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IMPACT ASSESSMENT OF ROOF-MOUNTED GRID-TIED PHOTOVOLTAIC SYSTEM AT THE CLIMATE CHANGE CENTER BUILDING, ISU, ECHAGUE, ISABELA

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ABSTRACT

A 20-kW roof-mounted grid-tied photovoltaic system (GTPVS) installed at the Climate Change Center building was assessed in terms of its actual power generated, grid power and electric bill reduction and contribution to climate change mitigation. Running power from ordinary electricity meter was 0.4 kW/sec. Input current and voltage with running heavy-load equipment (5 tonner aircon, 600 watts server and workstations) were 40.5-98.8 A and 234-235 V, respectively, yielding 9.5-23.12 kW power range. Daily generation power ranged between 5 and 10 kW from 7am to 3pm. Daily exported power reached as high as 30 kW. Exported energy was highest in 2019 at 70 MWh that was dumped to avoid added kWh readings payable by the University. Electric consumption ranged from 1,011 kwh in January 2020 (cold season) to 2,562 kwh in April 2019 (summer season). Indicative electric bill reduction was P32,677 from 4,736 to 1,237 kWh power reduction resulting to a 5 years payback period for the P2M GTPVS investment. Cash flow analysis over 25 years life span indicated an The P2M worth roof-mounted GTPVS indicated an NPV, BCR, IRR and break even of P896,717, 1.33, 16.27% and 7-8 years, respectively considering 10% discount rate and P10,000 scrap value on declining balance depreciation. Carbon offset was 41.71 tons equivalent to 112 trees planted since it was commissioned in December 11, 2017. Roof durability due to PV panel railings was also observed since it withstood a 180 kph strong typhoon "Rosita" in October 2018.

Keywords: *carbon offset; climate change mitigation; exported power; generation power; roof-mounted grid-tied photovoltaic system (GTPVS).*

1. INTRODUCTION

1.1 Importance

The Climate Change Center's vision is a Center of Excellence in climate change adaptation, mitigation and climate- risk resiliency in Cagayan Valley, the country, and the ASEAN region. It is committed to exist as a self-sustaining holistic functional service and capacity-building facility on climate change R&D providing climate change adaptation, mitigation and disaster risk reduction education and expert services to various clients and utilizing science-based information/technology in addressing climate change all geared towards climate-risk resiliency.

After the construction of the Climate Change Center building in 2016, the Isabela State University (ISU), Echague, Isabela provided support for its facilities and equipment such as automatic weather station (AWS), GNSS, Photovoltaic Water System and the 20 kW roof-mounted grid-tied photovoltaic system (GTPVS).

Aside from electric power generation that reduce the electric consumption from the Grid, the roof-mounted GTPVS contributes to climate change mitigation in terms of equivalent carbon emission reduction as a result of fossil-based fuel driven electric power plants in the country.

Scientific data and information as well as economic analysis are needed to be used as proof of concept for the GTPVS technical feasibility, economic viability and climate soundness inorder to be used as basis in replicating roof-mounted GTPVS in other major buildings (e.g. administration, colleges) of the University in all its campuses.

1.2 Review of Literature/State of the Art

According to Sunpower Builders (2008), a grid tied system has two essential parts, the solar modules and the inverter. The solar modules are typically installed on a roof or a pole, and convert sunlight into DC power. The inverter converts the DC power into AC power for use in electric devices. The inverter then feeds the AC power into the existing breaker panel and/or to the utility grid. A solar PV system has no moving parts and typically no batteries.

Selling electricity to the grid is possible because when the power generated by the PV system exceeds the actual electricity used, the electric current flows to the utility power grid. At the end of each month, the utility subtracts the solar power produced from the total power used. Electric power is measured in kilowatt-hours (kWh), which equals 1000 watts for an hour. The solar generated kWhs reduce the number of kWhs purchased from the utility. The average break even for the cost of a solar power system is about 8–10 years. The average lifespan is 25 years or longer.

Net metering is a billing mechanism that credits solar energy system owners for the electricity they add to the grid. For example, if a residential customer has a PV system on their roof, it may generate more electricity than the home uses during daylight hours (Wikipedia). Net-Metering is a program under RA 9513, the Renewable Energy (RE) Act of 2008. It allows customers to install an RE facility within their premises up to a capacity of 100kW. Any excess electricity not consumed in the home or business is exported to a distribution utility (e.g. ISELCO).

Over 30 years, a 4.8 kW system will reduce 138 tons of greenhouse gas (Sunpower Builders, 2008). From the National Framework Strategy for Climate Change (NFSCC), one of the strategies for climate change mitigation or reducing greenhouse gases (GHGs) is through the use of renewable energy such as the solar/photovoltaic systems for electricity (CCC, 2009).

1.3 Objectives

The general objective of the study was to assess the impact of utilizing the 20-kW roof-mounted fixed-type grid-tied photovoltaic system (GTPVS) installed at the Climate Change Center building in terms of actual electric power generated, grid power and electric bill reduction and contribution to climate change mitigation.

The following were the specific objectives: 1) To determine the actual electric power generated from the 20-kW roof-mounted GTPVS; 2) To determine the grid power and electric bill reduction of using the 20-kW roof-mounted GTPVS; and 3) To determine the contribution of the 20-kW roof-mounted GTPVS to climate change mitigation (GHG reduction).

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2. METHODOLOGY

2.1 Installation and Operation of the Grid-tied Photovoltaic System

The 20 kw fixed-type GTPVS was installed using four units 5-kW inverters in October to December 2017. It started its operation in December 11, 2017 until at present (Figure 1).

Figure 1. Roof-mounted photovoltaic system of the climate change center building comprising 80 solar/PV panels and four 5-kW inverters connected to the main circuit breaker.

Since it was not provided with net metering device that credit exported power to the Grid (ISELCO), a current dumper was installed to avoid adding of kwh readings to the ordinary electric meter.

Figure 2. Current dumper (dummy load) as export power limiter installed at the main circuit breaker to avoid adding of kwh readings to the existing electric meter.

2.2 Web-based Online/Real-time Inverter Monitoring System

The Solax brand inverter were monitored through web-based dashboard (Figures 3 and 4). Real-time graphs of generation and exported powers, inverter energy flows, and records and analyses of yield and consumption could be displayed, and digital data were automatically archived/stored and could be downloaded as needed.

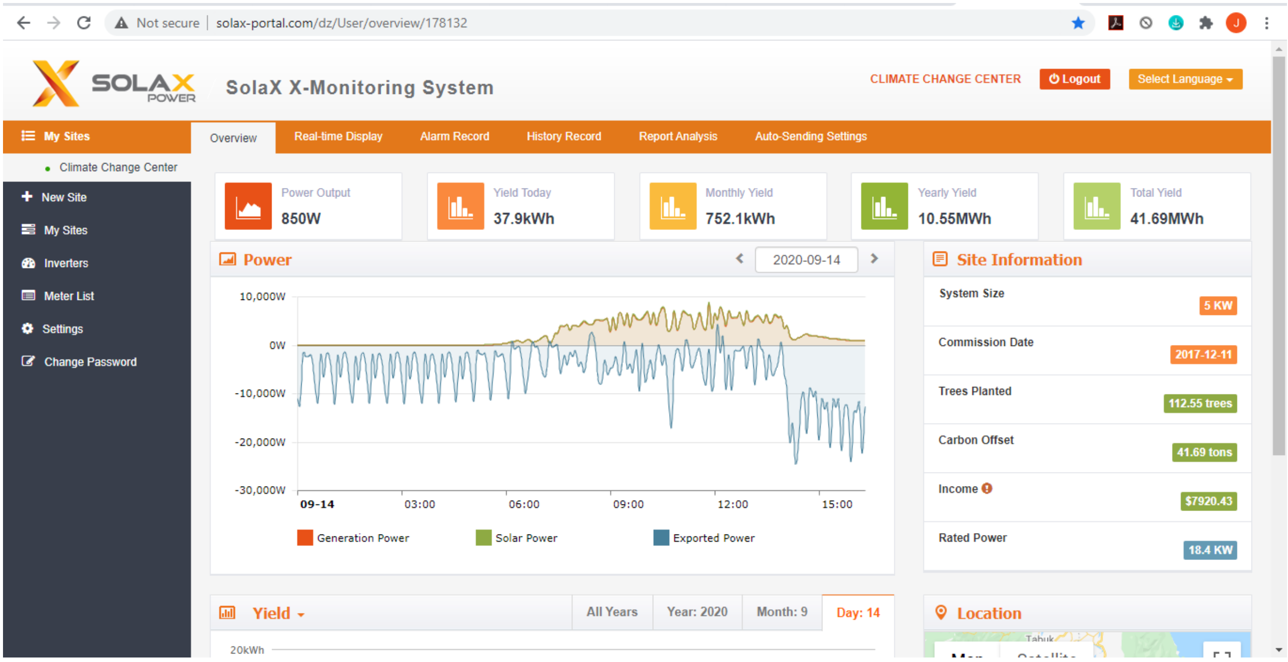

Figure 3. Inverter monitoring dashboard displaying real-time graphs of solar power generated and exported (negative values indicated utilization by dummy loads).

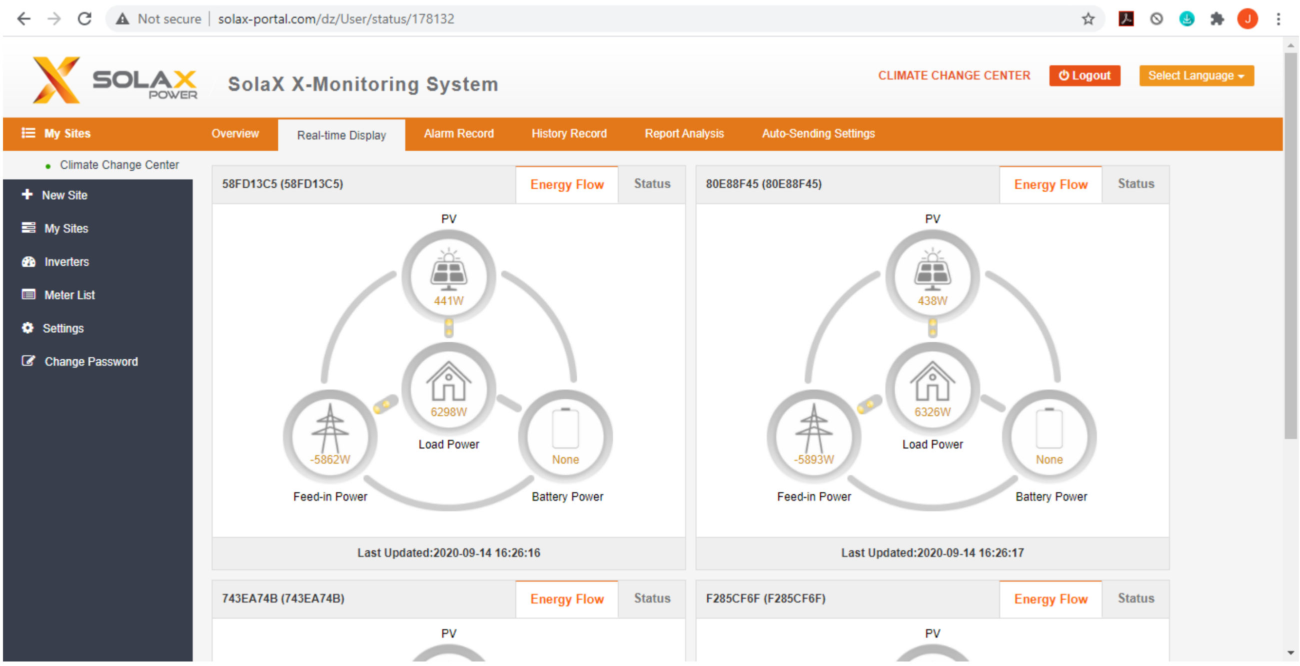

Figure 4. Inverted monitoring dashboard displaying real-time current inflow from PV panels, Grid (ISELCO) and load utilized. The system has no battery.

2.3 Actual Running Power Measurements

The CCC building's total actual running power was measured during the daytime office hours where all the heavy load equipment such as 5 tonner airconditioners, 600 watts server, 600 watts workstation/ desktop and laptop computers, and fluorescent lights were running (Figure 5).

Figure 5. Actual running power (current x voltage) measurements by electrical Engr. Sabas Lazaro and Dr. Januel Floresca, Study Leader.

3. RESULTS AND DISCUSSION

3.1 Running Electric Power in the CCC Building

As shown in Figure 6, the running power indicated from the ordinary electricity meter was only 0.4 kW/sec.

Figure 6. Digital electricity meter showing real-time running power.

Actual reading of input current and voltage with running heavy-load equipment (e.g. 5 tonner aircon, 600 watts server, 600 watts workstations) were 40.5-98.8 A and 234-235 V, respectively, yielding a power range of 9.5-23.12 kW.

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3.2 ISELCO Electric Consumption

Based on the ISELCO monthly electric bill from January 2019 to February 2020 as presented in Table 1, the electric consumption ranged from a low value of 1,011 kWh in January 2020 to a high value of 2,562 kWh in April 2019. This was expected because April has the highest temperature during the summer season having the highest load requirement for cooling in contrast with January which is in the cold season (Northeast monsoon or "Amihan").

Table 1. Electric consumption and bills for the months of January 2019 to February 2020.

MONTH	REFERENCE #	DATE	PREVIOUS	PRESENT	KWH	DEBIT
Jan	637781	1/23/2019	90118	91254	1,136.00	11,416.83
Feb	21910480543	2/24/2019	91254	92574	1,320.00	14,234.02
Mar	31910480537	3/22/2019	92574	93792	1,218.00	12,374.52
Apr	41910480460	4/29/2019	93792	96354	2,562.00	27,343.90
May	51910480459	5/21/2019	96354	97817	1,463.00	15,766.03
June	61910480540	6/21/2019	97817	99521	1,704.00	16,261.47
July	71910480535	7/21/2019	99521	1397	1,876.00	19,523.78
Aug	81910480538	8/21/2019	1397	3264	1,867.00	17,471.25
Sept	91910480518	9/23/2019	3264	5068	1,804.00	15,566.96
Oct	101910480533	10/26/2019	5068	6723	1,655.00	13,982.62
Nov	111910480461	11/25/2019	6723	8000	1,277.00	11,554.62
Dec	203148045	12/19/2019	8000	9277	1,277.00	11,757.81
Jan	12010480532	1/24/2020	9277	10288	1,011.00	10,751.15
Feb	22010480531	2/23/2020	10288	11293	1,005.00	9,383.71

3.3 GTPVS Generation Power

Displayed from the real-time inverter monitoring dashboard, the daily mean generation power of the 20-kW GTPVS ranged between 5 and 10 kW from 7am to 3pm (Figure 7).

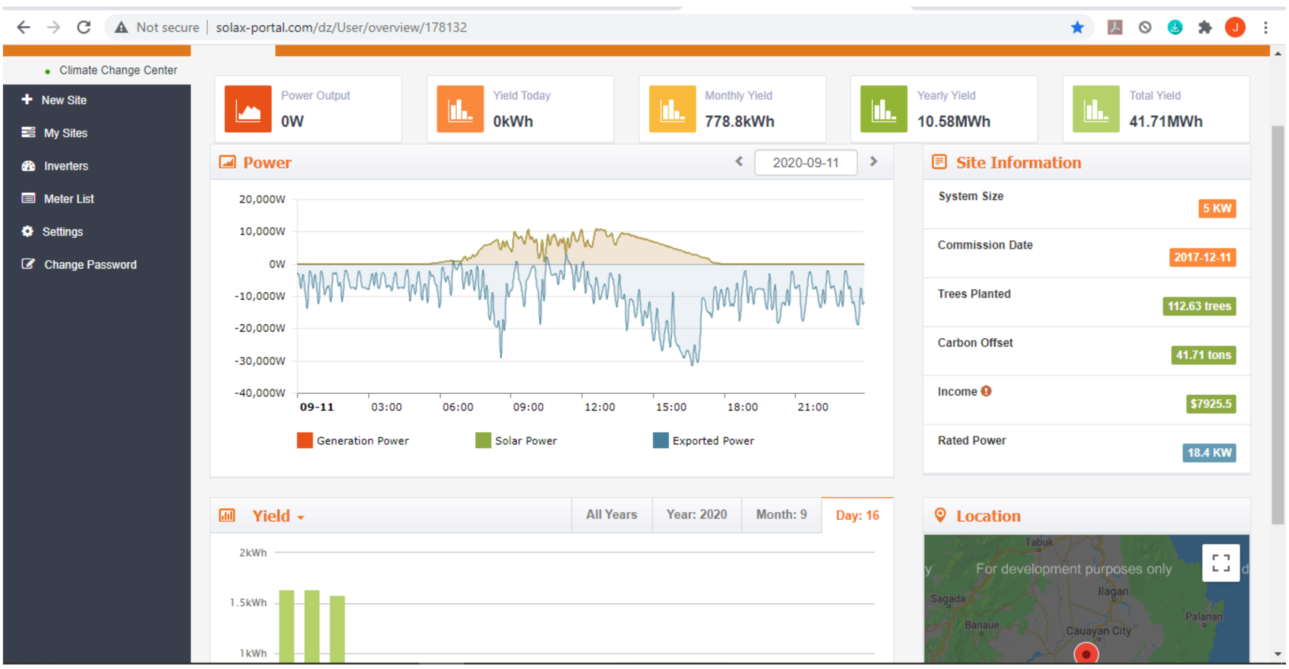

Figure 7. Real-time graph of inverter monitoring dashboard showing highest power ranges between 7am to 3pm.

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3.4 GTPVS Exported Power

Also, as displayed in the inverter monitoring dashboard (Figure 8), exported power reached as high as 30 kW.

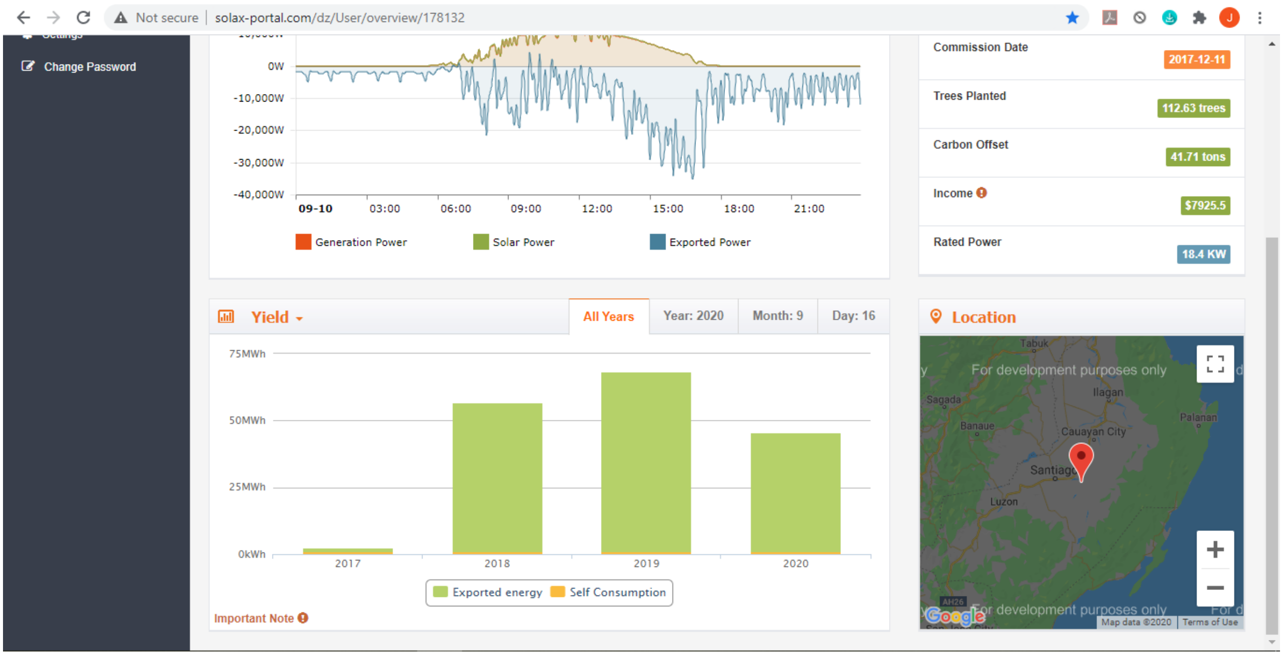

Figure 8. Real-time graph of inverter monitoring dashboard showing highest dumped exported power of 30 kW.

From 2017 to present (September 2020), the exported energy was highest in 2019 at 70 MWh. This amount of exported energy was just dumped to avoid added counters in the existing electric meter that will be paid by the University.

3.5 Indicative Electric Bill Reduction

An indicative electric bill reduction was observed based on the records of electric bills before and after the installation of the roof-mounted GTPVS. As shown in Table 2, the power consumption was reduced from 4,736 kWh to 1,237 kWh and the amount from P44,232.49 to only P11,555.45 despite continuous operation (24/7) of the 600 kW server cooled by a 5 tonner split-type airconditioner.

Using the savings of P32,677/month, the payback period of the P2M worth 20 kW roof-mounted GTPVS will only be 5 years. Since its start in December 2017, the investment cost will be reimbursed/recovered/regained in January 2023

Table 2. Electric bill of the Climate Change Center building with and without the roof-mounted GTPVS.

PERIOD	kWh	AMOUNT	REMARKS
Jan 26 - Feb 24	1237	11,555.45	LiDAR 1 24/7 A/C + Server
Dec 27 – Jan 25, 2018	4284	40,013.81	with Grid-tied PV system
Sept 21 – Oct 23, 2017	4637	43,314.18	LiDAR 1&2 Proj ended
Apr 23 – May 21, 2017	4736	44,232.49	with LiDAR 1&2 Projects

3.6 Cash Flow Analysis of the Roof-mounted GTPVS over 25-years

Using a 25-year life span, the P2M worth roof-mounted GTPVS considering a discount rate of 10% and a scrap value of P10,000 on a declining balance depreciation, indicated an NPV, BCR, IRR and break even of P896,717, 1.33, 16.27%, 7-8 years, respectively (Table 3).

Table 3. Cash flow analysis of the P2M roof-mounted GTPVS over 25 years.

YEAR	COSTS (P)	RETURNS (P)	NET INCOME (P)	CUMMULATIVE (P)
1	2,160,000.00	392,004	-1,767,996	-1,767,996
2	147,200.00	392,004	244,804	-1,523,192
3	135,424.00	392,004	256,580	-1,266,612
4	124,590.08	392,004	267,414	-999,198
5	114,622.87	392,004	277,381	-721,817
6	105,453.04	392,004	286,551	-435,266
7	97,016.80	392,004	294,987	-140,279
8	89,255.46	392,004	302,749	162,470
9	82,115.02	392,004	309,889	472,359
10	75,545.82	392,004	316,458	788,817
11	69,502.15	392,004	322,502	1,111,319
12	63,941.98	392,004	328,062	1,439,381
13	58,826.62	392,004	333,177	1,772,558
14	54,120.49	392,004	337,884	2,110,442
15	49,790.85	392,004	342,213	2,452,655
16	45,807.58	392,004	346,196	2,798,851
17	42,142.98	392,004	349,861	3,148,712
18	38,771.54	392,004	353,232	3,501,945
19	35,669.82	392,004	356,334	3,858,279
20	32,816.23	392,004	359,188	4,217,467
21	30,190.93	392,004	361,813	4,579,280
22	27,775.66	392,004	364,228	4,943,508
23	25,553.61	392,004	366,450	5,309,958
24	23,509.32	392,004	368,495	5,678,453
25	31,628.57	392,004	360,375	6,038,829
		NPV =	860,445	
		BCR =	1.32	
		IRR =	16.01%	

ASSUMPTIONS:

Discount rate:	10%
Useful Life	25
Scrap Value:	10,000
Depreciation Method:	Declining balance

3.7 Equivalent GHG Reduction

Based also from the real-time inverter monitoring dashboard (Figure 7), a carbon offset of 41.71 tons equivalent to 112 trees planted was contributed by the 20 kW roof-mounted GTPVS since it was commissioned in December 11, 2017.

3.8 Other Observed Benefits of the 20 kW ISU-CCC GTPVS

Aside from electric power savings and climate change mitigation (GHG reduction), the installation of the GTPVS enhanced the durability of the CCC building roof due to the PV panel railings that withstood a 180 kph strong Typhoon "Rosita" in October 2018. Even the PV panels were not destroyed by metal debris that struck these (Figure 9).

Figure 9. Damaged sidings of the climate change center building and **intact/undamaged** roof installed with PV panels after Typhoon "Rosita" in October 2018.

3.9 Conclusions

Based on the results of the study, the following are the conclusions:

1. Running power indicated from the ordinary electricity meter was only 0.4 kW/sec.

2. Actual reading of input current and voltage with running heavy-load equipment (e.g. 5 tonner aircon, 600 watts server, 600 watts workstations) were 40.5-98.8 A and 234-235 V, respectively, yielding a power range of 9.5-23.12 kW.

3. Daily mean generation power of the 20-kW GTPS ranged between 5 and 10 kW from 7am to 3pm.

4. Electric consumption ranged from a low value of 1,011 kwh in January 2020 (cold season) to a high value of 2,562 kwh in April 2019 (summer season).

5. Daily exported power reached as high as 30 kW. Exported energy was highest in 2019 at 70 MWh that was just dumped to avoid added counters in the existing electric meter that will be paid by the University.

6. Indicative electric bill reduction was P32,677 for a power reduction from 4,736 kWh to 1,237 kWh resulting to a payback period of only 5 years of the P2M worth 20 kW roof-mounted GTPVS.

7. The P2M worth roof-mounted GTPVS indicated an NPV, BCR, IRR and break even of P896,717, 1.33, 16.27% and 7-8 years, respectively considering 10% discount rate and P10,000 scrap value on declining balance depreciation.

8. A carbon offset of 41.71 tons equivalent to 112 trees planted was contributed by the 20 kW roof-mounted GTPVS since it was commissioned in December 11, 2017.

9. Durability of the roof due to PV panel railings was also observed since it withstood a 180 km/hr strong typhoon "Rosita" in October 2018.

3.10 Recommendations

The following are the recommendations to maximize the proven benefits from the roof-mounted GTPVS:

1. The Climate Change Center building should be applied for a net metering to ISELCO based from the provision of the RE Act of 2008. ISELCO could either pay the University the exported power or deduct from its electric bills.

2. At least 5 kW (1 inverter) roof-mounted GTPVS should be installed to other major buildings of the University such as the Administration building and the buildings of the different Colleges and other Research Centers in the ISU Echague campus and other ISU campuses.

3. Further study on the use of solar trackers could be explored although this requires additional cost and its moving parts are more vulnerable to strong winds damage.

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5. ACKNOWLEDGMENT

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