ATTACHMENTS

Attachment-1 Member list of the Study Team

Name	Assignment	Company
Mr. Tadayuki OGAWA	Team leader / PV Dissemination Policy / CDM / Environmental and Social Considerations	Yachiyo Engineering Co., Ltd.
Mr. Fumikazu DOI	Grid-connected PV System	Shikoku Electric Power Co., Ltd.
Mr. Yoshitetsu FUJISAWA	Institutional Framework for PV Grid-connection / DSM	Shikoku Electric Power Co., Ltd.
Mr. Teruo KURUMADA	Architectural Design / Cost Estimation	Yachiyo Engineering Co., Ltd.
Mr. Akihir SHIMOMURA	Financial and Economic Analysis	Yachiyo Engineering Co., Ltd.
Mr. Tomonori KONDO	Equipment Planning / Detail Design	Yachiyo Engineering Co., Ltd.
Mr.Nobuaki TACHIBANA	Coordinator 1	Yachiyo Engineering Co., Ltd.
Ms. Natsuki SEKI	Coordinator 2	Yachiyo Engineering Co., Ltd.
Mr. Makoto ABE	Coordinator 3 / Distribution Planning	Yachiyo Engineering Co., Ltd.

Attachment-2 List of Parties Concerned in the Recipient Country

President Office

Mr. Ahmed Nasheed	Utility Development Advisor
Mr. Ibrahim Haleem	Assistant Director
Mr. Ahmed Mausoom	Finance Secretary

Ministry of Finance and Treasury

Mr. Ali Hashim	Minister
Mr. Ahmed As-Ad	Minister of State
Mr. Ismail Shafeeq	Permanent Secretary
Mr. Hamdhy Ageel	Executive Director
Ms. Aminath Nashia	Director, External Resources Management Division
Ms. Fathimath Rasha	Assistant Programme Officer
Mr. Mohamed Ifah	Officer, External Resources Management Division
Mr. Ahmed Mush-hid Rasheed	Desk Officer, External Resources Management Division

Ministry of Foreign Affairs

Dr. Hussain Niyaaz	Executive Director
Ms. Farzana Zahir	Director
Mr. Mohamad Shujao	Desk Officer, Economic & Development Dept.

Ministry of Housing, Transportation and Environment

Mr. Mohamed Aslam	Minister
Dr. Mohamed Shareef	Deputy Minister
Mr. Akaram Kamaludeen	Deputy Minister
Mr. Ahmed Saleem	Permanent Secretary
Mr. Ahmed Rasheed	Executive Director, Acting Permanent Secretary
Mr. Amjad Abdulla	Director General
Mr. Ahmed Ali	Assistant Director
Mr. Amir Hassan	Assistant Director
Mr. Khalid Sulaiman	Project Manager
Mr. Shifaz Ali	Senior Engineer
Mr. Mohamed Fazeeh	Electrician
Mr. Ibrahim Naufal	Engineer
Mr. Mohamed Inaz Rasheed	Assistant Project Officer
Mr. Zammath Khaleel	Environment Analyst
Ms.Fathimath Raufa Moosa	Assistant Engineer

Department of National Planning

Mr. Mohamed Imad	Asst. Executive Director

Ministry of Education

Mr. Ahmed Shafeeu	Director General
Mr. Mohamed Yoosuf	Director

Ministry of Tourism, Arts & Culture

Mr. Ahmed Salih	Permanent Secretary

Ministry of Human Resources, Youth and Sports

Mr. Ali Zaki Ahmed	Deputy Director General

Ministry of Civil Aviation & Communication

Mr. Mahmood Razee	Minister
Mr. Aminath Solih	Director General

Maldives Energy Authority

Mr. Abdulla Wahid	Director General
Mr. Muawiyath Shareef	Director

Environmental Protection Agency

Mr. Mohamed Zahair	Director General

Maldives Energy Authority

Mr. Abdul Muhusin Ramiz	Director
Ms. Aishafu Shimana	

Male municipality

Mr. Adam Manik	Chairman
Mr. Ismail Zahir	Director General
Mr. Ahmed Haleem	Deputy Director
Mr. Ishaq Ahmed	Director
Mr. Adam Shakim	Deputy Director General

State Electric Company Limited

Mr. Mohamed Rasheed	Chief Executive Officer
Dr. Zaid Mohamed	Managing Director
Mr. Ali Azwar	Deputy Managing Director
Mr. Mohamed Latheef	Director
Mr. Ahmed Niyaz	Director
Mr. Ali Niyaz	Senior Supervisor
Mr. Ahmed Shafeeu	Senior Engineer
Mr. Amjad Mohamed	Administration Supervision
Mr. Aboobakuru Mohamed	Deputy Director
Mr. Azzam Ibrahim	Senior Engineer
Mr. Ibrahim Athif	Senior Engineer
Mr. Ibrahim Nizam	Electrical Engineer
Mr. Mohamed Shahid	Asst. Engineer
Mr. Ibrahim Nashid	Assistant Engineer
Mr. Ahmed Marsoom	Assistant Engineer
Ms. Emas Ahmed	Finance & Accounting Dept.

Huluhumale Development Corporation

Mr. Mahjoob Shujau	Managing Director
Mr. Ahmed Azleem Ibrahim	Planning Engineer

Faculty of Education Maldives College of Higher Education

Mr. Fathimath Mohamed	Director

Thaajidheen School

Mr. Thoha Saleem	Principal
Mr. Mohamed Shereef	Cash

Maldives Center for Social Education

Ms. Fathimath Ismail	Director
Mr. Ali Saleem	Deputy Principal

Kalaafaanu School

Mr. Naazleem Wafir	Assistant Principal

Hiriya School(New Secondary School for Girls)

Mr. Ali Nazim	Principal

Dhiraagu

Mr. Moosa Ahmed Manik	Manager Power & Infrastructure
Mr. Mohamed Shafiu	Engineering Power Generation

Male' Water & Sewerage Company Pvt. Ltd.

Mr. Ahmed Mujthaba	Manager

CDE Pvt. Ltd

Dr. Simad Saeed	Managing Director

Gedor Architecture Pvt. Ltd

Mr. Thoriq Ibrahim	Director

MITTS Enterprises Pvt. Ltd

Mr. Ali Shareef	Manager

Indira Gandhi Memorial Hospital (IGMS)

Mr. Mohamed Saeed	Deputy Director

Embassy of Japan, Sri Lanka

Mr. Katsuho Hayashi	Second Secretary Economic Cooperation

JICA/JOCV Maldives Office

Mr. Makoto Nonobe	Resident Representative
Ms. Satoko Iwashige	Coordinator

JICA Sri Lanka Office

Mr. Akira Shimura	Chief Representative
Ms. Yasuko Nishino	Senior Representative
Ms. Kotohi Inoue	Assistant Resident Representative
Dr. Keiji Mitsuhashi	Representative
Mr. Cabral Indika	Project Specialist

Attachment-3 Study Implementation Work Flow

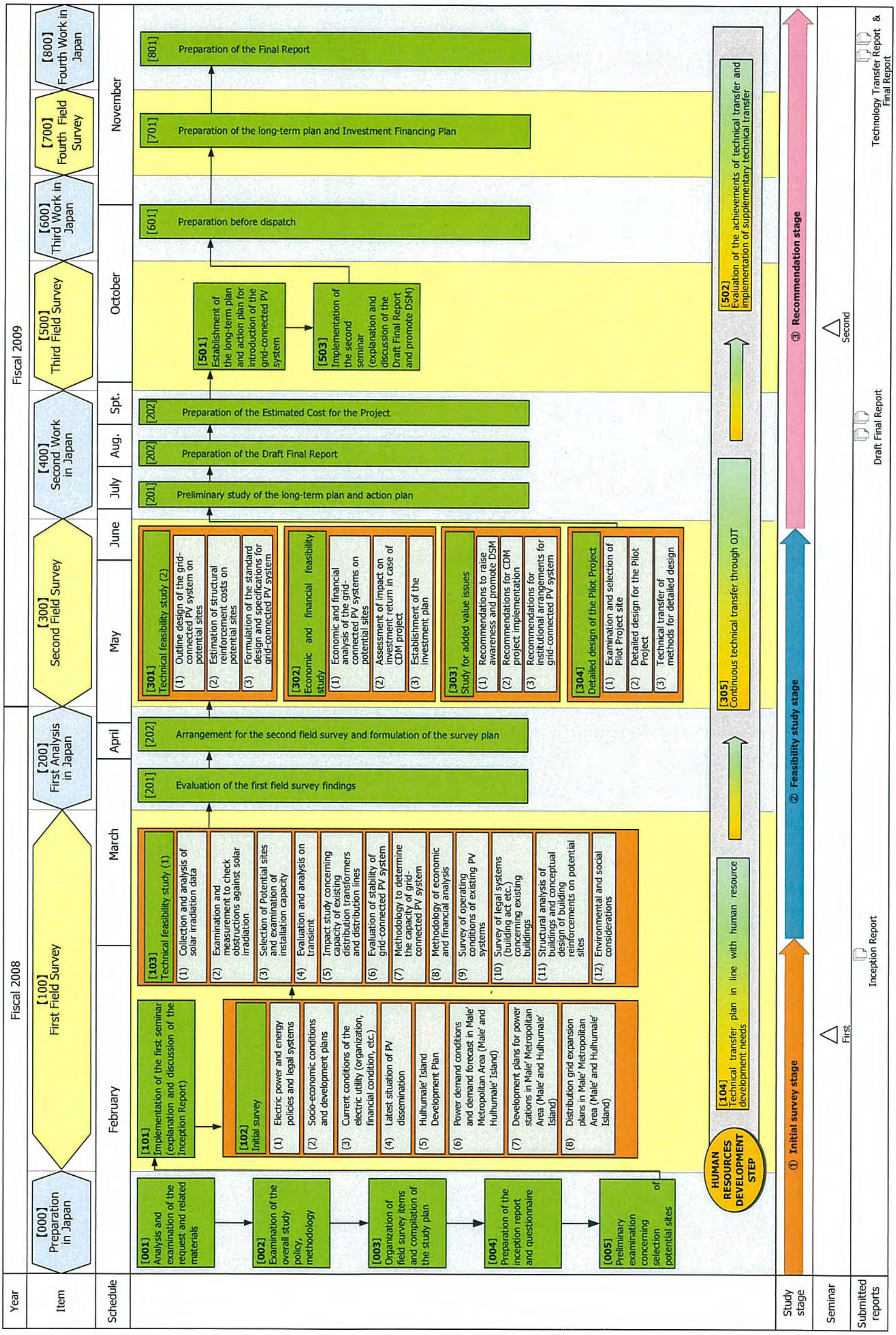


Figure 2-1 Study Implementation Work Flow

AGENDA

1st SEMINAR

FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES

25th February 2009, From 9:00 to 12:30

STELCO 5th Floor Training Room

1. Welcome remarks by Deputy Minister of Housing, Transport and Environment (Dr. Mohamed Shareef)

2. Welcome remarks by JICA (Japan International Cooperation Agency) (Mr. Makoto Nonobe)

3. Presentations by the Study Team

(1) "Introduction of the Study" by Mr. Tadayuki Ogawa (20 minutes)

(2) "Institutional Frameworks to introduce Grid-connected PV system" by Mr. Yoshitetsu Fujisawa (20 minutes)

(3) "Technical Issues to introduce Grid-connected PV system" by Mr. Fumikazu Doi (20 minutes)

(4) "Economic and Financial Analysis" by Mr. Akihiro Shimomura (20 minutes)

(Followed by Q&A Session for each presentation)

Record of Discussion

Project Name	FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES
Date	25th February 2009 9:00～12:00
Venue	Training Room, STELCO 5th Floor
Attendant	See attached page
Contents	Deputy Minister of MHTE MHTE and Mr. Nonobe (Resident Representative of JICA/JOCV Maldives Office) made a speech. After that, JICA STUDY TEAM explained the Inception Report and discussed the following matters. 1. General Matters of the Study - MHTE has conducted the study on development of renewable energy so that information like the grid-connection by private sector and tariff structure of renewable energy, which the Study Team may need, can be shard. → The study team would like to enhance such information sharing in order to conduct the Study efficiently. 2. Institutional Framework - It was explained that RPS should be introduced before introduction of Feed-in Tariff. What is the advantage for doing that? → RPS is the system that obliges utility companies to purchase a certain amount of power from the renewable energy, and can stimulate introduction of PV system. Therefore, RPS is suitable for the initial step of dissemination of the grid-connected PV system. Feed-in Tariff is the system which obliges utility companies to purchase power at a certain price from the renewable energy. Although this system can stimulate private investment, the PV system will not be disseminated unless the private sector does not promote the investment. That's why this system should be adopted when a certain level of introduction is achieved. - As a result of comparing the systems, it was concluded that RPS and Feed-in Tariff was suitable. What is the reason? For example, subsidies for capital investment are provided in UK. Especially, assistance for capital investment is needed in the Maldives. → Currently, STELCO received the subsidies from the government for operation and management of diesel gen-sets. If the subsidies are not provided for the PV system, cost competition cannot be realized on even ground with the existing diesel gen-set. Therefore, the subsidies from the government are also required for introduction of new energy system like PV system.

	- After adoption of the RPS, how many years does it takes to make the shift to the next stage? → Phased introduction of the institutional frameworks is very meaningful for dissemination of the PV system. The number of years for the transition cannot be projected because it depends on the actual conditions of dissemination. Needless to say, if the subsidies for the PV system can be provided, the dissemination of the PV system will be accelerated. 3. Technical Issues - How much is the capacity and cost of PV panels and total system? → For example, in case of installation on the roof top of STELCO building, the capacity will be approximately 40kW, considering that capacity of one panel is 208W. The cost depends on types of components like inverter which will be identified from the results of the Study. However, based on the experiences, cost of a PV panel is about US$ 5/W and total cost would be US$ 10,000/kW. As for the inverter, three-phase type should be installed because single-phase type could cause misalignment of distribution lines. - How about salt erosion of the PV system? →The Study Team visited MHTE and investigated the legal framework on the salt erosion. It is confirmed that there is no regulation on the salt erosion and the PV system can be installed in line with the regulation like Japanese standards. However, the salt erosion will be examined properly in the Study. - How often should the system be maintained? →Once the system is installed, the maintenance work is not needed frequently compared with that for the existing system. - How much is the cost for installation in small island with several thousand of population? →For such case, not only the number of users but also demand data is required . 4. Economic and Financial Analysis - Laying an undersea cable was planned between Male' and Hulhumale'. However, it has not been realized because there is no knowledge and techniques in the Maldives. Is it possible to provide the cost of undersea cable? →The cost would be very expensive although the Study Team does not have such information. The reason of comparatively high price is due to necessity of advanced technology for detection of fault points, specialized equipment for maintenance, etc. - It is explained that CDM project formulation would be examined. Will economical efficiency be improved when the CDM project formulation is applied? →Generally, it will be improved. However, cost of the project formulation like formulation of PDD is very expensive so that it is necessary to examine feasibility carefully for the case of CDM application.
Submission materials	Presentation materials

Attachment-5 AGENDA (2nd SEMINAR)

AGENDA

2nd SEMINAR

FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES

11th October 2009, From 10:00 to 12:15

STELCO 5th Floor Training Room

1. Welcome remarks by Ministry of Housing, Transportation and Environment by Mr. Ahmed Ali (10 minutes)
2. Welcome remarks by JICA (Japan International Cooperation Agency) by Mr. Makoto Nonobe (5 minutes)
3. Presentation 1 (10 minutes)
   "Outline of the Study" by Mr. Tadayuki Ogawa
   Q&A Session
4. Presentation 2 (20 minutes)
   "Technical Feasibility Study" by Mr. Fumikazu Doi
   Q&A Session
5. Presentation 3 (20 minutes)
   "Economic and Financial Feasibility Study" by Mr. Akihiro Shimomura
   Q&A Session

   Tea Break (10 minutes)

6. Presentation 4 (20 minutes)
   "Detail Design for Pilot Project" by Mr. Tomonori Kondo
   Q&A Session
7. Presentation 5 (20 minutes)
   "Institutional Framework for Grid-connected PV system" and
   "Demand Side Management" by Mr. Yoshitetsu Fujisawa
   Q&A Session
8. Presentation 6 (10 minutes)
   "Medium and Long-Term Action Plan" by Mr. Tadayuki Ogawa
   Q&A Session
9. Closing remarks by STELCO by Mr. Ibrahim Nizam (10 minutes)

Record of Discussion

Project Name	FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES
Date	11th October 2009 10:00 - 13:00
Venue	Training Room, STELCO 5th Floor
Attendant	See attached page
Contents	Mr. Ahmed Ali, Assistant Director of MHTE and Mr. Nonobe (Resident Representative of JICA/JOCV Maldives Office) made a speech. After that, JICA STUDY TEAM explained the Draft Final Report and discussed the following matters. ● Technical Feasibility Study - Should off-load loss of the PV system interconnection transformer during night time be considered for assumption of power generation by the PV system? → In the assumption, a loss from PV panel and a transform loss from power conditioner are considered. The off-load loss is not considered because the order is smaller than them. If the specifications of the transformer would be submitted, such condition could be incorporated into the report. - As for the factors of applying the battery-less system, can the condition that a load is larger than the PV power generation at any time be considered? →Yes, that's right. - Voltage simulation is conducted for connection with 11kV line. Is the PV system simulated on the case that the system will be connected to the lower voltage line? →The simulation is carried out under the condition. - How much is the amount of irradiation which was used for assumption of annual PV power generation? →Annual average 5.15kWh/m^2/day is used for the assumption. - Are the current load conditions considered for the estimation of possible installation capacity of the PV system? →Both the current conditions and future demand projection are considered. - What kinds of protective devices are mounted in the PV system? →The devices like overcurrent relay (OCR), overvoltage relay (OVR), undervoltage relay (UVR), overvoltage ground-fault relay (OVGR), underfrequency relay (UFR), overfrequency relay (OFR) are included in the power conditioner as standard devices. ● Detailed Design of the Pilot Project - How is the monitoring device for measurement managed and connected?

	→STELCO will manage the system server and security of the system will be controlled by password. The system will be connected via internet line. ● DSM - In case of operation of heat storage type air conditioning system, where is the power supplied from? →When it is operated during night time, the energy from the heat storage system can be utilized if the system has remaining power. If not, the power should be purchased from the STELCO's grid. - Regarding the suggestion of energy auditing, The Maldivian side has no basic knowledge for that. How are the concrete steps for realization considered? →The following two steps are considered. It is expected that the basic knowledge can be accumulated step by step. STEP 1 : STELCO will appoint 2 energy manager. Those two managers will implement energy auditing in Male' and Hulhumale' as trial basis. STEP 2 : Results of the trial operation during 5 years will be evaluated. If an effect is seen, the Energy Saving Act will be formulated, considering the cost and the necessity. Utility companies operating in every province will be obliged to appoint an energy manager. Major facilities which have a load at certain level should have a regular energy auditing by the energy managers. - Importance of DSM is recognized in the Maldives. Curently, MHTE is proposing to the President's Office that preset temperature of the air conditioning system should be kept at 25℃ or more in the government facilities. The proposal will be shortly approved. JICA STUDY TEAM requested MHTE to provide a photocopy of the proposal letter.
Submission Materials	None

AGENDA

2nd SEMINAR

FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES

13th October 2009, From 10:00 to 11:55

STELCO 5th Floor STELCO Hall

1. Welcome remarks by STELCO by Mr. Ali Azwar (10 minutes)
2. Welcome remarks by JICA (Japan International Cooperation Agency) by Mr. Makoto Nonobe (5 minutes)
3. Presentation 1 (20 minutes)

   "General Concept of PV System" by Mr. Tadayuki Ogawa

   Q&A Session
4. Presentation 2 (20 minutes)

   "Technical Aspects of PV System" by Mr. Fumikazu Doi

   Q&A Session

   Tea Break (10 minutes)
5. Presentation 3 (20 minutes)

   "Economic and Financial Aspects of PV System" by Mr. Akihiro Shimomura

   Q&A Session
6. Presentation 4 (20 minutes)

   "Demand Side Management (DSM)" by Mr. Yoshitetsu Fujisawa

   Q&A Session
7. Closing remarks by STELCO by Mr.Ahmed Niyaz (10 minutes)

Record of Discussion

Project Name	FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES
Date	Tuesday, 13th October 2009 10:00 - 13:00
Venue	Auditorium, STELCO
Attendant	See attached page
Contents	Deputy Managing Director of STELCO and Mr. Nonobe (Resident Representative of JICA/JOCV Maldives Office) made a speech. After that, JICA STUDY TEAM made presentation related to dissemination of the PV system and discussed the following matters. • Technical Aspect of the PV System - Conversion efficiency of PV panel depends on the types of panels. Does the installed area also depend on the conversion efficiency? → In the presentation, 10% of the conversion efficiency was applied for simplifying the explanation. Currently, silicon solar cells are popular and the conversion efficiency of crystal silicon cells exceeds 14%. For the crystal silicon cells, the installed are will be smaller than the example in the presentation. - How should the tilt angle and direction of the PV modules be considered on equator? →It should be installed horizontally in theory. But 5 degrees of tilt angle is preferable, considering the influence of dust. Both directions, north and south, can be applicable. - As for the CO_2 emission reduction, should emission from production of PV modules and installation works be considered? In case that the emission is considered, is the reduction effect still positive? How many years does it take to recover the emission from production? →Today, such information is not available. For the detail analysis, such emission should be incorporated for the calculation. However, the emission from the production and installation works does not offset the reduction effect of the PV power generation. • Financial and Economic Aspect of the PV System - Data of cost saving for schools shown in the presentation is only for the private schools. Is the figure for the government schools the same with the private ones? →The figure would not be the same due to different consumption volume. - How many years does it take to pay back for the installation? How about the life tile of the equipment? →Payback period is not estimated because it depends on the conditions like place of installation and type of PC panels. As for the life time of the equipment, 20 to 30 years for PV panels and 15 years for other components like inverter.

	- Regarding the calculation of the saved amount of bill under the case that half of power consumption will be supplied from the PV system, are factors of the supply side considered? →Such factors are not included. The figure is obtained from the consumption volume and electricity tariff paid by consumers. • DSM - It is explained that DSM is under discussion with the Government of the Maldives. What is the concrete proposal for addition of type of electricity tariff? →Tariff at maximum consumption and tariff by use of time. Under The tariff at maximum consumption, the maximum consumption is set in proportion to contract capacity. Utility company can charge for the maximum consumption at basic rate. This system fixes the power consumption which the customer is allowed at one time in advance between customers and utility company, and contributes to control peak demand. As for the tariff by time of use, different tariff is set for time of use. For example, in Japan, tariff in day time is set at about JPY 20/kWh, while the tariff in night time is set at about JPY 10/kWh. This tariff system can help the power consumption by home appliances like washing machine and iron used during daytime shift to use during nighttime.
Submission materials	

AGENDA

2nd SEMINAR

FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES

15th October 2009, From 10:00 to 11:55

STELCO 5th Floor STELCO Hall

1. Welcome remarks by Ministry of Housing, Transportation and Environment by Mr. Akram Kamaaludeen (10 minutes)
2. Welcome remarks by JICA (Japan International Cooperation Agency) by Mr. Makoto Nonobe (5 minutes)
3. Presentation 1 (20 minutes)
   "General Concept of PV System" by Mr. Tadayuki Ogawa
   Q&A Session
4. Presentation 2 (20 minutes)
   "Technical Aspects of PV System" by Mr. Fumikazu Doi
   Q&A Session

   Tea Break (10 minutes)

5. Presentation 3 (20 minutes)
   "Economic and Financial Aspects of PV System" by Mr. Akihiro Shimomura
   Q&A Session
6. Presentation 4 (20 minutes)
   "Demand Side Management (DSM)" by Mr. Yoshitetsu Fujisawa
   Q&A Session
7. Closing remarks by STELCO by Dr. Zaid Mohamed (10 minutes)

Record of Discussion

Project Name	FEASIBILITY STUDY FOR APPLICATION OF PHOTOVOLTAIC POWER ON MALE' AND HULHUMALE' ISLANDS IN THE REPUBLIC OF MALDIVES
Date	Thursday, 15th October 2009 10:00 - 12:30
Venue	Auditorium, STELCO
Attendant	See attached page
Contents	Deputy Minister of MHTE and Mr. Nonobe (Resident Representative of JICA/JOCV Maldives Office) made a speech. After that, JICA STUDY TEAM made presentation related to dissemination of the PV system and discussed the following matters. • Technical Aspect of the PV System - Is the loss from PV module and inverter general figure? → Conservative figures are applied to the calculation because the purpose is to estimate the annual power generation from the PV system. • DSM After presentation, DSM methods implemented in the resort islands are shared with the participants. The activities carried out by MITTS Enterprises Pvt Ltd, which is presented by Mr. Ali Shareef, are as follows. - The company provides consulting services for construction in Male'. They give advices on promotion of energy saving equipment and layout of effective lighting in newly developed facilities. - Power consumption by air conditioning system is very huge in resort islands. Therefore, the water heater system introduced in the presentation, which utilizes recovery system of waste heat from the air conditioning system, is very effective. - Environment-friendly efforts in not only in the resort islands but also in whole Maldives will contribute to development of the country.
Submission materials	

Design Manual
for
Grid-connected Photovoltaic System

June 2009

JICA Study Team

TABLE OF CONTENTS

LIST OF ANNEXES

1 INTRODUCTION

1.1 Background

The Republic of Maldives (hereinafter referred to as "Maldives") is an island nation with an altitude of just one (1) meter above sea level; it is one of the countries most prone to the effects of rising sea level caused by climate change. The Government of Maldives (hereinafter referred to as "the GOM") intends to promote renewable energy in place of petroleum and to increase the share of total energy demand. In doing so, the GOM aims to reduce greenhouse gas emissions from diesel power station and ensure energy security.

Under these circumstances, the GOM issued a request to the Government of Japan (hereinafter referred to as "the GOJ") for implementation of the Feasibility Study for Application of Photovoltaic Power in Male' and Hulhumale' Islands in the Republic of Maldives (hereinafter referred as "the Study"), as a way to improve energy efficiency and mitigate climate change for the purpose of realizing stable power supply in medium to long term.

1.2 Objective of the Manual

This Design Manual has been developed to provide basic knowledge for the engineers who design the grid-connected Photovoltaic (hereinafter referred to as "PV") in the Maldives. It provides procedures and requirements for the design.

1.3 Intended users

The intended users of this design manual are primarily the followings:

- Ministry of Housing, Transport and Environment (MHTE)
- Maldives Energy Authority (MEA)
- State Electric Company Limited (STELCO)

2 EVALUATION OF POTENTIAL SITES

2.1 Requirements for potential sites

In order to introduce the grid-connected PV system, the site must follow the several requirements. The following items are the principle requirements.

The requirements must be checked based on the site survey and the investigation of structural design drawings. As for the capacity of existing power system, SETLCO must examine the power quality of existing grid including the possible impact after the installation.

Table 2-1 Requirements for potential sites

1	Plentiful insolation and less impact of shade by nearby obstructions
2	Enough strength of the existing structure (roof, rooftop, etc.)
3	Space to install the peripheral equipment (inverter, junction box, etc.)
4	Enough capacity of existing power system (transformer, distribution lines, etc.)
5	Safety with respect to human error, harmony with surrounding landscape
6	Approval from site owner

2.2 Examination method to check obstructions against solar irradiation

1) Obstacles against sunlight on PV Array

As Male' is already crowded with existing buildings, it will be necessary to install PV systems on building rooftops. Therefore, potential sites for PV systems have to be selected as sunlight on PV array is not shielded by surrounding buildings, etc. while taking into account changes in the direction and angle of sunlight by season and time. Generally, if direct sunlight is shielded and PV array is fell into shadow, generated power output could fall by 10~20% compared with the case of no obstacles.

2) Measures to avoid shielding sunlight

In case candidate sites are located on building rooftops or roofs, surrounding obstacles will be surveyed using shade examination maps to check for angle of elevation and direction of such obstacles. The surveyed results will be used to evaluate the potential site. It is ideal to conduct site survey between AM 9:00~PM3:00 in the winter solstice when the possible shadow by obstacles is the largest. The following tools will be used to project the area of shade during the field survey:

① Shade examination map: Chart projecting the trajectory of the sun onto a circular graph at the target area and time (Please refer to ANNEX 1)

② Transit: An instrument to measure the angle of elevation of obstructions

③ Compass: An instrument to measure the direction of obstructions

In the field survey, equipment that can simultaneously measure ② and ③ above must be utilized (Please see Photograph 1). In Figure 2-1Table 2-1 Requirements for potential sites, the red shaded area between the red line and the trajectory of the sun will be affected by shadow. According to this graph, the site will be affected by shadow between 09:30~11:00 in the winter solstice when shadows are the largest.

The drawing on the Figure 2-1 shows the case where the angle of direction of the building edge is directed to the east angle between 15°and 50°, and the angle of elevation is 70° at point A and 40° at point B based on the conditions given in Figure 2-2

Photo 1 Transit

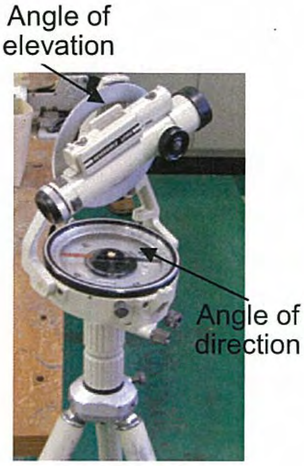


Photo 2 Transit

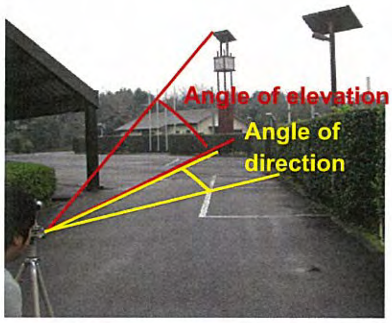
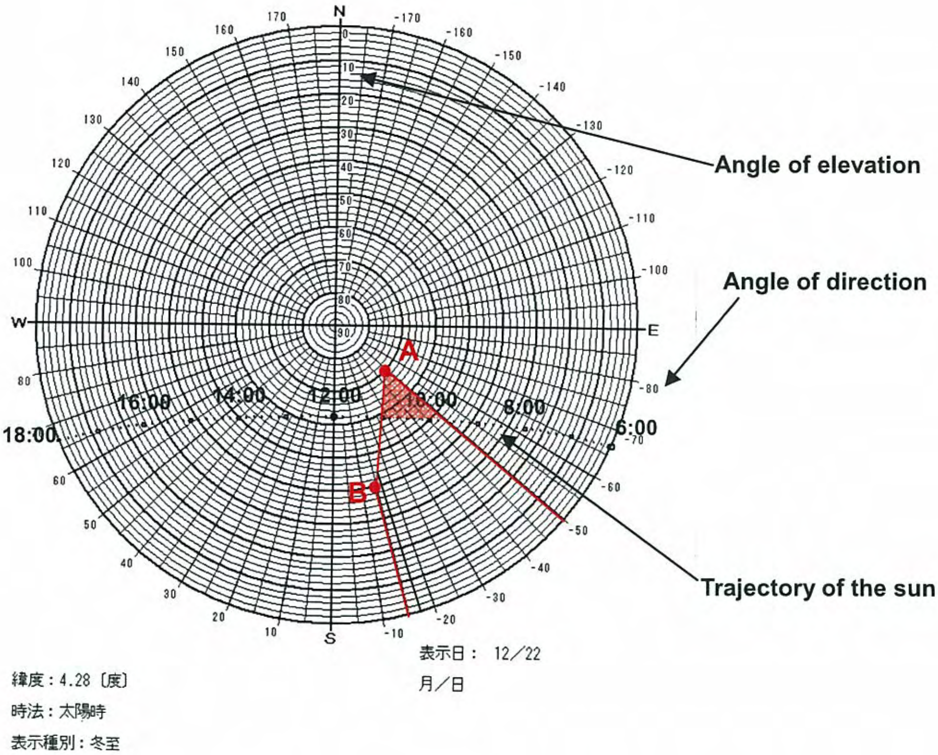


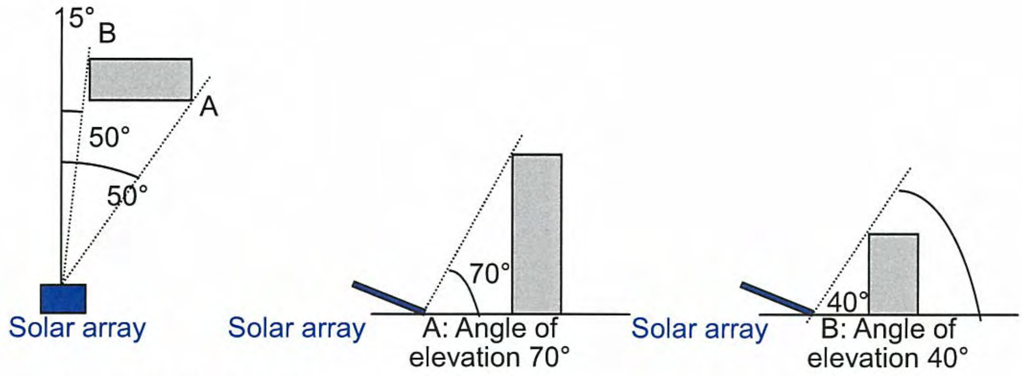
Photo 3 Site Survey

Shade Map



Source: Prepared by the Study Team

Figure 2-1 Shade Examination Map for Maldives (North Lat. 4.8˚, winter solstice)



Source: Prepared by the Study Team

Figure 2-2 Conditions to draw Shade Examination Map (Figure 2-1)

2.3 Evaluation criteria for candidate sites

In order to evaluate candidate sites, as much as possible information must be collected during the field survey.

The following items are necessary information which can be criteria for the evaluation.

Table 2-2 Evaluation criteria

Necessary Information	Points of view
PV installation area	- Angle, direction - Mounting method - Structural strength
PV capacity (kW), Estimated power generation (kWh)	- Daily insolation (kWh/m^2/day) - Impact of shade from surrounding obstructions
Grid-connection	- Connection point - Capacity of existing transformer and distribution lines - Load demand - Power quality
Installation work	- Allowable duration for black out work - Space for carrying in and installing peripheral equipments - Space for temporary storage - Cable routes
Operation and maintenance	- Skill and knowledge of operators - Issues for protection relays - Maintenance space
Ownership of sites	- Approval from site owners
Safety & environmental impact	- Risk of human failure (break, theft) - Harmonization with surrounding environment
Cost	- Equipment costs, installation costs - Generating cost, cost effectiveness

3 DESIGN OF GRID-CONNECTED PV SYSTEM

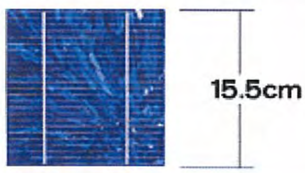
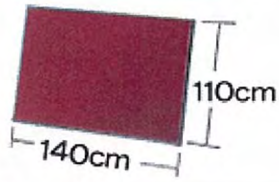
3.1 Selection of PV module type

There are many types of PV module in the world market. Among of them, silicon type of PV module is popular. In general, there are tree (3) types of silicon PV module. The following table shows comparison of each type of PV module.

In Maldives, the crystalline silicon type is recommendable to install on the rooftop because the necessary space is smaller than amorphous type due to the high efficiency.

The efficiency and price depends on the manufacturer and also marketability must be considered. Therefore, it is better to ask quotation to suppliers. At the same time, latest catalogue and specification sheet is required for system design.

Table 3-1 Comparison of Silicon Solar Cell

	Monocrystallne Silicon	Polycrystalline Silicon	Amorphous Silicon
Type			
Efficiency	15~20%	12~17%	8~12%
Price	5~6 US$/W	4 US$/W	4~5 US$/W
Characteristics	Higher efficiency but more expensive than polycrystalline silicon.	Manufacturing process is easier than monocrystalline silicon. Lower price but lower efficiency than monocrystalline silicon.	Thinner than crystal silicon. Light and flexible.

Source : Prepared by the Study Team based on data from NEDO and NEF

3.2 Examination of PV panel layout

In accordance with acquired available space for PV array and module size, PV panel layout can be examined.

For easy computation, the approximate PV capacity can be calculated based on available area utilizing the following formula.

$$\text{PV capacity [kWp]} = \text{Available area [m}^2\text{]} / \text{Module efficiency [\%]} / 100$$

In order to determine the exact PV capacity, the dimension and connection must be considered.

For the investigation of PV module connection, the specification of inverter is necessary. The number of series connection can be calculated as follows:

$$\text{Series number of PV module } (S_n) = \frac{\text{DC input voltage of inverter } (V_{DCIN})}{\text{Maximum Power Voltage } (V_{pmax})}$$

Layout of PV panels can be arranged taking into consideration this series number, module size, cable connection and shade condition.

Each group of PV modules must be composed of multiples of series number. In case that there is enough space, it is advisable to consider the maintenance space to clean the panels. The sample layout is shown in Figure 3-1.

After the determination of PV layout, the rated PV array output can be calculated as follows:

$$P_{array} = P_{module} * N$$

Where

P_{array} : Rated PV array output (kWp)

P_{module} : Rated PV module output (kWp)

N : Total number of PV modules

On the other hand, the parallel number of PV array can be determined as follows.

Parallel number of panels (P_n) = Number of panels (N) / Series number of panels (S_n)

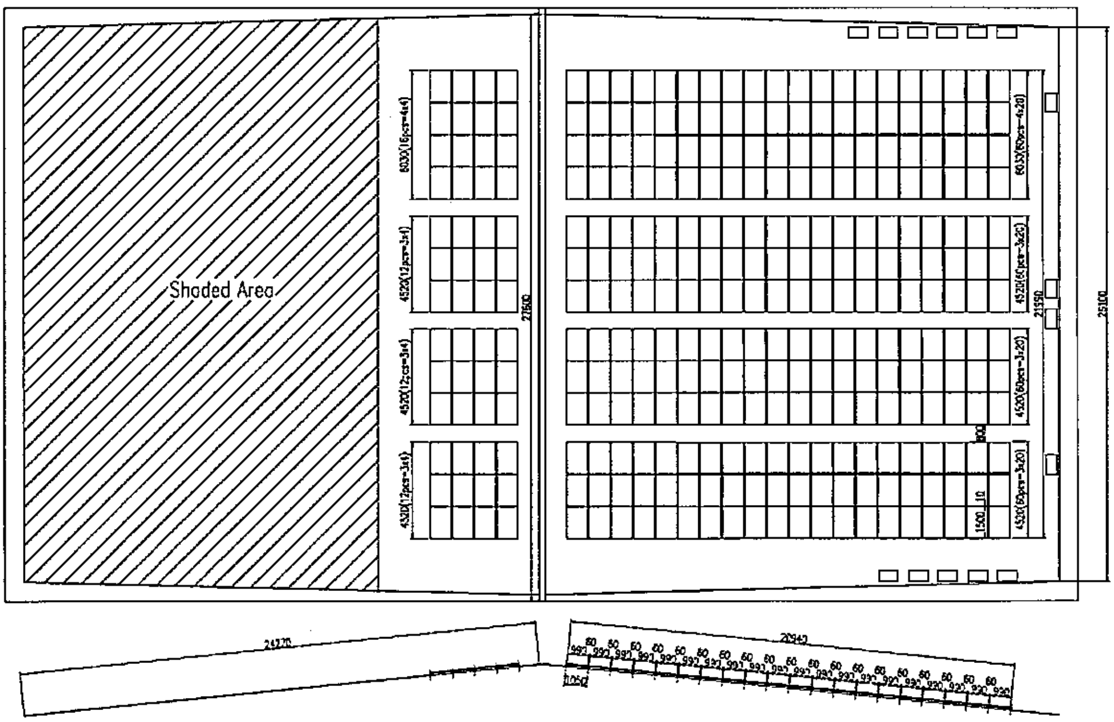


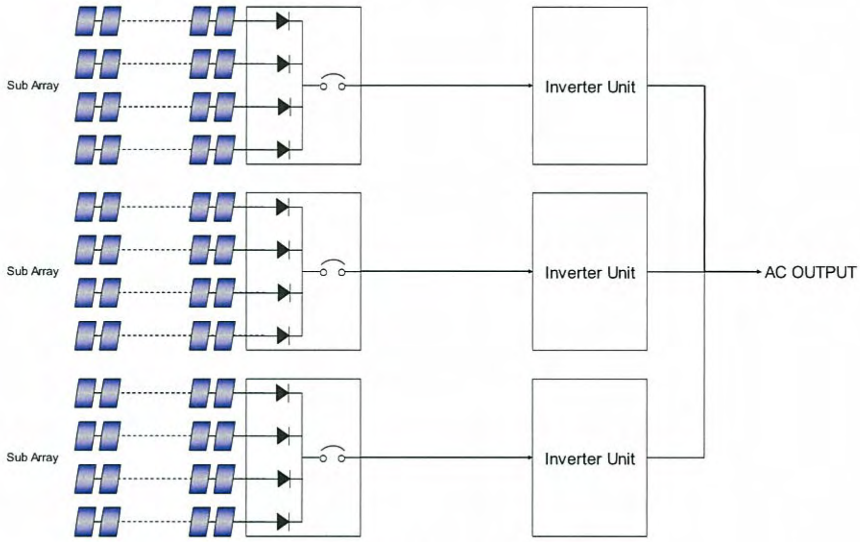
Figure 3-1 Sample PV panel layout (Series Number = 12 pcs)

3.3 Sizing of grid-connected PV inverter

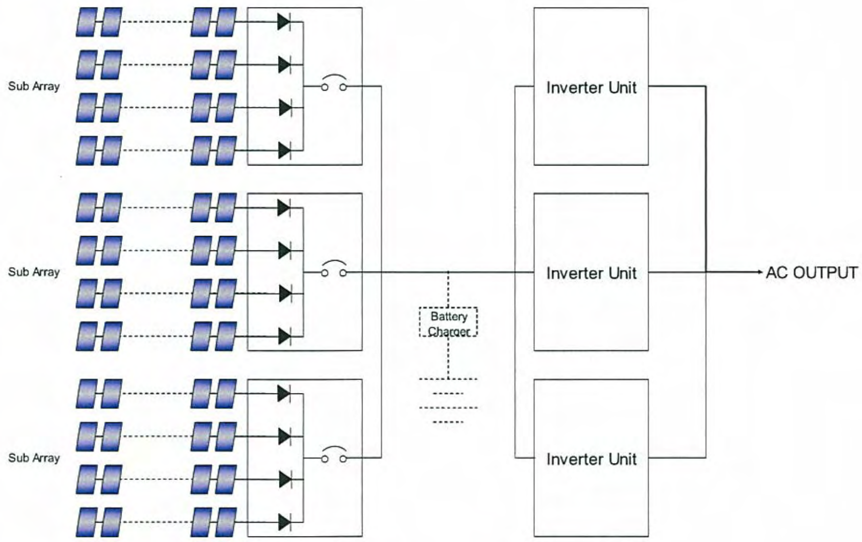
Based on the rated PV array output, capacity of the grid-connected PV inverter can be determined.

Usually the inverter capacity is same or more than the rated PV array output. However the plural inverters also can be applied depending on the availability in the market.

In case of that, two types of system can be considered as shown in Figure 3-2. Type (b) can reduce the cable length. However the signal interchange among inverters is required. Battery base system uses type (b).



(a) DC division type



(b) DC common type

Figure 3-2 Type of inverter composition

The inverter capacity can be calculated as follows:

$$P_{INV} = P_{array} / PF$$

Where

P_{INV} : Inverter output (kVA)

P_{array} : Rated PV array output (kW)

PF : Rated power factor

4 ESTIMATION OF POWER PRODUCTION

4.1 Daily Insolation

In order to estimate the power production from grid-connected PV system, daily insolation data is necessary.

The shows the monthly average insolation data in Male. Also hourly data are attached in ANNEX 2.

If the PV location has shade influence, insolation during shading time must be eliminated from total daily insolation.

For example, in case that the location has an impact of shade from 6 a.m. to 8 a.m. in January, The daily insolation at the site will be 4.808 kWh/m²/day.

Month	Monthly Average Insolation [kWh/m²/day]
1	5.23
2	5.61
3	5.99
4	5.24
5	4.86
6	5.06
7	4.51
8	5.60
9	4.56
10	6.06
11	4.00
12	5.10
AVE	5.15

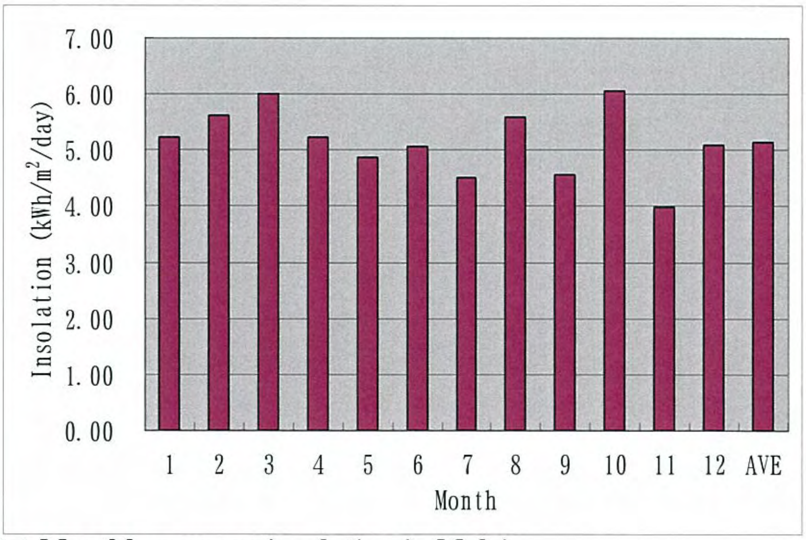


Figure 4-1 Monthly average insolation in Male'

Table 4-1 Example of calculation of insolation reduction by shade

Time	Month Jan
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.000
7	0.127
8	0.295
9	0.469
10	0.620
11	0.724
12	0.760
13	0.724
14	0.620
15	0.469
16	0.295
17	0.127
18	0.000
19	0.000
20	0.000
21	0.000
22	0.000
23	0.000
24	0.000
Total	5.230

[Shade impact]

Insolation from 6 a.m. to 8 a.m. = 0.127+0.295 = 0.422 kWh/m^2

[Daily insolation]

Daily insolation = Monthly average insolation – Shade impact

= 5.230 – 0.422

= 4.808 kWh/m^2/day

4.2 Estimation of annual PV power generation

The annual PV power generation can be estimated utilizing the following formula:

$Ep = \Sigma\ H_A / Gs * K * P$

Where

- Ep : Estimated annual power generation (kWh/year)
- H_A : Monthly average insolation at location (kWh/m^2/day)
- Gs : Irradiance @ STC (Standard Testing Condition) = 1 (kW/m^2)
- K : Loss coefficient = Kd * Kt * η_{INV} * η_{TR}

Kd : PV loss coefficient. Dirt on the PV surface, loss caused by irradiance fluctuation, difference of PV characteristics. Usually 0.8.

Kt : Temperature correction coefficient. Correction coefficient to consider the change of PV efficiency by heat

$Kt = 1 + \alpha\ (Tm - 25) / 100$

α : Temperature coefficient @ maximum output (% ・ ℃$^{-1}$)
= - 0.5 (% ・ ℃$^{-1}$) [In case of Crystalline Silicon]

Tm: Module temperature (℃) = Tav + ΔT

Tav: Monthly average temperature (℃)

ΔT: Module temperature increase (℃)

Open back type	18.4
Roof installation type	21.5

η_{INV}: Inverter efficiency. Usually 0.9 – 0.95

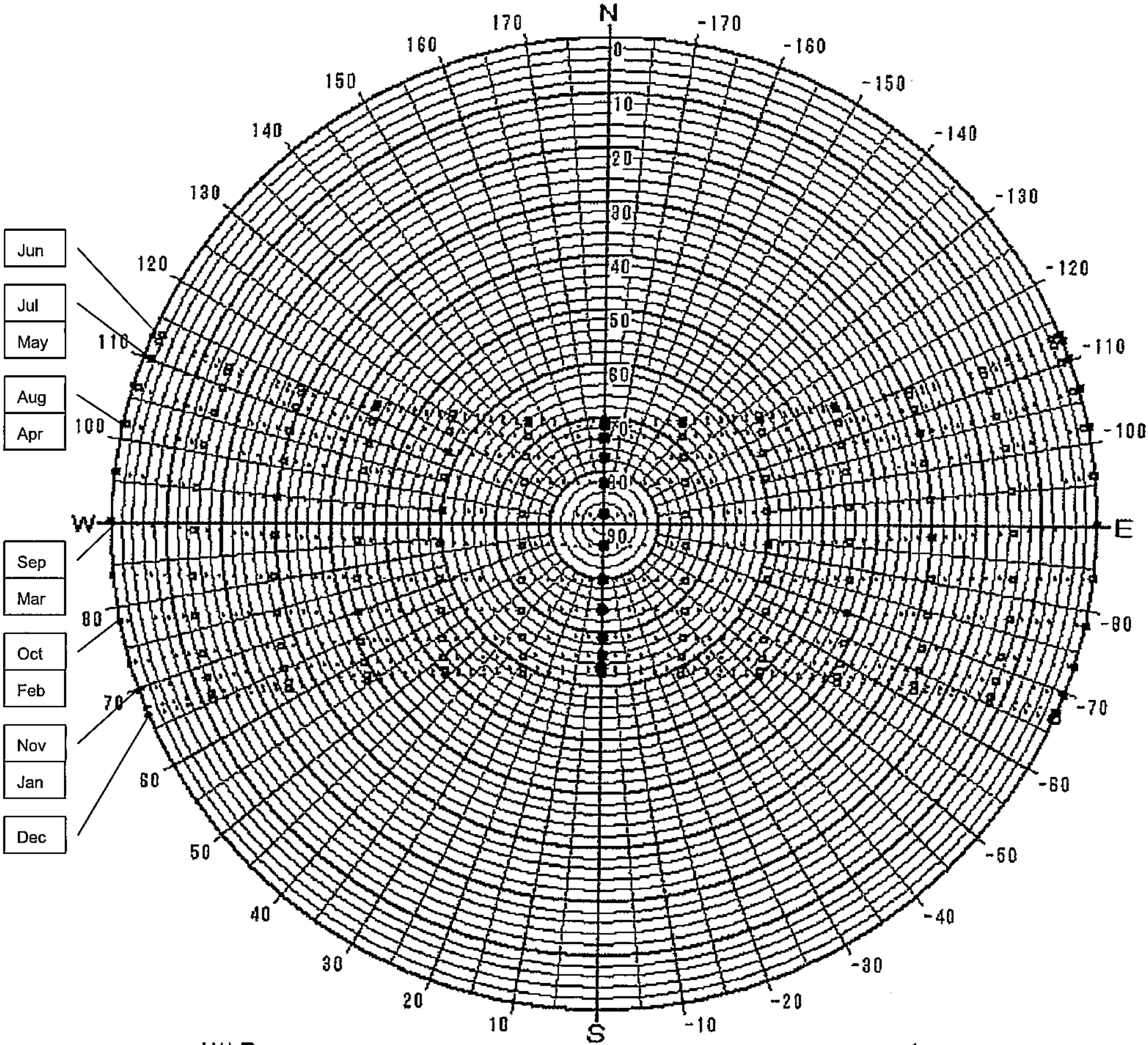
η_{TR}: Transformer efficiency. Usually 0.98 – 0.99

Σ means the integration of each month.

In order to reduce the time for investigation, the calculation template (Excel file) has been developed as shown in ANNEX 3.

Input methods also are described in the same sample.

Shade Examination Map



Site Name : MALE

Latitude : 4.18 [°]

Indicated Date :

6／21	
6／ 6	7／ 7
5／21	7／23
5／ 6	8／ 8
4／20	8／23
4／ 5	9／ 8
3／21	9／23
3／ 6	10／ 9
2／20	10／24
2／ 4	11／ 9
1／20	11／23
1／ 6	12／ 7
	12／22

Hourly Average Insolation in Male'

[kWh/m^2/day]

Time	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.006	0.010	0.013	0.011	0.009	0.002	0.000	0.000	0.000
7	0.127	0.141	0.157	0.143	0.136	0.144	0.128	0.155	0.122	0.155	0.098	0.123
8	0.295	0.320	0.345	0.304	0.284	0.297	0.265	0.326	0.264	0.347	0.226	0.287
9	0.469	0.503	0.538	0.470	0.435	0.453	0.404	0.502	0.410	0.544	0.358	0.457
10	0.620	0.663	0.706	0.613	0.566	0.588	0.525	0.653	0.536	0.716	0.473	0.606
11	0.724	0.773	0.820	0.711	0.654	0.679	0.607	0.756	0.622	0.833	0.552	0.707
12	0.760	0.811	0.860	0.745	0.686	0.711	0.636	0.793	0.653	0.874	0.580	0.743
13	0.724	0.773	0.820	0.711	0.654	0.679	0.607	0.756	0.622	0.833	0.552	0.707
14	0.620	0.663	0.706	0.613	0.566	0.588	0.525	0.653	0.536	0.716	0.473	0.606
15	0.469	0.503	0.538	0.470	0.435	0.453	0.404	0.502	0.410	0.544	0.358	0.457
16	0.295	0.320	0.345	0.304	0.284	0.297	0.265	0.326	0.264	0.347	0.226	0.287
17	0.127	0.141	0.157	0.143	0.136	0.144	0.128	0.155	0.122	0.155	0.098	0.123
18	0.000	0.000	0.000	0.006	0.010	0.013	0.011	0.009	0.002	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	5.230	5.611	5.990	5.237	4.858	5.058	4.514	5.595	4.563	6.063	3.996	5.103

ANNEX 3

Excel template for estimation of annual PV power generation

Location	
Island:	Male'
Place:	

PV Spec		
PV Capacity (kWp):	100	kWp

Please input rated PV array output

Coefficient	
η_{INV}: Inverter efficiency	0.95
Kd: PV loss coefficient	0.8
α : Temp. coefficient @ Pmax	-0.5
η_{TR}: Transformer efficiency	0.98

Data from spec. sheet

Data from spec. sheet

Default is no shade condition. In case of shade, please input calculated insolation data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
H_A: Daily Insolation [kWh/m²/day]	5.23	5.61	5.99	5.24	4.86	5.06	4.51	5.60	4.56	6.06	4.00	5.10	-
Monthly Days	31	28	31	30	31	30	31	31	30	31	30	31	365
Hm: Mnthly Integrated Insolation [kWh/m²]	162.1	157.1	185.7	157.2	150.7	151.8	139.8	173.6	136.8	187.9	120.0	158.1	1880.7
Average of daily maximum temperature [°C]	30.5	30.9	31.5	31.8	31.5	31	30.7	30.6	30.4	30.4	30.2	30.1	
Kt: Temperature correction coefficient	0.865	0.863	0.86	0.8585	0.86	0.8625	0.864	0.8645	0.8655	0.8655	0.8665	0.867	-
Ep: Estimated PV Power Generation(kWh)	10,445	10,097	11,894	10,052	9,650	9,751	8,997	11,178	8,818	12,110	7,744	10,209	**120,946**

Data form Department of Meteorology