	N	Penetration	N	Penetration
Small colour tv	182	21%	60	30%	56	16%
Big colour tv	308	36%	66	33%	151	43%
Black and White tv	86	10%	6	3%	41	12%
VCR	61	7%	23	12%	17	5%
Radio	31	4%	15	8%	10	3%
Radio cassette player	157	18%	36	18%	68	19%
Small refrigerator	180	21%	39	20%	97	27%
Big Refrigerator	192	22%	63	32%	111	31%
Small freezer	41	5%	10	5%	19	5%
Big Freezer	50	6%	23	12%	28	8%
Cell phone charger	31	4%	13	7%	3	1%
Incadescent lights	228	27%	12	6%	35	10%
Flourescent lights	233	27%	15	8%	74	21%
Fan	177	21%	61	31%	93	26%
Flash light	6	1%	2	1%	1	0%
Sewing machine	26	3%	9	5%	8	2%
Electric iron	65	8%	22	11%	131	37%
Coil heater	73	8%	13	7%	41	12%
Table-top single burner cooker	38	4%	7	4%	45	13%
4 burner electric cooker	12	1%	5	3%	10	3%
Total No. of Respondents	859		200		353	

(Source) JICA Study Team

From Table 4.3.11, it can be seen that: 1) needs for electric lights are highest in unelectrified communities, 2) needs for refrigerators and fans are highest in communities already electrified, and 3) needs for TV sets are strong regardless of the electrification status.

It is often said that, as electrification spreads, people come to desire more sophisticated types of electrical product. The second and third observations above, however, indicate that wants for TV sets and refrigerators remain strong, and that all sorts of electrical product are not in widespread diffusion even after electrification. In other words, it cannot be assumed that, once electricity is available, people will use all sorts of electrical product right from the start or gradually expand the scope of products they buy; in general, usage remains on the level of lights and TV sets.

Comparison with the status of electrical product use noted above shows that the shares of all respondents occupied by those desiring to buy the various electrical products are low overall, in spite of the low rate of electrical product ownership at present (the highest rate belonged to TV sets in communities electrified by off-grid PV systems at 43%). The conceivable reasons are as follows: 1) people were unable to think of electrical products that they wanted due to the limited circulation of such products in their area; and 2) many households do not have enough funds to purchase electrical products and did not want any to the point of having to cut back on purchase of other needed items. Table 4.3.12 shows market prices for home electrical products.

Table 4.3.12 Electrical product capacity and market price

	Item	Typical wattage	Average price *1	Average price *1 (Tamale)	Average price *1 (Local town)
1	Color TV (20 inch)	77	1,900	1,930	1,870
2	Sec. Color TV (20 inch) *2		1,600	NA	1,600
3	Color TV (14 inch)	53	1,365	1,450	1,280
4	B&W TV	30	360	340	380
5	VCR/VCD/DVD	13	1,300	1,100	1,500
6	Radio	DC3V	75	80	70
7	Stereo (including Radio)	150	335	290	380
8	Ref. big		4,680	4,430	4,930
9	Ref. mid	130	2,895	3,390	2,400
10	Sec. Ref. mid *2		2,000	NA	2,000
11	Ref. small		1,950	2,000	1,900
12	Sec. Ref. small *2		1,600	NA	1,600
13	Freezer big	180	4,970	4,970	NA
14	Freezer small	140	3,750	3,200	4,300
15	Light (incandescent)	40	2	1	2
16	Light (fluorescent) 4feet	36 (2feet-18)	55	50	60
17	Fan	55	215	170	260
18	Ceiling fan	65 (big-78, middle-70)	110	50	170
19	Air Conditioner	2,000	6,385	5,570	7,200
20	Flash light		18	NA	18
21	Sewing Machine	100	720	720	NA
22	Electric Iron	750	95	80	110
23	Washing machine	350	1,710	1,710	NA
24	Hair dryer	1,300	120	120	NA
25	Rice cooker	700	260	210	310
26	Coil heater		10	NA	10
27	Table top single burner	1,500	170	160	180
28	Computer/Printer		8,500	8,500	NA
29	Telephone/Fax machine	20	3,130	3,130	NA
30	Micro phone/Speaker	1,000	725	950	500
31	Hand Speaker	A battery-6	155	130	180
32	Keyboard		1,290	1,290	NA

*1 Price unit = Thousand cedi
*2 Sec. = Second-hand

Kerosene		15	15	NA
Manual Sewing Machine		480	480	NA
Generator (1000W)		4200	4200	NA

(Source) JICA Study Team

People cannot buy electrical products without the money needed to purchase them. They also cannot easily buy or repair them if there are no stores selling quality products or spare parts in the vicinity.

Upon electrification, the first product people typically buy is simple, low-cost lights. However, lights alone are not enough to produce a feeling of contentment. Use of electricity gradually increases once they are able to purchase various other electrical products and come to appreciate their convenience and entertainment value.

This, in turn, depends on the existence of disposable income, i.e., income beyond the minimum requisite for subsistence. With disposable income, people can buy various electrical products. In rural communities of Ghana, however, the livelihood of most households is on the subsistence level; few have sufficient disposable income. The household diffusion of electricity is consequently anticipated to proceed only gradually.

While the questionnaire survey did not probe the kinds of electrical product for which there were strong needs among commercial and public facilities, the KII revealed strong needs for TV sets and video decks among junior secondary schools, which want to make use of educational programs for remote education. Because of the high indoor temperatures, many interviewees also expressed desires for electric fans to make classrooms more comfortable.

(3) O&M setup and capabilities

The availability of O&M setups and capabilities on the local level is another key factor for the spread of PV electrification systems. The main parameters of such setups and capabilities are: 1) whether or not various organizations already established are functioning properly, and 2) degree of knowledge about electricity among residents.

The FGD obtained data about the activities of various existing organizations. These data evidence vigorous activity by community development committees, infrastructural improvement committees, and various self-help groups, as described above. Efforts are also being made by local and international NGOs. This situation indicates the potential for some orchestrated activity.

The activities led by communities (such as the operation of mills and BCS), however, do not always proceed well, due to causes including a lack of capabilities for management of funds and other items, lack of technology, and insufficient awareness of ownership. As regards PV system O&M, in contrast, small service enterprises handling local PV systems are functioning smoothly in some cases.

In other words, communities have various organizations with the potential for PV system O&M, but there is an undeniable shortage of management and technical capabilities that demands further education and training for correction. On the question of the key personnel for O&M performance, the FGD and other sources produced opinions in favor of effective use of the energies of small local service enterprises and proposals for education and employment of women as O&M supervisors, in keeping with the goal of empowerment.

The degree of knowledge about electricity is another vital factor for estimating O&M setups and capabilities. Table 4.3.13 shows the results of the questionnaire survey for this item.

Table 4.3.13 Knowledge about electrification

Knowledge about Electrification (%)

	About National Electricity Grid	About SHEP	About SHS
Unelectrified	19.5	25.1	69.3
Electrified off-grid	8.8	30.0	84.1
Electrified on-grid	36.5	22.6	50.0

(Source) JICA Study Team

Understanding of on-grid electrification and access to the SHEP is low regardless of the electrification status. In the case of communities that have already been electrified by on-grid systems, this finding indicates that many residents still do not have access to electricity. In other words, even among electrified communities, there are gaps in respect of the electrification level.

In the questionnaire survey, about 89% of the respondents in communities electrified with off-grid PV systems said they had not received any particular O&M instruction.

These findings underscore the importance of conducting campaigns for enlightenment and publicity about electricity among the end-user customers as well.

Chapter 5 Off-grid PV RE plan

5.1 Renewable energy potential

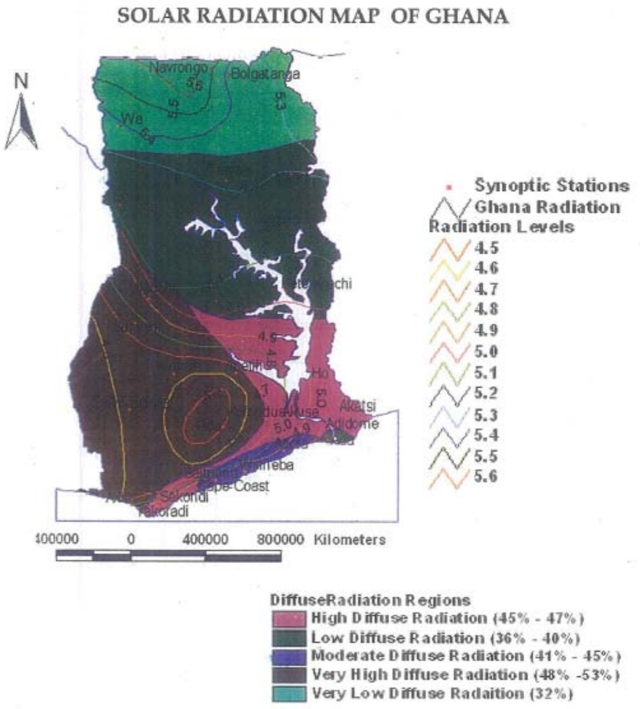
5.1.1 Solar power potential

(1) Irradiation

In Ghana, annual average irradiation is high; it ranges from 4.57 to 5.52kWh/m^2・day and averages 5.10kWh/m^2・day nationwide. This is about 1.5 times as high as in Japan (Tokyo), where the corresponding average is 3.34kWh/m^2・day. These figures underscore its high PV power generation potential.

To estimate the generation potential from the average irradiation, use of 0.1% of the national area of 238,537km^2 for PV power generation with a conversion efficiency of 10% would translate into an output of 44,400 million kWh/year. This is equivalent to a power station in the 5 million kW class.

Figure 5.1.1 presents an irradiation map, and Table 5.1.1, the average annual levels in individual districts. The levels tend to be higher in the northern districts and lower in the southwestern districts. They are highest in Wa (in the Upper West Region), where they average 5.52kWh/m^2・day. In the three northern regions, irradiation averages 5.42kWh/m^2・day, higher than the nationwide average.



(Source) EC Annual Report

Figure 5.1.1 Irradiation map

Table 5.1.1 Annual average irradiation in each district

(kWh/m^2・day)

Navrongo	Wa	Yendi	Tamale	Bole
5.51	5.52	5.37	5.39	5.32
Krachi	Wenchi	Ho	Abetifi	Kumasi
5.28	5.02	5.12	5.15	4.63
Akuse	Koforidua	Akim Oda	Bekwai	Ada
4.81	4.84	4.57	4.73	5.41
Accra	Saltpond	Takoradi	Axim	**average**
5.06	5.17	5.01	4.91	**5.10**

(Source) EC data

(2) Trend of irradiation

In Ghana, insolation gradually increases beginning in January and peaks in April. It begins to decline in June and is at its lowest in August. It starts to increase again from October to November, and declines slightly in December. The ratio of the minimum to the maximum averages 1:1.29 nationwide and 1:1.22 in the three northern regions. The level is stable throughout the year.

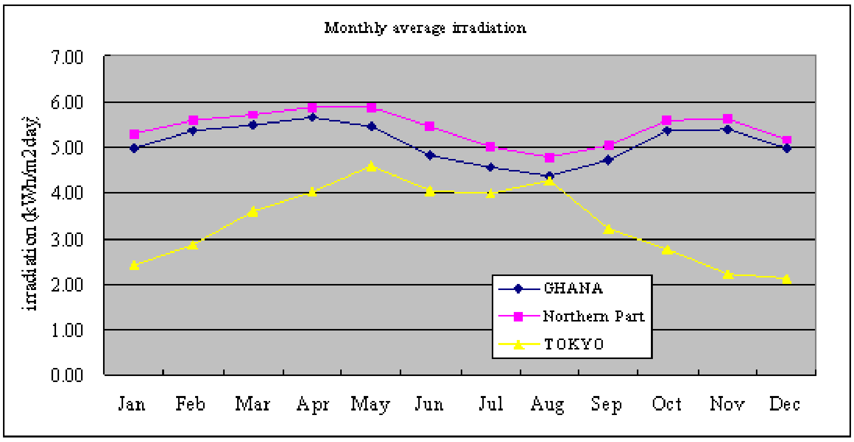
Table 5.1.2 shows the monthly trend of irradiation, and Figure 5.1.2, a graph of the same (including a line for Tokyo for the purpose of comparison).

Table 5.1.2 Monthly irradiation

(kWh/m^2・day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
GHANA	4.97	5.36	5.48	5.65	5.46	4.83	4.56	4.38	4.73	5.36	5.41	4.98	5.10
Northern Part	5.31	5.59	5.70	5.87	5.86	5.47	5.02	4.80	5.05	5.59	5.63	5.17	5.42
TOKYO	2.40	2.85	3.59	4.02	4.60	4.05	3.98	4.26	3.20	2.76	2.23	2.12	3.34

(Source) EC data and the NEDO national insolation data book



(Source) Prepared from Table 5.1.2

Figure 5.1.2 Trend of monthly irradiation

(3) Influence of climatic phenomena (harmattan)

As described above, irradiation is higher in the dry season and lower in the rainy season. This section takes up the influence of harmattans, a meteorological phenomenon distinctive to Ghana (and neighboring countries), on PV power generation. Harmattans arise in the dry season, when fine sand from the Sahara is carried up by the seasonal winds and transported down to the vicinity of the equator. They cloud the air for days, and occur mainly from November to February. They resemble the fallout of yellowish dust from China in Japan.

Table 5.1.3 and Figure 5.1.3 show the levels of irradiation based on ground observation and satellite data. The two sets of data exhibit basically the same trends. However, although the levels are about the same from April to October, that based on satellite data is about 10% higher from November to March. This is thought to be because of the diffusion and absorption of sunlight in the atmosphere due to harmattans, resulting in a decline in the amount that reaches the surface of the ground. The amount of insolation peaks in February according to the satellite data and from March to May according to the ground observation data. This difference reflects the influence of harmattans. Even during the harmattan season, however, there is a sufficient amount of insolation, and it appears that PV generation would not be significantly affected by the decrease.

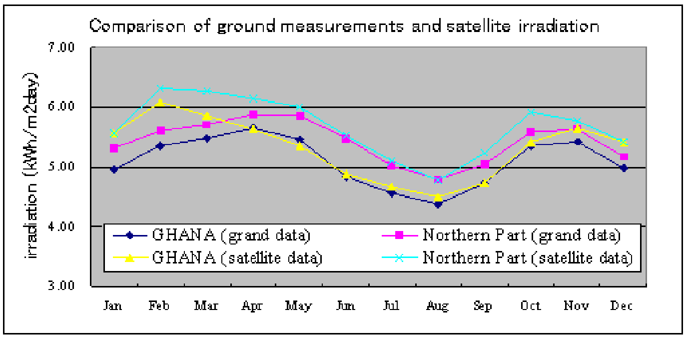
The influence of harmattans on PV generation would derive less from the decrease in insolation and more from the fine sand brought by them. The fallout of this sand on solar panels would reduce the generation efficiency. Harmattans arise in the dry season, and there is no rain to wash away the fallout on panels, which brings down the efficiency. Cleaning the panels is consequently an important task.

Table 5.1.3 Comparison of irradiation measurements by ground observation and satellite

(kWh/m^2·day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
GHANA (ground data)	4.97	5.36	5.48	5.65	5.46	4.83	4.56	4.38	4.73	5.36	5.41	4.98	5.10
Northern Part (ground data)	5.31	5.59	5.70	5.87	5.86	5.47	5.02	4.80	5.05	5.59	5.63	5.17	5.42
GHANA (satellite data)	5.56	6.09	5.86	5.62	5.36	4.87	4.66	4.51	4.73	5.42	5.65	5.41	5.31
Northern Part (satellite data)	5.56	6.32	6.26	6.15	6.00	5.51	5.10	4.78	5.23	5.91	5.77	5.41	5.67

(Source) EC data



(Source) Prepared from Table 5.1.3

Figure 5.1.3 Trend of irradiation based on ground observation and satellite data

5.1.2 Mini hydropower potential

(1) Large-scale hydropower potential

Ghana has usable hydropower resources of about 2,400MW. About half of this potential has been developed by stations at Akosombo (912MW) and Kpong (160MW) downstream of it in the southeastern part of the country. The rivers possible hydropower development are the Volta (whose catchment area accounts for almost two-thirds of the national land area of about 240,000km^2), Pra, Tano, and Ancobra. The undeveloped hydropower output is estimated at 1,240MW for a yearly generated output of 4,500GWh. Table 5.1.4 shows the plans for development on each water system.

Table 5.1.4 Hydropower sites on each water system

River Basin	Catchment Area (km^2)	Potential (MW)	Annual Generation (GWh)
Black Volta	148,820		
- Kouibi		68	392
- Ntereso		64	257
- Lanka		95	319
- Bui		400	1,000
- Jambito		55	180
Total		682	2,148
White Volta	105,540		
- Pwalugu		50	184
- Kulpawn		40	166
- Daboya		43	194
Total		133	544
Oti	71,940		
- Juabo		90	405
Tano River	14,700		
- Asuaso		25	129
- Sdukrom		17	67
- Jomuro		20	85
- Tasnoso		56	259
Total		118	540
River Basin	Catchment Area (km^2)	Potential (MW)	Annual Generation (GWh)
Pra River	22,290		
- Awisam		50	205
- Heman		90	336
- Abaumesu		50	233
- Kojokrom		30	136
Total		220	910
Grand total		1,243	4,547

(Source) MOE, *Hydropower Development in Ghana, Summery Description of Potential Sites, January 2004*

Of these sites, those at Bui (400MW) and on the Pra and Tano rivers are under the direct jurisdiction of the MOE. The VRA handles mainly the stations on the Volta river system. In 1993, it implemented preliminary feasibilty studies at the three sites of Juale, Pwalugu and Kulpawn. The plan for a station at Bui is faced with problems because of the presence of a protected zone (national park) and necessity of relocating residents, and those for other sites are confronting funding difficulties. As such, the development is not moving ahead.

(2) Mini hydropower potential

The Ghana government is promoting the development of mini-hydropower projects to encourage the utilization of renewable energy. Since 1999, the Energy Foundation has been reviewing the existing reports and surveying promising sites for mini-hydropower in the southern part of the country[5]. The Ghanaian government is promoting mini hydropower development as part of its policy for use of renewable energy, and regards such development as possible at 21 sites. All of these sites, however, are located in the southern part of the country; no potential sites have been confirmed in the northern regions that are the subject of this study[6]. Table 5.1.5 shows the potential sites for mini hydropower stations, and Figure 5.1.4, their location.

Table 5.1.5 Potential mini hydropower sites

No.	Name	Firm capacity (kW)	No.	Name	Firm capacity (kW)
1	Wli Falls	325	12	Woranae Falls A	12
2	Nuboi D/S of Wli Falls	45	13	Woranae Falls B	20
3	Tsatsadu Falls I	100	14	Randall Falls	4
4	Tsatsadu Falls II	75	15	Fuller Falls	7
5	Tsatsadu Falls III	170	16	Kokuma Falls	60
6	Mensu	65	17	Nkoranza	35
7	Ahamansu	125	18	Maabang	15
8	Dodi Papase I	210	19	Buofuom Falls	10
9	Dodi Papase II/Abuoe	100	20	Wurudu Falls A	30
10	Dodi Papase lia	210	21	Wurudu Falls B	45
11	Sanwu Falls	20			

(Source) MOE, *Hydropower Development in Ghana, Summery Description of Potential Sites, January 2004*

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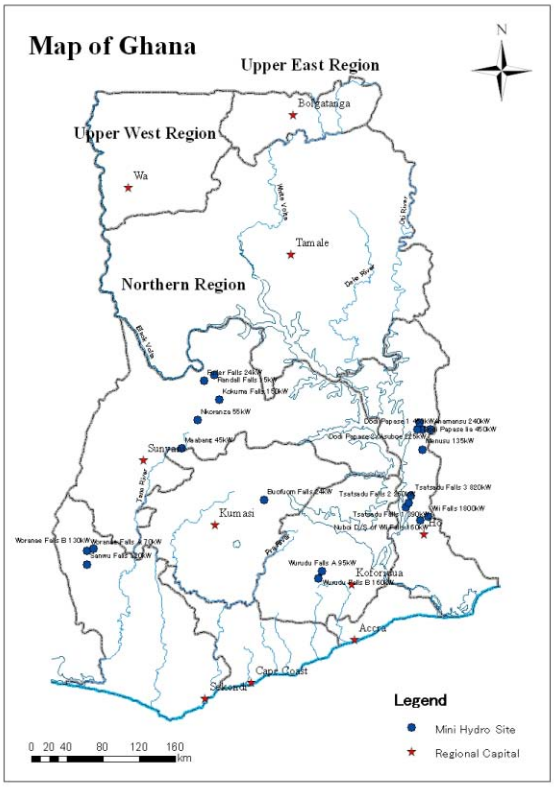
[5] Mini Hydro Power in Ghana Prospect and Challenges, October 2002, Energy Foundation,

[6] According to the MOE, which is in charge of mini hydropower development, and information from the NGO Energy Foundation, which is conducting the field study



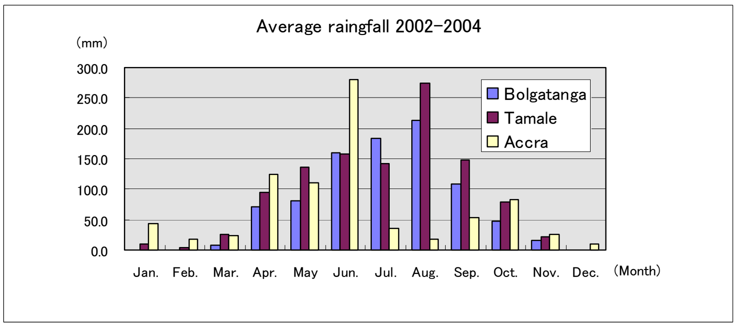
(Source) Prepared by JICA Study Team

Figure 5.1.4 Map of potential mini hydropower sites

(3) Mini hydropower potential in the three northern regions

1) Consideration from the meteorological and geographical aspects

As noted above, there are no confirmed potential mini hydropower sites in the three northern regions. The terrain is flat and virtually devoid of areas with the head needed for hydropower development. In addition, in the dry season (from December to March), almost no rain falls and rivers dry up, thereby ruling out generation throughout the year[7]. Figure 5.1.5 shows the average rainfall over the last three years at Bolgatanga in the Upper East Region and Tamale in the Northern Region.



(Source) Meteorological Department

Figure 5.1.5 Average monthly rainfall over the last three years (2002 - 2004) in the northern regions

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[7] Even at Nakpanduri, a site thought to have a sufficient head on the border between the Upper East and Northern regions, the river was completely dried up at the time of the study in May 2005.

2) Irrigation dam utilization possibilities

A study was made of the irrigation dams that could possibly have a flow throughout the year in the northern regions of Ghana. The dams studied were the Botanga Dam in the Northern Region and the Tono Dam in the Upper East Region (see Table 5.1.6). Both dams supply water to irrigation projects downstream by gravity flow, mainly in the dry season.

Table 5.1.6 Irrigation dam specifications

Dam	Botanga	Tono
Location	Northern Region	Upper East Region
Year of completion	1980	1985
Catchment area(km^2)	168	650
Inundation area(km^2)	7.7	18.6
Total capacity($\times 10^6 m^3$)	25.0	93.0
Effective capacity ($\times 10^6 m^3$)	20.0	83.0
Dam height(m)	12	9

(Source) Botanga:Ministry of Agriculture,Tono:ICOUR(Irrigation Company of Upper Region)

Because the area is flat and would make it difficult to use the discharge head, the study considered the prospects for power generation using the dam head. It found that the dam could not be expected to have much potential. Even at the maximum, the output in the dry season would come to only about 26.5kW.

* Outline study of possible generation output at the Tono Dam[8]

- The requisite monthly flow in the dry season at the Tono Dam would be $2.4 \times 10^6 m^3 = 0.9 m^3/s$
- The half-day (12-hour) discharge would be 1.8m3/s.
- The possible output would be Q (kw) = 2 (dry season head, m) x 1.8 (amount of water used, m3/s) x 9.8 (gravity acceleration) x 0.75 (turbine and generator efficiency) = 26.5kW

In addition, as both dams have almost no surplus water in the dry season, it would, in effect, be impossible to increase the amount of water use for power generation[9]. An increase in the dam height would present a problem as regards the burden of construction costs. It would also increase the dam water area and create apprehensions about impact on the residents and environment in the surrounding area. As such, the situation would be difficult to resolve in the near future.

The three northern regions are consequently thought to have no mini hydropower potential that could be developed at an early date.

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[8] Based on ICOUR(Irrigation Company of Upper Region)annual operation statistic

[9] Downstream of the Botanga Dam, for example, residents cultivate rice, and water for farming is circulated in accordance with agreements among the users in the dry season, when water is in short supply.

5.1.3 Wind power and biomass potential

(1) Wind power potential

1) Average wind velocity

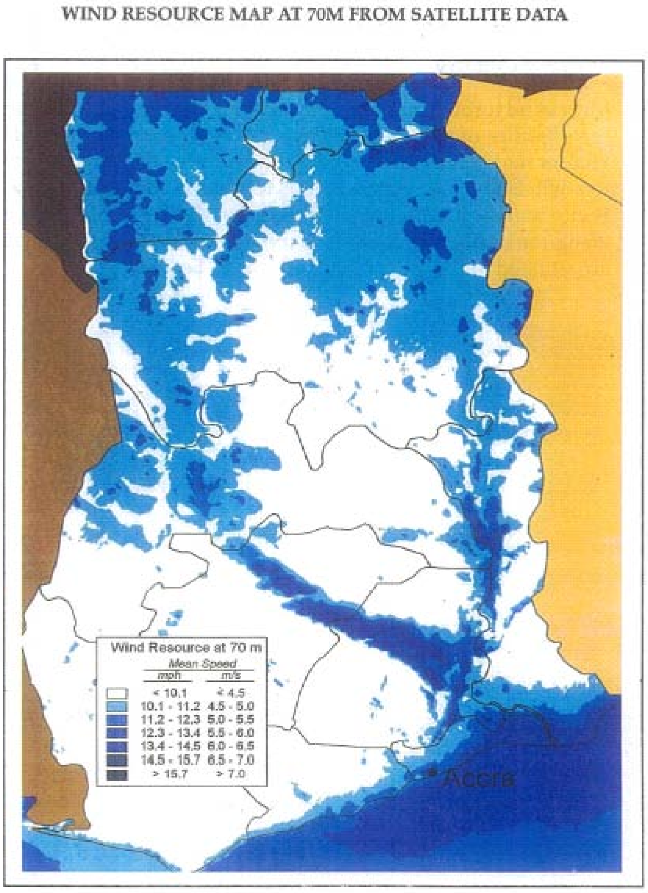
Figure 5.1.6 presents a map of wind velocities 70m above ground, based on satellite data. In most parts of Ghana, the wind velocity is less than 5m/s. Areas with comparatively good wind circumstances are confined to the southeastern coast, the Volta basin, the highlands stretching from the southeastern coast to the midwestern area, and the mountainous area near the northern border. Table 5.1.7 shows the average monthly wind velocitties 12m above the ground. The ground observation data exhibit the same trend as the satellite data. In Ada, which has the best wind, the average velocity is 5.1m/s. In the Northern Region, it is 3.9m/s in Tamale and 3.0m/s in the other points. The generation potential is therefore not thought to be high.

Table 5.1.7 Monthly average wind velocity (at a height of 12 m)

(m/s)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Abetifi	3.9	4.4	4.7	4.5	4.2	4.4	4.7	4.6	4.2	4.0	4.0	3.7	4.3
Accra	3.3	3.8	4.0	4.0	3.5	3.7	4.6	4.9	5.0	4.2	3.4	3.1	4.0
Ada	4.6	5.5	5.6	5.2	4.7	4.7	4.9	4.9	5.7	5.7	5.2	4.7	5.1
Akatsi	2.6	2.9	2.9	2.8	2.5	2.5	3.3	3.5	3.3	2.6	2.2	2.6	2.8
Akim Oda	2.3	2.5	3.0	3.1	2.4	2.4	3.0	2.8	2.8	2.5	3.3	2.7	2.7
Akuse	3.5	4.1	4.4	4.4	3.7	3.5	4.1	4.3	4.0	3.4	3.0	3.2	3.8
Axim	2.9	3.4	3.6	3.4	3.2	3.5	3.5	3.4	3.5	3.6	3.3	3.1	3.4
Bekwai	2.0	2.2	2.3	2.2	2.1	2.0	2.1	2.2	2.2	2.1	2.1	2.0	2.1
Bole	3.3	3.5	3.7	3.6	3.2	2.9	3.0	2.6	2.1	2.3	2.6	3.1	3.0
Ho	2.5	2.7	2.8	2.7	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.5
Koforidua	2.3	2.4	2.5	2.4	2.4	2.4	2.5	2.6	2.5	2.4	2.3	2.2	2.4
Krachi	2.8	3.4	3.7	3.6	3.2	2.8	2.8	2.6	2.5	3.0	2.6	2.5	2.9
Kumasi	3.2	3.8	4.2	4.0	3.7	3.7	4.4	4.3	4.1	3.6	3.4	3.2	3.8
Navorongo	3.6	3.7	3.1	3.2	3.2	2.9	2.8	2.8	2.6	2.7	2.8	3.3	3.0
Saltpond	3.6	4.3	4.2	3.9	3.7	3.7	3.9	4.2	4.5	4.2	3.8	3.5	4.0
Sunyani	3.5	3.9	4.4	4.2	3.8	3.9	4.1	4.1	3.7	3.5	3.4	3.4	3.8
Takoradi	3.5	3.9	4.4	4.4	3.9	4.1	4.2	4.6	4.9	4.4	4.0	3.3	4.1
Tamale	4.1	4.6	4.7	4.9	4.3	3.9	4.0	3.6	3.0	3.1	3.3	3.8	3.9
Tema	4.3	4.7	4.8	4.5	4.2	4.4	5.0	4.9	5.1	5.0	4.6	4.2	4.6
Wa	3.9	4.1	3.8	4.0	3.7	3.5	3.3	2.7	2.3	2.8	2.9	3.2	3.3
Wenchi	3.4	3.7	4.1	3.9	3.7	3.7	3.7	3.7	3.5	3.1	3.1	3.1	3.6
Yendi	2.9	3.2	3.0	3.2	3.0	2.8	2.8	2.7	2.4	2.4	2.3	2.7	2.8

(Source) EC Data



(Source) EC Annual Report

Figure 5.1.6 Map of wind velocity (70 m above ground) based on satellite data

2) Estimate of generated output

The Study Team estimated the output in the event of installation of wind power generation systems in Ada, which has the best wind in Ghana, and Tamale, which has the best in the three northern regions.

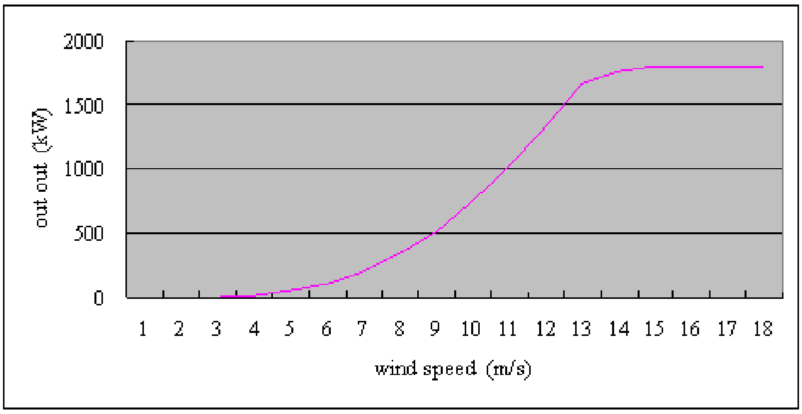
(a) Windmill specifications

It was assumed that the systems would use windmills in the class of 2,000kW, the mainsteam type in recent years. Table 5.1.8 shows the windmill specifications, and Figure 5.1.7, the windmill power curve.

Table 5.1.8 Example of windmill specifications

Type	Upwind
Rotor diameter	70m
Hub height	65m
Number of blades	3
Cut-in wind velocity	2m/s
Cut-out wind velocity	25m/s

(Source) Enelcon



(Souce) Enelcon

Figure 5.1.7 Example of a 2,000kW windmill power curve

(b) Calculation of generated output

Calculation of the windmill generated output requires a conversion of the wind velocity at the observation height to that at the rotor height. The observation height is 12m, and the average velocity at a rotor height of 65m was estimated at 6.5m/s in Ada and 5.5m/s in Tamale. Table 5.1.9 shows the wind velocity appearance rates calculated from the converted average velocity and annual generated output.

Table 5.1.9 Wind velocity appearance rates and annual generated output

Wind velocity (m/s)	Appearance rate		Annual generated output (kWh)	
	Ada	Tamale	Ada	Tamale
0	0.0%	0.0%	0	0
1	3.7%	5.1%	0	0
2	6.9%	9.5%	0	0
3	9.4%	12.4%	6,208	8,171
4	11.1%	13.8%	46,499	58,015
5	11.7%	13.6%	106,490	124,038
6	11.4%	12.2%	200,201	214,404
7	10.5%	10.1%	311,643	302,211
8	9.0%	7.8%	407,930	352,772
9	7.4%	5.6%	485,574	368,795
10	5.8%	3.8%	518,887	340,872
11	4.3%	2.4%	507,555	284,026
12	3.1%	1.4%	446,853	209,779
13	2.1%	0.8%	320,187	124,192
14 or more	3.7%	1.3%	580,344	206,060
Total	100.0%	100.0%	3,938,372	2,593,335

* The empirical rule V = V0 x (H/H0) 1/n was used for the wind velocity altitude distribution. The n value ranges from 2 to 10 based on terrain. It was 7 in Ada, a coastal area, and 4 in Tamale, a rural area.

** The appearance rates were calculated on the basis of a Reyleight distribution.

(Souce) JICA Study Team

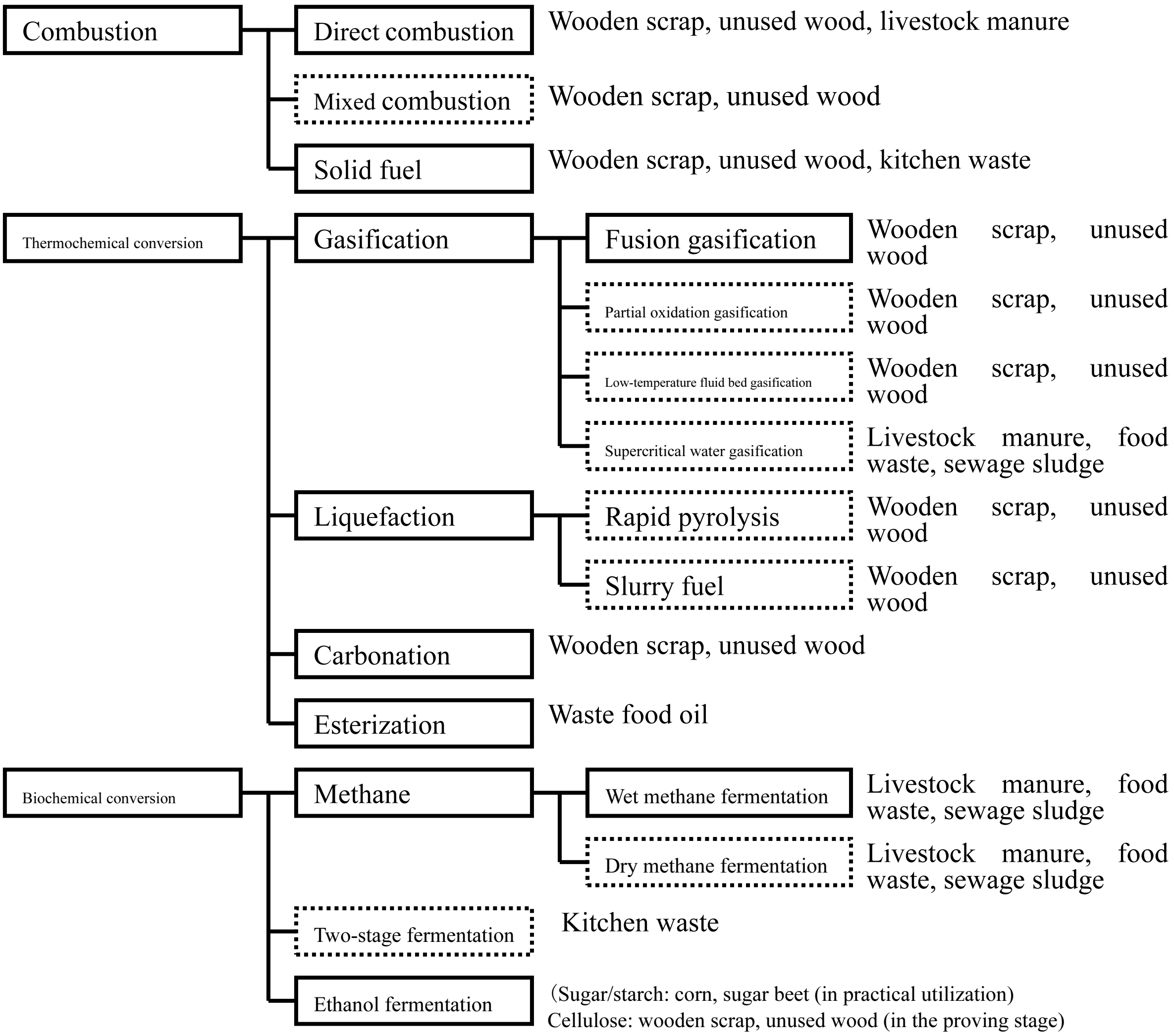
The calculation yielded a wind power generation output of 3,938MWh for Ada and 2,593MWh for Tamale. Because it assumed use of a windmill with a rated output of 1,800kW, the capacity factor would be 25% at Ada and 16.5% at Tamale.

These results indicate that, even in the coastal area, which has the best wind conditions in Ghana, wind power generation would have a low capacity factor and not be very viable. Nevertheless, the output figures were estimated from the average wind velocity, and the question requires a more in-depth study of the wind situation.

(2) Biomass potential

1) Biomass utilization technology

In terms of energy conversion technology, the methods of using biomass resources can be broadly divided into the classes of direct combustion, thermochemical conversion, and biochemical conversion. Figure 5.1.8 shows the system of technology for biomass energy conversion.



*Dotted lines indicate technology at the stage of R&D or proving.

(Source) NEDO guidebook for biomass energy utilization

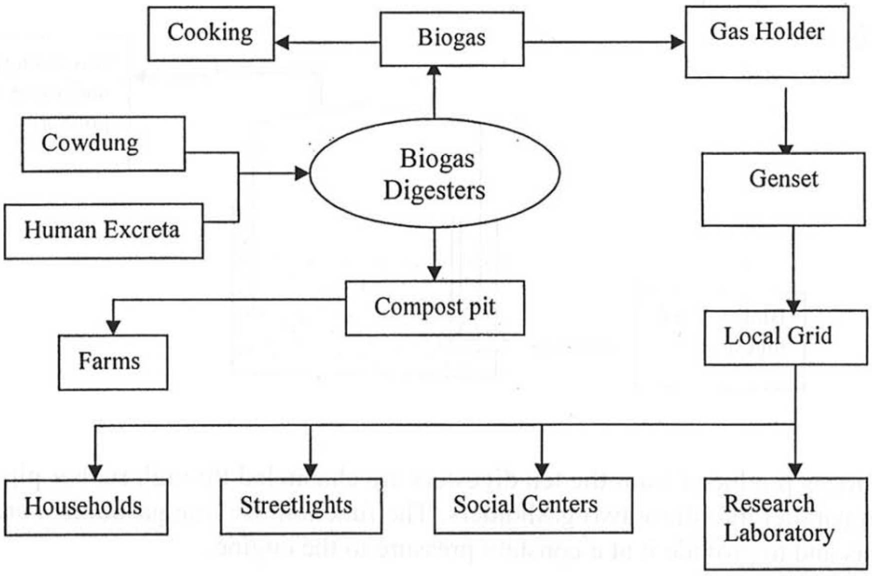
Figure 5.1.8 System of biomass energy conversion technology

2) Actual biomass power generation in Ghana

In Ghana, the MME executed a biomass generation research and demonstration project in Appolonia, in the district of Tema. It fermented livestock manure and human excreta, and used the resulting methane as fuel for cooking and power generation. Figure 5.1.9 shows a distribution diagram for energy use in this project.

Set-up Of The Bio-Power Project

Fig. 1



(Source) MME, *BIOGAS ELECTRIFICATION FOR RURAL APPLICATION:THE APPOLONIA EXPERIENCE*

Figure 5.1.9 Energy use distribution diagram

In this system, facilities are connected to two generators in a local grid with an extended length of about 1km. The facilities consist of 21 households, two churches, one mosque, one video center, two bars, one school, and 20 street lights. The generation cost was calculated to be 0.34 dollars/kWh with biomass generation, 0.25 dollars/kWh with diesel generation, and 0.48 dollars/kWh with PV generation.

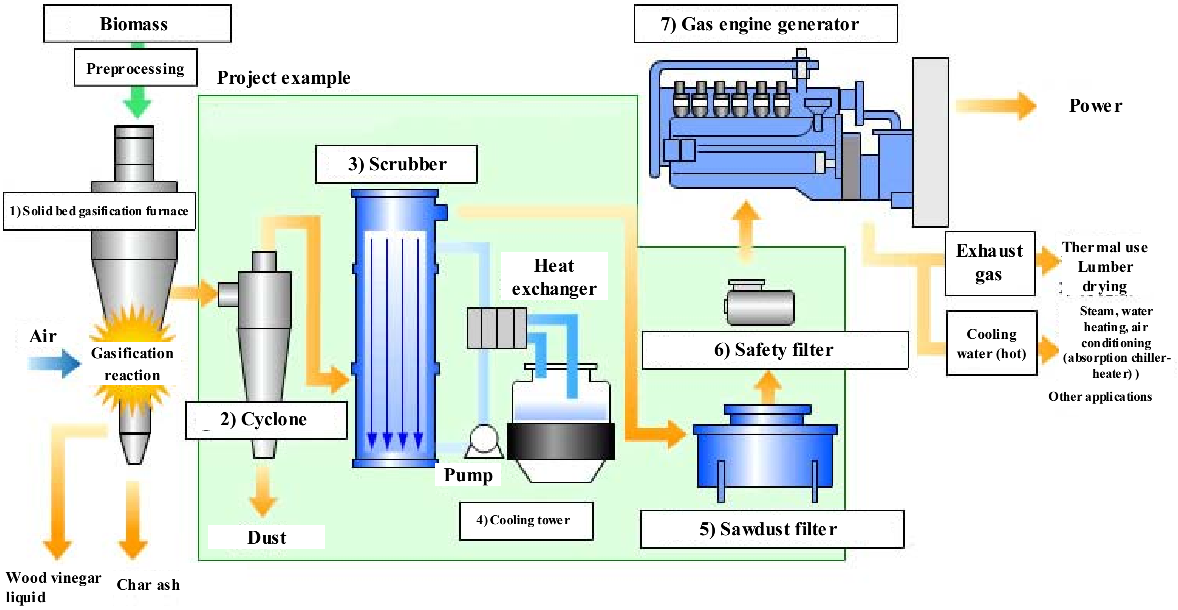
The main problems encountered in the project were an imbalance between supply and demand, and the high cost of transporting the base material. After the end of the project, a transition was made to a biogas-based toilet system with the generator removed.

The project proved that biogas power generation would be effective and workable technology in Ghana. The spread of biogas power generation requires the development of ways to collect material efficiently.

3) Other biomass potential

In Ghana, there is a lot of agricultural and wooden waste that could serve as raw material for biomass power generation, and this points to a high potential for generation by pyrolysis (thermal decomposition). Figure 5.1.10 shows a system diagram of pyrolytic gasification power generation. Table 5.1.10 shows the main types of agricultural waste in Ghana.

Agricultural waste amounts to about 117,000 ton/year. Assuming a gasification generation efficiency of 20% and calorific value averaging 17.7GJ/ton from agricultural waste, this amount would represent some 3,918,780GJ (1,088GWh) in energy reserves. This is equivalent to a 124MW power station. However, this is the nationwide amount, and development of such power generation is thought to be difficult at present considering the low collection efficiency because of the low waste concentration (density). Development will presumably require a more intensive and systematic agricultural production and higher productivity.



(Souce) JICA Study Team

Figure 5.1.10 Pyrolytic gasification generation system

Table 5.1.10 Main agricultural waste in Ghana

Crop	Residue	Residue Production (1000 t)
Maize	Cob	553
Oil Palm	Shell	193
Paddy Rice	Husk	19
Sorghum	Husk	136
Millet	Stalk	150
Ground nut	Stalk	56
Total		1,107

(Source) JICA Report on the Master Plan Study on Rural Electrification Using Renewable Energy Resources in Ghana (preliminary project formation study), December 2004

5.2 Clarification of PV RE needs and roles

5.2.1 Confirmation of the role played by RE in poverty reduction

The GPRS deems RE necessary as a component of the social infrastructure supporting public services for assurance of health/medical care, education, and supply of water for drinking and irrigation, as well as of the economic infrastructure for stimulation of local economic activity. RE plans must be drafted only after getting a firm grasp of how power will be utilized in response to these socioeconomic needs.

5.2.2 Concerns about differences of quality and capacity between on-grid electrification and off-grid PV electrification

This study is premised on the preparation of plans for off-grid PV RE in communities in northern Ghana that would be hard to electrify by on-grid electrification under the SHEP. Care is required due to the difference between PV and grid power in respect of quality and capacity (see Table 5.2.1).

Users and dealers must acquire a deeper understanding of these differences and devise methods for use of the limited power supply as fairly as possible.

Table 5.2.1 Difference of quality between grid electrification and PV electrification

	Grid power	PV (SHS) power
Power capacity	High	Low (usually no higher than 100W)
Scope of use	Capable of use for large-capacity products such as cookers, refrigerators, and motors	Small-capacity products such as lights, radios, and B/W TV sets
Use duration per day	24 hours	A few hours
O&M	Performed by the utility	Need for a separate entity

(Source) JICA Study Team

In reality, according to the NED, which provides distribution services in the northern regions, there are the following apprehensions about the commencement of off-grid PV electrification services.

- Conformance with tariffs for grid service (income aspect)
- Difference between off-grid PV and on-grid power in respect of quality and quantity
- User concerns about the lack of grid power supply if PV systems are installed

5.2.3 Identification and analysis of needs for PV electrification in the northern regions

Interviews were conducted with community residents, public facilities, commercial facilities, and other parties to ascertain problems encountered in daily life and work, and the attendant electrification needs. These may be summarized as follows.

- Among public facilities, there are strong needs for lighting, vaccine refrigerators, and communications facilities in clinics for better primary care. Schools expressed desires for lighting for more night classes.

- Electricity is wanted by commercial facilities for lights and audio facilities that would be linked directly to increased income. There are also needs for power for grain mills, but PV systems cannot address them.

- Households have needs for lights to enable study and communication at night, and for entertainment devices such as radios and TV sets.

- Ideas for ways of utilizing PV power to produce additional income include mobile telephone stations and driers for agricultural crops, but they have not yet been put into practice.

Table 5.2.2 presents a more detailed summary of problems, electrification needs, and tasks for fulfilling them.

Table 5.2.2 Needs for off-grid PV electrification in northern Ghana

Facility type		On-site problems and needs	Type of electrical product/facility needed	Comments/tasks
Public facilities	Hospitals/clinics	・ Nighttime examination, surgery, birth	・ Lighting	・ Very strong needs for a higher level of medical services
		・ Sure storage of vaccine and medicine	・ Refrigerators	・ More stable use than refrigerators fueled with kerosene or gas ・ Necessity for an independent system in the 200-W class or higher due to the high capacity required
		・ Swift and sure contact and action between cntral hospitals and clinics	・ Radio communication	・ Need for a management setup revolving around central hospitals
		・ Installation of examination equipment for early detection of disease	・ Examination equipment	・ Difficulty to apply in remote rural areas considering the large capacity of the equipment and need for maintenance arrangements
	Schools	・ Rise in the level of education through provisions for independent study at night and instatement of combined classes containing more than one grade	・ Lighting	・ Limited number of users due to the difficulty of commuting long distances at night
		・ Spread of educational information through mass media	・ Radios and TV sets	・ Problem of comprehension due to language differences
		・ Diffusion of remote education services and improvement of the education network	・ Computers and Internet materials	・ Need for systems larger than the ordinary 100-W type ・ Difficulty to install in remote villages considering the delivery of materials and O&M requirement ・ Need for assurance of communications circuits
	Staff houses (for teachers, nurses, etc.)	・ Permanent stationing of staff through a rise in satisfaction with the lifestyle ・ Improvement of teacher capability (educational material preparation and learning)	・ Lighting, radios, TV sets, etc.	・ Necessary for heightening the incentive for service in rural villages among teachers and clinic employees
	Water supply system	・ Assurance of a stable supply of water ・ Improvement of hygiene through simple water supply facilities ・ Freedom from the labor of hauling water	・ Pumping facilities	・ Need for measures to prevent theft due to installation in open space ・ Strong need to build a setup for O&M
	Irrigation facilities	・ Promotion of stable and efficient farming ・ Freedom from heavy labor	・ Pumping facilities	・ Need for a comparatively big system and hard O&M to pump up groundwater
	Street lights	・ Guidance for nighttime walks ・ Improvement of public order		・ No perceived needs for installation on public roads, but a certain degree of need for installation around schools and clinics ・ Need for clear definition of ownership and an O&M setup
	Religious facilities (churches, mosques, etc.)	・ Promotion of religious activity	・ Lighting and audio facilities	・ High possibility of coverage of costs with donations ・ Not suitable for execution as a governmental project
	Communication centers	・ Venues for gathering and recreation	・ Lighting, TV sets, video sets	・ Use of the chief's house in some cases ・ Need for clear definition of ownership and construction of an O&M
Private facilities	Housing (compound)	・ Higher levels of convenience in ordinary activities in the home at night ・ Spread of nighttime learning (including reading of newspapers and scriptures) ・ Venue for recreation (dancing) and gathering	・ Lighting	・ Upper limit of about 100 W in the size of system able to be purchased for housing in the northern regions ・ Needs thought to be highest for entertainment products such as TV sets and radios (problem posed by language differences)
		・ Provision of entertainment ・ Acquisition of various information	・ Tools of entertainment and information (radio-cassette, TV sets)	
		・ Preservation and sales of foods and beverages ・ Increase in comfort	・ Refrigerators, freezers, electric fans	・ Presence of needs among ordinary homes, but also difficulties related to PV system capacity and purchasing ability ・ Unsuitability of PV systems for use of heat for ironing, cooking, etc.
	Commercial facilities (small-scale)	・ Increase in income through extension of business hours	・ Lighting	・ Purchase of systems with a capacity of at least 100 W based on cash income; latent demand for diverse electrical products ・ Strong needs associated with grinding of nuts and other mechanical use, but PV systems are not suitable for it
		・ Increase in the drawing power of bars and restaurants	・ Radios, audio facilities, TV sets	
		・ Preservation and sales of foods and beverages ・ Increase in comfort	・ Refrigerators, freezers, electric fans	
	Other	・ Promotion of use of electrical products based on battery systems	・ Battery charge stations	・ Charging about twice a month; applicable for households with a low income due to the low cost (3,000 cedi per charge) ・ Limited scope of use (on the level of lights and radios)
		・ Increase in opportunities for communication	・ Mobile telephone stations	・ Expansion of the service area through installation of relay stations ・ Mobile telephones could be recharged with the ordinary home system
		・ More efficient drying of nuts and other agricultural products	・ Drying of agricultural products	・ Degree of need uncertain at present, as the northern regions have enough sunlight for drying in the dry season

5.3 Power demand forecast

5.3.1 Objective and methodology of demand forecast

A power demand estimate will be made to determine the size of demand associated with socioeconomic activities in the areas covered and existing projects, and to calculate the size of system and electrification cost in individual sites. There are two major types of estimate method: engineering (micro) and econometric (macro). Table 5.3.1 shows the features of each.

Table 5.3.1 Ordinary techniques for estimating power demand

Technique	Description
Engineering technique (addition, micro)	Need for a lot of data, but not necessarily time-sequence data Easier to explain the background of the forecast results due to the corroborative data
Econometric technique (macro)	Does not require a lot of data, but long-term time-sequence data are necessary Difficult to explain the background of the forecast results due to the use of economic indicators as explanatory variables for the demand

(Souce) JICA Study Team

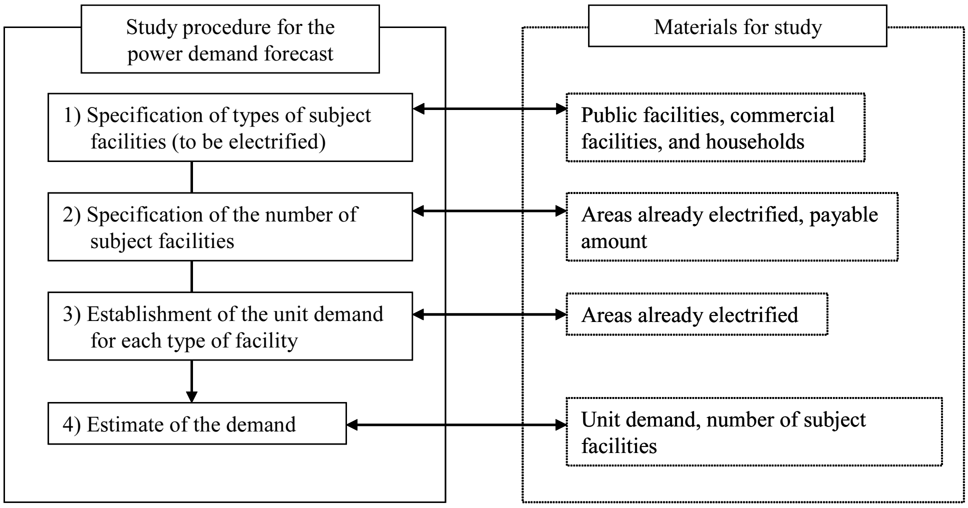
For this study, it was decided to apply the engineering (micro) technique, for the following reasons.

1) The ordinary residential demand, which occupies a big part of the power demand in rural areas of Ghana, is greatly influenced by changes in economic activities, the degree of diffusion of electrical products, and changes in the economic status.

2) In unelectrified areas and areas electrified only by dispersed sources such as batteries, time-series data for the past power demand are not available or insufficient.

5.3.2 Perspective and procedure of demand forecast

In the case of off-grid PV electrification, the scope of usable products is limited, and the size options for ordinary systems are confined to capacities on the order of 50W or 100W. It was therefore assumed that the latent demand would be actualized in correspondence with such system sizes. The Study Team is also going to make a supplementary estimate for on-grid electrification to obtain material allowing comparison with off-grid electrification. Figure 5.3.1 shows the study flow for the demand forecast, and is followed by a discussion of the perspectives on each item of study.



(Souce) JICA Study Team

Figure 5.3.1 Study flow for power demand forecast

(1) Specification of subject facilities and estimate of the number

It is the goal of the Ghanaian government to make electricity accessible nationwide; it has not set a specific target for the household electrification rate. For the number of houses and commercial facilities to be electrified by off-grid PV systems, the Study Team set an electrification rate with consideration of the following items, based on the findings of the village socioeconomic survey.

- Points already electrified by PV systems
- Points electrified by extension of the grid [10]
- Amount of money residents can pay

In the case of public facilities, the number of subject facilities were determined with reference to the size, necessity of electrification, and other factors for schools, health care facilities, water supply facilities, and other types.

(2) Establishment of the unit demand for each type of facility

The Study Team used the figures shown in Table 5.3.2 for the capacity of electrical products that form the basis of the unit demand for each type of facility. These figures are based on the data obtained from the survey of electrification products and the village socioeconomic survey in the second field study. Generally speaking, products with a large capacity are not amenable to PV power, and are shown in the separate table for on-grid electrification.

Table 5.3.2 Unit demand associated with electrical products

PV electrification products	
Electrical product	Capacity(W)
Fluorescent bulb (small)	8
Fluorescent bulb (large)	18
B/W TV set	30
Radio-cassette player	15
Electric Fan	55
Vaccine refrigerator	54
Radio communication	5.4

On-grid electrification products	
Electrical products	Capacity(W)
Color TV set (14-inch)	53
Color TV set (20-inch)	77
Stereo set	150
Medium-sized refrigerator	140
Incanjdescent bulb	40
Fluorescent bulb (4 feets)	36
Fluorescent bulb (2 feets)	18
Ceiling fan (small)	65
Air conditioner	2,000
Electric Iron	750
Washing machine	350
Drier	1,300
Rice cooker	700
Electric stove (for cooking)	1,500
Sewing machine	100

(Source) JICA Study Team estimates

Concerning the unit demand (maximum power) in each house, it can be noted that, in the case of PV electrification, the system size is determined to a certain degree by the capacity of the panels. The Study Team posited prime units for the system sizes generally installed in houses (50W and 100W) based on analysis of existing PV projects.

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[10] According to New Energy, which implemented the village socioeconomic survey in electrified areas of the northern regions, the household electrification rate in the pertinent communities is about 30 %.

5.3.3 Electricity demand forecast (off-grid electrification)

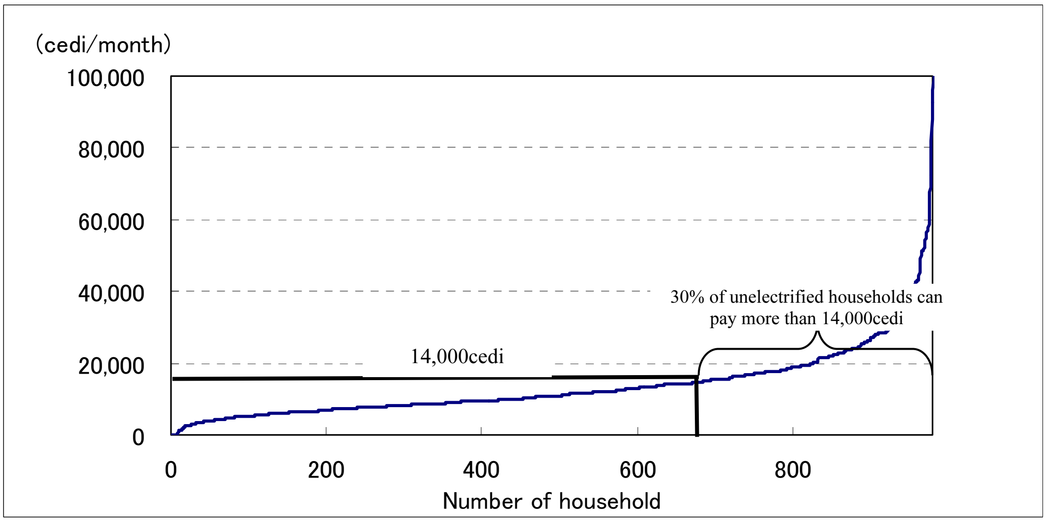
(1) PV electrification demand among unelectrified households

As was noted in the section on the results of the village socioeconomic study, households electrified with PV systems still use kerosene and batteries as sources of energy, and the PV systems account for only about one fourth of their entire energy expenditures. Assuming that PV systems would occupy the same share of energy spending among currently unelectrified households, the monthly expenditure on them would come to about 14,000 cedi (1.5dollars) per month on the average.

As for the question of the amount unelectrified households would be willing to pay, the village socioeconomic study found that many residents would not be willing to pay a larger sum for energy even if electricity became available, and the average amount of tolerable increase is lower than that of desired decrease. In addition, many users of SHS and BCS do not want to pay any more than at present. For these reasons, not much can be expected as regards expenditures even if PV systems are installed among unelectrified households.

Virtually no households would be able to make cash payments for the initial cost of about 650 dollars (6 million cedi) for a 50W SHS. The study on household electrification consequently focused on BCS. Assuming that batteries are charged at the rate of once a week for a fee of 3,000 cedi (0.3 dollars), the cost could be met by the aforementioned sum of 14,000 (1.5 dollars) cedi per month. This is about the same as that of 15,500 (1.7 dollars) cedi per month spent by BCS households, and therefore indicates that households could be electrified by BCS.

However, the distribution of unelectrified households shows that few of them have a lot of energy expenditures. Only about 30% of the total number would be able to pay a sum of 14,000 (1.5dollars) cedi per month (see Figure 5.3.2).



(Source) Prepared by the JICA Study Team based on the results of the village socioeconomic study

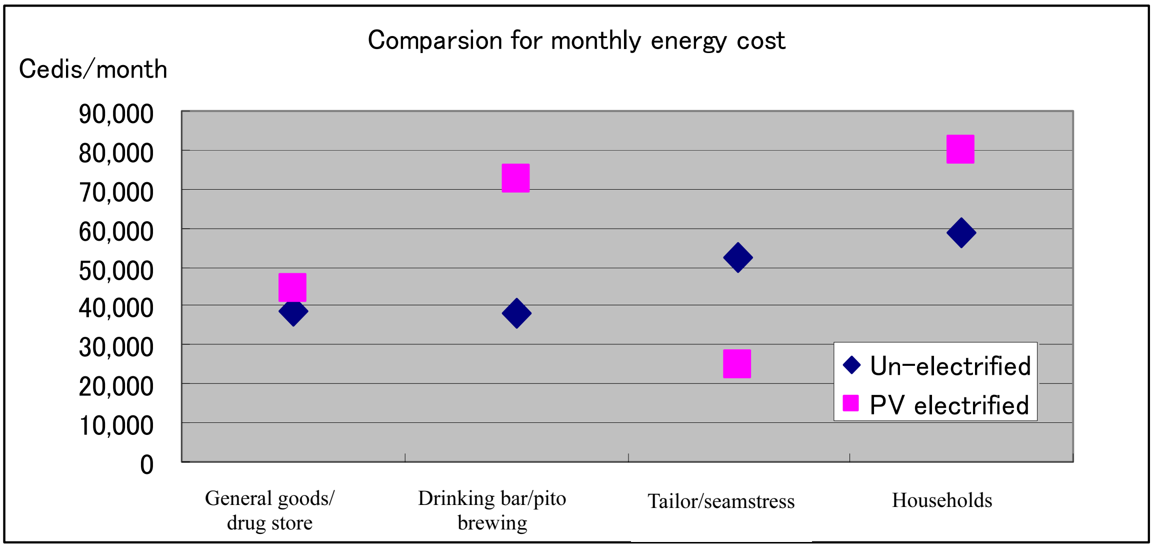
Figure 5.3.2 Distribution of payable monthly sum among unelectrified households

As for initial cost, whereas total payments are held to 120,000 cedi (13.3 dollars) per month on the average among unelectrified households, the corresponding figure for households electrified with PV systems is more than twice as high at 291,000 cedi (32.3 dollars). While this is not as high as the cost of a car battery (about 50 dollars or 450,000 cedi), there are thought to be some households capable of purchase.

Judging from these points and the monthly sum capable of payment, it is estimated that about 30% of the households in unelectrified communities could be electrified with BCS. It would be more realistic to put the figure at about 20%, considering the ability to pay the initial cost for batteries.

(2) PV electrification demand among commercial facilities

Figure 5.3.3 compares the average energy cost per month among the types of commercial facilties with a fairly large number of samples, i.e., stores (general goods/drug stores), bars (drinking bars/pito brewing), and tailor shops (tailor/seamstress), and unelectrified households.



(Source) JICA Study Team

Figure 5.3.3 Average monthly energy cost among major commercial facilities

Among both commercial facilities that are unelectrified and those that are electrified with PV systems, energy expenditures are lower than among households. This is mainly because of the small size (the facilities are generally single-room buildings) and the relatively low level of power consumption as occupants leave for their homes after closing. In the case of restaurants, another factor is that food is prepared in the residence behind them. For this reason, it would not be appropriate to estimate capability for purchase of PV systems on the basis of their current energy expenditures. It may also be noted that a fairly large proportion of the stores with SHS receive RESPRO services, and their monthly PV energy expenditures are therefore about 25,000 cedi (2.8 dollars). This figure, too, is consequently not a good indication of payment capabilities.

Unelectrified stores and bars have monthly income in the range of about 1.0 - 1.2 million cedi (110 -

130 dollars) from a daily cash income, and are thought to have a higher latent ability to purchase PV systems than ordinary households. If they directed 10% of their income to energy expenditures and 25% of their energy expenditures to PV electricity, stores could pay from 25,000 to 30,000 cedi (2.8 - 3.3 dollars) per month on PV systems. This is slightly higher than the corresponding figure for households.

The electrical products used by stores electrified with PV systems are basically on the level of lighting and stereo (audio) sets, and the scope of system use is limited. (According to New Energy, which conducted the village socioeconomic study, people generally use dry cell batteries for radios instead of connecting them to the PV system because the requisite voltage varies (from 4.5 to 12.0 volts) depending on the radio size.) Considering all of these factors, it is thought that, of the total number of stores, about 25% could use BCS electricity, and 5%, SHS.

(3) PV electrification demand among public facilities

The electrification of public facilities must be promoted by the government as a means of mitigating poverty through improvement of social services. However, the status of the national finances makes it impossible to electrify all such facilities and compels selection of the minimum requisite ones to be electrified.

Table 5.3.3 shows the electrification status of educational and medical (health) facilities. While some of the unelectrified facilities could be electrified through SHEP, detailed data were not available on this point, and it was therefore assumed that all of them were potential candidates for PV electrification.

Table 5.3.3 Electrification of educational and medical facilities in the three northern regions

Electrification Status of Educational & Health Facilities in the Northern Part																
SUMMARY-UER		**EDUCATIONAL FACILITIES**							**HEALTH FACILITIES**							
No.	**District**	**Pre/ Prim.**	**JSS**	**SSS**	**Voc**	**Trg Col.**	**Tertiary**	**Adult Lit.**	**CHPS**	**Clinic**	**Health Cen.**	**Hosp.**	**Dist. Hosp.**	**Reg. Hosp.**	**Nut. Cen.**	**Trg Inst.**
1	**SUMMARY-NR**	2013	354	37	3	3	2	3797	12	46	89	7	6	1	9	3
2	**SUMMARY-UER**	719	218	22	2	2	2	2015	17	48	26	0	2	1	3	4
3	**SUMMARY-UWR**	619	264	17	7	2	2	1858	30	5	50	5	3	1	?	2
	Total	*3351*	*836*	*76*	*12*	*7*	*6*	*7670*	*59*	*99*	*165*	*12*	*11*	*3*	*12*	*9*
	Electrified grid	455	211	74	12	7	6	455	8	22	54	12	11	3	10	9
	Electrified PV	2	144	1				1350	1	11	28					
	Unelectrified	2894	481	0	0	0	0	6320	50	66	83	0	0	0	2	0
	% Unelectrified	86%	58%	0%	0%	0%	0%	82%	85%	67%	50%	0%	0%	0%	17%	0%

(Source) JICA Study Team

- Medical facilities

According to the results of the village socioeconomic study, almost all medical facilities on the order of hospitals or higher have been electrified. A total of 199 facilities (CHIPS compounds, clinics, and health centers) have not been electrified. In interviews conducted as part of the second field study, the MOH indicated that it was promoting the electrification of all of these unelectrified facilities. This study therefore proposes all unelectrified medical facilities as subjects of electrification with PV systems.

- Educational facilities

In the category of educational facilities, the study found that electricity was not available to 481 junior secondary schools and 2,894 primary schools (58 and 86% of the respective totals). It also found that electrification by connection to the grid is not making much headway, that electrification of the 2,894 primary schools by such means would carry an enormous cost, and that the MOEdu is pushing electrification for the diffusion of ICT on the district level. In light of these factors, the Study Team proposes all junior secondary schools as subjects of electrification with PV systems.

- Staff houses

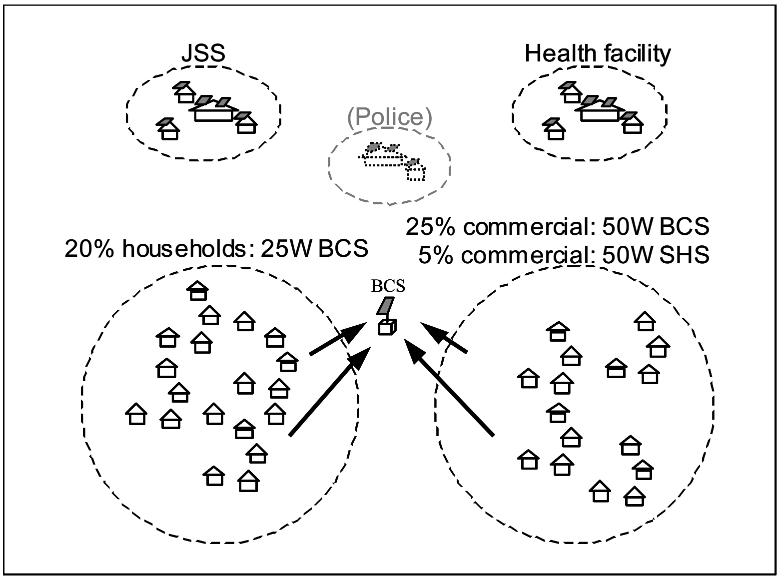
Along with the improvement of services through electrification of medical and educational facilities, it is also important to electrify staff houses in order to encourage personnel to work in remote communities. Seeing that these staff are transferred from urbanized districts, the Study Team proposes the installation of one 100W SHS for each of three houses for staff of educational and medical facilities (one house in the case of CHIPS compounds) and for one house for staff of police and equivalent governmental facilities.

- Other public facilities

Other public facilities that are prospective subjects of PV electrification are police stations and street lights whose purpose is to preserve law and order, and pumping facilities for wells and bore holes. The Study Team decided to exclude street lights because of the relatively high cost of measures for protection of the battery, for example, and the virtual impossibility of constructing an O&M setup because the beneficiaries are not clearly defined. Similarly, it also essentially excluded pumping facilities because of the need for design of systems for each separately and the few cases of actual installation. Although their electrification requires the agreement of the MOE and other stakeholders, police and other such governmental facilities are subjects of electrification given their official status.

(4) Proposal of a model for electrification with PV systems in unelectrified communities in the northern regions

Figure 5.3.4 shows the electrification model taking account of the aforementioned electrification subjects and proportions (the estimated rate of all potential subjects occupied by those that would actually be electrified). Public facilities would be electrified mainly by SHS, and households and commercial facilities, by BCS.



(Source) JICA Study Team

Figure 5.3.4 Model for electrification with PV systems

(5) Demand forecast for PV electrification

The Study Team made the following assumptions about the size of PV systems for the various subjects.

a) Households: 25W, envisioning use mainly for lighting

b) Commercial facilities: 50W, envisioning use mainly for lighting, but also for small fans and radio cassettes

c) Public facilities: as follows, based on the MOE proposal

- Clinics and health centers: Buildings: 100W x 2 = 200W (including wireless equipment), Refrigerators: 200W, Staff houses: 100W x 3
- CHIPS compounds: Buildings: 100W, Staff houses: 100W x 3
- Junior secondary schools: Buildings: 250W, Staff houses: 100W x 3
- Police facilities: Building: 100W, Staff houses: 100W x 11

Table 5.3.4 presents the forecast figures (estimates) for the PV system demand in unelectrified communities covered by the reconsigned village study. Churches and mosques are included in the category of commercial facilities.

Table 5.3.4 PV system demand in unelectrified communities

Community name	District Name	Region Name	Total Population	Num. of Compounds	Demand HH (25W) (W)	Total business entitiy	Demand business ent. (5%SHS,25% BCS,50W)	Junior secondary school	Chips compound	Clinic	Health center/health post	Governmental office	Staff house	Demand for public facilities (W) *	Total demand (W)
Bimbini	West Mamprusi	Northern	138	14	100	7	100	0	0	0	0	0	0	0	200
Lampur	West/Central Gonja	Northern	261	49	300	3	50	0	0	0	0	0	0	0	350
Langatire	West/Central Gonja	Northern	326	31	200	5	50	0	0	0	0	0	0	0	250
Kakale	West/Central Gonja	Northern	350	30	200	7	100	0	0	0	0	0	0	0	300
Bethlehem	West/Central Gonja	Northern	409	35	225	8	100	0	0	0	0	0	0	0	325
Kafulwurape	West/Central Gonja	Northern	465	83	525	4	50	0	0	0	0	0	0	0	575
Butei	West/Central Gonja	Northern	495	43	275	1	0	0	0	0	0	0	0	0	275
Kananto	West/Central Gonja	Northern	506	50	325	13	200	0	0	0	0	0	0	0	525
Kudani	Saboba/Chereponi	Northern	549	87	550	19	300	0	0	0	0	0	0	0	850
Kokope	West/Central Gonja	Northern	585	81	500	11	200	0	0	0	0	0	0	0	700
Yachadom	Zabzugu/Tatale	Northern	872	109	675	30	500	1	0	0	0	1	4	750	1,925
Kpani	Saboba/Chereponi	Northern	957	83	525	8	100	0	0	0	0	0	0	0	625
Sheini	Zabzugu/Tatale	Northern	980	130	825	28	400	1	0	0	0	0	3	550	1,775
Wenchiki	Saboba/Chereponi	Northern	1,131	168	1,050	17	250	1	0	0	1	1	7	1,450	2,750
Kandin	Zabzugu/Tatale	Northern	1,142	170	1,075	47	700	1	0	0	1	0	6	1,250	3,025
Kulkpaligu	Zabzugu/Tatale	Northern	1,250	173	1,075	23	350	1	0	0	1	0	6	1,250	2,675
Kpabuso	West/Central Gonja	Northern	1,443	378	2,375	34	550	1	0	0	0	1	4	750	3,675
Nahuyili	Zabzugu/Tatale	Northern	1,616	135	850	23	350	0	0	0	0	0	0	0	1,200
Wapuli	Saboba/Chereponi	Northern	1,695	291	1,825	40	600	1	0	0	1	0	6	1,250	3,675
Tamaligu	Gushiegu/Karaga	Northern	1,720	150	950	32	500	0	0	0	0	0	0	0	1,450
Sheri	West/Central Gonja	Northern	1,978	207	1,300	12	200	1	0	0	0	0	3	550	2,050
Busunu	West/Central Gonja	Northern	2,572	576	3,600	27	400	1	0	0	1	0	6	1,250	5,250
Mandari	Bole	Northern	2,790	356	2,225	41	600	1	0	0	0	0	3	550	3,375
Duu	West Mamprusi	Northern	4,500	57	350	32	500	1	0	1	0	0	6	1,250	2,100
Kusawgu	West/Central Gonja	Northern	4,848	175	1,100	41	600	1	0	0	1	0	6	1,250	2,950
Mpaha	West/Central Gonja	Northern	7,000	711	4,450	32	500	1	0	0	1	1	7	1,450	6,400
Kpasenkpe	West Mamprusi	Northern	14,200	498	3,125	40	600	1	1	0	1	0	7	1,450	5,175
Vortkom	Bawku East	Upper East	214	18	125	1	0	0	0	0	0	0	0	0	125
Kanjam	Bawku East	Upper East	445	52	325	20	300	0	0	0	0	0	0	0	625
Tanga Natinga	Bawku East	Upper East	600	78	500	79	1,200	1	0	1	0	1	7	1,450	3,150
Sumaduri	Garu Tempane	Upper East	738	200	1,250	23	350	0	0	0	1	0	3	700	2,300
Zongoyire	Bawku East	Upper East	768	33	200	29	400	0	0	0	0	0	0	0	600
Goriga	Bawku East	Upper East	1,198	105	650	168	2,500	0	0	1	0	0	3	700	3,850
Apodabogo	Garu Tempane	Upper East	1,247	228	1,425	23	350	0	0	0	0	0	0	0	1,775
Duuri	Garu Tempane	Upper East	2,000	122	775	39	600	0	0	0	0	0	0	0	1,375
Bugri Natinga	Garu Tempane	Upper East	2,122	183	1,150	145	2,150	2	0	2	0	1	13	2,700	6,000
Windnaba	Garu Tempane	Upper East	3,000	160	1,000	66	1,000	0	0	1	0	0	3	700	2,700
Bas Yonde Central	Garu Tempane	Upper East	5,209	875	5,475	90	1,400	0	0	1	0	1	4	900	7,775
Kongo	Jirapa/Nandom	Upper West	223	19	125	11	200	0	0	0	0	0	0	0	325
Gbelle	Sissala	Upper West	229	17	100	13	200	0	0	0	0	0	0	0	300
Banu	Sissala	Upper West	253	36	225	3	50	1	0	0	0	0	3	550	825
Wasai	Sissala	Upper West	325	21	125	12	200	0	0	0	0	0	0	0	325
Wuru	Sissala	Upper West	370	32	200	1	0	0	0	0	0	0	0	0	200
Puzene	Sissala	Upper West	611	30	200	5	50	0	0	0	0	0	0	0	250
Bichemboi	Sissala	Upper West	646	56	350	9	100	1	0	0	0	0	3	550	1,000
Duwie	Sissala	Upper West	759	75	475	25	350	0	0	0	0	0	0	0	825
Kogle	Jirapa/Nandom	Upper West	839	92	575	32	500	1	0	0	0	0	3	550	1,625
Ketuo	Jirapa/Nandom	Upper West	960	102	650	56	850	1	0	0	1	0	6	1,250	2,750
Dasima	Sissala	Upper West	982	189	1,175	42	650	1	0	0	0	0	3	550	2,375
Kulkpong	Wa	Upper West	1,455	94	600	26	400	0	1	0	0	0	1	200	1,200
Buo	Sissala	Upper West	2,100	90	575	31	500	1	1	0	0	0	4	750	1,825

* Demand for public facilities: 250W@JSS + 100W@CHIPS compound + 400W@Clinic + 400W@Health center + 100W@Governmental office + 100W@staff house

(Source) JICA Study Team

5.3.4 Electricity demand forecast (on-grid electrification)

Through the reconsigned study, the Study Team collected data from a total of 12 communities connected to the grid on items such as the types of electrical products used and the duration of use. It should be noted, however, that the number of community samples was low because the study's main subject is communities electrified with off-grid PV systems, and that the data are not sufficient reflection of all communities because the lowest population of those sampled was 1,022 (whereas 91.74% of all communities have a population of less than 1,000). These factors were borne in mind in examination of the results, as follows.

(1) Demand for on-grid electrification among unelectrified households

For the communities that furnished responses for this item in the FGD, the average rate of household electrification was 32% (when the unrealistic responses of 100 and 90% are excluded). Even in districts connected to the grid, it appears that household electrification is being held down by factors such as payment capabilities and physical distribution of compounds.

Table 5.3.5 presents figures for the use rates and hours for electrical products in unelectrified communities, communities connected to the grid, and districts electrified with PV systems. It can be seen that, even in on-grid communities, the main electrical products are lights, radios, and radio cassettes, and that other products are not in widespread use. In addition, there is not a big difference between the communities electrified by on-grid systems and those electrified by off-grid ones in respect of the use duration. This indicates the lack of a major change in the economic structure even in communities connected to the grid in the northern regions.

Table 5.3.5 Use of electrical products in the three northern regions

Appliance owned and in use	Unelectrified			Electrified on grid			Electrified off-grid		
	N	Penetration	Hours of use	N	Penetration	Hours of use	N	Penetration	Hours of use
Small colour tv	4	0%	5	14	7%	3.42	5	1%	2.3
Big colour tv	9	1%	2.9	43	22%	3.95	9	3%	1.9
Black and White tv	17	2%	2.2	21	11%	3.41	23	7%	3.5
VCR	11	1%	3.2	30	15%	2.71	15	4%	2.4
Radio	563	66%	5.9	96	48%	4.52	225	64%	5
Radio cassette player	401	47%	4.2	123	62%	4.35	185	52%	3.7
Small refrigerator	1	0%	6	20	10%	16.2	3	1%	12
Big Refrigerator	0	0%	0	12	6%	15.09	2	1%	8
Small freezer	0	0%	0	6	3%	17.2	0	0%	0
Big Freezer	0	0%	0	5	3%	17	1	0%	24
Cell phone charger	3	0%	24	7	4%	17.14	0	0%	0
Incadescent lights	3	0%	3	107	54%	8.1	8	2%	8
Flourescent lights	2	0%	7.5	50	25%	8.8	60	17%	7.6
Fan	7	1%	2.6	55	28%	5.4	8	2%	2.8
Flash light	453	53%	5.3	91	46%	3.8	328	93%	3.4
Sewing machine	1	0%	0	1	1%	0	0	0%	0
Electric iron	1	0%	0	28	14%	1	4	1%	1
Coil heater	0	0%	0	19	10%	1.6	2	1%	1.2
Table-top single burner cooker	0	0%	0	0	0%	0	0	0%	0
4 burner electric cooker	0	0%	0	0	0%	0	0	0%	0
Total No. of Respondents	859			200			353		

(Source) JICA Study Team

The Study Team analyzed the data for the 156 on-grid households that were actually using power from the grid when the interviews were held. Because information was not available on the times (of day) of electrical product use, the Study Team calculated the average household demand (W) by multiplying the average number of electrical products per household (among all on-grid households) by the capacity, and multiplying the resultant product by a diversity factor (= 0.5). It also calculated the demand in kWh based on the use durations (hours) shown in Table 5.3.6. At 107 W, the average demand was larger than in the case of households electrified with PV systems, due to the use of color TV sets and fans.

Table 5.3.6 On-grid electrification demand among unelectrified households

	TV (colour) – big	VCRR/ VCD	Radio cassette	Radio cassette	Incandescent light	Flourescent light	Fan	Diversity factor	Total Capacity (W)
Capacity (W)	77	13	15	15	40	18	55		
Number	0.29	0.21	0.88	0.88	3.08	0.76	0.46		
Subtotal (W)	22.7	2.7	13.3	13.3	123.3	13.7	25.0	0.5	107.0
Usage hour	3.95	2.71	4.35	4.35	8.1	8.8	5.4	Total demand (kWh)	
Annual Demand (kWh)	32.7	2.6	21.1	21.1	364.6	44.1	49.3	535.6	

(Source) JICA Study Team

Therefore, multiplication of 32% of the total number of households by 107.0W would yield the scale of the demand in the community. In light of the low payment capabilities of unelectrified households in communities with a population of under 1,000, it was decided to adopt a level 80% as high as the 50kWh per month for which the lifeline tariff is applied as the ceiling demand (equivalent to 480kWh per year).

(2) On-grid electrification demand among commercial facilities

Grain mills must be considered demand for on-grid electrification because they each use motive power amounting to 20kW (and 58,4000kWh in operation for eight hours per day). This is a significant point of difference from communities electrified with PV systems. Of the 116 grain mills in communities connected to the grid, 31 (27%) were electrified.

Other commercial facilities (i.e., excluding grain mills) electrified through connection to the grid that were covered by the detailed questionnaire survey categorized 22 in all, but used fewer types of electrical products than households. Properly speaking, demand should be estimated by adding up totals for individual facilities, but there are few (or no) data on the individual level. In response, the Study Team decided not to treat commercial facilities other than grain mills separately and instead to ascertain the overall trend for them.

As was done for households, the Study Team averaged the totals for electrical products used in the various facilities by the number of the latter, and multiplied the result by the diversity factor. This yielded a figure of 195.7W for the average commercial facility (see Table 5.3.7). In this case as well, products with an appearance rate of less than 10% were not taken into account. The level 80% as high as the 50kWh per month for which the lifeline tariff is applied was again adopted as the ceiling demand (equivalent to 480kWh per year) in the case of unelectrified commercial facilities in communities with a population of less than 1,000, as in the case of households.

Table 5.3.7 On-grid electrification demand among commercial facilities

	Capacity (W)	General goods/ drug store	Drinking bar/pito brewing	Tailor/ seamstress	Hair salon/ barber shop	Repair shop	Guest house	Others	Mosuque/ church	Total	Avarage Cap.(W)	Total Cap.(W)	Div. factor	Cap. for commercial (W)
Num. of facilities		3	2	2	4	2	1	3	5	22				
Big freezer	180			1	1			2		4	32.7	391.3	0.5	195.7
Incand. light	40	2	19	1	1			2	4	29	52.7			
Flours. light	18	2	2	2	6		3	2	21	38	31.1			
Fan	55			1	7	1	3	2	25	39	97.5			
Hair dryer	1300				3					3	177.3			

	Big freezer	Incandescent light	Flourrescent light	Fan	Hair dryer	Total demand (kWh)
Capacity (W)	180	40	18	55	750	715.5
Average cap. (W)	32.7	52.7	31.1	97.5	177.3	
Usage hour	17.0	8.1	8.8	5.4	1.00	
Annual Demand (kWh)	202.9	155.8	99.9	192.2	64.7	

(Source) JICA Study Team

The on-grid electrification rate among commercial facilities other than grain mills came to 31%. The scale of the demand in the community was obtained by multiplying the aforementioned average demand by 31%.

(3) On-grid electrification demand among public facilities

In the case of public facilities, policy for electrification of subject facilities ranks alongside actual electrification as a key factor in the preparation of a demand model. The reconsigned study was not able to obtain data on the electrification status of public facilities other than medical ones. The Study Team therefore prepared an electrification model for public facilities in accordance with the following guidelines.

- Educational facilities

  Among primary schools, the reconsigned study found that the electrification rate was only 1.9% in the 12 communities connected to the grid (54 schools in all). It can also be noted that the government is not taking active steps to raise this rate as a matter of policy. As a result, the Study Team decided not to take primary schools into account as demand. As for junior secondary schools, the government is expected to actively execute policy for their electrification, which is anticipated to be on the level of lighting, as in the case of electrification with PV systems.

  To estimate the demand per junior secondary school, the Study Team assumed the installation of eight 18-W fluorescent bulbs and one 77W color TV set, for a total of 221W. Application of the diversity factor (50%) yielded a total facility capacity of 110.5W. The amount of power use was put at 321.2kWh per year on the premise of use of lighting for a duration of four hours a day.

- Medical facilities

  Medical facilities were studied as electrification subjects regardless of their size, because the government has posted electrification of all of them as a policy objective. Based on the results obtained for three facilities in the reconsigned study, the demand (facility capacity) was put at 278.2W per facility. The calculation of the amount of power use assumed a lighting duration of four hours (see Table 5.3.8). For CHIPS compounds, the facility capacity was put half as high at 139.1W.

Table 5.3.8 On-grid electrification demand among medical facilities

(For 3 facilities)	Big clour TV	Big refrigerator	Incandescent light	Flourscent light	Fan	Div. Factor	Total Capacity (W)
Capacity (W)	77	130	40	18	55		
Total number	1	2	16	14	8		
Capacity for 1 facility(W)	25.7	86.7	213.3	84.0	146.7	0.5	278.2
Usage hour	3.95	16.2	4	4	5.4	Total demand (kWh)	
Annual Demand (kWh)	37.0	512.5	311.5	122.6	289.1	1,272.7	

(Source) JICA Study Team

- Other public facilities

As for other types of public facility, the reconsigned survey found that 89.7% of all governmental offices (39 total) had been electrified. The Study Team considered facilities in this category as electrification subjects because their electrification could presumably be promoted as a matter of official policy. The level of electrification (capacity) was put on a par with that for households.

(4) On-grid electrification demand

Table 5.3.9 presents figures for the on-grid electrification demand in unelectrified communities covered by the in-depth survey in the village socioeconomic study. This demand is higher than the PV electrification demand.

Table 5.3.9 On-grid electrification demand in unelectrified communities

Community name	District Name	Region Name	Num. of Compounds	Demand HH (107@32%) (W)	Num. of grain milling	Demand for grain milling (20000@27%) (W)	Num. of other business entitiy	Demand for business ent. (195.7@31%) (W)	Total demand for business ent. (W)	Junior secondary school	Chips compound	Clinic	Health center/health post	Governmental office	Demand for public facilities (W) ＊	Total demand (W)
Bimbini	West Mamprusi	Northern	14	479	0	0	7	425	425	0	0	0	0	0	0	904
Lampur	West/Central Gonja	Northern	49	1,678	0	0	3	182	182	0	0	0	0	0	0	1,860
Langatire	West/Central Gonja	Northern	31	1,061	1	5,400	4	243	5,643	0	0	0	0	0	0	6,704
Kakale	West/Central Gonja	Northern	30	1,027	1	5,400	6	364	5,764	0	0	0	0	0	0	6,791
Bethlehem	West/Central Gonja	Northern	35	1,198	2	10,800	6	364	11,164	0	0	0	0	0	0	12,362
Kafulwurape	West/Central Gonja	Northern	83	2,842	1	5,400	3	182	5,582	0	0	0	0	0	0	8,424
Butei	West/Central Gonja	Northern	43	1,472	1	5,400	0	0	5,400	0	0	0	0	0	0	6,872
Kananto	West/Central Gonja	Northern	50	1,712	1	5,400	12	728	6,128	0	0	0	0	0	0	7,840
Kudani	Saboba/Chereponi	Northern	87	2,979	6	32,400	13	789	33,189	0	0	0	0	0	0	36,168
Kokope	West/Central Gonja	Northern	81	2,773	3	16,200	8	485	16,685	0	0	0	0	0	0	19,459
Yachadom	Zabzugu/Tatale	Northern	109	3,732	12	64,800	18	1,092	65,892	1	0	0	0	1	218	69,842
Kpani	Saboba/Chereponi	Northern	83	2,842	1	5,400	7	425	5,825	0	0	0	0	0	0	8,667
Sheini	Zabzugu/Tatale	Northern	130	4,451	6	32,400	22	1,335	33,735	1	0	0	0	0	111	38,296
Wenchiki	Saboba/Chereponi	Northern	168	5,752	4	21,600	13	789	22,389	1	0	0	1	1	496	28,637
Kandin	Zabzugu/Tatale	Northern	170	5,821	0	0	47	2,851	2,851	1	0	0	1	0	389	9,061
Kulkpaligu	Zabzugu/Tatale	Northern	173	5,924	5	27,000	18	1,092	28,092	1	0	0	1	0	389	34,404
Kpabuso	West/Central Gonja	Northern	378	12,943	7	37,800	27	1,638	39,438	1	0	0	0	1	218	52,598
Nahuyili	Zabzugu/Tatale	Northern	135	4,622	4	21,600	19	1,153	22,753	0	0	0	0	0	0	27,375
Wapuli	Saboba/Chereponi	Northern	291	9,964	5	27,000	35	2,123	29,123	1	0	0	1	0	389	39,476
Tamaligu	Gushiegu/Karaga	Northern	150	5,136	3	16,200	29	1,759	17,959	0	0	0	0	0	0	23,095
Sheri	West/Central Gonja	Northern	207	7,088	4	21,600	8	485	22,085	1	0	0	0	0	111	29,284
Busunu	West/Central Gonja	Northern	576	19,722	2	10,800	25	1,517	12,317	1	0	0	1	0	389	32,428
Mandari	Bole	Northern	356	12,189	4	21,600	37	2,245	23,845	1	0	0	0	0	111	36,145
Duu	West Mamprusi	Northern	57	1,952	7	37,800	25	1,517	39,317	1	0	1	0	0	389	41,657
Kusawgu	West/Central Gonja	Northern	175	5,992	10	54,000	31	1,881	55,881	1	0	0	1	0	389	62,261
Mpaha	West/Central Gonja	Northern	711	24,345	0	0	32	1,941	1,941	1	0	0	1	1	496	26,782
Kpasenkpe	West Mamprusi	Northern	498	17,052	8	43,200	32	1,941	45,141	1	1	0	1	0	528	62,721
Vortkom	Bawku East	Upper East	18	616	1	5,400	0	0	5,400	0	0	0	0	0	0	6,016
Kanjam	Bawku East	Upper East	52	1,780	1	5,400	19	1,153	6,553	0	0	0	0	0	0	8,333
Tanga Natinga	Bawku East	Upper East	78	2,671	3	16,200	76	4,611	20,811	1	0	1	0	1	496	23,977
Sumaduri	Garu Tempane	Upper East	200	6,848	3	16,200	20	1,213	17,413	0	0	0	1	0	278	24,540
Zongoyire	Bawku East	Upper East	33	1,130	4	21,600	25	1,517	23,117	0	0	0	0	0	0	24,247
Goriga	Bawku East	Upper East	105	3,595	3	16,200	165	10,010	26,210	0	0	1	0	0	278	30,083
Apodabogo	Garu Tempane	Upper East	228	7,807	5	27,000	18	1,092	28,092	0	0	0	0	0	0	35,899
Duuri	Garu Tempane	Upper East	122	4,177	7	37,800	32	1,941	39,741	0	0	0	0	0	0	43,919
Bugri Natinga	Garu Tempane	Upper East	183	6,266	15	81,000	130	7,887	88,887	2	0	2	0	1	884	96,037
Windnaba	Garu Tempane	Upper East	160	5,478	5	27,000	61	3,701	30,701	0	0	1	0	0	278	36,457
Bas Yonde Central	Garu Tempane	Upper East	875	29,960	8	43,200	82	4,975	48,175	0	0	1	0	1	385	78,520
Kongo	Jirapa/Nandom	Upper West	19	651	1	5,400	10	607	6,007	0	0	0	0	0	0	6,657
Gbelle	Sissala	Upper West	17	582	1	5,400	12	728	6,128	0	0	0	0	0	0	6,710
Banu	Sissala	Upper West	36	1,233	2	10,800	1	61	10,861	1	0	0	0	0	111	12,204
Wasai	Sissala	Upper West	21	719	2	10,800	10	607	11,407	0	0	0	0	0	0	12,126
Wuru	Sissala	Upper West	32	1,096	1	5,400	0	0	5,400	0	0	0	0	0	0	6,496
Puzene	Sissala	Upper West	30	1,027	3	16,200	2	121	16,321	0	0	0	0	0	0	17,349
Bichemboi	Sissala	Upper West	56	1,917	2	10,800	7	425	11,225	1	0	0	0	0	111	13,253
Duwie	Sissala	Upper West	75	2,568	1	5,400	24	1,456	6,856	0	0	0	0	0	0	9,424
Kogle	Jirapa/Nandom	Upper West	92	3,150	1	5,400	31	1,881	7,281	1	0	0	0	0	111	10,541
Ketuo	Jirapa/Nandom	Upper West	102	3,492	2	10,800	54	3,276	14,076	1	0	0	1	0	389	17,957
Dasima	Sissala	Upper West	189	6,471	3	16,200	39	2,366	18,566	1	0	0	0	0	111	25,148
Kulkpong	Wa	Upper West	94	3,219	3	16,200	23	1,395	17,595	0	1	0	0	0	139	20,953
Buo	Sissala	Upper West	90	3,082	4	21,600	27	1,638	23,238	1	1	0	0	0	250	26,569

＊Demand for public facilities: 110.5W@JSS + 139.1W@CHIPS compound + 278.2W@Clinic + 278.2W@Health center + 107.0W@Governmental office

(Source) JICA Study Team

5.3.5 Calculation from population statistics

Demand can be estimated through the procedure outlined in the previous section when the number of subject public facilities, commercial facilities, and households can be obtained through a village socioeconomic study. Ordinarily, however, such data are not fully available at the stage of planning formulation.

This section therefore presents the procedure for calculation of the approximate demand from population statistics. It should be emphasized that the procedure described in this section is to be used solely for getting a rough grasp of the demand for PV systems in communities; for actual electrification, it is necessary to determine the presence or absence and number of facilities. In order to grasp the trend by the simplest possible expression, the correlation with population may be expressed by means of a linear function passing through the origin.

For this purpose, the Study Team made an analysis of 30 communities for which more reliable data were obtained through confirmation of the number of facilities in the FGD. The data were compiled separately for each region in consideration of differences of community structure. Table 5.3.10 presents data for population, number of households, number of commercial facilities, and number of facilities that are candidates for electrification with PV systems in the communities in each region.

Table 5.3.10 Population and number of households, commercial facilities, and public facilities

Community name	Region Name	District Name	Total Population	Num. of Compounds	Total business entity	Junior secondary school	Chips compound	Clinic	Health center/ health post	Total health facility	Government al office
Bimbini	Northern	West Mamprusi	138	14	7	0	0	0	0	0	0
Bethlehem	Northern	West/Central Gonja	409	35	8	0	0	0	0	0	0
Kananto	Northern	West/Central Gonja	506	50	13	0	0	0	0	0	0
Kpenteng	Northern	Bunkpurugu Yunyoo	776	110	108	1	0	0	0	0	0
Mangol	Northern	Bunkpurugu Yunyoo	900	100	136	0	0	0	1	1	0
Demon	Northern	Saboba/Chereponi	1022	96	53	1	0	0	0	0	1
Sabare	Northern	Zabzugu/Tatale	1078	143	26	1	1	0	0	1	0
Wenchiki	Northern	Saboba/Chereponi	1131	168	15	1	0	0	1	1	1
Kandin	Northern	Zabzugu/Tatale	1142	170	47	1	0	0	1	1	0
Kpabuso	Northern	West/Central Gonja	1443	378	34	1	0	0	0	0	1
Binde	Northern	Bunkpurugu Yunyoo	1579	162	196	1	0	0	1	1	6
Jimbale	Northern	Bunkpurugu Yunyoo	1590	137	102	1	0	1	0	1	0
Tamaligu	Northern	Gushiegu/Karaga	1720	150	32	0	0	0	0	0	0
Kusawgu	Northern	West/Central Gonja	4848	175	41	1	0	0	1	1	0
Tatale	Northern	Zabzugu/Tatale	6100	526	10	1	0	0	1	1	1
Yapei	Northern	West/Central Gonja	6524	640	80	2	0	0	1	1	1
Bunkpurugu	Northern	Bunkpurugu Yunyoo	12000	700	1038	3	0	2	1	3	5
Kambatiak	Northern	Bunkpurugu Yunyoo	22008	621	317	1	0	1	0	1	0
Vortkom	Upper East	Bawku East	214	18	1	0	0	0	0	0	0
Goriga	Upper East	Bawku East	1198	105	168	0	0	1	0	1	0
Sarabogo	Upper East	Bawku East	2308	199	5	0	1	0	0	1	0
Bongo	Upper East	Bongo	4787	413	323	3	0	2	0	2	0
Pusiga	Upper East	Garu Tempane	6823	589	187	3	0	0	1	1	2
Paga	Upper East	Kasena Nankane	7819	675	244	1	0	0	0	0	0
Kongo	Upper West	Jirapa/Nandom	223	19	11	0	0	0	0	0	0
Kogle	Upper West	Jirapa/Nandom	839	92	32	1	0	0	0	0	0
Buo	Upper West	Sissala	2100	90	31	1	1	0	0	1	0
Nadowli	Upper West	Jirapa/Nandom	3882	437	94	3	0	0	1	1	13
Fielmo	Upper West	Sissala	6074	398	88	2	0	0	1	1	1
Wechau	Upper West	Wa	13341	1340	86	1	0	0	1	1	0

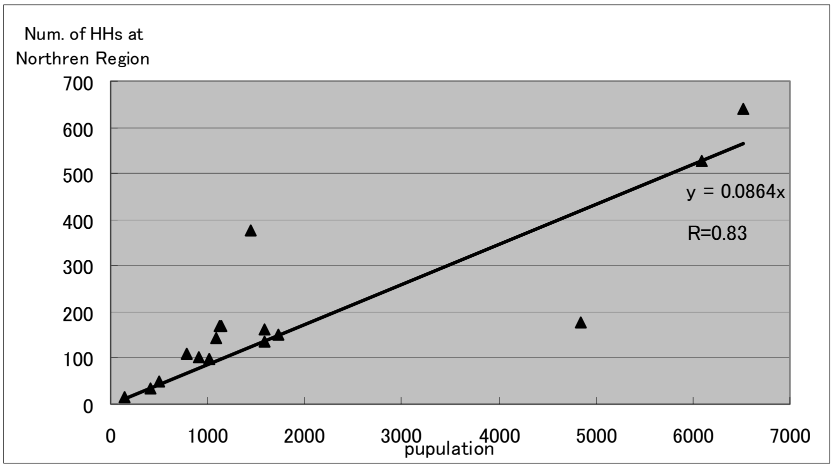
(Source) JICA Study Team

(1) Population and number of households

The data available at present do not exhibit a significant difference among the regions in respect of population and number of households. The number of households was consequently put at 9% (0.09) of population (excluding data for Kambatiak and Bunkpurugu).

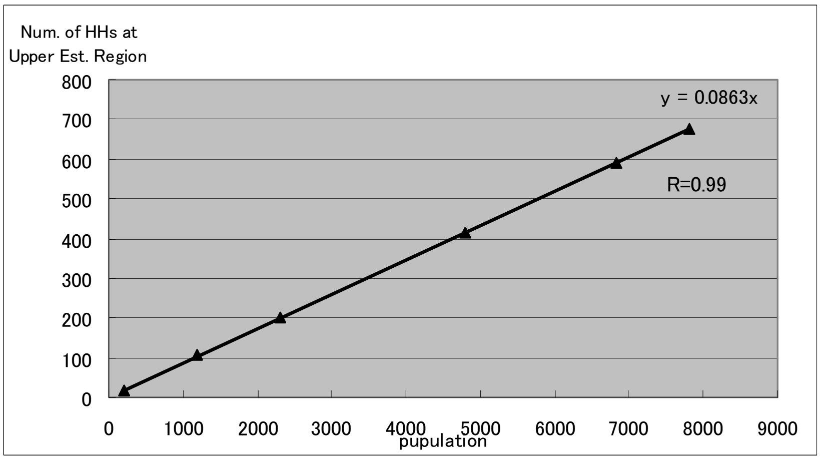
$N_H = 0.09 \times P$ (here, N_H indicates the number of households, and P, the community population)

Figures 5.3.5 - 5.3.7 show the population and number of households in each region.



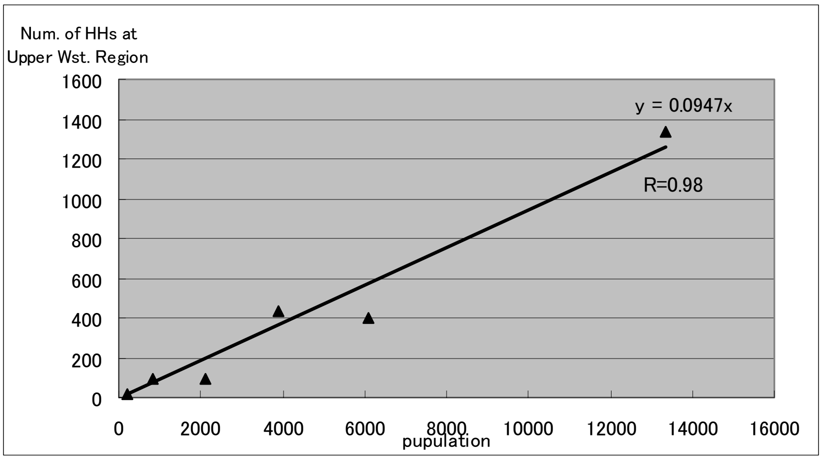
(Source) JICA Study Team

Figure 5.3.5 Population and number of households (Northern Region)



(Source) JICA Study Team

Figure 5.3.6 Population and number of households (Upper East Region)



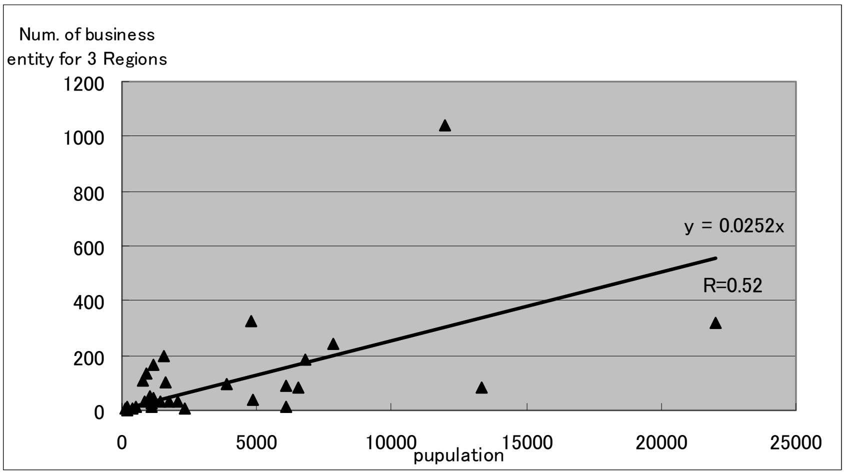
(Source) JICA Study Team

Figure 5.3.7 Population and number of households (Upper West Region)

(2) Population and number of commercial facilities

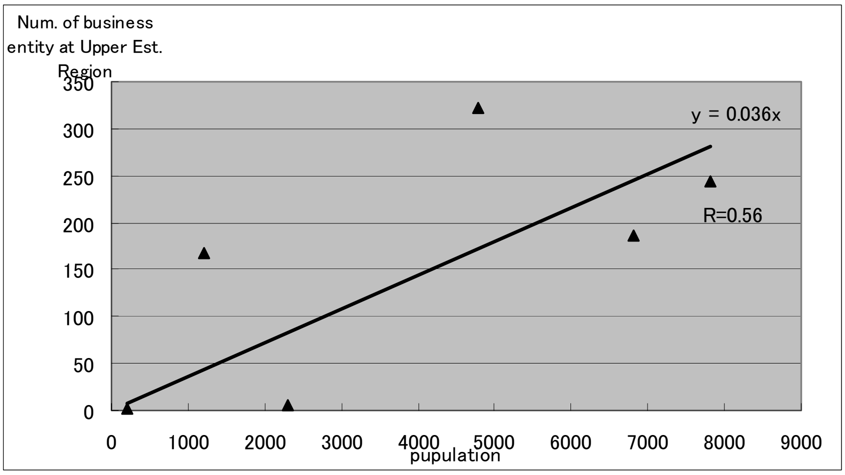
As for households, there was also no major difference among the three regions in respect of the correlation between population and the number of commercial facilities. The number of commercial facilities was put at 2.5% (0.025) of the population. Figure 5.3.8 shows the correlation between population and the number of commercial facilities in the three northern regions taken together, and Figure 5.3.9 - 5.3.11, that in each region taken separately.

$N_B = 0.025 \times P$ (here N_B indicates the number of commercial facilities, and P, community population)



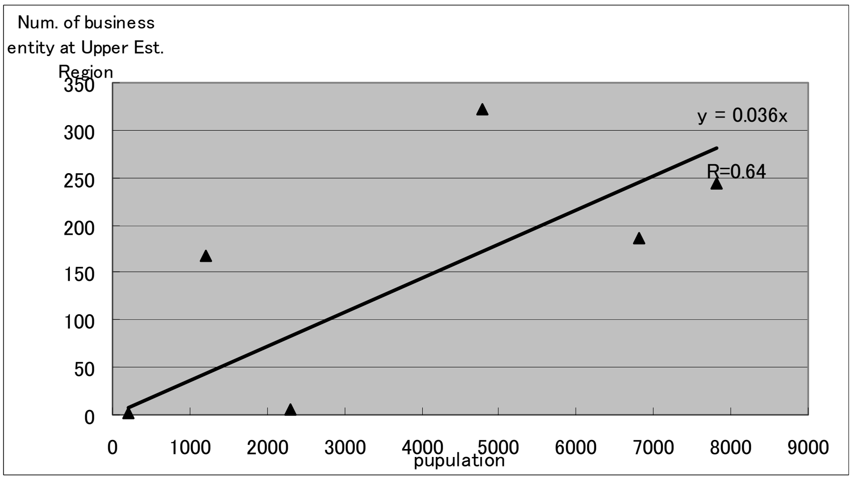
(Source) JICA Study Team

Figure 5.3.8 Population and number of commercial facilities (three northern regions)



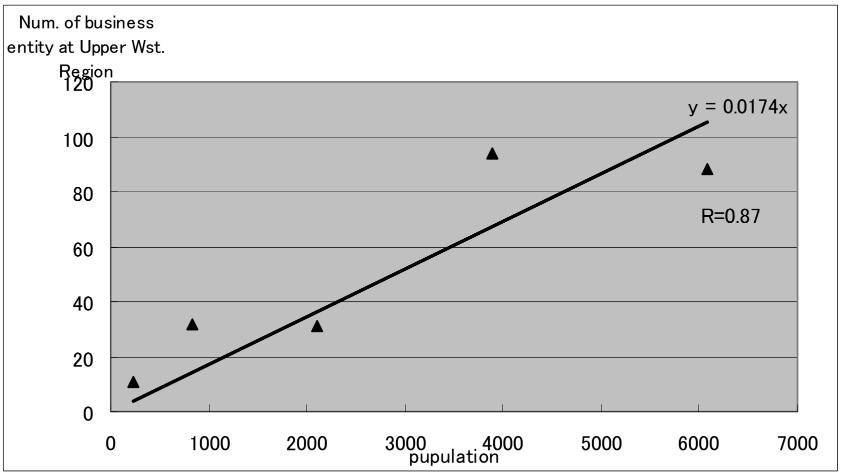
(Source) JICA Study Team

Figure 5.3.9 Population and number of commercial facilities (Northern Region)



(Source) JICA Study Team

Figure 5.3.10 Population and number of commercial facilities (Upper East Region)

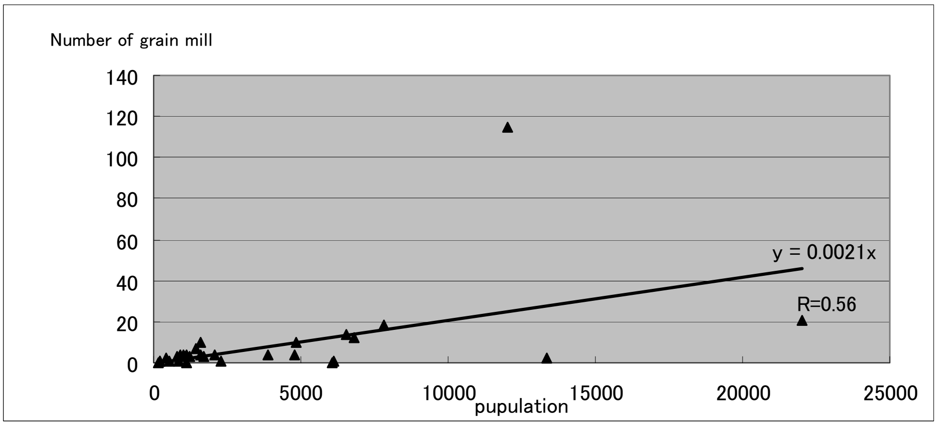


(Source) JICA Study Team

Figure 5.3.11 Population and number of commercial facilities (Upper West Region)

The number of communities with grain mills was found by multiplying the population by a factor of 0.0021. Figure 5.3.12 shows the correlation between population and the number of grain mills.

N_G= 0.0021 x P (here N_G indicates the number of grain mills, and P, community population)



(Source) JICA Study Team

Figure 5.3.12 Population and number of grain mills (three northern regions)

(3) Population and number of public facilities

- Junior secondary schools: one in communities with a population of 1,000 - 5,000, and two in those with a population of more than 5,000.
- Medical facilities: one in communities with a population of over 1,000; these facilities were all assumed to be health centers or clinics due to the appearance of few CHIPS compounds in the communities covered by the socioeconomic study.
- Other public facilities: one in communities with a population of over 5,000 (the number is hard

to estimate from the data, but this assumption was made considering the presence of police stations in district capitals and major cities).

5.3.6 Summary of the demand forecast results

Table 5.3.11 presents totals for the results of the forecast by the method described above (when the number of subject facilities was clear). Table 5.3.12 outlines the procedure for estimating the number of facilities from population.

Table 5.3.11 Demand forecasting procedure (when the number of facilities is clear)

Facilities	Electrification with PV systems	Electrification with on-grid systems
Households	25W x number of households x 20%	107.0W × number of households ×32%
Commercial facilities	50W x number of facilities x 30% (25%BCS, 5%SHS)	195.7W× number of facilities ×31%
Grain mills	NA	20,000W× number of facilities ×27%
Junior secondary schools	250W x number of facilities	110.5W× number of facilities
Clinics and health centers	400W x number of facilities (including refrigerators and wireless systems)	278.2W× number of facilities
CHIPS compounds	100W x number of facilities	139.1W× number of facilities
Offices	100W× number of facilities	107.0W× number of facilities
Staff houses	100W x 3 x (number of clinics and health centers) + 100W x 1 x (number of CHIPS compounds) + 100W x 3 x (number of junior secondary schools) + 100W x 1 (offices)	NA

(Source) JICA Study Team

Table 5.3.12 Procedure for estimating the number of facilities from population

Facilities	Procedure for estimating the number (P = population)
Households	$N_H = 0.09 \times P$
Commercial facilities	$N_B = 0.025 \times P$
Grain mills	$N_G = 0.0021 \times P$
Junior secondary schools	One in communities with a population of 1,000 - 5,000, and two for those with one of over 5,000
Clinics and health centers	One for communities with a population of over 1,000
CHIPS compounds	NA
Offices	One in communities with a population of over 5,000

(Source) JICA Study Team

5.4 Demarcation of the target areas for on- and off-grid electirification

5.4.1 On-grid approach

(1) Perspectives on selection of candidate areas for on-grid electrification

In Ghana, RE is proceeding in the context of the SHEP. The SHEP itself is more of a selection of sites for implementation than a plan, and it would not be going too far to say that Ghana in effect lacks a master plan for RE. In light of this situation, the Study Team made a trial selection of on-grid electrification from three approaches, as follows.

1) Economic approach

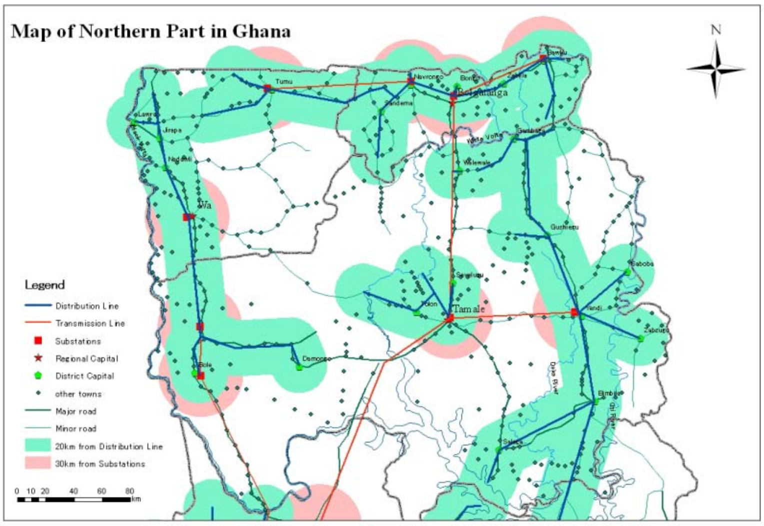
This approach lies in comparison of on-grid and off-grid electrification costs, and selection of the sites where the former is lower. Because the on-grid electrification cost varies greatly with the community location and demand, it would, strictly speaking, be necessary to make the calculation on the basis of the actual on-grid electrification plan. At present, however, no such plan exists. The Study Team therefore decided to calculate the electrification cost through a study utilizing the simple distribution line model and standard community model for comparison of economic merit. It also decided to make use of the following two other approaches in a supplemental manner as needed to estimate the on-grid electrification areas.

2) Policy approach

In SHEP policy, candidate areas for on-grid electrification must be located no more than 20km from an existing distribution line.

3) Physical approach

Considering physical factors such as the thickness of ordinary cable, current, and voltage drop, it was assumed that candidate areas for on-grid electrification would have to be located within a 50-km radius of a 33-kV distribution substation or a 30km radius of an 11kV substation. Figure 5.4.1 shows the scope of the policy and physical approaches.



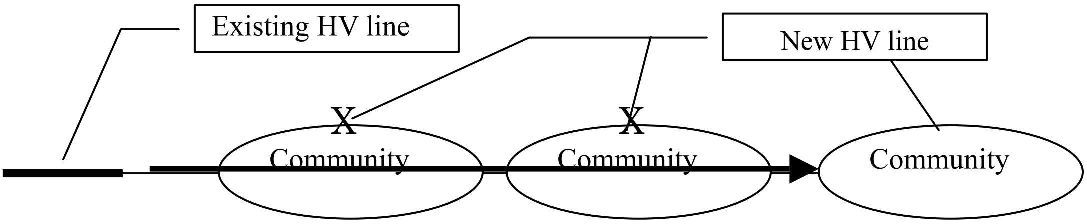
(Source) JICA Study Team

Figure 5.4.1 Candidate on-grid electrification areas based on policy and physical approaches

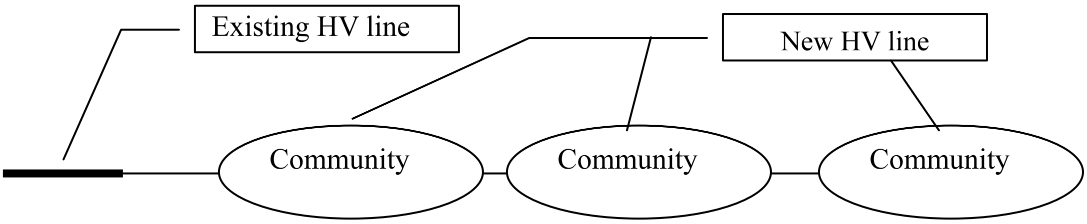
(2) Method of calculating on-grid electrification costs

Regarding on-grid electrification, the Study Team considered two model cases. One is to electrify only the target community like SHEP (i.e., other communities on the route will not be electrified); the other is to electrify all communities on the route (see Figure 5.4.2).

All communities on the route can share the costs of high-voltage (HV) distribution line equally for the latter case, while only the target community must pay all the electrification costs. Therefore it will be possible to reduce cost burden for "the case of electrifying all communities on the route" to increase beneficial lies compared to "the case of no other communities on the route".



In the case that there are no other communities on the route (SHEP)



In the case that all communities on the route are electrified

(Source) JICA Study Team

Figure 5.4.2 On-grid electrification model

1) Initial cost

(a) Distribution line construction cost (material cost, transportation cost, construction cost, etc.)

There are two major categories of construction cost: that which rises along with extension of distribution lines, like that for high-voltage distribution facilities (HV conductors, supports, etc.), and that which rises along with the scale of the community, like that for low-voltage distribution facilities (distribution transformers, LV conductors, supports, etc.). The Study Team made calculations of each and converted the results into annual cost.

(b) Running cost

Maintenance cost, transmission and distribution loss, fuel cost, and generation and transmission cost

(3) Specific calculation method

The Study Team made a calculation of the electrification cost in a standard community in each of the three northern regions, based on the costs in the three demand patterns in the standard model and in accordance with the distribution estimated from the results of the village socioeconomic study. Table 5.4.1 shows the makeup of the standard demand model, and Table 5.4.2, the premises of the cost calculation.

Table 5.4.1 Standard demand model (the bold enclosure indicates on-grid electrification)

	Share of the total number of communities	Off-grid	On-grid
Demand pattern 1 (Population = 500)	91.74% (communities with a population of less than 1,000)	* Households: 25 W x 10 households (BCS use); 23 kWh/year x 10 households) * Commercial facilities: 50 W x 3 facilities (BCS use); 40 kWh/year x 3 facilities * Grain mills: none * Clinics: none * JSS: none * Offices: none * Staff houses: none	* Households: 107 W x 10 households; 480 kWh/year x 10 households * Commercial facilities: 50 W x 3 facilities (BCS use); 40 kWh/year x 3 facilities * Grain mills: none * Clinics: none * JSS: none * Offices: none * Staff houses: none * 50-kVA transformers: 1
Demand pattern 2 (Population = 2,000)	- 7.55% (communities with a population of 1,000 - 4,999)	* Households: 25 W x 40 households (BCS use); 23 kWh/year x 40 households) * Commercial facilities: 50 W x 13 facilities (BCS use); 40 kWh/year x 13 facilities - 50 W x 3 facilities (SHS); 56 kWh/year x 3 facilities * Grain mills: none * Clinics: 400 W x 1 * JSS: 250 W x 1; 277 kWh/year x 1 facility * Offices: 100 W x 1; 100 kWh/year x facility * Staff houses: 100 W x 7; 106 kWh/year x 7 facilities	* Households: 107 W x 60 households; 535.6 kWh/year x 60 households) * Commercial facilities: 195.7 W x 15 facilities; 715.5 kWh/year x 15 facilities * Grain mills: 20,000 W x 1; 58,400 kWh/year x 1 * Clinics: 280 W x 1; 1,272 kWh/year x 1 * JSS: 110.5 W x 1; 321.3 kWh/year x 1 * Offices: 107 W x 1; 535.6 kWh/year x 1 * Staff houses: none * 50-kVA transformers: 1
Demand pattern 3 (Population = 5,000)	- 0.71% (communities with a population of 5,000 or more)	* Households: 25 W x 100 households (BCS use); 23 kWh/year x 100 households) * Commercial facilities: 50 W x 31 facilities (BCS use); 40 kWh/year x 31 facilities - 50 W x 6 facilities (SHS); 56 kWh/year x 6 facilities * Grain mills: none * Clinics: 400 W x 1; 381 kWh/year x 1 facility * JSS: 250 W x 2; 277 kWh/year x 2 facilities * Offices: 100 W x 1; 100 kWh/year x 1 facility * Staff houses: 100 W x 10; 106 kWh/year x 10 facilities	* Households: 107 W x 150 households; 535.6 kWh/year x 150 households) * Commercial facilities: 195.7 W x 38 facilities; 715.5 kWh/year x 38 facilities * Grain mills: 20,000 W x 2 facilities; 58,400 kWh/year x 2 * Clinics: 280 W x 1; 1,272.7 kWh/year x 1 * JSS: 110.5 W x 2; 321.3 kWh/year x 2 * Offices: 107 W x 1; 535.6 kWh/year x 1 * Staff houses: none * 50-kVA transformers: 2

** It was assumed that the number of transformers would increase by one every 50 kW (50,000 W) of capacity.

(Source) JICA Study Team

Table 5.4.2 Premises of the cost calculation

Service life	30 years
Maintenance cost	2% of the initial cost
Loss rate	12%
Interest rate	8%
Exchange rate	1 dollar = 9,000 cedi

(Source) JICA Study Team

1) Initial cost

The Study Team calculated the initial cost for high- and low-voltage distribution lines based on actual costs at the NED.

Table 5.4.3 Distribution line costs at the NED

(Unit: dollars)

	Materials	Personnel expenses	Total
High-voltage lines	11,649	1,096	12,745
Low-voltage lines	12,190	595	12,785
50-kVA transformers	7,993	195	8,188

(Source) NED

(a) High-voltage distribution line cost

Table 5.4.4 shows the cost (C) of high-voltage distribution facilities that would have to be shared by the communities on the termini of the lines in the case of the above model.

Table 5.4.4 Cost to be shared by terminal communities

Total number of communities electrified per feeder	1	2	3	4	5	6	7	8	9	10
High-voltage distribution line cost to be shared by terminal communities	C_0L	$1.5C_0L$	$1.83C_0L$	$2.08C_0L$	$2.28C_0L$	$2.45C_0L$	$2.59C_0L$	$2.72C_0L$	$2.83C_0L$	$2.93C_0L$

(Note) Co: cost of construction of high-voltage distribution lines per kilometer (12,745 dollars)

L: average distance between communities (see Table 5.4.5)

(Source) JICA Study Team

Approximation of the relationship between the total number of communities electrified and Ch (the high-voltage distribution line cost to be shared by terminal communities) in Table 5.4.4 may be expressed by the following equation.

$$Ch = C_0 L \times (0.934 \times \mathrm{Ln}(N) + 0.8158)$$

Table 5.4.5 shows the results of an estimate of the average distance between communities in each region based on the regional area and number of communities.

Table 5.4.5 Average distance between communities in the northern regions

Region	Average distance between communities (L)
Northern	6.05km
Upper East	2.66km
Upper West	5.47km
Average	5.14km

(Source) JICA Study Team

(b) Low-voltage distribution line cost

The Study Team calculated the cost of transformers on the assumption that it would require a 50 meter low-voltage distribution line (including the service line) to supply electricity to a single household. The low-voltage distribution line cost (C1) may be expressed by the following formula.

C1 = (50* number of households electrified/1,000) *12,785 + 8,188* number of transformers

(c) Conversion into annualized cost

Applying the interest rate and service life figures used in Table 5.4.2, the annualized initial cost (Ci) is as follows.

Ci = (Ch + C1) *annualized cost rate (30 years: 0.088827)

2) Running cost

(a) Maintenance cost

The maintenance cost (Cm) is as follows assuming that it is 2% of the initial cost.

Cm = (Ch + C1) *2%

(b) Transmission and distribution line loss

Assuming that it occupies 12% of the technical loss, the transmission and distribution line loss (Cs) is as follows.

Cs = amount of power loss *0.046 dollars/kWh

(c) Fuel cost and generation/transmission cost

The fuel and generation/transmission cost (Cb) was calculated by the following equation, based on the figure of 0.046 dollars per kWh derived from the VRA income from power sales to the NED in fiscal 2003.

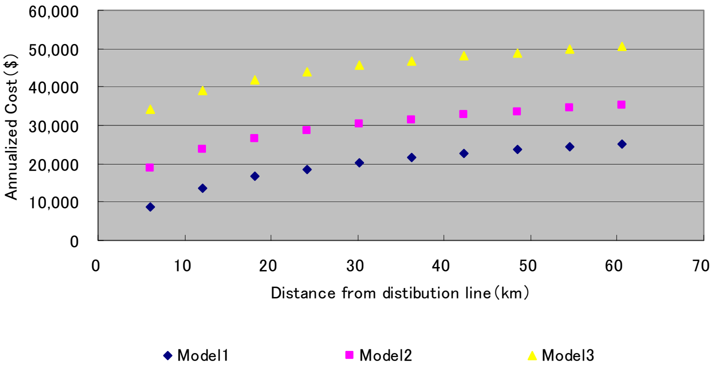
Cb = amount of power sales *0.046 dollars/kWh

3) On-grid lifecycle cost

Based on the results above, the life cycle cost of on-grid electrification may be expressed as follows.

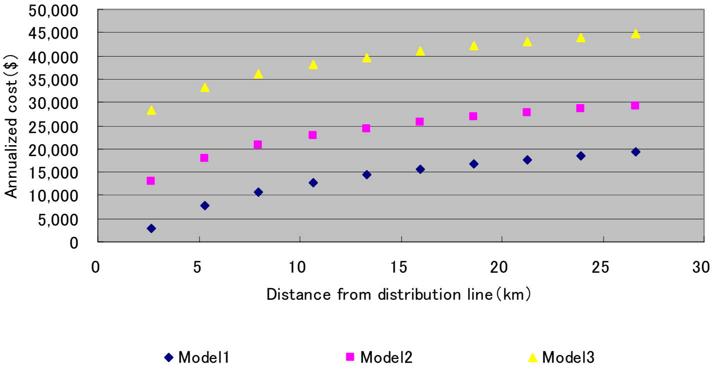
$$C = Ci + Cm + Cs + Cb$$

Figures 5.4.3 - 5.4.5 graph the results for the three northern regions.



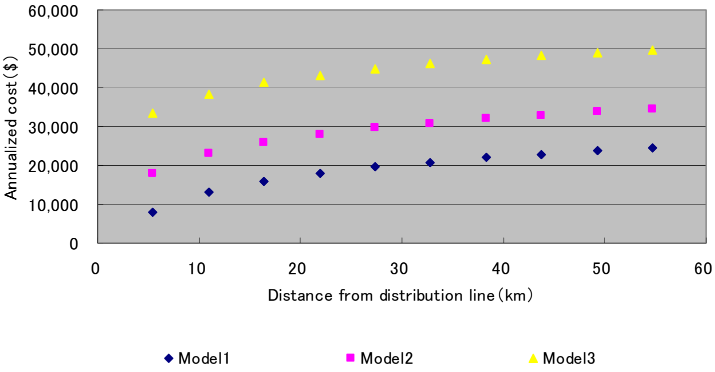
(Source) JICA Study Team

Figure 5.4.3 Annualized cost of on-grid electrification in the Northern Region



(Source) JICA Study Team

Figure 5.4.4 Annualized cost of on-grid electrification in the Upper East Region



(Source) JICA Study Team

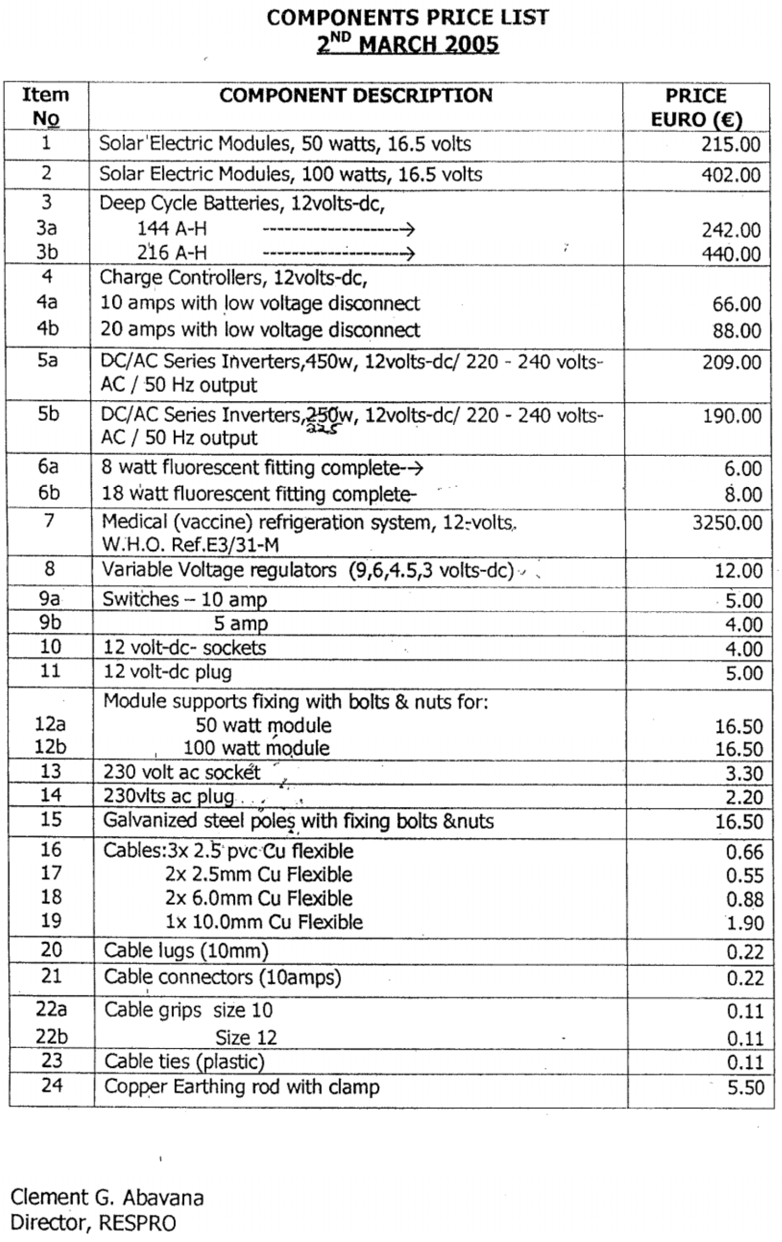
Figure 5.4.5 Annualized cost of on-grid electrification in the Upper West Region

5.4.2 Off-grid approach

(1) PV equipment prices

At present, PV equipment is not sold in the open market; specified PV system enterprises sell them directly to the customers. Equipment prices are set with reference to the specific customer and case. The enterprises were reluctant to displose their prices for this study. Be that as it may, many PV systems have been installed in Ghana, and price gaps between suppliers are apparently being diminished. Table 5.4.6 presents PV equipment prices of the RESPRO.

Table 5.4.6 PV equipment prices (RESPRO)



COMPONENTS PRICE LIST
2ND MARCH 2005

Item No	COMPONENT DESCRIPTION	PRICE EURO (€)
1	Solar Electric Modules, 50 watts, 16.5 volts	215.00
2	Solar Electric Modules, 100 watts, 16.5 volts	402.00
3	Deep Cycle Batteries, 12volts-dc,	
3a	144 A-H -------------------→	242.00
3b	216 A-H --------------------→	440.00
4	Charge Controllers, 12volts-dc,	
4a	10 amps with low voltage disconnect	66.00
4b	20 amps with low voltage disconnect	88.00
5a	DC/AC Series Inverters,450w, 12volts-dc/ 220 - 240 volts-AC / 50 Hz output	209.00
5b	DC/AC Series Inverters,250w 225, 12volts-dc/ 220 - 240 volts-AC / 50 Hz output	190.00
6a	8 watt fluorescent fitting complete--→	6.00
6b	18 watt fluorescent fitting complete-	8.00
7	Medical (vaccine) refrigeration system, 12-volts, W.H.O. Ref.E3/31-M	3250.00
8	Variable Voltage regulators (9,6,4.5,3 volts-dc)	12.00
9a	Switches – 10 amp	5.00
9b	5 amp	4.00
10	12 volt-dc- sockets	4.00
11	12 volt-dc plug	5.00
	Module supports fixing with bolts & nuts for:	
12a	50 watt module	16.50
12b	100 watt module	16.50
13	230 volt ac socket	3.30
14	230vlts ac plug	2.20
15	Galvanized steel poles with fixing bolts &nuts	16.50
16	Cables:3x 2.5 pvc Cu flexible	0.66
17	2x 2.5mm Cu Flexible	0.55
18	2x 6.0mm Cu Flexible	0.88
19	1x 10.0mm Cu Flexible	1.90
20	Cable lugs (10mm)	0.22
21	Cable connectors (10amps)	0.22
22a	Cable grips size 10	0.11
22b	Size 12	0.11
23	Cable ties (plastic)	0.11
24	Copper Earthing rod with clamp	5.50

Clement G. Abavana
Director, RESPRO

(Source) RESPRO

Table 5.4.7 shows examples of PV equipment prices in Japan. It can be seen that the prices in Ghana are about 60% as high as those in Japan.

Table 5.4.7 PV equipment prices in Japan

Item	Capacity	Price (YEN)	Price (US $)
PV Module	55W	47,400	431
	110W	115,000	1,045
Charge controller DC12V	10A	15,000	136
	20A	26,000	236
	40A	39,800	362
	60A	49,800	453
DC/AC Inverter DC12V-AC100V	250W	39,000	355
	600W	67,500	614
Deep cycle battery liquid type	65Ah	29,200	265
	100Ah	35,000	318
	145Ah	54,900	499
	160Ah	62,400	567
Deep cycle battery sealed type	65Ah	38,900	354
	100Ah	48,400	440
	150Ah	68,800	625

(Source) JICA Study Team

Some enterprises in Ghana have standardized their systems and sell them in the form of kits complete with all necessary items except the indoor wiring. Figure 5.4.6 is a photo of an SHS and street light kit. Table 5.4.8 shows the prices for a standard PV system kit. An SHS with a capacity of 100 Wh/day (equivalent to a PV panel output of 50 W) is 885 dollars.

(At center: street light system At right: SHS)

(Source) JICA Study Team

Figure 5.4.6 PV system example

Table 5.4.8 PV standard system prices

System	Price (US $)	note
100Wh／day SHS system	660	Contain to 25W PV Module DC system
200Wh／day SHS system	885	Contain to 50W PV Module DC system
400Wh／day SHS system	1,335	Contain to 100W PV Module DC system
Street light system	1,200	Automatic On-Off

(Source) JICA Study Team

Ordinarily, deep-cycle batteries are used with PV systems. These batteries carry a high price and are hard to obtain because they are not handled by regular battery stores. In some cases, PV system and BCS users instead utilize automobile batteries, which are not exactly suited to PV systems due to their shallow discharge depth and short life. In light of their low price (about one-third as high as that of deep-cycle batteries) and ready availability, though, they are thought to be effective for use in the transitional period before widespread PV system diffusion. Table 5.4.9 shows battery prices in Ghana.

Table 5.4.9 Battery prices

Deep cycle battery		Auto motive battery (in Accra)		
Capacity	US $	Capacity	Cedi	US $
12V 60Ah	94.00	12V 55Ah	380,000	42.22
12V 100Ah	121.00	12V 66Ah	400,000	44.44
12V 102Ah	152.00	12V 77Ah	450,000	50.00
12V 105Ah	158.00	12V 88Ah	520,000	57.78
12V 170Ah	254.10	12V 120Ah	750,000	83.33
12V 250Ah	375.10	12V 150Ah	950,000	105.56

(Note) $1 = 9,000 Cedi

(Sourc) JICA Study Team

(2) PV system models

Calculation of the cost of electrification by means of off-grid PV systems requires an estimate of the subject facilities and modeling of the systems based on the demand associated with those facilities. The Study Team performed such modeling on the assumption of the following subject facilities: SHS1 households (with a low demand equivalent to 50W), SHS2 households (with a medium demand equivalent to 100W), governmental offices, clinics, junior secondary schools, BCS households (with a demand equivalent to 25W), and BCS stores (with a demand equivalent to 50W). Table 5.4.10 shows the estimated (forecast) electricity demand for each type of subject facility.

Table 5.4.10 Estimated electricity demand for each type of subject facility

Facility	Electrical products	Power requirement W	Number	Number of hours of use h	Power consumption Wh
SHS1 (50W equivalent; commercial facilities)	Fluorescent lights	8	2	4	64
	B/W TV set	30	1	2	60
	radio-cassette player	15	1	2	30
				Total	154
SHS2 (100W equivalent; staff houses)	Fluorescent lights	8	5	4	160
	B/W TV set	30	1	2	60
	radio-cassette player	15	1	1	15
	small fan	55	1	1	55
				Total	290
Governmental offices (100W equivalent)	Fluorescent lights	8	3	6	144
	B/W TV set	30	1	2	60
	radio-cassette player	15	1	1	15
	small fan	55	1	1	55
				Total	274
Clinics (400W equivalent)	Lights	8	10	6	480
	vaccine refrigerator	54	1	6 (24)	324
	wireless set	5.4	1	(24)	130
	small fan	55	1	2	110
				Total	1044
Junior secondary school (250W equivalent)	Lights (faculty room)	8	4	4	128
	lights (warehouse)	18	6	4	432
	B/W TV set	30	1	2	60
	radio-cassette player	15	1	2	30
	small fan	55	1	2	110
				Total	760
BCS household (25W equivalent)	Fluorescent light	8	1	4	32
	B/W TV set	30	1	1	30
				Total	62
BCS store (50W equivalent)	Fluorescent light	8	2	4	64
	B/W TV set	30	1	1	30
	radio-cassette player	15	1	1	15
				Total	109

(Source) JICA Study Team

With a 1,000W system, BCS could charge four or five batteries per day for use in BCS stores (with a demand equivalent to 50W), and therefore meet the needs of from 20 to 25 stores.

Table 5.4.11 presents estimates for battery capacity and voltage for the modeled systems.

Table 5.4.11 Estimates for battery capacity and voltage in the modeled systems

System	PV Capacity	Battery Capacity	Load Voltege
SHS 1	50W	60Ah	12V-DC
SHS 2	100W	170Ah	220V-AC
Office	100W	100Ah	12V-DC
Clinic system	400W	680Ah	220V-AC
School system	250W	340Ah	220V-AC
BCS (1,000W)	1,000W	80～120Ah×4batteries/day	12V-DC

(Source) JICA Study Team

(3) Off-grid PV electrification cost

Table 5.4.12 shows calculation results for the cost of installation of the PV systems modeled in accordance with the demand forecast, based on the cost of PV system equipment in Ghana. For the installation cost per W of PV system output, the calculation yielded figures of about 12 dollars for the SHS1 50W system, 12 dollars for the SHS2 100W system, 20 dollars for the clinic system, 10 dollars for the school system, and 6 dollars for the BCS system. It is therefore thought that the BCS system would be the least costly.

Table 5.4.12 Cost of off-grid PV electrification

	Item	Qty.	unit	Sub total
SHS 1 (50W)	PV module 50Wp	1	260.2	260.2
	Charge Regulator 20A	1	106.5	106.5
	Deep Cycle Battery 60Ah	1	94.0	94.0
	Lamp-Fluorescent or CFL 8W	2	1.7	3.4
	installtion, wiring	1	100.0	100.0
	Metal Mounting Structure	1	39.9	39.9
			TOTAL	604.0
	Item	Qty.	unit	Sub total
SHS 1 (100W)	PV module 100Wp	1	486.4	486.4
	Charge Regulator 10A	1	79.9	79.9
	Deep Cycle Battery 170Ah	1	254.1	254.1
	Inverter 250W	1	229.9	229.9
	Lamp-Fluorescent or CFL 8W	5	1.7	8.5
	installtion, wiring	1	100.0	100.0
	Metal Mounting Structure	1	39.9	39.9
			TOTAL	1198.7
	Item	Qty.	unit	Sub total
Office (100W)	PV module 100Wp	1	486.4	486.4
	Charge Regulator 10A	1	79.9	79.9
	Deep Cycle Battery 100Ah	2	121.0	242.0
	Lamp-Fluorescent or CFL 8W	3	7.3	21.9
	installtion, wiring	1	100.0	100.0
	Metal Mounting Structure	1	39.9	39.9
			TOTAL	970.1

	Item	Qty.	unit	Sub total
Clinic (400W)	PV module 100Wp	4	486.4	1945.6
	Charge Regulator 20A	1	106.5	106.5
	Charge Regulator 10A	2	79.9	159.8
	Vaccine Refrigerator WHO standard	1	3932.5	3932.5
	Deep Cycle Industrial battery 170Ah	4	254.1	1016.4
	Inverter 250W	2	229.9	459.8
	Lamp-Fluorescent or CFL 8W	10	1.7	17.0
	installtion, wiring	1	300.0	300.0
	Metal Mounting Structure	4	39.9	159.6
			TOTAL	8097.2
JSS (250W)	Item	Qty.	unit	Sub total
	PV module 100Wp	2	486.4	972.8
	PV module 50Wp	1	260.2	260.2
	Charge Regulator 20A	1	106.5	106.5
	Deep Cycle Battery 170Ah	2	254.1	508.2
	Inverter 250W	1	229.9	229.9
	Lamp-Fluorescent 18W	6	3.3	19.8
	Lamp-Fluorescent or CFL 8W	4	1.7	6.8
	B/W TV set	1	40	40.0
	installtion, wiring	1	200.0	200.0
	Metal Mounting Structure	3	39.9	119.7
			TOTAL	2463.9
BCS (1000W)	Item	Qty.	unit	Sub total
	PV module 50Wp	4	260.2	1040.8
	PV module 100Wp	8	486.4	3891.2
	Charge Regulator 20A	4	106.5	426.0
	installtion, wiring	1	400.0	400.0
	Metal Mounting Structure	8	39.9	319.2
			TOTAL	6077.2

(Source) JICA Study Team

Generally speaking, the service life is about 20 years for PV panels, five years for deep-cycle batteries, ten years for charge controllers and inverters, and 20 years for cables. On this basis, the Study Team made a calculation of the annual cost for each type of PV system over its service life, assuming a facility operating life of 20 years and annual cost factor of 0.102. In addition, the calculation for BCS assumed an operating personnel cost of 30 dollars per month. The results are shown in Table 5.4.13.

Table 5.4.13 Annual cost for each type of PV system

System	PV Capacity	Initial	Spare	Total	Service/year	annual cost
SHS 1	50W	604	388	992	0	101
SHS 2	100W	1,199	1,072	2,271	0	232
Office	100W	970	806	1,776	0	181
Clinic	400W	8,097	7,707	15,804	0	1,612
School	250W	2,464	1,860	4,324	0	441
BCS 1	1,000W	6,077	9,600	15,677	360	1,959
BCS 2	2,000W	12,154	19,200	31,354	360	3,558
BCS 3	3,000W	18,231	28,800	47,031	360	5,157
BCS 4	4,000W	24,308	38,400	62,708	360	6,756
BCS 5	5,000W	30,385	48,000	78,385	360	8,355

* Figures for BCS include the cost of 88-ampere-hour batteries owned by residents and business proprietors (58 dollars per household).
(Source) JICA Study Team

The Study Team estimated the yearly generated output of each model system and used the findings to calculate the cost per kWh for each. The results are shown in Table 5.4.14 and Figure 5.4.7.

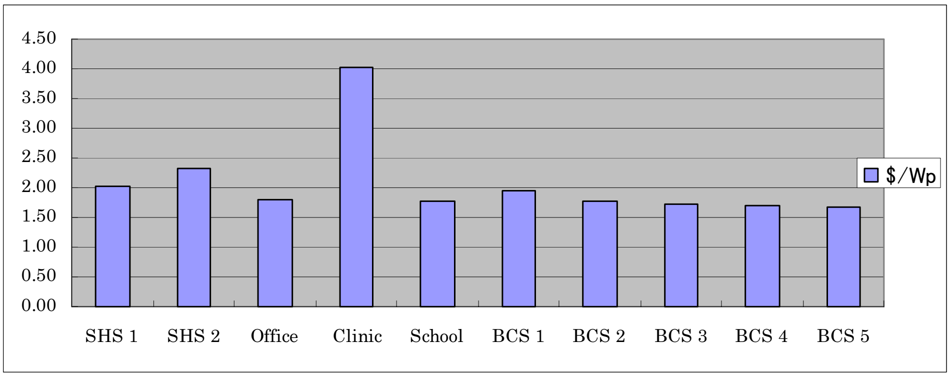
While the cost per kWh of output varies with the system, comparison of systems of the same type (e.g., the SHS DC system) shows that this cost declines as the capacity rises. The trend for BCS shows that the cost per kWh of output declines in a hyperbolic curve as capacity increases. This indicates that efforts to expand system capacity and curtail annual costs would have less effect once a certain level of capacity is exceeded.

BCS have the lowest cost per kWh in spite of their need for operators. It is thought that a 5-kW BCS could handle aboout 20 batteries per day, and that the operation of BCS with a larger capacity would require additional personnel to operate. A 5-kW BCS could accommodate about 100 households with a demand on the SHS1 level (equivalent to a PV system with a capacity of 50W), and could be termed an efficient approach to electrification when customers (households) are clumped together.

Table 5.4.14 Power generation

System	PV Capacity	annual cost	annual kWh	$/kWh	$/Wp
SHS 1	50W	101	56	1.800	2.024
SHS 2	100W	232	106	2.188	2.316
Office	100W	181	100	1.811	1.812
Clinic	400W	1,612	381	4.230	4.030
School	250W	441	277	1.590	1.764
BCS 1	1,000W	1,959	796	2.462	1.959
BCS 2	2,000W	3,558	1,591	2.236	1.779
BCS 3	3,000W	5,157	2,387	2.160	1.719
BCS 4	4,000W	6,756	3,183	2.123	1.689
BCS 5	5,000W	8,355	3,979	2.100	1.671

(Source) JICA Study Team



(Souce) JICA Study Team

Figure 5.4.7 Unit generation cost for each system

(4) PV system electrification cost for the purpose of comparing community electrification costs

The electrification cost calculation in the preceding section envisioned the case of ordinary PV system projects, i.e., certain electrical products such as lights and refrigerators, and indoor distribution wiring. Cost comparison with on-grid electrification, however, requires an alignment of bases. The Study Team therefore considered the situation when the equipment cost is excluded.

A calculation was made of the off-grid (PV) electrification cost in the case of the standard community (demand) model prepared from the findings of the village study in order to compare the community electrification costs of on-grid and off-grid systems. Table 5.4.15 presents the makeup of the standard demand model, and Table 5.4.16, the conditions applied in the cost calculation.

Table 5.4.15 Standard demand model (the bold enclosure indicates off-grid electrification)

	Share of the total number of communities	Off-grid	On-grid
Demand pattern 1 (Population = 500)	91.74% (communities with a population of less than 1,000)	* Households: 25 W x 10 households (BCS use); 23 kWh/year x 10 households) * Commercial facilities: 50 W x 3 facilities (BCS use); 40 kWh/year x 3 facilities * Grain mills: none * Clinics: none * JSS: none * Offices: none * Staff houses: none	* Households: 107 W x 10 households; 480 kWh/year x 10 households * Commercial facilities: 50 W x 3 facilities (BCS use); 40 kWh/year x 3 facilities * Grain mills: none * Clinics: none * JSS: none * Offices: none * Staff houses: none * 50-kVA transformers: 1
Demand pattern 2 (Population = 2,000)	7.55% (communities with a population of 1,000 - 4,999)	* Households: 25 W x 40 households (BCS use); 23 kWh/year x 40 households) * Commercial facilities: 50 W x 13 facilities (BCS use); 40 kWh/year x 13 facilities - 50 W x 3 facilities (SHS); 56 kWh/year x 3 facilities * Grain mills: none * Clinics: 400 W x 1 * JSS: 250 W x 1; 277 kWh/year x 1 facility * Offices: 100 W x 1; 100 kWh/year x facility * Staff houses: 100 W x 7; 106 kWh/year x 7 facilities	* Households: 107 W x 60 households; 535.6 kWh/year x 60 households) * Commercial facilities: 195.7 W x 15 facilities; 715.5 kWh/year x 15 facilities * Grain mills: 20,000 W x 1; 58,400 kWh/year x 1 * Clinics: 280 W x 1; 1,272 kWh/year x 1 * JSS: 110.5 W x 1; 321.3 kWh/year x 1 * Offices: 107 W x 1; 535.6 kWh/year x 1 * Staff houses: none * 50-kVA transformers: 1
Demand pattern 3 (Population = 5,000)	0.71% (communities with a population of 5,000 or more)	* Households: 25 W x 100 households (BCS use); 23 kWh/year x 100 households) * Commercial facilities: 50 W x 31 facilities (BCS use); 40 kWh/year x 31 facilities - 50 W x 6 facilities (SHS); 56 kWh/year x 6 facilities * Grain mills: none * Clinics: 400 W x 1; 381 kWh/year x 1 facility * JSS: 250 W x 2; 277 kWh/year x 2 facilities * Offices: 100 W x 1; 100 kWh/year x 1 facility * Staff houses: 100 W x 10; 106 kWh/year x 10 facilities	* Households: 107 W x 150 households; 535.6 kWh/year x 150 households) * Commercial facilities: 195.7 W x 38 facilities; 715.5 kWh/year x 38 facilities * Grain mills: 20,000 W x 2 facilities; 58,400 kWh/year x 2 * Clinics: 280 W x 1; 1,272.7 kWh/year x 1 * JSS: 110.5 W x 2; 321.3 kWh/year x 2 * Offices: 107 W x 1; 535.6 kWh/year x 1 * Staff houses: none * 50-kVA transformers: 2

(Source) JICA Study Team

Table 5.4.16 Cost calculation conditions

Item	Conditions
Service life	PV panels: 20 years - Electrical equipment (C/C, INV, etc.): 10 years - Deep cycle battery: 5 years - Stands and other structures: 20 years
Initial cost	Consisting of PV panel, battery, C/C, INV, and installation and wiring work; excluding indoor wiring and electrical products
Maintenance cost	Cost of requisite equipment replacement over a period of 20 years
BCS operating personnel cost	- BCS capacity of 250 W as the basic unit - No personnel cost for BCS with a capacity in the range of 250 - 750 W because of their small number and the ability of personnel to engage in other work in parallel - Personnel cost of 30 dollars per month for BCS with a capacity in the range of 1 - 5 kW
Interest rate	8% (annualized cost rate of 0.102)
Exchange rate	1 dollar = 9,000 cedi

(Source) JICA Study Team

The calculation of electrification costs applied the costs for PV system electrification presented in Table 5.4.12 and Table 5.4.13, excluding indoor wiring, lights, and electrical products. Per kWh, it yielded costs of 2.36 dollars for demand pattern 1, 2.19 dollars for demand pattern 2, and 2.15 dollars for demand pattern 3.

The calculation results for the cost of electrification under the standard demand model are presented in Table 5.4.17.

Table 5.4.17 Electrification costs under the standard demand model

(Unit: dollars)

Demand model		Num.	Power (kWh)	Initial	Maintenance/20 years	Annualized cost	Operating cost/year	Yearly cost	Cost/ kWh
Demand pattern 1 (population: 500)	Households(BCS25W)	10	226.3	420	2940	342.7	0	342.7	2.36
	Commercial facilities(BCS50W)	3	119.4	174	1218	142.0	0	142.0	
	*BCS	2	-	3038	212	331.5	0	331.5	
	Subtotal		345.7	3632	4370	816.2	0	816.2	
Demand pattern 2 (population: 2,000)	Households(BCS25W)	40	905.2	1680	11760	1370.9	0	1370.9	2.19
	Commercial facilities(SHS50W)	3	168.6	1653	1164	287.3	0	287.3	
	Commercial facilities(BCS50W)	13	517.2	754	5278	615.3	0	615.3	
	Clinics	1	381.1	3998	3774	792.7	0	792.7	
	JSS	1	277.4	2297	1860	424.0	0	424.0	
	Offices	1	100.0	898	806	173.8	0	173.8	
	Staff houses	7	741.0	7980	7504	1579.4	0	1579.4	
	*BCS	7	-	10633	742	1160.3	360	1520.3	
	Subtotal		3090.5	29893	32888	6403.7	360	6763.7	
Demand pattern 3 (population: 5,000)	Households(BCS25W)	100	2263.0	4200	29400	3427.2	0	3427.2	2.15
	Commercial facilities(SHS50W)	6	337.3	3306	2328	574.7	0	574.7	
	Commercial facilities(BCS50W)	31	1233.3	1798	12586	1467.2	0	1467.2	
	Clinics	1	381.1	3998	3774	792.7	0	792.7	
	JSS	2	554.8	4594	3720	848.0	0	848.0	
	Offices	1	100.0	898	806	173.8	0	173.8	
	Staff houses	10	1058.5	11400	10720	2256.2	0	2256.2	
	*BCS	17	-	25823	1802	2817.8	360	3177.8	
	Subtotal		5928.0	56017	65136	12357.6	360	12717.6	

** The assumptions for BCS batteries were as follows. 25-W: 55 Ah (42 dollars) - 50-W: 88 Ah (58 dollars)

(Source) JICA Study Team

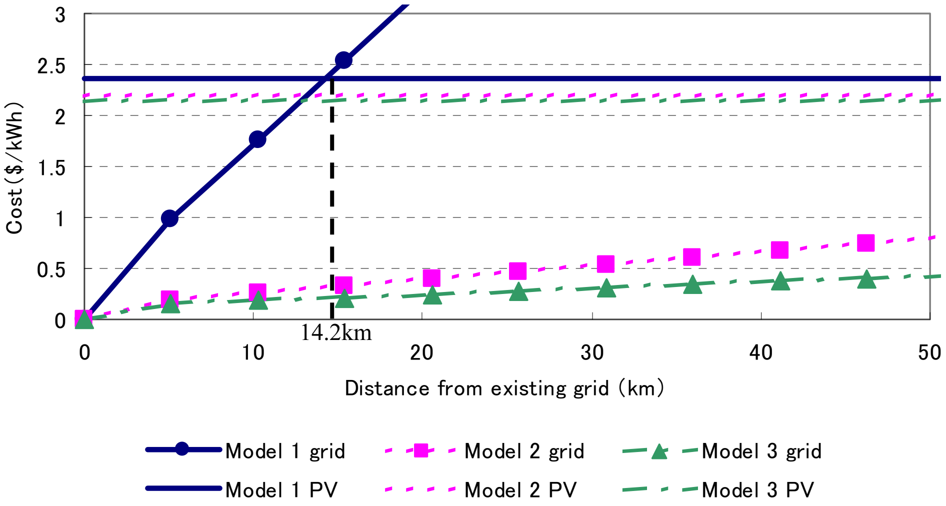
5.4.3 Demarcation based on cost analysis

For cost comparison, the Study Team made assessments in terms of kWh taking account of the hours of electrical product use. Cost comparison between on- and off-grid electirficaiton, however, must be done on the same basis (e.g., off-grid electirificaion includes inhouse wiring, but on-grid electrificaiotn does not). The Study Team therefore considered the situation when the equipment cost is excluded for PV systems.

In the case that there are no other communities on the route (SHEP)

Figure 5.4.8 shows the point of division between the on- and off-grid systems when there are no other communities on the route.

Under demand model 1, the most prevalent one in the northern regions, PV power generation would be more economical than extension of the grid as a means of electrifying communities that are more than about 14km away from the grid. Even in this case, however, cost exceeds 2 dollars per kWh. On-grid electrification would be preferable for electrification of communities with demand pattern 2 or 3.



(Source) JICA Study Team

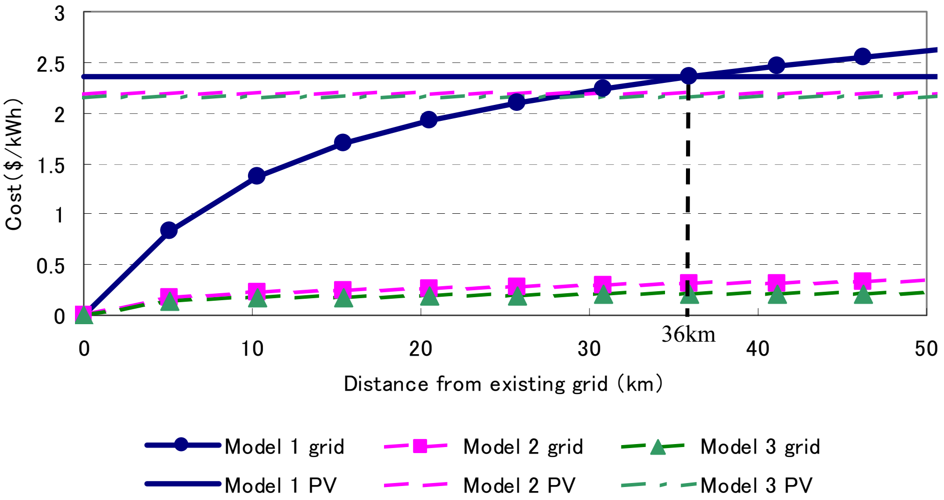
Figure 5.4.8 On- and off-grid costs of electrification in the three northern regions (In the case that there are no other communities on the route)

In the case that all communities on the route are electrified

Figure 5.4.9 shows the calculation results in the event of electrification of all communities. On-grid electrification is more economical for demand models 2 and 3, and would also be preferable for demand pattern 1 up to a distance of 36km.

Even for communities with demand model 1 that are about 5km away from the existing grid, however, on-grid electrification would cost about 1 dollar per kWh. As such, extensive electrification would have to be preceded by full studies of measures in the institutional aspect, such as the setting of tariffs by the NED, curtailment of maintenance costs, and instatement of subsidies as necessary.

In the northern regions, the electrification cost per kWh therefore becomes very high due to the small demand associated with the communities. RE promotion must proceed on the basis of a master plan that combines on- and off-grid approaches.



(Souce) JICA Study Team

Figure 5.4.9 On- and off-grid costs of electrification in the three northern regions
(In the case that all communities on the route are electrified)

5.5 Criteria for selection of areas

5.5.1 Criteria for selection of areas in past PV projects

In promotion of RE on a limited budget, it is important to analyze the socioeconomic benefits of electrification and execute projects in a strategic manner, beginning with areas offering the highest such effects. The accordance of precedence to on-grid electrification, which is superior in the aspects of power quality and capacity, is another means of heightening the electrification effects. Off-grid electrification is adopted as an electrification means for areas where on-grid electrification is not economical or physically impossible.

For these reasons, past projects, too, selected areas far from the existing distribution lines and SHEP coverage as subjects of electrification (see Table 5.5.1).

Table 5.5.1 Criteria for selection of areas in existing PV projects

Project	Selection criteria
Spain/MME	・Areas at least 20km from the existing grid
RESPRO	・Areas at least 20km from the existing grid ・Areas not anticipated to be reached by the grid in the SHEP for at least 10 years
JSSs (RESPRO)	・At least one or two schools in each district

(Source) Prepared JICA Study Team through intervies

5.5.2 Criteria for selection of areas for off-grid PV electrification in northern Ghana

To establish criteria for selection of areas for off-grid PV electrification, it is first necessary to clearly distinguish them from the areas for on-grid electrification. The most important means of doing so is comparison of the costs of the two. Areas where on-grid electrification is impossible due to cost factors ought to be designated for off-grid electrification. The continued promotion of on-grid electrification under the SHEP requires the sharing of information within the MOE and clear definition of the border between the two.

In ordering the areas to be electrified with PV systems in terms of priority, precedence must be accorded to the public facilities whose electrification is being pursued by the government (i.e., health centers, clinics, CHIPS compounds, junior secondary schools, and police stations). The criteria also must incorporate size of population as an indicator because it is a key determinant of the number of households, number of commercial facilities, and level of economic activity. Table 5.5.2 shows the items to be considered in establishing criteria for area selection.

Table 5.5.2 Items to be considered in establishment of standards for area selection

	Items	Comments
Technical aspect	Areas that cannot be electrified by extension of the grid	・Outlying islands, etc.
	Policy/technical decisions	・Areas that cannot be reached by SHEP for at least 10 years
	Cost comparison with on-grid electrification	・Distance from existing distribution line
Socioeconomic aspect	Number of public facilities	・Medical facilities, educational facilities, etc. ・Weighting in correspondence with facility importance
	Population (number of households and commercial facilities)	・Population as an indicator of the level of economic activity

(Source) JICA Study Team

For quantitative expression of the various items in the socioeconomic aspect, the Study Team proposes the preparation of a score sheet like that shown in Table 5.5.3. Each item would be weighted by allotting a certain number of points in correspondence with its importance, and communities would be scored by adding up the subtotals for the items they contain, with a perfect score being 100. Finally, communities would be ranked on the basis of their score.

Table 5.5.3 Score sheet for standards for area selection (draft)

Num. of Public Facilities (70)	* Health	Clinic	Health Centre	Chips Compound	
	30	30	30	15	
	Education	J.Secondary School	Primary School		
	30	30	-		
	Police Border Post	Police Border Post			
	10	10			
Num. of Population (Households) (30)	Population	Beyond 5000	2000～5000	1000～2000	～1000
	30	30	20	10	5
Total Score 100					

* Maximum 30 Points

(Source) JICA Study Team

5.6 Business model for PV system diffusion

5.6.1 Identification and analysis of issues in past PV projects

Promotion of off-grid PV electrification requires the selection of business models grounded in schemes (for funding, payment, and O&M) that are adapted to the national and local socioeconomic situation. Based on the lessons learned through the review of past PV electrification projects and the field surveys, this section sets forth and analyzes the problems and issues as viewed from the three aspects of the overall organizational scheme, type of customer, and business model.

(1) Identification of problems and tasks regarding the overall organizational scheme

As was pointed out in the review of past PV electrification projects, various problems can arise in the organizational aspect. In the planning stage, there are problems that cause difficulties after implementation due to a mismatch with the on-grid program (SHEP) or lack of basic consensus.

Once projects start, there can surface problems in respect of O&M and charge collection. The surest way is to have these duties performed by the project principal itself, but this drives up operating costs and squeezes earnings. When these duties were left to local governments and communities, however, projects became insolvent because of low levels of skill and ethics among operators.

Yet other problems are associated with factors such as customer ability to pay and inclinations to perform O&M. Table 5.6.1 summarizes these problems and the tasks to address them.

Table 5.6.1 Problems and tasks related to the organizational setup

	Problems in past projects	Issuess identified from the problems
Planning	・Due to a mismatch with the SHEP, the grid reached the community soon after the installation of PV systems, which consequently had to be relocated.	・Conformance with the SHEP
	・Problems occurred in O&M and collection of charges because the project principal did not fully explain things to the concerned parties in advance.	・Full advance explanation to and building of a consensus among all concerned parties before the project begins
O&M	・Operating costs were driven up by the large service area and lack of enough O&M support.	・Supporting setup in the vicinity of the electrified area (e.g., an initial management setup in the community)
	・The community resident selected to perform O&M did not have enough technical skill and was unable to solve problems.	・Technical instruction for community managers ・Management by customers themselves
	・In the case of public facility systems, the district and national governmental outpost offices responsible for O&M did not fully discharge this role.	・Ownership by the party managing the public facility
Setting of tariffs and loan repayment	・Costs were unable to be retrieved in fee-for-service schemes because the tariffs were set on low levels, on a par with the lifeline tariffs in grid service.	・Setting of tariffs on levels enabling retrieval of costs ・Provisions for subsidies ・Imposition of partial beneficiary (customer) burden for equipment
	・Loans were made to residents who had low income levels and could not repay them. The loans were unable to be recovered.	・Resident payment ability
Collection of charges	・The surest way is to have the project principal collect the charges itself, but this drives up operating costs and squeezes earnings.	・Efficient charge collection
	・When community residents were assigned to collect charges, they sometimes were unable to take a tough stance because of ties of blood, or pocketed payments themselves.	・Transparency in charge collection
	・Because many residents are farmers who do not have a steady income, payments were sometimes made in lump sums at irregular intervals.	・Flexibility in the scheme for collection of charges
Customers	・In spite of non-payment, customers refused to allow their systems to be removed.	・Making of rules regarding system use and advance agreement on them
	・In the case of systems in public facilities, breakdowns were left unrepaired because the users did not have a good understanding of the system ownership and O&M setup.	・System ownership

(Source) prepared by the JICA Study Team

(2) Identification of problems and issues in each customer category

Methods of power use and management, and ability to share the cost burden, vary with the customer needs and type (e.g., private- versus public-sector use). Each of these matters should be handled separately.

In the private sector, households in the northern regions tend to be poor. Many cannot afford payments for systems beyond the level of power for lights. Their O&M capabilities are also generally low. Commercial facilities, in contrast, have a cash income and the ability to own and maintain systems to a certain extent.

In the public sector, there are strong needs for electrification of medical and education facilities. The

MOH is particularly eager to have such facilities electrified and is appropriating budget of its own for this purpose. In spite of this, in many cases, systems go out of order because proper arrangements have not been made for O&M by the facility staff. Table 5.6.2 summarizes the electrification needs, problems, and tasks in each category of demand type and customer.

Table 5.6.2 (1) Problems and issues in each customer category for public sector

		Medical facilities	Schools	Water use	Other
Latent needs		・Strong needs for power for lights, vaccine refrigerators, communications, and other items that can have a direct bearing on human life	・Needs for lights for night classes ・Difference of opinion on the need for lights to assure time for study at night	・Needs for simple water supply facilities to provide hygienic drinking water ・Needs for use of irrigation pumps to increase farming productivity	・Strong needs for staff house electrification to attract nurses and teachers ・Needs for electrification of community halls and other places where people gather
Ability to assume a cost burden	Probl-ems	・The MOH recognizes the need for electricity, and the cost burden would presumably present little difficulty. ・However, it is unlikely that funding could cover costs down to the smallest medical facilities.	・There is not a solid agreement on installation of PV systems even at country schools at national expense.	・In the case of water supply facilities, it is not clear whether the cost burden should be borne by the user or by the manager. The cost is not shared.	・Costs of staff house electrification could be paid from wages. ・The cost burden for community halls would have to be clearly defined.
	Issues	・Appropriation of budget for electrification and O&M costs ・Possibility of defrayment of power charges with treatment fees and related subsidies	・Appropriation of budget for electrification and O&M costs	・Clear statement of perspectives on cost and benefit related to water use	・Staff houses: heightening of the customer awareness of staff ・Community halls: clear statement of parties who must shoulder the cost burden
O&M ability	Probl-ems	・Personnel have a higher level of knowledge than on the household level, and there are fewer difficulties deriving from a lack of basic knowledge. They are also capable of performing simple O&M.	・Personnel have a higher level of knowledge than on the household level, and there are fewer difficulties deriving from a lack of basic knowledge. They are also capable of performing simple O&M.	・There is a problem with theft because many panels are installed in open space.	・There are needs, but parties responsible for O&M must be clearly defined.
		・In some cases, problems cannot be solved because managers do not know who to contact.		・The systems are special and require a high level of technical skill.	
	Issues	・Reinforcement of arrangements for communication between the local staff and managers	・Reinforcement of arrangements for communication between the local staff and managers	・Need for construction of an O&M setup for the community (as the beneficiary)	・Need for construction of an O&M setup for the community (as the beneficiary)
Aware-ness of owner-ship	Probl-ems	・Much depends on the awareness and technical skills of the managers.		・In the case of water facilities and community halls, matters depend on the degree of need for systems. Tasks	
	Issues	・Incentives to increase the level of treatment through electrification	・Incentives to increase the level of treatment through electrification	・Need for management by an O&M committee or other facility management committee	

Table 5.6.2 (2) Problems and issues in each customer category for private sector

		Households	Commercial facilities
Latent needs		・ Lights and radios on the average ・Doubtful whether residents of poor unelectrified communities see electrification as the top priority	・Existence of demand on the order of 100W systems or installation of several systems (for lights, radios, TV sets) ・Strong needs to heighten added value in business
Ability to assume a cost burden	Probl-ems	・In the northern regions, income levels are generally low and many residents lack disposable income except at harvest time. ・The lifeline tariff (about 2 dollars per month) may be regarded as a benchmark.	・In spite of the general povery, stores and bars have a cash income. ・There are some systems with a capacity above 100 Wp, and there is no need for tariffs to be held to the lifeline level.
	Issues	・Aid for low-income residents through investment of public funds ・Recovery of funds through the fee-for-service model applied by the RESPRO	・Possibility of assumption of the cost burDENGiven the existence of a cash income and recognition of incentives based on electrification
O&M ability	Probl-ems	・Households lack basic knowledge, and this causes many problems in equipment use; they could not be expected to manage systems themselves.	・Commercial facilities also lack the basic knowledge, but are highly motivated to learn because of the direct connection with income.
		・Even if management is transferred to the community, problems often occur due to the low level of manager skills.	
	Issues	・Increase in the O&M awareness and technical level of users	・Advantage due to existence of a cash income and incentive for electrification
Aware-ness of owner-ship	Probl-ems	・There is little awareness of ownership because past projects were executed with grant aid.	・Sense of ownership is generally high due to the direct connection with income.
	Issues	・Measures to heighten the ownership awareness	

(Source) prepared by the JICA Study Team

(3) Business model problems and issues

In Ghana, past pilot projects applied the fee-for-service model (in which the business principal owns the system and collects service fees from the customer) and outright sales (based on cash or loans) model. Each of these models has its own problems.

This section views the problems and issues related to business models. The RESPRO fee-for-service model is saddled with two major problems of feasibility. One is the tariff, which is on the level of the lifeline tariff (2 dollars per month) and makes it impossible to recover costs. The other is the problem of operating costs due to the provision of technical services and scheme for collection of charges by the enterprise itself.

In outright sales, cash payment is the ideal, but it would not be realistic in the northern regions, where most households are poor, except in the case of certain wealthy customers and stores. In outright sales based on loans, there are problems deriving from the need to set up a scheme of financing for lump-sum reserves by dealers and for loans. In addition, difficulties are likely to be encountered in arrangements for O&M due to vagueness about the locus of ownership. Table 5.6.3 shows the problems and issues as viewed from the perspective of business models.

Table 5.6.3 Business model problems and issues

	Fee-for-service (RESPRO)	Outright sales (loan)	Outright sales (cash)
Overall	・Recovery of cost through a power tariff scheme patterned after that of utilities	・Provision of loans to customers unable to purchase systems with cash ・Problem of ownership ascription until loans are completely repaid	・Direct sale of systems costing a few hundred dollars; applicable only for affluent customers
O&M	・Establishment of offices in the northern regions for direct performance of O&M ・Little technical trouble, but high operating cost	・Occurrence of problems related to response in the event of breakdown and contract cancellation due to the vagueness about ownership ・Performance of O&M by the customer or through consignment to the community ・System condition dependent on the skills of customers and commissioned technicians	・Easy receipt of service because the customers have cash
Payment of charges and repayment of loans	・Inability to retrieve costs because of the constraints of the lifeline tariff (2 dollars/month) ・High operating cost due to the direct collection of charges (at the same time as O&M)	・Lack of establishment of financing schemes for dealers ・Lack of repayment ability on the part of most residents ・Susceptibility to the influence of exchange rates and inflation	・Difficulty of expanding the business because of the lack of arrangements for financing for dealers

(Source) prepared by the JICA Study Team

5.6.2 Issues to be considered for improvement

Studies aimed at identifying PV electrification business models applicable in the northern regions must clarify the principals to engage in the business, the manner of promoting the business, and the requirements for customers. This section summarizes the items to be considered by the concerned parties for improvement as regards the issues noted above.

(1) Project principals (who shall undertake projects?)

The principal executing projects differs depending on the socioeconomic purpose of power use and scale of electrifiction. The national government promotes the electrification of public facilities, but would find it difficult to operate projects by itself, and should rely on local power and communities for O&M performance. When power utilities embark on PV business, they must consider the existing tariff scheme and arrangements for grid customers. ESCOs and dealers must select realistic business models enabling retrieval of costs. Depending on the payment abilities of the residents, options should not be confined to SHS but include BCS, which entail less business risk.

Table 5.6.4 presents the prospective PV electrification project principals and their characteristics.

Table 5.6.4 Prospective PV business principals and their characteristics

Principal	Applicable project	Characteristics
National government	・Electrification projects in certain sectors (education and health)	・Need for involvement by outpost agencies on the regional and district levels because it would be, in effect, impossible for the competent national authority (ministry) to execute projects directly ・Need to make arrangements for on-site O&M
Local governments and communities	・The key entities for O&M and collection of charges, but may possibly be positioned as project principals	・Need for the appropriate technical skills and assurance of the transparency of charge collection.
Utilities	・Implementation of off-grid PV electrification as well as on-grid electrification	・Possibility to implement relatively larger size of installatins because of sufficient financial and human resources ・Need for conformance with on-grid tariffs ・Need to win customer consent as regards differences between on- and off-grid power
ESCOs	・Execution of O&M and charge collection rooted in the community to a certain extent (this approach is also applied by the RESPRO) ・This type also applicable for BCS operation as well as SHS	・Not commercially viable under the RESPRO model because of the lifeline tariff constraint ・Need for alleviation of operating risks by having customers assume the burden for batteries, as in the case of BCS
Dealers	・Sale of equipment directly by dealers, with contract-based O&M ・BCS operation as another option	・High business risks attached to non-cash sales because of the lack of a scheme of financing for dealers [11]。 ・Installation of systems for governmental facilities as the main market; business not yet on commercial footing on the private-sector basis。

(Source) prepared by the JICA Study Team

(2) Selection of business models

There are three basic types of model for the operation of off-grid PV systems: fee-for-service, outright sales (cash), and outright sales (loan). The fee-for-service model is thought to be difficult to apply under the current status of lifeline tariff application. Outright sale requires the development of customers with the purchasing potential (although it also depends on arrangements for financing). Table 5.6.5 presents the characteristics of each business model.

Table 5.6.5 Prospective PV business models and their characteristics

Principal	Characteristics and issues	Measures
Fee-for-service	・Not viable as a business under the current lifeline tariff scheme	・Need for study of ways to alleviate operating risks, such as having customers share the cost burden for the equipment and electrification by BCS
Outright sales (loans)	・Existence of poverty preventing payment even with loans in the northern regions ・Bank scheme not strong enough to provide security for loans	・Study of financing for customers with a certain degree of cash income, such as commercial facilities
Outright sales (cash)	・Applicable for few customers in the civil sector, considering the poverty in the northern regions ・Possibly applicable for customers in areas not covered by the SHEP, near cities	・Development of customers capable of purchasing equipment on the order of batteries in spite of their poverty ・Coordination with governmental projects

(Source) prepared by the JICA Study Team

(3) Requirements for customers

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[11] While training local installers, DENG Engineering is attempting to expand the market and lower business risks by having them sell equipment as well (at first leaving small lots to them).

Customers utilizing off-grid power naturally have the obligation to pay for the services received, and also must perform O&M for the systems to a certain extent. The following five items may be cited as the minimum requisite conditions to be met by customers.

- Possession of a firm grasp of electrification needs (lighting, etc.)
- Existence of a cash income large enough for purchase of equipment on the order of batteries at the least
- Acquisition of the minimum requisite knowledge regarding battery maintenance and handling of lights

5.6.3 Proposal of business models for off-grid PV electrification

Table 5.6.6 sets forth the possibilities in respect of the business principals and models in the Northern Part of Ghana at present, based on the problems identified and analyzed in the preceding sections. Models thought to be particularly practical are enclosed in bold lines.

Table 5.6.6 Business principals and business model application possibilities

Business model / Principal	Fee-for-service		Outright sales	
	SHS	BCS	Loans	Cash
Government	N／A	N／A	N／A	◎ For electrification of public facilities
Utilities	○ Need for conformance with the existing tariff scheme	△ Possible commercial feasibility	N／A	N／A
ESCOs	△ Need for mitigation of risk through sharing of part of the equipment cost burden by customers	◎ Low tariffs, comparatively easy retrieval of cost	N／A	N／A
Local governments (communities)	△ Some possibility, but problems in the operation aspect	N／A	N／A	○ Independent community projects
Dealers	△ Need for financing for equipment purchase	◎ Possible expansion of business through development of chain stores	△ Need to develop customers able to repay loans; high risks for the company side	○ Some potential, mainly among commercial facilities

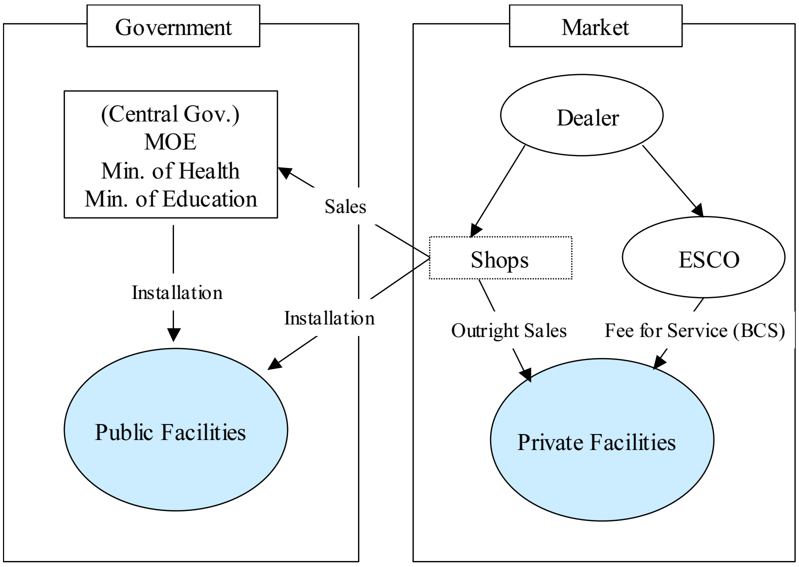
(Source) prepared by the JICA Study Team

5.6.4 Proposal of electrification model adapted to the socioeconomic status of communities in the northern regions

As discussed above, examinations of off-grid PV electrification models must draw a clear distinction between the public and private sectors, which obviously have a different market structure. It would be advisable to promote electrification in the public sector under government leadership through investment of tax revenues, and to stimulate the market and utilize the energies of dealers and other private enterprises in the private sector.

For the operation of business (projects) in the private sector, there are two basic approaches: system sales directly by dealers (including provisions for loans) and fee-for-service business operated through ESCOs. With the current RESPRO model, fee-for-service cannot subsist on commercial footing because of the low tariffs, and this point to a need for measures such as having the customers shoulder the cost burden of equipment such as batteries. In light of the level of payment capabilities in the northern regions, collection of fees by BCS could be the more realistic option for the operation at present.

While maintaining their own network of sales stores commensurate with the scale of their business, dealers could deliver systems to government projects and sell directly to the private sector in their operation. (Dealers could also possibly operate BCS.) Figure 5.6.1 diagrams these configurations.



(Source) JICA Study Team

Figure 5.6.1 Differentiation between civil use and public use

5.7 Roles of the government and the private sector for the spread of off-grid PV electrification

In Ghana, governmental policy on RE has posted the goal of electrification of (i.e., access to a supply of electricity in) all communities by 2020. In keeping with this goal, the government is promoting on-grid electrification with subsidies through the SHEP. In the SHEP, the cost of utility poles is to be borne by the community as a general rule, but funding has been injected in recent years to HIPC funds, and customers are receiving a substantial benefit from subsidies through the application of lifeline tariffs.

At the current stage, off-grid PV electrification is on the order of system installation with grant aid in the context of various pilot projects promoted by donor countries. As evidenced by the case of numerous developing countries, the establishment of a supply chain market on the private-sector basis is important for PV electrification, and the government must make provisions to support it.

5.7.1 Role of government

There are several measures which the national government could conceivably take to stimulate the spread of off-grid electrification, as follows.

- Formulation of long-term plans based on the Master Plan Study
- Establishment of efficient community electrification plans combining public facilities and private ones as electrification subjects
- Proposal of O&M methods and business models through the implementation of pilot projects
- Improvement of levels of technology through establishment of technical standards and code of practice
- Full provisions for technician education through official trainings
- Construction of test facilities to assure observance of PV equipment criteria
- Preparation of schemes of financing for enterprises
- Activities to increase knowledge and awareness of PV power use

5.7.2 Role of the private sector

The spread of off-grid PV electrification demands an expansion of the market led by private enterprises in coordination with the measures to be taken by the government. For example, in communities where governments are promoting PV electrification of public facilities, private enterprises could launch sales campaigns for residential PV systems at the same time.

Through its interviews with PV enterprises and NGOs, the Study Team collected information on approaches in their projects and views on ways to expand the market. It found that the enterprises faced problems in the aspects of money, organization, and technology, and were independently searching for solutions. Table 5.7.1 indicates their approaches to date and their requests for the future.

Table 5.7.1 Approaches and requests of PV enterprises and NGOs

Contents	Approaches and requests
Enterprise organization	• A cooperative organization of PV system enterprises is needed for advancement of the business. • Enterprises want to form a network with related NGOs.
Collection of charges and O&M	• The cooperation of residents is indispensable for efficient collection of charges. • Management of customers in the initial phase is a vital factor.
Business models	• Basically, enterprises want to develop the business through outright sales instead of holding assets. • Arrangements are currently being made for system sales and installation by local installation enterprises. • Enterprises are studying the prospects for developing chain store operations for PV power supply by BCS. • Considering the poverty in the northern regions, the fee-for-service model is too risky. Household electrification by BCS is thought by some enterprises to be the more realistic option[12]. • Some enterprises offer both fee-for-service and outright sales options to prevent their business from becoming biased toward one or the other.
Training	• Training courses are being held for PV system enterprises. • Training is also being offered to students on the site. • It is necessary to instruct customers in correct use of the systems.

(Source) JICA Study Team through interviews

5.8 Perspectives on off-grid PV electrification programs

Upon the completion of the Master Plan Study, the Ghanaian government is to promote off-grid PV electrification, in accordance with the criteria for area selection based on cost comparison and other factors. In the northern regions alone, thousands of communities are still without power, and electrification of all of them requires efforts to achieve the maximum effect at the minimum cost.

At the stage of execution, the government must clarify the time line for selection of off-grid electrification areas and implementation of projects. In RE, the general approach lies in extension of the grid where it is technically and financially possible and PV electrification for areas where grid extension is not effective. In the case of Ghana, the SHEP is a plan for on-grid electrification premised on contribution from residents, in that communities must assume the cost burden for low-voltage utility poles and house lines. As such, it could not be termed a program that is grounded in quantitative cost analysis.

Under these circumstances, it is difficult to acquire a firm grasp of the future plans for distribution line (on-grid) electrification. This, in turn, makes it hard to clearly define the scope of off-grid PV electrification with the exception of areas that are obviously too distant from the existing distribution

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[12] At the same time, some dealers thought that BCS was not a suitable business model because of the short battery demand duration of less than two years.

line network. In reality, even in existing PV projects, areas have been reached by the grid after PV systems were installed. This compels relocation of the systems and results in inefficiency.

As viewed from the standpoint of power utilities, electrification does not necessarily proceed from areas where it is most cost-effective, and this has the effect of squeezing business profit.

To promote off-grid PV electrification in a manner that conforms with on-grid electrification, the Power Unit of the MOE, as the planning party, must supervise the SHEP yearly plan and off-grid PV electrification plan in an integrated fashion. If priority is placed on the electrification cost and burden imposed on power utilities, it must consider to reveise the grid extension plan (SHEP) itself.

5.9 Discussion of incentives for PV system diffusion

5.9.1 Conditioning of the market environment in the institutional aspect

To pave the way for the growth of the PV market and spread of PV systems, the government must make institutional arrangements in various aspects while also formulating off-grid RE plans that are in conformance with on-grid electrification. These aspects include environmental conditioning to facilitate participation in the market by private enterprises, provisions for financing, the quality assurance scheme, the tariff scheme, and training programs.

Some of PV enterprises and NGOs are dissatisfied with the lack of subsidies for off-grid PV electrification. On-grid electrification is eligible for subsidies for initial investment, and is also a subject of cross-subsidization because of the low tariffs applied for the poor. In contrast, PV electrification rests on stand-alone systems and is structurally not conducive to cross-subsidization. It would also be difficult for the government to provide private facilities (households and stores) with subsidies for the initial cost. The relative merits of the subsidization scheme must be discussed from these angles.

Even aside from subsidies, enterprises want to see the instatement of various incentives, including rigorous application of (and simplification of requirements for) tax exemptions linked to lower costs, establishment of a financing system to improve access to funding, and improvements in the institution of official certification through items such as technical standards.

Although some of these desires would probably be impossible to fulfill, many deserve consideration. Table 5.9.1 outlines the incentives desired by enterprises and NGOs and the issues for their instatement.

Table 5.9.1 Incentives desired by enterprises and issues for their provision

	Requests for the government (incentives)	Issues for provision
PV electrification policy	・The installation of PV systems to electrify households in areas reached by the grid would make it possible to supply more grid power (short supply) to the industrial sector.	・It is the customers who choose between on- and off-grid electrification; it would be difficult for the government to intervene.
	・Rural offices should be established to manage procedures for tax exemptions and the financing system.	・Provisions for tax exemptions and micro financing must be made before the offices are established.
Subsidization arrangements	・About half of the government's RE Fund should be directed to funding for the import of equipment by PV enterprises. This would reduce costs at the time of installation.	・There are doubts about its practicality due to the dearth of government funds.
	・Subsidies are provided for on-grid electrification, and ought to be provided for PV electrification as well.	・It would be difficult to furnish subsidies for initial investment to private facilities. ・Cross-subsidization would probably be out of the question due to the stand-alone nature of PV systems.
Tax exemptions	・Import of complete PV systems is exempt from tariffs and value-added tax (VAT), but that of separate pieces of equipment is not.	・In separate import of batteries and other components, customs does not assess the purpose of use. This request was made by many enterprises and deserves study.
Financing system	・The government should construct a micro financing scheme with its own guarantees.	・Such a system met with failure in the BCS pilot project executed by DANIDA, but the proposal merits study.
	・It is hard to keep the business afloat because of the difficulty of getting loans from banks.	・A financing system must be instated for enterprises. Government guarantees should be offered, if possible.
Licensing system	・The details of the licensing system are not clear.[13]。	・The requirements here are augmentation of the licensing system for adaption to business models and provision of incentives for licensees.
Training	・Training must be provided to customers so they can perform system O&M.	・Many enterprises have a keen awareness of the need for training for their customers. This suggests that project execution should be accompanied by the preparation of manuals and instruction.
	・Enterprises would like arrangements for official qualification (certification) obtained by graduating from training courses held by the government.	・Besides raising the level of technical skill, official training acts as an incentive for enterprises by offering them official qualifications.

(Source) prepared by the JICA Study Team

5.9.2 Study of economic incentives based on energy prices and tariff settings

The provision of economic incentives for the spread of PV electrification demands, first and foremost, resolution of the perceived cost disadvantage relative to grid electrification. Desires for a supply of power are very high in all areas. The fact is, however, that, as compared to grid power, PV power entails a higher cost both initially and for subsequent O&M, and is also of inferior quality.

Nevertheless, it should also be noted that grid power, particularly in the case of small customers

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[13] The RESPRO believes that it does not have to obtain a license because it is a governmental agency. On the other hand, EC believes that RESPRO must obtain a licence.

targeted by RE, is clearly being subsidized in the aspect of tariffs, which are being artificially held to low levels (i.e., the lifeline tariff). It would consequently be very difficult for PV electrification to compete in the same arena. The lifeline tariff is not merely a barrier to the spread of PV electrification; because of this tariff scheme, the whole power sector is saddled with a backspread structure. This is to say that the power sector itself, inclusive of the ECG and VRA-NED, is facing financial difficulties.

To rectify this situation, it is vital to hike the lifeline tariff at least to the level of the bulk tariff plus alpha. This was actually done in 1998. In so doing, it is necessary to win the understanding of customers for a certain tariff hike by heightening their awareness that the (lifeline) tariff artificially held down to a low level with subsidization must be paid for with taxes of some other type, and therefore exerts a heavy burden on them in reality.

The enormous scale of the initial investment is cited as another drawback of PV electrification. In this connection, it is important to examine various measures that could lower the initial investment, including micro-credit-type loans.

A reduction in the initial investment could heighten the competitiveness of other energy sources such as biomass, kerosene, and coal. Nevertheless, off-grid electricity, unlike on-grid electricity, has the drawback of being harder to use as a power or heat source than these other energy sources. On the other hand, incentive for installation of PV systems could be increased by priority promotion of social development with use of the limited supply of electricity (e.g., in tasks such as construction of small irrigation facilities and provisioning of medical and educational facilities).