

# Social Life Cycle Assessment of Solar Suitcase in a Community of Doña Remedios Trinidad, Bulacan

**Dyan C. Gonzales-Rodriguez, PIE, AAE †**

Industrial Engineering Department, College of Engineering  
Bulacan State University, City of Malolos, Bulacan, Philippines  
Tel: (+6344) 919-7800 local 1068 to 69, Email: dyangonzales12@gmail.com

**Hazel A. Caparas, CIE, AAE**

Industrial Engineering Department, College of Engineering  
Bulacan State University, City of Malolos, Bulacan, Philippines  
Tel: (+6344) 919-7800 local 1068 to 69, Email: hazel.caparas@yahoo.com

**Abstract.** Majority of the barangays in Doña Remedios Trinidad, a municipality in Bulacan, are unelectrified due to its mountainous structure. Because of this, the researchers deploy the Solar Suitcase in a barangay. Based on initial observation and interview, the researchers found out that Barangay Kalawakan is one of the barangays that is unelectrified. One can reach this barangay using a vehicle that can be driven on a muddy road for almost four hours from the mainland. A Social Life Cycle Assessment approach will be used to develop an evaluation process tool in assessing the social and socio-economic impact of Solar Suitcase in this isolated and unelectrified community. The potential benefits of the product to the community as well as the associated accountability while utilizing the product are included on the analysis. Subjective data which may be comprised of stakeholders' preferences are just some of the qualitative measures to be used in order to demonstrate the social impact of the product under study. Nevertheless, the outcome of the study will not dictate the decision making process relating whether the Solar Suitcase is recommended to be produced or not.

**Keywords:** Social Life Cycle Assessment, Solar Suitcase, social and socio-economic impact

## 1. INTRODUCTION

The case study conducted by the Alliance For Mindanao and Multi-Regional Renewable/Rural Energy Development Program emphasized that the population of the Philippines is estimated to be 94.6 million and 22 million of whom has no access to the electricity. This becomes an inspiration for the researchers to deploy the Solar Suitcase in a community of Doña Remedios Trinidad (DRT), a municipality in Bulacan. DRT is part of Bulacan's third district and also the largest municipality of the province since it occupies almost 1/3 of its total land area. It was founded on 1977 with a total area of 932.96 km<sup>2</sup> (360.22 sq mi) and with population of at least 19, 878 people. Given this figure, DRT is considered as the least populated part of the province. DRT is classified as first class rural area with untouched landscape and natural resources.

Based on initial observation and interview, the researchers found out that Barangay Kalawakan of DRT is one of the barangays that is not electrified. One can reach this barangay using a vehicle that can be driven on a muddy road for almost four hours from the poblacion (downtown). The barangay is composed of twelve sitios with its

households are kilometers away from each other because they are located in the mountainous area. This is the reason why for the past years, power provider like Meralco cannot provide electricity to the barangay. Majority of the barangays in DRT are unelectrified because of its mountainous structure.

A Social Life Cycle Analysis approach will be established to evaluate the social and socio-economic impact of Solar Suitcase in an isolated and unelectrified community. Additionally, Social LCA is an assessment technique to investigate the positive and negative impacts on every stage of the product system's life cycle. Different phases of product life cycle will be considered in the study encompassing use, re-use and maintenance. The potential benefits of the product to the community as well as the associated accountability while utilizing the product are included on the analysis. Subjective data which may be comprised of stakeholders' preferences are just some of the qualitative measures to be used in order to demonstrate the social impact of the product under study. Nevertheless, the outcome of the study will not dictate the decision making process relating whether the Solar Suitcase is recommended to be produced or not.

The results of the study may help the local government determine the impact of the product to the community and how can the product be used by other communities with the same situation as Barangay Kalawakan.

## 2. REVIEW OF RELATED LITERATURE

A social and socio-economic Life Cycle Assessment (S-LCA) is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal. S-LCA complements Environmental LCA with social and socio-economic aspects and it can either be applied on its own or in combination with E-LCA.

S-LCA differs from other social impacts assessment techniques by its objects: products and services, and its scope: the entire life cycle. Social and socioeconomic aspects assessed in S-LCA are those that may directly affect stakeholders positively or negatively during the life cycle of a product.

S-LCA does not have the goal or provide information whether a product should be produced or not. S-LCA documents the product utility but does not have the ability or the function to inform decision making at that level. Also, S-LCA is a technique that helps inform incremental improvements but does not in itself provide a breakthrough solution for topics go well beyond the scope of the tool.

Since Social LCA adopted the methodology of Environmental LCA, it also consists of four major phases:

1. Goal definition,
2. Scope definition,
3. Inventory analysis,
4. Impact assessment

Unlike E-LCA which normally estimates the negative effect of products and processes in different stages of life cycle, S-LCA considers both positive and negative impacts to various stakeholders in the society. Dreyer et al. (2006) recommended "human dignity and well-being" as a new area of protection for S-LCA. Similar to other LCA studies, the scope of S-LCA includes indicators, data quality, all of the assumptions and limitations of the study. According to Nazarkina and Le Bocq (2006), indicators are generally defined at the level of the organization and not at the level

of the individuals. S-LCA evaluates these parameters which can be quantitative, qualitative or semi-qualitative data. Indicators may also be midpoint or endpoint indicators based on their locations in the causal chain from process to impact (UNEP, 2009). Most S-LCA studies used midpoint indicators to evaluate social impacts throughout the products life cycle.

Inventory analysis in S-LCA is the stage where relevant information are collected and analysed. Since there is lack of database tools for S-LCA (UNEP, 2009), different methodologies like direct and proxy measurements are utilized to gather gauge different social indicators. This condition is an evident that conducting S-LCA at this present time is expensive and cumbersome. Inventory data are assigned to impact categories in classification process (ISO 14044 Environmental Management - Life Cycle Assessment - Requirements and Guidelines, 2006).

As defined on the guidelines by United Nations Environmental Program (2009), interpretation phase is the process of assessing results in order to analyze the results, reach conclusions, explain the limitations of the study, provide recommendations and report adequately. One of the main setbacks is the inadequacy of database tools for data management and inventory analyses. Nevertheless, advancement on framework and methodology of S-LCA may contribute significantly in assessing sustainable production and consumption of products from a social perspective.

Some of the earliest study of the S-LCA is provided in Table 1 (on the next page).

The overall goal of Social Life Cycle Assessment is to evaluate the human and society well-being obtained from the product under study. This assessment is possible by setting different impact categories which are to be gauged by identified stakeholders. S-LCA has been used nowadays to evaluate the collective benefits of some products to society.

Table 1: The summary of the related studies and the gap.

Title	Authors	Main Focus	Contribution	Stakeholders Involved	Scope	Gap
Social Life Cycle Analysis (S-LCA): Some Methodological Issues and Potential Application to Cheese Production in New Zealand	U. Paragahawewa and P. Blackett	To assess the comparative advantage of a particular company's pasture-based products in terms of environmental and social performance against with products produced in furthest markets.	It discusses the evolution of S-LCA with an agenda of formulating an effective method to incorporate social impact assessment on the life cycle of products.	Workers	Gate-to-use (from entering the farm gate through consumption of final products)	Apply S-LCA to other products
"Pilot 1: Tire," Handbook for Product Social Impact Assessment	J. Fontes	It supports the understanding of the overall importance of a product and provide a full picture of improvement opportunities beyond environmental and economic aspects in order to generate more sustainable solutions.	The outcome of social impact assessment for tire can be used in decision-making of the company as well as for marketing purposes through promoting the social benefits related to the use of products	Supply chain, society, employer	Cradle-to-gate(from the production of raw materials to receiving them) and Gate-to-use (from distribution to consumption)	Get an overview of the whole life cycle of a product and supply chain, refine results from important life cycle steps, and identify areas where improvements would be most effective.
"Pilot 3: Hair Care Product," Handbook for Product Social Impact Assessment	J. Fontes	The scales-based approach can be used by companies to create awareness and understanding of potential hotspots (negative scores) or product differentiators (positive scores) within a relatively short period of time.	The intended application of the study was to support product development and product marketing in order to gain consumer insights and increase market share.	Consumers	Use	It expects that all types of products can be assessed. The outcome depends on the scoping or coverage, the complexity of the selected product, the complexity of supply chain (N-Tier) and willingness or ability to provide information.

### 3. STUDY DESIGN PARAMETERS (SDPs)

ISO requires a series of parameters to be qualitatively and quantitatively described for an LCA study, which refers to as the study design parameters (Matthews, et. al.). SDPs are a summary of the most important organizing aspects of an LCA. The SDPs are a subset of the required elements in an LCA study, but are generally the most critical considerations and thus those that at a glance would tell nearly everything that is needed to know about what the study did and did not seek to do. Thus, these are items that need to be chosen and documented very well so there is no confusion. This study follows the following SDPs:

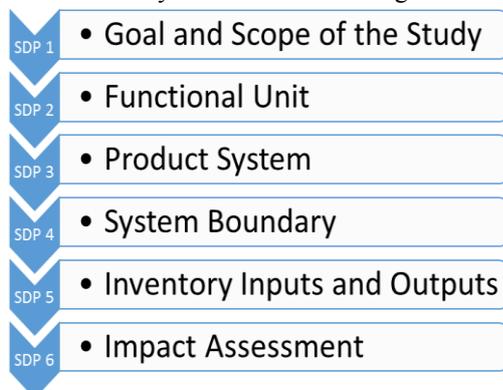


Figure 1: The Study Design Parameters used in this study.

#### 3.1 SDP 1: Goal and Scope of the Study

The goal of this Social LCA is to assess the social impact of a solar powered product system on remote areas in Doña Remedios Trinidad, Bulacan where there is very limited access to electricity. This will be the basis of the stakeholders for the decisions that may greatly affect them in the future – for the local community to purchase more items and use them in household appliances; for the local government unit to determine the feasibility of providing other communities with the product; for the supply chain actors to determine the demand of the product and the needs in providing support and maintenance; and, for other communities, LGUs and NGOs to adapt the system.

This Social LCA is viewed to be released to the public particularly to the local government of Doña Remedios Trinidad, Bulacan to understand how newly developed product system powered by renewable energy solution may uplift the lives of rural communities.

#### 3.2 SDP 2: Functional Unit

The functional unit of this Social LCA study is the

utility acquired from one unit solar powered suitcase by identified stakeholders. The data to be evaluated in Social LCA is semi-quantitative or qualitative thus it cannot be summarized per unit of process output.

### 3.3 SDP 3: Product System

The Solar Suitcase is a portable solar power system. It includes a 50W solar panel, a solar charge controller, battery, mod sine inverter and comes with 2 LED light bulbs, a multi-headed USB charger, and a DC fan. Solar power is converted into electricity; under the regulation of solar controller, the converted electricity is stored into the battery (this process is called charging). When using the device, turn it on, and the battery will supply power for the load (this process is called discharging). The main function of controller is to regulate the process of charging and discharging. When the battery is too drained, the controller will cut off the power automatically to protect the battery from over discharging; when the battery is full, but the solar panel is still supplying power, it will start over charging protection automatically.

### 3.4 SDP 4: System Boundary

Figure 3 shows the system boundary along the product's life cycle. This study is focused primarily on the social impact on the distribution phase, use phase and maintenance phase of its life cycle.

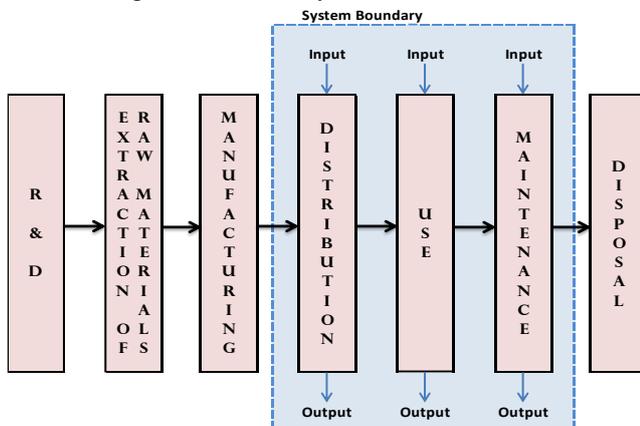


Figure 2: The system boundary of the study.

### 3.5 SDP 5: Inventory Inputs and Outputs

The study focuses on the social impact of the Solar Suitcase. The Table 2 (at the top of the next page) illustrates the SIPOC of the study. SIPOC, stands for Supplier-Input-Process-Output-Customer, is a visual tool for documenting

a business process from beginning to end. This will summarize the SLCA of the study. It will also be observed that all process units have similar sets of inputs and outputs.

### 3.6 Impact Assessment

ISO 14040 (Environmental Management - Life Cycle Assessment - Principles and Framework) requires to explicitly list the impact categories selected and methodology of impact assessment, and subsequent interpretation to be used. The study considers six impact categories to assess the social benefit that different stakeholders can acquire from the product under evaluation. These social topics are as follows (1) health and safety, (2) experienced well-being, (3) access to tangible resources, (4) local capacity building, (5) community engagement and (6) employment. Identified stakeholders utilize scale-based approach to evaluate impact categories.

The succeeding sections describe the impact categories to be used in order to measure the social impact of Solar Suitcase.

#### 1. Health and safety

Solar Suitcase is expected to provide its intended functions and not pose a risk to local community's health and safety. This social topic evaluates the negative and positive impacts that Solar Suitcase may contribute to health and safety of the end-users. Positive impacts pertain to the degree of benefits that different stakeholders can obtain from using the product. Negative impacts may be attributable to factors that can threaten health and safety of the community. Some example of these adverse impacts is hazardous waste from using or disposing the product. Adverse impacts may be identified through number of complaints, petitions and legal disputes which are highly related to the usage of the product.

#### 2. Experienced well-being

Experienced well-being is defined as the personal assessment of positive and negative feelings or emotional states that the consumer experiences in relation to the use of a product. The key performance indicator used in measuring experienced well-being is the composite measure of experienced well-being that balances the respondents' positive and negative mood. The indicators evaluate which emotional state is stronger compared to the other.



Table 2: The SIPOC diagram of the study.

Supplier	Input	Process	Output	Customer
Product distributor to the Philippines	<ul style="list-style-type: none"> <li>Working time</li> <li>Human Body</li> <li>Energy consumption</li> </ul>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Distribution and Installation</div>	<ul style="list-style-type: none"> <li>Health and safety</li> <li>Access to tangible resources</li> <li>Local capacity building</li> <li>Community engagement</li> <li>Employment</li> </ul>	Local government
Local government	<ul style="list-style-type: none"> <li>Working time</li> <li>Human Body</li> <li>Energy consumption</li> </ul>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Use</div>	<ul style="list-style-type: none"> <li>Health and safety</li> <li>Experienced well-being</li> <li>Access to tangible resources</li> <li>Local capacity building</li> <li>Community engagement</li> <li>Employment</li> </ul>	Local community
Product distributor to the Philippines	<ul style="list-style-type: none"> <li>Working time</li> <li>Human Body</li> <li>Energy consumption</li> </ul>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Maintenance</div>	<ul style="list-style-type: none"> <li>Health and safety</li> <li>Experienced well-being</li> <li>Access to tangible resources</li> <li>Local capacity building</li> <li>Community engagement</li> <li>Employment</li> </ul>	Local government  Local community

### 3. Access to tangible resources

Tangible resources refer to fundamental needs of the community such as water, land, mineral resources and tangible forms of cultural heritage. Infrastructure pertains to physical and technical structures that support the community, for example, roads, street lighting, telecommunications, sanitation and waste disposal systems. Adverse impacts on access to tangible resources may include limited supply of water or land, polluting rivers, and other conditions that have significant effects on community open access to tangible resources. It can also be measured through monitoring the number of complaints, petitions and legal disputes.

This social topic identifies the extent to which the local community has easy access to, tangible resources and infrastructure. Also, it measures how the local government and supply chain actors effectively make available these needs by providing the community with the product being studied. Since the subject community of S-LCA is an isolated community in Dona Remedios Trinidad, Bulacan and there are identified tribes living in the area, this social topic also includes respect for indigenous peoples' and women's land rights and tangible forms of cultural heritage.

### 4. Local capacity building

Local capacity building deals with the extent to which the local government and supply chain actors work to contribute to the long-term development of local communities by enhancing and unlocking their human

potential through improved access to knowledge, information, technology and skills.

### 5. Community engagement

In the study, community support refers to the direct involvement of local government and supply chain actor in initiating community projects which aim to enhance other areas other than health or education. This aspect involves diminishing grievances or any complaint from a member of a local community. Thus, community engagement as a social topic discusses the extent to which the local government and supply chain actors participate in open dialogue with the community and how they respond to their concerns and inquiries impartially and promptly. These activities continuously develop trust and harmonious relationships, most especially with indigenous people and women within the community.

### 6. Employment

Employment brings up the extent to which the local government and company create new jobs for the members of the community. It involves generating income-generating activities for community people, thus uplifting their lives. Employment improves the economic livelihood of the community and their families. Employment also promotes sustainable development across the community.

## 5. LIFE CYCLE INVENTORY

Inventory analysis follows a straightforward and repeating workflow, which involves the following steps (as taken from ISO 14044:2006) done as needed until the inventory analysis matches the then-current goal and scope:

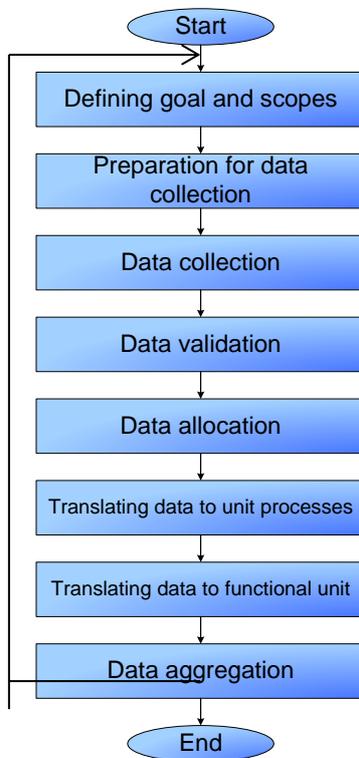


Figure 2: The LCI process.

### 5.1 Preparation for Data Collection

Barangay Kalawakan located in the municipality of Dona Remedios Trinidad in Bulacan is the focus of the study. It has sixty-nine households with an average of two families per household, in which each family has an average of four members.

### 5.2 Data Collection

The collection procedures used in SLCA for Solar Suitcase are (1) face-to-face interviews, (2) literature review, (3) documentary review, and (4) survey. In addition, S-LCA for Solar Suitcase uses scale-based approach in evaluating the positive and negative impact of the product to different stakeholders. The proponents utilized the primary data gathered from surveys the proponents had conducted.

### 5.3 Data Validation

Data validation should be done after data is collected

but before the actual inventory modelling activities of the LCA. In case of Social LCA, the validation of the impact of different parameters to the stakeholders may be validated through related literature and studies.

In this study, data validation is done through assessment of the current situation in the country and interviews conducted to different stakeholders.

### 5.4 Data Allocation

Allocation is the quantitative process done by the study analyst to assign specific quantities of inputs and outputs to the various products of a process based on some mathematical relation between the products. In this study, data allocation is not applicable.

### 5.5 Translating Data to Unit Processes

In this step the various collected data will be conducted into a representation of the output of the unit process. Regardless of how the study has been defined overall, this step requires the collection of all of the inputs and outputs as needed for 1 unit output from that process.

### 5.6 Translating Data to Functional Unit

This step is included in the ISO LCA Standard to remind that an overall study is on the basis of one functional unit of product output, in this study, one unit of solar powered suitcase. It is needed to do conversion so that the relative amount of product or intermediate output of the unit process is related to the amount needed per functional unit. Eventually, all of unit process flows will need to be converted to a per-functional unit basis.

### 5.7 Data Aggregation

All unit process data in the product system diagram are combined into a single result for the modelled life cycle of the system. It is summing all quantities of all inputs and outputs into a single result on a functional unit basis.

Table 4: Data aggregation for distribution phase.

DATA PER UNIT OF SOLAR POWERED SUITCASE	
<b>Input</b>	
Working time	4.15 min.
Human body energy consumption	2456.71 kcal
<b>Output</b>	
Health and safety	+1 The product reduces the risk of disease or it helps prevent accidents or injuries. In addition, the product is labelled for safe handling and there is a procedure in place in the event of the recall of an unsafe product.
Access to tangible resources	0 The risks and impacts on community access to tangible resources are regularly monitored. No actual damage is identified, but either no or only minimum measures necessary to prevent adverse impact are implemented.
Local capacity building	0 Capacity-building initiatives which target community members are undertaken on an ad-hoc basis.
Community engagement	0 Communications channels between the company and the community are formally established and used regularly. Community queries and grievances are addressed voluntarily in a transparent and systematic way.
Employment	+2 The company ensures that the number of new jobs created is greater than the jobs lost.

Table 5: Data aggregation for use phase.

DATA PER UNIT OF SOLAR POWERED SUITCASE	
<b>Input</b>	
Working time	
Human body energy consumption	
<b>Output</b>	
Health and safety	+1 The product reduces the risk of disease or it helps prevent accidents or injuries. In addition, the product is labelled for safe handling and there is a procedure in place in the event of the recall of an unsafe product.
Experienced well-being	8 happy
	7.7 calm
	8.3 comfortable
	7.1 self-esteem
	7.9 proud
	6.5 connected
	7.5 pleased
	1.6 angry
	1.4 sad
	2.3 pain
	3.5 tired
	4.5 uncomfortable
	4.5 insecure
	1.7 ashamed
	1.7 lonely
1.8 annoyed	
Access to tangible resources	+1 The risks and impacts on community access to tangible resources are regularly monitored. Appropriate measures to prevent and mitigate adverse impact are implemented.
Local capacity building	+2 The capacity building through formal programmes which target community members is ongoing with transparent guidelines and timelines.
Community engagement	+1 The communication channels between the local government, the company and the community are formally established and used regularly. Community queries and grievances are addressed voluntarily in a transparent and systematic way.
Employment	+2 The company ensures that the number of new jobs created is greater than the jobs lost.

Table 6: Data aggregation for maintenance phase.

DATA PER UNIT OF SOLAR POWERED SUITCASE	
<b>Input</b>	
Working time	
Human body energy consumption	
<b>Output</b>	
Health and safety	0 Risks and impacts on community health and safety are regularly monitored. No actual damage is identified, but either no or only minimum measures necessary to prevent adverse impact are implemented.
Experienced well-being	8.5 happy
	10 calm
	8 comfortable
	8 self-esteem
	8.5 proud
	9 connected
	8.5 pleased
	0 angry
	0 sad
	0 pain
	0 tired
	1 uncomfortable
	0 insecure
	0 ashamed
	0 lonely
0 annoyed	
Access to tangible resources	+1 Risks and impacts on community access to tangible resources are regularly monitored. Appropriate measures to prevent and mitigate adverse impact are implemented.
Local capacity building	+2 The capacity building through formal programmes which target community members is ongoing with transparent guidelines and timelines.
Community engagement	+1 The communication channels between the local government, the company and the community are formally established and used regularly. Community queries and grievances are addressed voluntarily in a transparent and systematic way.
Employment	+2 The company ensures that the number of new jobs created is greater than the jobs lost.

## 6. CONCLUSION AND RECOMMENDATION

Rural electrification is one of the costly plans that private firms and local government can develop due to high electrical infrastructure investment and operating cost. This is the case of Barangay Kalawakan in Dona Remedios Trinidad in which majority of the communities are not yet electrified. In an article “Lighting up a Village, Developing a Toolbox of Renewable Energy Rural Lighting Systems”, it is to be expected that the bottom 20% of the homes in the developing world will never get power in the foreseeable future running into a couple decades or more. Given this approximation, providing power to bottom of the pyramid communities can significantly uplift their standard of living and in the long run might result to positive impact on the economic growth. In view of this, renewable energy sources as an alternative for national grid extension is seen to be more feasible for isolated rural communities.

The researchers conduct a survey using a scale-based

approach questionnaire in order to evaluate the social and socio-economic impact of Social Powered Suitcase in different stakeholders. Same set of impact categories are utilized as the criteria of local community, local government and supplier in assessing the positive and negative impact of using the product. Generally, the introduction of Solar Suitcase has strong positive impact on the local residents and local government of Barangay Kalawakan in Dona Remedios Trinidad, Bulacan.

The average monthly income of a household in Barangay Kalawakan which ranges from Php200.00 to Php3,000 is a primary factor that might impede the residents to acquire a device powered by renewable energy source like the Solar Powered Suitcase. The residents in Barangay Kalawakan depend on kerosene bottle lamps and battery-powered flashlights during night time. The average cost of kerosene consumption is Php10.00 per day. Hence, firms that will technically and financially support the community is necessary to promote the use of renewable energy source. A community level cooperative is seen to be advantageous for the sustainability of the renewable energy source in isolated rural areas. The community level cooperative may also initiate small-scale enterprises that provide the community's needs that could pay for itself continually. These enterprises will require personnel that will operate the business thus generating employment in the community. Some enterprises which seen to be viable are the following:

#### 1. Communication center for the community

Since most of the households do not have cellular phones or any gadget intended for communication, the community level cooperative can develop a communication center that is beneficial to the residents especially during emergency cases.

#### 2. Processing of agricultural products

The main source of income in Brgy. Kalawakan is agriculture, particularly crop production. In line with this, residents can venture for ways on how to process agricultural crops like turmeric, corn, and others. These delicacies are seen to be sold in Bulacan Pasalubong Center.

#### 3. A Battery-Charging Centre for Rechargeable Flashlight Batteries

The community level cooperative may encourage the use of rechargeable batteries for households. The enterprise may initially provide a unit of rechargeable battery for households to help the residents switch from using kerosene lamps or disposable flashlight batteries. As a result, the action can also promote the small scale

enterprise of battery-charging center.

The community level cooperative may collect an amount to its members as their monthly tariff in order to sustain the operation of the cooperative. The revolving fund is beneficial to the maintenance of the product systems and also for the future common good of the residents. The community fund may also use in potential expansion of small scale enterprises in the future.

The most important social impact of building a community level cooperative is the collective effort and unity enhancement of the residents. With this value, the community may venture into more progressive programs.

## 7. AREAS FOR FUTURE STUDY

Researchers may consider the study on the economic impact of the product to the community. Also, researchers may expand the scope of the study along the life cycle of the product.

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