No.

MINISTRY of ELECTRICITY,
NATIONAL ENERGY RESEARCH CENTRE
SYRIAN ARAB REPUBLIC

THE PREPARATORY SURVEY ON THE PROJECT FOR SOLAR STREET LIGHTING SYSTEM

MARCH 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS CO., LTD.

EID
JR
10-037

MINISTRY of ELECTRICITY,
NATIONAL ENERGY RESEARCH CENTRE
SYRIAN ARAB REPUBLIC

THE PREPARATORY SURVEY
ON
THE PROJECT FOR
SOLAR STREET LIGHTING SYSTEM

MARCH 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS CO., LTD.

PREFACE

In response to a request from the Government of Syrian Arab Republic, the Government of Japan decided to conduct a preparatory survey on the Project for Solar Street Lighting System and entrusted the survey to the Japan International Cooperation Agency (JICA).
JICA sent t Syria a survey team from 18th July to 4th August, and 2nd to 31st October, 2009.
The team held discussions with the officials concerned of the Government of Syria, and conducted a field survey at the survey area. After the team returned to Japan, further studies were made and as this result, the present report was finalized.
I hope that this report will contribute to the promotion of the project and the to the enhancement of friendly relations between our two countries.
I wish to express may sincere appreciation to the officials concerned of the Government of Syrian Arab Republic for their close cooperation extended to the teams.

28th February, 2010

Vice-President
Japan International Cooperation Agency

February, 2010

Letter of Transmittal

We are pleased to submit to you the preparatory survey report on the Project for Solar Street Lighting System in the Syrian Arab Republic.

This study was conducted by Oriental Consultants, under a contract to JICA, during the period from July, 2009 to May, 2010. In conduction the survey, we have examined the feasibility and rationale of the project with due consideration to the present situation of Syria and formulated the most appropriate preparatory survey for the project under Japan's Environmental Program Grant Aid scheme.

Finally, we ho hope that this report will contribute to further promotion of the project.

Very truly yours,

Nobuo Monoe
Project manager,
Preparatory survey team on
the Project for Solar Street Lighting System
Oriental Consultants

SUMMARY

1. OUTLINE OF RECIPIENT COUNTRY

The Syrian Arab Republic (hereinafter "Syria") is located North of the Arabian Peninsula in South-West Asia (north latitude 32° ~ 37°). The land is east of the Mediterranean and is a gentle mountainous area with large desert tracts in hinterlands. It has a border approximately 2,400km long and borders Turkey, Iraqi, Lebanon, Israel and Jordan. The coastal area on the Mediterranean is only 200km long and this is where the major city Latakia is located. National land area is 185,180km^2 and 75% of the area is desert which is termed "Badia". The political form is socialist republic and 90% of the population is Arab.

Climate of Syria belongs to the steppe climate and the rainy season is from October to March, and snowfalls in the mountain areas in winter. Rainfall is not stable and rainfall data spreads from 2,000mm to 200mm. Climate characteristic of the coastal area is dry and hot summers and humid winters, on the other hand it is extremely dry and hot in hinterland desert area.

GDP of Syria is US$ 35 billion and GDI US$ 1,760 (2007). Industrial structure is 30.0% primary industry, 26.9% second industry and 42.8% tertiary industry. Main agricultural products are wheat, barleycorn, sugar beets, cotton, oranges and milk products. Other industrial products are fabric, leather, metal products, food processing, and chemical products. Demand for crude oil is comparatively small in Middle Eastern Countries and almost all crude oil is exported. Domestically produced natural gas is used for power generation in Syria.

2. BACKGROUND AND OUTLINE OF THE PROJECT

Electric needs of Syria are forecasted to be 8 million kilowatts in 2010, therefore a huge amount of investment will be needed for development of electric power resources and transmission lines. Diesel and hydro power was mainly produced electricity 20 years ago, however in recent days power generation has been made more efficient by advanced techniques including combined cycle and hot gas turbine power generation. The Syrian Government makes positive efforts to plan a solar power generation system.

Regarding improvement of street lighting, the Syrian Government started a solar street lighting system in the national roads of Adra which is a suburb of Damascus, because most street lighting is poor in suburban areas.

This project is for the prompt procurement and installation of a Solar Power Street Lighting System that does not rely on fossil electric power generation.

3. CONTENTS OF THE PROJECT AND RESULT OF THE STUDY

To carry out the project, the preparation study team has been dispatched to Syria from 18th June to 4th August 2009, and 2nd October to 31st October 2009.

The Solar Power Street Lighting System will be installed on the Damascus – Jordan highway based on the request from the Syrian Government. Installation sites are two interchanges and in front of universities along the highway, and sites are divided for effectiveness because of limited amount of equipment.

Location	Length	Quantities
Hir Jalha Interchange	600m (2 directions)	62
Der Ali Interchange	260m+200m (2 directions)	50
SIUST University	140m (2 directions)	16
IUST University	140m (2 directions)	16
AIU University	140m (2 directions)	16
SIUST University	140m (2 directions)	16
Total		176

LED lamps were nominated, however, high sodium pressure lamps were selected, because reliability and life time of LEDs is not clear. From viewpoints of carbonic anhydride and environmental burden reduction, high pressure sodium lamps are advanced lamps compared with mercury lamps. However, electric power generation by solar power is limited and can only supply low-power for 70 watts. High pressure sodium lamps are in general use in Syria, and operation and maintenance is of no matter.

Implementation schedule for this project assumes five months for equipment production and inspection, one and half months for transportation and three months for installation. Total project schedule is estimated t 14 months from signing of the E/N.

4. BENEFITS OF THE PROJECT

The implementation of the project will effectively contribute to the reduction of CO_2 emission and increase of traffic safety. The following benefits are expected from the implementation of the project.

Direct Effects

Lamp wattage of conventional street lights is 180W to 400W. In case of 200W lamps and average operation of 10.75 hours per day, 1.034 kg of CO_2 will be emitted due to one street light per day. This value is same as 0.45 liters of combusted gasoline. A total of 66,424 kg of CO_2

and 28,908 liters of gasoline will be reduced per annum by use of the 176 Solar Street Lights of this project.

Traffic accidents and street lighting are in an affinitive relation, and it is reported by the International Commission of Illumination that after development or improvement of street lighting, traffic accidents at night were reduced to 21% ~ 76%.

Improvement of visibility by street lighting will contribute to reduce traffic accidents at night on the highway.

Indirect Effects

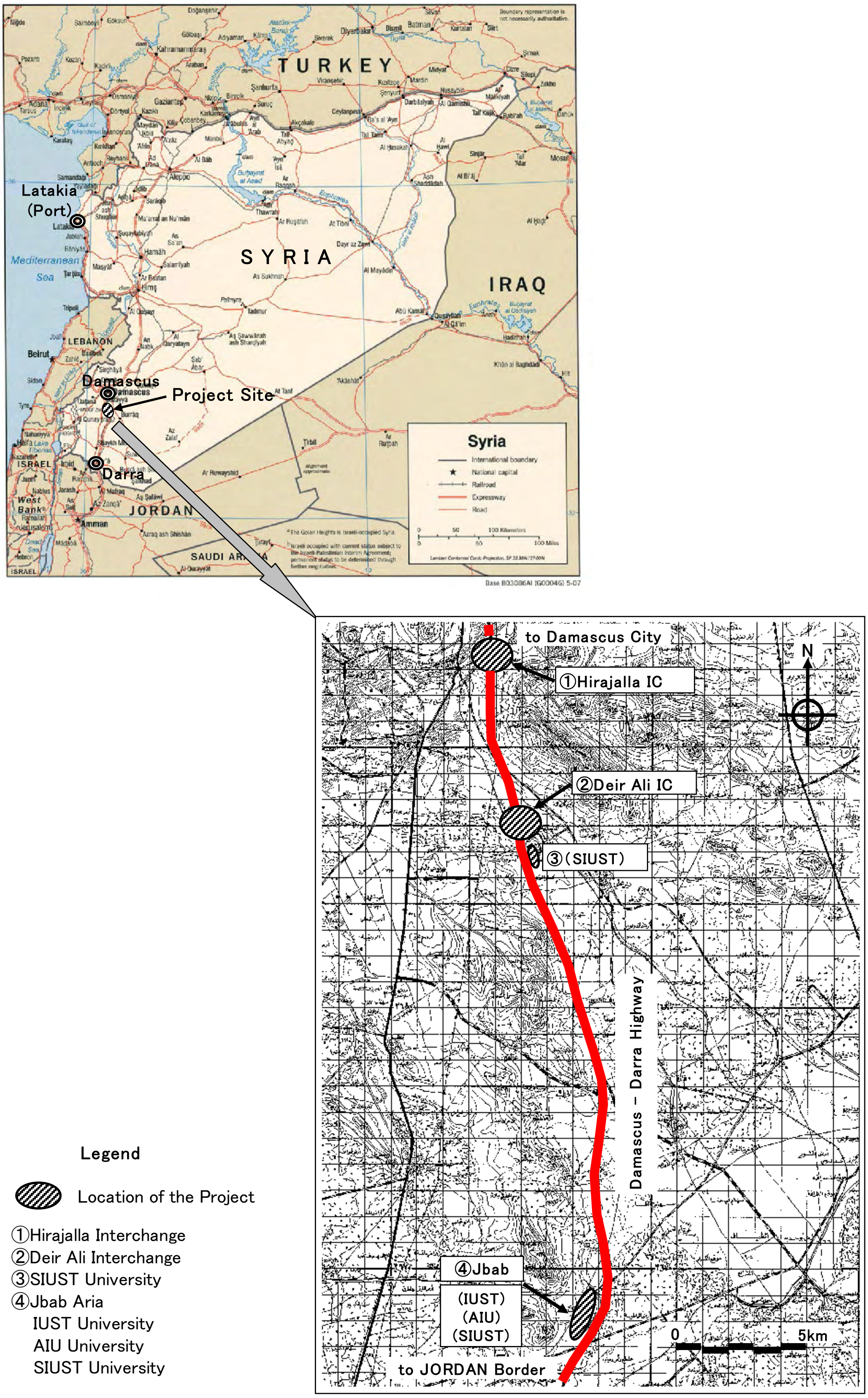
The Syrian government is now implementing several solar power generation project by own budget.

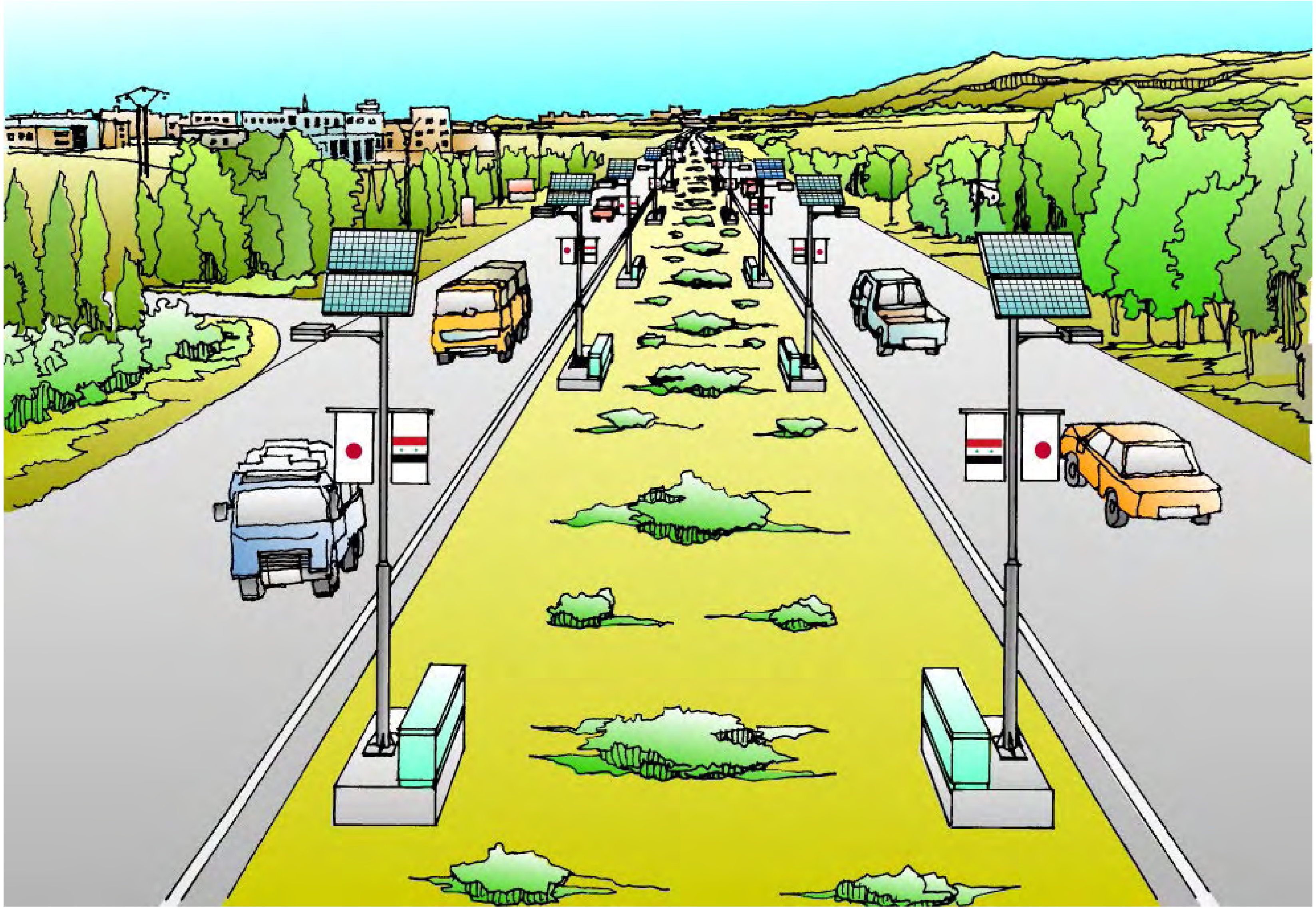
Dissemination and enlightenment activities of solar power generation will be intensified by this project in Syria.

5. RECOMMENDATIONS

This project contributes to prevent global warming by using solar power and this results in a reduction in the use of ordinary power. In addition, the Syrian Government has positive plans for using solar power and the skill for operation and maintenance of Solar Power Street Lighting Systems. In consideration the above, this project will be meaningful and promising for promoting use of solar power in Syria.

Location Map





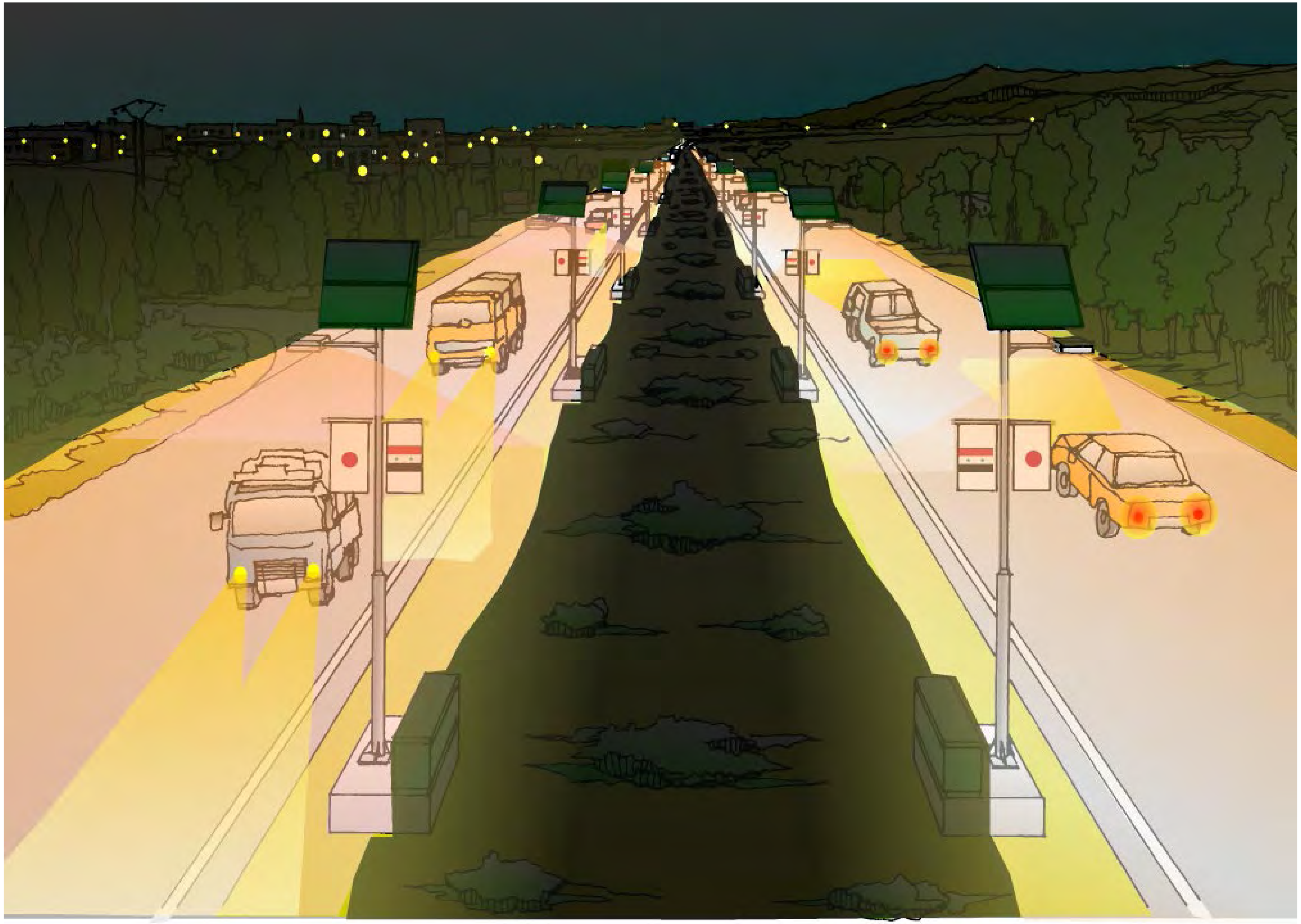


Table of Contents

List of Figures & Tables

FIGURE

TABLE

Abbreviations

Ah	: Ampere
AIU	: Arab International University
CO_2	: Carbon Dioxide
E/N	: Exchange of Note
GDP	: Gross Domestic Product
GDI	: Gross Domestic Income
Imax	: Maximum Current
Isc	: Short Circuit Current
IUST	: International University of Science and Technology
JICA	: Japan International Cooperation Agency
kWh	: Kilowatt hour
MoE	: Ministry of Electricity
MoF	: Ministry of Foreign Affair
MoT	: Ministry of Transport
MPPT	: Maximum Power Point Tracking
NERC	: National Energy Research Center
LED	: Light Emitting Diode
Lm	: Lumen
Pmax	: Maximum Output Power
PV	: Photovoltaic
Ra	: Color Rendition
SIUST	: Syria International University of Science and Technology
SP	: Syrian Pound
SSRC	: Scientific Studies and Research Center
UNDP	: United Nations Development Programme
Vmax	: Maximum Voltage
Voc	: Open Circuit Power

CHAPTER 1 BACKGROUND OF THE PROJECT

1-1. Introduction

In January 2008, the former Prime Minister Mr. Fukuda made a public speech titled Cool Earth Partnership in the Davos Forum that satisfied both reduction of green house gas and economic growth, and contributed to stabilization of the climate. In this speech, the Japanese Government had made decision to support developing countries, in which climate change will affect serious damage.

Based on the above political measure, JICA had made a public decision to aggressively carry out Co-Benefit cooperation projects that utilize clean energy which includes renewable energy, and Japanese advanced technology.

Against the background of the above measurers for global warming, advanced Japanese solar power generation systems that are quite competitive for clean energy should be aggressively utilized in the international cooperation program. That a solar power street lighting system is required in Syria became clear, and also the Syrian Government requested from the Japanese Government the procurement and installation of solar power street lighting in the main streets of Damascus City or the Damascus-Jordan Border highway.

1-2 Existing Conditions of Solar Power Generation in Syria

Electric power demand in Syrian is forecast to increase 8 million kilo watt in 2010 accompanying the increasing of population and dissemination of electricity by urbanization. Therefore a large investment for development of electric power resources and power transmission facilities will be required. About 20 years ago, diesel and hydro electric power generation were the main generation systems, however in these days, advanced technology that includes combined cycle and hot gas turbine electric power generation systems are utilized.

Regarding development of street lights, MoT is the main authority for operation and maintenance, and they have installed lights in most roads in the urban areas however there are no street lights on the intercity highway.

1-3 Solar Power Generation Conditions in Syria

The implementation agency for research and development of renewable energy, including solar power, is NERC （National Energy Research Center）, and the SSRC（Scientific Studies and Research Center）was established to support NERC. The first NERC activity involving solar power was the pilot project called the “3km Solar Street lighting System Project” on the Damascus-Homs highway of suburban Damascus City. NERC have provided technical support for 10 KW solar power generation systems (this project will be increased to 30 KW in future) and development of a 1 MW solar power plant in a suburb of Damascus City. Five KW solar power generation systems for auxiliary power supply have been installed on the rooftop of the NERC office and have operated from September 2009.

Figure 1-1 Solar Power Generation System on the Rooftop of NERC Office

NERC is also working on a biogas generation projects that will utilize animal manure and marsh gas and a solar hot water plant as other renewable energy projects.

1-4 Natural Conditions

Past climate data in Damascus City is shown in the following table. Days of rain fall that affect solar power generation are quite low, and the fine weather ratio is very high. Average fog days are 92 days in year, however fog clears in the afternoon because the humidity in the afternoon is low. In consideration of the above weather conditions, Damascus City is well suited for solar power generation. The project site is located in a flat and dry desert area, and there is nothing significantly special to mention regarding the natural conditions around the project site.

Table 1-1 Weather Conditions in Damascus City

【Average Temperature (Years of Record: 21)】

	Av.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
℃	16.6	6.1	8.3	11.1	15.5	20.0	23.9	26.7	26.1	23.3	18.3	12.2	7.7

【Average Rain fall (Years of Record: 40)】

	Av.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
mm	19.3	3.8	3.3	2.3	1.3	0.5	—	—	—	—	1.0	2.5	4.3

【Maximum Rain Fall (Years of Record: 40)】

	Av.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
mm	42.9	14.7	9.9	9.4	4.8	4.8	1.5	—	—	10.1	8.3	13.5	4.3

【Days of Fog (Years of Record: 20)】

	Av.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
days	92	15	9	10	7	4	2	5	8	5	5	7	15

【Average Humidity in Morning (Years of Record: 18)】

	Av.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
%	81	89	86	83	78	75	74	79	83	77	75	83	90

【Average Humidity in Afternoon (Years of Record:18)】

	Av.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
%	37	64	53	42	31	24	19	20	21	23	35	52	68

Source: National Diet Library, Weather base

1-5 Environmental and Social Impacts

Solar Power Street Light will be installed in the median strip of the highway. Regarding the natural environment in the highway, there is nothing significant or special to mention regarding natural environmental impact or land acquisition around the project site. Category investigation for the environment and social impact are not need in the project.

Battery disposal after end of lifetime is a considerable environmental issue. Study team had confirmation from Damascus City Cleaning Department that illegal dumping of hazardous west is prohibited and segregation of disposal of dry batteries is implemented. Illegal dumping of car batteries is also banned, however, collection of car batteries is not carry out. Batteries are essential equipment for the Solar Street Lights of the project, because generated power must be stored in a battery in the day time for use in the night time. Life time of the batteries is assumed to be five years and after five years a large number of batteries must be disposed of. Used batteries will be kept in the dangerous objects warehouse of the Damascus Governorate Solid West Treatment Plant, which is located 45km from Damascus City in the south-east direction. The warehouse is constructed of concrete; the thickness of the walls is 40cm and 48 rooms of 16 m^2 are reserved. The volume of the used batteries for 200 street lights is 16 m^3, so the warehouse room is large enough to keep all the used batteries.

Carrier charge for the used battery is SP5,600(US$28)/$m^3$ and this is borne by MOE from MOT's own budget.

Figure 1-2 Dangerous Objects Warehouse of Damascus Governorate Solid West Treatment Plant

CHAPTER 2 CONTENTS OF THE PROJECT

2-1 Basic Concept of the Project

The street lighting system is developed inside city areas in Syria, however there are no installations outside of city areas such as this project site. In case of no street lighting, vehicles must drive using only headlights of the vehicles. In these conditions, traffic safety is not secure at night time. Street lighting is needed, not only in city areas but suburban roads for traffic safety, however electric power for street lighting is not supplied in suburban areas.

The Syrian Government is expending efforts to develop solar power street lighting in areas where electric power is not supplied. The basic concept of the solar power street lighting project is in accord with Syrian policy which is development of the renewal energy.

This project is procurement and installation of a solar power street lighting system that will contribute to the accomplishment of the above mentioned goal and effectiveness of the project.

2-2 Basic Design of the Requested Japanese Assistance

2-2-1 Design Policy

1) Basic Policy

Standards for the street lighting regarding height, luminance and other structures must be adapted to the Syrian standards, and equipment of the solar power street lighting system of this project will be formulized by Japanese products. Project site of the project is an interchange that has complicated traffic flow and land use area along the Damascus – Jordan Highway.

2) Policy for the Natural Environment

Solar power generation system is affected by amount of isolation of the area. Clear sky ratio of the project site is quite high throughout the year. This natural condition is better suited for solar power generation however it must be designed for 2 days without sunshine. Pole structure must be designed to withstand 130km/hour wind speed. Maximum temperature batteries must withstand is +45℃ for high temperature in summer season.

3) Policy for the Social Economic Condition

Design of the solar power street lighting must be simple so that it will not affect religion or traditional culture and allow for easy maintenance. Batteries are essential for solar power street lighting systems because the electric power will be charged in the day time and it will use the power in the night time. Batteries can be used for other uses and fixing an antitheft measure is essential.

4) Policy for the Procurement

All equipment of this project will be procured from Japan, and there are no local products. Scope of this project includes not only procurement of the street lighting but installation works. The street lighting will be installed inside the median-strip of the highway, and so land acquisition is not required for this project. Lane control during street lighting installation is needed and the contractor must be in accordance with the regulations of the MoT.

5) Policy for Utilization of Local Companies

The Syrian Government is carrying out the pilot project for solar power street lighting on the Damascus – Homs Highway 25km north of Damascus city. A Syrian private company contracted this pilot project and the Syrian private company has technical skills for solar power street lighting and the local company can be utilized for the installation work of this project.

6) Policy of Operation and Maintenance (O&M)

Existing street lighting is operated and maintained by the MoT. O&M of Solar Power Street Lighting System of this project will be by joint efforts of the MoE and MoT. Existing O&M budget for street lighting is $200 per pole and 2,000 poles are maintained each year. All equipment for the Solar Power Street Lighting System of the project will be procured form Japan, and O&M manuals and instructions must be prepared by the supplier.

7) Policy of Equipment Grade

Main equipment of the project is photovoltaic panels. Photovoltaic panels are prepared to global standards and a special grade of the equipment is not required. The other lamps, bulbs, batteries and poles are common equipment in Syria.

8) Policy of Procurement of Equipment and Construction Schedule

All equipment for the project is to be prepared in Japan and transported from Japan. Especially, material for the photovoltaic panels including photovoltaic cells must be for Japanese products. Other equipment is not limited to Japanese products, however all equipment will be assembled and integrated at the project site and Japanese products will be suitable for the Solar Street Lighting System. The Solar Street Lighting System will be installed in the median-strip of the highway and land acquisition is not required. Construction schedule is assumed to be three (3) months for excavation work, base-concrete preparation work and installation work of the equipment.

2-2-2 Basic Plan (Equipment Plan)

1) Overall Plan

The Solar Power Street Lighting System of the Project will be installed on the Damascus – Jordan Border Highway based on the request from the Syrian side. At Hir Jalla and Der Ali interchange, before the site survey it was proposed that the Solar Power Street Lighting System would be installed on the loop-ramp, however the shoulder width of the loop-ramp is too narrow to install the lighting, and therefore it was decided to install it on the median-strip of the main road. In the median-strip, there is no vegetation and 11m width is suitable for installation of the Solar Power Street Lighting System. If total quantities are 200 lights, planed location and quantities are shown in the following table.

Table 2-1 Location and Quantities of the Installation

Location	Length	Quantities
Hir Jalha Interchange	600m (2 directions)	62
Der Ali Interchange	260m+200m (2 directions)	50
SIUST University	140m (2 directions)	16
IUST University	140m (2 directions)	16
AIU University	140m (2 directions)	16
SIUST University	140m (2 directions)	16
Total		176

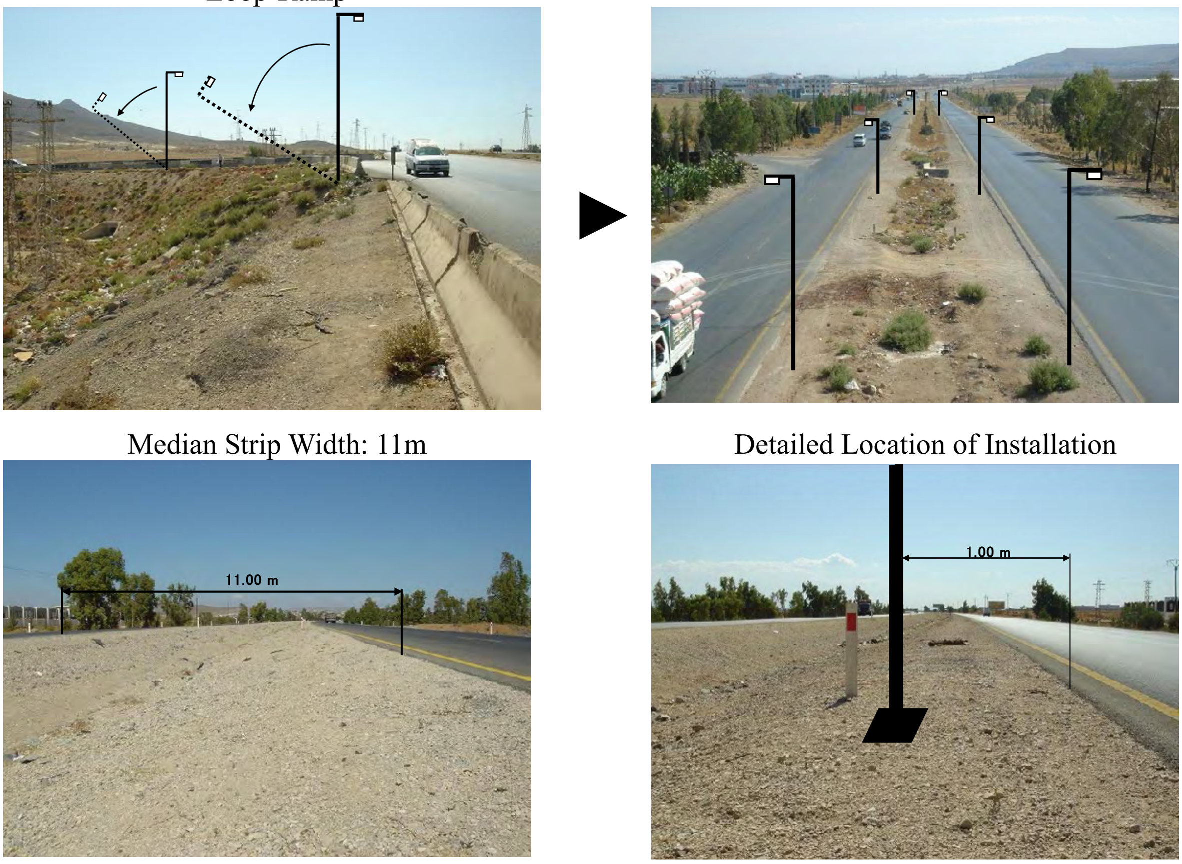


Figure 2-1 Location of the Solar Power Street Lighting System

Detailed Location of each section is designed in the basic design drawing.

2) Equipment Planning

【 Basic Components of the Solar Power Street Lighting System】

Procured Solar Power Street Lighting System utilizes the electric power that is generated in day time by photovoltaic panels and stored batteries to supply the electric power for street lighting. Main components of the equipment are photovoltaic panels, lamp fittings, bulbs, batteries, charge controllers and poles.

【Maximum Lamp Power】

Electric power supplied to the street lights is limited because the electric power will be generated by photovoltaic panels in day time, and lamp power will be designed by the number of photovoltaic panels. Photovoltaic panels must be intergraded with the light poles and strength of the light poles must be calculated by the number of the photovoltaic panels including wind effect.

As a result of the calculation, the maximum number of photovoltaic panels is two, and 70 watt lamp is maximum power for two photovoltaic panel generation.

【Lamp Bulbs】

Lamp bulbs for the project were selected on the basis of the following table. Metal halide lamps are excellent at reduction of O&M cost and environmental burden. Color rending of metal halide lamps is higher than high pressure sodium lamps, and power consumption is 50% and life time is half that of mercury lamps. However there is no experience utilizing metal halide lamps in Syria. Low pressure sodium lamps were requested from the Syrian side, however high pressure sodium lamps have an advantage in the color rendering and life time, and 70 watt low pressure sodium lamps are common in Syria. In consideration of the above points, high pressure sodium lamps were selected for the project. LED lamps were cancelled because their lumen and life time was not clear.

High pressure sodium lamps have an advantage in power consumption and life time compared with mercury lamps and reduce maintenance cost and emission of greenhouse gas.

Table 2-2 Comparison of Lamp Bulbs

Comparative Items	High Pressure Sodium Lamps	Low Pressure Sodium Lamps	Metal Halide Lamps
Finish	Clear	Clear	Clear
Wattage	70w	55w	70w
Power Consumption	85w (90va)	70w (76va)	92w(120va)
Lumens Flux	6,400 Lm	7,600 Lm	6,000 Lm
Efficiency	91 Lm/w	138 Lm/w	85 Lm/w
Life Time	12,000 hrs	9,000 hrs	12,000 hrs
Color Temperature	1,900 K	1,700 K	3,200 K
Color Rending Index	Ra = 15	Ra = 0	Ra = 90
Evaluation	○	△	△

【PV Panel】

For several years, the amount of photovoltaic panels of Japanese manufacturer was less than newly-established companies in the United States, Europe, China and Taiwan. However, Japanese companies have taken a leadership role for solar power generation based on many years of good manufacturing technology, quality control technology and research and development.

Especially, Solar Power Street lighting Systems of this project must install the PV panels with street lighting poles and generate electric power to supply street lighting. Therefore, PV panels should be selected for most efficient electric power generation capability. Japanese manufactures produce the PV panels that have one of the best generating efficiencies in the world. Reliable Solar Power Street Lighting Systems for the project can be integrated by utilizing of Japan products. Capacity of PV panels was calculated based on following conditions.

3) Setting Angle of Photovoltaic Panels

Angle of PV panels will be set at 25 degrees from horizontal where average radiation is at a maximum level. Average radiation by each setting angle from 0 degree to 35 degree is shown in the following table.

Table 2-3 Average Radiation in Damascus

(latitude: 33.4, longitude: 36.5 degrees)

Inclination	degrees	0	5	10	15	20	**25**	30	35
Average Radiation	kWh/m^2/day	5,29	5.44	5.56	5.64	5.70	**5.73**	5.72	5.68

4) Required Radiation for Capacity PV Panels

PV panels must generate electric power under pessimum conditions. Minimum radiation is in December, and this value should be adopted for minimum radiation (3.18 kWh/m2/day). Monthly average radiation of 25 degree PV panel setting angle is shown in the following table.

Table 2-4 Monthly Average Radiation (PV panel setting angle: 25 degrees)

Month	Jun.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Av.
Radiation on Flat (kWh/m^2/day)	3.10	3.50	4.60	5.80	7.40	8.00	7.90	7.20	6.10	4.50	3.00	2.30	5.29
Radiation on 25 degree (kWh/m^2/day)	4.40	4.37	5.19	5.98	7.09	7.39	7.41	7.23	6.78	5.57	4.04	**3.18**	5.73
Average Temperature (°C)	6.1	8.3	11.1	15.5	20.0	23.9	26.7	26.1	23.3	18.3	12.2	7.7	16.6

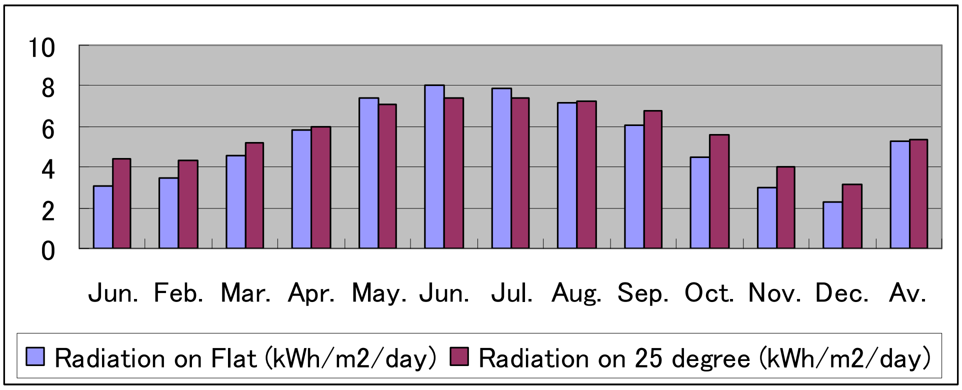


Figure 2-2 Monthly Average Radiation (PV panel setting angle: 25 degrees)

5) Electric Energy of PV Panel in December: 0.40 kWh/day/module

Average electric power generation of PV panel for each month is shown in the following table. PV panel is commonly used silicon cell type and setting angle is 25 degrees.

Table 2-5 Average Electric Power Generation of PV Panel

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Av.
Average Temperature (°C)	6.1	8.3	11.1	15.5	20.0	23.9	26.7	26.1	23.3	18.3	12.2	7.7	16.6
Cell Temperature (°C)	30.0	31.4	34.6	39.9	44.7	48.7	50.8	50.5	47.7	42.3	38.8	31.3	40.7
K1: Temp. Coefficient	0.98	0.97	0.95	0.93	0.90	0.88	0.87	0.87	0.89	0.91	0.95	0.97	0.92
K2: Dirt Coefficient	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
K3: Inverter Efficiency	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
K4: Deviation from Pmax.	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
K5: Environmental Coefficient	1.00	0.93	0.95	0.97	0.99	1.00	0.99	0.97	0.95	0.93	0.91	0.90	0.96
K: K1×K2×K3×K4 ×K5	0.86	0.81	0.81	0.81	0.80	0.79	0.77	0.75	0.76	0.76	0.77	0.78	0.79
Radiation: 25 degree (kWh/m2/d)	4.40	4.37	5.19	5.98	7.09	7.39	7.41	7.23	6.78	5.57	4.04	3.18	16.7
Area of PV Panel (m2)	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Efficiency of Module (%)	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
Daily Power Generation (kWh/d)	0.62	0.57	0.68	0.78	0.91	0.94	0.92	0.88	0.83	0.68	0.51	**0.40**	0.73
Day/month	31	28	30	31	30	31	30	31	30	31	30	31	365
Average Power Generation (kW/d)	21.48	19.88	26.35	29.10	35.65	35.40	35.96	34.41	30.90	26.66	18.90	15.50	322.89

6) Necessary Capacity of PV Panels

Average power generation per one PV Panel is 0.40 kWh in December. On the other hand, daily watt-hour of 70W high pressure sodium lamps is 0.7525 kWh (0.070 kWh×10.75 hour) under the condition of maximum daily average 10.75 lighting hour in December. Therefore two (2) PV Panels are essential to power a single light. (0.80kWh for two PV Panels)

Calculation conditions are as follows;

- Lamps: 70W High pressure sodium lamps
- Lighting hours in December: 10.75 hours (16:30~24:00: 100%, 24:00〜6:30: 50%)
- Dimensions of PV Panel: 1,500×800 mm (Area： 1.20 m2)

【Batteries】

Electric power generated by PV Panels must be stored in a battery. In case of utilization of conventional batteries, maintenance of electrolyte is needed periodically, and new facilities for water purifying and density measuring should be prepared for maintenance. Maintenance-free control valve lead batteries can reduce depth of discharge by 30% to increase the battery life time, and reduce maintenance cost.

Capacity of batteries was calculated under the following conditions.

i) Preconditions
- Power consumption per day: 0.7525 kWh/day
- No sunshine days: 2 days
- Depth of discharge: 32% to maintain 5 year life time
- Design coefficient: 0.8165

  Charge and discharge efficiency: 90%
  Charge controller efficiency: 95%
  Power loss: 4.5%
  Design coefficient = (Charge and discharge efficiency) × (Charge controller efficiency) × (Power loss) = 0.9 × 0.95 × (1-0.045) = 0.8165

ii) Charging Capacity

Battery Capacity to supply the power in night time under the condition of 2 days no sunshine is calculated as follows;

Charging Capacity = (Power consumption per day × No sunshine days) / (Depth of discharge × Design Coefficient) = (0.7525kWh/day × 2 day) / (0.32×0.8165) = 5.760 kWh

iii) Selection of Battery

a) Preconditions

- Mono silicon voltage: 2V
- Terminal voltage: 24V
- Charging Capacity: 5.765 kWh

b) Battery Capacity = (Charging Capacity) / (Terminal voltage) = 5.765 × 1000Wh/24V = 240Ah

Stable electric power can be supplied to the Solar Power Street Lighting by use of 24V terminal voltage and battery capacity of more than 240Ah.

Based on the above conditions, the following specifications are proposed for this project.

Table 2-6 Specification of Solar Power Street Lighting System

Component	Specification	Quantity	Intended Use
1. PV Panel		352	Generate electric power and lead to the battery. Mono-crystalline silicon type account for 94% of currently used PV Panels, and have a lot of practical accomplishments.
(1) Type	Mono-Crystalline Silicon		
(2) Maximum Power (Pmax)	180W or more/pc (Total 360W or more/2 pc)		
(3) Module Efficiency	Maximum 13.5 %		
(4) Dimensions	L: 1,600mm or less, W: 820mm or less (1 pc)		
(5) Weight	16kg or less		
2. Light Poles		176	Main structure of Solar Power Street Lighting System. PV Panel and lighting equipment are installed on them. Light poles are produced in Syria, however Japanese products are recommended in consideration of installation, match-up with base anchors, quality and life time.
(1) Height	8m or more (from ground level to center of bulb)		
(2) Base Anchor Bolts	Depends on structure; the anchor bolt assembly should be folding type to secure accuracy of the bolt installation.		
(3) Material	Hot Dip Galvanized Steel (thickness depends on structure)		
(4) Color	Manufacturer's original color (Brown or Gray)		
3. Lighting Equipment		176	Main components of street lighting include lamps fittings and bulbs. High pressure sodium lamps are recommended in consideration of light efficiency and lifetime.
(1) Bulb type	High pressure sodium (AC220V, 50Hz, Single-Phase)		
(2) Power Consumption	70W or more (85W for input power consumption from battery)		
(3) Initial Life Time	25,000 hours or more, or guarantee for 25,000 hours for spare parts		
(4) Lighting Fixture	Built-in Controller		
(5) Reflector Type	Wide intensity distribution type		
(6) Ingress Protection (IP)	IP 43 or more		
(6) Illumination	1) Under the condition of Road width: 7.5 m, pole spacing 20 m; ・ Illuminance: 15 Lx or more (at under the center of the bulb) ・ Average illuminance: 11.4 Lx or more ・ Uniformity ratio of illuminance: 0.4 or more		
(7) Color Temperature (K) and Color Rendering Index (Ra)	1,900 K to 2,100 K 17 Ra to 20 Ra		

Component	Specification	Quantity	Intended Use
4. Controller		176	Automatic lighting device for activation of on/off switch, and generated solar power lead to output efficiently.
(1) Charging Control Method	Maximum Power Point Tracking (MPPT)		
(2) Average Running Time	10.75 hours lighting time per day		
(3) Activation Switch On/Off	Automatic lighting after sunset and timer		
(4) Battery Charging Method	Pulse Width Modulation (PWM)		
5. Battery		704	Storage of electric power generated by PV Panels. Sealed type is recommended in consideration of electric performance, lifetime, safety, cost and recyclability.
(1) Type	Lead-Acid battery (sealed type)		
(2) Expected Lifetime	5 years or more (depending on maximum air temperature)		
(3) Nominal Voltage	DC 24 V (DC 12 V×2)		
(4) Nominal Capacity	min. 240 Ah/pole		
6. Battery Box	Install at ground level, with lock system	176	Steel storage box for battery. Install at ground level in consideration of weight of battery, and provide antitheft lock system.

2-2-3 Basic Design Drawing

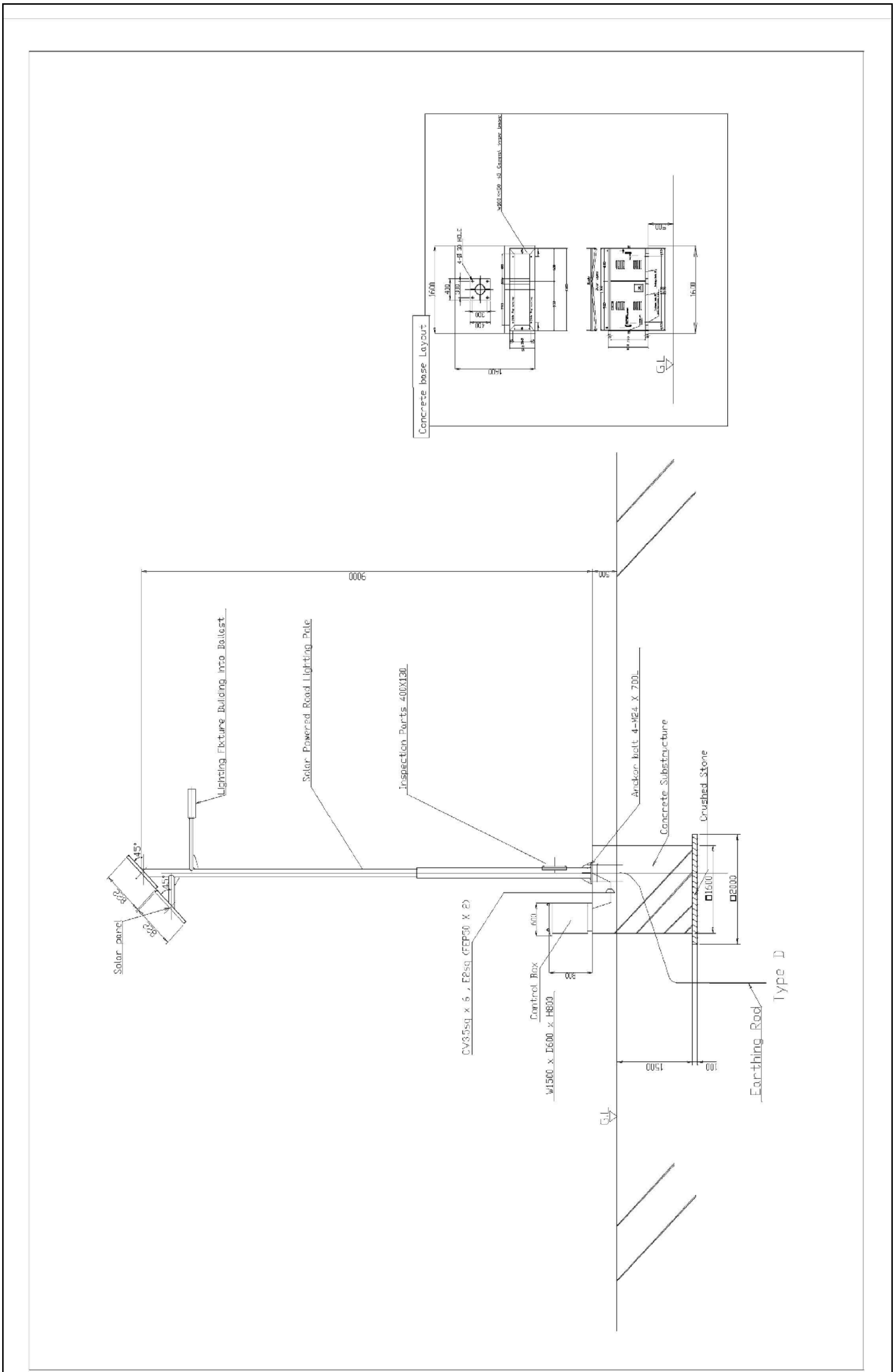


Figure 2-3 Typical Drawing of Solar Street Lighting System

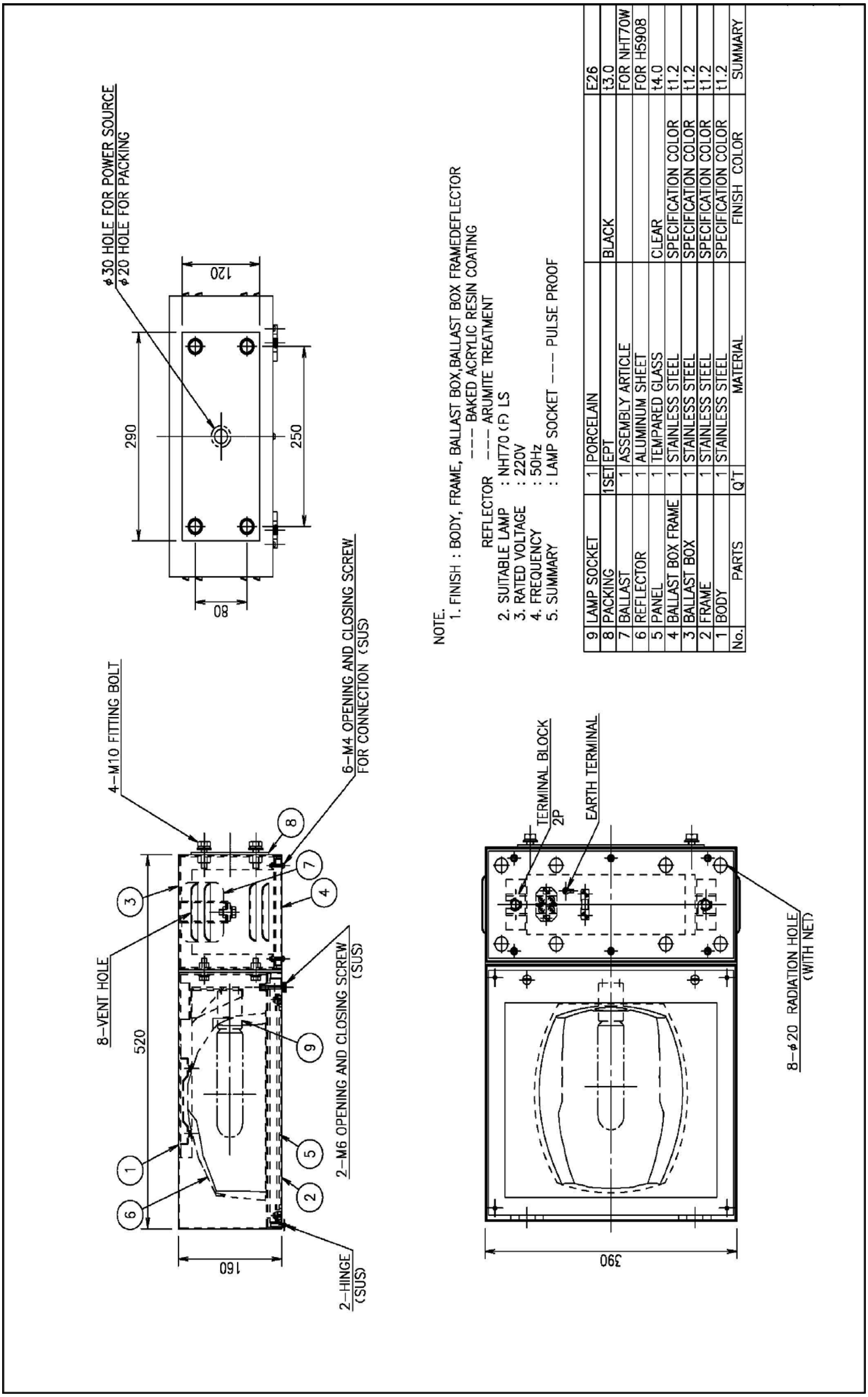


Figure 2-4 Detail Drawing of Lighting Fixture

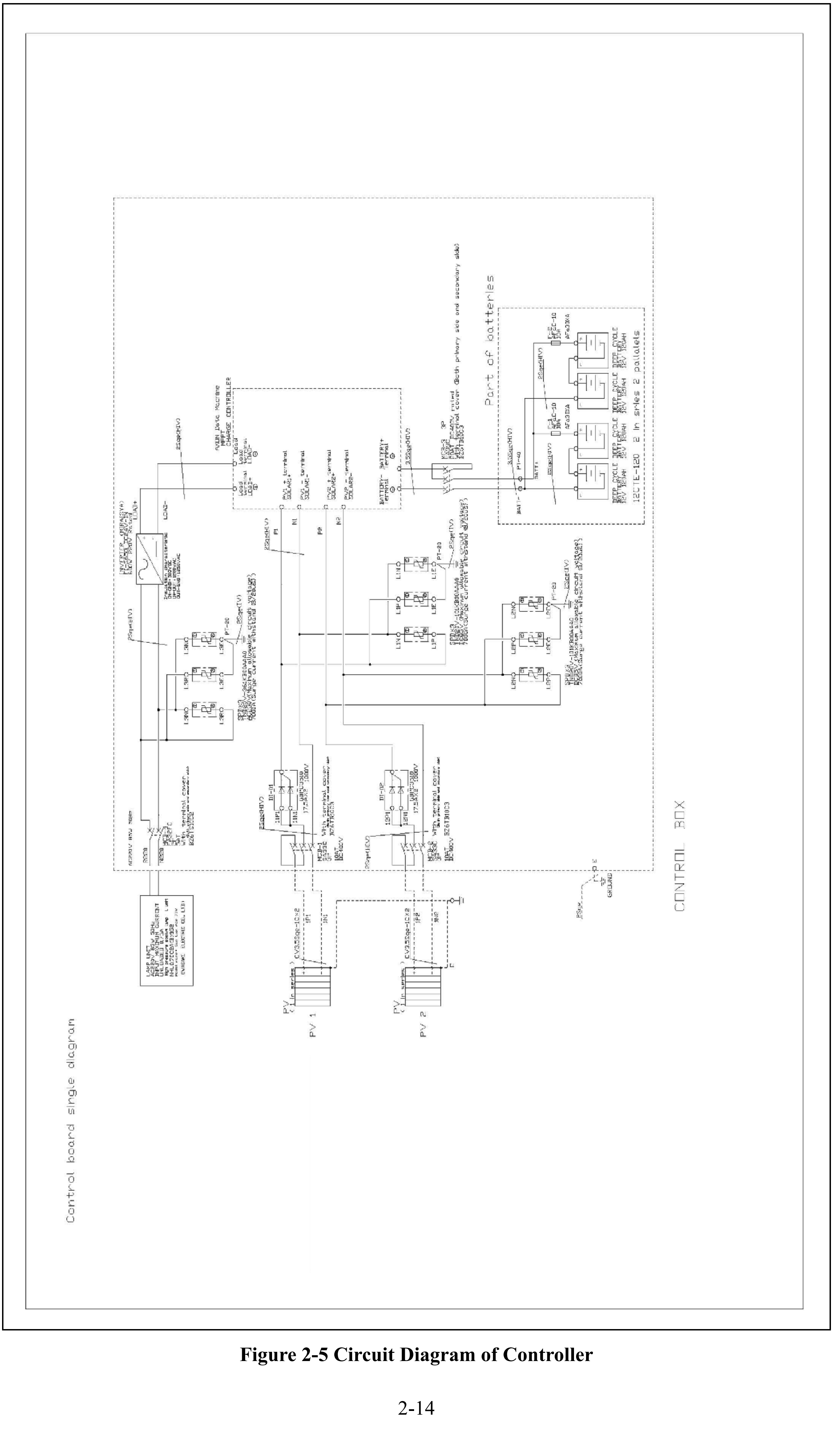


Figure 2-5 Circuit Diagram of Controller

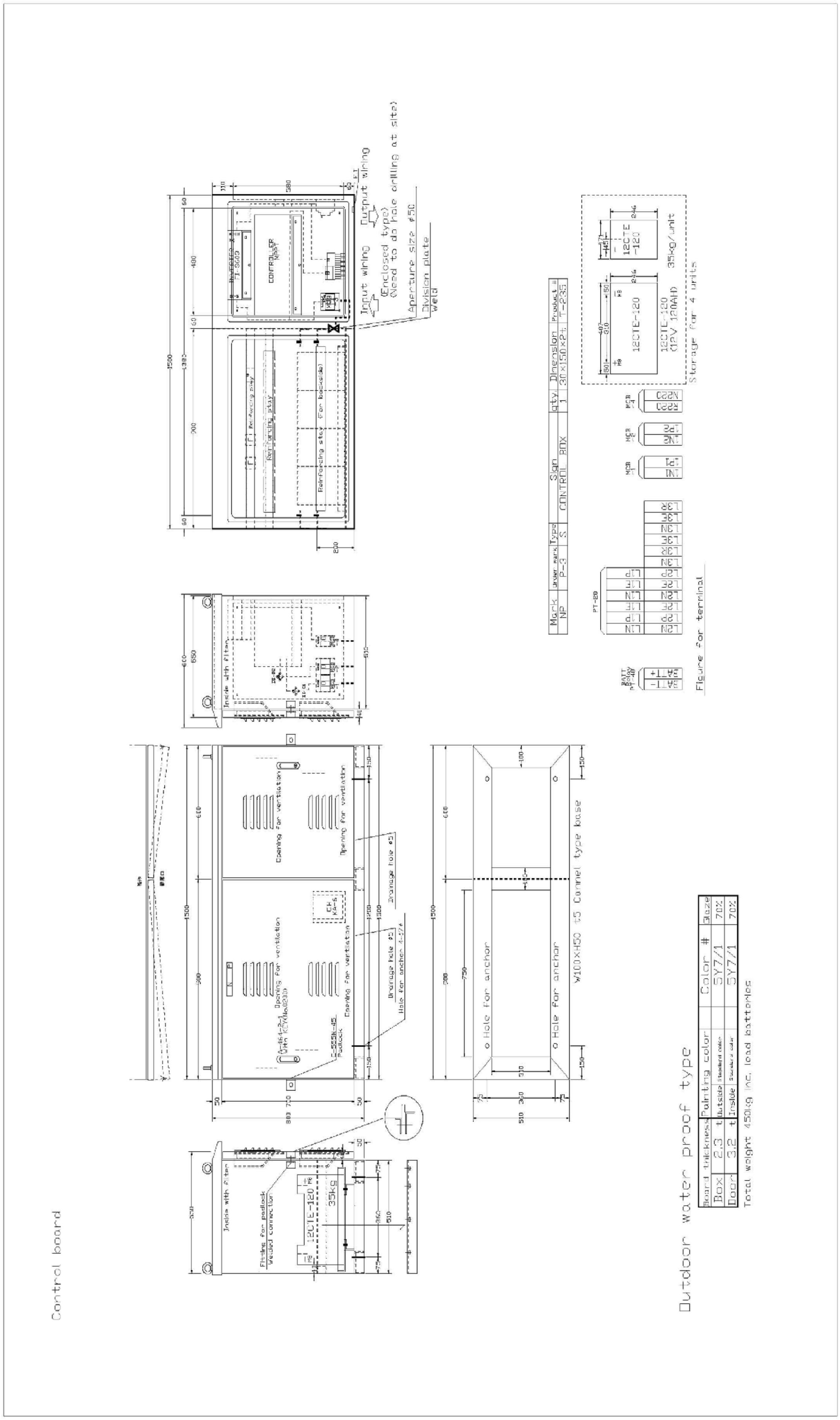


Figure 2-6 Detail Drawing of Battery Box