No.

Japan International Cooperation Agency (JICA)

Ministry of Electric Power
Myanma Electric Power Enterprise
Union of Myanmar

The Study on Introduction of Renewable Energies in Rural Areas in Myanmar

Final Report

Volume 8 Supporting Report

Renewable Energy

September 2003

Nippon Koei Co., Ltd.
Institute of Energy Economics Japan

M P N
JR
03 – 101

MYANMA ELECTRIC POWER ENTERPRISE
MINISTRY OF ELECTRIC POWER
UNION OF MYANMAR

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

FINAL REPORT

VOLUME 8 SUPPORTING REPORT

RENEWABLE ENERGY

SEPTEMBER 2003

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
INSTITUTE OF ENERGY ECONOMICS, JAPAN

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES
IN RURAL AREAS IN MYANMAR

Final Report

List of Volumes

ABBREVIATIONS

Organizations

DEP, DOEP	Department of Electric Power of MOEP
DHP	Department of Hydroelectric Power of MOEP
GOM/SPDC	Government of Myanmar/State Peace and Development Council
GOJ	Government of Japan
ID	Irrigation Department of Myanmar
IOE	Institute of Economics of Myanmar
ITC	Irrigation Technology Centre, Irrigation Department
JICA	Japan International Cooperation Agency
MADB	Myanma Agricultural Development Bank
MAPT	Ministry of Agricultural Products and Trade
MEC	Myanmar Economic Commission
MELC	Myanma Electric Light Co-operative Society Ltd.
MEPE	Myanma Electric Power Enterprise
MPBANRDA	Ministry for Progress of Border Areas and National Races and Development Affairs
MOC	Ministry of Cooperatives
MOE	Ministry of Energy
MOEP	Ministry of Electric Power
MOST	Ministry of Science and Technology
MSTRD	Myanma Scientific and Technological Research Department
NCEA	National Commission for Environmental Affairs
NEDO	New Energy & Industrial Technology Development Organization, Japan
SPICL	Sein Pann Industrial Production Co-operative Limited
USDA	Union Solidarity and Development Association (an NGO)
VEC	Village Electrification Committee
VPDC	Village Peace and Development Council
YIE	Yangon Institute of Economics
YIT	Yangon Institute of Technology

Government Administration

Division/State

Township

Quarter

Village Tract

Village

Economics, Finance

ATP	Ability to Pay
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product
IRR	Internal Rate of Return
WTP	Willingness to Pay

Unit

kVA	kilo Volt ampere
kWh	kilo-Watt-hour
MWh	Mega-Watt-hour (10^3 kWh)
K	Currency unit of Myanmar (Kyat)
toe	Tons of oil equivalent (10^7 kcal)
US$, $	Currency unit of USA (US dollar)
Yen	Currency unit of Japan (Yen)

Others

BCS	Battery Charging Station
FS	Feasibility Study
HRD	Human Resource Development
IPP	Independent Power Producer
MP	Master Plan
NGO	Non Governmental Organization
OJT	On-the-Job-Training
O&M	Operation and Maintenance
R&D	Research and Development
RE	Rural Electrification
SHS	Solar Home System

Exchange Rates	US$ 1.00 = K500 = Yen 120 (May 2001) US$ 1.00 = K1,000 = Yen 120 (May 2003) unless otherwise specifically noted

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

FINAL REPORT

Volume 8 Supporting Report

Renewable Energy

Part 8-1	**Biomass Power**
Part 8-2	Solar and Wind Power
Part 8-3	Inspection Memos

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES
IN RURAL AREAS IN MYANMAR

Final Report

Vol. 8 Supporting Report: Renewable Energy

Part 8-1 Biomass Power

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 BIOMASS ENERGY

1.1 Introduction

The agricultural residues such as firewood, charcoal, rice husk, cob、 and stalks of maize etc., have been used as the fuel source in homes in Myanmar. There are many kinds of agricultural residues that are produced from the output and the process of farm products. Although the quantity of such agricultural residues is extremely large, usually the value of biomass is recognized rather low, since the moisture contents are high and the collection works are not easy. Wood chips, sawdust from sawmills, bagasse (squeezed waste material out of squeezed sugarcane) from sugar mills, and rice husk from rice mills are such biomass that can be utilized as energy sources. They are used in the kitchen and restaurants as the fuel at present.

Biomass generation using steam turbine and boiler unit is applied for most of governmental sugar mills and a part of rice mill. Rice husk harnesses the rice mills and bagasse powers the sugar mills. Reportedly, there exist 15 large-scale sugar mills and 13 rice mills that are powered by this kind of system owned by the Myanmar government and provide power from 200 kW up to 3,000 kW, though some units need to be repaired. Generally, the biomass steam turbine generation systems have such characteristics as follows;

- The scale of the power generation by steam turbine units is big;
- The fuel consumption is large; and
- The construction cost is high.

Therefore it is most important to secure the installation cost and supply of the biomass as fuel. In this regard, it would be efficient that sugar mills use bagasse from sugar cane and rice mills use rice husk from paddy, so that less waste materials are produced. There are no examples of power generation unit of steam turbine by biomass combustion other than rice mills and sugar mills, because the collection of the material and its transportation is hard task that requires manpower and cost. Some sawmills installed low-pressure type steam boiler with steam engine for their sawing power using biomass of the wood chips and sawdust that produced from timber production. Howerver, most of the waste materials coming from sawmills are sold to nearby households and restaurants for cooking fuel.

Recently, a gasification system has been developed and practically used in Myanmar. It utilizes combustion gases produced from rice husk by dry distillation as a fuel of reciprocating engine and alternator after purification process of the gas to remove tar and dust. The system requires skilled operator for the process of the dry distillation and purification of the gas. Although some improvements are necessary for this system, this type of biomass-gasification power generation system would become the trump card for the promotion of rural electrification in Myanmar at this moment. The Fuel is available on site at cheap price and the construction cost is very low. Rice husk, sawdust and piece of wood, and other biomass materials can be used as long as they are easily collected in large amount for the fuel of biomass-gasification power generation unit.

Meanwhile, the research of generation technology by biomass application is prosperous to use it for the alternative energy sources of the fossil fuels such as coal and petroleum in the developed countries. The research contains steam boiler, gasification technique, and the strategy for a continuous supply of biomass energy. The prospect of the biomass energy utilization for power generation in Myanmar, blessed with plenty of water and solar energy, can be said to be bright, even some problems would be seen such as competition between forest and cultivating field or production among food and energy.

1.2 Power plants for a factory own use

The application of the power generation by the biomass energy can be summarized in the table below.

Table 1 Power Plant for a Factory Use

Factory	Biomass	Size of power plant	Power generation method
Rice Mill	Rice husk	300-1,000 kW	Steam turbine
		20 kW-100 kW	Gas engine
Sugar Mill	Bagasse	2,000-3,000 kW	Steam turbine
Sawmill	Wood chips and sawdust	200-500 kW	Steam turbine
		20kW-100 kW	Gas engine
Maize factory	Cobb and stalk	200-500 kW	Steam turbine

Note: The required size of power plant depends on a scale of the factory, amount of production, capacity of collection of raw materials, and the demand for the electric power of the factory. Generally the scale of sugar mills is large and that of rice mills is in various sizes. The electric power consumption in sawmills and maize mills are relatively small. For the power generation, generally steam turbines by biomass combustion are applied to power of factories themselves. Biomass gasification engine system is not popular at present but is promising in the future. When the ongoing gasification technology is improved, *generation by gas turbine would be also possible. The bagasse is inappropriate for the gasification system because it contains the moisture contents at more than 50% on the wet base.*

If the factory is big enough, surplus of the electric power can be supplied to the National Grid.

Usually mechanical and electrical engineers are working in these factories. They can concurrently serve the post of the operation and maintenance works for the power generation unit.

1.3 Independent power plant

Recently some trials have been made to alternate coal to biomass such as wood chips in existing thermal power plants of coal combustion, and provide the power to national grid line in European countries. The alternation of diesel oil to biomass at independent small and middle scale power plants is studied in this section.

As for biomass fuel, the quantity and the available season is influenced by the harvesting and felling of the agriculture/forest products. It is important to check the relation of these factors as shown in the following chart.

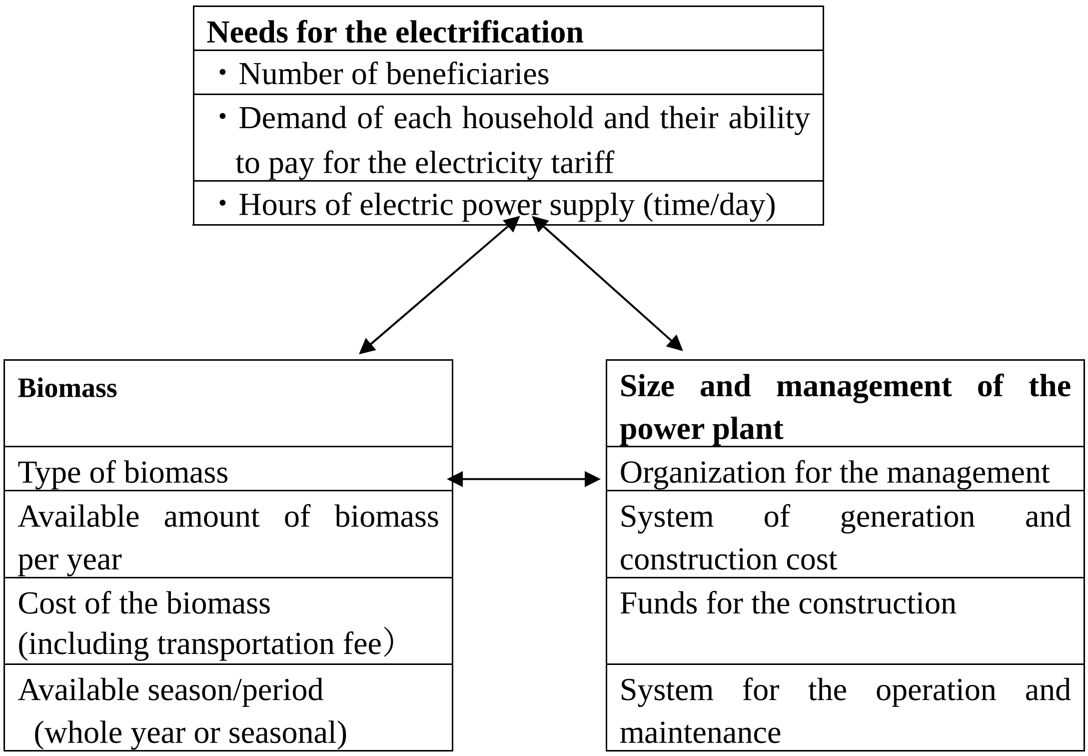


Figure 1 Required item for the electrification by biomass

2 APPLICATION AND ACTUAL CONDITIONS OF THE BIOMASS ENERGY TO POWER PLANT

2.1 Wood Combustion Steam Engine

As for sawmills under the control of Ministry of Forestry, there are 85 plants in the whole country and the amount of production is 433,300 wood-ton per year (1 wood-ton is equivalent to 50 ft^3). The biomass production in sawmills is shown in the following figure 2.

Table 2 Power Source of State Owned Sawmills

Power source	Numbers	Ratio
Steam engine	11	13%
Diesel engine	56	66%
MEPE electricity supply	18	21%
Total	85	100%

Source: Myanmar Timber Enterprise, Ministry of Forestry. 1999

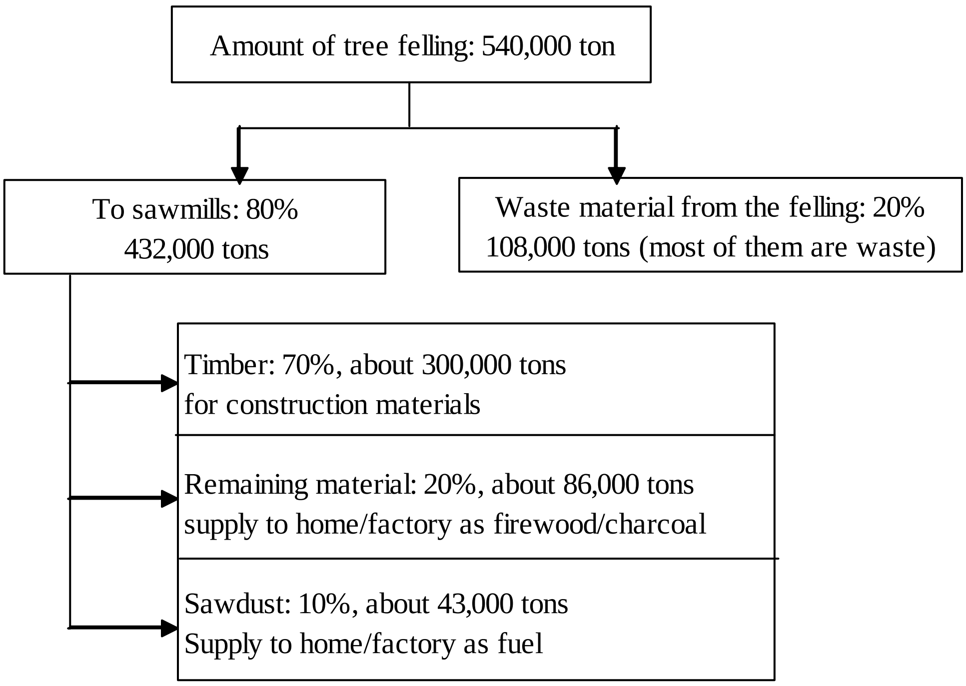


Figure 2 Timber production and wood-chips

Source: Myanmar Timber Enterprise, Ministry of Forestry. 1999

Assuming the amount of tree felling by private sawmills is the same as that of public sawmills, which the data was not available.

The gross weight of wood chips and sawdust will be:

(86,000 + 43,000) x 2 = 258,000 ton

The energy of this 258,000 ton of wood material would be equivalent to the heat energy of 1.29 billion kcal/year assuming the combustion energy of wood is 5,000 kcal/kg. This energy is equivalent to 129,000 tons of petroleum (TOE). The miscellaneous trees are felled as an integral part of forest control system in the mountainous area, other than the wood fuel supplied from sawmills.

If households in Myanmar stop using firewood, it would be possible to introduce steam turbine of wood combustion and/or wood gasification system for power generation. However, timber and charcoal will remain as the main source of fuel at homes in Myanmar for a moment.

2.2 Steam Turbine Power Generation Unit (PGU) by Rice Husk Combustion

1) Situation of the production and application of rice husk

Paddy production in Myanmar is 17.4 million ton (1997/98). As 20% of paddy weight is rice husk portion, the generation of husk is 3,480,000 tons/year. Based on the calorific value of rice husk of 3,000 kcal/kg, this amount is equal to 1,040,000 TOE. However, the actual amount of husk production that can be consumed as fuel is less than this figure.

Two types of rice mills exist in Myanmar. One is large-scale rice mills having special machines that remove rice husk from paddy prior to rice whitening process. Normally this type of medium or large-scale rice mills have a processing capacity at more than 1 ton/hour of paddy. The other type is a small-scale rice mills (capacity is around 0.5 ton/hour) where paddy is fed into a friction type chamber for rice whitening without any processes of removing husk. The latter type produces mixture of rice husk, rice bran, and small milled rice. The rice husk from the former one can be used as a fuel for combustion, but the mixture from the latter one is normally consumed as a feed of the poultry. Two to three units of this small-scale rice mills exist at each village for self-consumption of rice cultivating families. The estimated paddy amount being processed by medium and large-scale rice mills is 11,700,000 ton per year. Thus, rice husk that can be used as fuel will be 2,340,000 ton per year (equivalent to 700,000 TOE)

Most of medium and large-scale rice mills in Southeast Asian countries had equipped with husk combustion steam engine as a prime power source with intermediate axis drive method. However, rice millers are getting to replace this kind of prime engine with electric motors or driving systems by diesel engines due to the superannuating and shortage of spare parts for steam boiler and steam engine. As the result, there are huge amount of rice husk left without being used, and the disposal of the husk remains problem as an industrial waste in some countries such as Thailand and Malaysia. But brick factories, spirits distilleries, restaurants, homes and etc. in Myanmar are still using rice husk as an important fuel source and rice husk is being traded on the commercial base. However, much amount of husk still in surplus in rice producing area such as Ayeyarwaddy division.

2) Situation of Rice Husk Combustion Power Generation Unit (PGU)

There are 13 power plants installed and 12 power plants are still powered by rice husk combution PGU among 67 number of state owned rice mills.

Table 3 A list of Rice Mills Equipped With Husk Combustion PGU

	Name of Rice Mill	Division/ State	Capacity (ton/day)	Milled rice Processed		Capacity of PGU (kW)	Construction year	Project Name
				99/00	00/01			
1	Ngapudaw	Ayeyarwaddy	100	6,417	4,233	360	1987	ADB
2	Laputta	Ayeyarwaddy	100	9,907	6,105	360	1987	ADB
3	Laputta	Ayeyarwaddy	100	10,760	8,174	360	1987	ADB
4	Maubin	Ayeyarwaddy	100	9,824	8,586	360	1987	ADB
5	Bogalay	Ayeyarwaddy	75	6,068	5,263	200	1963	GER
6	Daedayee	Ayeyarwaddy	100	9,827	6,664	360	1984	OECF
7	Daedayee	Ayeyarwaddy	100	8,682	6,748	360	1987	ADB
8	Mawkyun	Ayeyarwaddy	75	10,240	6,063	200	1964	GER
9	Kanaungtoe	Yangon	150	18,952	12,568	*445	1985	OECF
10	Kwungyang	Yangon	100	10,321	5,857	360	1986	ADB
11	Kawmhu	Yangon	100	7,899	4,414	360	1986	ADB
12	Sittwe	Rakhine	75	2,493	1,780	200	1965	GER
13	Sittwe	Rakhine	75	3,207	729	200	1962	GER
Total	-	-	1,250	114,597	77,184	4,125	-	-
Total of 67 rice mills owned by the state			4,438	358,534	251,926	-	-	-
Percentage of R/M equipped with husk PGU in 67 state rice mills			28%	32%	30%			

Source: Myanma Agricultural Produce Trading, Ministry of Commerce

Note: * mark means out of order

2.3 Bagasse Combustion Steam Turbine Power Generation Unit (PGU)

1) Situation of Production and Application of Bagasse

Bagasse is a waste material of squeezed sugarcane produced in sugar mills. The weight is 25-29% of sugarcane. As its moisture contents is high as much as 50-55%, the combustion calorie is low. For the design purpose of bagasse combustion boiler, the heat value of 1,840 kcal/kg is normally applied.

The sugarcane production in Myanmar is about 4 million tons per year and the producing center is focusing on central part of Myanmar in Bago Division, Magwe Division, Mandalay District, and Shan State, and sugar mills are dotted in those area.

Myanma Sugarcane Enterprise (MSE) under Ministry of Agriculture & Irrigation owns 17 sugar mills from new one to old one (see the table in the next page). Total processing capacity is 25,600 tons of sugarcane per day. Seven sugar mills newly constructed have not been operated at full stretch, but total processing amount by state own sugar mills would be around 2,500,000 tons, equivalent to 50% of total sugarcane produced in Myanmar (5,050,000 ton)

Among 17 state sugar mills, 15 sugar mills are equipped with power generating unit of baggase combustion steam turbine. Private sugar mills are dispersed in many places in Myanmar but most of those mills are of small-scale and they are using diesel engine for the power source. These small-scale sugar mills use bagasse as the heat source for steam formation of boiler or scalding in the process of sugar juice. There seems to be no private sugar mills equipped with steam turbine power plant by baggase combustion.

Large-scale sugar mills in Myanmar have processing capacity of 1,500-2,000 tons per day in average. This size is not enough big to have a role of small-scale power producing company (SPP) in addition to power his own plant as the cases n in Thailand and Philippines. In the future, were these sugar mills to be integrated to extra-large mill having capacity of 5,000-8,000 ton/ day, it would be possible to supply his surplus electricity to the national grid of MEPE though the limited operation period of 5 to 6 months per year as SPP. If other source of fuel supply should be secured than bagasse in the season without harvest, these sugar mills would be able to operate as SPP throughout a year. State-owned sugar mills are listed in the table below.

Table 4 The outline and its PGU of state owned sugar mills

	Name of the factory	State/ Division	Capacity (Crushing capacity)	Bagasse combustion PGU	Start year	Remarks
1	Pyinmana No. 1	Mandalay	1,500 ton/day	2,000 kW	1957	Japan
2	Pyinmana No. 2	Mandalay	1,500 ton/day	2,000 kW	1984	Japan
3	Yedarshe	Bago	1,500 ton/day	2,000 kW	1991	Japan
4	Zeyawady	Bago	1,500 ton/day	2,000 kW	1986	Czecho
5	Kyauktaw	Rakhine	300 ton/day	None	1983	Netherlands
6	Shwenyaung	Shan	300 ton/day	None	1983	Netherlands
7	Bilin	Mon	1,000 ton/day	Indistinct	1966	China
8	Namti	Kachin	1,000 ton/day	Indistinct	1956	Netherlands
9	Pye Myayar	Bago	2,000 ton/day	3,000 kW	1999	Thailand
10	Dahatkone	Mandalay	1,500 ton/day	2,000 kW	1999	China
11	Taungzinaye	Mandalay	1,500 ton/day	2,000 kW	1999	China
12	Duyingabo	Magwe	2,000 ton/day	3,000 kW	1999	China
13	Paukkhaung	Bago	2,000 ton/day	3,000 kW	1999	China
14	Okatwin	Bago	2,000 ton/day	3,000 kW	1999	China
15	Myohla	Bago	2,000 ton/day	3,000 kW	1999	China
16	Okkan	Yangon	2,000 ton/day	3,000 kW	1999	China
17	Yoneseik	Magwe	2,000 ton/day	3,000 kW	1999	China
	Total	**---**	**25,600ton/day**	**(33,000 kW)**		

Source: MSE

Note: ① The PGU capacity is from actual output. Each mill has the turbine generator of 2-3 units and keeps 1 unit as a reserve unit. In Yedarshe Mill, there are 2 units of the steam turbine generator of 2,000 kW. Normally they operate the mill for 24 hours a day for 15 days and stop the operation for 2 days for cleaning of sugarcane processing lines. At the resumption, the generator kept reserve is used for the operation and the generators are used by turn. At Myohla Mill, 3 units of 1,500 kW PGU exist, 2 units are always operated, and 1 unit is kept waiting.

② The combustion energy of bagasse is insufficient in Pyinmana Mill and they have to utilize wooden materials as fuel together with bagasse. In Yedarshe Mill, meanwhile, bagasse surplus is used for a paper manufactory as raw materials. Some baggase is still remaining and is burnt in the field outside of the mill, which causes an environmental problem in Yedarshe mill.

③ 8 units of newly established Chinese mills started operation in 1999 but many mechanical problems have occurred. Therefore they cannot reach at its full operation and the maximum power output and the power consumption are not shown except for the nominal/designed capacity.

2.4 Biomass gasification engines

The biomass gasification method was curried out before the World War II for the driving power of engine. The systems takes out volatile gas (producer gas) from the biomass such as wood tip and rice husk by the imperfect combustion, reduction, and pyrolysis reaction, and utilize it as a fuel without burning the material directly. In spite of many examples tackled frequently by China and Thailand, the removal of tar in the gas which causes problem of engine plugging is so difficult that the application of the gas as the fuel for the engine was not made practical. The Science and Technology Agency of Myanmar and Myanmar Agricultural Produce Trading (MAPT) are also studying for the development of this system.

In recent years, a private company named Myanmar Innovators Cooperative Ltd. has succeeded in the commercialization of this device and it has been sold at 100 or more sets mainly to rice mills since 1995. As for this domestic product in Myanmar, some devices are made for the cooling water application and cleaning the gas. They apply rice husk itself for the filtering material in a filter of a refinement process (purification) of the producer gas which comes from the rice husk in the gasifier. The combustion chamber and the cleaning equipment of the gas are all made locally and they remodeled second-hand diesel engines from automobiles, and attached ignition system of spark plug to it.

One of the rice mills has already used it for more than 3 years continuously. Reportedly, they also have supplied this system to the gold mine where the producer gas formed from sawdust and lumber chip discharged from a sawmill is supplied to a reciprocating engine. It enabled the electrification of the actory and peripheral area.

The cost of this rice husk gasification engine and equipment is cheap and no maintenance expenses are needed such as water treatment for steam turbines. It can be mentioned that this system is the most suitable for the small/medium-scale electrification by the renewable energy application in Myanmar. The product list of the manufacturer is shown in the following table.

Table 5 The Product List of Rice Husk Gas Engine by MIC (Mar,2002)

Name of the Model	Output (kw)	Price (1,000Kyat)	Consumption of Rice Husk Per Hour: Number of Baskets	Consumption of Rice Husk Per Hour: (kg/h)	Rice Husk per Output (kg/kWh)
RH-3	13.5	2,028	4	21	1.54
RH-4	14.5	2,148	5	26	1.79
RH-6	23	3,138	7	36	1.58
RH-10	30	4,337	12	62	2.08
RH-15	65	8,694	18	94	1.44
RH-18	75	10,212	22	114	1.53
RH-20	85	11,647	24	125	1.47

The source: Myanmar Innovators Cooperative Ltd.

Note: ①"Basket" is commonly used as a unit to measure the amount of rice husk. One basket weighs about 5.2 kg.

② In the test data in Japan (Agriculture Mechanization Research Institute), to obtain the power generation of 1kWh, it requires 3-5kg of rice husk but 2.0-2.2kg is indicated in China.

③ It is necessary to scrutinize actual relation between the fuel consumption rate and power generation of the unit in Myanmar.

As mentioned in chapter 2.2, the rice husk discharged from commercial rice mills is estimated at 2,340,000 tons per a year. 2,340,000 tons of rice husk is equal to 1,064 GWh, when 2.2 kg of rice husk is required to produce 1 kWh by the gasification engine tentatively. This corresponds to as much as 21% of MEPE's total power generation of 5,020GWh in whole country in the fiscal year of 2000.

In addition, the gas volume discharged by the gasification of 1kg of rice husk is approximately $1m^3$. The combustion energy of this gas is 1,000 to1,300 $kcal/m^3$ (gasification efficiency is 30-33%). On the other hand, the low calorific value of rice husk is generally set to be 3,000 kcal/kg for steam turbine power generation. It can be said that most difference of the calorific value between gasification (1,000-1,300kcal/kg) and combustion (3,000kcal/kg) remains in the ash of husk as fixated carbon. Agriculture Mechanization Research Institute of Japan had an experiment that makes tar contained in producer gas is collected, dried, combined with husk ash, and made into charcoal briquette. If this technology is to be spread in Myanmar, it will be possible to utilize the briquette as an important heat source for cooking in household and small commercial use.

Also, it would be effective to some extent to decrease the amount of felled trees and prevent deforestation.

Following table shows the number of large scale rice mills in each state/division in Myanmar and the ability of power generation by producer gas engine generator using rice husk being discharged from these mills.

Table 6 Large Scale Rice Mills in Myanmar

Upper: Private Sector (Source: Myanmar Rice Millers Association)

Lower: State Enterprise Owned by MAPT. (Source: Myanmar Agricultural Produce Trading, MAPT)

No.	Capa/24hrs / State/Division	10<	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-70	71-75	76-100	100<	Total	
1	Ayeyarwaddy	0	228	175	87	53	12	14	22	16	5	8	0	0	1	2	623	642
		0	0	0	0	0	0	1	0	2	0	0	0	4	0	12	19	
2	Bago	0	123	34	79	15	1	17	3	9	2	3	2	0	0	0	288	303
		0	0	0	1	0	0	2	0	3	0	0	0	4	0	5	15	
3	Yangon	0	127	22	21	6	1	16	2	4	0	1	0	0	0	0	200	212
		0	0	0	0	0	0	1	0	1	0	0	0	2	0	8	12	
4	Sagaing	2	20	37	49	6	0	0	0	1	0	0	0	0	0	0	115	121
		0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	6	
5	Mon	2	65	7	7	9	0	8	3	0	1	1	0	1	0	0	104	104
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6	Mandalay	4	58	5	8	4	0	3	0	0	0	0	0	0	0	0	82	82
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
7	Kachin	14	12	0	1	3	0	0	0	0	0	0	0	0	0	0	30	31
		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	
8	Magway	0	9	2	14	2	0	0	0	0	0	0	0	0	0	0	27	29
		0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	
9	Tanintharyi	0	15	1	1	0	0	0	0	0	0	0	0	0	0	0	17	17
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	Rakhine	0	13	0	1	0	0	0	0	0	0	0	0	0	0	0	14	25
		1	2	0	4	0	0	1	0	0	0	0	0	3	0	0	11	
11	Kayar	0	2	3	2	0	0	0	0	0	0	0	0	0	0	0	7	8
		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	
12	Shan	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Total ･Private	27	672	286	270	98	14	58	30	30	8	13	2	1	1	2	1512	1579
	Total ･State	1	2	10	5	0	0	5	0	6	0	0	0	13	0	25	67	
	TOTAL	28	674	296	275	98	14	63	30	36	8	13	2	14	1	27	1579	

Note: 1. The capacity of rice mill indicates the amount of white husk production per day, supposing continuous operation of 24 hour/day.

2. Data of private mills in each Division/State is derived from Cooperatives of Rice Mills. The liability of this data and the number of rice mills other than the member of the cooperative is unclear. The amount of processed paddy and operation days per year of each mills are changing depending on year and place.

3. It is said that there are 20,000 rice mills for the self-consumption of farmers domestically. No husk discharged from them is used for fuel, as they are mixed with rice bran and used for the feed of poultry.

4. Rice husk discharged from rice mills is not only used for the household fuel but also utilized widely for the fuel for the boiler of alcohol distillation, unglazed pottery, brick factory, and so on. It is important to study the consumption of those factors in addition to the amount of available rice husk when husk is used for the resource of power generation.

Table 7 Number of Potential Power Generating Unit (PGU) by Size in State/Division

No.	Rice Mill Capacity	10<	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-70	71-75	76-100	100<	Total
	Av. Capacity	5	13	18	23	28	33	38	43	48	53	58	65	73	88	150	
	Size of PGU(kW)	10	20	30	40	50	60	65	70	80	90	100	110	120	150	260	
1	Ayeyarwaddy	0	228	175	87	53	12	15	22	18	5	8	0	4	1	14	642
2	Bago	0	123	34	80	15	1	19	3	12	2	3	2	4	0	5	303
3	Yangon	0	127	22	21	6	1	17	2	5	0	1	0	2	0	8	212
4	Sagaing	2	20	43	49	6	0	0	0	1	0	0	0	0	0	0	121
5	Mon	2	65	7	7	9	0	8	3	0	1	1	0	1	0	0	104
6	Mandalay	4	58	5	8	4	0	3	0	0	0	0	0	0	0	0	82
7	Kachin	14	12	1	1	3	0	0	0	0	0	0	0	0	0	0	31
8	Magway	0	9	4	14	2	0	0	0	0	0	0	0	0	0	0	29
9	Tanintharyi	0	15	1	1	0	0	0	0	0	0	0	0	0	0	0	17
10	Rakhine	1	15	0	5	0	0	1	0	0	0	0	0	3	0	0	25
11	Kayar	0	2	4	2	0	0	0	0	0	0	0	0	0	0	0	8
12	Shan	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
	TOTAL	28	674	296	275	98	14	63	30	36	8	13	2	14	1	27	1579

Calculation:

Av. Capacity:	Average Capacity of the Rice Mill in White Rice output per 24hours operation per day.
	Milling Recovery (White rice amount from paddy) is 0.61 as per MAPT's standards.
Husk disposal per Hour:	(Av. Capa ÷ 0.61) ÷ 24 hours x 0.2
	Husk amount is approx. 20% of paddy weight
PGU capacity:	1 kWh requires 2.2kg of husk by Gas-Engine, thus husk amount ÷ 2.2kg/kWh = Electric power output
Plant Factor:	0.4. Therefor (PGU Capacity) ÷ 0.4 = Size of Power Plant
Example:	23 ton rice mill
	Paddy amount can be milled per day: 23 ÷ 0.61 = 38 ton/24hr (1.58 ton/hour)
	Husk amount can be available per hour: 20% of paddy (1.58 x 0.2 = 0.316ton = 316kg)
	Electric power generation capacity: 2.2 kg of husk can generate 1 kWh ; 316 ÷ 2.2 = 143kW
	Rice mill operation rate: 8hours/24hrs and 120days/365days ; 143kW x (8/24) x (120/365) = 16kWh
	Power factor is 0.4: Power Plant is ; 16 ÷ 0.4 = 40kW

The number of the rice mills by State/Division is derived from the List of Rice Mills in the table above. To assess the power output from rice husk, the following calculation is applied;

1) The processing capacity of the mills is presented as the amount of polished rice produced in 24 hour/day operation.

2) The amount of polished rice is converted into the amount of rice paddy, and the production of the rice husk is calculated. The yield rate of rice husk out of rice paddy is 0.61, the standard value used in MAPT.

3) The yield of rice husk is assumed from the amount of processed rice paddy per hour. 0.316 ton of rice husk is produced from the rice paddy processed at 1.58 ton per hour, where the ratio of the weight of the husk is 20 % of that of rice paddy.

4) The power generation from a rice husk gas engine is assumed that 1 kWh is generated from 2.2 kg of husk according to the information of MIC. (The study[*1] shows the required rice husk for the generation of 1 kWh is about 5 kg. Considering this data can be applied to Myanmar, the power output is assumed about half of the assumption above. MIC have studied the actual output for the rice husk gas engine.

5) The calculation above does not contain the consumption of the power for the factory-own use. It is supposed that the rice mill utilize the half production of rice husk for the driving power of the mill during eight hours operation. The rest of the biomass is suggested to be consumed for the electrification of the village in the nighttime according to the demand and availability of rice husk. When the amount of rice husk is insufficient, it is necessary to collect rice husk from peripheral areas. It is important to study the demand of the village, milling capacity of the mill and the amount of production of husk, and the location of the rice mill.

3 POSSIBILITY OF THE RURAL ELECTRIFICATION BY BIOMASS ENERGY APPLICATION

3.1 Comparison of the Biomass Energy in Rural Electrification (RE)

Regarding the electrification of rural area, rice husk is the most advantageous among biomass energies based on the present condition of Myanmar as shown in the following table. The application of wood chips and sawdust from the sawmills for the RE is also considerable in the near future.

Table 8 Comparison of the biomass energy for RE

Type of biomass	Availability (Low calorific value)	Application at present	Possibility of the fuel for RE
Rice husk	2,340,000 tons (7×10^{12} kcal)	Power source of rice mills (steam engine) Fuel for cooking stove in a home Fuel for other industries (alcohol brewery, brick factory, dairy products)	● Large possibility in the area where rice husk is available. ● Small possibility in the area where rice husk is insufficient, due to collection and transportation problems. ● It is possible to supply electricity through a year, depending on the operation of rice mills.
Bagasse	1,300,000 tons (2.4×10^{12} kcal)	Fuel for a boiler of sugar mills (The surplus bagasse is used as a material of a pulp factory)	● Most of the bagasse is self-consumed in the factory. ● Bagasse is able to be supplied only for 5 to 6 months per year. ● Application for RE is inappropriate.
Wood chips and Sawdust	258,000 tons (1.3×10^{12} kcal)	For the fuel at home /restaurants For other industries	● The demand as the fuel for home is very high. ● Possibility in the future is very high.
Others		Fuel of farmhouses	● Collection of material and seasonal fluctuation would be problems

3.2 Biomass application for RE at rice mills/sawmills periphery

At present, as for application of biomass power generation in Myanmar, there are two kinds of the ongoing power generation systems, that is steam turbine method by biomass combustion and engine-drive method by biomass gasification. The characteristics of those two methods can be compared as seen in the table below.

Table 9 Comparison of the Characteristics of Steam Turbine and Gasification Engine

	Steam turbine		Gasification engine	
Type of biomass	Rice husk	Bagasse	Rice husk	Sawdust (Wood chips)
Power generation (kW)	360, 450	2,000-3,000	15-100	20
Operational condition	State owned 8 rice mills (MAPT) are under operation 10-12 hours operation per day, 200 days operation per year in average	State owned 15 sugar mills (MSE) are under operation 24 hours operation per day, 150 days operation per year in average. (Continuous operation for 15 days and 2 days for the maintenance)	Several private rice mills use PGU Introducing RE in Ayeyarwaddy and Kachin 5-6 hours power supply per day (details are not known)	1 site of the gold mine has this PGU. MIC installed two sets in Kachin and Shan State.
Characteris-tics	PGU is installed for the self-consumption of the rice mills independently. It is not used for RE except for the power supply to accommodations for the workers. Construction cost: US$3,000/kW in around	PGU is installed for the self-consumption of the sugar mills independently It is not used for RE except for the power supply to accommodations of workers. Construction cost: US$2,000/kW in around	Mainly used for the power source of rice mills. Recently it is introduced to RE. Operation & maintenance system need to be established. Construction cost: US$4-800/kW in around	The self-consumption power source for the gold mine. Wood materials as fuel seems to be cut in the periphery forest around the mine.

Advantage in RE	It is possible to provide the power to the national grid in addition to the self-use when a high efficiency PGU is introduced. Planning continuous operation is possible.	Same as the left column.	It is possible to introduce PGU in accordance with the needs and availability of biomass. Construction cost is low	Same as the left column
Problem in RE	Power supply for RE is not possible when the operation is paused.	Same as the left column	Fuel, operation engineers, and management group need to be secured. Construction funds need to be procured. Continuous power supply hours per day is limited.	Same as the left column.

3.3 Biomass Gasification Power Generation at Rice Mills & Sawmills Periphery

3.3.1 Advantages and Disadvantages of Biomass Gasification engines

(1) Advantages

- Local Technology

Biomass gasification is the local technology and is manufactured domestically in Myanmar. The gasifier is fabricated by the local producer, which enables both installation and repair of the gasifier unit with lower cost and shorter time than the international traded products. On the other hand, as the engine is generally imported or obtained as second handed one, the parts of the engine for repair is sometimes difficult to obtain.

- Locally available and renewable fuel

It utilizes local energy of waste materials that is produced from water, minerals from soil, and sun shine. Although the materials such as saw dust and rice husk is used as fuel in homes and industries, the price of the fuel is much less than fossil fuel and it saves foreign currency that is required for importing fossil fuel used for power generation.

- Continuous operation

Operation is possible to be held continuously at maximum 20 hours/day, depend on the fuel availability and engine condition.

- Low installment cost

The installment cost, 400-800 $/kW, is lower than other renewable sources of solar and wind. Different from solar and wind power, the cost would be lower than the maximum level for villagers that is managed to be prepared by themselves.

(2) Disadvantages

- Secure of the fuel

Fuel must be secured and managed in accordance with the consumption. Usually rice husk produced minimum before paddy harvest season. It requires a storage to prepare the annual consumption so that not to run out the rice husk in the shortage season.

- Labor work and maintenance

The system has to be operated by a trained engineer. Regular removal of tar and clean of the system is necessary.

- Ventilation

Producer gas contains much amount of carbon monoxide, which is hazardous to the health combining with haemoglobin and preventing oxygen absorption and distribution in the blood. Although there is little possibility that the gas could leak from the gasifier system, the operation house should be enough ventilated in case.

- Transportation

Rice husk is bulky, for the specific weight is about 0.1 and the transportation of rice husk is costly and time consuming. The power house should be located to be near the place where the biomass is produced such as rice mill.

3.3.2 Technical Matters to be Considered

(1) Tar

The producer gas formed from gasifier contains tar, which causes the trouble of plugging the engine. Tar is very sticky and adhesive material consists of hydrocarbon compounds mainly heavier than benzene. This tar problem has been an obstacle of the development of biomass gasification technology.

Daily maintenance is necessary such as cleaning, removal of tar in the gas pipes and towers, and changing rice husk filters.

As for the study of tar removal, Termiska, Swedish company, has commercialized biomass gasification system with tar-cracking unit using dolomite. Tar cracker is set at 900 degree-C in the gasifier before the producer gas is induced into the cyclone for removing dust in Biomass Integrated Combined-cycle, circulation fluidised gasification system.

Dolomite is a mineral consists of carbonate and magnesium calcium, and it behaves as a catalyst in the reaction for the decomposition of tar. Catalytic tar removal is said to be one of the most efficient ways to clean the producer gas.

The other way for removing tar is to inject moisture and air of high temperature (400-1000 degree-C) in the reformer and decompose the tar into CO and H_2[*4]. This system requires rather complicated equipment and higher installation cost.

In Japan, they have developed the dry system of the gasification, which does not discharge wastewater in consideration of the environmental problem. The tar mixed in the gas is removed by the combination of cyclone and water spray system to the outside of the gas pipes and husk filters.

The technology that produces ash-briquette, mixing the ash with the tar, separated from the gas had been achieved. If this ash-briquette is supplied in stable as the cooking fuel to households, it would have some contribution to the prevention of the deforestation being caused by the collecting the wood materials by households.

- Ash

Some farmers take out the ash and use it as a fertilizer. The black material consists of silica, carbon, minerals, and other organic materials.

If the ash is formed by a perfect combustion of rice husk, most of the component would be a silicate and the color of the ash would become white. However, the ash from the gasifier is black. Much amount of carbon is supposed to remain in the husk after gasification. This carbon content and mineral contributes soil improvement.

Basically the ash from partial combustion contains plenty of potassium and is used as a fertilizer for gardening. Moreover, the use of ash produced by incomplete combustion of rice husk can improve permeability and effluence of the water in the soil.

However, the waste water discharged with the ash may contain phenol-like compounds. Microorganism remediation is tested for the treatment of waste water in gasification experiment in Philippines[*2]. Further study would be needed to assess detailed environmental effect.

Table 10 Composition of Rice Husk Charcoal and Ash

Components	Rice Husk Charcoal Weight (%) *	Ash Weight (%) **
SiO_2	51.55	93.21
C	30.82	N.A.
K_2O	1.34	1.52
Na_2O	N.A.	0.3
CaO	0.14	0.51
MgO	0.20	0.07
Fe_2O_3	1.95	0.45
P_2O_5	N.A.	2.65
SO_3	N.A.	0.42
Cl	N.A.	0.15

Source: * Fertilizer Analysis Association, Japan. **
N.A.: Not analyzed

- Spear parts

The power generation system of biomass gasification made in Myanmar uses second-handed diesel engine that was procured in a market in Yangon city. It is suggested that an organization should be set up for the supply of the spare parts of second hand engines.

- Consumption of biomass

The rice husk is widely used as the power sources of rice mills, the heat source for alcohol brewery, brick factory, and for the cooking fuel of homes in surrounding areas. Accordingly, it is necessary to check the consumption of the rice husk that has been required in addition to the location of the rice mills in detail, when the construction of rice husk gasification power plant is planned. However, if the rice mill uses an old fashioned smoke-cube boiler and a steam engine of which heat efficiency is very low and consumes a lot of husk, it is possible to utilize husk from this rice mill for RE by exchanging the smoke-cube boiler to the gasification engine.

- Technology improvement for the large scale generation

It will be necessary to improve and enlarge the existing local gasification system. The study of the high voltage system such as 6 kV transmission line from the powerhouse of gasifier to the site will be needed. Furthermore, it may be necessary that the technical test of the synchronous power generation of the plural power stations with biomass gasification engine be examined.

4 SELECTION STANDARD AND THE PRIORITY FOR RE BY BIOMASS GASIFICATION

4.1 Factors of RE site selection

For planning and executing biomass gasification PGU by an organization for electrification such as village electrification committee, following factors must be considered and clarified.

(1) Strong Willingness to the Electrification.

This is the most important factor in terms of sustainability. Building up an electrification committee, operation, maintenance, funding, collection of tariff, etc.., are all dependent on this issue.

(2) Willingness to Pay for the Electricity

It is important for villagers to have the willingness and ability to pay for both installation cost and monthly tariff for maintenance. The initial cost per household would be 50$ to 150$, depend on the size and number of the household of beneficially.

(3) Size of the Village

It is preferable that the number of the household of the village should be more than 200, otherwise the allocation of capital cost per a household become large. Generally, the larger number of households participate and the more concentrated they live, the smaller the amount of the allocation for each household would be.

(4) Secure of the Fuel

Biomass resources for generation must be secured continuously throughout the year. There should be rice mills or sawmills beside the powerhouse and the output of agricultural residuals such as rice husk and wood materials are available from them. They have to secure the biomass of daily consumption, annual consumption, and place and building for storage.

(5) Human Resource

The operation/maintenance engineer(s) of the biomass gasification PGU must be selected from the target village. Line engineer, tariff collector, and accountant would also be necessary. Cooperation of rice mill/saw mill owner is important.

4.2 The Standards for the Priority of RE by Biomass Gasification PGU

Considering the factors discussed in chapter 4.1, the following would be the standard for the site selection of the village electrification.

(1) Governmental development priority area or the area of JICA development plan

(2) Areas that high cost efficiency is expected

(3) Influence on the adjacent areas is expected to be large, for example, along the main road.

(4) Effects of the economic development by RE is expected such as an introduction of the agro-industries

5 POWER GENERATION BY BIOGAS APPLICATION

5.1 General Aspect

Generally the gas produced from biomass by a microbial process of anaerobic fermentation process (methane fermentation) is called “biogas”. It is different from producer gas formed from the pyrolysis of biomass gasification. Biogas is used as a fuel for heating, cooking, and generating electricity. Biogas introduction as a fuel for the cooking is advanced in China and India and large plants are installed in Europe, especially in Germany. It can be applied for broad variety of generation, from a few kW to a scale of MW. Power generation plants using biogas and refueling facilities for the gas engine are also under operation by a large-scale facility of methane production in the world. In Europe, on the other hand, the introduction of the fermentation facilities is being promoted for the processing of organic disposals and the excreta of livestock for the prevention of global worming in recent years. It is said that a lot of plants of large scale power generation use biogas, produced from excreta of livestock, agricultural residues, commercial kitchen garbage, home kitchen refuse and etc. In Germany, the segregated disposal is performed thoroughly, which enables large-scale biogass power plant using excrete of milk caw, agricultural residuals, commercial and domestic raw materials. There are more than 1,000 units of biogass power plants installed in Germany by the year of 2,000.

This gas is made of 50 to 70% of methane gas, which is a main combustible component. The rest mainly consists of carbon dioxide, small component of ammonia, hydrogen, nitrogen, oxygen, and hydrogen sulfide at 6-8%. This gas has calorific value at 5,500 to 6,500 kcal/m^3, which corresponds to the half of city-provided gas or 1/4 of propane gas. Biogas fermentation is held in a strict anaerobic (oxygen free) condition and produced in an airtight fermenting tank with biomass such as excrement of livestock and human being, agricultural residues, kitchen garbage, waste from beer industry, etc., inside it. The produced methane gas is stored in a gas holder and is consumed for cooking, hot water supply, and heating.

The advantages of biogas is low NO_x is exhausted from the engine using biogas after combustion. It was about 1/3 that of natural gas when it is used as a fuel of engine. Biogas contains H_2S, which causes erosion of pipe and equipment and would be a source of SO_x. H_2S can be removed by absorption of iron oxide.

5.2 Large Scale Biogas Plant

One example for large-scale biogas plant consists of 2 units of each 630 kW, total 1,260 kW, and 1,700 kW hot water supply system. It is operated by 2 units of 3,300 m^3 fermentation tank, processing 13,000 tons of organic industrial wastes, 15,000 tons of classified raw garbage, tons of and 57,000 tons of agricultural residues per year. The component of the biogas and its amount is variable depending on the type of biomass source and the condition of fermentation such as temperature and time. The production of biogas fluctuates widely by the type of organic source. Also, in order to maintain the biogas production constant every day, the residue and other processed materials is treated appropriately, the biomass is supplied continuously, and the temperature control and stirring in the tank is operated properly.

The average production of the biogas obtained from 1 ton of biomass material is shown in the table below.

Table 11 Volume and Heat Capacity of the Biogas Obtained from 1 ton of the Biomass

Type of the material	Organic composition	Amount of produced biogas (unit: m^3/ton)	Heat value (unit: 10^3 kcal)	Amount of kerosene conversion (unit: liter)
Home food residues	Carbohydrate, protein, lipid	150-240	900-161	101-161
Drain sludge	Carbohydrate, protein, lipid	17-22	102-132	11-15
Margarine	Vegetable oil 90%	800-1,000	4,800-6,000	539-674
Fish oil	Lipid 30-50%	350-600	2,100-3,600	235-404
Livestock residue	Carbohydrate, protein, lipid	50-70	300-420	33-47

Note: Heat capacity conversion, the heat capacity of biogas as 6,000kcal/Nm^3 is used.

The heat balance of the above Germany case is be calculated as follows.

Table 12 Heat Balance of Biogass

Biomass	Processing amount/year	Processing amount/day	Gas Production/day	Calorific value/day
Industrial waste (organic nature)	13,000 ton	35.6 ton	3,560 Nm^3	21.36×10^6 kcal
Collected raw garbage	15,000 ton	41.1 ton	4,110 Nm^3	24.66×10^6 kcal
Agricultural residue	57,000 ton	156.2 ton	15,600 Nm^3	93.72×10^6 kcal
Total	85,000 ton	232.9 ton	23,290 Nm^3	139.7×10^6 kcal

Note: The amount of gas generation is calculated as 100 Nm^3/ton.

1) Yearly discharged biomass: 85,000 ton, the average is 232.9 ton/day
2) Output:

Power generation: 630kW x 2 units = 1,260 kW x 860 kcal/kW

= 1,083,600 kcal/24hrs = 26.0×10^6kcal

Hot water supply: 1,700kW x 860kcal/kW = 1,462,000 kcal/24hr

= 35.1×10^6 kcal

Total: 61.1×10^6 kcal/24hr

3) Heat efficiency: output ÷ calorific value

= 61.1×10^6 kcal/24hr ÷ 139.7×10^6 kcal x 100

= 43.7%

In order to construct biogas combustion power plant in rural areas in Myanmar, the collection of biological scrapped material is necessary to curry out constantly with a regular amount every day. Same as the case of biomass combustion power plant, for the introduction of biogas generation device and combustion power plant, it is necessary to investigate the available quantity of biological materials and its gasification plan in such areas. It would be easier if there are large scale hog raising facility, poultry farming, or cow farming. However, the utilizing system of the organic disposals may be commercialized first as the solution plan of the raw garbage processing of Yangon or Mandalay cities in Myanmar.

5.3 Small Scale Biogas Application

The advantages of small scale application are as follows;

1) Easy construction and low installation cost;
2) Easy maintenance and operation as there is no moving machinery;
3) Heat loss is low as it is a closed system;
4) Fermentation is held around 20℃, and no temperature control is necessary.

In Myanmar the mean temperature is rather high, which is advantage for biogas production as the bacteria is more active in higher temperature and the production of the biogas is increased. However, generally, the component of the methane fermented in the high temperature become less than that of low temperature. The amount and ingredient of the input of material may need to be adjusted.

This system is also suitable for household use who have ability of preparing the materials and costs. For village electrification, the collection of raw materials would be difficult.

Reference

1. Studies on the Development of a Rice Husk Gasification and Utilization System, Hironoshin Takao, Toshizo Bam, Kotaro Kubota, 1990, Technical Report of the Institute of Agrivultural Machinery No.25
2. Project Report, "Wood-Waste/Agri-Waste Gasification for Power Generation Project" Mar. 2002, Engineering Advancement Association of Japan, Industrial Technology Development Institute, Philippine
3. "Efficient Power Generation from Wood Gasification", Ichen -3h5 Conference paper, Michel Morris and Lars Waldheim, TPS Termiska
4. "Small Scale Gasification and Power Generation from Solid Wastes", Kunio Yoshikawa, 2001 International Joint Power Generation Conference

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

FINAL REPORT

Volume 8   Supporting Report

Renewable Energy

Part 8-1	Biomass Power
Part 8-2	**Solar and Wind Power**
Part 8-3	Inspection Memos

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES
IN RURAL AREAS IN MYANMAR

Final Report

Vol. 8 Supporting Report: Renewable Energy

Part 8-2 Solar and Wind Power

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER1 INTRODUCTION

Both of photovoltaic (PV) and wind power generation system are considered as one of the major options for remote area electrification respectively. However, as the processes of remote area electrification may be completely different among target countries or regions, the details on their background about the variation of current economical conditions have to be sufficiently investigated and analyzed prior to decide the way of electrification.

The reconnaissance was conducted in limited areas in the study. The actual conditions of the rural areas were investigated from the point of possibilities of electrification with PV or wind energy. It lead us easy to recognize that the current system of battery charge station (hereinafter, BCS) for small electronic utensils such as lighting has been prevailing widely not only in non-electrified areas but also in electrified ones.

On the one hand, there exists a social system of BCS where batteries are charged by the grid power for lighting in the electrified regions and those charged by diesel engine generators in non-electrified regions, though this is small number. There also exists an additional social system of battery recycle shop (BRS), of which function is to recycle innumerable numbers of expired batteries, and to reproduce and put them into the domestic market. It captures our attention that combined systems of those two have been widely prevailed in Myanmar.

The current conditions of the rural areas in Myanmar would be summarized as follows:

1. Almost all rural villages form a type of concentrated colonies;
2. The battery could be an extremely effective way as a small-scale power supply for lighting or other small power demand of electric utensils; and
3. Bad conditions of roads make it impossible even for local residents to get access to such isolated areas. Especially during a rainy season there may happen entire disruptions of commuter service among villages in the remote areas. Generally speaking, the transportation of fuel to such regions may be extremely disadvantageous.

The PV or wind powered BCS which basically requires no supply of energy other than renewable energy will become effective in the electrification of isolated areas in Myanmar very much. Therefore, the current BCS is focused by JICA Study Team through the reconnaissance. There would be no question that these systems of BCS and BRS will jointly play more important role to the local electrification in Myanmar in the future. Moreover, the way of the application of BCS system for the new and local electrification business will occupy an important position for PV and wind power generation systems.

Table 1 Site Reconnaissance

Survey No	Stage No	Duration	Locations of Reconnaissance
Survey-1	1st Stage	2/12-16	Bago, Mandalay, Sagain
	2nd Stage	2/26-3/1	Rahkinne(Thantwe, Taung-gok)
	3rd Stage	3/9-14	Kachin(Mitkyina, Putao)
Survey-2	4th Stage	5/18-20	Ayeyarwady(Pathein, Chaung Tha)
	5th Stage	5/27-31	Sagain(Monywa), Magwey(Potta)
	6th Stage	6/4-6	Kachin(Putao, Machambau)
Survey-3			No Site Reconnaissance

CHAPTER 2 SOLAR AND WIND POWER GENERATION IN MYANMAR

2.1 System of Battery Charge Station

Because the electric power demand and supply circumstances in Myanmar have been stringent due to the chronic electric power shortage, MEPE limits the supply of electric power, for example three hours a day, by operating diesel power stations and (small) hydro power plants in most of local cities except very small number of large cities such as Yangon or Mandalay. Moreover, there may be some risks of damages in electric or electronic appliances due to frequent and large fluctuations of voltage even when the grid power is supplied. Not only lighting tools but also radio-cassettes or televisions, etc., are commonly used in spite of a poor power supply.

These tendencies for using electrical appliances are accelerated by using indigenous batteries in every area, whether it is electrified by the grid or not. In a word, batteries are charged at nearby battery charge stations (BCS), and considerably used widely as so-called "mobile power suppliers" in Myanmar. This BCS system has deeply taken root in the Myanmar society as one of the most simple electrification systems. The BCS system has been practically approved in the background of the Myanmar society, "the people’s hope for electrification could not be realized easily".

The features of current BCS is as follows:

- Capacity of battery: 12V and 5-30 Ah;
- Price of new purchase: around US$3 or K1500; and
- Battery charge fee: US$0.03-0.1 or K15-50.

As for the power source of charging batteries, the grid power supply is mainly used in the regions where it is available. In regional cities, however, diesel generators (DG) are usually operated for charging along with the grid power due to a limited power supply such as three hours a day. In the regional areas, isolated DG is the only way of charging batteries.

The usages of batteries are completely different in user's financial condition. Their applications are extend from 3 W bulb or fluorescent lamps of 6-8W to radio-cassettes and televisions supported with inverter sets. The capacity of the batteries varies according to the type of electric appliances. The batteries bigger than 12V and 50Ah classes are normally applied for TVs, and some of wealthy families have been enjoying TVs for long time by two or more batteries in their homes.

2.2 Battery Recycle Shop (BRS)

In the background of the BCS system spread widely in Myanmar, the existence of the BRS system helped the development and dissemination of BCS widely in this country. The BRS can supply recycled batteries for customers easily at a reasonable cost. In this respect, it can be said that the BCS system has developed together with the BRS system, and that the relation between them would be just the same as the one between two wheels of a car.

Usually not a few BCS owners run BRS too, but constant supply of new batteries into the market indicates that the number of BRSs is a smaller than that of BCSs. According to the example of the town area in Taung Gok Township in Rakhine State investigated in the Study, there are 12 numbers of BCSs, and eight of them were running BRSs. This shows that there exist so many BRSs of which presence is essential to the dissemination of the BCS in Myanmar.

As in Myanmar, most of relatively small batteries used for lighting and radio-cassettes can be reproduced. Almost all materials are to be used for renewal, and only used electrolyte liquid is to be thrown away.

On the other hand, lager size car-batteries (12V and 75Ah or more) are mainly used to supply power for TV sets. Several electrodes manufacturing companies in Yangon and other cities buy used electrodes from BRSs and supply renewed plates for battery reproduction in Myanmar market again. Other materials such as lead electrode heads are to be renewed at local BRSs, and to be used again as battery parts. The containers are washed. Lead material such as electrode heads is dissolved after cleaning, and cast into the electrode heads again.

It does not seem that a uniform quality could be obtained in renewed products because all works other than the electrode reproduction are done by a home industry system, and some improvements of quality are necessary.

Typical BCS Powered by MEPE Grid in Bago

Business of Transporting Charged Batteries to Customers

Typical BCS Powered by Diesel Generator

Many Batteries Charged in Serial Connection

Battery Charger

Parallel connection should be adopted to avoid damage (deterioration) to batteries in good conditions.

Figure 1 Typical Battery Charging Station

Electrodes Heads from Recycled Lead

Piled-up Battery-Electrodes Reproduced by national companies in Yangon

Stocked Raw Materials of Lead

Lead Bars for Connecting Electrodes

Recycled Battery

Figure 2 Primitive, Simplified Method of Battery Reproduction with Recycled Materials

2.3 Solar Power

2.3.1 Solar Irradiation Potential

(1) Data of Solar Irradiation and Sunshine

Myanmar is located in the southeast of the Asian continent, and there are two seasons, the rainy season (April to October) and the dry season (November to March), but solar irradiation is rich all year round. Especially, because of long continuation of fine days in the central dry zone (CDZ), the solar energy could be abundantly applicable in CDZ. However, solar irradiation data is so limited in Myanmar that only the "sunshine-hour data" collected and arranged by Department of Meteorology and Hydrology (DOMH) can be applicable at present.

There are some of joint researches concerning PV and wind Power generation, undertook by New Energy and Industrial Technology Development Organization (NEDO Japan) and Myanmar Governmental Agencies in the past several yeas. NEDO data output could be applicable together with the original DOMH data. Table 2 shows the meteorological data about solar irradiation and sunshine-hour.

Table 2 Myanmar Solar Data Cited in Published Documents

Location	Insolation	Energy	Sunshine Hour	Data Source
Applicability of Potential Energy		51973.8 Terra Wh/year		Myanmar Government Home Page
Surrounding area of Yangon	More than $20MJ/m^2/day$			1999/NEDO Research Report*/1
Myitkyina	$362Cal/cm^2/day$ (Daily Mean)		2291h/year	1996/NEDO Research Report FS Report*/2
Yangon	$395Cal/cm^2/day$ (Daily Mean)		2372h/year	-ditto-

*/1 “Research on Meshed-Presumption of Renewable Energy in Myanmar as a Typical Country in Southeast Asia”, 1999/NEDO

*/2 “Feasibility Study on New Energy Introduction in Asian Villages”, 1996/NEDO

(2) Global Solar Irradiation processed from the data of DOMH

There are very few data of solar irradiation in Myanmar. The Myanmar global irradiation is estimated by using its sunshine-hour data (Ver.1994-2000), newly obtained from DOMH in this study, along with the former data (Ver.1961-1980) currently referred in some study reports. When converting, the global solar irradiation was calculated by using the conversion formulae shown in the Yearly Research Report in 1991 by NEDO and Japan Weather Association. The result is shown in Table 3. The conversion method of the global irradiation from the sunshine-hour data is specified below in Column-1.

Table 3 Monthly Average Irradiation Record for the Period 1961-1980

($kWh/m^2/day$)*1/

No	Location/ Cities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly mean
1	Monya	4.45	5.63	6.11	6.47	6.09	5.45	4.93	4.66	4.75	4.37	4.11	4.05	5.08
2	Meikhtila	4.55	5.64	6.25	6.64	5.98	4.97	4.84	4.79	4.79	4.55	4.21	4.05	5.10
3	Magway	4.90	5.52	6.06	6.50	5.91	5.08	4.83	4.79	4.90	4.69	4.16	4.31	5.13
4	Lashio	4.45	5.71	6.07	6.07	5.71	4.91	4.34	4.29	4.52	4.23	4.00	3.84	4.84
5	Mandalay	4.50	5.65	6.06	6.33	5.97	5.45	4.88	4.64	4.70	4.34	4.07	3.99	5.04
6	Pyay	4.79	5.88	6.12	6.19	5.61	4.45	4.22	4.21	4.56	4.58	4.35	4.28	4.93
7	Myitkyina	4.16	5.05	5.56	5.82	5.48	4.07	3.69	4.18	4.31	4.15	3.83	3.78	4.50
8	Sitway	4.65	5.68	5.84	6.19	5.42	3.78	3.54	3.73	4.40	4.70	4.29	4.31	4.70
9	Yangon(Kaba Aye)	4.92	5.77	6.04	6.40	4.92	3.70	3.41	3.50	4.05	4.63	4.52	4.47	4.69
10	Dawai	5.06	5.82	6.00	6.29	4.85	4.68	3.42	3.33	4.04	4.86	4.94	4.84	4.83
11	Kawthaung	5.07	5.52	5.93	6.09	4.71	3.61	3.30	3.27	3.85	4.72	4.70	3.54	4.52

Data Source: Myanmar Government Home Page

*1/ The Unit has been processed from original one, $Cal/cm^2/day$.

+++++ Column-1 +++++

Conversion Method from Sunshine-hour Data to Global Horizontal Radiation

Analysis of Solar Irradiation

a) Presumption Work on Solar Irradiation

If no data on the Global Solar Irradiation are available, it can be presumed from the daily sunshine-hour data by using the approximation conversion equation.

The way of the approximation conversion equation is:

$Q = Q_0 \times (A+B \cdot S/S_0) + C$ ・・・・・・Equation (1)

Here,

Q : amount of irradiation/day received at the surface location, $cal/cm^2/day$

Q_0 : the amount of irradiation/day available at the location outside the atmosphere, $cal/cm^2/day$

A = 0.149

B = 0.546

$C = 0.037 \times \sin(h_{15})$

S : sunshine hours actually recorded at the site, hour

S_0 : maximum monthly sunshine hours at the site, hour

h_{15}: Solar angle of the culmination on 15th each month

+++++ End of Column-1 +++++

(3) Global Solar Irradiation Data Issued by Private Organizations

During the reconnaissance, following two data were obtained. Private database were compared to them for reference with above mentioned DOMH data. In some of these private data, solar irradiation data and wind data in Myanmar were found. Private data bases available at present are as follows:

- METEONORM (Version 4.0); and
- Siemens Solar.

And typical data collected through the reconnaissance are shown in Table 4 and Figure 3.

Table 4 Monthly Mean Irradiation Record in Myanmar

(Unit:kWh/m²/day)

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
[Kachin State]															
	PUTAO	DOMH*1/	-	-	-	-	-	-	-	-	-	-	-	-	
		Mekong PV Seminar*2/	4.16	5.1	5.37	5.57	5.31	3.81	3.46	3.45	3.5	3.73	4.18	3.85	4.29
		Meteonorm*3/	3.35	4.04	4.42	5.23	5.03	4.53	4.06	4.19	3.77	3.55	3.67	3.32	4.1
	MYITKYINA	DOMH (1994-2000)	4.46	4.69	5.05	5.6	5.27	3.77	3.25	3.63	3.89	4.3	4.23	4.24	4.35
		Mekong PV Seminar	4.16	5.05	5.56	5.82	5.48	4.07	3.69	4.18	4.31	4.15	3.83	3.78	4.51
		Meteonorm	4.03	4.82	5.23	5.87	5.61	4.93	4.48	4.48	4.33	4.16	4.3	4.06	4.69
[Sagaing Division]															
	MONYWA	DOMH	-	-	-	-	-	-	-	-	-	-	-	-	
		Mekong PV Seminar	4.45	5.62	6.1	6.46	6.09	5.45	4.93	4.66	4.74	4.37	4.1	4.04	5.08
		Meteonorm	4.39	5.21	5.68	6.23	6.19	5.37	4.71	4.65	4.77	4.74	4.73	4.45	5.09
[Shan State]															
	LASHIO	DOMH (1994-1998)	4.51	5.05	5.08	5.24	5.59	3.75	3.42	2.95	3.83	3.91	3.6	3.78	4.23
		Mekong PV Seminar	4.45	5.71	6.07	6.07	5.71	4.91	4.34	4.29	4.52	4.23	4	3.84	4.85
		Meteonorm	4.48	5.14	5.52	5.93	5.84	5.33	5.16	4.42	4.67	4.55	4.53	4.48	5.01
[Mandalay Division]															
	MANDALAY	DOMH (1994-1998)	4.88	5.27	5.5	6	5.91	5.33	4.18	3.92	4.45	4.74	4.5	4.25	4.91
		Mekong PV Seminar	4.5	5.65	6.06	6.33	5.97	5.45	4.88	4.64	4.7	4.34	4.07	3.99	5.05
		Meteonorm	4.52	5.21	5.61	6.1	6.06	5.4	5.06	4.48	4.77	4.74	4.7	4.55	5.1
		JMH*4/	5.57	6.2	7.22	7.66	6.24	3.97	4.68	4.7	5.42	5.43	5.22	4.83	5.6
	MEIKTILA	DOMH (1994-1998)	4.75	4.98	5.71	6.27	5.94	5.23	4.59	4.23	4.11	4.77	4.3	4.41	4.94
		Mekong PV Seminar	-	-	-	-	-	-	-	-	-	-	-	-	
		Meteonorm	4.55	5.25	5.61	6.03	6	5.43	5.23	4.42	4.77	4.77	4.67	4.58	5.11
[Chin State]															
	HAKHA	DOMH (1994-2000)	4.57	4.98	5.3	5.96	5.09	3.63	2.91	2.86	3.21	3.74	3.79	4.09	4.18
		Mekong PV Seminar	-	-	-	-	-	-	-	-	-	-	-	-	
		Meteonorm	4.35	5.18	5.68	6.3	6.23	5.37	4.58	4.68	4.77	4.74	4.77	4.42	5.09
[Rakhine State]															
	SITTWE	DOMH	-	-	-	-	-	-	-	-	-	-	-	-	
		Mekong PV Seminar	4.65	5.68	5.84	6.19	5.42	3.78	3.54	3.73	4.4	4.7	4.29	4.31	4.71
		Meteonorm	4.35	5.18	5.68	6.3	6.23	5.37	4.58	4.68	4.77	4.77	4.77	4.39	5.09
[Kayah State]															
	LOIKAW	DOMH (1999-2000)	5.12	5.23	5.57	6.14	4.33	3.79	3.75	3.86	3.91	4.24	4.47	4.77	4.6
		Mekong PV Seminar	5.11	6.38	6.68	6.81	5.83	5.52	5.57	5.25	5.18	4.92	4.93	4.69	5.57
		Meteonorm	4.68	5.29	5.58	5.87	5.87	5.5	5.61	4.26	4.77	4.77	4.6	4.71	5.13
[Bago Div.]															
	PYAY	DOMH	-	-	-	-	-	-	-	-	-	-	-	-	
		Mekong PV Seminar	4.79	5.88	6.11	6.18	5.6	4.45	4.22	4.21	4.56	4.58	4.35	4.28	4.93
		Meteonorm	4.58	5.25	5.61	6.03	6	5.47	5.26	4.42	4.8	4.77	4.67	4.61	5.12
[Yangon Div.]															
	KABE AYE	DOMH (1994-1998)	5.32	5.68	5.94	6.43	4.97	3.46	3.25	3.11	3.72	4.64	4.69	5.08	4.69
		Mekong PV Seminar	4.92	5.77	6.04	6.4	4.92	3.7	3.41	3.5	4.05	4.63	4.52	4.47	4.69
		Meteonorm	4.68	5.25	5.58	5.83	5.81	5.43	5.55	4.29	4.73	4.71	4.57	4.71	5.09
		JMH	5.54	6.4	7.33	7.75	6.72	5.36	5.26	4.89	5.46	4.77	5.08	5.03	5.8
[Ayeyanwady Div.]															
	PATHEIN	DOMH (1994-1997)	5.71	6.14	6.36	6.97	5.26	3.73	3.72	3.51	4.06	4.75	4.86	5.32	5.03
		Mekong PV Seminar	-	-	-	-	-	-	-	-	-	-	-	-	
		Meteonorm	4.65	5.25	5.61	5.9	5.87	5.43	5.42	4.35	4.73	4.71	4.6	4.68	5.1
		JMH	5.38	6.16	7.29	7.76	7.12	5.98	6.13	5.6	5.47	4.91	5.06	4.92	5.98
[Mon State]															
	MAWLAMYINE	DOMH (2000)	5.25	5.21	5.51	4.76	3.57		-	-	-	-	-	-	4.86
		Mekong PV Seminar	-	-	-	-	-	-	-	-	-	-	-	-	
		Meteonorm	4.68	5.21	5.58	5.83	5.74	5.37	5.52	4.32	4.7	4.68	4.57	4.71	5.08
[Taninthayi State.]															
	DAWEI	DOMH	-	-	-	-	-	-	-	-	-	-	-	-	
		Mekong PV Seminar	5.06	5.82	6.02	6.29	4.85	4.68	3.42	3.33	4.04	4.86	4.94	4.84	4.85
		Meteonorm	4.58	4.96	5.65	5.63	5.29	4.87	4.87	4.58	4.27	4.19	4.47	4.74	4.84
	KAWTHOUNG	DOMH	-	-	-	-	-	-	-	-	-	-	-	-	
		Mekong PV Seminar	5.07	5.52	5.93	6.09	4.71	3.61	3.3	3.27	3.85	4.72	4.7	4.58	4.61
		Meteonorm	4.65	5.07	5.55	5.47	5.06	4.8	4.77	4.68	4.47	4.32	4.37	4.45	4.8

Data Source *1/: DOMH (1994-1997)
*2/: Mekong PV Seminar
*3/: Meteonorm, Switzerland
*4/: JMH

Figure 3 Yearly Mean Irradiation in Myanmar

2.3.2 Experience Records of Photovoltaic Generation Projects in Myanmar

A high priority has been given to apply PV systems for remote area electrification in Myanmar, as the electrification by PV is based upon renewable energy that effect little on environment. Recently, Myanmar government has been working positively on joint research development in the field of PV systems with NEDO.

Table 5 shows the pilot PV projects undertaken by international organizations so far, and Table 6 is about feasibility study projects and joint research projects on PV systems by NEDO.

Table 5 Pilot Projects Executed in Myanmar

	Project/ Program	Donor	Project Details	Implementation Site	Year
1	Technical Cooperation among Developing Countries	Royal Thai Energy Industry Development ESCAP		Kwayma Village, Tharkyta Tsp. near Yangon	
2	The Solar Battery Charging Community Enterprise	Yoma Bank Project-ENSIGN[*/1] EPD of MOE[*/2]	BCS[*/3]	Pale Village (Thongwa Tsp.)	1997

[*/1] Energy Services and Income-Generating Opportunities for the Poor

[*/2] Energy Planning Department of Ministry of Energy

[*/3] Battery Charge Station by PV System

Table 6 NEDO's Cooperation Project on Renewable Energy with Myanmar Government Organizations

	Project/ Program	Counterparts/ Organizations involved	Project Details	Implementation Site	Year
1	Feasibility Study on New Energy Introduction in Asian Villages	1) MEPE	FS on RE Source in Myanmar, etc.		1995 -1996
2	PV Power Generation Joint Research FS in Myanmar	MEPE	FS on a Hybrid System among PV, Wind Turbine and Gen-set	Wind Monitoring Station: Nyaung Weather Station Kantagyi Village	1997 -1998
3	Research on Meshed-Presumption of Renewable Energy in Myanmar as a Typical Country in Southeast Asia	DOMH MEPE	Analysis of Solar and Wind Energy in Myanmar	Monitoring Station: Yangon Tharawwady Pathein	1998 -1999
4	Experimental Study on Grid System with PV Power Generation System	MEPE DOMH	Actual Study by using a Hybrid System among PV-Wind-DG	Observation Points: 5 Study Site: Chaungtha Tsp.	1998 -2004 (Scheduled)

However, number of PV systems implemented for actual use seems to be smaller than other developing countries, though it is impossible to compare accurately without concrete data on PV implementation collected officially in Myanmar. Through the reconnaissance, some of PV implementation lists shown in Table 7 have been made for the seven states and districts of Kachin, Sagain, Bago, Magway, Mandalay, Rakhine, and Ayeyawady under cooperation with Renewable Energy Association Myanmar (REAM), one of NGOs in Myanmar.

The PV system implementation data could not cover all even for the investigated districts and states. The features are as follows;

A) Types of PV systems were not so many. There are a lot of vaccine storage systems and PV systems for pumping water;

B) Most of PV Systems were implemented as a part of assistances by foreign organizations such as UNDP, UNICEF or foreign NGOs;

C) One set of BCS powered by PV was installed in 2000 as a contribution by a domestic volunteer;

D) The Solar home systems (SHS) are used in relatively well-off houses, whose number may be limited;

E) Not a few lighting systems have been operated in monasteries in rural villages as one of the expanded application systems from the SHS, most of which were donated by villagers;

F) There are a lot of PV powered pumping systems for supplying potable water in CDZ; and

G) One of special cases, there is a solar powered pump supplying water from a near-by pond to a water purification system for the city hospital use.

Table 7 List of PV Implementation in Myanmar

KACHIN STATE (As of March 1, 2001)

Code	Site locality District/ Township/ Town, Village	Capacity (W)	Usage	Year of Establishment	Project Status Donor	Organization
	Myitkyinar Tsp./ Myitkyinar	450	Vaccine Refrigerator	1996	UNDP	MOH
	Bamaw Tsp./ Bamaw	450	Vaccine Refrigerator	1996	UNDP	MOH
	Putar-o Tsp./ Putar-o	450	Vaccine Refrigerator	1996	UNDP	MOH
	Winemaw Tsp./ Winemaw	450	Vaccine Refrigerator	1996	UNDP	MOH
	Naungmon Tsp./ Naungmon	450	Vaccine Refrigerator	1996	UNDP	MOH
	Phar-kent Tsp./ Phar-kent	450	Vaccine Refrigerator	1996	UNDP	MOH
	-Ditto-	640	SHS	1997	Private	Individuals
	Moenyin Tsp./ Moenyin	450	Vaccine Refrigerator	1996	UNDP	MOH
	Moekung Tsp./ Moekung	450	Vaccine Refrigerator	1996	UNDP	MOH
	Machanbaw Tsp./ Machanbaw	450	Vaccine Refrigerator	1996	UNDP	MOH
	Suprabon Tsp./ Suprabon	450	Vaccine Refrigerator	1996	UNDP	MOH
	Mansi Tsp./ Mansi	450	Vaccine Refrigerator	1996	UNDP	MOH

Sagain Division (As of March 1, 2001)

Code	Site locality District/ Township/ Town, Village	Capacity (W)	Usage	Year of Establishment	Project Status Donor	Organization
	Sagaing Tsp./Kyaukse villagee	11133	Pumping	1998	UNDP	MOA
	Sagaingg Tsp./Yonepin-Kan village	896	Pumping	1998	UNDP	MOA
	Chaung-U Tsp./Ahmyint village	900	Vaccine Refrigerator	1989	UNDP	MOH
	Myaung Tsp./Lema village	1500	Pumping	1989	UNDP	Village community
	Monywa Tsp./Monywa	1113	Pumping	1989	UNDP	MOA
	Myinmu Tsp./Hti-saung village	1113	Pumping	1989	UNDP	MOA
	Ayar-taw Tsp./Inkyin-hla village	896	Pumping	1989	UNDP	MOA
	Butalin Tso./ Tharyo-gone village	896	Pumping	1989	UNDP	MOA
	Shwebo Tsp./ Mabay village	896	Pumping	1989	UNDP	MOA
	Pokoke-ku Tsp./ Magyipin-pu village	896	Pumping	1989	UNDP	MOA
	Remote railway stations	2120	Radio Telephone	1975	Govarnment	MOA
	The whole area average	6	SHS	1989	Private	Individual

Bago Division (As of March 1, 2001)

Code	Site locality District/ Township/ Town, Village	Capacity (W)	Usage	Year of Establishment	Project Status Donor	Organization
	Natalin Township	132W	SHS	1996	Private	Individual
	Thanut-pin Township	150W	SHS	1995	Private	Individual
	Taungu Township	1410W	SHS	1997	Private	Individual
	Taungu Township	150W	SHS	1997	Private	Monastery
	Taungu Township	100W	Radio Telephone	1998	Private	Individual

Magway Division (As of March 1, 2001)

Code	Site locality District/ Township/ Town, Village	Capacity (W)	Usage	Year of Establishment	Project Status Donor	Organization
	Magway Tsp./ Daung-nay village	896	Pumping	1998	UNDP	MOA
	Magway Tsp./ Kyarpyac-in village	896	Pumping	1998	UNDP	MOA
	Myothit Tsp./ Manaw-kone village	896	Pumping	1989	UNDP	MOA
	Mageway Tsp./ Kungshar-taw	500	Pumping	1989	UNDP	Village community
	Taungdwin-gyi Tsp./ Pyint-pyu village	1113	Pumping	1989	UNDP	MOA
	Myaing Tsp./ Thar-tut village	1113	Pumping	1989	UNDP	MOA
	Yasa-kyo tsp./ Nipasataw village	1113	Pumping	1989	UNDP	MOA
	Minbu Tsp./ Konethar village	1113	Pumping	1989	UNDP	MOA
	Sinpaung-we Tsp./ Chaung gouto village	1113	Pumping	1989	UNDP	MOA
	Pakoke-ku Tsp./ Magyinpinppu village	1113	Pumping	1898	UNDP	MOA
	Remote railwaay stations	1060	Radio Telephone	1975	Government	MOA
	The whole area average	9	SHS	1989	Private	Individual
	WATSAN Project	2688	Pumping	1999	UNDP	Village community

Mandalay Division (As of March 1, 2001)

Code	Site locality District/ Township/ Town, Village	Capacity (W)	Usage	Year of Establishment	Project Status Donor	Organization
	Madayar Tsp./ Nathar-myaing village	1113	Pumping	1998	AMDA	MOH
	Kyaukese Tsp./ Kha-o-gyi village	1113	Pumping	1989	UNDP	MOA
	Meiktilar Tsp./ Meiktilat	1200	Pumping	1999	MIS	MOH
	Meiktilar Tsp./ Kwet-nge village	1113	Pumping	1989	UNDP	MOA
	Meiktilar Tsp./ Chaungma-gyi village	318	Lighting	1999	Government	MOA
	Meiktilar Tsp./ Than-gone village	896	Pumping	1989	UNDP	MOA
	Meiktilar Tsp./ Maizali-gone village	1113	Pumping	1989	UNDP	MOA
	Tharsi Tsp./Kyatee village	896	Pumping	1989	UNDP	MOA
	Pyawbwe Tsp./ Yalegwe vilage	400	BCS	1989	JAPAN	MO Religious
	Mahling Tsp./ Magyipin-pu village	896	Pumping	1989	UNDP	MOA
	Mahling Tsp./ Sai-doe village	896	Pumping	1989	UNDP	MOA
	Mahling Tsp./ Yae-atekyin village	896	Pumping	1989	UNDP	MOA
	Ywan-dwin Tsp./ Palawa village	896	Pumping	1989	UNDP	MOA
	Remote ralway stations	2120	Radio Telephone	1975	Government	MOR
	The whole area average	12	SHS	1989	Private	Individual
	Mogoke Tsp./ Mogoke	1500	Telecom Station	1999	Government	MOPT

RAKHINE STATE (As of March 1, 2001)

Code	Site locality District/ Township/ Town, Village	Capacity (W)	Usage	Year of establishment	Project Status Donor	 Organization
	Sittwe Tsp./ Sittwe	640	SHS	1996	Private	Individual
	Kyaukphyu Tsp./ Kyaukphyu	450	Vaccine Refrigerator	1996	UNDP	MOH
	-Ditto-	22	SHS	1995	Private	Individual
	Taungoke Tsp./ Taungoke	360	Vaccine Refrigerator	1996	UNDP	MOH
	Myauk-oo Tsp./ Myauk-oo	450	Vaccine Refrigerator	1996	UNDP	MOH
	Kyauk-taw Tsp./ Kyauk-taw	450	Vaccine Refrigerator	1996	UNDP	MOH
	-Ditto-	172	Water pump & light	1997	Private	Monastery
	Mye-pone Tsp./ Mye-pone	450	Vaccine Refrigerator	1996	UNDP	MOH
	Buthi-daung Tsp./ Buthi-daung	450	Vaccine Refrigerator	1996	UNDP	MOH
	-Ditto-	384	Vaccine Refrigerator	1999	UNDP	MOL&H
	-Ditto-	192	Refrigerator	1997	UNDP	UN, Office
	Maung-taw Tsp./ Maung-taw	450	Vaccine Refrigerator	1996	UNDP	MOH
	-Ditto-	384	Vaccine Refrigerator	1999	UNDP	MOL&H
	-Ditto-	192	Refrigerator	1996	UNDP	UN, Office
	Pauk-taw Tsp./ Pauktaw	450	Vaccine Refrigerator	1996	UNDP	MOH
	Thandwe Tsp./ Thandwe	450	Vaccine Refrigerator	1996	UNDP	MOH
	Gwa Tsp./ Gwa	450	Vaccine Refrigerator	1996	UNDP	MOH
	Yathe-taung Tsp./ Yathe-taung	450	Vaccine Refrigerator	1996	UNDP	MOH
	Min-bya Tsp./ Min-bya	450	Vaccine Refrigerator	1996	UNDP	MOH
	Ponnar-gyun Tsp./ Ponar-gyun	450	Vaccine Refrigerator	1996	UNDP	MOH
	Man-aung Tsp./ Man-aung	450	Vaccine Refrigerator	1996	UNDP	MOH

Ayeyawady Division (As of March 1, 2001)

Code	Site locality District/ Township/ Town, Village	Capacity (W)	Usage	Year of Establishment	Project Status Donor	 Organization
	Bogalay Tsp.	2560	BCS	1997	UNDP	MOF
	Remote railway stations	530	Radio Telephone	1975	Government	MOR
	The whole area average	3	SHS	1989	Private	Individual
	Pthein Tsp./ Chaung-thar	384	Research	2001	NEDO	MEPE
	Township health centre	4452	Vaccine Refrigerator	1990	UNDP	MOH

2.4 Wind Power

2.4.1 Potential Map

Myanmar has a coastline extended up to 2,832 km in length, and has such tendencies that southwest monsoon blows for nine months along the coastal zone. For another three months, northeast monsoon blows. In Myanmar, the utilization of wind energy is still at the only primitive stage, though her wind potential energy is so huge as up to 365.1 TWh/year (Source: Myanmar government/website).

Any kinds of assessment, however, introducing wind power generator could not directly be applied in Myanmar at present, because detailed area-based wind data have never been collected so far. Still, following four data are only applicable as reference:

- Data W-1: A Study of Wind Speed in Myanmar (Recorded Period, 1964-1980), DOMH;
- Data W-2: ditto newly acquired DOMH (Recorded Period, 1994-2000);
- Data W-3: NEDO/Meteorological Association; and
- Data W-4: METEONORM (Switzerland).

Inferred from these data, the average of wind velocity is very low as a whole in Myanmar, and the favorable points with high average wind velocity all over a year are not found. In the both States of Chin and Shan, however, there extend the mountainous areas supposed to be suitable for the wind power generation with high yearly mean wind velocity exceeding 4 m/s (Data W-3).

Moreover, along the western coastal area, especially in Sittwe, a capital city in the northern part of Rakhine State, the average monthly wind velocity shows almost 3 m/s or more (Data W-1, W-2, and W-3), and it seems that there is a possibility of wind power generation also in these regions. In addition, the average yearly wind velocity shows about 3 m/s in the surrounding central area in Nyaung Oo (Mandalay Division) (Data W-1), and this region is also presumed to be an applicable area for the wind power generation.

It was confirmed that there are some of local wind-favored areas through the reconnaissance in addition to above-mentioned regions, which could be specified as suitable places for the wind power generation from the collected data above. It seems that there are many locally wind-favored sites in all over Myanmar. To pile up these data of the locally wind-favored areas would also be necessary for future implementation of wind power generators.

The typical wind data collected through the reconnaissance are listed in the following Table 8 and Figure 4, 5, and 6.

Table 8 Yearly Mean Wind Speed in Myanmar

(Unit: kWh/m2/day)

State/Division	Location	Data Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
[Kachin State]															
	PUTAO	DOMH (1996-1999)*1/	0.22	0.45	0.45	0.67	0.89	0.00	0.45	0.45	0.45	0.15	0.15	0.60	0.41
		Wind Study Report*2/	-	-	-	-	-	-	-	-	-	-	-	-	-
		Meteonorm*3/	1.60	2.00	2.10	2.00	1.80	1.70	1.70	1.40	1.20	1.20	1.30	1.30	1.61
	MYITKYINA	DOMH (1994-1998)	0.59	0.88	1.13	1.10	0.80	0.87	0.62	0.57	0.46	0.53	0.57	0.62	0.73
		Wind Study Report (1966-1980)	0.87	1.14	1.42	1.58	1.23	0.98	1.14	0.98	0.87	0.80	0.88	0.88	1.06
		Meteonorm	1.60	1.90	2.00	1.90	1.70	1.70	1.70	1.40	1.20	1.20	1.20	1.30	1.57
[Sagaing Division]															
	MONYWA	DOMH (1994-1998)	1.41	1.44	1.34	1.41	1.52	1.73	1.54	1.07	1.05	1.06	1.41	1.35	1.36
		Wind Study Report (1966-1980)	0.76	0.71	0.97	0.91	1.10	1.45	1.49	1.18	0.74	0.65	0.69	0.59	0.94
		Meteonorm	0.60	0.70	0.90	1.20	1.10	0.90	0.90	0.80	0.60	0.60	0.60	0.50	0.78
[Shan State]															
	LASHIO	DOMH (1994-1998)	1.17	1.38	1.17	1.31	0.80	0.89	1.08	0.63	0.54	0.17	0.21	0.46	0.82
		Wind Study Report (1965-1980)	0.88	1.22	1.45	1.54	1.49	1.63	1.60	1.26	1.01	0.82	0.67	0.70	1.19
		Meteonorm	1.40	1.70	1.80	1.80	1.60	1.70	1.70	1.40	1.10	1.10	1.10	1.20	1.47
[Mandalay Division]															
	MANDALAY	DOMH (1994-1998)	0.34	0.62	1.16	1.29	1.70	1.87	2.08	1.30	0.70	0.39	0.25	0.22	0.99
		Wind Study Report (1968-1980)	0.93	1.23	1.72	1.89	2.14	2.78	2.91	2.29	1.67	1.22	1.01	0.85	1.72
		Meteonorm	0.50	0.70	0.90	1.20	1.10	0.90	0.90	0.80	0.60	0.60	0.50	0.50	0.77
	MEIKTILA	DOMH (1994-2000)	0.86	1.03	1.51	1.81	2.27	3.28	3.42	2.33	1.39	0.70	0.81	0.87	1.69
		Wind Study Report (1965-1980)	0.65	0.80	1.16	1.72	2.46	3.30	2.65	2.46	1.37	0.74	0.66	0.63	1.55
		Meteonorm	0.40	0.50	0.70	1.00	0.90	0.70	0.70	0.60	0.40	0.40	0.40	0.30	0.58
[Chin State]															
	HAKHA	DOMH (1994-1998)	1.63	2.26	2.91	1.94	2.41	1.97	2.27	1.76	1.12	1.10	1.00	1.09	1.79
		Wind Study Report (1966-1980)	-	-	-	-	-	-	-	-	-	-	-	-	-
		Meteonorm	1.10	1.20	1.50	1.80	2.00	1.70	1.50	1.40	1.30	1.00	1.00	1.00	1.38
[Magway Div.]															
	MAGWAY	DOMH (1994-1998)	0.61	0.56	0.71	0.62	0.79	0.97	0.90	0.85	0.80	0.59	0.61	0.71	0.73
		Wind Study Report	-	-	-	-	-	-	-	-	-	-	-	-	-
		Meteonorm	0.50	0.60	0.80	1.10	1.00	0.80	0.80	0.70	0.60	0.50	0.50	0.40	0.69
[Rakhine State]															
	SITTWE	DOMH (1994-1998)	2.85	2.66	2.80	2.95	3.46	3.66	4.00	3.22	3.00	2.40	2.87	2.51	3.03
		Wind Study Report (1965-1980)	1.96	2.45	2.65	2.65	2.82	3.37	3.35	2.86	2.47	2.06	1.77	1.73	2.51
		Meteonorm	0.90	1.00	1.40	1.80	1.90	1.50	1.30	1.30	1.20	0.90	1.00	0.90	1.26
[Kayah State]															
	LOIKAW	DOMH (1994-1998)	-	-	-	-	-	-	-	-	-	-	-	-	-
		Wind Study Report (1968-1977)	0.82	0.53	0.88	0.99	1.08	1.18	1.04	0.97	0.88	0.71	0.67	0.63	0.87
		Meteonorm	0.40	0.50	0.70	1.00	0.90	0.70	0.70	0.60	0.40	0.40	0.40	0.30	0.58
[Bago Div.]															
	PYAY	DOMH (1994-1998)	0.41	0.35	0.41	0.33	1.31	0.46	0.40	0.43	0.33	0.30	0.37	0.38	0.46
		Wind Study Report (1964-1977)	1.09	1.13	1.30	1.65	1.74	1.40	1.37	1.22	1.02	0.92	1.25	1.39	1.29
		Meteonorm	0.50	0.70	0.90	1.30	1.10	0.90	0.90	0.80	0.60	0.60	0.60	0.50	0.78
[Yangon Div.]															
	KABE AYE	DOMH (1994-1998)	1.06	1.12	1.09	1.18	1.31	1.34	1.33	1.06	1.07	1.05	1.28	1.28	1.18
		Wind Study Report (1968-1980)	1.18	1.43	1.65	1.91	1.70	1.50	1.65	1.55	1.22	1.18	1.17	1.29	1.45
		Meteonorm	0.70	0.90	1.20	1.50	1.20	1.00	1.10	1.00	0.70	0.70	0.70	0.70	0.95
[Ayeyanwady Div.]															
	PATHEIN	DOMH (1994-1998)	0.97	1.19	1.30	1.58	1.39	1.01	0.97	0.78	0.72	0.72	1.35	1.18	1.10
		Wind Study Report (1964-1980)	1.12	1.34	1.68	1.54	1.50	1.31	1.05	1.01	0.86	0.90	1.06	1.05	1.20
		Meteonorm	0.70	0.90	1.30	1.60	1.30	1.10	1.20	1.10	0.80	0.70	0.70	0.70	1.01
[Kayin State]															
	HPA-AN	DOMH (1994-1998)	0.88	0.97	0.99	1.20	1.04	1.06	1.36	1.13	1.04	1.05	0.97	0.81	1.04
		Wind Study Report (1964-1972, 1976-1979)	1.10	1.16	1.59	1.81	1.76	1.91	1.78	1.51	1.46	1.19	0.97	1.10	1.45
		Meteonorm	0.80	1.00	1.30	1.60	1.30	1.10	1.20	1.20	0.80	0.70	0.80	0.80	1.05
[Mon State]															
	MAWLAMYINE	DOMH (1994-1998)	1.11	1.03	1.12	0.96	0.92	0.93	1.09	0.84	0.80	0.89	1.30	1.55	1.04
		Wind Study Report (1964-1980)	1.58	1.70	1.85	2.04	1.99	2.10	2.11	1.94	1.68	1.46	1.94	1.89	1.86
		Meteonorm	1.00	1.30	1.80	2.20	1.70	1.50	1.60	1.50	1.10	1.00	1.10	1.10	1.41
[Taninthayi State.]															
	DAWEI	DOMH (1994-2000)	0.19	0.54	0.45	0.49	0.45	0.34	0.46	0.44	0.33	0.31	0.52	0.29	0.40
		Wind Study Report (1965-1980)	1.01	0.97	1.06	0.99	1.15	1.12	1.05	1.15	0.89	0.85	1.05	1.26	1.05
		Meteonorm	1.20	1.40	1.70	1.80	1.70	1.80	1.80	1.80	1.40	1.10	1.50	1.50	1.56
	KAWTHOUNG	DOMH (1994-2000)	0.80	0.80	0.58	0.51	0.63	0.82	1.20	1.11	0.75	0.52	0.64	1.37	0.81
		Wind Study Report (1964-1980)	1.74	1.54	1.47	1.36	1.40	1.64	1.51	1.53	1.19	0.89	1.41	1.86	1.46
		Meteonorm	1.70	1.60	1.50	1.40	1.40	1.80	1.60	1.70	1.40	1.00	1.40	1.80	1.53

Data Source
*1/: DOMH(1994-2000)
*2/ :DOMH, Wind Study Report(1964-1980)
*3/ :Metronomrm, Swizerland

Figure 4 Yearly Mean Wind Speed in Myanmar (DOMH 1994-2000)

Figure 5 Yearly Mean Wind Speed in Myanmar (Wind Study Report)

Figure 6 Yearly Mean Wind Speed in Myanmar (Meteonorm)

2.4.2 Application of Wind Power Generation System

As a general trend, the size of wind power generation system has been increasing. And even the model machines exceeding 1,000 kW as rated capacity have been developed. Many the introductions of the large-scale wind power generation systems would be realized through an enterprise of IPP (Independent Power Producer), which commercially forms a grid connection with an existing grid line. This trial should be definitely backed up with detailed, concrete data of wind conditions. However, the introduction of the large-scale wind power generation system into Myanmar is impossible at this moment because there is no detailed wind data, and because there are no stable power grid lines in the western coastal zone so far.

In this condition, the introduction of a wind power generation set in Myanmar has to be started by applying a small-scale system with BCS at local wind-favored spots. The development procedures shall be as follows:

First of all, select locations favored in strong wind by interviewing local people nationwide. And then, select some of candidate sites to install the instrument for acquisition of one-or-two year's data of wind velocity. Analyzing the data, a plan is to be prepared to implement a wind powered BCS system onto a wind-favored site if some of locations have a yearly mean velocity exceeding 4 m/s.

Moreover, if the monthly mean wind velocity in rainy season from April to October is bigger than 3 m/s, a hybrid system with PV and wind-power generators could be one option due to compensation of natural potential each other.

2.4.3 Mean Wind Velocity and Capacity of Wind Power Generator

The formula of the wind energy is given as follows.

$$P = (1/2) \cdot \rho \cdot A \cdot V^3$$

Here,

P : Wind energy

ρ : Air density (kg/m^3)

A : Area of receiving air of wind turbine blade(m^2)

V : Wind velocity (m/s)

And the wind energy per unit area is called as "wind energy density" and expressed as follows.

$$P_0 = (1/2) \cdot \rho \cdot V^3$$

Air density (ρ) changes by temperature and atmospheric pressure, and 1.225 kg/m^3 is used in the standard condition (1 atmospheric pressure and 15℃).

The wind energy is proportional to the wind receiving area, which corresponds to the cube root of the wind velocity. In a word, when the wind velocity doubles, the power output will be eight times. The power output is greatly depended upon the wind velocity itself.

Table 9 shows calculation examples of the relationship between numbers of wind turbine generators and wind mean velocity, when the energy by a wind turbine is supplied to each sample power demand with rated capacity of 3 kW.

Table 9 Sample Calculation of Numbers of Wind Turbines based on Daily Mean Wind Velocity

Daily Mean Wind Velocity (m/s)	2.7	3.1	3.6	4.0	4.5	4.9	5.4	5.8	6.3	6.7	7.2
Rated Capacity of Machine, 76 kWh/d	41 sets	23	14	10	8	6	5	4	4	3	3
Ditto, 38.4 kWh/d	21 sets	12	8	5	4	3	3	2	2	2	2
Ditto, 20 kWh/d	11 sets	6	4	3	2	1	1	1	1	1	1

As shown in the above table, eleven sets of rated 3 kW wind power generators would be required to supply the power for the demand at 20 kWh/day when daily mean wind velocity is 2.7 m/s. On the other hand, one set of the same capacity would do for it if the daily mean wind velocity exceeds 4.9 m/s, which implies how important it is to select wind-favored locations.

Therefore, it is important for a plan of a power generation system (unit machine, rated capacity, kW) to assess the numbers and other fundamental factors by analyzing wind-related data collected at the intended location prior to actual introduction of wind turbine generators.

2.4.4 Examples of Actual Implementation

In Myanmar, examples of implementation or operation of wind turbine generators at present are very few. And only one set has been confirmed in the mountainous region of Shan State through the reconnaissance. It was implemented by Karamosia Foundation (Aug. 2000, Japan) as one of cooperation projects by NGO. This is a small BCS powered by a hybrid system of the small wind turbine and the solar panel.

However, the development of wind turbine generators has been undertaken by a few indigenous manufacturers in Myanmar, which can be considered that the trial of wind power development has just been started.

The development projects confirmed through the reconnaissance are as follows:

1) Myanmar Science and Technological Research Development (MSTRD) and Department of Physics at Yangon University have jointly undertaken the research and development work concerning utilization of wind energy.

2) One company of REAM member named “Ambient Resources Mover Co., Ltd.” has been doing a demonstration test on a multi-bladed wind turbine set at a site on the fringe of Yangon City since October, 2000. A multi-bladed wind turbine generator has a general property, which can generate electric power even under the very low wind velocity, but the cut-in velocity of their test machine set is 3.1m/s (7 mph), which will have to be more improved. However, it is so much appreciated that they have strong intention to launch their remodeled wind turbines, based on the actual data in another one year.

In addition, NEDO has undertaken a series of projects, technical development study and international joint research, shown in Table 6 for the wind power generation technology development with Myanmar government. These study and research projects were started from "Feasibility Study on New Energy Introduction in Asian Villages" continues to the current project, "Feasibility Study on Grid Connection System with PV Power Generation System (1998-2004, scheduled)". These are going to give a lot of applicable data in the near future.

The project of "Feasibility Study on Grid Connection System with PV Power Generation System" was started in 1998, and is scheduled to extend for seven years long. It is still under the study of application of a stable system by using a dummy load and the hybrid power source with PV, wind and DG on the supply side. Prior to this stage, NEDO installed a unit for measuring the wind and solar data at several locations around central and southern regions. A several tens of kW wind power generators will be implemented in this project in total.

Figure 7   Multi-blade Type Wind Power Generator under Development

CHAPTER 3 PROSPECTS OF SOLAR/WIND BCS

3.1 Features of Rural Electrification by BCS

It can be said that people settle the BCS system in order to obtain minimum electricity in Myanmar, where unfortunately the electricity supply service has not been improved for a long time. The BCS has been commercialized with the establishment of an excellent system of the BRS where the batteries are used as energy storage containers that can be recycled easily. They have made progress of one of the most important systems for the Myanmar society.

Table 10 shows the market prices of the batteries currently distributed in Myanmar based on types, brand-new or recycled, and charging cost etc., all of which were checked through the reconnaissance.

Followings are prevailing features of the BCSs used where the MEPE's grid power is not applicable:

1) Cheapness and readiness: The electric power demand for the minimum electricity use such as lighting and radio-cassettes can be supplied relative cheaply in the region where the electricity from MEPE grid is not available.

2) Increasing power demand: Installation capacity is dependent on the interval of charging and procurement of new batteries or recycled batteries based on customers' financial conditions

3) Sustainability based on self-responsibility: All of the procurement and payment are to be done on the commercial basis based on self-responsibility.

4) Small installation of BCS: The power for BCS can be supplied very simply with small equipment such as DG set and chargers, which will require only small capital investment. In this case, it is possible to choose a power source depended on the availability and regional conditions such as single power supply from MEPE grid or both supply of MEPE and private power line.

5) Applicability of near-by BRS: It is necessary that there is a commercial base BRS in the neighborhood, and that the recycled electrode plates can be commercially supplied. If not, the BRS has to be annexed to the BCS.

3.2 Solar/Wind BCS

3.2.1 Advantages of Solar/Wind BCS

Though PV and wind power generation systems have advantages respectively as a power generation unit, the common advantages to the both are as follows;

1) No need of fuel supply: Because of using renewable energy such as sun shine and wind power, any supply of fuel is not necessary;

2) Maintenance free: Small-scale generator powered by a PV system or a wind-turbine system is basically maintenance-free though regular small maintenance is necessary such as cleaning.

3) Easy implementation with small weight and good portability: The light weight and good portability make it simple and easy to implement both of the systems even at remote and isolated areas, where other kinds of power generation systems are not applicable from a financial point of view due to small demand and hard accessibilities as is the case in hydro power generators.

4) Commercialized existence of BCS and BRS: The utilization of techniques concerning the battery required for solar or wind BCS is so popular in Myanmar. The problems to introduce solar or wind BCS are how to maintain the batteries, in general. There seem to be no problems in Myanmar in the way of using batteries due to management skills in maintenance and recycling batteries.

Here, a small-scale system of the rated capacity of 10 kW or less is targeted as an assumption of the comparison for BCS installation.

Table 10 Particulars of the Batteries Currently Distributing in Myanmar

Code	Recyclable or Non-R	Plate Type		Capacity Calculated	Battery Cost		Charging Cost	Place & Date, Check conducted at/on		Usage & others
		Volt	Plates	Ah	Brand-new	Recycled		Location	Date	
101	Recyclable	2				1000		Ayar-Taw	27/05/01	
111		6	9				25	Kyauktaga	12/02/01	
112		6	9			1300	20	Meiktilar	15/02/01	
113		6	S	(15)	700			Myint-Nge	27/05/01	Manufacture
114		6	L	(20)	1250			Myint-Nge	27/05/01	Manufacture
115		6				2000	12	Ayar-Taw	27/05/01	
116		6					50	Machan-Baw	04/06/01	
121		8	9				40	Kyauktaga	12/02/01	
122		8	9			1800	35	Meiktilar	15/02/01	
123		8	S[*3]	(15)	1000			Myint-Nge	27/05/01	Manufacture
124		8	L(B)	(20)	2100			Myint-Nge	27/05/01	Manufacture
125		8	L(W)	(20)	1900			Myint-Nge	27/05/01	Manufacture
126		8				2700	15	Ayar-Taw	27/05/01	
127		8					60	Machan-Baw	04/06/01	
128		8					60	Putao Dist	06/06/01	
131		12	9		2100		40	Bago	12/02/01	
132		12	9	(20)	3000			Myint-Nge	27/05/01	Manufacture
133		12		20			75	Kyauktaga	12/02/01	
134		12	11		1500[*1/]		30	Pyinmana	13/02/01	Radio Cassette
135		12	11	(30)	4000			Myint-Nge	27/05/01	Manufacture
136		12	13		2100		40	Bago	12/02/01	
137		12	13	(35)	6000			Myint-Nge	27/05/01	Manufacture
138		12		(35)	4000			Ayar-Taw	27/05/01	
139		12					20-60	Ayar-Taw	27/05/01	
140		12					70	Machan-Baw	04/06/01	MEPE's Q
141		12					70	Putao Dist	06/06/01	
151		For 6-8V Batteries					10	Thit-Taung Vil	29/05/01	UNDP[*2]
201	Non-Recyclable	12		70	3700[*1]		70	Pyinmana	13/02/01	Video
202		12		120			100	Bago	12/02/01	
203		12		150			100	Bago	12/02/01	
204		12		150	4000[*1]		70	Pyinmana	13/02/01	TV
301	Recyclable	2	15	250	9000			Myint-Nge	27/05/01	Manufacture

Source: Data collected by JICA Study Team

[*1] These Prices are a bit old, about several yeas ago. [*2] Provided by UNDP/WATSAN Project in 1998. [*3] L: Large, S: Small, (B): Black, (W): White

3.2.2 Technical Issues of Solar/Wind BCS

(1) The Development of the BCS Project Combined with the PV and Wind Data Collection

Solar/wind data on their installation sites should be provided in advance to introduce PV or wind turbine systems. In Myanmar basically only weather records collected at local meteorological stations are available. They can offer weather data and wind velocity and direction data, but very few for irradiation data. Localized data at planning sites will be necessary for planning especially for wind power systems. It needs time and financial supports to launch the due projects of collecting detailed PV and wind data in the future. Therefore, at the introduction stage of PV or wind power generation, small-scale model projects supplying power to BCSs or pumping systems should be promoted simultaneously collecting PV or wind data instead of promoting a project only for collection of meteorological data. The followings are some of ideas for projects based on the Grassroots schemes financed by Embassy of Japan.

0) For arrangement of PV database

A compact units to be annexed to BCS in operation. As the PV cell generates power in proportion to solar radiation, the inclined daily insolation or irradiation could be measured by daily power generation with checking current and voltage data on a DC line. The checking intervals are to be every five minutes or every ten minutes, and the value will be recorded in a special recording media. And the collected data is to be saved once every two or three months.

1) For arrangement of wind database:

The projects of collecting wind data have to be curried out only for the purpose to implement wind power generators in the future. Therefore, it is very important to confirm the positive result that the wind data is highly available for a wind power generation at a candidate site on the site selection stage. Acquisition of wind data would be possible in operating BCS powered by wind turbine generators as is the case in PV systems, but it is not much recommended. The wind turbine generator has a different character from PV. As it has a certain speed range such as cut-in, rated and cutout speed, the relation between power output and wind velocity is not corresponding. Therefore, it is highly advisable that wind velocity should be measured by a special tool at the project site in case that priority is given to data collection of wind velocity.

However, it is possible to introduce a small-scale wind turbine generator as a trial even if there is no particular correspondence, and to collect the wind data while supplying limited BCS functions. It is necessary to sample data very simple only to collect wind velocity just the same as irradiation data of PV.

In any cases, the following actions would be required when analyzing the compiled data:

- To add further installation of wind turbine generators in case if favorable wind velocity is obtained;
- To add further installation of PV systems if complementary relationship between PV and wind power are found; and
- To move the total facility to another sites for further data collection in case that no favorable data is collected.

(2) Issues Concerning Battery

The existence of battery recycle system with BCS currently prevailing in Myanmar can be highly evaluated. However, it is necessary to standardize the specifications of the battery recycling techniques and the method of recycling battery components in the BRS. It will be necessary to build up trustful relations between customers and business promotion activities of BCS. It is difficult to tell whether a battery is charged enough or not, because the electric energy conserved in a battery cannot be seen. Over-discharging of battery is a problem. Customers use batteries at their own judge and they use batteries until electricity is completely consumed, which makes battery life short. Such many issues turned out in the present BCS and BRS through the reconnaissance.

The countermeasures for them would be an introduction of a daily management system about battery charging and a battery test unit to check battery characteristics on charging and discharging. The former is to be solved at the stage of battery maintenance, and the latter requires introduction of an automatic battery tester.

3.3 SHS and BCS, and Renovation of Charging Method of BCS

3.3.1 Brief Explanation about SHS and BCS

(1) Solar Home System

In the strict sense, a solar home system (SHS) is a domestic PV system, of which capacity would vary from a small system to power a lighting unit to larger utensils supplying enough power to all the requirements as being used in a grid-connected home. As a general rule, however, it means a tiny, stand-alone power generation system with 12 V direct-current (DC) used in non-electrified areas, which use PV panels to electrify small rural homes.

A typical SHS consists of a PV array with batteries, a charge controller, wirings, fluorescent lights, and outlets for other appliances as shown in Figure 8. The capacity of SHS has to be decided dependent on what kind of electric appliances he wants to use and his ability of payment for not only the SHS but also for its sustainable operation.

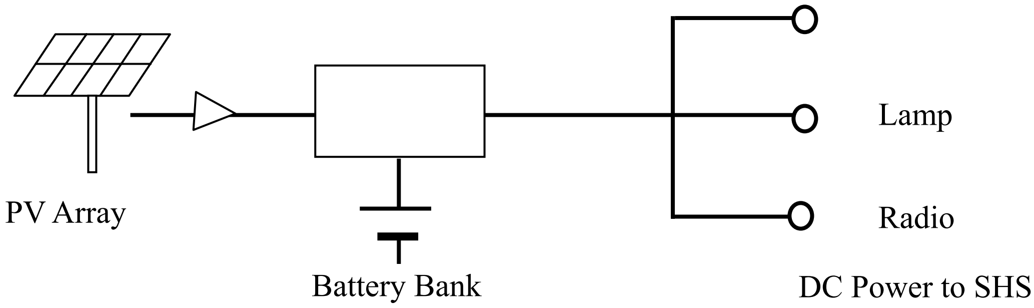


Figure 8 Configuration of SHS

Table 11 Power Output and Operational Hours Depending on PV Capacity

Capacity of PV Panel	Size of Power Output (kWh/day)			Operation Hours (Hours)		
	Dry Season	Mean	Rainy Season	Lamp (20W)	Radio Cassette (5W)	Others
50W	95	80	65	1set x 3	1set x 1	
100W	190	160	130	1set x 5	1set x 5	
200W	380	320	260	2sets x 5	1set x 10	(TV)
300W	570	480	390	3sets x 5	1set x 10	TV

Note: This Table is calculated based on the Irradiation Data at Myityina (DOMH).

(1) Battery Charging System

A PV-powered BCS can provide a cost-effective electrification in remote areas. The BCS is one of the most reliable PV systems on account that it requires only a PV array and a battery controller but no stationary batteries as furnished in a SHS. Batteries are normally privately owned. Customers bring batteries to BCSs to have their batteries charged when discharged. In short, batteries in the BCS system will act just as mobile energy containers.

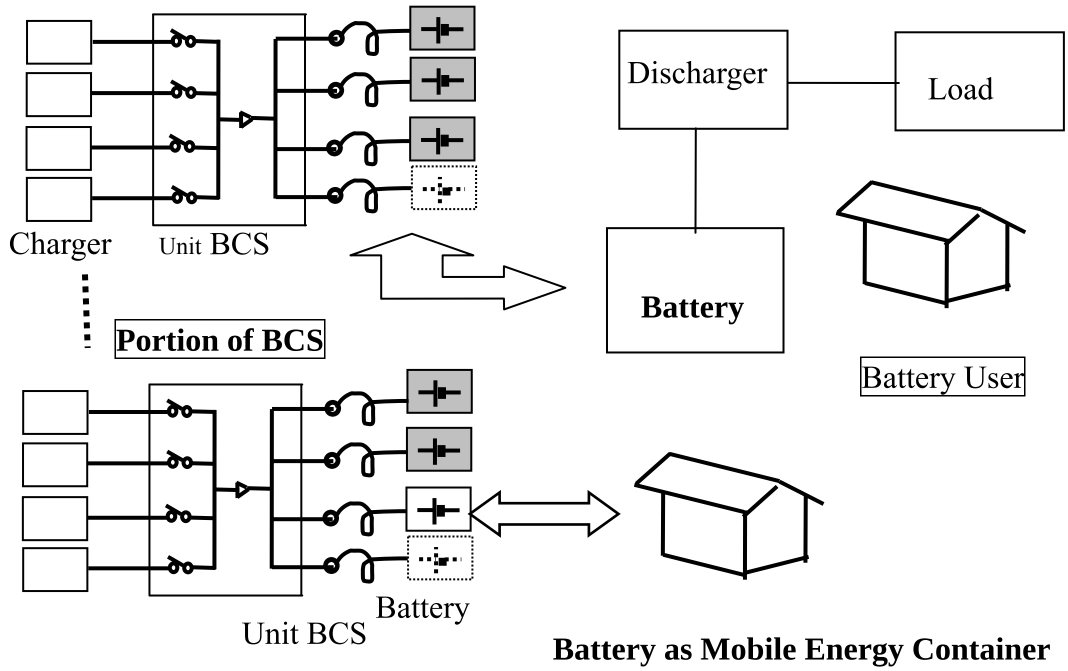
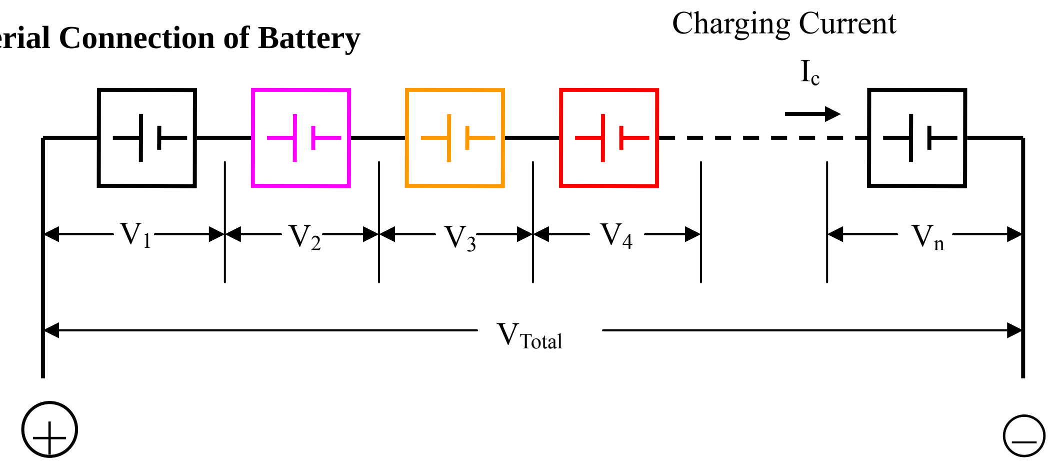


Figure 9 Image of BCS

3.3.2 Issues about Serial Connection of Batteries in BCS

It is very popular, in Myanmar, that batteries are serially connected when charged in grid-connected BCSs. However, this is by no means good for charge batteries. In the BCS all of batteries are to have different conditions of left life expectancy, charging impedance, state of energy remainder, and capacity. When charged in serial connection, some of batteries are to be over-charged and others are to be insufficiently charged. Repetition of over-charge or under-charge will make the life of batteries shorter than the life they originally have. To avoid this problem, all of batteries that have the same rated voltage, say 12V, have to be connected in parallel, where all batteries are to be charged under the same voltage up to a full charged voltage level.

Serial Connection of Battery



$$V_{total} = V_1+V_2+V_3+V_4+ \cdot \cdot \cdot +V_n = I_c \times R_1+ \cdot \cdot \cdot I_c \times R_n$$

$$V_1 = I_c \times R_1$$

$$V_n = I_c \times R_n$$

here、 V_{total} : Tatal Voltage

$V_1 \cdot \cdot V_n$: Battery Voltage under charge

I_c : Charging Current

$R_1 \cdot \cdot R_n$: Charging Impedance of Batteries

Figure 10 Serial Connection and Charging Voltage

One battery, about to expire its life (say, V_4 in Figure 10), has so small electric capacity that it will have a large impedance and passes only small current, and it is full-charged very early. However, other new batteries are not fully charged when they are serial-connected. If this state of charging is to happen continuously, even life of new batteries will be short their life very soon.

3.3.3 Recommendation for Parallel Connection of batteries in BCS

BCS system is comprised of some portions of independent unit BCSs. In a unit BCS, the basic combination between PV panels and batteries should be separated one by one so as to avoid toughing each other in a multiple series. Several connections of unit BCSs are composed of parallel-connected PV panels and batteries, for example, three to four each side and form BCS system as shown in Figure 11. As the radiation is assured to some extent in Myanmar, it would be effective to install a BCS in the region even where there is no meteorological data such as irradiation, and collect data during operation. The method could be applicable to a SHS as well. It is important to connect each battery in parallel to keep line voltage at 12 V DC for charging 12 V batteries.

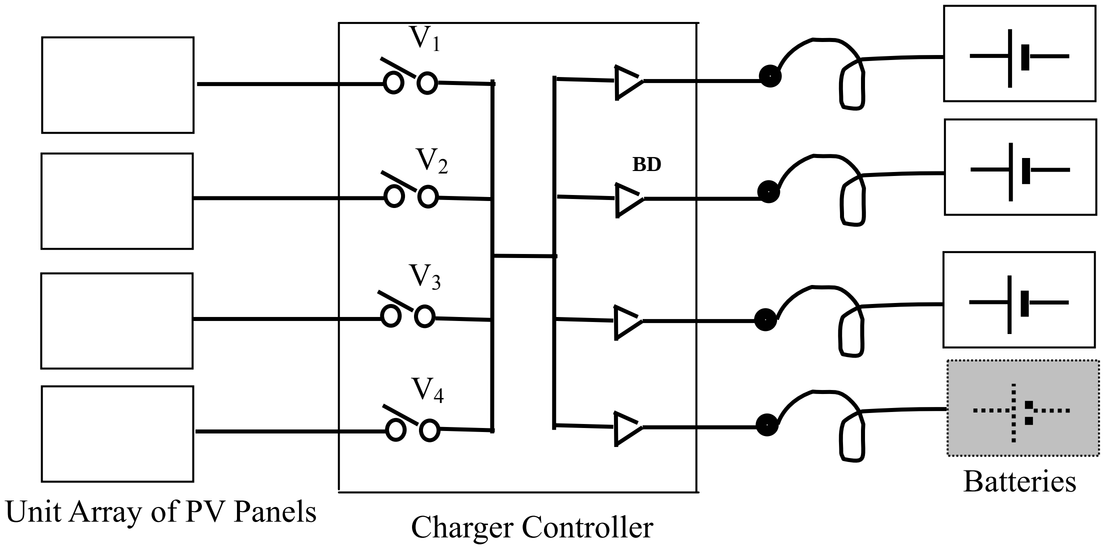


Figure 11 Configuration of Unit BCS

CHAPTER 4 PROPOSED STRATEGY FOR USING SOLAR/WIND BCS

4.1 Future Prospects of Solar and Wind Energy

4.1.1 Dissemination Base of PV and Wind Power Generation System in Myanmar

The possibility of remote electrification by PV systems can be enormous, as its power generation system is applicable to various usages of not only BCSs but also requirements from the demand side. In a word, the usage is multifarious. As a matter of fact, many types of PV systems were confirmed through the reconnaissance, and some of which were strongly requested to promote the PV or wind system by residents at the time of our interviewing with them. Details are shown in Chapter 7. Some of them have an advantage to apply other renewable energy sources suck as rice husk than PV or wind turbine generator.

The major weak points in PV and wind power generation systems are as follows;

1. An energy storage device should be furnished into a power generation system for stable use of electricity because of time difference between power generation and its utilization;
2. The power output is always unstable due to the difference among day and night, weather conditions, seasons and so on. The output fluctuates to some extent even under the same weather conditions.

To cover these weak points, the batteries should be introduced into the PV or the wind power generation systems as the only way of energy storage.

Among components comprising the PV or the wind power generation systems, the life of PV panels (20-30 years or more) and small wind turbine generators (ten years or more) are relatively long, while the life of batteries are very short compared with other power components. It might be about 1,000 cycles for batteries of highest quality under practical use, and about 300 cycles or less for car batteries. It is no exaggeration to say that the PV and wind popularization is depends on by the presence of expensive batteries, because the life of low-graded batteries will be expired within a few years or so even if they have been well maintained.

4.1.2 Systems with Dissemination Possibility

(1) SHS

Actual use of SHSs, which have already started to be used among wealthy families in Myanmar, will be sure to become very popular even in far isolated areas from now on. It could be said that PV systems will play a one-man show to power SHSs, but it is said, of course, that the wind power generators would also be applicable in windy areas as stand-alone systems or hybrid systems with PV.

(2) PV and wind pump requires no batteries

PV and wind pumping systems become the most effective among the usages powered by PV or wind turbine power generation systems as described above, because they have reservoir portion within the systems themselves instead of storage batteries. This means the pumping systems require no batteries as energy storage, as long as water storage tanks are involved in the systems.

(3) BCS as a system without batteries

Since a customer buys batteries and has to maintain them by himself, it may be said that a BCS system requires no batteries in it, depending on the perspective. Furthermore, this shows that there is neither inconvenience nor damages for the maintenance of BCS system. Therefore, similar to the absence of storage batteries between the BCS and the pump systems, it seems to be one of the most effective means for electrification on the suitable ways.

(4) Grid connection systems

It is difficult that both of PV or wind power generation have a major position as a power generation system. As mentioned in Chapter 4.1.1, the most efficient usage of PV or wind power generation is to connect grid system. Though it may be too early to think a grid connection system acceptable right now in Myanmar, mini or micro hydro power generators could possibly make one of the applicable options. The grid connection system uses its huge power supply capacity for huge demand instead of energy storage devices. Accordingly, almost all the electric power generated by capricious power generators such as PV or wind power generation systems, affected greatly by changeable weather, can be used efficiently. Anyway, the expensive cost fixed by the current power generation system will become considerably reasonable by the time when these renewal energy power generators are applied to the grid system in Myanmar.

4.1.3 Production Rate of PV Module and Transition of Price

The demand for a worldwide PV has been expanding rapidly since 1996, which decrease PV price greatly along with it. As shown in Table 12, comparing 1997, 1983, and 1990, the prices have been depreciated to 26.5% and 81.5% respectively. According to the estimation by Ministry of International Trade and Industry (former MITI, at present Ministry of Economy, Trade and Industry, Japan), the prices in 2005 and 2010 will be decreased down to 21.5% and 15.4% respectively against the basic price in 1990. Their estimation foretells that the PV cost will be 1,170 $/kW (140,000 yen/kW) in 2005, and 840 $/kW (100,000 yen/kW) in 2010 on the condition that the yearly production rate is 100 MW.

Table 12 PV Production and Decrement of PV Cell Unit Cost

Item	Nation	Unit	1983	1985	1990	1993	1995	1996	1997	1998	1999*/4	2000*/4	2005	2010
PV Cell Production*/1	Japan	MW				16.70	17.40	21.20	35.00	49.00	80.00	128.60	100*/3	
	Others	MW				43.39	62.20	67.40	90.80	104.20	127.00	149.20	-	-
	World	MW				60.09	79.60	88.60	125.80	153.20	207.00	277.80	-	-
Unit Cost of PV Cell*/2	Japan	USD	16667	10000	5416.7		5000		4416.7				1166.7	833.3
	Japan	k\/kW	2,000	1,200	650		600		530				140	100

*/1 Source: PV News February, 2000
*/2 Source: MITI, December, 1999 First New Energy Session of General Energy Investigation Committees
*/3 Unit Cost estimated with assumed production rate of 100MW/Year
*/4 Source: PV News, February and March, 2000

In this background, MITI started the scheme of the field test project in Japan for the dissemination and promotion of the PV power generation business. The outline of this project is as follows. "Upon introducing the renewable energy power generation systems such as PV and wind power into industrial use or into home use, all of renewable power generation systems are to be connected with commercial power grid lines so as to make the best of the power output from renewable power generators". For this purpose MITI launched two kinds of promotion systems backed up with subsidy in 1992 and 1994. The PV power generation business in Japan has tremendously expanded through these business developments. This subsidiary system brought about competition and standardization into the business, which has made all the cost of PV components including installment cost lower and lower (Table 13).

Table 13 Standard Unit Price/kW of the Field Test Project System for Public and Industrial Applications

	1992		1993		1994		1995		1996		1997		1998	
Item	600	14.2%	600	16.1%	600	18.5%	580	25.5%	466	28.0%	506	37.6%	537	45.9%
PV Pannel	998	23.7%	900	24.1%	750	23.1%	558	24.6%	479	28.8%	284	21.1%	193	16.5%
Inverter	642	15.2%	420	11.3%	370	11.4%	246	10.8%	141	8.5%	129	9.6%	101	8.6%
Other Equipment	642	15.2%	420	11.3%	370	11.4%	246	10.8%	141	8.5%	129	9.6%	101	8.6%
Construction Cost	1337	31.7%	1390	37.3%	1150	35.5%	641	28.2%	437	26.3%	296	22.0%	237	20.3%
Total	4219	100.0%	3730	100.1%	3240	99.9%	2271	99.9%	1664	100.1%	1344	99.9%	1169	99.9%

Source: Material for a Lecture of NEDO Promotion Department

4.1.4 BCS Cost Estimation in 2010

The cost estimation for PV components after ten years could be calculated by those two data mentioned above.

(1) Calculation Condition

1) The major preconditions are based on the current state of Myanmar. Therefore, neither an inflation rate nor other economic fluctuation factors are put into the preconditions.

2) Almost all PV systems, irrespective of home or industry use, it is the grid connection systems that currently being installed on large scale in Japan. And the batteries are not included in the current system of BCS in Myanmar, which seems to have a common point to the grid connection system in Japan.

3) It is necessary to pile up cost of yearly reduction by technology transfer and improvement.

4) In calculating the price of PV, the standard calculation value, 100,000 yen, fixed by MITI (Japan) as a yearly production basis of 100 MW is adopted. As the calculation value has already been cleared enough because of the output more than 116.5 MW in 2000 of Japan. The calculation conditions will be improved better in the near future.

5) The cost reduction rates of the components other than PV are assumed to be about 80% of PV. Therefore, the ratio of the PV prices will fall compared with the one in 1998, and other units or elements will increase vice versa.

6) Myanmar CIF (certificate, insurance, and freight) price of the PV panel adopts standard cost calculation. The proportion of this price in the whole

is decided by referring to mass-produced data of Japan. The cost ratio of all other components is defined, and a cost of each component is calculated.

Table 14 Standard Unit Price/kW of the Field Test Project System for Public and Industrial Applications-1

(Unit:1000\)

Item	1992		1993		1994		1995		1996		1997		1998	
PV Pannel	600	16.8%	600	18.1%	600	20.9%	580	28.6%	466	30.6%	506	41.6%	537	50.3%
Inverter	998	27.9%	900	27.2%	750	26.1%	558	27.6%	479	31.5%	284	23.4%	193	18.1%
Other Equipment	642	17.9%	420	12.7%	370	12.9%	246	12.1%	141	9.3%	129	10.6%	101	9.5%
Construction Cost	1337	37.4%	1390	42.0%	1150	40.1%	641	31.7%	437	28.7%	296	24.4%	237	22.2%
Total	3577	100.0%	3310	100.0%	2870	100.0%	2025	100.0%	1523	100.1%	1215	100.0%	1068	100.1%

Source: Material for a Lecture of NEDO Promotion Department
(The Japan Electrical Manufactures' Association, 2000/2/10)

Table 15 Standard Unit Price/kW of the Field Test Project System for Public and Industrial Applications-2

(Unit:1000USD)

Item	1992		1993		1994		1995		1996		1997		1998	
PV Pannel	5.0	16.8%	5.0	18.1%	5.0	20.8%	4.8	28.4%	3.9	30.7%	4.2	41.2%	4.5	50.6%
Inverter	8.3	27.9%	7.5	27.2%	6.3	26.3%	4.7	27.8%	4.0	31.5%	2.4	23.5%	1.6	18.0%
Other Equipment	5.4	18.1%	3.5	12.7%	3.1	12.9%	2.1	12.4%	1.2	9.4%	1.1	10.8%	0.8	9.0%
Construction Cost	11.1	37.2%	11.6	42.0%	9.6	40.0%	5.3	31.4%	3.6	28.3%	2.5	24.5%	2.0	22.5%
Total	29.8	100.0%	27.6	100.0%	24.0	100.0%	16.9	100.0%	12.7	99.9%	10.2	100.0%	8.9	100.1%

Source: Material for a Lecture of NEDO Promotion Department
(The Japan Electrical Manufactures' Association, 2000/2/10)

(2) Calculation procedures

1) PV Panel

- The data of MITI is adopted as a cost of the PV panel. The contingency rate is assumed to be 30%, which should be added to the Japanese unit price, 100 kyen/kW. (kyen = 1000yen). Then Japanese unit price :130 kyen/kW.
- CIF-Yangon expenditure: 40%
- Price ratio in PV system configuration: 40%

2) Controller

- Experiences will be acquired through projects such as "Grass-root Project" etc. by 2010. Moreover, the production of controllers has already arrived at the stage of the indigenous production in Myanmar.
- Price ratio in PV system configuration: 40%

3) Other Equipment

- Most materials are procured from Myanmar-made goods, though foreign products such as a special cable, small electronic units, etc., might be procured.

- Price ratio in PV system configuration：5%

4) Construction

- Weight is low though there exist uncertain factors such as difficulty of transportation, but the disadvantage of the road condition is very low as a whole.

- Price ratio in PV system configuration: 15%

The kW-based unit price of the PV panels in 2010 is shown in Table 16, assumed from the conditions above.

Table 16 Estimation of kW-Unit Cost in Myanmar in 2010

Item	U-Price	Contin	Japn in 2010		Myanmar in 2010		Myanmar in 2010	
Unit & %	kYen/kW	gency	kYen/kW	%	kYen/kW	%	USD/kW	%
PV Pannel	100	1.3	130	30%	182.0	40%	1,517	40%
Controller			130	30%	182.0	40%	1,517	40%
Other Equipment			65	15%	22.8	5%	190	5%
Construction Cost			108.3	25%	68.3	15%	569	15%
Total			433.3	100%	455.1	100%	3,793	100%

The unit cost of BCS is estimated around US$3,800 in 2010, and thus around US$19,000 for 5 kW-BCS and around US$11,400 for 3kW-BCS.

4.2 Application to Small Villages in Remote and Hardly Accessible Areas

4.2.1 Issues and Countermeasures for Rural Electrification by PV and Wind Power Generation

The promotion of the remote area electrification in Myanmar seems to be difficult. Especially, the electrification in the far remote area with inconvenient traffic access is very difficult where PV or wind turbine generators are the only way to electrify. In this chapter, some of the countermeasures are presented against issues supposed to encounter when introducing PV or wind turbine generators in these remote areas.

(1) Data of Energy and Weather Condition

At the planning stage, it becomes very important to check whether sufficient energy of solar radiation or wind could be obtained so as to supply enough power to the demand in the proposed area. These energy sources are indigenous to the natural conditions in the region. The data for the analysis is not, to our regret, enough.

The sunshine-hour data could be used in place of the irradiation data to some extent. Because the whole land of Myanmar is blessed with relatively good sunshine, introduction of PV systems seems be no problem. However, some of countermeasures should be taken against the low irradiation days in a rainy season. The insolation data during the rainy season, June to September, is as low as 3-4 kWh/m^2/day, and it is almost half as much as dry season (4-6 kWh/m^2/day) in some regions as shown in Table 3. Followings are the countermeasures:

1) Upon designing, the value, 3 kWh/m^2/day, is applied for the capacity calculation of solar insolation;

2) The selection of a hybrid system with wind turbine generators should be considered for the windy area with strong wind during rainy seasons.

(2) Establishment of BCS System as a Total System

The system of BCS has to be installed based on the two points. That is, the best charging of batteries and best usage of them. These two aspects become a prerequisite for using batteries in the best condition. In case of future introduction of BCSs, installation of charge controllers is needed for BCS side and the discharge controllers is needed for the consumers' sides. Especially, the same problems in regard to charging and discharging often occur in SHSs. The introduction of necessary devices into the systems would become an important point of maintenance of the BCSs.

(3) Stable Acquisition of Good-qualified Batteries

The batteries occupy the most important part in the BCS system. It is not an exaggeration to say that the batteries play a crucial part for sustainability of the BCS system. Stable supply of inexpensive batteries is very important in order to disseminate the BCS system. The present BRS system seems to be a precondition of the BCS system dissemination, taking into consideration of current state of Myanmar. In such areas that BCS will be implemented in the future, a traffic infrastructure seems to be so poor that parts and materials for a

BRS could not be transported for several months due to a long rainy season. Following measures have to be taken;

- Setting up a BRS system as an annex to a BCS is necessary;
- Upon introducing a BCS, certain amount of parts and materials for a BRS system should be provided in the region where a traffic infrastructure is not enough;
- Establishment of training method on the technology about battery recycle and material reproduction;
- Regulation of examination about battery quality verification should be established in capacity calculation method; and
- Environment measures for battery reproduction should be established.

(4) Standardization of Battery

It is necessary to specify the voltage for at least 12V class of batteries in the BCS system, which would be a basic specification for the purpose of keeping batteries in better conditions upon charging and discharging with proper controllers. Battery charging mixing with different voltage specification is likely to be performed very much in current ways of battery usage in Myanmar. Therefore, some restrictions such as raising the charging price might be needed to prevent from mixing batteries other than the specified voltage. Moreover, it is necessary to set up the management system of charging batteries. It is needed to record their history, say, date of initial installment, numbers of battery charge, water refill, etc.

4.2.2 Dissemination and Promotion of Remote Electrification by PV- or Wind-Power Generation System

(1) Dissemination Procedure of Wind Power Generation

Upon introduction of wind power generators, wind velocity data have to be checked in advance, as described already. 3.5-4m/s might be at least necessary as the monthly average wind velocity. However, it would be better to start some of small-scale, practical projects, through which wind velocity data could be collected in many locations for future provisions of the wind data as much as possible. Only the accumulation of these preliminary projects could enable Myanmar to start actual introduction of wind power generators.

Followings are the due procedures:

- Extract regions favored in high wind velocity
- Planning of preliminary small-scale projects
  - Establishing some of installation of system for recording wind power generated as an annex
  - Small-scale, practical systems for community center
  - Rated output: 1-3 kW
  - Project execution
  - 2- years operation, data collection, and analysis
  - Promotion of actual projects by evaluating collected data

What is important here is to verify the 2 years' actual operation data collected from BCSs, and to decide weather the location is favored with wind energy for implementation of wind power generators in the future.

It is, in addition, necessary to make a complete plan of a wind power generation system when it is supposed to be effective, and to promote the project implementation. On the contrary, in case of disadvantaged wind conditions for the wind power generation, it is also necessary to verify possibilities with a hybrid system with PV or a PV mono system. It is necessary to transfer the small-scale system to another site when supposed not to be applicable in all respects.

It seems that only such a scheme of projects that has a flexibility have to be used for disseminating the wind power generation system in Myanmar.

(2) Dissemination Procedure of PV-powered BCS

The dissemination procedure of PV-powered systems can be made simpler than that of wind systems. Good wind conditions would be the top priority for an introduction of wind power generators. On the contrary, PV system would be simpler because almost all area in Myanmar is blessed with solar radiation value of 3 kWh/m^2/day except for particular areas. An introduction of PV systems can be planned only by confirming consecutive no-sun-days and rainy days, usually taken as 3 to 4 days, which would be hard to be fixed.

Upon introduction of a PV-powered BCS, it would be important to adopt a special set of compact equipments to record data, which enable engineers to infer solar radiation values. Of course, this solar-powered BCS is actually to supply power to a battery charge section or to a dummy load in case of excess power generated like wind-powered BCS. The system has a function as follows;

- Acquisition of PV-generated power by measuring primary voltage and current every one minute
- Collection of accumulated data once every one or two months
- Analysis of collected data

These compiled data can complement DOMH data. Followings are the procedures:

- Analysis of collected data of candidate projects among locations in remote area with relatively high irradiation

  Sample Project Plan

  - Selection from each state
  - Practical installation
  - Measurement of irradiation data

  Project Execution, Data Sampling, and Analysis

  - 2 years operation
  - Data analysis

  Project Trial `Period and Number of Trial Projects

  - 10 sets/year
  - Target region：Kachin, Chin, Magwe, Mandalay, Rakhine, etc.

4.3 Technical Support

Upon starting projects of PV wind BCSs, it is very important to evaluate efforts by the Myanmar Government and Myanmar NGOs for disseminating BCSs powered by renewable energies. As subsidiary projects to support their independent endeavors for RE promotion, some of foreign assistance projects such as Japan Grassroots Grant or other schemes for environment should be offered.

The problem solution and the standardization according to introducing BCSs in Myanmar will be started one by one, and this attempt will lead establishment of organizations for introduction very shortly. Necessary components are basically supplied other than consumers' personal appliances such as batteries and lamps, though assistance items would vary depended on project schemes. All functions necessary for their own operation and maintenance management by residents have to be included as an electrification system. Technical support will be needed for an introduction stage and a subsequent stage of operation. Next chapter shows problems expected and the assistance requested, including schemes of short-term dispatch specialists.

4.3.1 Planning Stage

A planning stage can be crucial to forecast the issues in due course of encounter at every stage of future implementation of the BCSs and the countermeasures and organizations to cope with the issues. The outline of technical support is shown as follows.

- System design: Calculation of system capacity and design of specification
- Estimation of budget: Collection of cost estimates based on brief specifications
- Documentation of whole plan of maintenance: Maintenance management manuals and BRS technological standards
- Preparation of application form: Detailed forms about implementation and maintenance management provided by a village electrification committee.

4.3.2 Introduction Stage

It is necessary to arrange, examine the information gathered along with the procurement of the system equipment, and provide the detailed instruction manual for construction based on them. The management over progress for implementation is needed as follows;

- Preparation and check of specifications for construction
- Preparation of technical manuals for the BRS and engineer who train users
- To undertake inspection and to provide instruction for start-up operation

- Preparation of maintenance management
- Preparation of BCS users' regulations

4.3.3 Operation and Maintenance Stage

The detailed operation data including maintenance will be very important for the future promotion of BCSs, as there exists few experience about PV-powered BCSs so far.

- Registration of customers and batteries: Checking batteries (12V class) and numbering
- History management of battery
- Individual check by customers: Use of a discharge controller and life of apparatus, etc.
- Stable acquisition of recycling parts or materials for a BRS

CHAPTER 5 CRITERIA FOR SELECTION AND PRIORITIZATION OF RENEWABLE ENERGY PROJECTS

5.1 Criteria of Electrification by Adopting Solar or Wind BCS

The decision-making procedures to electrify remote villages with renewable energy equipment is as follows:

(1) Villagers' Wilingness for Electrification

First of all for village electrification, there exists a strong desire of "Using electricity" among villagers.

(2) No plan to extend a grid line to a targeted village so far and in the future

(3) Examination of resources of electrification

There are not a few variations for remote electrification such as biomass, wind and PV power generation systems other than micro or mini hydro power generation. The selection of systems has to be decided by checking size of electrification, financial conditions, difficulty of implementation and so on.

As a whole, a bigger priority could be given to hydro or rice husk power generation systems due to their relatively bigger output and cheaper cost. And, therefore, only in case of difficulty in implementation, neither potential for hydropower nor rice husk, possibility of PV or wind power generation should be examined.

(4) No existence of power generation by other power units

Such villages that some part have been locally electrified with private-own line supplied by DG or micro hydro generators and indirectly electrified with the BCS+BRS systems have to be excluded from the targeted villages.

5.2 Criteria for Selection of Appropriate Areas or Locations to be electrified by using Solar- or Wind-BCS

(1) Rural Electrification Strategy

The rural electrification business to be promoted as a national policy in the future aims at "full-scaled electrification" that supply power for 24 hours. The next electrification strategy would be set for an electrification target using each renewable energy source in accordance with this target.

- Hydropower potential region: In a region with hydro potential, remote electrification should be prompted by a small or micro hydro power generation in order to supply power for 24 hours.
- Rice field region: As short or mid-term electrification measures until future coverage with a power grid around the village areas, a "semi-scaled electrification" should to be promoted so as to supply power for five to twenty hours a day with rice husk power generators.
- Mountainous region: "Simple electrification" by micro or pico hydro power generators and PV or wind powered BCS to should be promoted in mountainous regions without rice field

(2) Rural electrification strategy

Depended on the remote electrification strategy shown in the preceding clause, the targeted area where PV or wind BCS is applied is limited at present, but many of areas are actually suitable for PV-or Wind BCS.

- In general, the regions with abundant hydro potential, rice husk or sawdust would have priorities of hydropower generation or gas engine power generation.
- In the region without potential of biomass gas or hydropower generation, PV BCSs could be applied and, especially in the wind-favored locations wind BCSs could be applicable.
- Because PV or wind generation will be used in BCS, the selection of village scale will be less than 100 households, and a BCS should be annexed with a BRS.

(3) Standard for Selection of Rural Electrification Project

Electrification with PV BCSs should be selected among small villages with no other alternative energy resources than solar energy from the viewpoint that there is nationwide radiation potential. Moreover, a wind PV hybrid system would be applicable for the area with good wind potential. The selection standard is shown in Table 17.

Table 17 Selection Criteria of Solar/Wind BCS Schemes

No.	Parameters	Criteria for Selection(Qualification)
1	Possibility of extension of distribution lines from Grid	L>1km
2	Existence of rice-mills or sawmills nearby	Not existing nearby except for small scale ones which cannot meet fuel requirement of Biomass Gas Engine
3	Existence of adequate hydro potential nearby	Not exists.
4	Accessibility to the target villages(road driving hours from Yangon, Mandalay, or other large urban centers nearby in the rainy season)	T>3 hrs or road not passable in the rainy season
5	Number of households (N) in target one village	N<approximately 100 households

Source: JICA Study Team

CHAPTER 6 TECHNICAL STANDARDS

6.1 Technical Data to be Collected for Basic Planning

6.1.1 Method of Sizing PV Capacity of BCS System

(1) Preconditions for Calculation

- Village facilities and load assumptions are shown in Table 18.
- The future increment factor of 25% on power demand to be taken into the plan.
- A battery recycling shop to be established as one of the complementl facilities to a BCS.
- The facility of a BCS to be operated along to the regulation manuals,

(2) Conditions of calculation of PV capacity

- No of households: 200, 150 and 100, respectively
- Interval of battery charging: Once every 4 days
- Margin factor for the system capacity: 1.25

  Here, the margin factor includes:

  - Increment factor on power demand: 15%
  - Power provide for public facilities other than primary school, community center etc: 5%
  - Margin for unknown factors from no data of weather conditions: 5%
- Output capacity of PV array: 2 kWh/m^2/day
- Battery capacity for calculation: 20 to 50Ah as a mean capacity
- Battery DOD (depth of discharge): 70%
- Efficiency factors of PV systems;
  - Charge-discharge efficiency of lead–acid battery: 0.83
  - Degradation factor of recyclable batteries compared with normal lead-acid batteries: 0.85
- Circuit Loss: 0.138(= (1.5V/12V) x 1.1)

- Specification of PV Panel
  - Energy conversion efficiency: 13.5%
  - Area of PV panel: $0.4 m^2$
  - PV output: 54 Wp
- Degradation factor with temperature rise on the PV panel: Δt = 45 to 50℃ from a standard temperature, 25℃
- Other loss factor: 10%

(3) Calculation Method

- Required Power Generation, $\mathbf{P_q}$ [kWh/day]

$P_q = M \times P_d / (K_3 \times K_4 \times K_5)$

Here, P_d: Power demand, [kWh/day]

M: Margin factor for the future miss-much, 1.25

K_3: Battery charge-discharge efficiency for recycling battery, 0.83, and here 0.85 to be taken into calculation as a degradation factor by using recyclable batteries

K_4: Energy transmission efficiency on DC including controllers,

(1- loss factor)=0.87

K_5: Efficiency of controller, here included in K4

Table 18 Scale of Village and Estimation of Power Demand

Case Study	Village and Facilities	Load	Power	Operation	No.	Power Demand
			W	hour/day	Set	Wh/day
Study-1 200Households	Household	Lamp	20	5	1	100
		Others	5	5	1	25
	Primary school	Lamp	20	5	4	400
		Others	5	3	4	60
	Village Office	Lamp	20	3	5	300
		Others	5	3	5	30
	Clinic	Lamp	20	3	3	180
		Others	5	3	5	75
	Total Power Demand					26,045
Study-1 100Households	Household	Lamp	20	5	1	100
		Others	5	5	1	25
	Primary school	Lamp	20	5	2	200
		Others	5	3	2	30
	Village Office	Lamp	20	3	4	240
		Others	5	3	2	30
	Clinic	Lamp	20	3	2	120
		Others	5	3	4	60
	Total Power Demand					13,180
Study-1 50Households	Household	Lamp	20	5	1	100
		Others	5	5	1	25
	Primary school	Lamp	20	5	2	200
		Others	5	3	1	15
	Village Office	Lamp	20	3	3	180
		Others	5	3	2	60
	Clinic	Lamp	20	3	2	120
		Others	5	3	4	60
	Total Power Demand					6,855

- Unit PV Power Generation based unit area(m^2), $\mathbf{P_u}$, [$kWh/day/m^2$]

$P_u = R_m \times K_0 \times K_1 \times K_2 \times K_m$

Here, R_m: Insolation data on the inclined surface

K_0: Energy conversion factor of PV panel, 13.5% (54 W, 0.4 m^2)

K_1: Degradation factor in accordance with temperature rise, declination Rate: 0.5%/deg,

1. Standard temperature: 25℃

2. K_1=1- 0.005 x (T-28), T = 60℃, K_1 = 0.84

K_2: Factor of dirt on a PV panel, 0.9

K_m: Miscellaneous factors, 0.9, or to be calculated with concrete evaluation.

(2) Required PV Array Area, S [m^2]

$S = P_q / P_u$

(3) Required PV Capacity, C [kW]

$C = C_u \times S / S_u /1000$

Here, C_u: Capacity a PV Panel, 54 W/set

S_u: Area of a PV Panel, 0.4 m^2/set

Then,

$C = 54 \times P_q / P_u / S_u /1000$

The results of sizing calculations for the sample systems are shown in Table 19 to Table 22.

Table 19 Worksheet-1: Calculation of Power Demand (1)

Worksheet 1: Daily Energy Requirement
Fill out this worksheet to estimate Power Demand.
Date:
Name: No of family menbers:

	Utensils	Type	Power	Number	Voltage	Daily Use	Daily Energy Use	When, provided	Others
			watts		V	hours	watt-hour		
			A	B	C	D	AXBXD		
1	Lamp								
2	Lamp								
3	Lamp								
4	Radio								
5									
6									
7									
		Total Appliaces No:		0	Total Power Use:		0	Wh/day	
							(E)		

2. Calculation of Battery Capacity

Total Power Use:(E)=	0	Wh/day	
Battery Voltaga: V=	12	Volt	
Charging Interval:	4	days	
Calculation=(E)XVX4/0.7):		0	Ah
Choose from here:	10, 20, 30, 5(	Ah	
Your Battery Capacity:		Ah X		Cells

Note for Input:
- Data Input Column
- Automatic Calculation

Note-1: In the Column"When, provided", please mark, "within one year:",1, and " In the future": F.
Note-2: If nothing particular, please select appliances based on 12V, which is highly recommended, and ecnomical.

Table 20 Worksheet 2: Calculation of Power Demand (2)

Worksheet 2: Daily Energy Requirement
1. CalculationPower Demand
Date **Name of Personel in charge:**
Name of Public Facilitiy:

	Utensils	Type	Power watts A	Number B	Voltage V C	Daily Use hours D	Daily Energy Use watt-hour AXBXD	When, provided	Others
1	Lamp								
2	Lamp								
3	Lamp								
4	Radio								
5									
6									
7									
8									
9									
10									
		Total Appliaces No:		0	Total Power Use:		0 Wh/day (E)		

2. Calculation of Battery Capacity

Total Power Use:(E)=	0	Wh/day
Battery Voltaga: V=	12	Volt
Charging Interval:	4	days
Calculation=(E)X4/V/0.7):	0	Ah
Choose from here:	10, 20, 30, 50	Ah
Your Battery Capacity:		Ah X [ ] Cells

Note-1: In the Column"When, provided", please mark, "within one year:",1, and " In the future": F.
Note-2: If nothing particular, please select appliances based on 12V, which is highly recommended, and ecnomical.

Table 21 Worksheet 3: Calculation of Power Demand (3)

Worksheet 3: Planning Sheet for Village Electrification

Village Name **Township:**
Total No of Household **State:**
Rate of Electrification

No.	Name	Power Demand		Classfication of Volatage			Notes and Memo for Calculation
		within 1Year Wh/day	Future Wh/day	12V	8V	Others	
1							
2							
3							
4							
5							
Total for Housholds Use:							
	Primary School						
	Village Office						
	Clinic						
	Others						
Total for Public facilities Use:							
Grand Total of Power Demand for Village			0	kWh/day			

Table 22 Calculation Sheet of PV Capacity for BCS

Calculation Model: 200 Housholds | 20 W x 5 hours | 1 Set

	Calculation Item	Case Study		Notes and Calculation Form
1.	Village Facilities	Total Power Demand		Note for Input:
1)	Power Demand for Public Facilities			▨ Data Input Column
a)	Primary School	460	wh/day	▨ Coefficient, fixed
b)	Village Office	330	wh/day	▨ Coefficient, variable
c)	Clinic	255	wh/day	▨ Automatic Calculation
d)	Community Center	0	wh/day	
	Power Demmand for P-facilities	1045	wh/day	
	No of allotted batteries	13	Batteries	
2)	Households Use	No. of Households: 200	HH	
	Total Power Dmand	25000	wh/day	
	No of allotted batteries	400	Batteries	
3)	Grand Total of Power Demand	26045	wh/day	
	Total No of Batteries	413	Batteries	
2.	Battery			
a)	Type of Battery	Recyclable Batteries commonly used in Myanmar		
b)	Ah-Capacity and Nos Ah		Ah	(Note-3) (Note-4)
	Nos		Cells	
c)	Nominal Voltage	12	Volt	
d)	Capacity	251	kWh	=E23*E25
e)	Charge-discharge efficiency of L/A Battery	83.0%		Degradation Factor
f)	Inferiority against L/A Battery	85.0%		Assumption Factor
g)	Total Efficiency of Charge-discharg	70.6%		=E27*E28
h)	Circuit Loss Factor	0.87		=ROUND(1-(1.5/12)*1.05,2)
f)	DOD	70%		
3.	Calculation of PV Array Capacity			
a)	Unit Capacity of PV Panel	54	W	PV Caracteristic
b)	Conv. Efficiency of PV Panel	13.5%		PV Caracteristic
c)	Area of PV Panel	0.4	M2	PV Caracteristic
b)	Interval of Battery Charge:	4	days	
c)	Irradiation	4.35	kWh/m2/day	Note-3
d)	Margin Factor for PV Capacity	1.25		0capacity Margin
e)	Temp Degradation Factor	0.84		Degradation Factor
f)	Other Loss Factor	0.90		Degradation Factor

Power Demand for Public Facilities furnished with Lamps and Radio & Others

		Power W	Duration hour/day	No set	Total Wh/day	Load	Power W	Duration hour/day	No set	Total Wh/day
Primary School	Lamp	20	5	4	400	Radio	5	3	4	60
Village Office	Lamp	20	3	5	300	Radio	5	3	2	30
Clinic	Lamp	20	3	3	180	Radio	5	3	5	75
Community Center	Lamp				0	Radio				0
Total				12	880	Total			11	165

Power Demand for Households

	Power W	Duration hour/day	No set	Total Wh/day
Lamp	20	5	1	100
Lamp				0
Cassette	5	5	1	25
Total			2	125

Calculation of Battery Capacity for:

Demand Objects	Battery Cap & No: Ah Cap	Ah	Nos	Total No	Battery Nos & Capacity: Ah-Class		Nos	Wh Capacity	
H/H	97	50	2	400	30	Ah	0	0	
P School	356.9	75	5	5	40	Ah	0	0	
V Office	256.1	75	4	4	50	Ah	404	242400	
Clinic	197.9	50	4	4	75	Ah	9	8100	
C Center	0				100	Ah	0	0	
Total				413	150	Ah			
					200	Ah			
					Total		413	251	kWh

Data Sheet: PV Panel Specification

Output	Wp	52	54	56	60	64
Efficiency	%	13.0%	13.5%	14.0%	12.3%	11.5%
Area	m2	0.40	0.40	0.40	0.490	0.5583
Manufacture		Mono-Silicon Type			Kyosera	MSK

		(Total for BCS)	(BCS/Household)	(SHS/P School)	(SHS/V Office)	(SHS/Clinic)	(SHS/C Center	(Total for BCS+SHS)	Notes and Calculation Form
4.	Array Capacity								
a)	Calculated No of PV Module:	298 Sheets	286 Sheets	6 Sheets	4 Sheets	3 Sheets	0 Sheets	299 Sheets	Note-1
b)	Calculated PV Array capacity:	16.09 kW	15.44 kW	0.32 kW	0.22 kW	0.16 kW	0 kW	16.14 kW	=ROUND(E42*E33/1000,2)

		(Household)	(P School)	(V Office)	(Clinic)	(C Center)	Notes and Calculation Form
5.	Durability of Battery for H/H						
a)	Calculated Interval	4.124635 days	4.203092935 days	4.6871 days	4.0438 days	days	Note-2
b)	Durability	OK	OK	OK	OK		=IF(E46/$E36>1,"OK","No Good")

Note-1: =ROUNDUP(E19*E38/1000/E37/E29/E30/E39/E40/E34/E35,0)
Note-2: =(Battery Capacity in use)x12x(DOD/100)/(Daily Power Demand)
Note-3: =IF(K23<50,10*ROUNDDOWN((K23/10+1),0),10*ROUNDDOWN((K23/2/10+1),0))
Note-4: =1+ROUNDDOWN(K23/E23,0)

+++++ **Column-2** +++++

Calculation of Insolation of an inclined surface, R_m [kWh/m^2/day]

1) Insolation of an Inclined Surface and Global Horizontal Insolation:

   Daily total energy received is more important than the instantaneous solar irradiance at a site. In most cases, a solar array tends to be tilted to an angle close to the geographical angle of latitude of the site in order to maximize the solar energy received. As the insolation data collected by weather stations are normally the Horizontal Global Insolation (HGI), it is necessary to convert the HGI to the Inclined-surface Insolation for making a plan of a PV system.

2) Conversion Equation:

   $R_m = R_{hm} X \{\cos(\theta_l + \theta_m - \theta_o) / \cos(\theta_l + \theta_m)\}$

   Here,

   R_m : Inclined-surface insolation、kWh/m^2/day

   R_{hm}: HGI、kWh/m^2/day

   θ_l: Solar latitude at an implementation site. If it is on the southern hemisphere, each figure changes positive to negative, and negative to positive ones.

   θ_m: Correction of solar latitude as shown in Table 23. If it is on the southern hemisphere, each figure changes from positive to negative, and from negative to positive.

   θ_o: Set angle of PV array

3) Offsets for Solar Latitude:

Table 23 Offsets for Solar Latitude

Month	1	2	3	4	5	6
θ_m, deg.	21.2	12.9	2.4	–9.5	–18.7	–23.3
Month	7	8	9	10	11	12
θ_m, deg.	–21.7	–14.3	–3.9	8.2	18.3	23.2

(Note) On the southern hemisphere, each figure has to be changed from positive to negative, and negative to positive.

4) Decision of set angle of PV array: If there exist seasonal or temporal fluctuations in the power demand, detailed calculations have to be performed so as to supply sufficient energy for the maximum power demand, and to decide an optimum design fixing the set-angle of a PV array and a PV capacity. As a general rule, an angle of

inclination of PV arrays should be synchronized with the latitude. And the minimum angle of inclination have to be fixed at 10 degree so that leaves or other subjects contaminated on the array surface could easily be removed away by rain or wind.

5) Following Table 24 is the results of calculating R_m at typical locations such as Yangon, Mandalay and so on.

Table 24 Inclined Surface Global Insolation Calculated for Typical Locations in Myanmar

Name of Location	Latitude (Deg)	R_{hm} Yearly Mean kWh/M^2/d	Month / Solar Altitude Offset	Upper Colum: R_{mh} and Lower Colum: R_m Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Myitkyna	25.37	4.51		4.16	5.05	5.56	5.82	5.48	4.07	3.69	4.18	4.31	4.15	3.83	3.78
		4.83		4.86	5.67	5.98	6.02	5.51	4.03	3.68	4.26	4.54	4.57	4.41	4.47
Lashio	22.93	4.85		4.45	5.71	6.07	6.07	5.71	4.91	4.34	4.29	4.52	4.23	4.00	3.84
		5.14		5.13	6.34	6.48	6.23	5.70	4.83	4.29	4.34	4.72	4.61	4.55	4.48
Mandalay	21.97	5.05		4.50	5.65	6.06	6.33	5.97	5.45	4.88	4.64	4.70	4.34	4.07	3.99
		5.33		5.16	6.25	6.44	6.48	5.94	5.35	4.81	4.68	4.89	4.71	4.61	4.63
Meikhtila	20.87	5.11		4.55	5.64	6.25	6.64	5.98	4.97	4.84	4.79	4.79	4.55	4.21	4.05
		5.37		5.19	6.21	6.62	6.77	5.93	4.86	4.75	4.81	4.97	4.92	4.74	4.67
Kaba Aye	16.77	4.69		4.92	5.77	6.04	6.40	4.92	3.70	3.41	3.50	4.05	4.63	4.52	4.47
		4.90		5.51	6.25	6.31	6.44	4.82	3.57	3.31	3.47	4.15	4.93	5.00	5.05
Dawai	14.08	4.84		5.06	5.82	6.00	6.29	4.85	4.68	3.42	3.33	4.04	4.86	4.94	4.84
		5.01		5.60	6.25	6.22	6.28	4.71	4.48	3.29	3.28	4.10	5.13	5.41	5.41

Preconditions for Calculation of R_m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a) Solar altitude Offset	21.2	12.9	2.4	-9.5	-18.7	-23.3	-21.7	-14.3	-3.9	8.2	18.3	23.2
b) Inclination of setting PV Panels:	10 deg											

6.1.2 Method of selecting Wind Turbine Power Generator for BCS System

(1) Procedure of Planning Wind Power Generation

The decision of capacity and the selection of the model of a wind power generation system, which differs from that of PV, are a little troublesome. For the wind power generation, the wind data must be obtained, while the radiation data are not always requested because of the general presence of solar radiation, 2 kWh/m^2/day as a minimum value. The "wind" could never be counted on, and it blows off and on repeatedly. So often there is no wind for many days. A basic procedure of planning the wind power generation system is as follows.

- Acquisition of wind data: It is no exaggeration that the success of wind power generation relies on favorable wind conditions. It requires more than 4 m/s as a monthly mean wind velocity for implementation of the power generation system with a wind turbine.

- Aiming step-by-step configuration: At the stage where the wind data could not be applicable enough, it is also important to count daily experiences. Therefore, the site where the wind condition is regarded relatively good-favored is selected and a test plant is to be implemented so that the wind data may be collected for about a year or so. The collected data would be of a great help to consider its possibility and to decide its capacity.

- Selection of wind power generation model: A small wind turbine of the ratings about 2-5 kW would be recommended as a test machine without exception. Upon selection of a machine, it is necessary to be taken into consideration about the model accompanied with detailed characteristics such as the relation between the power output and the monthly mean wind velocity.
- Electricity use: The generated power is mostly supplied to the BCS, where recyclable batteries are charged and used in an ordinary village.

(2) Calculation

- Prerequisite for calculation: The village composition and the load condition are the same conditions as the PV-BCS. (Refer to Chapter 6.1.1)
- Wisper3000 (Iwanaka Electric Machine Factory, Sgamihara, Japan) is shown as an example of wind turbine generators. In this example, related data of each model such as the relationship between monthly mean wind velocity and power generation for every machine type is shown in Table 25.

Table 25 Examples of Estimated Power Output from Small Wind Turbine

(Unit: kWh/Month)

No	Type of Wind Turbine	Monthly Mean Wind Velocity										
		2.7m/s	3.1m/s	3.6m/s	4.0m/s	4.5m/s	4.9m/s	5.4m/s	5.8m/s	6.3m/s	6.7m/s	7.2m/s
1.	Whisper 600	11	20	32	47	63	82	102	122	143	164	183
2.	Whisper H900	11	20	32	47	65	86	109	134	160	187	214
3.	Whisper 1000	19	34	54	78	105	136	156	204	238	273	305
4.	Whisper H1500	18	34	54	79	108	143	181	223	265	312	357
5.	Whisper 3000	56	102	162	233	316	408	507	611	715	818	916
6.	Whisper H4500	54	100	161	236	325	428	543	668	800	936	1070

Data Source: Iwanaka Denki Seisakusyo, Sagamihara city, Japan

(3) Calculation Method

- Required Power Generation, P_q [kWh/day]

$$P_q = M \times P_d / (K_3 \times K_4 \times K_5)$$

Here, P_d: Power Demand, [kWh/day]

M: Margin factor for the future miss-much, 1.25

K_3: Battery charge-discharge efficiency for recycling battery, 0.83, and here 0.85 to be taken into calculation as an inferiority factor by using recyclable batteries

K_4: Energy transmission efficiency on DC including controllers,

(1 - loss factor)=0.87

K_5: Efficiency of controller, here included in K_4

- Decision of sizing the wind power generator and its numbers
  - To choose a W-TG (Wind turbine generator), whose rated capacity is bigger than 2 kW.
  - To calculate numbers of W-TG for every month by using:

$N = P_d \times D_m/O_t$

Where, N: Numbers of W-TG, [sets]

P_d: Power demand, [kWh/day]

D_m: days/month, (31, 30 or 28)

O_t: Mean, monthly, minimum power output of W-TG

  - To chose the Maximum numbers of Wind Turbine Generators

(4) Results of Sizing Calculations for the Sample Systems

The results of the sizing calculation for the sample systems are shown in Table 26.

Table 26 Calculation of Wind Power Generator for BCS

Calculattion Model: 50 Househol 20W X 5hours X 1Set

	Calculation Item	For Households					For Primary School					For Village Office					For Clinic				
1.	Village Facilities		Power, W	Hour	No.	Wh/day		Power, W	Hour	No.	Wh/day		Power, W	Hour	No.	Wh/day		Power, W	Hour	No.	Wh/day
		Lamp	20	5	1	100	Lamp	20	5	2	200	Lamp	20	3	3	180	Lamp	20	3	2	120
1)	Primary School		3	0		0					0					0					0
2)	Village Office	Radio	5	5	1	25	Radio	5	3	1	15	Radio	5	3	2	30	Radio	5	3	4	60
3)	Clinic	Others				0	Others				0	Others				0	Others				0
		Total	*	*	**2**	**125**	Total	*	*	**3**	**215**	Total	*	*	**5**	**210**	Total	*	*	**6**	**180**
4)	No. of Household	50																			
5)	Net Power Demmand for Public Facilities	6855	Wh/day																		

	Calculation Item	For Households	For Primary School	For Village Office	For Clinic
2.	Battery				
a)	Type of Battery	Recyclable Batteries commonly used in Myanmar			
b)	Ah-Capacity and Nos Ah	20 Ah	30	30	30
c)	Nos	5 Cells Note-1	8	7	6
d)	Nominal Voltage	12 Volt	12 Volt	12 Volt	12 Volt
e)	Battery Bank Capacityfor Each	240 Wh 5 Cells 1200	360 Wh X 8 Cells 2880	360 Wh X 7 Cells 2520	360 Wh X 6 Cells 2160
f)	Charge-discharge efficiency of L/A Battery	83%			
g)	Inferiority against L/A Battery	85%			
h)	Total Efficiency of Charge-discharge	71%			
i)	Circuit Loss Factor	0.87			
j)	Interval of Battery Charge:	4 days			
k)	DOD	70%			
d)	Margin Factor for PV Capacity	1.25			
l)	Calculated Capacity of Battery	6647.9 Ah			
3.	BCS Specification				
a)					
5.	Durability of Battery				
a)	Calculated Interval	4.12464 days Note-2			
b)	Durability	OK			
6.	Total PV Capacity				
a)	No. of Household	50 H/H			
b)	Total Batteries used in theVillage	271 Sets			
c)	Present Net Power Demand	1330 Ah/day Note-3			
d)	Grand Total Wind Capacity as a village	20.0 kWh/day Note-4			

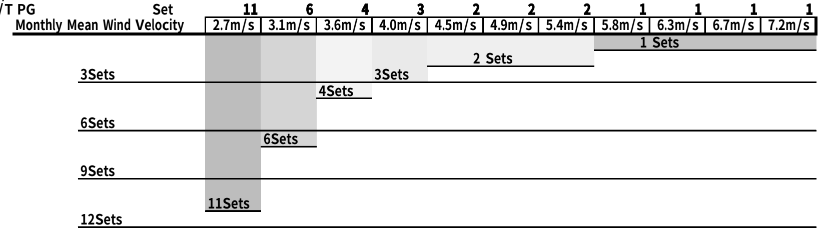
Battery Sizing

180	Ah	279.297	50	Ah	77.5826
100	Ah	155.165	30	Ah	46.5496
		0	25	Ah	38.7913
		0	15	Ah	23.2748

Note-1: =ROUNDUP(I9*E22/E16/E20/E21/E23/E14,0)
Note-2: =(Battery Capacity in use)x12x(DOD/100)/(Daily Power Demand)
Note-3: =ROUNDUP(E11*E24/E16/E20/E21/E23,0)
Note-4 =ROUNDUP(E11*E24/E20/E21/E23,0)

Table Wind Power Generator

1)	Type of Wind PG		**Whisper 3000**	**(IWANAKA, Japan)**									
2)	Monthly Mean W.V.		2.7m/s	3.1m/s	3.6m/s	4.0m/s	4.5m/s	4.9m/s	5.4m/s	5.8m/s	6.3m/s	6.7m/s	7.2m/s
3)	Monthly Power Output	kWh/Month	56	102	162	233	316	408	507	611	715	818	916
4.	Calculation of Wind PGS												
a)	Calculated Power Demand		600 kWh/Month										
b)	Calc of W/T PG		10.7	5.9	3.7	2.6	1.9	1.5	1.2	1	0.8	0.7	0.7
c)	Nos of W/T PG	Set	**11**	**6**	**4**	**3**	**2**	**2**	**2**	**1**	**1**	**1**	**1**



6.2 Environmental Impact Assessment

It could be said, as often referred, that the current BCS+BRS system in Myanmar has been established as one of the social systems so far in the market. This system has an outstanding merit that it delivers electric power that can be installed in the worst conditions for power generation to as many consumers as possible. Nevertheless, it is true that in the current system there would be some points for an efficient distribution of the generated power.

6.2.1 Issues

(1) Shortening of Battery Life by Over-charge and Over-discharge

- Overcharge operation in battery-charge: Batteries are likely not to be charged with charge controllers but to be judged the completion of charge by a sense of the temperature on batteries with touching hand, among which there existed very hot batteries almost untouchable. Almost all batteries are considered to be over-charged. In the hearing at around thirty sites of the reconnaissance, no BCSs are equipped with battery-charge controllers.
- Over-discharge operation in using: Every time, the batteries are usually discharged to the bottom until no power would come out.
- Deterioration of battery quality due to using tube well water to refill: Almost all consumers are to refill river or tube well water into their batteries instead of qualified refilling water. The tube well water seems to be inadequate for refilling because frequently it contains colloid materials. In some places, even seawater is filled into the batteries.

(2) Water Treatment Method for Waste Battery Electrolyte from BRS

- Though a present BRS system has a profile of small effect on environment that most materials are to be recycled, major part of electrolytes are abandoned to the surrounding.
- It turned out through the reconnaissance that the waste battery electrolyte is abandoned onto soil or into rivers, but only small portion is used to clean a lavatory.

6.2.2 Countermeasures

In a sense, it is a fact there are favorable aspects that no other countries have in the BCS system in Myanmar might. That is, there are a lot of developing countries that directly dispose used batteries any treatment. On the contrary, Myanmar has an outstanding point that almost all materials are recycled in the BRS system. To make this merit more effective is important for its sustainability.

(1) Elongation of battery life

Major ways to expand battery life are to avoid triggers for shorten the battery life such as over-charge and over-discharge, to keep its water level constant to avoid exposure of battery-electrodes to the air, and to refill pure water into the battery when the water level reaches the lower permissible zone. The followings are the major maintenance requested for the battery.

- Measures against over-discharge: "electrical discharge" in the BCS happens while the battery is used at each home. Batteries are likely to be used in a wrong way without discharge controller at the consumer side, which have to be avoided definitely. It is necessary to let the consumers understand that the usage of the battery without discharge-controller is not pay to consumers themselves.
- Measures against overcharge: Because of an issue limited on the BCS side, the function to avoid overcharge should be essentially provided in the introduced facilities. There are many methods to charge batteries without overcharge. In brief, never connect batteries in series, but in parallel. It is suggested to overcharge intentionally about 4 times of a year regularly. By this, battery plates will be refreshed that gives them some possibilities to extend their life.
- Treatment of battery electrolyte: Electrolyte is the solution of sulfuric acid. The treatment has to be taken care because it shows a strong acidity. Therefore, it is necessary to process neutralization for its disposal, though it could be used to clean lavatories. Trials have to be done to find out simple ways to treat it by using surrounding materials such as alkali soil or lime. This can to be handed to researchers at universities or institutes in Myanmar.
- Acquisition of purified water: The purified water is used to fill up water to batteries, and is relatively expensive in daily life. It is possible to have so-called distilled water with a tiny combination unit of soil, sunshine, and solar-power fans. The easiest way is to apply rainfall water, if it is a remote area that have no air pollution. in the mountainous area. Battery supplement water should be checked if it is applicable through analysis of the collected water upon introduction of a BCS. For large scale factory of water refine, ion exchange resin by the combined system of soil and active carbon may do for it.

CHAPTER 7 PROPOSED RE PROJECTS WITH SOLAR/WIND BCS

As stated so far, the existence of many kinds of PV systems was confirmed through the reconnaissance, and some of which were strongly requested for prompt introduction of a PV or a wind system by residents at the time of interviewing. Though all of them are not always applicable to PV or Wind power generation systems, the requested projects are shown in Table 27.

Two proposals, project sheet SW-01 and project sheet SH-02 was formulated (See Volume 5 Appendix-A) and extended by REAM by selecting most possible projects from the list shown in Table 27.

Table 27 PV and Wind Power Generation Systems Requested Through Reconnaissance

No	State	Township	Village Name	Households	Population	Usage	Power Source		Capacity	Others
							RE Source	Grid		
1	Kachin									
1a		Putao	Dote-tan/Putao	304	1808	School/AV Room	PV+Grid	O	23kWh/d	
1b		Machanbaw	Kaungmu-lon	262	1572	BCS	PV+W	X	18kWh/d	with data log system
			Taran-dum	150	600	BCS	PV	X	9kWh/d	with data log system
2	Sagaing									
2a		Ayar- taw	Ingyin- kan	102	615	BCS	PV	X	5.4kWh/d	with data log system
2b		Myaung	Pwa-saw	320	1728	Domastic water	PV	X	7.2kWh/d	with data log system
2c		Sagaing	Yone-pin-kan	155	467	BCS	PV	X	5.4kWh/d	with data log system
2d			Kyaukse	406	3490	BCS	W	X	10kWh/d	with data log system
3	Yangon									
3a		Thanlyin	Kayinseik	215	1075	BCS	PV	X	9kWh/d	with data log system
3b		Hlegu	Ohne-gone	135	617	BCS	PV	X	5.4kWh/d	with data log system
4	Mandalay									
4a		Kyaukse	Kya-o-gyi	98	578	BCS	PV	X	5.4kWh/d	with data log system
4b		Nyaung-U	Thitaung	350	1620	BCS	PV	X	9kWh/d	with data log system
4c			Myae-ne-lay	140	760	BCS	W	X	10kWh/d	with data log system
4d		Ma Hling	Yae-htwet	270	1600	BCS	PV	X	7.5kWh/d	
4e			Ma-gyi-kone	80	454	BCS	PV	X	5.4kWh/d	
4f			Thone-taung	336	1830	BCS	PV+W	X	15kWh/d	with data log system
4g		Kyaukpadaung	Than-pin	101	670	BCS	PV	X	9kWh/d	
4h			Sin-zin	178	1068	BCS	W	X	10kWh/d	with data log system
5	Magway									
5a		Pokoku	Pokoku			Child hospital	PV+Grid	O	36kWh/d	
5b		Yasakyo	Pakangyi			BCS	PV+W	X	9kWh/d	
5c		Yasakyo	Pakangyi			Community center	PV+W	X	18kWh/d	with data log system
5d			Kine-ma-gyi	556	3330	BCS	W	X	10kWh/d	with data log system
5e			Ahlae-thaung	622	3725	BCS	W	X	10kWh/d	with data log system
5f			Thar-si	512	4554	BCS	W	X	10kWh/d	with data log system
5g		Magwe	Tegyi-gone	121	1232	BCS	PV	X	5.4kWh/d	with data log system
5h			Ywarthit-kyi	385	1995	BCS	PV	X	9kWh/d	
5i		Salin	Myaukchaung-pyu	160	1012	BCS	PV	X	7.5kWh/d	
5j		Min Bu	Kone-thar	178	1210	BCS	W	X	10kWh/d	with data log system
6	Rakine									
6a		Thandwe	Maungshwe-lay	360	1620	BCS	PV+W	X	15kWh/d	with data log system
6b		Taung-goke	Nuaung-tang	860	3825	BCS	PV+Grid	O	18kWh/d	
6c		Yathaetaung	Kanyin-chaung	125	588	BCS	W	X	10kWh/d	with data log system
7	Ayeyawady									
7a		Ngaputaw	Zegaing	680	4080	BCS	PV+W	X	18kWh/d	with data log system
7b		Bogalay	Kadone	1200	6250	BCS	PV+W	X	36kWh/d	with data log system
8	Chin									
8a		Tunzun	Hane-zan	187	1112	BCS	PV+W	X	15kWh/d	with data log system
8b			Han-kin	13	72	BCS	PV	X	2kWh/d	
8c			Mwar-pee	185	1075	BCS	PV	X	7.5kWh/d	
8d			Twee-mwe	150	850	BCS	PV	X	7.5kWh/d	with data log system
8e			Sel-bone	90	630	BCS	PV	X	5.4kWh/d	
8f			Lane-htoke	30	400	BCS	PV	X	3.5kWh/d	
8g			Hi-kyin	240	1488	BCS	PV+W	X	15kWh/d	with data log system
8h			Zam-pee	108	837	BCS	PV	X	5.4kWh/d	
8i			Darl-khine	105	260	BCS	PV	X	5.4kWh/d	
8j			Kyar-o-lin	34	190	BCS	PV	X	3.5kWh/d	
8k			Kan-saung	80	528	BCS	PV	X	5.4kWh/d	
8k		Tetain	Saung-zan	170	1380	BCS	W	X	10kWh/d	with data log system
	Bago									
9a		Kawa	Welpa-tan	430	2900	BCS	PV+W	X	15kWh/d	with data log system
	Mon									
10a		Chaung-sone	Ywar-lut	720	4250	BCS	PV+W	X	19kWh/d	with data log system

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

FINAL REPORT

Volume 8 Supporting Report

Renewable Energy

Part 8-1	Biomass Power
Part 8-2	Solar and Wind Power
Part 8-3	**Inspection Memos**

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES
IN RURAL AREAS IN MYANMAR

Final Report

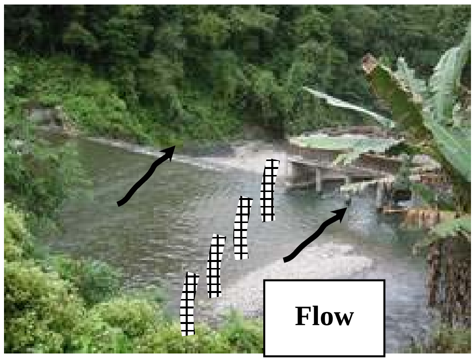
Vol. 8 Supporting Report: Renewable Energy

Part 8-3 Inspection Memos

TABLE OF CONTENTS

Inspection Memo 1 Monitoring of Zi Chaung Hydropower Station

1.1 Findings of the Monitoring

No.	Issues	Possible Countermeasures
1.	**Intake Complex** Forebay of Intake Dam has been filled with sediment up to the dam crest level. The sediment mainly consists of pebble stone and sand with less silt. Some of these sediments intruded into Headrace Channel as seen in the riverside chammber of the Desander attached to the Regulating Pond. 	To provide protection work upstream of the Intake to guide the sediment flow around the intake toward the dam overflow crest.  **Protection work of intake by gabion**
2.	The river flow is rushing into the Intake with forming a critical depth at the inlet, therefore, the sedimentation level in front of the Intake is relatively low due to scouring by high velocity flow there and carrying the sediments into the Headrace Channel.	

<table>
<tr><td></td><td>
Flow at intake gate, trees clogged in the opening on the right side


Intake gates viewed from upstream</td><td></td></tr>
<tr><td>3.</td><td>The right hand part of the Intake Trashracks was washed off by the high velocity flow with drift woods and the water pressure caused by leaves trapped and adhered to the Trashracks. The structural strength of fixing the Trashracks to the concrete support may not have been sufficient.

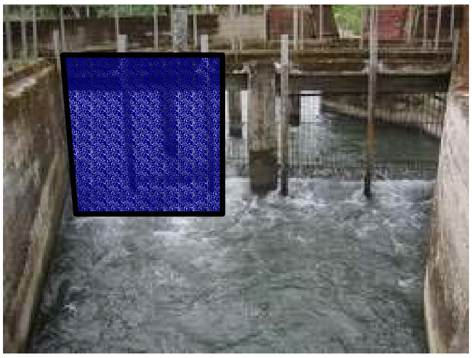
</td><td>To provide a skimmer wall with the inlet opening below the water surface to protect the Trashracks and the Gate from attack of flowing debris during a flood.


Skimmer wall at inlet</td></tr>
</table>

<table>
<tr>
<td></td>
<td>

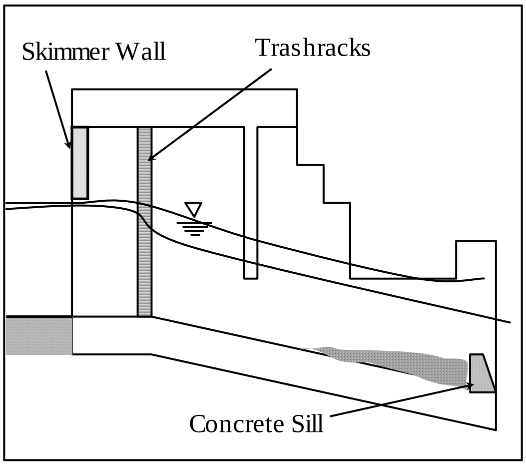
It was recorded in the Operation Log Book of the Zi Chaung Power Station that the power generation was stopped from 23:00 on 19.9.2002 to 08:00 on 20.9.2002 and from 12:00 on 20.9.2002 to 20:00 on 20.9.2002 due to clogging of rocks and sediments at the Intake Gates of the Intake Weir.

The trashrack above might have been washed down at this occasion. This need another detailed hearing to the operators.</td>
<td>To repair and re-install the Trashracks as illustrated below:



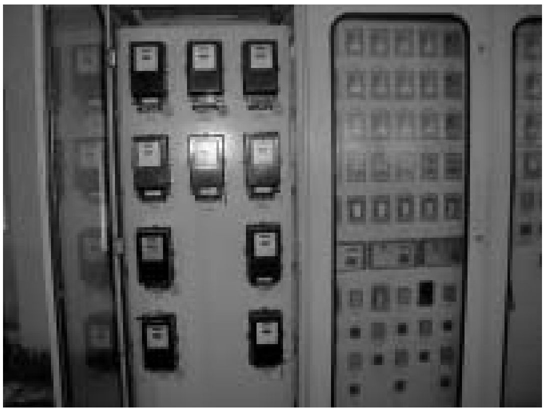
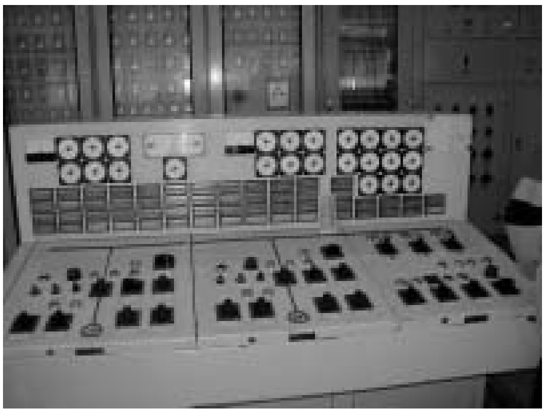
Trashracks to be repaired</td>
</tr>
<tr>
<td>4.</td>
<td>Intake Gates are being clogged partially with flowing debris because a part of the Trashracks has been damaged and removed. As shown on the pictures, the partial removal of the Trashracks is causing the turbulence of the flow around the Intake and accelerating the flow velocity. The higher velocity flow would carry more sediments into the Intake and Headrace Channel.</td>
<td>The countermeasures above will apply.</td>
</tr>
<tr>
<td>5.</td>
<td>The Side Spillway is provided downstream of the Intake Gates to overflow excess water from the Channel back to the river. But it can’t function properly because the velocity in the Channel is too high and turbulent.</td>
<td>To carry out the hydraulic analysis for the flow characteristics of the waterway to clarify the water surface profile, overflow from the Side Spillways, sand flushing, sedimentation, and water hammer in penstock based on the completion drawings.

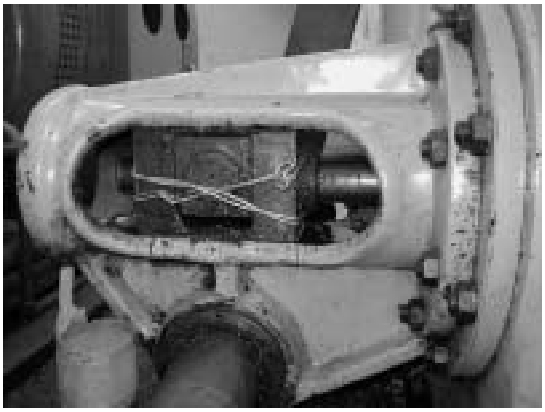
To provide a properly designed concrete sill on the channel floor at the downstream section of the Side Spillway so as to create a more stable flow</td>
</tr>
</table>

	  It is likely that the above flow conditions are caused mainly by a significant drop in the head from Intake to Side Spillway, which energy are being dissipated as turbulent flow above.	conditions with low velocity, and to take only the design discharge into the downstream Headrace Channel without excessive flow, sediments and debris. Heightening of the Channel walls would be required at the Side Spillway section and nearby. To check the water surface profile, it is required to make leveling survey of the top of side walls and to measure the water depth and height of side walls at the same leveling points. 
6.	**Open Channel** The flow in the channel is of sub-critical state, but the velocity is relatively high, probably more than 2 m/s, because of steep channel slope.	To carry out leveling survey of the Channel for confirmation of the water surface profile, discharge capacity, and necessary heightening works of the side walls around the excess water spillway in particular.
7.	Debris from slope failure on the mountain side of the Headrace Channel and leaves are likely to enter the Channel where no cover is provided.	To periodically inspect the Waterway System from the Intake down to Power House to find any sign of slope failure. To execute slope protection works if found necessary after the inspection. To provide cover to the open channel section where judged required. To periodically clean inside the Channel and cut grass along the Channel.

		
8.	**Desander** The riverside chamber, in particular, of the Desander at the entrance to Regulating Pond was heavily deposited with sediment of particle size up to about 2 cm.  Sedimentation in the river side chamber.  Sediment particles.	To periodically flush sediment of the Desander based on the findings of Periodical Waterway Inspection. To prepare a maintenance manual for sand-flushing based on the sediment characteristics and flushing flow capacity. To study and test on the applicability of Siphon to sand-flushing without stopping power generation.

	 Little flow in the river side chamber	
9.	**Regulating Pond** The present layout of Approach Channel to Penstock is likely to carry sediments, passing through the Desander without depositing there, directly to the inlet of the Penstock pipe.  Significant sedimentation of sand and silt was observed in the Regulating Pond, suggesting some of the sediments have been discharged through turbine.	The sand-flushing above of the Desander will reduce the sediment transport to the Regulating Pond. To remove the sediment deposited in the Regulating Pond. To prepare a maintenance manual for such removal works.
10.	Drain valve of the Regulating Pond cannot be operated and sediments have to be removed manually.	To study and test on the applicability of Siphon to sand-flushing without stopping power generation and without emptying the Regulating Pond.
11.	Water level gauge needs to be installed for facilitating the peak-power generation during a dry season utilizing the capacity of the Regulating Pond as designed. The peak power generation will reinforce	To install a water level gauge. To monitor and record the water level of the Regulating Pond daily.

	the power output of Zi Chaung in the dry season.	
12.	Zi Chaung Power Station has been shut down for 124 times and 545 hours in the past one year (Dec. 2001-Nov. 2002). During the past one year, Unit 2 governor caused shutdown for 39 times and 199 hours. The 11 kV line incidents took place for 38 times and 147 hours. Lowering in the water level of Regulating Pond also caused station shutdown. Such station shutdown occurred not only in the dry season but also in the rainy season. It was reported due to clogging of rocks and sediments at the Intake Gate.	Comprehensive review and countermeasures are required to substantially improve the operating conditions. Among these would be: To provide sediment-guide walls, skimmer walls, trashracks, and sill in the Channel as discussed in Item Nos. 1, 3, and 5 above. To rehabilitate generating equipment including governors To inspect the 11 kV lines and cut down tree branches below the lines and grass around guy-wires.
13.	Most of the meters in the power station did not show correct value but presented conflicting figure to each other, e.g., kW meters and kWh meters for Units 1 and 2 do not match with meters for total.  	To calibrate, adjust, or replace meters.

14.	Governors need repairing and adjustment.  Crosshead broken and tentatively managed with wire  Load limiter set at 35% of guidevane opening	To replace with spare crosshead.
15.	Casing have been heavily rusted and there are many points of water leakage from the guidevane seats. 	To check thickness of the casing plate, and replace the casing if judged necessary. To close the holes with bolts if applicable. The leakage from above the gate-ring arm is temporarily closed with wood. In case of loosing off of the closing wood, the jet of water leakage would directly affect the generator. The urgent and substantial repairing is needed. The leakage from the two guidevane seats at the lower part were discharging significant water. The urgent repairing is essentially required.

		failure on one side would affect the operation of the other side. (4) Operators are not well trained to keep the generators in good conditions and need intensive capacity building and training.
18.	Each diesel generator incurs technical issues as represented below: Skoda 608: Governor is out of order. Manufactured and installed in 1986.  Skoda 860: Manufactured in 1981 and installed in Kalaymyo in 1992 by shifting from the other place. Four bearing seats out of seven got cracked and need repairing. These cracks suggest Skoda 860 is at the time of replacement.  Caterpillar 320: Manufactured in 1995 and installed in 1996. Engine and turbo-charger got overheated and radiator need direct application of cooling water also from outside.	

		
19.	In the last one year from Dec. 2002 to Nov. 2002, a total of 4,140 MWh was generated. Of the total Zi Chaung hydro generated 3,740 MWh or 90 % while three diesel generators 400 MWh or 10 %. The plant factor of Zi Chaung hydro was 0.34 or 430 kW in the average power output. During the same period, a total energy of 3,590 MWh was sold and Kyat 11.5 million was received. The distribution losses amounted to 550 MWh or 13.3 %. The unit revenue was K3.21/kWh. The annual expense was Kyat 15.7 million, that exceeded the annual revenue above by Kyat 4.2 million. The unit production cost was K4.37 per kWh sold. Of the annual expense, diesel fuel (37,200 gallon) amounted to Kyat 9.8 million or 62 %. The unit fuel cost of diesel generators was Kyat 24.5, which was 7.6 times the average unit revenue. If the market price of HSD at Kyat 2,000/gallon is applied, the unit fuel cost of the diesel generators would be about Kyat 200/kWh.	To maximize the generation output of Zi Chaung through minimizing the station shutdown. Also the spill out from the waterway and Regulating Pond should be minimized by supplying to a wider area in Kalaymyo city if parallel operation of diesel generators is realized. Even before depreciation costs of the generators of both hydro and diesel, the unit production cost at Kyat K4.37/kWh was higher than the unit revenue at K3.21/kWh. The power tariff needs thorough review and revision.

1.2 Monitoring Data

1.2.1 Energy Output

Average energy output per day is shown below. Hours of accidental power cut were excluded to calculate the average value to see the actual output. The energy output becomes low from March to June, when the river flow recedes and only turbine Unit 2 is operated.

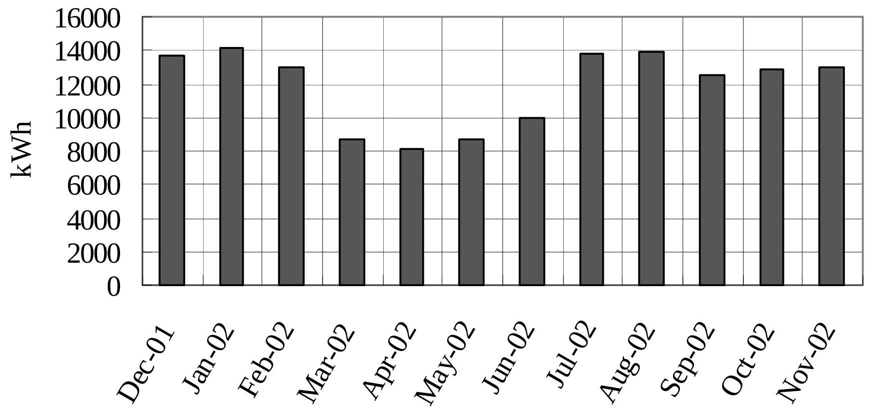


Figure Average Daily Energy Output in Zi Chaung

Monthly energy output from 1996 to 2002 is shown in the table below. The seasonal fluctuation may be due to the low river flow in the dry season. Also shutdown of generating equipment affected the energy outputs.

Monthly Energy Generated at Zi Chaung Hydro-Electric Power (1996-2002)

(unit : kWh)

	Year						
Month	1996	1997	1998	1999	2000	2001	2002
January		361,020	523,050	482,460	461,387	609,307	394,780
February		427,680	404,217	244,695	393,277	506,002	384,870
March		281,584	279,015	240,933	309,540	368,750	333,070
April		231,231	282,975	232,650	262,350	491,571	303,350
May		232,115	226,050	276,245	219,450	338,400	192,768
June		269,115	334,950	379,945	254,400	228,000	224,345
July		440,335	480,456	480,480	260,400	379,730	280,431
August	150,000	456,274	516,450	510,000	324,120	389,225	319,679
September	192,000	459,360	455,812	528,000	409,365	418,700	307,320
October	50,866	371,810	526,680	557,535	478,995	371,910	253,370
November	105,391	425,700	501,600	534,435	460,350	363,611	323,465
December	284,497	468,600	507,754	494,505	528,660	419,100	
TOTAL	782,754	4,424,824	5,039,009	4,961,883	4,362,294	4,884,306	3,317,448
Month Ave.	156,551	368,735	419,917	413,490	363,525	407,026	301,586

Monthly peak power is shown below:

Monthly Peak Power

From November 2001 To November 2002

No.	Date	Peak Power (kW)
1	Nov, 2001	810 kW (21:00hrs, 1.11.01 Thursday)
2	December, 2001	800 kW (07:00hrs, 22.12.01, Saturday)
3	January, 2002	800 kW (07:00hrs, 7.1.02, Monday)
4	February, 2002	820 kW (19:00hrs, 4.2.02, Monday)
5	March, 2002	720 kW (19:00hrs, 6.3.02, Wednesday)
6	April, 2002	500 kW (09:00hrs, 27.4.02, Saturday)
7	May, 2002	500 kW (09:00hrs, 14.5.02, Tuesday)
8	June, 2002	780 kW (21:00hrs, 26.6.02, Wednesday)
9	July, 2002	890 kW (20:00hrs, 28.7.02, Sunday)
10	August, 2002	900 kW (20:00hr, 7.8.02, Wednesday)
11	September, 2002	820 kW (19:00 hr,7.9.02, Saturday)
12	October, 2002	900 kW (19:00 Hr,19.10.02, Saturday)
13	November, 2002	850 kW (20:00 Hr, 9.11.02, Saturday)

NOTE: Reading on kw meter for line 2

1.2.2 Financial Condition

Zi Chaung expense in each month and revenue are shown in the table below.

Monthly Expense (from Dec. 2001 to Nov. 2002)

No.	Month	Employee (Kyats)	HSD (Kyats)	Repairing Cost (Kyats)	Total (Kyats)
1	December, 01	237,506	925,775	-	1,163,281
2	January, 02	239,464	852,975	-	1,092,439
3	February, 02	227,376	852,975	-	1,080,351
4	March, 02	246,602	852,975	1,900,091	2,999,668
5	April, 02	236,216	854,575	-	1,090,791
6	May, 02	238,420	854,575	1,151,290	2,244,285
7	June, 02	246,540	854,575	-	1,101,115
8	July, 02	222,501	854,575	-	1,077,076
9	August, 02	226,115	854,575	-	1,080,690
10	September, 02	235,410	676,425	105,091	1,016,926
11	October, 02	221,926	676,425	-	898,351
12	November, 02	218,720	672,070	-	890,790
	TOTAL	**3,035,509**	**9,782,495**	**3,156,472**	**15,735,763**

NOTE: HSD means High Speed Diesel Oil

Energy Sold and Operating Revenue

No.	Month	Nos. of Consumer	Energy Sold (kWh)	Revenue (Kyat)	Unit Revenue (Kyat/kWh)
1	December, 01	1,972	403,180	1,003,243	2.49
2	January, 02	1,982	378,422	1,075,423	2.84
3	February, 02	1,964	356,092	1,015,466	2.85
4	March, 02	1,962	319,105	761,531	2.39
5	April, 02	1,992	283,666	648,545	2.29
6	May, 02	1,997	186,837	693,523	3.71
7	June, 02	2,005	221,184	815,850	3.69
8	July, 02	2,035	273,263	1,093,750	4.00
9	August, 02	2,004	302,071	1,122,096	3.71
10	September, 02	1,013	298,380	1,069,544	3.58
11	October, 02	2,044	256,632	1,069,315	4.17
12	November, 02	2,066	312,903	1,174,277	3.75
	TOTAL	2,066	3,591,735	11,542,563	3.21

1.2.3 Diesel Generation in Kalaymyo Township

Below shows energy output from diesel generator and fuel consumption which effects large portion of financial condition.

Energy Output and Fuel Consumption of Diesel Generators (Dec. 2001-Nov. 2002)

Month	860kVA			608 kVA			320 kVA		
	Energy Output (kWh)	Diesel (gallon)	kWh/ gallon	Energy Output (kWh)	Diesel (gallon)	kWh/ gallon	Energy Output (kWh)	Diesel (gallon)	kWh/ gallon
Dec-01				22,860	2,181	10.481	21,580	1,707	12.642
Jan-02				24,040	2,313	10.393	17,068	1,377	12.395
Feb-02				26,840	2,634	10.190	-	-	-
Mar-02				28,760	2,913	9.873	6,166	523	11.790
Apr-02				22,520	2,270	9.921	-	-	-
May-02				20,040	2,030	9.872	-	-	-
Jun-02				13,240	1,389	9.532	15,907	1,402	11.346
Jul-02				10,260	1,111	9.235	22,846	1,929	11.843
Aug-02	60	87	0.690	-	-	-	27,259	2,131	12.792
Sep-02	12,300	1,465	8.396	-	-	-	23,910	1,928	12.401
Oct-02	23,040	2,110	10.919	-	-	-	21,614	1,811	11.935
Nov-02	-	-		20,680	2,319	8.918	19,169	1,619	11.840
TOTAL (Average)	**35,400**	**3,662**	**(9.658)**	**189,240**	**19,160**	**(8.841)**	**175,519**	**14,427**	**(10.898)**

Source: U Kyee Nyo, MEPE Kalaymyo

Monthly Peak Power Generated by Three Diesel Engines in Kalaymyo

(from November 2001 to November 2002)

	860kVA		608kVA		320 KVA		
Month	Peak Power (kW)	Date	Peak Power (kW)	Date	Peak Power (kW)	Date	Remarks
Nov-01			320	14.11.01	215	14.11.01	860kVA is repaired about liner and piston ring 6 sets within July and August 2002 at Mandalay.
Dec-02			320	19.11.01	219	11.12.01	
Jan-02			320	23.12.01	222	26.12.01	860 kVA is repaired again because of some cracks at main bearing at November 2002.
Feb-02			300	20.1.02	-		
Mar-02			260	27.2.02	190	10.3.02	608 kVA is repaired for grinding and polishing for No.3 crank shaft from August to October 2002.
Apr-02			240	21.3.02	-		
May-02			260	4.5.02	-		In February, April, March 2002, 320kVA is repaired for bush and engine oil seal from turbo charger was not good.
Jun-02			240	18.5.02	197	29.5.02	
Jul-02			240	22.6.02	219	14.7.02	
Aug-02	60	8.8.02	-		220	14.8.02	
Sep-02	330	15.9.02	-		219	31.8.02	
Oct-02	330	1.10.02	-		212	20.9.02	
Nov-02	-		240	26.10.02	200	23.10.02	

Source: U Kyee Nyo (306411), MEPE, Kalaymyo

1.2.4 Zi Chaung Accident Record

Power cut by accident or maintenance is listed in the table below.

According to the records above, Unit 2 governor caused unit shutdown for 199 hours and 39 times in a year. The 11 kV line incidents took place for 147 hour and 38 times. Lowering in the water level of Regulating Pond also caused station shutdown. It is recorded that such station shutdown occurred not only in the dry season but also in the rainy season. It was reported due to clogging of rocks and sediments at the Intake Gate.

Power Cut in Zi Chaung PS in Dec 2001-Nov 2002

No.	Cause	nos. of power cut	hours of power cut
by Accident			
1	Governor frequency error (No.2)	39	199
2	11 kVA line drop	38	147
3	Low water level	14	79
4	frequency trouble	3	44
5	Low air pressure of governor (No.2)	2	18
6	Crack in turbine body (No.1)	2	9
7	Transformer related accident	2	4
8	Other accident	2	6
by Maintenance			
9	11 kVA line maintenance	5	13
10	Carbon brush change	5	7
11	Other maintenance	2	2
12	No record	10	17
	TOTAL	**124**	**545**

Monthly Power Cut

Month	nos. of power cut	hours of power cut
Dec.2001	3	5
Jan. 2002	10	23
Feb.	6	13
Mar.	12	100
Apr.	8	42
May.	12	42
Jun.	13	28
Jul.	17	77
Aug.	13	66
Sep.	17	115
Oct.	2	2
Nov.	11	32
TOTAL	**124**	**545**

The detailed information of the causes is shown in below table.

Record of Station Shutdown in Dec 2001-Nov 2002

No.	Date	from	to	stop hours	Detail
1	23.12.2001	15:00	16:00	1	11 kVA line drop
2	27.12.2001	15:00	17:00	2	Governor (No.2) frequency error
3	29.12.2001	10:00	12:00	2	Governor (No.2) frequency error
	Dec total	3	times	5	hours
4	08.01.2002	20:00	21:00	1	Governor (No.2) frequency error
5	11.01	13:00	15:00	2	Excitation cable connection loose
6	13.01	6:00	7:00	1	Governor (No.2) frequency error
7		8:00	10:00	8	Governor (No.2) frequency error
8	18.01	11:00	13:00	2	Governor (No.2) frequency error
9		15:00	16:00	1	Governor (No.2) frequency error
10	20.01	13:00	15:00	2	11 kVA line drop
11		17:00	18:00	1	11 kVA line drop
12	26.01	15:00	19:00	4	Cable connection of energy meter
13	27.01	12:00	13:00	1	11 kVA line drop
	Jan. total	10	times	23	hours
14	02.02	9:00	10:00	1	Governor (No.2) frequency error
15	03.02	7:00	11:00	4	Governor (No.2) frequency error
16	04.02	13:00	16:00	3	Low water level
17	08.02	7:00	8:00	1	Governor (No.2) frequency error
18	14.02	19:00	20:00	1	Low water level
19	21.02	24:00	3:00+1	3	Governor (No.2) frequency error
	Feb. total	6	times	13	hours
20	07.03	12:00	13:00	1	11 kVA line drop
21	09.03	22:00	23:00	1	Low water level
22	11.03	12:00	13:00	1	11 kVA line drop
23	13.03	21:00	23:00	2	Low water level
24	18.03	8:00	17:00+2	58	Governor (No.2) frequency error
25		20:00	21:00	1	Governor (No.2) frequency error
26	21.03	6:00	13:00	7	Low water level
27	25.03	3:00	8:00	5	11 kVA line drop
28		12:00	14:00	2	11 kVA line drop
29	27.03	20:00	12:00+1	16	11 kVA line drop
30	28.03	20:00	21:00	1	11 kVA line drop
31	29.03	7:00	12:00	5	Governor (No.2) frequency error
	Mar. total	12	times	100	hours
32	02.04	18:00	20:00	2	Transformer alley break down in Kalaymyo MEPE
33	04.04	20:00	21:00	1	Governor (No.2) frequency error
34	06.04	10:00	11:00	1	Carbon brush change (No.2)
35	08.04	18:00	10:00+1	16	Low governor air pressure (No.2)
36	10.04	15:00	16:00	1	Governor (No.2) frequency error
37	13.04	9:00	12:00	3	11 kVA line maintenance in
38	18.04	0:00	10:00	10	Low water level
39	30.04	9:00	17:00	8	11 kVA line drop
	Apr. total	8	times	42	hours
40	01.05	7:00	13:00	6	11 kVA line drop
41		15:00	18:00	3	Low water level
42	13.05	12:00	13:00	1	Low water level
43	14.05	23:00	8:00+1	9	Governor (No.2) frequency error
44	16.05	23:00	8:00+1	9	Low water level
45	17.05	7:00	11:00	4	Governor (No.2) frequency error
46	20.05	18:00	19:00	1	11 kVA line drop
47	21.05	11:00	12:00	1	11 kVA line drop
48	22.05	14:00	16:00	2	Transformer connection replace in Kalaymyo
49	23.05	18:00	20:00	2	11 kVA line drop
50	24.05	13:00	15:00	3	11 kVA line drop
51	27.05	18:00	19:00	1	11 kVA line drop
	May. total	12	times	42	hours
52	04.06	17:00	18:00	1	Governor (No.2) frequency error
53	05.06	16:00	19:00	3	11 kVA line drop

No.	Date	from	to	stop hours	Detail
65	06.07	9:00	11:00	2	11 kVA line maintenance
66	07.07	6:00	9:00	3	Governor (No.2) frequency error
67		16:00	17:00	1	Governor (No.2) frequency error
68	08.07	3:00	4:00	1	11 kVA line drop
69	09.07	0:00	7:00	8	11 kVA line drop
70	10.07	21:00	8:00+1	11	Low water level
71	13.07	13:00	17:00	4	11 kVA line maintenance
72		20:00	10:00+1	14	Governor (No.2) frequency error
73	14.07	19:00	9:00+1	14	Governor (No.2) frequency error
74	17.07	15:00	17:00	2	Governor (No.2) frequency error
75	18.07	10:00	13:00	3	11 kVA line drop
76	19.07	15:00	16:00	1	11 kVA line drop
77	22.07	22:00	0:00	2	11 kVA line drop
78	23.07	8:00	10:00	2	Governor (No.2) frequency error
79		11:00	13:00	2	11 kVA line drop
80	24.07	17:00	20:00	3	Carbon brush change (No.1)
81	25.07	4:00	8:00	4	no record
	Jul. total	17	times	77	hours
82	02.08	5:00	11:00	6	11 kVA line drop
83	05.08	8:00	10:00	2	11 kVA line maintenance
84	14.08	11:00	14:00	3	Crack in turbine body (No.1)
85		16:00	18:00	2	11 kVA line drop
86		21:00	22:00	1	no record
87	15.08	2:00	13:00	11	Low water level
88	16.08	4:00	14:00	10	Cirquit breaker parts change
89		18:00	20:00	2	no record
90	18.08	23:00	14:00	16	11 kVA line drop
91	19.08	22:00	05:00+1	7	Governor (No.2) frequency error
92	20.08	12:00	15:00	3	Low water level
93	23.08	17:00	18:00	1	Excitation cable maintenance (No.1)
94	29.08	1:00	3:00	2	Low air pressure of governor (No.2)
	Aug. total	13	times	66	hours
95	01.09	23:00	24:00+1	26	Governor maintenance of pipe cleaning (No.1)
96	02.09	19:00	21:00	2	Governor (No.2) frequency error
97	03.09	17:00	19:00	2	11 kVA line drop (target relay)
98	05.09	1:00	3:00	2	Excitation cable cleaning (No.1)
99		13:00	14:00	1	11 kVA line drop
100		15:00	21:00+1	31	11 kVA line drop
101	07.09	10:00	12:00	2	11 kVA line drop
102	08.09	7:00	10:00	3	Governor (No.2) frequency error
103	09.09	12:00	13:00+1	13	Governor (No.2) frequency error
104	12.09	11:00	17:00	6	Crack in turbine body (No.1)
105	13.09	15:00	18:00	3	no record
106	14.09	5:00	8:00	3	no record
107	19.09	23:00	8:00+1	9	Low water level, rocks stuffed in intake wair
108	20.09	12:00	20:00	8	Low water level, rocks stuffed in intake wair
109	21.09	10:00	11:00	1	no record
110	24.09	8:00	10:00	2	11 kVA line drop
111	27.09	20:00	21:00	1	11 kVA line drop
112	Sep. total	17	times	115	hours
113	27.10	11:00	12:00	1	Carbon brush change in No.2 turbine
114		16:00	17:00	1	Carbon brush change in No.2 turbine
115	Oct. total	2	times	2	hours
116	06.11	16:00	18:00	2	11 kVA line drop
117	11.11	12:00	17:00	5	Governor (No.2) frequency error
118	13.11	16:00	18:00	2	Governor (No.2) frequency error
119	14.11	14:00	20:00	6	Governor (No.2) oil pump change
120	17.11	6:00	7:00	1	Governor (No.2) frequency error
121		10:00	11:00	1	Gorvenor (No.2) open limit rope break

Inspection Memo 2 Inspection of Nam Khan Kha Small Hydropower Station in Moe Gaung, Kachin

26.11.2002

2.1 Township Information

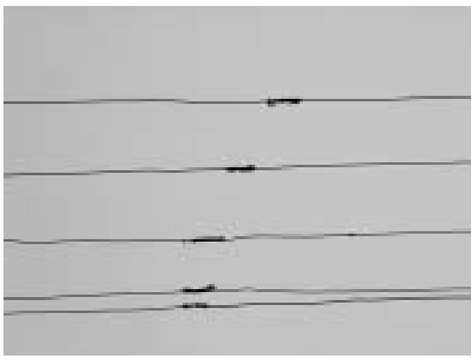
- Moe Gaung, Kachin State
- Power demand
  - Moe Gaung Township
    - 3,000 households, 2,400 consumers
    - Peak load 1,600 kW
    - No D/G
    - 16 mile 33 kV distribution lines
    - Household demand
    - Power tariff

1.	0-50 units	2.5 Kyat/kWh
2.	50-200	10
3.	>200	25

  - Namtee SS
    - 1,000 households, 700 consumers
    - 33/11 kV transformer 1.25 MVA
    - Small sawmill of 20 kW

- Power distribution

Receiving voltage at hotel at 200 V



Cable connection in Moe Gaung

2.2 General Information of Nam Khan Kha Power Station

- General layout

Nam Khan Kha Powerhouse

Upstream view of the Nam Khan Kha

- Location : 22 km from Mogaung, 30 km west of Myitkyina, Kachin State
- Commissioning : Sep. 1996
- Output : 1,250 kW x 4 units = 5,000 kW
- Head : 128 m
- Discharge : Q = 5.3 m^3/sec
- Penstock : D1.52m x L335m, D1.30m x L31m
- Turbine : Francis type with horizontal shaft, made in China
- Transmission line : 33 kV line to Mogaung via Nam Ti for power supply to 3,000 h.h.

Pondage

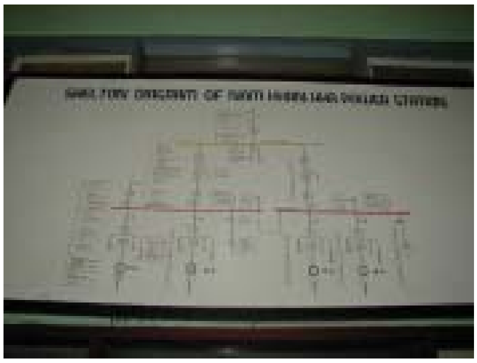
Pondage and approach channel

De-silting basin

De-silting basin

- Generating equipment
  - There are no other generators in the grid.
  - 1,250 kW x 4 units = 5,000 kW
  - Horizontal axis Francis
  - Commissioned in September 1996
  - Penstock D5’ x L1,130’ and D4.25’ x L103’ = 1,203’ in total
  - Hd = 420’
  - Q = 47.5 cusec/turbine
  - Generator output is 11 kV and is sent to Namtee and Moegaung by 33 kV line.
  - Penstock presented black color.
  - One penstock feeds four turbines.
  - Nam Khan Kha→Namtee SS→Moegaung SS by 33 kV line
  - Operators 34 including ones at power station, 16 persons per shift x 2 shifts
  - 24 hour generation in the 7 months from June to December
  - 3 hour peak operation in the 5 months from January to May.

Generator floor



Single line diagram

Control of thiristor

Damaged board of Thyristor controller

Damaged board of Thyristor controller

Inlet valve, locked at full open position

Inlet valve removed for maintenance

Hydraulic for valve operation

Cooling pipe that broke and watered stator coil

Burnt coils replaced by operators with spare coils

Plates of the equipments

Synchronous Generator

Type : SFW1250-6/1430 No. 65-1

Output : 1,250 kW Phase : 3 Winding : Y

Voltage : 11,000 V Current : 82 A

Rotation : 1000 rpm Frequency : 50 Hz

Raway Speed : 1900 rpm Power Factor : 0.8

Excitation Voltage : 52.9 V, Current : 273 A

Excitation System : SCR

Tech Conditions : 6B7894-87

Weight : 12365 kg

Power Transformer

Type : S10-3150/33VA Standard : DB831-91

Capacity: 3150 kVA Phase : 3

Type of Cooling : Onan Service Condition : outdoor

Connection Symbol : YN.oll

Tapping Position	H V winding		L V winding		Impedance Voltage
	V	A	V	A	
1	34650				
2	33825				
3	33000	55.1	11000	165.3	6.86
4	32175				
5	31530				

LL 200 AC 85/Ll75AC35 S/N : 1164

Untanking mass : 4550 kg, Mass of oil : 2325 kg

Total mass : 8695 kg

Symbol of the product 1TB/710/427.1

Year: 1995 06

Feiling Type Automatic Governor

Type : YDT-600 No. 95-054

Rated Oil Pressure : 2.5 MPa

Pressure Oil Pot Volume : 180 L

Work Capacity : 6600 Nm

Date : 1995 06

天津市水電控制設各所

Tianjing City Hydroelectric Control Equipment Works

Break Panel

No. 033

Type ZM-01 220 V 117 kg

Air Pressure : 0.7 MPa

Temp : 100 ℃

Date : 1995 10

中国雲南玉渓麦欣電器開関場

Yuxi Machine Electric Switch Factory

2.3 Particular Information of Nam Khan Kha Power Station

- Conditions of generating units
  - Two units (Nos. 1 and 2) were ready for operation both on 10 March 2001 and 26 November 2002.
  - Inlet valve of No. 4 unit was removed at the two inspections above.
  - Turbine casing was significantly rusted when inspected on 10 March 2001 and was repainted on 26 November 2002.
  - The governor of only No. 3 unit was in operational condition while the

others are out of order and manually controlled.

- Multiplier for kWh meter is 3,300. For example, a reading of 0.1 on the kWh meter is 330 kWh.
- There is no water level gauge of the regulating pond. The gauge height is transmitted to the power station by telephone.
- Operational conditions in November 2002

Items	Unit 1	Unit 2	Unit 3	Unit 4
In operation or not	Yes	Yes	No	No
Machine trouble	Governor not good, guidevane automatically open and cannot be fully closed.		Phase shift electronic card of exciter controller damaged.	Stator wire burnt in 2001 due to watering resulting from burst of cooling pipe. Control piston of butterfly valve damaged and sent to Mandalay for repairing.
Output at 18:15 on 26.11.2002	550 kW	850 kW		

- Incident in December 2000
  1. The pressure lowered even though the guidevane was fully opened.
  2. It was found through the manhole that the penstock was filled with sand.
  3. The sand was removed in 10 days. It amounted to about 500 cubic feet.
  4. No abnormal conditions were recognized before that.

- Penstock pipe was clogged with sand in Dec. 2000 due to no sand flushing at Intake and Pond

Sand removed from Penstock

2.4 Issues

- Waterway Complex
  - De-silting basin is provided at the downstream end of the headrace channel, but it appears that the velocity in the basin is not low enough to settle sand and silt included in the flow. In addition, the flow including sand is being conveyed through the approach channel directly to the inlet of penstock, since the approach channel and the pondage is separated by the concrete wall. Accordingly, sand/silt is likely to enter the penstock when sand trap is not made efficiently in the de-silting basin. To improve this situation, the following measures are recommended:
    1) Hydraulic analysis is to be carried out to clarify the flow conditions such as water surface profile, velocity, and sand-settling function based on the completion drawings.
    2) Structural renovations may be required to minimize the sand inflow at the intake, and to settle the sand included in the flow at the de-silting basin according to the flow characteristics.
    3) Periodical sand flushing operation both at the intake and the de-silting basin is essential to minimize the sand/silt inflow into the penstock, for which the maintenance and operation manual should be prepared properly and the training of operational staff is required. The completion drawings as well as O&M manual needs to be provided at the site office.
  - Water level gauge at the pondage is indispensable for peak power operation in a dry season to utilize the storage as efficiently as possible.

- Generating equipment and transmission lines
  - Nam Khan Kha Power Station with 5,000 kW is operated as an isolated power system to supply the electricity to Moe Gaung Township only with the electricity demand of 1,600 kW. While the electric power is insufficient in Myitkyina, the capital of Kachin State, the load shedding is inevitable until the completion of Mali and Nam Tabet Power Stations. Myitkyina grid system including Nam Khan Kha Power Station will contribute not only to the stable power supply to this area, but also to the fuel saving for the diesel generators operated in Myitkyina.