Chapter 6 Basic Design of Combined PV System

6.1 Design of Community Solar System

6.1.1 Basic Design Concept

There are basically two components of CSS for public facilities: power supply system of public facilities and battery charging system for local people. In Kenya, CSS may contain the following four subsystems:

1) Power supply system of public facilities
2) Power supply system of public facilities' staff houses
3) Power supply system for refrigerator to store vaccines at health center
4) Battery charging system for community people

The voltage for subsystem 3) is 12V DC, while for the rest requires 240V AC, similar to the main power supply in Kenya. In general, converting PV electricity into 240V AC is not common. However, the Ministry of Energy (MOE) sets it as a rule in case of PV systems at public facilities. According to MOE, installing PV systems at school staff houses is discouraged due to past troubles. Therefore, the Survey Team proposes to install PV systems only at high-level staff houses. Furthermore, subsystem 4) is only operational during the daytime, which is inherently different from the other systems where electricity is used during the nighttime. As for the charging system capacity, the estimated demand at present is only for changing mobile phones. However, the Survey Team proposes a larger capacity to meet the expected demand growth in the future, such as use of rechargeable lamps.

6.1.2 Demand Estimation

To design PV systems, it is necessary to estimate the daily power demand for the PV system. Then, the PV array and battery bank capacities can be estimated based on the power demand. It is necessary to take into account that facility managers tend to request for a system that will supply power to many electric appliances, which they plan to utilize for long hours. All these claims lead to the over-sizing of PV systems which may cause trouble during maintenance, and may be subject to criticism later. Also, it is important to estimate the average power demand for CSS rather than the maximum demand . The battery bank can store electricity and deal with surges of power demand.

According to the Technical Specifications prepared by MOE which is used as a guideline, security lights installed outside the public facilities account for a large part in power demand, as these lights are operational for 12 hours during nighttime. Therefore, PV array and battery bank would become very large. As a result, operation and maintenance (O&M) costs would increase, which may become a burden to public facilities. Therefore, it is recommended to limit the number of security lights to as few as possible, to save energy and avoid over-sizing.

6.1.3 Estimation of PV System Capacity

Sizing of PV array and battery bank can be done as follows:

Basic formulas are developed by assuming a power demand of 100 Wh per day. Table 6.1.1 indicates the average of nationwide solar insolation in Kenya.

Table 6.1.1 Average of Nationwide Solar Insolation in Kenya (kWh/m^2/day)

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

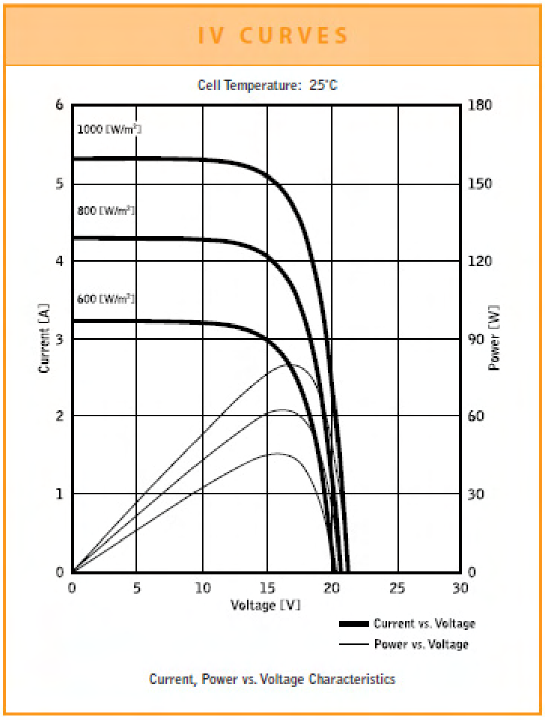
Source: NASA (http://eosweb.larc.nasa.gov/)

The next step is to identify PV panel characteristics. Figure 6.1.1 shows a typical I-V curve of a PV panel[1]. The maximum power of 80 W is given at the point of maximum power voltage (17.1 V) and maximum power current (4.67 A). However, when the panel is connected to 12 V batteries, the operating voltage becomes approximately 14 V. Accordingly, its actual current is determined through the graph below, which is approximately 5.2 A. Thus, the actual power output at this point is calculated as 72 W. In other words, the actual capacity of PV panel will decrease by about 10% when connected with 12 V battery.

1 Sharp NE-80U1

ELECTRICAL CHARACTERISTICS

Cell	Multi-crystal silicon
No. of Cells and Connections	36 in series
Open Circuit Voltage (Voc)	21.3V
Maximum Power Voltage (Vpm)	17.1V
Short Circuit Current (Isc)	5.3A
Maximum Power Current (Ipm)	4.67A
Maximum Power (Pm)*	80W
Minimum Power (Pm)*	72W
Encapsulated Solar Cell Efficiency (ηc)	14.11%
Module Efficiency (ηm)	12.60%
PTC Rating (W)**	70.24
Maximum System Voltage	600VDC
Series Fuse Rating	10A
Type of Output Terminal	Lead Wire with MC Connector



Source: Internet (http://www.rentech.com/content/solar_electricity/Sharp_80W.pdf)

Figure 6.1.1 Typical Electrical Characteristics and I-V Curves

Considering these conditions, PV panel capacity to supply 100 Wh/day can be calculated as follows:

$$Wp \times 5.75 \times 0.9 = 100 \quad (1) \qquad \therefore Wp = 100/(5.75 \times 0.9) = 19.3$$

However, from a conservative aspect, 5.0 insolation hours is a commonly adopted design condition for PV system in Kenya. Also, it is necessary to consider various loss factors such as direction and angle of PV panels, dirt on surface, high temperature, losses from battery charging and discharging, and losses from inverters. There are many aspects in evaluating losses. For this survey, the Survey Team assumes that there is a total loss of 40% from a conservative viewpoint. Thus, formula (1) can be modified as follows:

$$Wp \times 5.0 \times 0.9 \times 0.6 = 100 \quad (2) \qquad \therefore Wp = 100/(5.0 \times 0.9 \times 0.6) = 37.0$$

Hence, a 37 W PV panel is suitable for the power demand of 100 Wh/day.

The next step is to estimate the battery bank capacity. The maximum voltage of 12 V batteries sold in the market is approximately 13.6 V, and the average voltage is around 13 V. Consequently, when 100 Wh is discharged, the capacity decreases by 7.7 Ah (100 Wh/13 V). Also, the battery bank capacity depends on the number of days of autonomy. It is a common practice in Kenya to design PV systems considering three days of autonomy. In addition, it is also important to consider the allowable depth of discharge. For deep-cycle batteries, the maximum depth of discharge is approximately 70%. By considering these conditions, it is possible to calculate a battery capacity, X (Ah), for a power demand of 100 Wh/day as follows:

$$13 x X x 0.7 = 100 Wh x 3 \quad (3) \qquad \therefore X = (100 x 3)/(13 x 0.7) = 33.0$$

Thus, the recommendable battery bank capacity for power demand of 100 Wh/day is 33 Ah (12 V).

From the results above, the basic formulas for sizing of the solar array and battery bank can be defined as follows:

Solar Array Capacity (Wp) = Power Demand (Wh/day) x 0.37

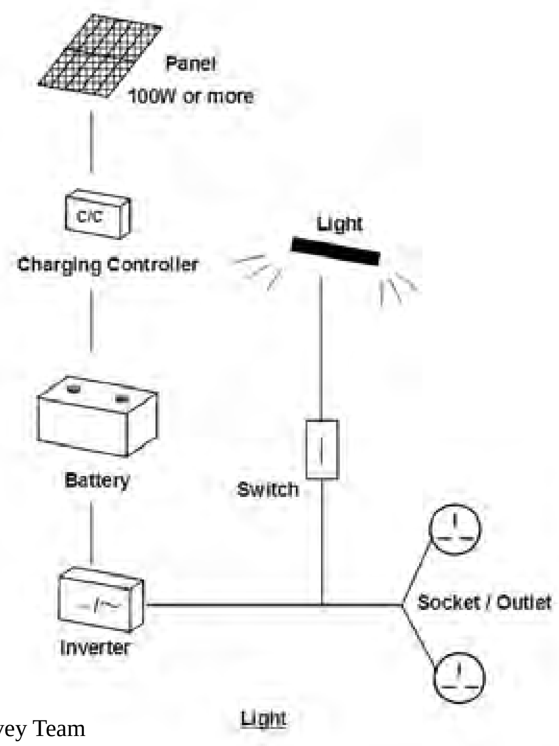
Battery Bank Capacity (Ah) = Power Demand (Wh/day) x 0.33

6.1.4 Important Factors for Design Work

To avoid over sizing and high maintenance cost, the efficiency of security lights must be considered as a priority issue. Hence, the use of energy efficient light-emitting diode (LED) lights is strongly recommended. However, marketed LED lights in Kenya are still limited. Hence, the Survey Team proposes to use 18 W compact fluorescent lamps (CFL) as security lights, which have standardized sockets compatible with LED lights that are to become more available in the market in the near future.

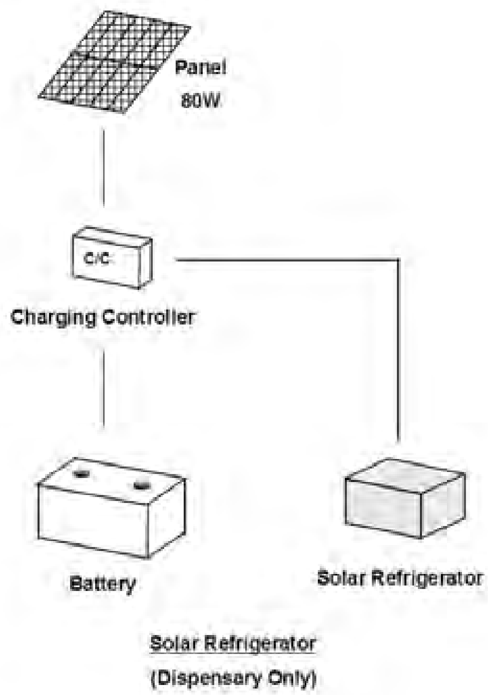
As for PV refrigerator, the Survey Team designed a standard typed solar refrigerator (165 L and 168 Wh/day) with dedicated wires (12 V DC) to be installed at Olopironito and Meto Dispensaries for the sole purpose of storing vaccines. The Survey Team also proposes that the days of autonomy should be for five days based on the recommendation of World Health Organization (WHO).

For the battery charging system, the Survey Team recommends that power be converted to 240 V AC through an inverter. The estimated number of customers for mobile phone charging is around 60, and the power demand is around 126 Wh/day. In the long run, rechargeable lamps will be used, which will create a new electricity demand. If there are 30 customers for rechargeable lamp charging, the addition demand will be around 360 Wh/day. To meet these needs, a battery charging station with 160 W PV is proposed. A deep-cycle battery is used as backup to secure necessary power for charging during on rainy days. Car batteries (12 V) should be charged separately through dedicated PV panels and controllers. The standard size of car batteries is 12 V 50 Ah of 12 V 70 Ah. To recharge a battery of that size will also require a 160 W class PV panel. The Survey Team proposes a battery charging station with one 240 V AC charging system and two car battery charging systems. Based on these design policies, the Survey Team has proposed the standard design of subsystems of CSS as shown in Figure 6.1.2, 6.1.3 and 6.1.4.



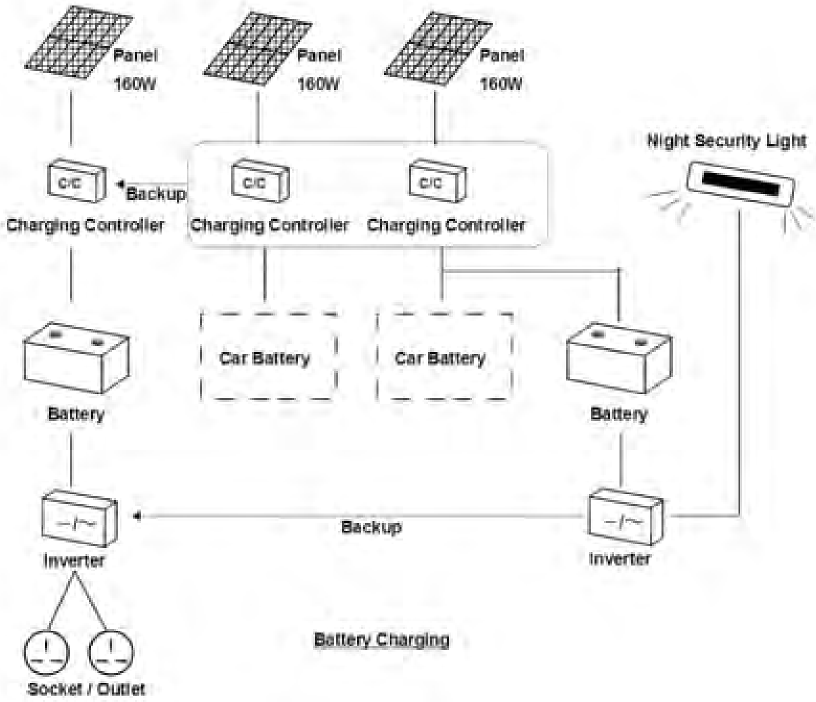
Prepared by JICA Survey Team

Figure 6.1.2 Conceptual Diagram of PV System (Lighting and other appliances)



Prepared by JICA Survey Team

Figure 6.1.3 Conceptual Diagram of PV System (Solar Refrigerator for Dispensary)



Prepared by JICA Survey Team

Figure 6.1.4 Conceptual Diagram of PV System (Battery Charging)

6.2 Basic Design and Cost Estimates for Candidate Sites of Pilot Projects

6.2.1 Survey Result for the Six Candidate Sites

The Survey Team carried out the detailed surveys of each facility at the six candidate sites based on the results of the detailed village socio survey during the field work period. They confirmed the outlines of the facilities and planned lighting and battery charging systems with PV system to be introduced in the future.

Basically, the facilities do not need lighting systems during the daytime since sunlight is enough, and the systems will be only used during cloudy and rainy days, and at night time. As for the schools, the plan is to save energy by preventing unnecessary power consumption, assuming that students will use designated class rooms for night classes. For dispensaries, the sun will be the source of light during daytime medical services to avoid subsidized lighting systems. Such lighting systems are mainly for emergency purposes at night, but are recommended to be turned off when not in use to minimize power consumption.

The Survey Team initially introduced energy-saving plans as much as possible to avoid early deterioration of battery banks, while minimizing PV panel capacities for sustainable O&M, the numbers of batteries and power consumption. As a result, the Survey Team designed six lighting fixtures per large-scaled class room with areas of more than 8 m x 6 m, and four lighting fixtures per small-scaled room. Principally, there will be one lighting fixture per dispensary, except for large rooms.

The Technical Specifications for PV projects implemented by MOE, some model plans are shown as follows.

Schools

1) Power Package No. PP1

Load	:	Between 5 and 10 Lights and between 1 and 4 Sockets to be Installed
Array Capacity	:	2 No. Panels of 110W, Total Wp=220
Battery	:	1 No. Battery of 200Ah, Total Capacity = 200Ah
Inverter/Charger	:	One Inverter, 500 - 1,000W
For a single classroom block or building of similar size and usage		

2) Power Package No. PP2

Load	:	Between 10 and 18 Lights and between 3 and 7 Sockets to be Installed
Array Capacity	:	4 No. Panels of 110W, Total Wp=440
Battery	:	2 No. Battery of 200Ah, Total Capacity = 400Ah
Inverter/Charger	:	One Inverter, 500 - 1,000W
Mainly for a two classroom block or building of similar size and usage		

3) Power Package No. PP3

Load	:	Between 19 and 25 Lights and between 5 and 10 Sockets to be Installed
Array Capacity	:	6 No. Panels of 110W, Total Wp=660
Battery	:	3 No. Battery of 200Ah, Total Capacity = 600Ah
Inverter/Charger	:	One Inverter, 1,000W

Mainly for a three classroom block or building of similar size and usage

4) Power Package No. PP4

Load	:	Between 26 and 32 Lights and between 8 and 12 Sockets to be Installed
Array Capacity	:	8 No. Panels of 110W, Total Wp=880
Battery	:	4 No. Battery of 200Ah, Total Capacity = 800Ah
Inverter/Charger	:	One Inverter, 1,500W
Mainly for a four classroom block or building of similar size and usage		

5) Power Package No. PP5

Load	:	Between 33 and 40 Lights and between 10 and 15 Sockets to be Installed
Array Capacity	:	10 No. Panels of 110W, Total Wp=1100
Battery	:	5 No. Battery of 200Ah, Total Capacity = 1000Ah
Inverter/Charger	:	One Inverter, 1,500W
Mainly for a five classroom block or building of similar size and usage		

<u>Medical Institutions</u>

1) Power Package No. MP1

Load	:	Between 5 and 10 Lights and between 1 and 3 Sockets to be Installed
Array Capacity	:	2 No. Panels of 110W, Total Wp=220
Battery	:	2 No. Battery of 200Ah, Total Capacity = 400Ah
Inverter/Charger	:	One Inverter, 1,000W
Mainly for lighting and providing basic power in small buildings (e.g. maternity, general ward, etc.) at health centers, large dispensaries and sub-district hospitals		

2) Power Package No. MP2

Load	:	Between 10 and 20 Lights and between 2 and 5 Sockets to be Installed
Array Capacity	:	5 No. Panels of 110W, Total Wp=550
Battery	:	3 No. Battery of 200Ah, Total Capacity = 600Ah
Inverter/Charger	:	One Inverter, 1,000W
Mainly for lighting and providing basic power in medium size buildings (e.g. maternity, general ward, etc.) at health centers, large dispensaries and sub-district hospitals		

3) Power Package No. MP3

Load	:	- Between 5 and 10 Lights and between 1 and 3 Sockets to be Installed - 1 Solar Medical Refrigerator. Only 12 V DC Socket/Plug set to be installed, wired directly from the load terminals of the Charge Controller. Refrigerator Cabinet not included as will be supplied separately
Array Capacity	:	5 No. Panels of 110W, Total Wp=550
Battery	:	3 No. Battery of 200Ah, Total Capacity = 600Ah
Inverter/Charger	:	One Inverter, 1,000W
Mainly for lighting, running one 12V DC solar medical refrigerator and power in out-patient department (OPD) at small-sized dispensaries		

4) Power Package No. MP4

Load	:	- Between 10 and 20 Lights and between 3 and 5 Sockets to be Installed - 1 Solar Medical Refrigerator. Only 12 V DC Socket/Plug set to be installed, wired directly from the load terminals of the Charge Controller. Refrigerator Cabinet not included as will be supplied separately
Array Capacity	:	7 No. Panels of 110W, Total Wp=770
Battery	:	4 No. Battery of 200Ah, Total Capacity = 800Ah
Inverter/Charger	:	One Inverter, 1,500W
Mainly for lighting, running one 12V DC solar medical refrigerator and power in out-patient		

department (OPD) at medium-sized dispensaries

5) Power Package No. MP5

Load	:	- Between 10 and 20 Lights and between 3 and 5 Sockets to be Installed - 2 Solar Medical Refrigerators. Only 12 V DC Socket/Plug set to be installed, wired directly from the load terminals of the Charge Controller. Refrigerator Cabinet not included as will be supplied separately
Array Capacity	:	9 No. Panels of 110W, Total Wp=990
Battery	:	5 No. Battery of 200Ah, Total Capacity = 1,000Ah
Inverter/Charger	:	One Inverter, 1,500W
Mainly for lighting, running two 12V DC solar medical refrigerators and power in out-patient department (OPD) at Health Centers and sub-district Hospitals.		

Source: MOE

Table 6.2.1 describes the comparison of JICA design and MOE model plan in case of the three candidate school and dispensaries for the pilot projects.

Table 6.2.1 Numbers of Indoor Lightings (compared with the model plans by MOE)

Facility Category	JICA Survey Team	MOE
School	26 lighting fixtures (Ilimotiook Secondary School's Class Rooms, 5 rooms exist)	At least 33 lightings fixtures for 5 rooms per building
Dispensary	8 lighting fixtures (Meto Dispensary, 8 rooms exist)	At least 10 lighting fixtures for 5 rooms per building
	12 lighting fixtures (Olopironito Dispensary, 8 rooms exist)	

Source: JICA Survey Team, MOE

From the comparison above, it is concluded that the planned number of lighting is appropriate in saving energy and cost reductions for future O&M.

Outdoor lighting systems will be needed for approximately 12 hours during nighttime for security purposes. The long hour use of lighting induces an increase in the numbers of PV panels and batteries. At the same time, it serves as an obstacle in reducing O&M costs. Accordingly, the Survey Team introduces an energy-saving policy by adopting efficient lighting distributions. Lighting fixtures are to be installed at facility corners for two-directional lighting purposes wherever possible.

6.2.2 Results of Detailed Survey and Basic Design of the Three Candidate Sites

Based on the results of the detailed village socio survey, the Survey Team has appropriately shortlisted three candidate sites for the pilot projects. The following table describes the supposed power demands of the three sites including plans for indoor and outdoor lighting systems, and battery charging systems.

Candidate Sites	Estimated Power Demand Per Day
Ilimotiook Secondary School	12,488.9 Wh (See Table 6.2.2)
Olopironito Dispensary	4,664.75 Wh (See Table 6.2.3)
Meto Dispensary	3,482.75 Wh (See Table 6.2.4)

1) <u>Ilimotiook Secondary School</u>

In the case of Ilimotiook Secondary School, the Survey Team supposes six lighting fixtures per large-scaled class room and four fixtures per small-scaled class room. The Survey Team also assumes that students will only use small-scaled classrooms for their night classes, and indoor lighting systems at other classrooms which are to be used approximately for an hour as subsidiary lighting, to reduce unnecessary power consumption. Moreover, the Survey Team also proposed that lighting systems at the staff office and other rooms are to be used for a maximum of two hours to conserve energy.

For classes and office work, the Survey Team considers the use of personal computers, printers, a copy machine, and a TV with a DVD player.

Its night lighting systems are to be used for 12 hours after sunset, for security purposes. To save energy, the Survey Team proposed installation of lighting systems at the corners of the facilities for two-directional lighting purposes wherever possible. Also, the Survey Team's designs consider installation of lighting systems at main doors of dormitories, for security purposes. On the other hand, accesses through other doors at night time will be restricted to reduce number of lighting fixtures.

With regards to charging of mobile phones, rechargeable lanterns and car batteries which need DC power, the Survey Team proposes to install the charging station at the security office near the entrance gate to minimize disturbance to classes. .

Table 6.2.2 Estimated Power Demand per Day at Ilimotiook Secondary School

Load Description	Power Demand (Wh/day)
1) Group 1	2,988.00
2) Group 2	1,784.25
3) Gropu 3	1,499.75
4) Group 4	2,092.50
5) Group 5	1,332.00
6) Group 6	1,188.00
7) Group 7	1,604.40
Group 7 (AC)	432.00
Group 7 (DC)	1,172.40
Total	12,488.90

Prepared by JICA Survey Team

2) <u>Olopironito Dispensary</u>

At Olopironito Dispensary, the Survey Team designed four lighting fixtures at a large-scaled room, and one or two fixtures at its other rooms. The dispensary basically operates by utilizing the sunlight during daytime, while its indoor lighting systems serve subsidiary functions. The Survey Team supposes that the dispensary will use the indoor lighting systems only for emergency purposes during nighttime. A 165 L refrigerator operated through solar power for vaccine storage at the dispensary will be installed. Moreover, the design also considers installation of a personal computer, a printer, a copy machine, and a TV with a DVD player which may be required during trainings and seminars.

As for the staff houses, the Survey Team plans to install three indoor lighting fixtures for large-scaled house (1 block/house) and two fixtures per block for small houses (3 blocks/house). They are six fixtures in total for three blocks.

Night lighting systems are essential to prevent thefts of expensive items, such as medicines and medical equipment. Therefore, the Survey Team designs the location of lighting systems carefully, while considering two-directional lighting by installing them at the corners of the dispensary.

For charging mobile phones, rechargeable lanterns and car batteries, the Survey Team plans to install the battery charging station inside the dispensary building.

Table 6.2.3 Estimated Power Demand per Day at Olopironito Dispensary

Load Description	Power Demand (Wh/day)
1) Dispensary Building	3,152.75
Dis Bldg. (AC)	1,652.75
Dis. Bldg. (DC)	1,500.00
2) Staff House (Large) (1 Block in 1Building)	756.00
3) Staff House (Small) (3 Blocks in 1 Building)	756.00
Total	4,664.75

Prepared by JICA Survey Team

3) <u>Meto Dispensary</u>

The Survey Team designs one indoor lighting fixture at each room of Meto Dispensary. The dispensary basically offers medical services during daytime, and its indoor lighting systems are for subsidiary purposes. It was also proposed to install a refrigerator with a 165 L capacity operated by solar power for vaccine storage at the dispensary. Moreover, the Survey Team also supposes that trainings and seminars require a personal computer, a printer, a copy machine, and a TV with a DVD player in the future.

Night lighting systems are necessary to prevent thefts of expensive items, such as medicines and medical equipment. Therefore, the Survey Team designs the locations of lighting systems carefully, while considering two-directional lighting systems by placing them at the corners of the dispensary.

For charging mobile phones, rechargeable lanterns and car batteries, the Survey Team plans to install battery charging station inside the dispensary building.

Table 6.2.4 Estimated Power Demand per Day at Meto Dispensary

Load Description	Power Demand (Wh/day)
1) Main Building	3,482.75
Main Bldg. (AC)	2,129.75
Main Bldg. (DC)	1,353.00
Total	3,482.75

Prepared by JICA Survey Team

6.2.3 Cost Estimates for Pilot Projects at Three Candidate Sites

Under the assumptions and conditions mentioned above, Table 6.2.5 reveals the cost estimates for the implementation of pilot PV systems at the three candidate sites, based on the results of the detailed village socio survey.

Table 6.2.5 Cost Estimates of Pilot Projects

(Ksh)

	Ilimotiook Secondary School	Olopironito Dispensary	Meto Dispensary	**Total(Ksh)**
PV power supply system	4500W 4200Ah(12V)	1300W 1400Ah(12V)	900W 800Ah(12V)	
PV charging system	480W	480W	480W	
Material costs	4,773,548	1,846,599	1,383,119	8,003,266
Installation	381,884	147,728	110,650	640,262
Transportation	27,600	24,600	24,000	76,200
Total	5,183,032	2,018,927	1,517,769	**8,719,728**

(VAT16% not included)

Prepared by JICA Survey Team

The locations of the three candidate sites have been already revealed. However, because PV contractors have not yet visited the sites, they cannot exactly estimate detailed costs for installation and transporation. Thus, the Survey Team appropriately estimates that the installation cost is approximately 8% of the total material costs and the transportation cost is Ksh120 per km respectively in Kenya according to a result of interviews with the PV contractors.

The following table lists the specifications of major PV materials and equipment to be requested for the pilot projects.

Item	Main Specification
PV Module	Mono-crystalline or Poly-crystalline Minimum voltage at maximum power 16.5V
Charge Controller	12V PWM control
Inverter	Input 12V DC Output 220-240V AC Modified Sine Wave (500W) Pure Sine Wave (1000W)
Battery	Deep Cycle, Sealed 12V Lead Acid Battery, Maintenance Free type Cycle life 1,500 cycle at 20% daily depth of discharge
Lamp	FL18W, CFL18W 240V AC

6.2.4 Installation Plan, Procurement Method and After-Sales Service

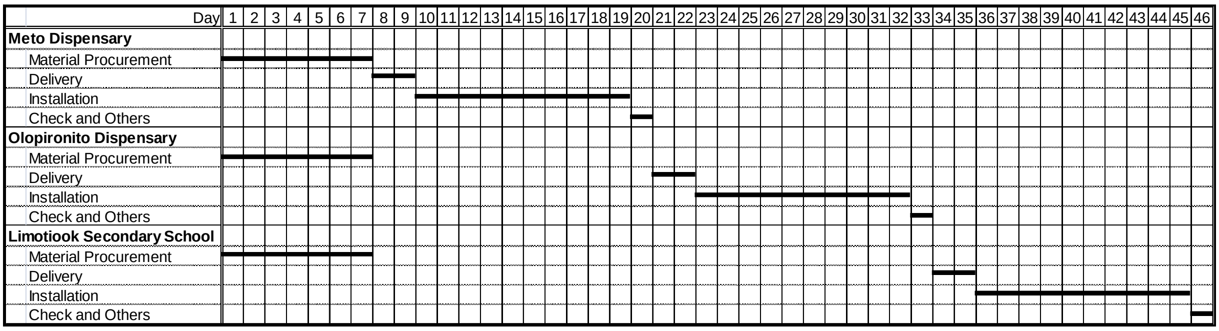
1) Installation Plan

It can be supposed that widely distributed PV equipment and materials can be procured in seven days maximum in Kenya. After that, transportation to the sites can be completed within two days. Installations can be completed in ten days maximum. Then, another day is necessary for final checking and miscellaneous work.

It is supposed that all necessary equipment and materials shall be procured for the three sites within the first seven days. After that, the first installation work shall be carried out at Meto Dispensary while setting a base camp in Namanga. Then, the remaining works at Olopironito Dispensary and Limotiook Secondary School shall be continued while setting the base camp in Narok for the works at the two sites. Since unpredictable troubles often come up just after commencement, it is necessary to consider mentally comfortable and relaxable working conditions for techinicians and workers on the first installation work only at one site with the base camp in Namanga. After the first work, then, they shall move to Narok to continue the remaining works at Olopironito Dispensary and Limotiook Secondary School.

As Table 6.2.6 presents the planned installation timetable of the PV system implementations for the pilot project, it is supposed that a series of the works at the three sites shall take for approximately 1.5 months.

Table6.2.6 Tentative Installation Timetable



2) Procurement Method and Route

Major PV contractors located in Nairobi have their branch offices and/or authorized agents both in Namanga and in Narok. However, it is unsure whether or not they always store PV equipment and materials suitably and recognize defects appropriately. Accordingly, it is necessary to transport most of the equipment and materials from Nairobi to the sites by land with 2 ton trucks/lorries. In the case of batteries and fluorescent lamp fittings, which are widely distributed, they may locally be procured in Namanga and Narok.

3) After-Sales Service

Major PV contractors have their branch offices and/or authorized agents in Namanga and Narok. Although the actual after-sales service shall be provided when the contactor is selected and the installation work is completed, a conceptual plan on the after-sales service is illustrated in Figure 6.2.1.

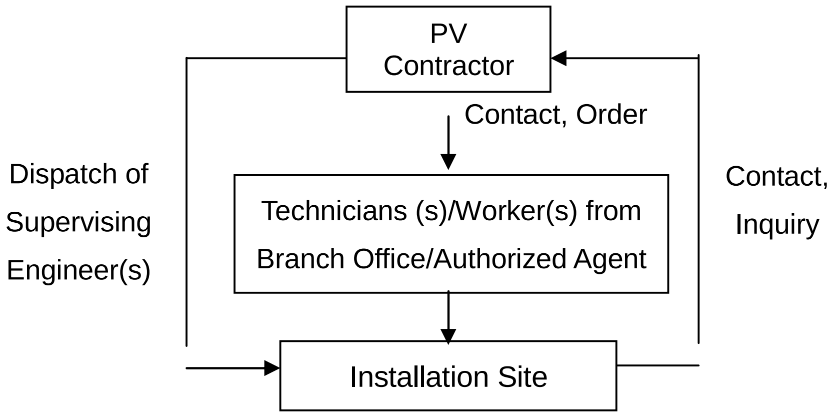
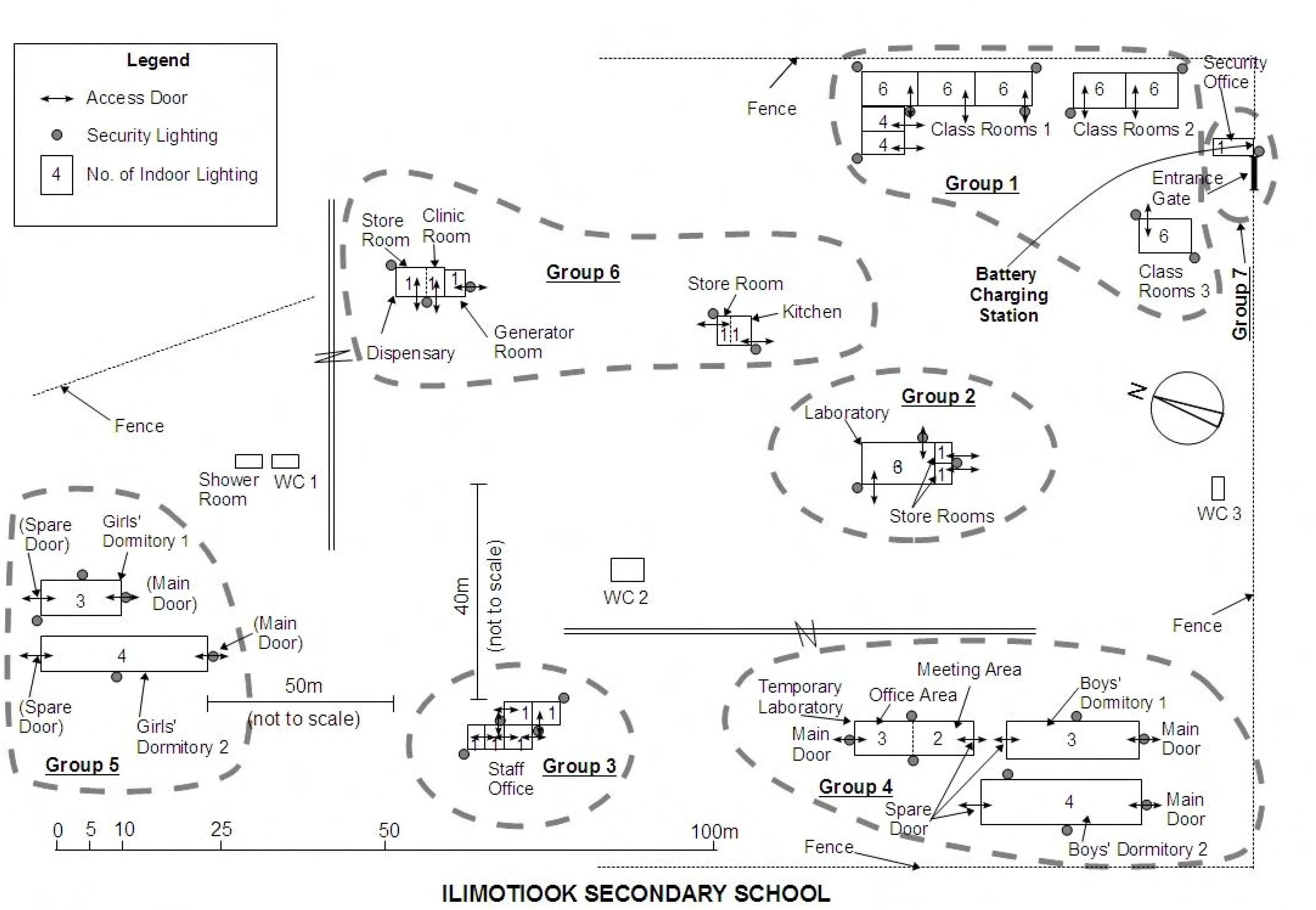


Figure 6.2.1 Conceptual Plan on After-Sales Service System

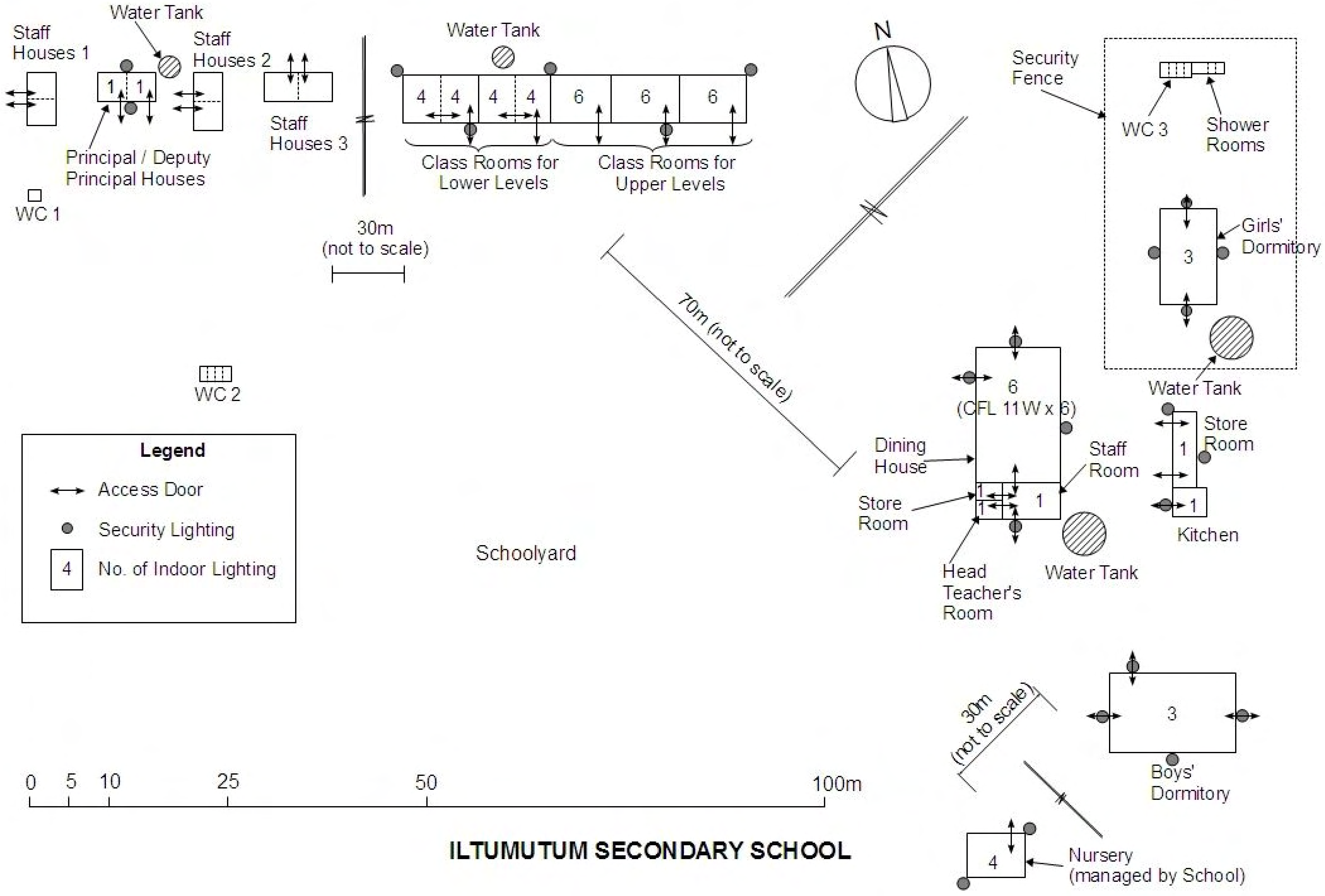
The list of facility layouts and isometric drawings of PV pilot systems is provided as follows, which include indoor and outdoor lighting fixtures, solar refrigerators, and battery charging stations at the three candidate sites:

Candidate Site	Layout Drawing	Isometric Drawing
Ilimotiook Secondary School	Figure 6.2.2	Figure 6.2.8 Figure 6.2.9 Figure 6.2.10 Figure 6.2.11 Figure 6.2.12
Iltumtum Primary School	Figure 6.2.3	
Olopironito Dispensary	Figure 6.2.4	Figure 6.2.13 Figure 6.2.14
Meto Dispensary	Figure 6.2.5	Figure 6.2.15
Mailwa Dispensary	Figure 6.2.6	
Iloodokilani Secondary School	Figure 6.2.7	



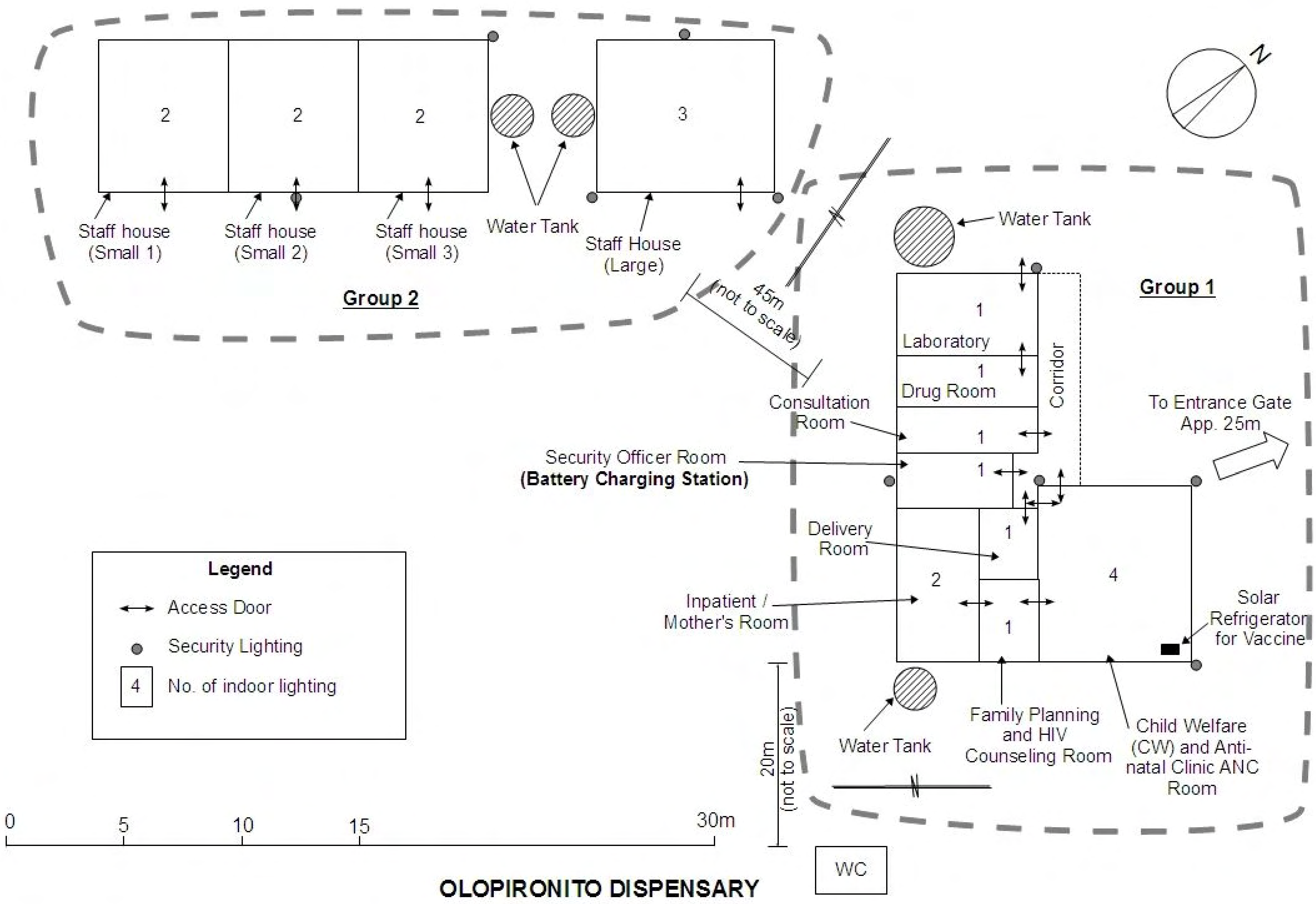
Prepared by JICA Survey Team

Figure 6.2.2 Layout Drawing of Ilimotiook Secondary School



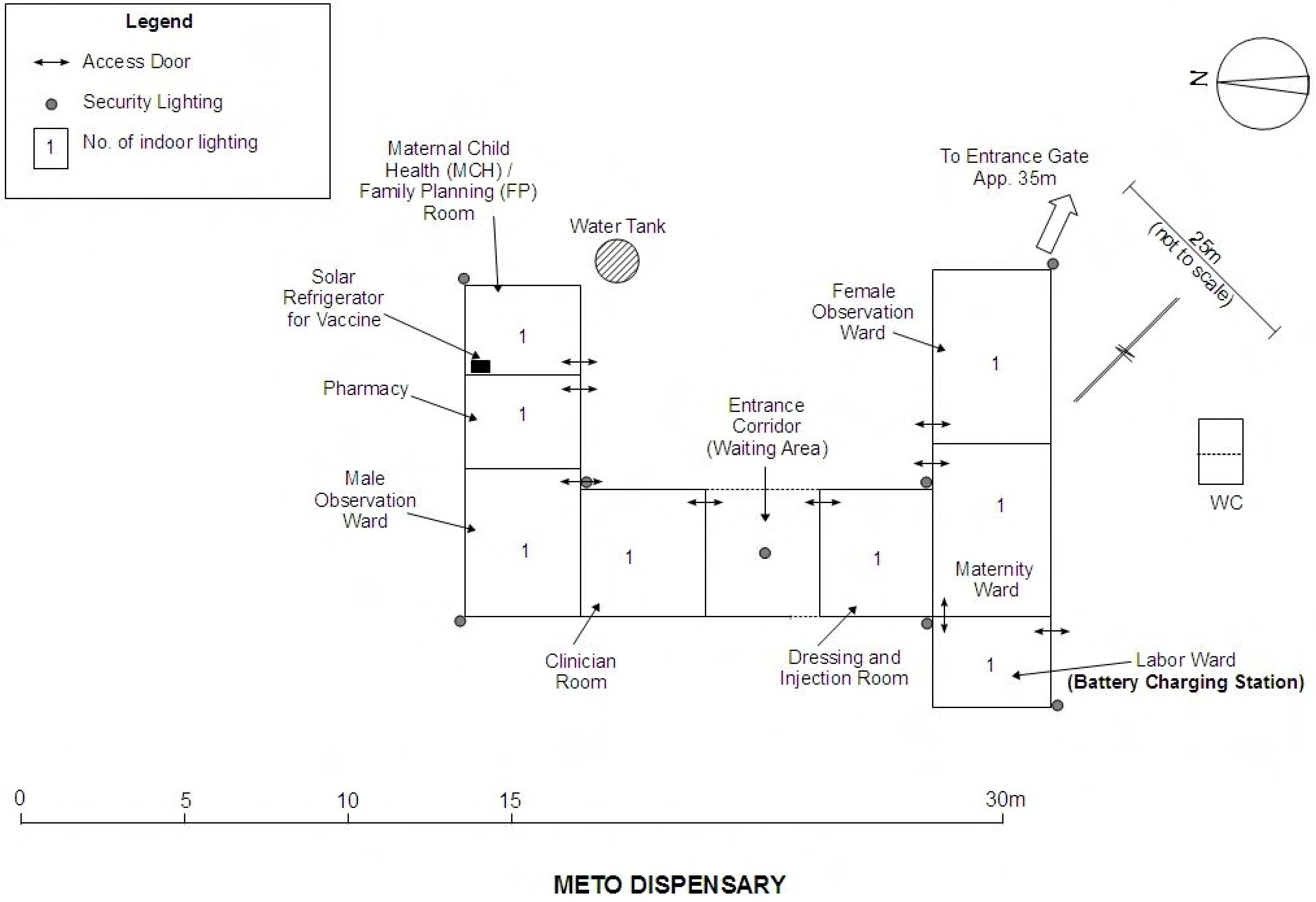
Prepared by JICA Survey Team

Figure 6.2.3 Layout Drawing of Iltumtum Secondary School



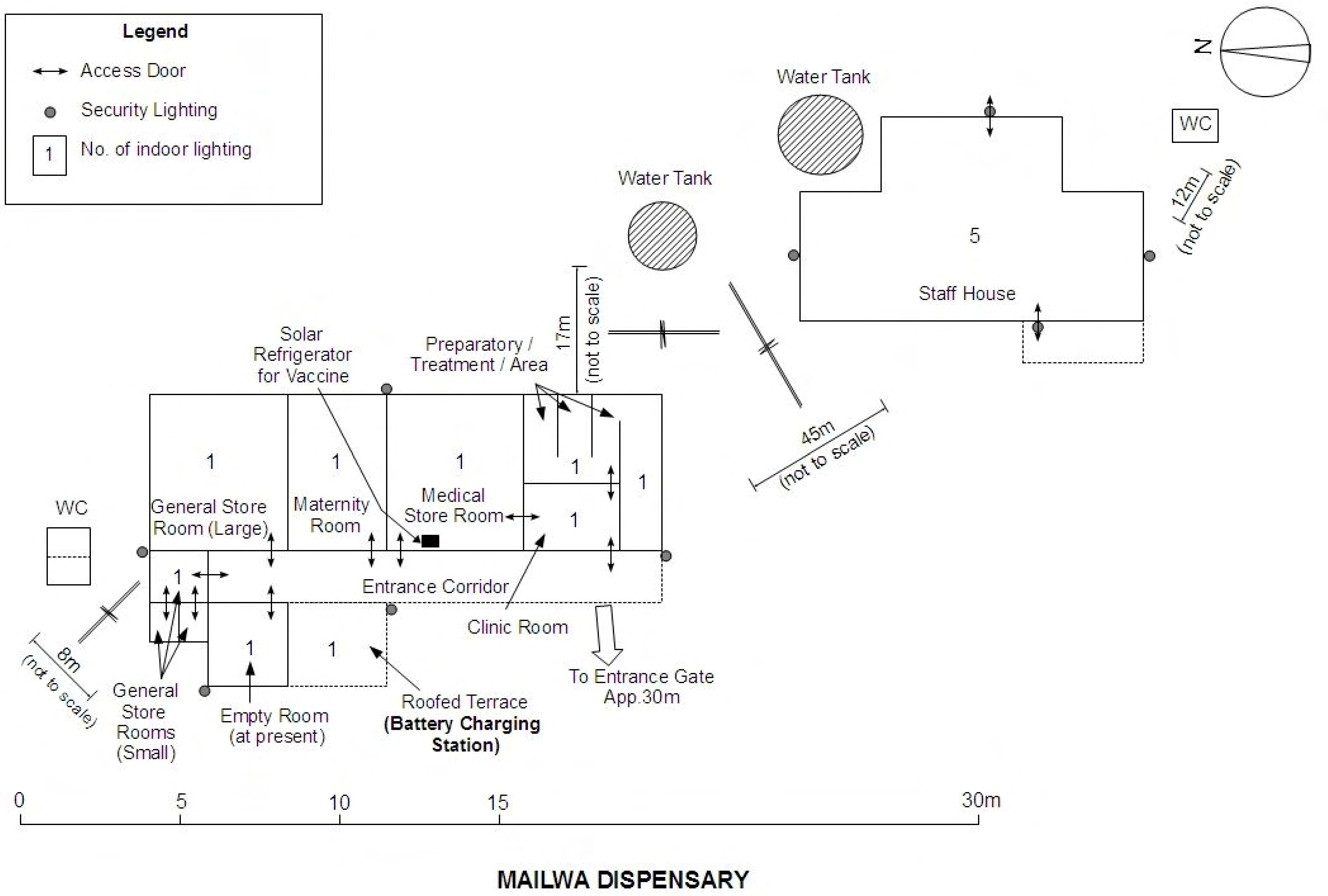
Prepared by JICA Survey Team

Figure 6.2.4 Layout Drawing of Olopironito Dispensary



Prepared by JICA Survey Team

Figure 6.2.5 Layout Drawing of Meto Dispensary



Prepared by JICA Survey Team

Figure 6.2.6 Layout Drawing of Mailwa Dispensary

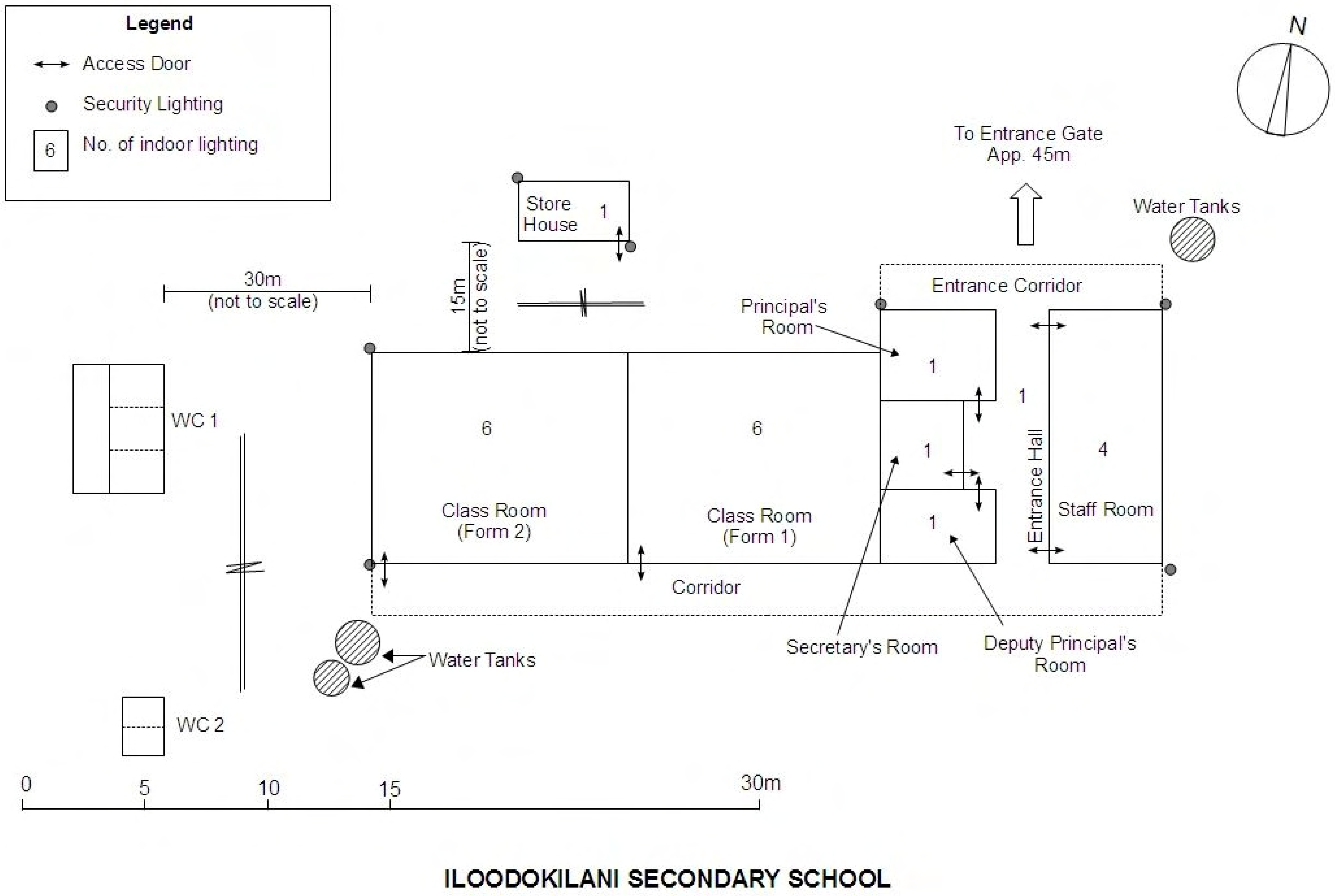


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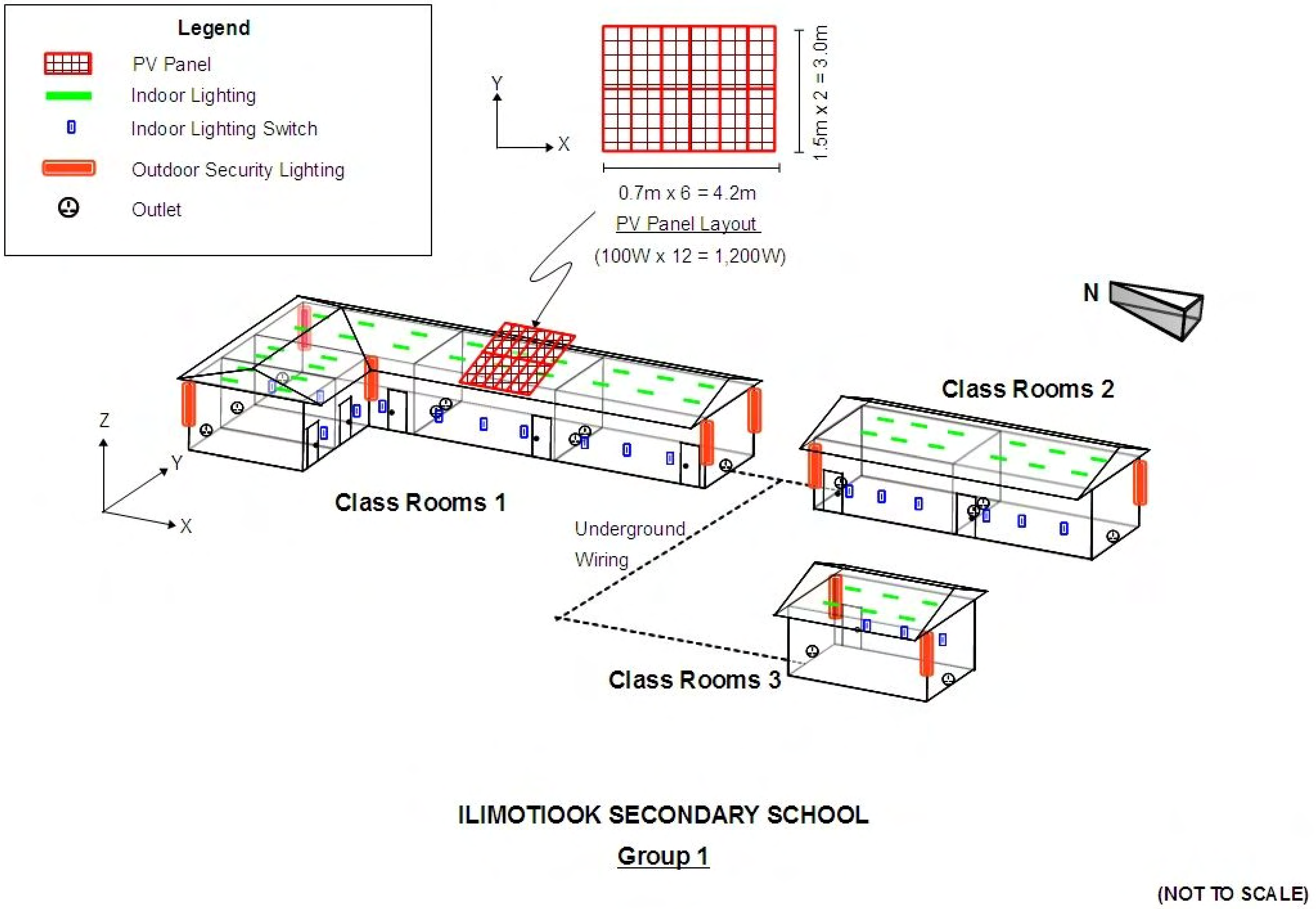
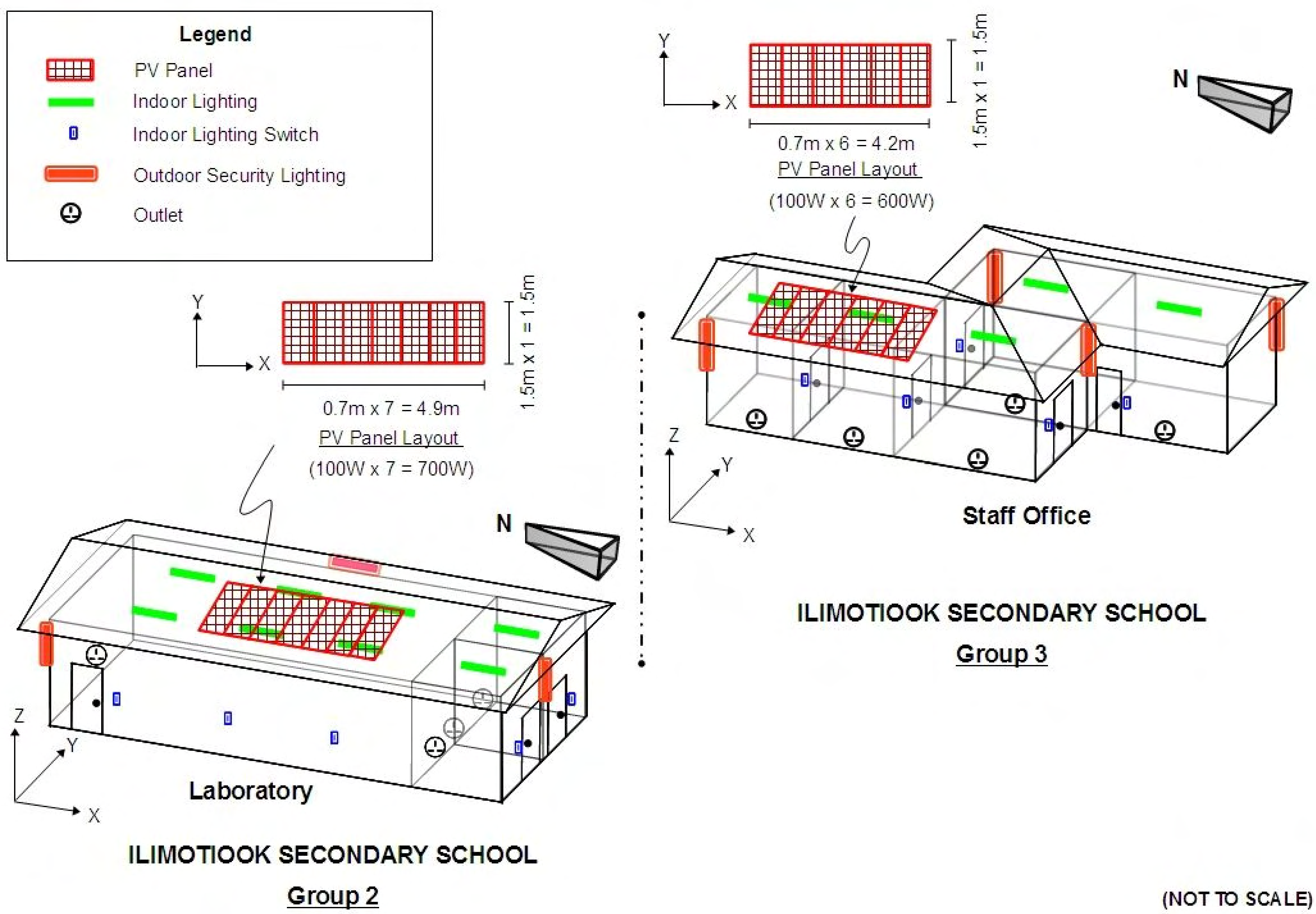
Figure 6.2.7 Layout Drawing of Iloodokilani Secondary School



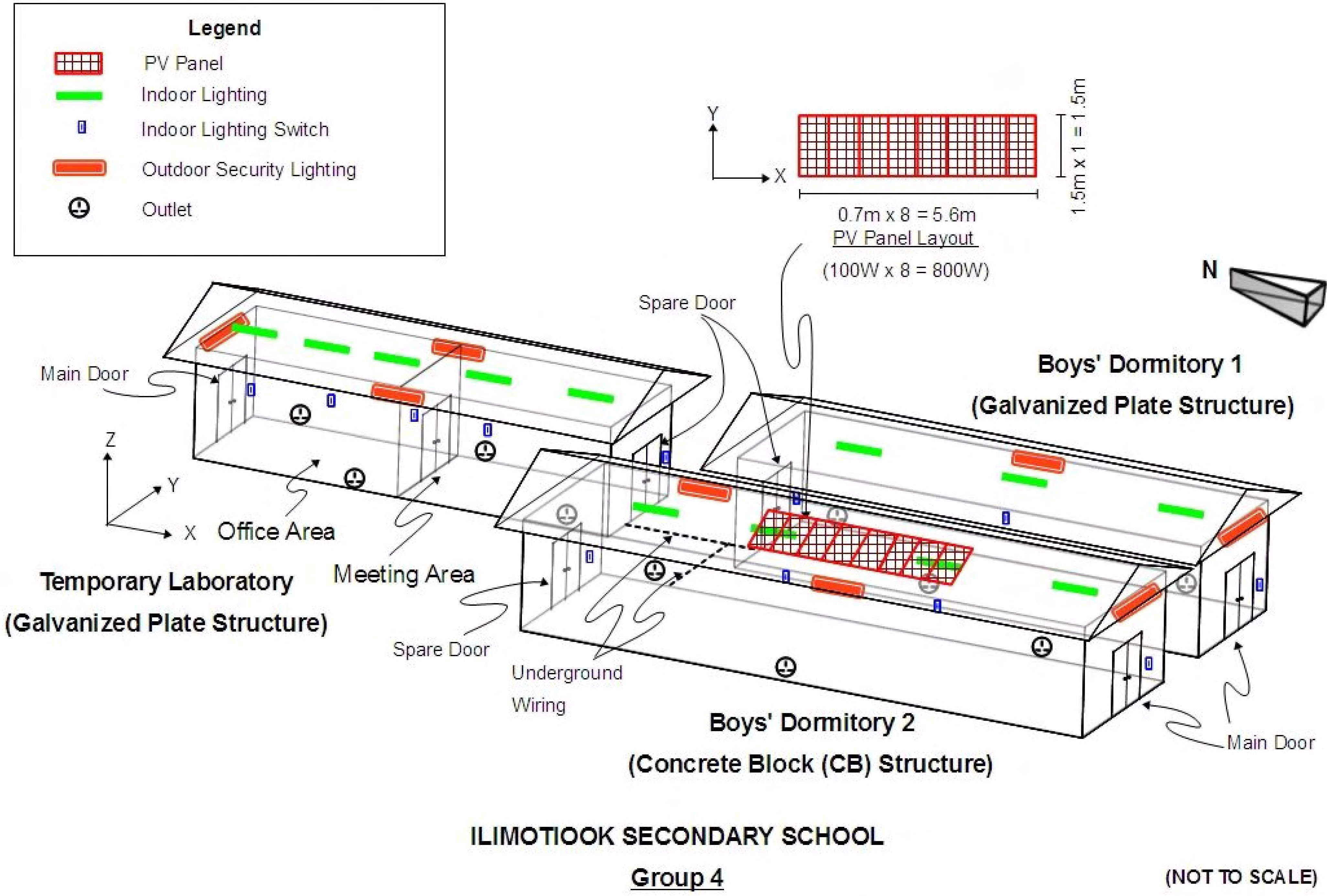
Prepared by JICA Survey Team

Figure 6.2.8 Isometric Drawing of Ilimotiook Secondary School (Group 1)



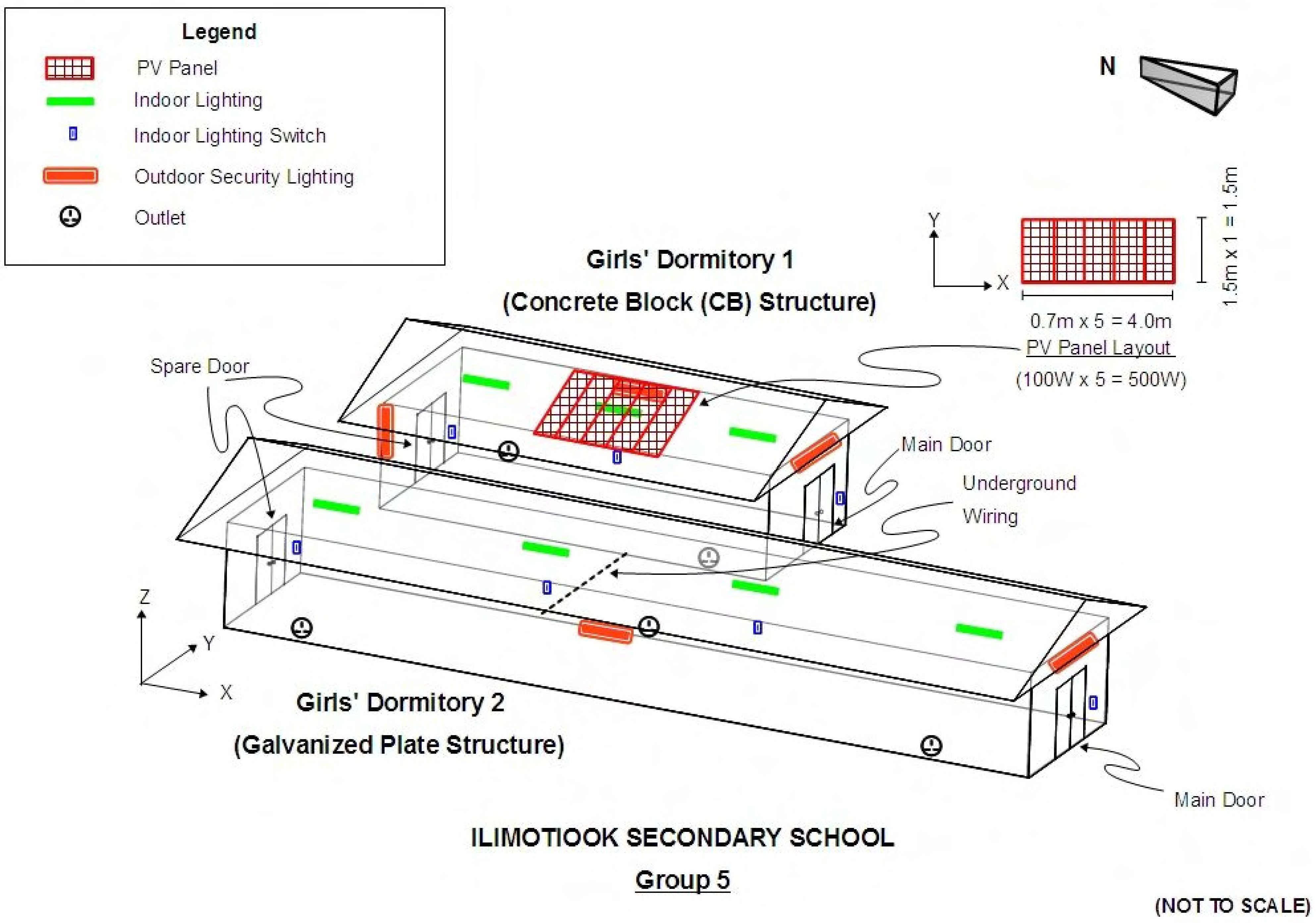
Prepared by JICA Survey Team

Figure 6.2.9 Isometric Drawing of Ilimotiook Secondary School (Groups 2 and 3)



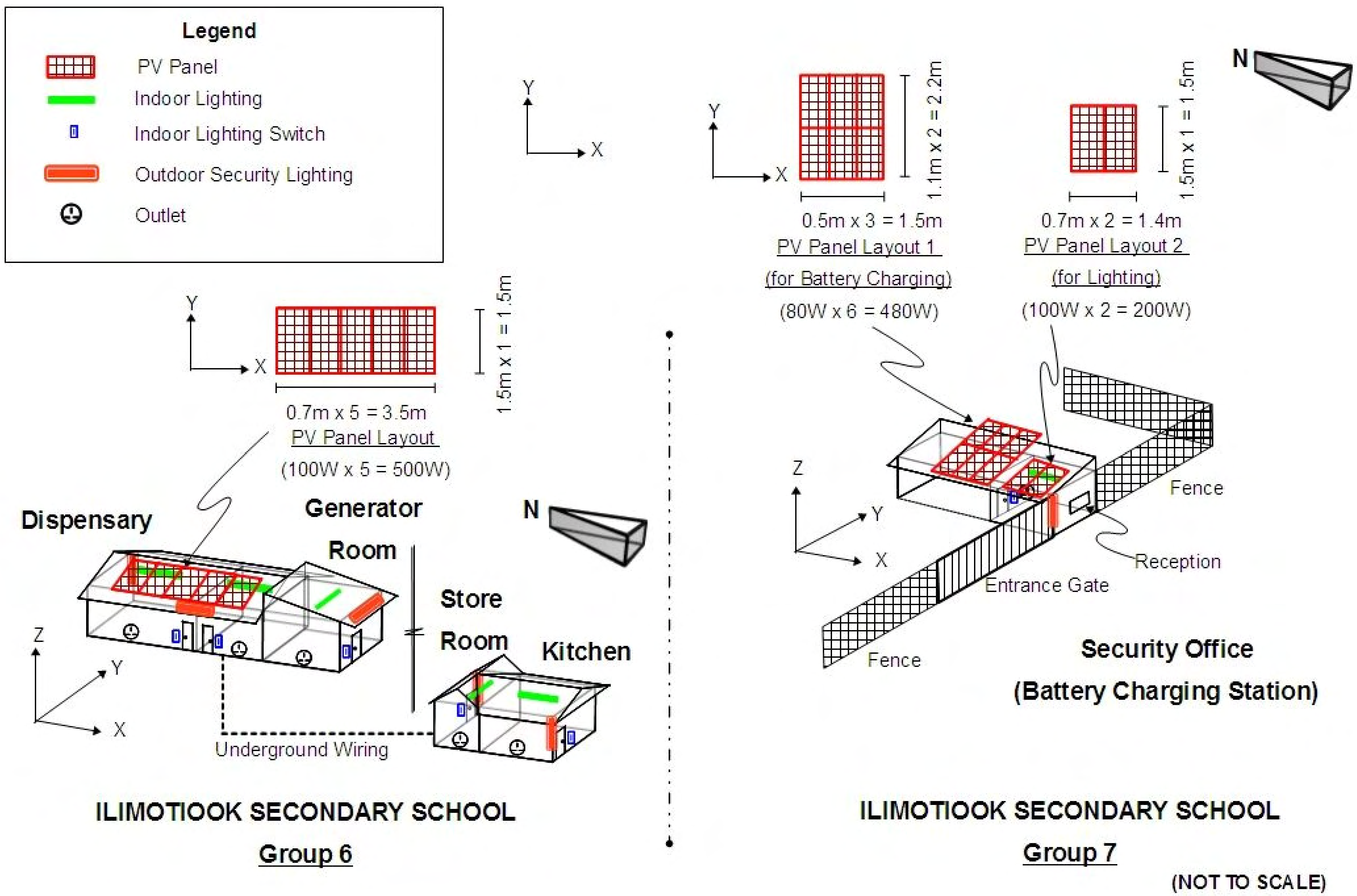
Prepared by JICA Survey Team

Figure 6.2.10 Isometric Drawing of Ilimotiook Secondary School (Group 4)



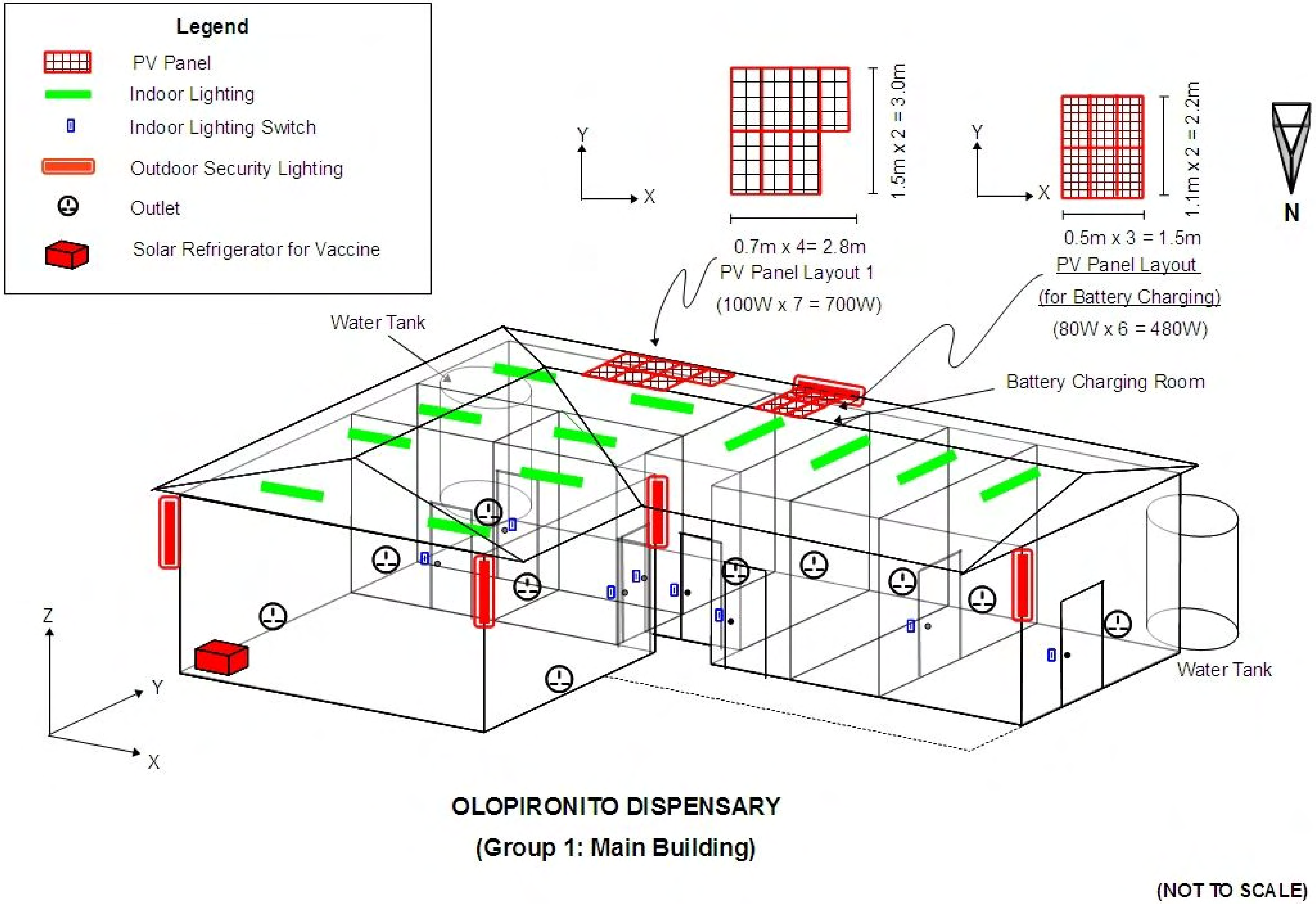
Prepared by JICA Survey Team

Figure 6.2.11 Isometric Drawing of Ilimotiook Secondary School (Group 5)



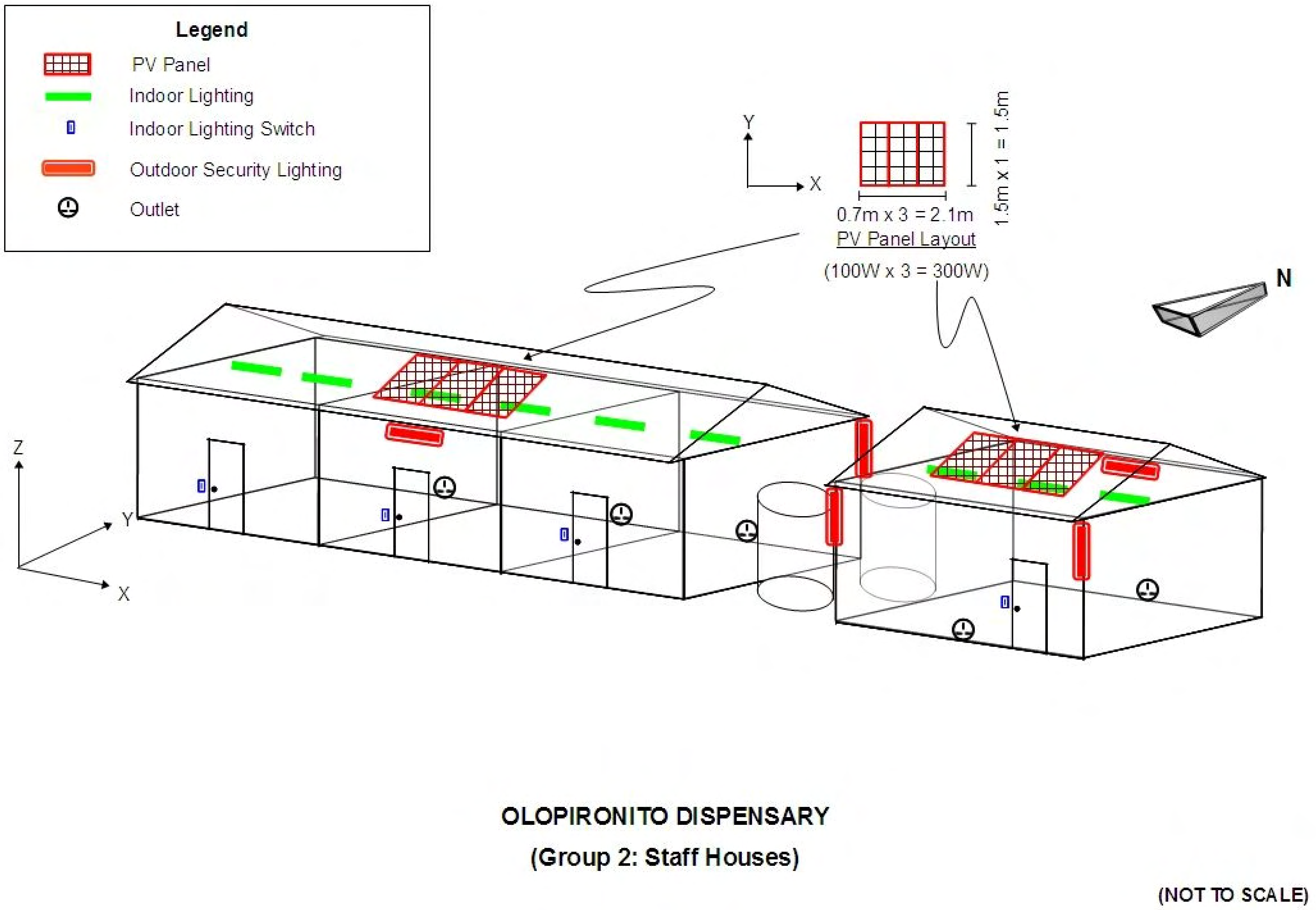
Prepared by JICA Survey Team

Figure 6.2.12 Isometric Drawing of Ilimotiook Secondary School (Groups 6 and 7)



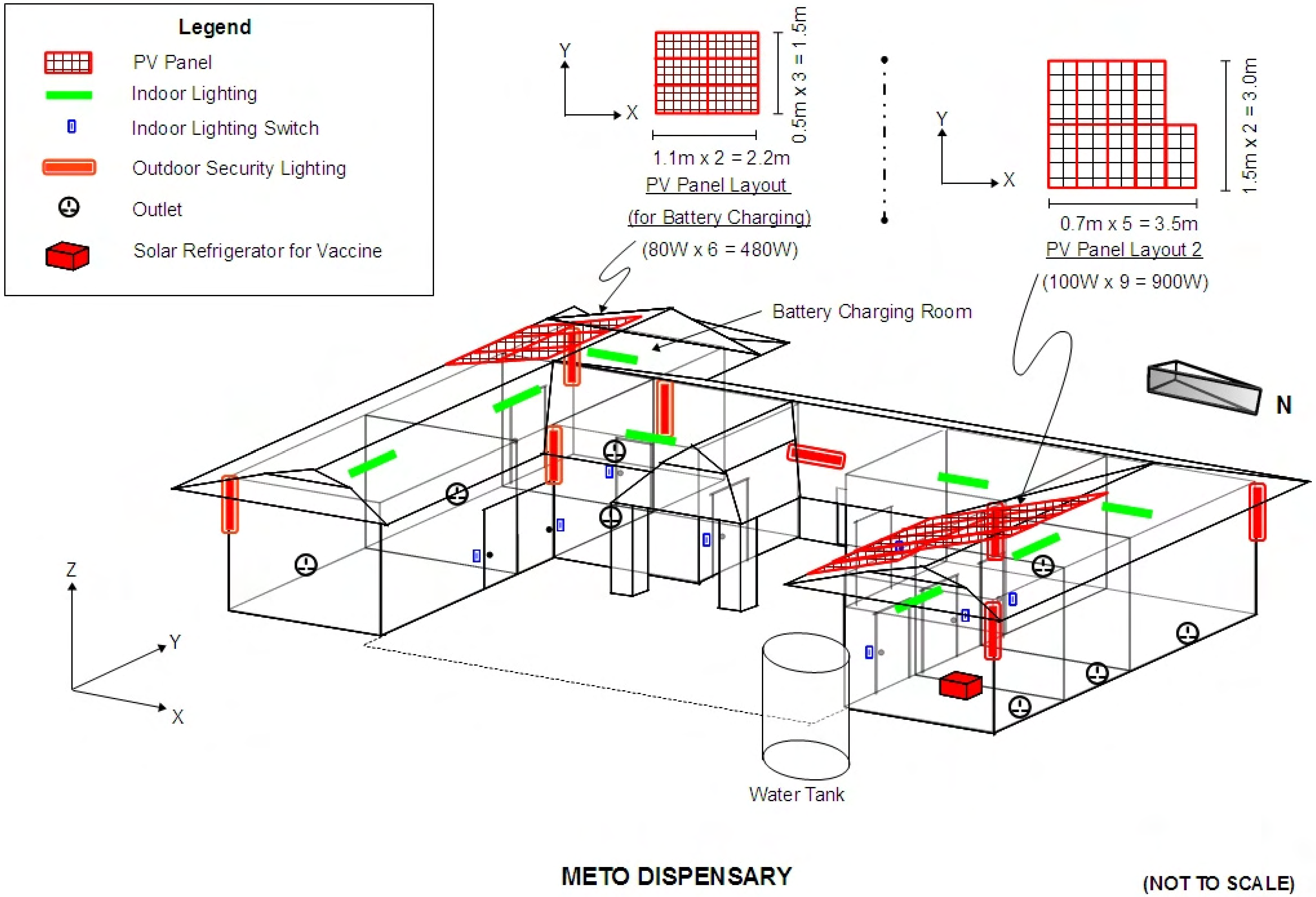
Prepared by JICA Survey Team

Figure 6.2.13 Isometric Drawing of Olopironito Dispensary (Group 1)



Prepared by JICA Survey Team

Figure 6.2.14 Isometric Drawing of Olopironito Dispensary (Group 2)



Prepared by JICA Survey Team

Figure 6.2.15 Isometric Drawing of Meto Dispensary

Chapter 7 Proposals on Maintenance Scheme

7.1 Operation and Maintenance (O&M) of Community Solar System

7.1.1 Operation of Public Facilities

The following issues regarding the operation of public facilities in un-electrified areas were indentified in this Study:

For schools, particularly secondary schools, building dormitories is a common practice, which leads to a larger electricity demand. At night, some classrooms are used for night classes in which students do use lights for doing their homework. Computer education has also started and therefore electricity needs are growing. At some schools, gasoline or diesel generators are being used.

In health centers, medical examination and providing medicines are the major activities. Some facilities are intended for delivering childbirth and in-patient treatments. Moreover, health education is important. Compared with schools, the size of health centers is smaller than schools, and therefore electricity demand is less. It is also noted that health center staff collect fees from patients. Furthermore, a gas-operated vaccine refrigerator is installed and lighting is necessary for treating patients during emergency at nighttime, although this does not happen everyday.

A facility management committee is organized at each school and health center, which acts to support the operation of public facilities. If a Community Solar System (CSS) is installed, the facility management committee will lead in ensuring the smooth operation of battery charging station and proper maintenance of CSS by using their proceeds.

Most schools and health centers hire security officers on a 24 hour basis. As a result, this will ensure security of the battery charging services.

7.1.2 O&M of PV System at Public Facilities

PV systems installed at public facilities in Kenya are designed to provide 240 V AC. As a result, standard 18 to 20 W fluorescent lamps are used, and hence, the size of PV system becomes large. PV system users, in this case, often do not pay attention to limited energy produced by PV and tend to overuse electricity, which shortens the battery life. Since the PV system at public facility often has many batteries, the necessary cost for battery replacement will be enormous. Therefore, it is important to conduct appropriate training on the proper use of the PV system and on battery maintenance to users before commissioning. In addition, handing of booklets and posters to users which illustrate necessary tips on system’s O&M would be effective. Furthermore, support from the PV contractors who installed the PV system would be useful, and has become easier recently due to wide use of mobile phones in remote areas.

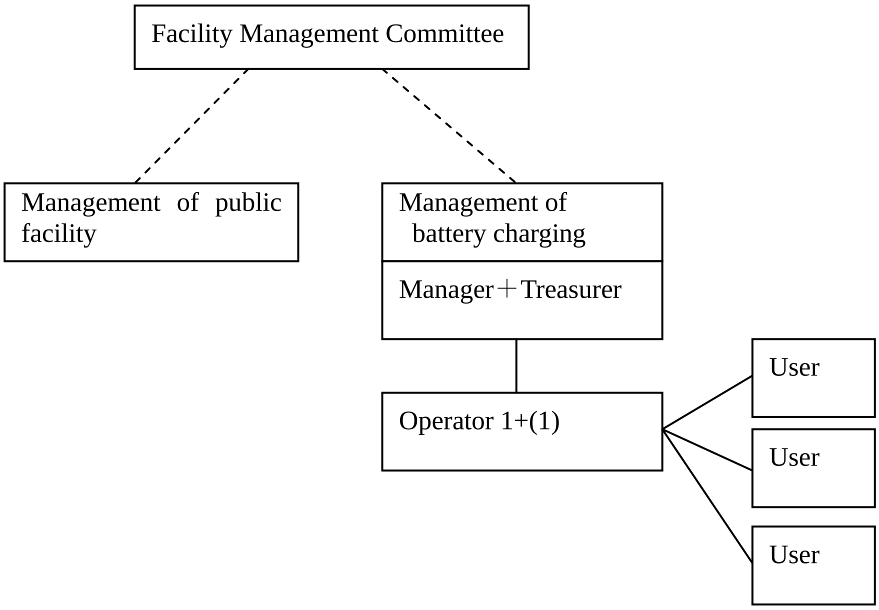
7.1.3 Operation of Battery Charging Station

Management of battery charging stations, which is a unique feature of CSS, to provide charging service and generate income requires a special arrangement as the nature of this service is different from the daily activities of public facilities. The battery charging service initially targets mobile phone users, and will possibly extend to provide charging services for other appliances. It will attract many customers soon after commissioning, typically around 50, and will expand over time.

Customers will bring their mobile phones and other appliances to the charging station and will pick them up when batteries are fully charged. They have to pay predetermined fees to the operator. Also, there is another possibility of providing charging service only to students who bring their appliances from home in the morning and pick them up as they return.

The required works such as dealing with customers, fee collection, record keeping, and accounting, would be time-consuming and labor-intensive. The staff of public facilities are busy in carrying out their assignments and therefore cannot conduct these additional tasks. Thus, establishing a good management system with newly-hired operators will be the key to a successful battery charging system. Similar to water supply services, battery charging is important for the community and, therefore, should be properly operated daily. Moreover, the revenue should be managed in a transparent way and be used primarily for PV system maintenance.

Usually, there is one operator at each charging station. However, it is recommended to have a substitute operator to ensure a stable operation. Operators need to undergo intensive training before commissioning. In addition, it is recommended to designate a manager and a treasurer who will oversee the operation of battery charging service and assume responsibility for financial management. Thus, it is recommended to combine the management of battery charging station with the activities of facility management committee of each public facility, and managers and treasurers must be selected by the committee, which is agreed by the committee members at the three candidate sites. The proposed organizational framework is shown below.



Tasks of Manager and Treasurer	Tasks of Operator
■ Management of revenue (cash) ■ Planning and disbursement of expenditure (salary, maintenance costs) ■ Auditing accounts ■ Keeping accounting records	■ Checking of user and set up of battery charging ■ Checking the status of battery charging ■ Fee collection and recording ■ Daily system maintenance ■ Dealing with claims

Prepared by JICA Study Team

Figure 7.1.1 Organization Framework for the Battery Charging Service

It is not difficult to develop the management scheme by community people. However, the scheme will need some time before it takes shape. Therefore, it is recommended to develop a special framework in Kenya that will provide support to the development of the management scheme.

7.1.4 Measures against Negative Impacts

Some people express concern on the CSS regarding the possible negative impacts on the operation of public facilities caused by potential customers. Many customers who will avail of the battery charging service at the station could disturb patients and students. Therefore, the following measures need to be developed and executed:

a) Place the battery charging station near the boundary of premises, or establish a customer's desk separately to keep the customers away from the public facility.

b) Security officers should watch over customers and properly deal with problems as necessary.

7.1.5 Relationship with Existing Battery Charging Providers

There are situations where some villagers have already started operation of small PV battery charging stations at communities where CSS is planned. In fact, there were private battery charging businesses identified at some communities surveyed during this study. However, these privately-owned stations are relatively small, and, consequently, their number of users is limited.

CSS is designed as a public system to serve people and, hence, profit is not a priority. Therefore, it is recommended to avoid inducing negative impacts to the existing battery charging stations. If the charging fee of the CSS is set at the same level as the existing charging stations, the latter can also serve other customers who live far from the CSS facilities Moreover, it is important to acquire new customers of PV battery charging inside and outside the community. CSS can recharge large batteries used for rechargeable lamps and other appliances, which is very difficult for the existing small battery stations to cater. Furthermore, it will be feasible to have a CSS focusing on customers with large-size batteries and promote a mutually beneficial situation.

7.1.6 Educational Effects

With CSS, villagers who come to the battery charging station will interact with the operator and other customers. They will eventually learn about PV products and rechargeable appliances, thus, CSS will promote education of such system. If new products such as rechargeable lamps are introduced as a result of said information exchange, the community people will benefit a lot. Thus, such effect of CSS should not be overlooked. In the past, PV vendors did not make efforts to market PV products in remote areas due to difficult access. Hence, dissemination of PV systems has been limited. The system operator, therefore, should be mainly tasked to spread information on PV to the whole community, which should be developed through well-designed training.

7.1.7 Consideration of Environmental Impact

This electrification plan is studied with solar PV system which is one of renewable energy, and there is basically no environmental impact. However, the minimization of impact was considered on the basis of the Environmental Impact Assessment and Audit Regulation, 2003 which is as environmental standard for National Environmental Management Authority (NEMA) as follows:

（１） The Contractor for the CSS installation shall take the packaging waste back and clean up.

（２） Through the operation and maintenance of CSS, batteries to be replaced with new one shall be taken back and cleaned up with adequate process.

These considerations shall be clearly instructed to the Contractor at the time of tender and contract, and should be mentioned in the operation and maintenance manual.

7.2 Financial Analysis

7.2.1 Financial Forecast of Battery Charging Service

In the short term, most users will come to the battery charging station to charge their mobile phones. The estimated number of customers per day at the three candidate sites ranges from 44 to 120. Assuming the price for phone charging is KSh20, which is common in Kenya, and the number of customers is 50 per day, the revenue would reach KSh25,000 per month, or KSh300,000 per year.

On the other hand, mandatory expenditure would include salary of operator (about KSh3,000 to KSh5,000 per month), manager, and treasurer, and maintenance costs. The most costly item in maintenance is battery replacement, which costs about KSh20,000 to KSh30,000 per unit. PV systems at public facilities often have around ten batteries, which are subject for replacement every five years. Some cases of cash flow analysis related to battery charging services are shown in Table 7.2.1.

Table 7.2.1 Financial Forecast of Battery Charging Service

Case 1: Yearly income KSh300,000 Battery replacement cost KSh300,000

Year	1	2	3	4	5	6	7	8	9	10	Total
Income	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	3,000,000
Earned interest	2,250	11,363	20,931	30,477	40,501	35,526	45,302	55,567	58,846	69,788	370,551
Salary	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	1,200,000
Replmt Battery	0	0	0	0	300,000	0	0	0	0	300,000	600,000
Replmt Con./Inv.	0	0	0	0	0	0	0	150,000	0	0	150,000
Maintenance Misc.	0	0	10,000	10,000	20,000	20,000	20,000	20,000	20,000	20,000	140,000
Profit/Loss	182,250	191,363	190,931	200,477	−99,499	195,526	205,302	65,567	218,846	−70,212	
Deposit	182,250	373,613	564,543	765,020	665,521	861,047	1,066,350	1,131,917	1,350,763	1,280,551	

- Interest 5% per year
- Wage and salary KSh10,000 per month
- Battery replacement KSh300,000 every 5 years
- Other component replacement KSh150,000 every 8 years

Case 2: Yearly income KSh200,000 Battery replacement cost KSh400,000

Year	1	2	3	4	5	6	7	8	9	10	Total
Income	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	2,000,000
Earned interest	1,375	6,944	12,791	18,430	24,352	10,070	15,073	20,327	18,343	23,760	151,465
Salary	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000	900,000
Replmt Battery	0	0	0	0	400,000	0	0	0	0	400,000	800,000
Replmt Con./Inv.	0	0	0	0	0	0	0	150,000	0	0	150,000
Maintenance Misc.	0	0	10,000	10,000	20,000	20,000	20,000	20,000	20,000	20,000	140,000
Profit/Loss	111,375	116,944	112,791	118,430	−285,648	100,070	105,073	−39,673	108,343	−286,240	
Deposit	111,375	228,319	341,110	459,540	173,892	273,962	379,035	339,362	447,705	161,465	

- Interest 5% per year
- Wage and salary KSh7,500 per month
- Battery replacement KSh400,000 every 5 years
- Other component replacement KSh150,000 every 8 years

As a result, it can be concluded that maintaining a PV system is feasible as long as the battery charging station can serve 40 to 50 customers every day. However, phone charging customers may decrease over time due to competition. Therefore, to keep the PV system sustainable, it would be necessary to also promote charging services for other appliances to secure enough customers and income, and improve the standard of living of the community.

Chapter 8 Recommendations

It was confirmed that all candidate sites surveyed in this study requested PV electrification and income generation through provision of battery charging service. Given this result, the Study Team recommends to JICA the following issues for the implementation of the pilot project.

(1) Transfer of Management Experience

The proposed CSS can be built using standard PV components. Local technicians in Kenya can design, install, and maintain PV systems using their own technology and skills. Therefore, technology transfer from Japan is not strongly required. On the other hand, managing the battery charging system is very important in achieving the objectives of CSS. However, the community people can hardly develop appropriate schemes without assistance. Therefore, JICA will be responsible for the development of management schemes and the system. During the construction stage, appropriate guidance and training must be given to the community regarding the organizational development for managing the CSS as a soft component of the project. However, the battery charging service is a new type of community business that can potentially generate big income from the beginning. If assistance to the organization development will only be provided during the system development, it is unlikely for the community management system to become effective. Therefore, it is recommended that monitoring activities be continued for several years after the consulting services by JICA has been carried out, to reinforce the management structure.

(2) Demonstration of School System by Early Pilot Project

In this study, two health centers and one school were recommended as the sites for the first pilot project of CSS. However, the Ministry of Energy (MOE) expressed concern about the battery charging services at the school and, therefore, requires careful considerations in choosing the school for the pilot project. MOE prefers to demonstrate the concept of CSS in health centers first, before implementing to schools to avoid possible disturbance to education. For this issue, countermeasures are proposed to minimize the adverse effects of CSS to the school. It is recommended to study the effectiveness of the countermeasures at an early stage, which is vital in undertaking the pilot project. Therefore, discussions should be continued with MOE to reach an agreement on the implementation of the pilot project at the school. In the pilot project, the development of three systems will be conducted one at a time. Therefore, it is recommended to design the pilot project by firstly considering the health centers, and consequently applying the results to the school.

(3) Application of Battery Charging to other Public PV Systems

In Kenya, MOE has installed PV systems at around 230 public facilities and will continue the program to other facilities including police stations. In addition, around 380 PV systems are to be built at public facilities with assistance from the Spanish government. All these PV systems installed at public facilities are protected under one year warranty. However, after the warranty period, the public facilities will handle the maintenance of their PV system. Some components of a PV system, particularly batteries, need to be replaced every three to five years. If the public facilities cannot secure necessary funds for the replacement, the PV systems will stop working and, thus, electricity will not be available.

Therefore, if the funds for maintenance can be secured in the battery charging service in the pilot project, adding battery charging facilities to existing PV systems would be effective to improve sustainability. In this case, it is a priority to check the conditions of the PV systems and requirements for maintenance. When the need for generating income for maintenance is revealed, adding a battery charging facility is recommended.

(4) Contiuous Capacity Building

During the detail village social survey, the senior staff of the Jomo Kenyatta University of Agriculture and Technology joined to the survey team to strengthen the communication capacity of the team with the village people. In particular, he contributed in the discussion on the system of collecting money for the sustainable maintenance and operation of CSS with the community member of the facilities. On the other hand, he could understand the existing situation of the un-electrified area, the latest information of solar PV system and importance of the operation and maintenance of solar PV system. In further stage for the implementation of the pilot projects, a participation of the staff from the Jomo Kenyatta University of Agriculture and Technology will be quite important in order to formulate the maintenance and operation mechanize in the un-electrified villages with various situations and to transfer the solar PV technology to the local staff of Jomo Kenyatta University of Agriculture and Technology.