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Reduction estimates of CO_2 emission at the relocation site of typhoon victims: an alternate to climate resiliency

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Abstract

The increasing amount of carbon dioxide in the atmosphere that causes global warming is one of the major forces that challenges every country to search for alternative energy sources. The study attempted to quantify the carbon account reduction of using an alternative energy source, Solar Photovoltaic, SPV panel at the relocation site of Sendong Typhoon victims at the elevated part of Cagayan de Oro City, Philippines and to determine how it can provide residents resiliency to global warming. A total of 30 households were purposively selected to answer the survey questionnaire in terms of the family income, the components of solar system installed and its estimated costs as well as the generated electricity in kW/hr., the payback time and the avoided carbon dioxide, CO_2 emission. Results showed56.7% of the households were using basic SPV 50-wattage panel that supplies energy for lighting, battery charging and operating mini electric fans, but the energy generated per household varied depending on the SPV panel used. The lower the energy, the longer the payback period, generating an average of 6.12 kW-hr per month. Quantitatively, the CO_2 emission that can be avoided is approximately 0.861 metric ton per year for households using the 50-watts. Moreover, an estimate of 2.583 metric ton/year of CO_2 emission can be avoided for a-30 household respondents ranging from 50-200 watts usage of SPV panels. In general, the adoption of a household to spend for a panel to be used for energy generation can be an alternative measure for climate resiliency.

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Introduction

The climate change problem had begun during 1990, when energy related CO_2 emissions have sharply increased. The gas released can be attributed to anthropogenic activities such as excessive burning of fossil fuels and growing waste dumps, (Casis, 2008 and Dev, 2009). Although forecasting the exact impact of greenhouse gas emission may not be easy but studies have already recognized the large risks, potentially catastrophic ones that could bring about drastic climatic changes, (UNDP, 2007/2008). In the Philippines, this effect is represented by the intensity of tropical storms.

In 2011, Tropical storm Washi locally named as *Sendong* hit the city of Cagayan de Oro and Iligan, leaving behind about 2,000 casualties, sent off more than 39,437 damaged houses and displaced families (NDRRMC, 2011).

It was followed by typhoon Bopha, locally identified as *Pablo* in 2012, and typhoon Haiyan or *Yolanda* (2013). According to PAG-ASA, it was the most powerful typhoon to have made landfall in Philippine history, leaving three times the number of causalities during typhoon Washi and almost wipe out the city of Tacloban, part of Southern Leyte and Eastern Samar, (NDRRMC, 2014). And because the country is susceptible to an average of 20 typhoons annually, this can further threaten the food security, water supplies, health effects, infrastructure, energy supplies, and ultimately, its economy.

For this reason, adaptation and building resiliency is the least possible alternative that can be done in order to withstand the country's vulnerability to climate change. Mitigation actions must be done, before the scenario becomes worse. Since the household is a basic micro unit of the nation, correct and proper practices in curbing carbon emission can have significant part in addressing problem regarding excessive greenhouse gas emission (ESRI, 2008).

In support to RA 9729 (Climate Change Act of 2009, Philippines), a challenge to cut down carbon emission starting at the community level can be done to mitigate and become resilient to climate changes. Mitigation actions can be realized if the public is made aware of how much carbon dioxide can be potentially reduced when alternative energy resources were utilized.

The method of generating clean electricity from renewable energy technology to produce power can be derived from sources such as wind, sun, and biomass (Deveries *et al.,*2007).

The most common and currently being adopted is through the installation of solar panels on residential homes,(Pearce, 2002). Solar energy offers a clean, climate-friendly, abundant and inexhaustible energy resource to mankind, and because of new areas of competitiveness and global efforts in reducing greenhouse gas, the costs of solar photovoltaic technology (SPV) have been rapidly reduced, (Sasikumar, *et.al* 2013).

The study attempted to determine the amount of carbon dioxide emissions that can be avoided through the use of residential solar panels, SPV in selected resettlement households of Sendong victims in Cagayan de Oro City, Philippines and to quantify the approximate payback period not only to reduce global warming but provide resiliency measures for countries affected by climate changes.

Materials and methods

Sampling Site of the Study

The research was done at the relocation area for Typhoon Sendong's victims in NHA CDO Bayanihan Village Phase 1, located at Sitio Macapaya, Camaman-an, Cagayan de Oro City, Philippines. The site is in the Southeast upper part of Barangay Camaman-an approximately five kilometers away from the city proper. It is part of the National Housing Authority Resettlement Assistance Program with an area of 47,307 sq.m. composed of 420 households.

The population is mostly the displaced residents from different barangays of Cagayan de Oro City, who were affected by Typhoon Sendong in 2011. Selection of the research site (Fig. 1) was relevant because the study highlighted the possible mitigation for climate change.

The newly established community manifested as the best example of building resiliency among affected families from the devastating effect of climate change.

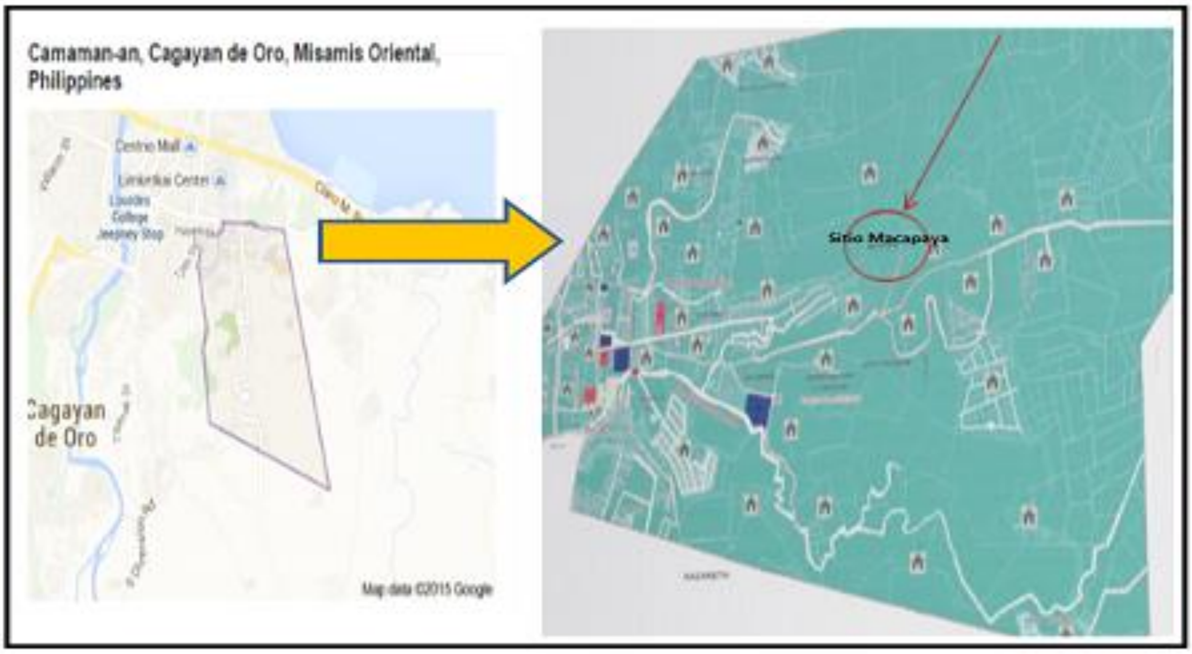

Fig. 1. Sampling site of the Relocation Area of the Sendong Typhoon victims.

Respondents of the Study

Respondents of the study were heads of the households that utilized solar power cells. A total of 30 household heads were purposively selected to answer the research questionnaires. Household heads were either the father, the mother, or children 18 years old & above who answered the questionnaire and who comprehensively gave the information needed. The sizes of the number of households were also determine and the ages of the members per household. Out of the 30 households, a total of 72 members were included in the analyses.

The Installed Solar System

The basic components of solar system used by the respondents were solar panel and battery.

The panel -absorbs photons from the sunlight that produces excess electrons and holes in the material generating the current through the flow of electrons (Agrawal, 2013); the battery stores the direct current produce in order to run basic load such as light bulb. However, when a household plans to run additional load, an inverter must be added to the system. An inverter is used to convert direct current (DC) to alternating current (AC). And to protect the battery from overloading, a battery charge controller must also be installed (Fig. 2).

Analysis on the installed solar system in every households showed that the average 50 per cent of the households have installed this type of solar system because of additional load utilized for appliances such as electric fan, sound system and television. However, the duration of utilization time varied based on the capacity of the battery used.

Estimation of the generated energy of solar power in kWh

To compute for the daily energy generation, the power of the solar cell (wattage), is multiplied by the number of households, the average sunshine duration, using 5.1 hours as the average sunshine hours in Philippines and the average percentage efficiency of charging time, which is 80 percent (Schaeffer, 2005).

Payback Period

The payback period is estimated as the number of years required recovering the cost of the investment for solar power installation, thus, solar power Payback Period is the cost of the system per annual income, considering, Philippine money, Php 8.29 per kWh (CEPALCO equivalent rate and the energy provider in the city at the time of the research). The formula for the payback period is given below;

$$\text{Payback period} = \frac{\text{Cost of the System}}{\text{Monthly/Yearly Savings}} \quad \text{(Equation 1)}$$

Calculation of Avoided Carbon Emission or CO_2 Reduction

An Emission Factor from EPA annual non-based load CO_2 output emission rate (2010), were used to calculate for the avoided carbon emission or CO_2 reduction;

6.89551×10^{-4} metric tons CO_2 / kWh

(eGRID, U.S. annual non-base load CO_2 output emission rate, year 2010 data).

From the factor, approximately 6.9×10^{-4} metric tons of CO_2 is emitted for the generation of one kWh of electricity, (EPA 2005). The carbon emissions that would result from producing fossil fuel electricity for an entire household is the amount of carbon emissions that were being avoided by installing one solar system (Arif, 2013) and the formula for calculating the avoided CO_2 emission per household is as follows;

$$CO_2 \text{ avoided per household} = (6.9 \times 10^{-4}\,*)\,(EPH) \quad \text{(Equation 2)}$$

Where; (6.9×10^{-4}) = approximate metric tons of CO_2 emitted for the generation of one kWh of electricity

EPH = Electricity Use per Household (in kWh).

Results and discussion

Demographic Data

The respondents' household were categorized according to the installed SPV panel and demographic profile were described in terms of the household size and age bracket, income, educational attainment occupation of the members per household (Total number of households, N = 30; Total members of household, M =72).

Table 1. Respondents' household demographic information grouped according to SPV panel used.

SPV Installed			Household Size						Age Group		
Wattage	Number Installed	% Distribution	1	2	3	4	5	6	0-25	26-50	51 up
50	17	56.7	2	12	1	1	0	1	12	23	4
100	7	23.3	3	3	0	0	1	0	6	6	2
150	4	13.3	1	2	1	0	0	0	4	2	2
200	2	6.7	0	0	0	0	1	1	6	4	1
Total	30	100	6	34	6	4	10	12	28	35	9
		% of M	8.3	47.2	8.3	5.6	13.9	16.7	38.9	48.6	12.5

The data in Table 1 showed that 56.7% of the respondents households were using the SPV 50-watts panel, 47.2% of whom had at least 2 members in the household with 48.6% of the mean age of respondents, between 26 to 50 years old.

It is an indication that the respondents using the most affordable SPV 50-watts were common for households having at least 1-2 members in the household. The less number of members per household could have been due to losses of members during the super typhoon. The respondents were matured enough to have answered the questionnaire/interview given and the answers were presumed to be reliable.

The socio-economic status of the members of all the households under study is shown in Table 2. At least 8% have attained college level and 19% were college graduates. Moreover, 46 % of the respondents has part-time jobs with 50% having an average income of Php10, 000 per month. Most of the household heads were laborers, single motor drivers (being the most accessible mode of transportation in commuting to the area) and some, were product dicer at the different establishments in the city. Only 30% were full time employees in both government and private offices.

Table 2. Frequency distribution of the respondents socio-economic status.

SPV panel (Watts)	Income Bracket (Php)				Educational Attainment					Occupation		
	<5000	<10000	<20000	<30000	Elem	HS	Voc	Coll	Coll Grad	Self-employed	Part time	Full-time
50	4	11	2	0	10	10	9	5	5	5	20	14
100	1	3	3	0	4	2	3	2	3	0	10	4
150	0	1	2	1	2	2	1	1	2	2	2	4
200	0	0	1	1	0	1	1	1	8	2	1	8
Subtotal	5	15	8	2	16	15	14	9	18	9	33	30
Total	N=30				M=72					M=72		
%	17	50	27	7	22	21	19	13	25	13	46	42

Estimated Energy of Solar Photovoltaic System in kWh

To have a quantitative estimation of energy generated from a solar panel installed, this study adopted the efficiency rate of solar panels that was benchmarked on a "full sun" that delivers 1, 000 watts (1 kilowatt) per square meter at noontime on a clear day at sea level. Photovoltaic, PV modules do not convert 100% of the energy that strikes into electricity because of particulate matter, water vapor, air pollution, seasonal variation, altitude and temperature.

Table 3. Energy generation of the respondents' household solar system in kW/hr.

SPV Panel (Watts)	Average Sun Time (hrs)	Efficiency % (ave)	Generated Energy Watts	kW-hr/day	kW-hr/mo
200	5.1	80	816	0.816	24.48
150	5.1	80	612	0.612	18.36
100	5.1	80	408	0.408	12.24
50	5.1	80	204	0.204	6.12

It was assumed that most sites actually received 80 to 85% of full sun on clear sunny day. At high altitudes and desert locations which do better on sunlight availability, 105to 110 % of full sun was normal, however, PV modules or solar panel were only seeing six to eight hours of active use per day, (Schaeffer, 2005). The sun time used in this study was based on the average of 5.1 hours in Northern Mindanao (NW) Philippines. The respondents were group in terms of the average wattage of solar panel mostly used in households, which ranged from 50 watts to 200 watts, and multiplied by the average 5.1 hours sunshine duration and 80 percent average efficiency charging of the system. The tabulated result is shown in Table 3.

The data in table 3 showed the calculated generation of energy of the respondents' household grouped according to the Solar Photovoltaic, SPV panel. The respondents using the 200 watts SPV panel has the highest generation of energy of 24.48 kW-hr per month, and the households using the SPV panel of 50 watts generated an energy of 6.12 kW-hr per month.

Payback Period

Using the value of energy generated per month in Table 3, multiplied by Php 8.29 per kW-hr energy cost, the monthly savings due to the use of solar panel were tabulated and used as the baseline to determine the payback period.

Based on the data presented in Tables 3&4, analysis showed that the SPV power of 50 watts had an average cost of Php 8, 000 pesos, gained energy saving of Php 50.73 pesos monthly and the payback period can be achieved after 13.1 years.

On the other hand, the SPV power of 200 wattage had an average cost of Php20, 000 pesos, gained an energy monthly savings of Php 202.94 pesos for a payback only of 8.2 years.

This estimation is relevant and can encourage more households to install much higher wattage such as 200 & above to achieve much shorter payback period.

Table 4. Monthly and Annual Payback Period of the Solar Panel installed based on the solar wattage used by the respondents.

SPV Panel	Energy/mo	Energy cost	Savings /month	Solar Panel Cost	Payback Period	
(Wattage)	kW-hr/mo	Php/kW-hr	Php	Php	months	years
200	24.48	8.29	202.94	20000	98.6	8.2
150	18.36	8.29	152.20	17000	111.7	9.3
100	12.24	8.29	101.47	12000	118.3	9.9
50	6.12	8.29	50.73	8000	157.7	13.1

It implied that more carbon dioxide would be avoided in installing much higher solar panel wattage because this electricity comes from clean energy resources and can sufficiently provide the basic energy requirements in lighting, cellphone battery charging, and running mini electric fans.

Avoided Carbon Emission or CO_2Reduction

Considering the fact that carbon emissions resulting from producing electricity from fossil fuel for an entire household is the amount of carbon emissions that are being avoided by installing one solar system (Arif, 2013).

Fig. 3 represents the distribution of the different SPV panel used by the 30 households in the study.

Table 5. Total CO_2 Avoided by installing solar panel in Households per year.

SPV Panel (Wattage)	Generated Energy (kW-hr/mo)	No. Of Households	Annual generation of Energy (kW-hr)	CO_2 avoided/year (metric tons)
200	24.48	2	587.52	0.405
150	18.36	4	881.28	0.608
100	12.24	7	1028.16	0.709
50	6.12	17	1248.48	0.861
Total		30	3745.44	2.583

The Figure (3) revealed that most households (17 out of 30 or 56.7%) have installed a 50 watts solar panel, which can generate 6.12 kW-hr electricity per month. Using the EPAemission factor of the annual non-based load CO_2 output emission rate of 6.9×10^{-4} metric tons of CO_2/kW-hr, the following data in Table 5 showed the approximate carbon dioxide emssion that can be avoided per wattage use of the SPV panel and the total value that can be avoided by the 30 households being sampled in the study.

For the Sendong victims' relocation site in Cagayan de Oro, Philippines, 56.7% of the households using the 50-watts solar panel (Table 5) have contributed approximately 0.861 metric tons of CO_2 /year reduction due to the solar panel installed and the number of households using it.

Moreover, if we sum up all the SPV panel users for the entire households under study, an estimated 2.583 metric tons of CO_2 /year can be avoided. Based on this result one can support the idea that even a little solar panel installed can reduce a significant percentage of carbon dioxide reduction in the atmosphere. If everyone would do the same, an individual minor percentage can accumulate into significant percentage as a whole.

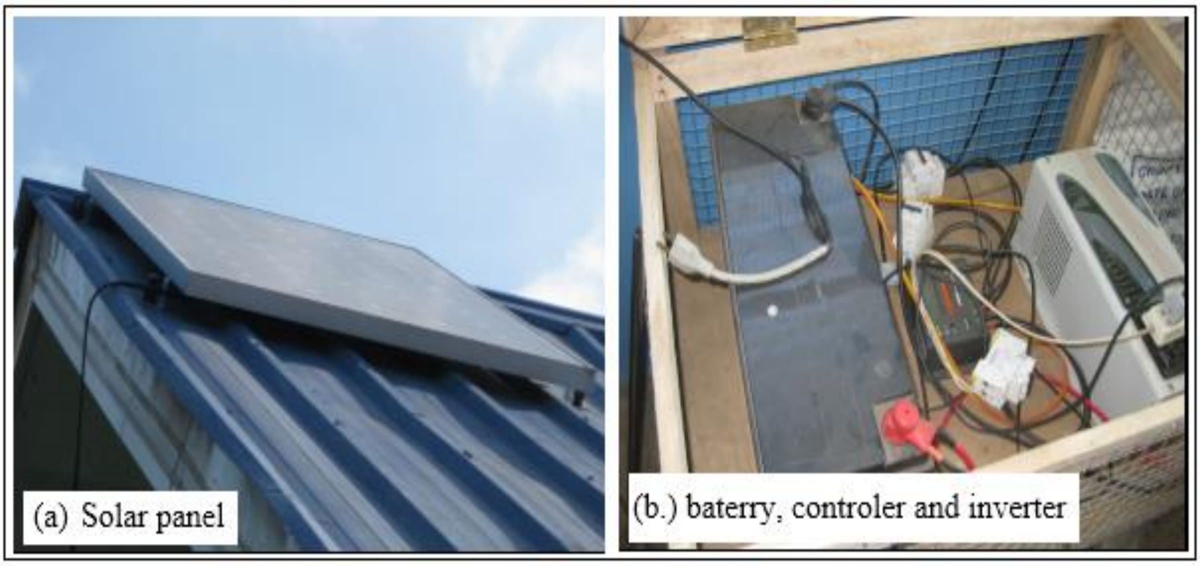

Fig. 2. The typical solar system installed at the respondents' homes.

Furthermore, when these households were asked on one's individual perception on solar power for abatement of energy crisis, about 97% agreed that solar power generation can help abate energy crisis in the region. However, the installation of solar system to supply sufficient energy requirements of household can be initially expensive but such costs can have a significant payback benefits per year.

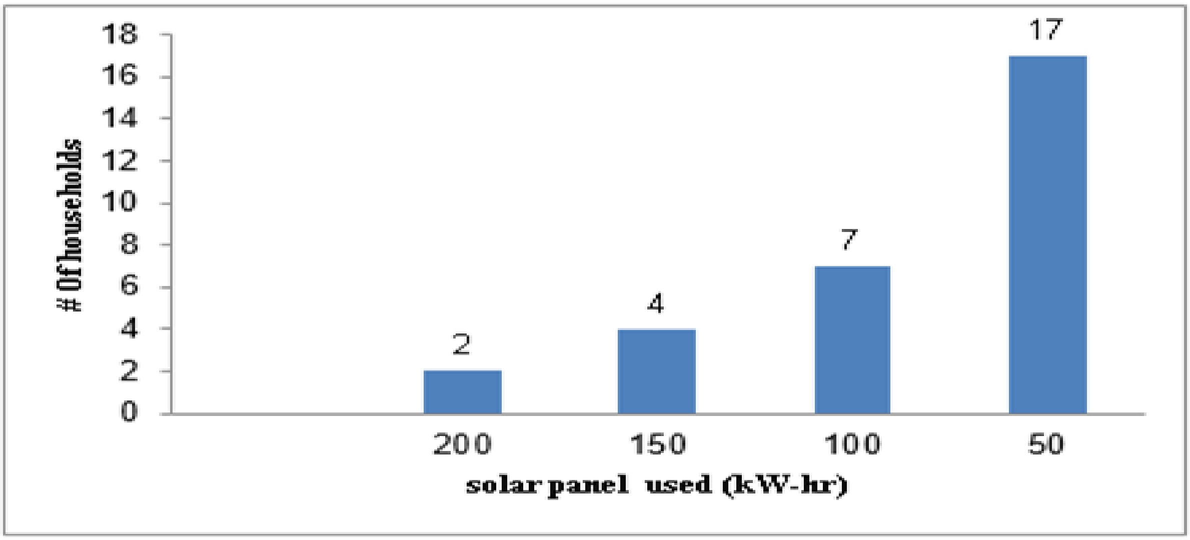

Fig. 3. No of households that installed different wattage of solar panel.

Findings and Recommendations

Adoption of SPV panel among the households in the relocation site of Sendong victims in Cagayan de Oro provided resiliency due to the tragedy encountered by the affected families. The use of solar power became a viable option to provide the basic energy requirement for lighting and electronic battery charging. Moreover an important value to consider by using the system is the environmental value of reducing carbon dioxide emission and ultimately minimizing the environment from hazards such that of global warming. For a total household population of 30, approximately 2.583 metric tons of CO_2 can be avoided or reduced per year with the use of solar power cells. Such mitigation for an alternative energy sources is a good motivating exemplar of environmental concern and living in sustainable manner without aggravating the global climate change that the world is experiencing. Finally, with the findings of this study, communities are encouraged to use SPV panels for energy generation especially in places where sunlight is in broad daylight twelve months a year. It will not only bring savings to every household but a good alternative to mitigate global warming. Similarly, the government officials may include in their policy making to require residents to have this alternative energy source as part of resiliency to climate changes.

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