Analyzing Energy Alternatives for an Orphanage in Rural Thailand

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Sponsored by:

Sarnelli House; Nong Khai, Thailand

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Abstract

Sarnelli House lacks a reliable energy source affecting the completion of regular, everyday tasks including bathing, cooking, and studying in the evenings. The goal of this project was to perform a comparative study for Sarnelli House and recommend alternative energy options that would provide them with reliable power and lower their electricity costs. We made observations during our site visit, conducted interviews with stakeholders, and held a focus group with middle school girls to collect data. The data collected revealed that power outages are a nagging inconvenience but reducing electrical costs and educating the residents on sustainability are priorities. We determined that solar power systems provided the best options for meeting our goals. This project provides large-scale, small-scale, and educational recommendations based on the collected data and analysis that will benefit Sarnelli House the most.

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Abstract	Kaitlin	Nicholas
Executive Summary	Meghan	Nicholas
1. Introduction	Kaitlin	Nicholas
2. Background	Meghan	Opel
2.1 Nong Khai, Thailand	Waleria	Heart
2.1.1 Current Energy Usage and Issues	Nicholas, Opel	Aim, Kaitlin
2.2 Alternative Energy Options	Heart, Meghan	Waleria
2.2.1 Solar power	Kaitlin, Opel	Heart
2.2.2 Other renewable sources	Meghan, Waleria	Meghan
2.3 Sponsor Profile	Opel, Waleria	Kaitlin
3. Methodology	Aim	Kaitlin, Meghan
3.1 Evaluate Current Energy Consumption	Aim, Kaitlin, Waleria	Nicholas, Opel
3.2 Assess the Feasibility of Energy Sources	Meghan	Nicholas
3.3 Construct Recommendations for Implementation	Nicholas, Waleria	Meghan
4. Results	Meghan	Kaitlin
4.1 Energy Requirements and Challenges	Aim	Kaitlin, Meghan
4.2 Feasible Energy Alternatives	Heart, Opel	Meghan, Nicholas
4.3 Other Findings	Waleria	Kaitlin
5. Recommendations	Opel, Meghan	Waleria

5.1 Large Scale Recommendations	Nicholas, Waleria	Meghan, Kaitlin
5.2 Small Scale Recommendations	Meghan, Heart	Waleria
5.3 Educational Recommendations	Kaitlin, Heart	Meghan
5.4 Conclusion	Meghan	Waleria
5.4.1 Summary of findings	Kaitlin	Nicholas
5.4.2 Limitations	Opel, Aim	Waleria
5.4.3 Concluding remarks	Waleria	Nicholas
Deliverable Document	Opel, Heart	Meghan
Infographics	Opel	Kaitlin

Table of Contents

Table of Figures

Table of Tables

Executive Summary

The Problem

While electricity is something that most people take for granted, 1.2 billion people worldwide do not have access to the electrical resources they need (Odarno, 2017). This lack of resources stems from many problems, including unreliable or no connection to grid power and high costs. Sarnelli House, an orphanage in Nong Khai, Thailand for children affected by HIV and AIDS, has both power outages and a high energy bill each month. Sarnelli House sponsored our team to look into this problem.

Our Goal

The goal of this project was to gain an understanding of why power disruptions occur at Sarnelli House and make recommendations of alternative energy options that would provide reliable power and lower their electricity costs. We conducted a comparative study to find the best solutions to satisfy both of these goals.

Our Objectives

For our first objective, we assessed the current electrical situation. We visited the orphanage, made observations of the electrical wiring and appliances, and conducted a series of interviews along with a focus group. We spoke with various stakeholders of Sarnelli House, including the founder, fundraising coordinator, and volunteer coordinator, some of the residents of one of the houses, and representatives from the Provincial Electricity Authority (PEA) of Nong Khai. From there, we learned about how much energy the site uses and its cost, how frequently they experience power outages, and how the PEA restores the power. For our second objective, we gathered information regarding all possible renewable energy options. The sources we found were solar, biomass, wind, hydroelectric, and geothermal energy. We researched how they worked, large-scale and small-scale examples, and where they had been effective.

Our third and final objective was to identify what alternative energies would be feasible and beneficial to our sponsor. Without biological wastes, a water source, appropriate wind speeds, or testing for geothermal temperatures, we quickly focused our research on various types and scales of solar energy. We spoke with representatives from solar cell vendors and manufacturers to discuss what would be most appropriate to install at Sarnelli House.

Our Findings

From our observations, research, and interviews, we identified six key findings. We discovered:

1. *Poor wiring, weather, and other uncontrollable factors cause the power outages.*

Every interviewee at Sarnelli House told us the power outages were most frequent during the rainy season, and data tracking the power outages from the PEA confirmed this. Other factors that cause power disruptions are animals, trees, scheduled maintenance, equipment failure, and unknown. These interruptions happen easily since the power lines in the villages where Sarnelli House resides, Don Wai and Pi Si Thong, are out of date. If the PEA were to update the bare-conductor wire to insulated cables, 98 percent of the power outages would not occur (Personal Correspondence, January 16th, 2019). However, there is little demand for electricity in the area, and this upgrade would not be a financially favorable investment to the company.

2. *The PEA replaces a fuse after receiving a phone call and then restores the power.*

Given that the PEA is unwilling to implement a long-term solution to the power outages at this time, they currently restore the power as quickly as possible whenever Sarnelli House calls. To do this, they must replace a fuse. This process generally takes 2-3 hours; however, it can last up to 48 hours if there is bad weather (B. O'Riordan, Personal Communication, January 15th, 2019).

3. *Sarnelli House has a greater need for electricity in certain buildings.*

Upon arrival at Sarnelli House, we could immediately see different houses used electricity for various functions, and at different times of the day. We later received a spreadsheet from Brian O'Riordan, fundraising coordinator, that estimated the yearly cost of energy, including electricity, at each house from the organization's total cost. This data allowed us to see what houses needed to focus on energy conservation and what houses could benefit the most from solar energy. The locations that had the highest electricity costs in 2018 were the Nazareth Girls Home, the farm, Sarnelli House for boys, and the office building. The buildings with the least demand for electricity were the Gary and Janet house and Our Lady of Refuge. From this, we ranked the houses that would benefit from renewable energy based on cost, but we then had to consider need-based rankings. The House of Hope for the infants requires constant electricity to provide care for the young. The office building and guesthouse are the only other two places that use electricity during the daytime when solar energy would be available without a battery. All of these factors had to be considered to make recommendations for Sarnelli House.

4. *Solar energy is the only feasible energy alternative for Sarnelli House.*

Sarnelli House has a farm which currently uses all of the animal and crop waste as feed or fertilizer. There is no running water on the Sarnelli House properties, nor is there sufficient wind for a small turbine. Geothermal requires extensive and expensive testing to determine where it would be feasible. However, Nong Khai experiences a monthly average of 7 sunny hours per day, and Sarnelli House has several southern-facing, unobstructed roofs that would be appropriate for solar panels (Weather Atlas, 2018). The average solar insolation in Thailand is 5.0-5.3 kWh/m^2 per day. Although the dust during the dry season must be accounted for, with proper cleaning and maintenance of the solar panels, Nong Khai has an ideal climate for solar energy.

5. *Sarnelli House prioritizes reducing electricity costs.*

Upon the start of this project, we had focused on providing alternative energy to Sarnelli House to provide them with power when grid power failed. However, after visiting the orphanage, we realized their priority was to lower their electric costs through renewable energy. The organization relies primarily on donations, and that is why it does not have a stable income. They view a renewable energy project as a way to lower a significant monthly bill; supplementing grid power during outages is an additional benefit. Given this finding, we shifted our goal to encompass both lowering costs and providing reliable electricity.

6. *Sarnelli House values educating its residents about sustainability.*

We added a deliverable to our project to include an educational aspect for the children. Sarnelli House, specifically Kate Introna, volunteer coordinator and health advisor, sees great value in teaching the children about energy, energy conservation, and sustainability. While she is aware that a project such as installing solar panels is an investment, she also sees it as an opportunity to teach the children about something they do not get to learn about in school.

7. *Solar Panel System Specifications.*

To provide detailed information to our sponsor, we first had to research many aspects of solar panel systems; including the type of panel, efficiency of each type, and their costs. We calculated the energy consumption of each building using a spreadsheet of annual energy cost. As solar companies provide information based on a minimum system of 5 kW, we calculated the amount of electricity that the systems can produce for both battery and no battery system. We carefully considered implementing batteries since their replacement every two years significantly increases their cost. We also received quotes which provided us the price of components from one solar company that we interviewed. The quotes helped in our calculations and provided a suitable scale of recommendations for Sarnelli House.

Our Recommendations

Our recommendations to our sponsor consist of large-scale, small-scale, and educational options for implementation. Large-scale options provide implementations of solar energy in different houses and areas to cover a large percentage of electricity at Sarnelli House. We recommend that they install 350W monocrystalline solar panels for either a 5 kW or 10 kW system based on their energy requirements in five different locations. We have recommended that Sarnelli House implement 5 kW systems for the farm, Pi Si Thong village, and the office and guest house. We also believe a 10 kW system for all of the water pumps throughout the facility would be beneficial. Finally, we found that to become solely dependent on solar energy, they would need to install a 20 kW system with 128 batteries; however, we do not believe this option is best for them due to a return on investment of 20 years. If Sarnelli House installs all five systems, they will save approximately 350,00 THB per year through renewable energy. Small-scale recommendations provide applicable appliances for our sponsor to achieve a goal of reducing energy cost by installing lamps, fans, and street lights that run off of solar energy. Lastly, educational recommendations propose infographics about basic information regarding solar energy, energy management, and minimization of waste.

Conclusion

Our project fulfilled our goal to provide our sponsor with recommendations to lower their electricity costs and provide reliable energy by installing solar panels and using solar-powered appliances. Additionally, we provided them with three infographics to help educate the residents about solar energy, advise ways to reduce their energy consumption from appliances, and five R's to help make Sarnelli House more environmentally friendly. We hope this project helps Sarnelli House move forward and become sustainable and more financially stable.

1. Introduction

In today's world, energy is a fundamental component of everyday life, facilitating the performance of daily activities, providing educational opportunities, and enhancing telecommunications needs, among others. However, 1.2 billion people worldwide do not have the electrical resources they need to complete everyday tasks, and 16 percent of the world's population has little to no access to electricity (The Rockefeller Foundation, 2018). Fossil fuel is most frequently used to produce energy for those who have access to it, but recently there has been a significant shift towards renewable energy. Renewable energy sources are now implemented in more homes and industrial installations worldwide for its low pollutive output, decreasing cost, reliability, and availability.

Thailand is one of the many countries affected by a lack of reliable energy resources, specifically in rural areas. In Nong Khai, a province in northeastern Thailand, the supply of energy can fall below expectations due to inadequate distribution systems. These unreliable systems cause Nong Khai to experience power disruptions that negatively impact the local population.

Our sponsor, Sarnelli House, an orphanage in the outskirts of Nong Khai, lacks a reliable energy source and experiences power outages causing their daily activities to be affected. They asked our team to explore alternatives that generate power to run bathroom water pumps, laundry machines, refrigerators, and lights for evening study hours. Sarnelli House, specifically the founder and director Father Michael Shea, has been caring for children affected by HIV and AIDS since 1999 (Sarnelli House, 2018). They have created a safe environment for children who would otherwise not have the opportunity to learn, play with other kids, or gain acceptance in society due to their illness. A change in the reliability of energy and decreased electric costs will not only better the completion of everyday tasks but will genuinely improve their quality of life.

This report contains information about how we gathered research and analyzed data to deliver a strategy to Sarnelli House for implementation of an alternative energy source. We assessed Sarnelli House's current energy consumption and energy needs by observing the appliances they use most frequently. We investigated the electrical system connected to Sarnelli House by interviewing representatives from the Provincial Electricity Authority (PEA) of Nong Khai. We have conducted a comparative study to explore feasible and sustainable energy alternatives to reduce their electrical costs as well as provide reliability. The focus of this study was on renewable energy; however, we also looked at nonrenewable energy options.

We divided our project into three objectives. The first of these objectives was to investigate the current energy requirements and challenges faced at Sarnelli House. This objective helped us in developing a better understanding of why power outages are occurring. The second objective was to collect and characterize reliable and feasible energy alternatives; this gave us a working knowledge of renewable energy and the small-scale systems available to us. The third objective was to identify energy alternatives that would be most beneficial to Sarnelli House. We completed extensive research and analysis of objectives one and two to narrow the scope of potential solutions, creating the team's top recommendations. It was crucial for our team to find energy alternatives that are cost-efficient, reliable, and meet their energy needs. At the conclusion of this project, we obtained the most suitable alternative energy options for Sarnelli House and provided recommendations to reduce their energy consumption.

2. Background

Thailand is one of many countries affected by a lack of dependable energy sources. The residents of Sarnelli House are part of the many people that do not have reliable energy. This chapter explains the current state of electricity and its problems in Nong Khai. We then lay out in detail various sources of renewable energy with their potential advantages and disadvantages that could be used to help people who suffer from unreliable power.

2.1 Nong Khai, Thailand

Nong Khai, established more than 200 years ago, provides a unique culture that lures tourist through different attractions, traditions, festivals, and shopping (Tourism Authority of Thailand, 2018). “The area is suitable for agriculture and freshwater fishery” that citizens profit from along with artisanal products including textiles, basketwork, and silverware (TAT Udon Thani Tourist Information Division, 2012). Nong Khai has been a logistic hub with global value for Laos, Southern China, and Thailand (Ongdee, 2018). Nong Khai is a province with great history, folklore, culture, and significant economic potential for Thailand. Muang Nong Khai is the capital city of the Nong Khai Province in northeastern Thailand. The city covers approximately 7,332 square kilometers and has a population of approximately 46,000 inhabitants (TAT Udon Thani Tourist Information Division, 2012). Figure 1 shows a population density map of the northern regions of Thailand; a circle indicates Nong Khai Province.

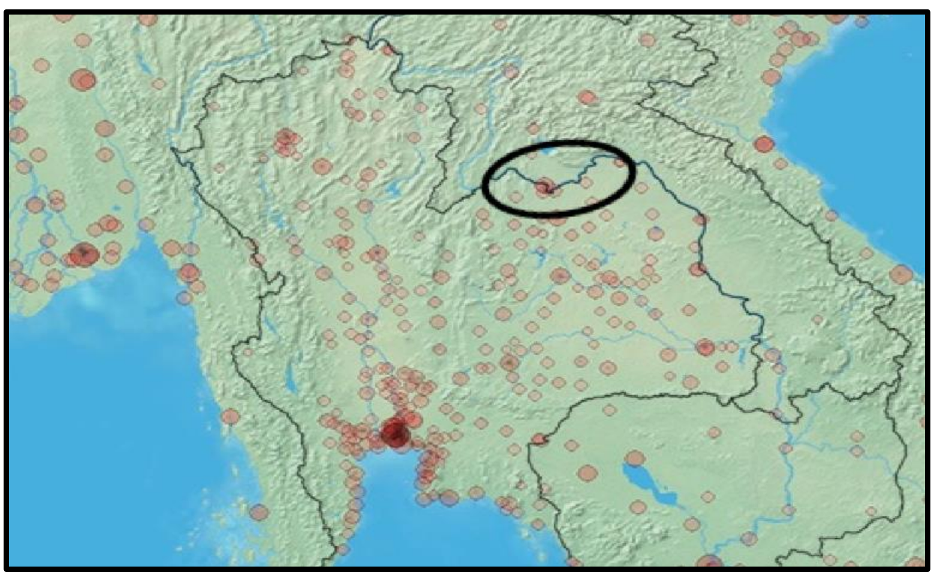

Figure 1**:** *Regional population density map of northern Thailand and surrounding countries. General region of the Nong Khai Province is encircled. For reference, darkest red area is Bangkok, Thailand. Reprinted with alterations from Population City, 2015.*

2.1.1 Current Energy Usage and Issues

Many provinces around Nong Khai use hydroelectric power from the Mekong River to generate electricity. The High Voltage Electricity Station of Nong Khai is an electrical connection point from Laos to Thailand and provides at least 120 megawatts (MW) of hydropower per day (MGR online, 2013). However, the energy supply in Nong Khai is unreliable due to disruptions as a result of inadequate power distribution systems and unorganized wires. In the outskirts of Nong Khai, electrical wiring is out of date and does not have appropriate insulation around them. The wiring creates a high risk for power-outages and village-wide black-outs for those who use their electricity.

Despite the hydroelectric power in Thailand from Laos, the dominant energy source is fossil fuels. As coal prices steadily decrease and the demand for electricity rises, especially in rural areas that are off the grid, the government imports more coal and oil (Chung, 2015). As reliance on fuel imports increases, Thailand's government projects to reach 3.2 trillion THB (USD 100 billion) by 2035, based on net oil and gas imports (Sutabutr, 2016). At that time, Southeast Asia expects coal to rise as the primary energy over natural gas with a 28 percent increase in demand (Hoeven, 2013). With such a steep demand for electricity in Thailand, the government tries to obtain whatever options can meet the demand fastest. Biomass follows coal as a secondary energy source. Thailand has a large surface area for its cash-crop agriculture, generating an abundance of raw materials from sugar cane, rice, corn, and urban waste. Implementation of "waste to energy" methods include incineration, gasification, and landfill gas (Brock, 2016). Unfortunately, waste to energy technology has not caught on and Dr. Suthee Traivivatana, a researcher at Energy Research Institute of Chulalongkorn University, has theorized a few reasons for this. Dr. Suthee Traivivatana discussed how the government often announces a grand plan of implementing renewable energy in rural areas but neglects to state clear objectives on how they plan to meet these goals and address grid integration (ibid.). There are no agencies troubleshooting obstacles to create clear solutions. As there is no system in place to monitor the distribution of electricity, the PEA cannot track all power outages that happen in Nong Khai (ibid.).

2.2 Alternative Energy Options

Thailand imports 60 percent of its primary energy sources, based on 2014 data, consisting mostly of crude oil (59 percent of imports) and coal (19 percent of imports) for energy production (Energy Forecast and Information Technology Center, 2015). However, with the finite resources of the world decreasing in supply as the years go on, we turn to renewable sources to sustain our lifestyles. People use renewable energy worldwide, and its usage rate has increased by 5.4 percent from 2005 to 2015 as seen in Figure 2 (REN21, 2018). Although the start-up expenses can be costly, these alternative sources are more environmentally and economically favorable in the long run (IRENA, 2018). The traditional sources of renewable energy that we explored are solar power, biomass energy, wind power, hydroelectric power, and geothermal power. While researching these sources, we observed several factors of each renewable energy option including their advantages, disadvantages, and cost. A spreadsheet including research on each renewable energy option is in Appendix A.

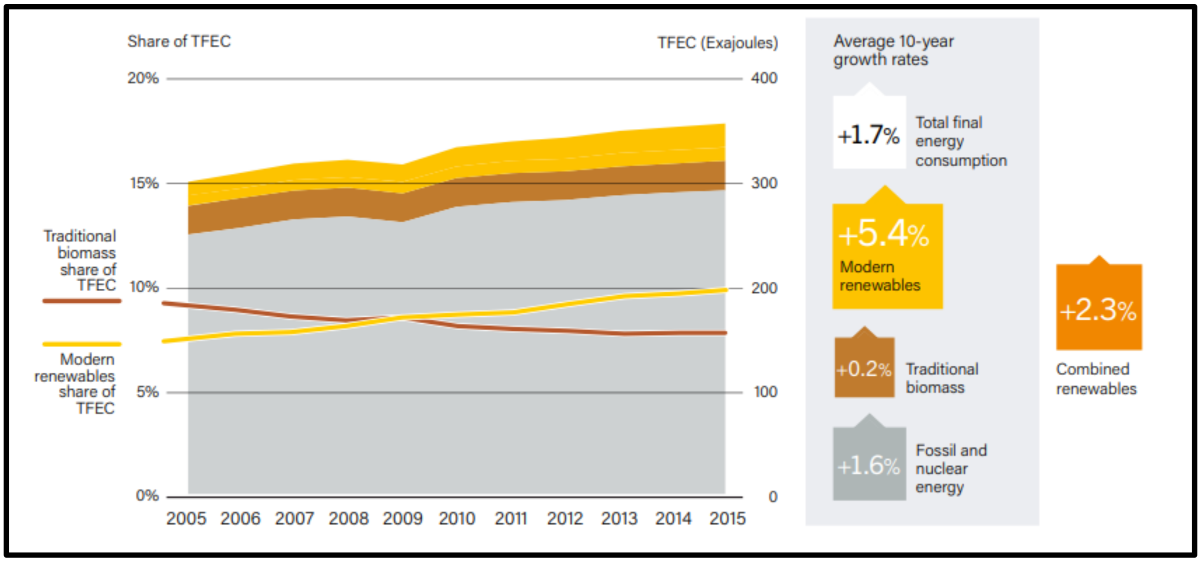

Figure 2: *Growth in Global Renewable Energy Compared to Total Final Energy Consumption (TFEC), 2005-2015. Reprinted from REN21, 2018.*

2.2.1 Solar power

Solar power requires the conversion of sunlight to electricity. In 1876, William Grylls Adams along with his student, Richard Day, discovered that when exposed to light, selenium produced electricity (Victoria, 2017). The selenium cells were not efficient, but the discovery proved that light could be converted into electricity (ibid.). In 1953, researchers discovered the silicon solar cell and that it produced enough electricity that could run small electrical devices (ibid.). Three years later, the first solar cells were available commercially, and since then many places around the world use solar cells (ibid.).

A solar cell or photovoltaic cell is an electrical device that consists of semiconductor materials that convert sunlight directly into electricity (Leonics, n.d.). The photovoltaic effect is the phenomenon where a material surface, such as silicon, absorbs sunlight, raising electrons to jump into a higher energy state. A positively charged electrode then attracts these negatively charged electrons. The circuit completes, and the light energy converts into electric energy and can support an electric current without attachment to any external voltage source (Knier, 2019).

Three types of solar systems are commercially available today. Over 90 percent of these devices are silicon-based and are most prevalent. However, there are cadmium-tellurium-based and indium-gallium-copper-selenide-based systems that have higher conversion efficiencies and can be made as thin-film modular units (Mulvaney, 2014). Solar cell systems are useful with many benefits. There are no gases or fluids that can leak out, and they do not need fuel to operate. These cells have a rapid response and can operate at moderate temperatures without producing any pollution. Various electrical applications such as lighting systems, water pumps, agricultural use, and satellite energy widely use solar cells as an energy source. There are two main classes of solar systems: a solar farm and a solar rooftop system and the major difference is the installation process. Solar rooftop systems are installed on a roof or high ground while the solar farm system is installed on a large plain-like area and are usually retail level to feed a grid (Darcey, 2016).

The developments in solar cell technologies have driven the cost of solar panels down over time (iTalk, 2013). Thailand is a tropical area and has several areas with great solar power potential such as the northeastern region, especially the Nong Khai, Sakon Nakhon, and Ubon Ratchathani provinces. Peak density of direct radiation in the northeastern region of Thailand is approximately 1,350-1,400 kWh/m^2-year (Department of Alternative Energy Development and Efficiency, 2013). However, in Thailand approval is necessary for any sales of commercial solar cells (iTalk, 2013). According to the Solaris Green Energy Company based in Thailand, a Simax monocrystalline solar panel of 275 W power would cost 6,525 THB (USD 210) (Solaris Green Energy Company, n.d.). This cost does not include other components and installation needed for a solar panel to function. The price of a solar panel varies based on cell type and module power. The cost range depends on the quality of the solar panel and equipment. The return on investment period is about eight to nine years, a relatively short period compared to the average solar cell lifespan of up to 25 years (SolarHub, n.d.). The table below shows typical characteristics of different solar system installations in Thailand.

Table 1: *The investment cost for different solar power usages. Reprinted from Department of Alternative Energy Development and Efficiency, 2013*

	Residential	**Small business building**	**Large-scale business buildings/ factories**
Nameplate Capacity (kWp)	0 - 10	10 - 250	250 - 1000d.l
Investment (THB/kW)	63.7	58.4	58.2
Operating and maintenance expenses (% per year)	0.68	0.60	0.57
Power factor (%)	14.84	14.84	14.84
Cell degradation (% per year)	1	1	1

With customers in 65 countries, the company d.light is an excellent example of small-scale solar energy (Goldman, 2008). The products by d.light include solar lanterns, solar home systems, and solar appliances. An affordable price and low maintenance make d.light capable of smooth operation for rural areas such as Sarnelli House (ibid).

The Foundation For Children (FFC), or “Baan Tarn Tawun” in Nakhon Pathom, Thailand installed 100 solar panels on one of their rooftops and save 17,000 THB (USD 545) on their monthly electricity costs (Electricity Generating Authority of Thailand, 2018). The Foundation site consists of three main buildings including a central office building, the Baan Tarn Tawun building that cares for the babies, and a school building for kindergarten and elementary students. The solar cells, located on the rooftop of an open multipurpose area, have 108 panels of 320 volts each. These panels are connected directly to the electrical wiring in the central office building. The total amount of electrical energy that their solar cells can produce is 34.56 kilovolts (ibid.).

The development of solar energy is present in many different capacities throughout the world. The use of solar photovoltaic systems in rural areas around the world shows the potential for implementation in other remote regions like Nong Khai. The possibility of a backup generator also provides reliability when there is not enough solar energy to convert into electricity.

2.2.2 Other renewable sources

Other renewable energy sources include biomass, wind, hydroelectric, and geothermal energy. This section provides a brief overview of our research on these renewable energies; however, it later became evident that these options would not be a feasible implementation for our sponsor.

Biomass energy is an organic, renewable energy source that comes from biological material from living organisms such as plants and animals that release energy when ignited or burnt. The wastes of any organic material used to produce electricity, better known as feedstocks, consist of varying amounts of carbon, water, and organic volatiles that give off energy during the conversion process (Biomass 101, 2015). Feedstocks include, but not limited to, wood, crops, and animal wastes (ibid.). Combustion, bacterial decay, or fermentation harvest the energy and produce a fuel source such as ethanol (ibid.).

In July 1887, Scottish electrical engineer and academic James Blyth created a way to harness energy from wind by creating the first electricity-generating wind turbine with a battery charging machine to light up his home (Abbate, 2013). Wind energy is the production of electricity using airflow that naturally occurs in the Earth's atmosphere (ibid). Using the kinetic energy captured from driving a magnetic coil and inducing a current, electricity is generated from the wind. Sophisticated monitoring and wind resource analysis give wind energy developers a reasonable estimate of implementation timing, how much it will cost, where wind energy is available, and what direction the blades should be facing to optimize wind consumption. The minimum speed necessary to operate a wind turbine is 4 m/s or 10 mph (Burton, 2011). Although this speed seems quite low, some regions do not produce enough wind to implement wind energy.

For centuries, hydroelectric power has been a primary form of renewable energy. This technique harnesses the energy of moving water and relies on the water cycle. A turbine converts the kinetic energy of falling water into mechanical energy (World Energy Council, 2018). Then a generator converts it into electrical energy. It is a very commonly used resource that last year accounted for 71 percent of the world's renewable electricity (ibid.).

Geothermal energy harnesses heat from within the Earth to directly act as a heat source or indirectly to generate electricity. Below the Earth's crust, there is a layer of hot molten rock, called magma. In this layer, the decay of naturally radioactive materials such as uranium and potassium continuously produce heat. The amount of heat within 10,000 meters (about 33,000 feet) of Earth's surface contains 50,000 times more energy than all the oil and natural gas resources in the world (Union of Concerned Scientists, 2018). Since the Earth's inner temperature is continuously present, power generation from this temperature difference is available at any time. One drills a borehole into the ground to allow steam or hot water to rise to the surface and either heat a working fluid or, if dry steam, directly turns a generator turbine (ibid.). The cooled vapors then return to the Earth through a second injection well. Like many other energy sources, the generation of geothermal energy is at a variety of scales. As of 2008, the United States produced 3,000 MW of geothermal power and was the world leader in the field (Levitan, 2011).

2.3 Sponsor Profile

There are an estimated 17.9 million children under the age of eighteen years old in Thailand of which one million live in vulnerable conditions (SOS Children's Villages International, 2012). Approximately 290,000 children do not have parental care due to HIV and AIDS, and there are more than 300 institutions who give love, care, shelter, and protection to these children in Thailand (ibid.). Each of these orphanages work to improve the quality of life year-round for children with severe mental, physical disabilities, and affected by HIV and AIDS through nutritional, educational, physical therapy programs, and medical treatment.

Sarnelli House, an orphanage in Nong Khai, Thailand, provides a home to children affected by HIV and AIDS. Father Michael Shea, in collaboration with the Redemptorist Fathers Foundation of Thailand, founded the orphanage in 1999. They strive to "empower children to study for their education or vocational training so they can become valuable members of their society and fulfill their potential as best they can" (Sarnelli House, 2018). Some people living with the AIDS virus are neglected and feared in rural Thailand, but Sarnelli House is a haven for children to be safe, learn, and loved. Today, there are 150 children at Sarnelli House, including 25 that are away at university (Sarnelli House, 2018). This refuge helps both children and young adults gain access to health care and treatment for HIV and AIDS and provides a nurturing environment for all.

At Sarnelli House the yearly expenses of the organization are around 16 million THB (USD 512,000). There are many sponsors, such as several Thai churches, the Thai Children's Trust, and private individuals from many countries including Germany, the United States, Canada, and Australia (B. O'Riordan, Personal Communication, 2019, January 15). This yearly income is sufficient to cover most expenses of the orphanage such as food, medicine, education, salaries, and utilities.

There are seven houses for children in two separate villages, Don Wai and Pi Si Thong, that are 2 kilometers apart as seen in Figure 3. The houses are divided based on age and gender except for the House of Hope for toddlers, where both boys and girls reside (Sarnelli House, 2018). The village of Don Wai includes Sarnelli House, Nazareth House, Our Lady of Refuge Home, the Gary and Janet Smith House, volunteer houses and the office building while the village of Pi Si Thong includes St Patrick's Boys Home, Jan and Oscar House, and House of Hope (ibid.).

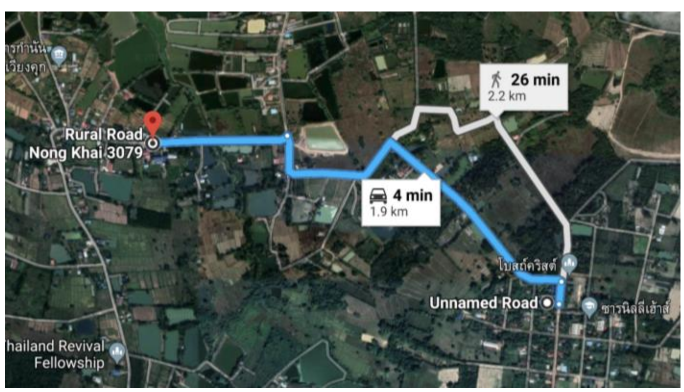

Figure 3: *The distance between Pi Si Thong village (17°46'41.2"N 102°41'15.7"E) and Don Wai village (17°46'24.3"N 102°42'01.0"E to). Reprinted from Google Maps, 2019*

Sarnelli House first began in the village of Don Wai. Initially, they did not have electricity but received power from a monastery nearby. Eventually, the orphanage was fortunate enough to receive electricity from the main power line that the government installed. Since the PEA did not initially install this electrical grid, the wiring and connections are unreliable and not secure. This poor wiring system increases the chances of the community not having power. Whenever a disturbance occurs to these wires connected to the main power lines, it affects the power connection for the entire community, causing the whole village to lose power.

Sarnelli House lacks a reliable energy source and experiences sporadic power disruptions affecting their daily activities. The electrical distribution in both Don Wai and Pi Si Thong have not been well-maintained causing disruptions to occur easily. We investigated renewable energy options that could help reduce their electricity costs and potentially solve this problem.

3. Methodology

In this chapter, we have outlined the steps our team took throughout our project to help us meet our three objectives:

1) Investigate current costs, energy requirements and challenges at Sarnelli House.
2) Collect and characterize information regarding reliable and feasible energy sources.
3) Identify energy alternatives that would be most beneficial to Sarnelli House.

To accomplish these objectives, we conducted a series of interviews and a focus group, as well as considered all observations made. These methods allowed us to complete an assessment of various stakeholders associated with Sarnelli House. We then analyzed the data collected from our fieldwork to prepare graphs, charts, tables and other deliverables that were useful in completing our objectives. We elaborate on the descriptions of our research methods to accomplish these objectives below.

3.1 Investigate Current Energy Consumption

To better understand how to lower costs and resolve the energy issues at the orphanage, we investigated questions regarding how much energy they require, their current energy source, their current average cost for electricity, how frequently they experience power outages, and their average duration without power. We asked Sarnelli House for a copy of their electric bill from the past year to see how much energy they consume and the average cost. We then requested the Provincial Electricity Authority (PEA), Sarnelli House's electrical provider, for documentation of all power outages that occurred in the previous year. This data includes when the power outages occurred, how long they lasted, and what caused it. We monitored the routines of the children and staff on an average day to determine an estimate of their daily electrical consumption. We prioritized these actions according to necessities and leisure activities. We analyzed any actions that led to overconsumption of electricity and created an infographic to help minimize overconsumption.

We obtained information regarding alternative energy and the orphanage by interviewing key stakeholders and conducting focus groups within the Sarnelli community. During our site visit, we interviewed Father Michael Shea, the founder of Sarnelli House, Father Ole, the assistant director, Kate Introna, the volunteer coordinator and health advisor, Brain O'Riordan, the fundraising coordinator, Ms. Wimon Thammawong, the general manager, Mr. Wittawat Savangnam, the orphanage's handyman, and representatives from the PEA of Nong Khai. Interviewing these primary and secondary stakeholders provided specific information about the sponsor, previous energy alternatives implemented in Thailand, and an understanding of why this problem happens. We gained insight from these interviews that impacted the direction of the project.

We designed the interviews for each specific interviewee and their area of expertise or experience. The format consisted of semi-structured open-ended questions that allowed elaboration of responses. The team translated these questions into Thai and conducted the appropriate interviews in Thai. The interview questions are in Appendix B.

As well as interviewing these stakeholders, the team conducted a focus group during our visit to Sarnelli House to evaluate the current energy challenges from the perspectives of a different audience. We completed this focus group with six middle school girls who volunteered to give us more information about their experience of the energy disruptions. During the focus group, we thanked everyone in attendance and gave a brief overview of why we were there and what we planned to accomplish. We then discussed their daily tasks and what they do when they are without power. The team translated questions and responses to both Thai and English to help us understand the views of the attendees. The questions asked during the focus group are in Appendix B.

3.2 Collect Reliable and Feasible Energy Sources

After gaining an understanding of the problem, we looked into possible solutions. We researched five sources of renewable energy: solar, wind, biomass, hydroelectric and geothermal. We describe this research in the background chapter. Appendix A contains a table outlining the data we found for each energy source.

To better understand how Thailand currently uses renewable energy, we conducted interviews with experts, each differently related to the issue of energy. We spoke with Dr. Suthee Traivivatana, a researcher in the Energy Research Institute at Chulalongkorn University. The purpose of this interview was to understand the advantages and disadvantages of feasible renewable energy options in Thailand. We then interviewed a representative from the Foundation For Children (FFC), an orphanage using renewable energy in Nakhon Pathom.

During our site visit, we toured the orphanage and made observations to gain an understanding of the infrastructure and layout of the various buildings that make up Sarnelli House. We identified structures that would be suitable for renewable energy installations as well as the distance between Don Wai and Pi Si Thong. We surveyed the site to identify surroundings such as plains, rivers and agricultural lands. Previously mentioned interviews also provided this data.

An assessment of the local climate also helped to accomplish this objective. The average number of days Nong Khai experiences sunshine, rain, cloud cover, wind speeds as well as the average temperatures throughout each month were determined. We assessed the climate through observations of the environment while we were on site as well as by collecting archived data regarding Thailand. We used information from the Thai Meteorological Department to determine the most efficient energy sources for this region. With all the information gathered, we organized Table 4, found in the Results (Chapter 4), to show which alternatives are viable options.

3.3 Determination of the Most Beneficial Energy Alternatives

The third and final objective required further research on specific products that provide energy. After collecting data from our visit to Sarnelli House, we contacted, via phone and electronic correspondence, companies that provide systems we believed to be viable options for our sponsor. The companies asked us for information regarding the surface area, equipment in the house that use electricity, number of watts used per equipment per house, how long equipment is in use in the house each day, etc. This information had to be categorized and sent to renewable energy companies to receive quotes and suggestions for implementation. Once we evaluated the products that these companies provided, we created a table and compared the prices for each company, found in Appendix E. We then explored the effect of combining these products in different ways to improve the overall outcome.

After completing our fieldwork, we performed an analysis on our data. Our data analysis consisted of translating, transcribing, and coding all interviews and the focus group, then grouping similar themes found in these discussions. We organized tables and charts that were beneficial in understanding which alternative energy sources will be both feasible and favorable and which will not. The visuals also aided in limiting the effects of the language barrier. This data analysis allowed us to draw conclusions and to make final recommendations to our sponsor.

4. Results

In this chapter, we will present and discuss key findings from our methods. We have summarized these findings in the table below.

Table 2: *The findings that correspond to the team's objectives.*

Objective	Findings
Investigate current energy costs, requirements and challenges	• Poor wiring, weather, and other uncontrollable factors cause the power outages • The power restoration process entails replacing a fuse • Sarnelli House has a greater need for electricity in certain buildings
Collect and characterize energy alternatives	• Solar energy is a favorable energy alternative
Identify the most beneficial energy alternatives	• Sarnelli House prioritizes reducing electricity costs
Other Findings	• Sarnelli House values educating its residents about sustainability • Solar panel system specifications

4.1 Energy Requirements and Challenges

Our first objective was to investigate the current costs, requirements, consumption, and challenges of electricity at Sarnelli House. Accomplishing this gave us insight on why power outages occur, the restoration process, and why Sarnelli House needs reliable electricity.

Finding 1: Poor wiring, weather, and other uncontrollable factors cause power outages.

Since Sarnelli House resides in the outskirts of Nong Khai, the electrical systems lack proper installation which can lead to failure of equipment such as transformers and electrical wires. The wiring system dramatically affects power outages at Sarnelli House. There are two types of overhead power lines, insulated and non-insulated, that transmit electricity long distances (PEA Representatives, Personal Communication, January 16th, 2019). Sarnelli House currently uses non-insulated wiring according to the PEA which leads to more frequent disruptions (ibid.). The PEA could prevent some of the power disruptions by updating the local power lines to an insulated cable, however, this is costly, and not seen as a good investment due to low energy demand in the neighborhood (ibid.).

Extreme weather events, such as lightning strikes, high winds, and heavy rain, strain the electric power systems (Kezunovic, 2019). During Nong Khai's rainy season from May to October, the weather is a catalyst for power outages. Our interviews and focus group responses confirmed that power outages occur most frequently during this time of the year.

From a record obtained from the PEA representative team, given in Figure 4, six main factors caused the power disruptions including animals, trees, equipment failure, scheduled maintenance and other. Electrical poles that connect each grid sometimes get disturbed by trees growing around electrical poles. The PEA spends almost 10 million THB per year in Nong Khai cutting down all trees growing on electrical poles and power lines in both public and private areas.

The PEA plans some disruptions, turning off the electrical transmission to do maintenance of the electrical system. Lastly, car accidents, construction, and unintentional events cause power outages as well. We collected this data from representatives of the Provincial Electricity Authority (PEA) of Nong Khai.

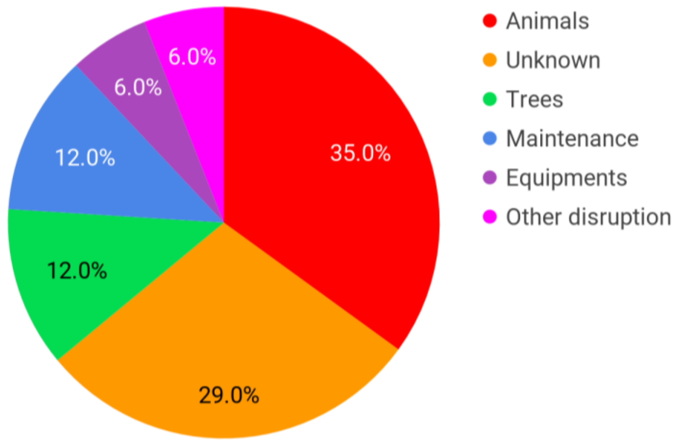

Figure 4: *Causes of the power disruptions at Sarnelli House in 2018. Reprinted from PEA presentation.*

Finding 2: The PEA replaces a fuse after receiving a phone call and then restores the power.

Sarnelli House is usually first to notify the PEA of any energy disruptions due to the number of children under their care. The PEA can usually restore power within a few hours. When informed that the power is out, the PEA sends a representative to investigate the main line. To fix the cables, they have to cut the electricity off to prevent further damage from the high voltage electricity. A dropout fuse protects the transmission system and is an expulsion-type fuse, commonly used in rural distribution networks. When the fuse blows, the resistor hangs down vertically from the bottom contact and allows for easy location of the problem area (Zoom AutoTech, 2019). A dropout fuse operates once; however, if the voltage is too high and the transformer does blow, it will require replacement as well (ibid.).

To change the bare-conductor wiring system into the insulated system requires significant investment. Since the area around Sarnelli House is small villages, they consume very little power. The PEA does not charge some households due to a policy stating houses that use electricity with the “2 wires single phase system not over than 5-amp 220 volt in 3 consecutive months”, will not be charged for electricity costs in the following month (Provincial Electricity Authority, 2015). Therefore, the PEA believes the investment to update all electrical wires to cables is not worth the returned profit from the electricity users (Personal Communication, January 16, 2019).

Finding 3: Sarnelli House has a greater need for electricity in certain buildings.

To understand the electrical usage at Sarnelli House, Brian O'Riordan, the fundraising chairman, compiled a spreadsheet with the estimated energy costs for each house at the orphanage from 2013 to 2018. Refer to Appendix C to view this spreadsheet. This data, along with our observations during our visit, showed us that some houses use significantly more electricity than others, and only a few houses consume energy during the daytime. These include the farm, office building and House of Hope. Table 3 summarizes each house’s electricity usage.

Table 3: *Summary of electricity usage per house based on 2018 data.*

House	Electricity Usage (kWh Per Day)	Electricity Cost (THB per Year)	Electricity used during the:	
			Day	Night
Office	21	105,063	✓	
St Patrick's Boys Home	10	76,843		✓
Sarnelli House for Boys	33	105,942		✓
Our Lady of Refuge	27	71,528		✓
House of Hope	36	76,844	✓	✓
Nazareth Girls Home	54	123,059		✓
Jan and Oscar	31	76,845		✓
Farm	25	108,644	✓	✓
Guest House	52	105,059	✓	✓
Gary and Janet	11	36,320		✓

Once we received the spreadsheet including electrical costs, we needed to quantify it in terms of kWh used per house. With the data from Sarnelli House combined with the price per kWh from the PEA, we estimated the number of kWh used in Sarnelli House per building. For these calculations, we assumed normal activity throughout the year. Refer to Appendix G to see the calculations. The PEA breakdown of cost per kWh is in Appendix D. We also discovered that the Sarnelli House prioritizes having running water and refrigerators, then all other electronic components and that the eleven water pumps on site account for a large portion of electricity consumption (Personal Communication, February 6, 2019).

4.2 Alternative Energy Sources

Our second objective was to collect information on alternative energy sources that Sarnelli House could use. We researched solar, wind, biomass, hydroelectric, and geothermal energy. However, after visiting the orphanage, we saw solar energy was the only feasible source.

Finding 4: Solar energy is the only feasible energy alternative for Sarnelli House.

During our visit to Sarnelli House, we investigated the site, observed the available resources, and interviewed related stakeholders to find which sources would be favorable. Table 4 shows the results of this investigation of each renewable energy source.

Table 4: *Results of investigation of each type of renewable energy.*

Renewable Energy Source	Characteristics to Look for	Observations
Biofuel	Agricultural areas, breeding grounds, metabolic byproducts	Agricultural areas and livestock, however, all wastes are used
Geothermal energy	Steam sources, hot brine sources, hot dry rocks	Unable to determine due to testing costs
Hydropower	Large water sources nearby	No flowing water source nearby
Solar energy	Vast plain areas, open unobscured rooftops (for solar cells installation), significant and consistent sunlight	Plenty of sunshine, several potential rooftops, and unoccupied surface area
Wind power	Areas with proper ventilation, moderate wind flow	Wind speed is insufficient

Sarnelli House has a total area of 104,000 square meters for agriculture including the cultivation of rice and raising animals such as pigs, cows, ducks, and fish. Animal waste management is wellestablished at Sarnelli House. According to Ms. Wimon Thammawong (General Manager), they use animal manure as fertilizers for the rice fields and food for fish (Personal Communication, January 16th, 2019). Animal wastes are often an input to produce energy; however, biomass energy is not feasible at Sarnelli House due to efficient utilization of the entire amount of biowaste produced.

Small scale wind power plants require a minimum average wind speeds of 4 m/s (10 mph) while utility-scale wind power plants require a minimum of 6 m/s (13 mph) (Thai Meteorological Department, 2019). According to Wind Energy Data Analysis of Nong Khai from 2012 to 2015, the annual wind speeds at the heights of 60, 90, and 120 meters were 2.84, 3.41, and 3.96 m/s, respectively. For a wind turbine to be efficient, the location must have an adequate supply of wind; therefore, wind energy is not feasible to implement in the Nong Khai area.

Harnessing the power of water is the cheapest form of energy, but environmental and other concerns cast doubts on its worth (Kindersley, 2009). Hydroelectric energy requires falling water to convert mechanical energy into electrical energy throughout its process, yet, Sarnelli House does not have a flowing water source, making hydropower production impossible.

Regarding geothermal energy, the most obvious and widely publicized barrier is cost, specifically the capital costs of digging through the Earth’s crust, installing heat pumps, and building a cooling tower. The construction of geothermal power plants should be in specific areas and require testing to determine if the land is a good site. Therefore, geothermal energy is not suitable for Sarnelli House.

Nong Khai currently uses the benefit of sunlight to convert solar energy into electricity and to use solar radiation directly. Two main variables affect the amount of solar energy delivered to every part of the world: the sun’s rays inclination at the specific geographical point and thickness of the atmosphere between the specific point and the sun (Gonzlez, 2005). Table 5 shows the average solar insolation, the amount of electromagnetic energy incident on the surface of the earth, in Thailand and its neighbor countries.

Table 5: *Average solar insolation per day in Asian countries. Reprinted from Shukla, 2017.*

Country	Average solar insolation ($kWh/m^2/day$)
Thailand	5.0 - 5.3
Laos	3.6 - 5.5
Myanmar	5.0
Indonesia	4.8
Cambodia	5.0

The climate in Nong Khai is tropical with an average of 13 hours of daylight from April to August (Weather Atlas, 2018). The number of hours that the sun is perpendicular to the earth's surface is the greatest during summer. According to the PEA, Nong Khai receives the highest solar radiation among other provinces in Northeast Thailand (Personal Communication, January 16th, 2019). Solar energy can be both small-scale, for personal use, and large-scale for business use. With a long lifespan and good durability of the photovoltaic system, solar power is the most suitable and feasible alternative energy option for Sarnelli House.

4.3 Feasible Energy Alternatives

After gaining a deeper understanding of the electrical situation at Sarnelli House, we then assessed what energy alternatives would be practical to implement. This required observations of the climate and grounds as well as detailed research on the characteristics of the viable options.

Finding 5: Sarnelli House prioritizes reducing electricity costs.

After speaking with our sponsor and seeing the orphanage, we found that they saw the power disruptions as an inconvenience, but the more pressing problem was a high electricity bill. Reducing energy costs is imperative as Sarnelli House does not have a steady income. Financially, the organization keeps afloat through 90 percent international funding, mostly from the United States and Germany (Personal Communication, January 15th, 2019).

Most of the energy usage in Sarnelli House happens in the evening when the children return from school and complete activities such as cooking, showering, and homework. During the visit, the team observed that there are many fans turned on all day long in the majority of the houses. The girls living at The Lady of Refuge building currently leave the light of the bathroom on during the night since they are afraid of the dark. The properties also have many privately-owned light posts outdoors that run continuously throughout the night.

Solar panels have a substantial upfront cost but will help to lower costs for Sarnelli House. However, there are many components to consider including the installation of equipment and connecting the system to the grid. As implementing solar panels is a substantial investment, if Sarnelli House were to install a solar array, they would require a sponsor or partner. To address this, we considered small-scale and large-scale solutions that could help reduce energy costs and provide relief during power outages.

4.4 Other Findings

Throughout our research, the team discovered two other key findings that did not fit into our objectives. These additional findings are below.

Finding 6: Sarnelli House values educating its residents about sustainability.

During our visit to Sarnelli House, our team conducted interviews and a focus group that gave insight into the desire for sustainability education. In the interview with Kate Introna, the volunteer coordinator and health advisor, said: “for me, going greener and being more energy conscious, aware of the planet, and educating our kids about that too is a huge mission” (January 15th, 2019). Currently, the children at Sarnelli House do not learn about sustainability or how their actions affect the world at school.

Sarnelli House has recently begun to take the initiative to become more sustainable. They started to separate waste, and Sarnelli House received a donation of LED light bulbs that are more energy efficient. We learned from the focus group with the middle school girls that they do not know about “going green” and “clean energy” but will learn about it soon in school (Personal Communication, January 15th, 2019).

Finding 7: Solar Panel System Specifications

When researching solar panels, the team needed to consider several aspects including types, systems, and components of solar panels. There are a variety of types of solar panels; however, the most common two are monocrystalline and polycrystalline. Monocrystalline solar panels have the highest efficiency rate of approximately 85 percent, are made of high-grade silicone, have higher efficiency in warm weathers, have a greater lifespan than other panels, and perform better in low light conditions making them useful during the rainy season (Solaris Green Energy Company, n.d.). On the other hand, polycrystalline panels are characterized by having lower efficiency of 70 percent, have a lower heat tolerance, and are less space-efficient than monocrystalline solar panels (Aarre Maehlum, n.d.). Even though polycrystalline panels are less expensive than monocrystalline panels, there are more positive aspects that outweigh the negative ones for monocrystalline panels.

Companies sell solar panel systems based on the amount of power they can produce over a period of time during peak hours. Even though we received a spreadsheet with the price that Sarnelli House spend every year, we had to calculate how much energy each house consumes. We took the number of appliances in each house and estimated the hours of energy consumption. To obtain an accurate estimation of the energy consumption of these devices, we had to account for the operating power. The operating power is the power required to keep the equipment on, but it is significantly lower than the initial start-up power. To account for this, we divided the total time of operation by 4, giving us the most accurate number of daily energy consumption per building.

The smallest system you can purchase is a 5 kW system, then the rest of the systems start at 10 kW and increase by increments of 10 kW (Amorn Electronics, 2019). The amount of energy produced by these systems depends on the number of peak sunlight hours there is that day (ibid.). On average, Nong Khai receives about five peak hours of sunlight per day, so running a 5 kW system will produce 25 kWh a day if the system is 100 percent efficient. Unfortunately, these systems typically perform at 85 percent efficiency, so it will only produce about 21 kWh. The solar system will never reach this maximum energy production due to power dissipation and solar panel efficiency. The efficiency of the system decreases about every five years, and after 25 years, the system needs to be replaced.

These systems can operate either with or without a battery. Installing a battery with the system can become quite expensive since the customer must purchase a large number of batteries and replace them about every three years (Electric Industries & Equipment Club Limited, 2019).

During our solar panel research, we received quotes from Amorn Electronic Center Spare Co., Ltd which we used to make calculations and assumptions. The quotes, which are in Appendix F, consist of 5 kW and 10 kW systems both with and without batteries. These quotes included the price of solar panels, components such as inverters and batteries, and installation cost. Based on the given rates, we estimated larger and smaller scale solar systems that would fit the needs at Sarnelli House.

5. Conclusions and Recommendations

In this section, we discuss our recommendations and deliverables for Sarnelli House. Our deliverables include a booklet of our large- and small-scale recommendations, as well as educational infographics for distribution throughout Sarnelli House. The infographics touch on the topics of how a solar panel system works, how to reduce energy consumption, and the 5 R's that ensure sustainability. These deliverables are in the supporting documentation attached to this report. We developed these to encompass the goals of reducing their electricity cost, providing reliable energy, and educating the children about sustainability.

5.1 Large-scale Recommendations

The following recommendations aim to solve current power issues on a large-scale and will require a substantial investment. With these alternative energy options, Sarnelli House will have sustainable energy, reliable power, and lower their electricity costs.

We recommend Sarnelli House installs solar panels

For Sarnelli House to simultaneously lower their electricity costs and have reliable power, we believe installing an array of solar panels will be the best option. Below, we have briefly discussed our recommendations for the four scenarios we think would be most beneficial as well as the requirements to run entirely on solar energy. For further data supporting these recommendations, please refer to Appendix H.

The four recommendations below include monocrystalline solar panels of high wattages to be installations. High wattage solar panels have a wattage above 300 W. For example, we investigated a 350 W monocrystalline panel that would be applicable to Sarnelli House. Installing solar panels of high wattages instead of panels with lower wattages allows Sarnelli House to decrease the number of panels required to cover their electricity needs and reduce the installation cost.

5 kW solar panel system for the farm

To begin implementing solar energy as an alternative energy source, our sponsor wanted to use the farm as a pilot. In 2018, the farm consumed 108,644 THB (USD 3,480) worth of electricity. The three water pumps used at the farm each require 3,000W to operate. Two of these pumps consume energy to pump water for about 4 hours a day, while the other consumes 2 hours of electricity. This amount of water pumping causes a total consumption of 26,000Wh a day. One pump is for the cattle on nine rai (3.5 acres) of land, and the other two pumps are for the piggery and Gary and Janet house on 70 rai (27.7 acres) of land. Since the water pumps are in use mostly during the day, we do not recommend installing a battery.

Based on our calculations, we recommend the installation of a 5 kW solar panel system at the farm. This system would accommodate for 84 percent coverage of the 25 kWh consumed daily. The cost of this system, including installation, will be approximately 300,000 THB (USD 9,600). This system will save Sarnelli House 62,000 THB per year. The return on investment period would be approximately five years.

Solar panel system in Pi Si Thong with and without batteries

House of Hope is the only house at the orphanage where children regularly stay home all day and use electricity. In 2018, the houses in Pi Si Thong, the Jan and Oscar House, St. Patrick's

House, and House of Hope, consumed 230,532 THB (USD 7,380) worth of electricity. The equipment that requires the most electricity are water pumps, refrigerators, and lights. With the addition of other appliances, they consume an average of 77 kWh daily. We believe that implementing solar panels would help reduce their electricity bill by saving 62,000 THB (USD 1,990) per year. The return on investment period for this project would be five years.

Since this village cares for the youngest children staying at Sarnelli House, the power outages impact them the most without emergency lights or running water. We investigated how much it would cost to provide Pi Si Thong with both solar panels and a battery so they could still have power during the disruptions. If Sarnelli House implements a battery, we recommend installing a 10 kW system so solar energy is available throughout the night. Based on the quote that we received from Amorn Electronic Company Limited, the total cost for Sarnelli House to install a 10 kW system with batteries throughout Pi Si Thong will cost 137,440 THB (USD 4,400) and would cover 55 percent of the total electricity cost. To cover the total electricity cost of Pi Si Thong, they would need to implement a 20 kW system with batteries. Although this solar panel system would cost double the price of the 10 kW system at 1,092,880 THB (USD 34,940), Sarnelli House would still have an 11-year return on investment. The price includes the cost of replacing the batteries every three years, during the duration of the system's lifespan.

5 kW solar panel system at the office and guest house

Sarnelli House would benefit from installing solar panels at their office building and the guest house since they both consume electricity throughout the day. In 2018, the cost of electricity for these locations combined was 210,122 THB (USD 6,730) with an approximate consumption of 73 kWh per day. Computers, water pumps, air conditioners, and refrigerators consume the majority of this electricity. We recommend installing a 5 kW solar panel system. This system would account for about 29 percent coverage of the two building's electricity use and save them approximately 62,000 THB (USD 1,985) per year. With these savings, the return on investment would be five years.

10 kW solar panel system for the water pumps at Sarnelli House

After a follow-up phone call with Mr. O'Riordan and Ms. Introna, we learned that having running water was the priority for Sarnelli House. After referring to our table of wattages for each house, we learned that the water pumps account for a significant amount of electricity consumption. This large amount of use is a result of washing clothes, taking showers, flushing toilets, cooking, and other needs for clean water in each building. There is a total of 11 water pumps at the Sarnelli complex, and each pump operates for a different amount of time, totaling in overall consumption of about 65 kWh a day. To accommodate for this energy consumption, we recommend Sarnelli House install a 10 kW solar panel system, resulting in a cost of approximately 600,000 THB (USD 19,200). At this cost, they would save 124,000 THB (USD 3,970) a year, and they would receive a return on investment after five years.

Other Options

Sarnelli House can implement a solar energy system throughout the entire Sarnelli House, but we do not advise that they implement this option at this time. This system would require a substantial investment and would take a long time to implement. The PEA provides them with reliable energy 95 percent of the time at a standard price; therefore, it would be best for Sarnelli

House to implement systems that will help reduce the electricity cost that they can expand upon in the future.

Installing solar panels for the entire Sarnelli House Complex

To become solely dependent on solar energy, we calculated that Sarnelli House would need to implement an 80 kW solar panel system with batteries. This system would cost approximately 17,000,000 THB (USD 543,3608) to purchase, install, and replace the batteries every three years, and the return on investment would be 17 years.

Although this would solve the issues of unreliable power and a high electric bill, this would be a significant investment and would take time to implement. Sarnelli House would need a sponsor or investor for this project and should know that this would take sixth months to a year to implement. At this time, we do not recommend this option to Sarnelli House. Other options we have put forward have a shorter return on investment and are steps in the right direction. Installing solar panels is a long-term goal for Sarnelli House if they want to be completely off-grid. Shown in Table 6 is a summary of the above recommendations.

Table 6: *Summary of recommendation characteristics*

Locations	Suggested system	Electricity cost in 2018 (THB)	Investment (THB)	Saving cost (THB/year)	Return on investment (years)
Farm	5 kW system	108,644	300,000	62,000	5
Pi Si Thong	5 kW system	230,532	300,000	62,000	5
	10 kW system with batteries		1,374,400	124,000	11
Office & Guest House	5 kW system	210,122	300,000	60,500	5
Water pumps	10 kW system	439,539	600,000	124,000	5
Entire complex	80 kW system	866,147	17,000,000	886,147	17

5.2 Small Scale Recommendations

While the following recommendations will not address all of the issues related to energy at Sarnelli House, they are steps to address consistent problems they face. These recommendations will provide results until long-term solutions can be implemented and will supplement the installation of long-term solutions later.

We recommend that Sarnelli House use solar powered appliances

Implementing solar appliances throughout Sarnelli House will be a step towards sustainability, lower costs, and alleviate some inconveniences of the power outages. We recommend solar lamps, fans, and motion sensor outdoor lighting. For the detailed recommendations, refer to Appendix H.

Solar Lamps

Solar powered lamps are a simple way to provide light at any time. These could be used as emergency lights during power disruptions, or simply as a night light for children afraid of the dark. If solar charging is unavailable, many come with the option to charge via USB port as well. We found the average cost to be 765 THB (USD 25) per unit and the potential savings will depend on how Sarnelli House chooses to use them.

Solar Fans

Solar fans can provide much-needed cooling without raising the electric bill. While not the largest appliance, fans are among the most numerous and commonly used appliances at Sarnelli House. We estimate Sarnelli House spent 78,000 THB (USD 2,500) on running fans in 2018. Solar fans can run for 5 hours before needing to be charged and cost approximately 4,450 THB (USD 143) depending on size and features such as lights.

Solar Motion Sensor Outdoor Lights

These are both powered by a renewable source and only turn on when movement is detected. Sarnelli House uses private lamp posts as a safety precaution during the night, however continuously running these lights overnight uses additional electricity. These lights could be lamp posts like Sarnelli House currently uses or smaller lights that adhere to a wall. These smaller lights cost approximately 850 THB (USD 28) while the larger lamp posts average cost is 2,500 THB (USD 80). These products could potentially save Sarnelli House around 100,000 THB (USD 3,200) on unnecessary electric costs.

5.3 Educational Recommendations

As seen in Finding 6 (Chapter 4), Sarnelli House staff has begun to take the initiative to be more sustainable. To continue this, the children must learn about energy and the environment.

We recommend Sarnelli House capitalize on solar energy.

If Sarnelli House installs solar panels, specifically without a battery, we recommend they encourage the children and staff to take advantage of that energy. The solar panels will be functional only during the five peak hours of sunlight when the sun is in contact with their surfaces. Therefore, Sarnelli House should perform and complete any activities that draw electricity during peak solar hours. For example, cooking meals, washing clothes, and children's showers should occur during peak hours to maximize the use of solar energy.

We recommend Sarnelli House use infographics to educate the residents and staff on energy.

We recommend the placement of infographics throughout Sarnelli House to educate residents and staff on solar energy, energy consumption, and sustainability. We have designed a series of three infographics for Sarnelli House to place throughout the houses. These provide basic information on what solar energy is, minimizing electricity waste, and sustainability. The use of these infographics will involve the children in our project and will give them the knowledge they would not have obtained on their own. Please refer to the supporting document attached to this paper to see these infographics.

Solar Energy to Electrical Energy

This infographic explains what solar energy is, how a solar cell works, and the advantages of using solar energy. This infographic uses basic terms so that everyone at Sarnelli House can understand the message that we are attempting to convey.

How to Save Energy Every Day

This infographic contains tips on how to reduce energy consumption every day to be placed throughout each house. This infographic will be a daily reminder of how to minimize electricity and water usage. By following this infographic, Sarnelli House can expect a 5 - 10 percent reduction in their electricity bill.

The 5 Rs

The final infographic touches on sustainability. Our team's concern is not only about renewable energy but also want residents of the Sarnelli House to reduce waste and energy. This infographic provides a simple explanation of the five main phrases that accomplish this concern: reduce, reuse, recycle, repair, and reject.

5.4 Conclusions

The goal of this project was to gain an understanding of why power disruptions occur at Sarnelli House and make recommendations of alternative energy options that would both provide reliable power and lower their electricity costs.

5.4.1 Summary of findings

Poor wiring, weather, and other uncontrollable factors cause power outages to occur as the wires used by Sarnelli House are non-insulated. The PEA is unwilling to replace the non-insulated wiring system with insulated cables as they do not believe it is worth the investment due to low energy demand in the area. When the power does go out, Sarnelli House notifies the PEA, and they usually restore the power within a few hours. This process typically involves replacing the dropout fuse and the transformer if the voltage is high enough to blow the transformer. We also learned that each house uses electricity at different times during the day and that the water pumps are the highest priority to have running, then refrigerators, then other appliances. After our site visit, we discovered that solar energy is the only feasible energy alternative for Sarnelli House. The requirements for biomass, geothermal, hydroelectric, and wind power are not available at Sarnelli House. Power disruptions are an inconvenience but reducing their electricity bill is a higher priority. Sarnelli House does not have a steady income and operates through outside funding. Our sponsor values educating the residents about sustainability as well as lowering costs. They want this project to provide a learning opportunity for the children in the orphanage.

5.4.2 Limitations

A significant limitation we encountered during our research was contacting solar panel companies. Most solar energy company representatives would not provide a cost estimate for solar panels, equipment, batteries, and installation cost. Attempting to obtain quotes from multiple companies was a time-consuming process. According to some company policies, this information could not be shared with the public as it is confidential data that requires protection from competitors.

We could only calculate the solar panel and equipment cost using the prices we received from the solar companies that were willing to provide quotes. We based our calculations of costs assuming regular electric activity throughout the year, our estimation of total kWh consumed last year based on the charge and cost breakdown from the PEA, and our estimations of the use of specific equipment in each house. Since we are not the direct buyer, we were only able to receive two quotes and package deals for purchasing a full system, one for 5 kW and one for 10 kW. Both were for polycrystalline panels, even though we recommended monocrystalline panels due to its higher efficiency. Sarnelli House should expect to receive different quotes once they provide specific information directly to the company. It is essential to understand and reduce where biases and knowledge gaps could affect our results. Due to the specific nature of this project, we cannot assume that this validity extends beyond Sarnelli House.

5.4.3 Concluding remarks

The goal of this project was to make recommendations of alternative energy options to Sarnelli House that would both provide reliable power and lower their electricity costs. We accomplished this, offering four options to install solar systems in various locations. The team had limitations including contacting solar panel companies, obtaining specific quotes, and working with estimations. However, even with these limitations we still accomplished to gather feasible options to implement renewable energy throughout Sarnelli House.

Our project went further than we initially anticipated by bringing in a small educational aspect. It was important to our team and our sponsor to include the children in some way. Teaching the children about sustainability through our infographics will not only contribute to lowering electricity cost by minimizing waste but will hopefully help them understand that they can have an impact on their community. We were able to present these infographics to them through a small interactive exercise.

We understand that in Thailand, and throughout the world, inexpensive and reliable power is not always attainable. We hope that this project can be a small effort toward resolving this issue at Sarnelli House.

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Appendices

Appendix A: Renewable Sources Research Table

	Energy Types				
Aspects	**Solar**	**Biomass**	**Wind**	**Hydroelectric**	**Geothermal**
Cost	-Average home system Cost: $15,000 for 4kW (Sunrun, 2018) - Dlight systems range from $12 for a solar lantern to $325 for a solar lgiht system (Goldman, 2008)	- Average Construction Cost: $2,198 per KiloWatt Capacity-Weighted Average Cost (U.S. Energy Information Administration, 2018) - Total Construction Cost: $0.2 billion (idid.)	- For China/India (since they are closer to Thailand) installment cost for an onshore wind turbine range from $1300 to 1450 USD per kW. (Gielen, 2016) - 64% to 84% of on shore cost is the actual turbine, grid connection, construction, and other cost make up the rest of the balance. (ibid.) - Overall cost expextected to reduce by 8% to 10% (ibid.) - Mall turbines in Asia cost between 1500 to 3000/kW ibid.()	- $200-$500 per kW, "entire MICROHYDRO system cost less than 1500 USD (Pascal, 2007) - Average costs - "A small power plant can cost between $1,000 and $20,000, depending on the site location and the electricity requirements. Plus, even though there are maintenance costs, these tend to be a lot smaller compared to other technologies." (Turbulent, 2018)	- "$0,10 – $0,20/kWh depending on geology and the size of the installation" (Richter, 2016)
Storage	- Solar energy is stored in batteries usually around 10kWh can be held in a battery(Energysage, 2018) - Wide range of storage	- Total capacity: 81 MW at New Plants (U.S. Energy Information Administration, 2018) - "The use of 1 EJ of unconverted biomass in a BECCS power plant results in around 0.3 EJ of electricity" (Aalbers & Bollen, 2017) - "The storage of 0.9 billion tonnes of CO2 allows the use of fossil fuels and resources in the petrochemical industry to increase by 0.7-1.1 EJ, respectively" (ibid.) - "In total, using 1 EJ of biomass in BECCS power plants, results in 1.0-1.4 EJ of energy." (ibid.)	- For a wind turbine w/ the generator size 3 MW, rotor of 90 m, and hub height of 80 m, the anual production is 7089 MWh (Gielen, 2016) - On shore turbines start generating electricity at 3 to 5 m/s and reach maximum power at 15 m/s (ibid.) - Small turbines are any turbine with a capacity <= 100W (ibid.) - Low towers have low capacity factors, but operate well in areas with low wind speed. (ibid.) - China/india account for 33% of the global instalment of wind turbines producing 78.4 MW (ibid.)	- Requires generator, - Microhydro = up to 100kW of power. " As a general rule, there are 9.8 kW available from each cubic meter per second of water falling through 1 meter. The greater the drop, or "head," the lesser the flow of water required to achieve the same electricity" (Pascal, 2007). - In general- output is limited depending on water flow (Turbulent, 2018)	- Energy is constant, minigeo is working on systems from 100 kW up to 1MW (Richter, 2016) . - Wells are drilled, steam turns turbine, turbine drives an electric generator, sixe of generator dictates storage capacity (Office of Energy Efficiency and Renewable Energy, 2018).
Environmental Impact	- "The potential environmental impacts associated with solar power - Land use and habitat loss, water use, and the use of hazardous materials in manufacturing - Can vary greatly depending on the technology, which includes two broad categories: photovoltaic (PV) solar cells or concentrating solar thermal plants (CSP)."(Union of Concerned Scientists, 2018)	- "If the application of biomass in power plants were to increase the underground storage of CO2, this may affect public safety" (Aalbers & Bollen, 2017) - "The simplest way of accommodating those concerns is to prohibit CO2 storage on land" (ibid.)	- Reducenoise and vibration levels, but at the expense of lower efficiency (Nextera Energy, 2018) - Due to ignorance people believe that they suffer symptoms from the wind energy being implemented, but lack evidence to prove so. (ibid.) - Improves air quality which reduces asthma and other breathing related illnesses. (ibid.) - Mechanical sound indistinguishable from natural nature sounds. (ibid.)	- Changes river patterns, affects ecosystem of river (Pascal, 2007)	- Holes must be drilled into the earth but doesn't require fuel and emits almost no CO2 (Richter, 2016)
Resources Available	- Enough sunshine to power solar photovoltaic systems and enough to be stored when the sun is not out	- Biomass and their uses: Wood and wood processing wastes—burned to heat buildings, to produce process heat in industry, and to generate electricity Agricultural crops and waste materials—burned as a fuel or converted to liquid biofuels Food, yard, and wood waste in garbage—burned to generate electricity in power plants or converted to biogas in landfills Animal manure and human sewage—converted to biogas, which can be burned as a fuel (U.S. Energy Information Administration, 2018)	- Enough wind to power the turbine is all that is necessary in order to provide energy (Gielen, 2016) - A five fold increase in height can double wind power production. (ibid.) - Cooler climates provide more energy (Nextera Energy, 2018) - Can compliment solar photovoltaic systems in off grid systems.	- Mekong river is nearby - will run into legal obsticals	- While the Earth's heat is always there, the temperature gradient from the must be 50 degrees C or more to be effective (Richter, 2016)
Mantainance	- Little maintenance, must be checked a few times a year for general cleaning (Union of Concerned Scientists, 2018)	- Biomass boiler mantainance Daily – A visual inspection and cleaning of any components where necessary Weekly – Check the ash level and empty if necessary. Check gear motors for oil leaks. Monthly – Scrape the combustion chamber and remove any bad ash. Also check the grate. 3 Monthly – Wipe the flue gas sensor, clean the lambda probe and check the grate. 6 Monthly – Check and clean the flue gas return, inspect the operational drives, check the motors, clean the heat exchangers and clean the combustion chamber. Annually – This is usually carried out via a service contract with the installer. Multiple checks, as well as cleaning the flue and greasing the bearings (The Green Age, n.d.)	- Operations and Maintance cost average between $ 0.01/kWh and $0.025/kWh (Nextera Energy, 2018) - 20% - 25% of total cost accounts for maintanance (ibid.) - Require maintanance about twice a year (ibid.)	- "Our maintenance has actually been nearly zero for a decade," (Pascal, 2007)	- May need routine visits by HVAC technician (Ross, 2018)
Easiness to Use	- Implementation will be the hardest part, maintenance will not be difficult	- Home scale biogas producers (HomeBiogas, 2017) - Turn Wastes into Energy (HomeBiogas - turn your waste into energy, 2015) - Set Up of the Biogas Structure (Cooking with home BioGas, 2018)	- Require an expert to come in and implement then the rest is left alone unless something is damaged. (Nextera Energy, 2018)	- Can set up and run themselves (Pascal, 2007)	- Must be professionally installed (Richter, 2016)
Scale	- Available on small (d.light) and large scale (solar plant)	Industrial BioMass Boilers - Needs quote (Hurst Boiler, 2018) Home boilers vs industrial (GreenMatch, 2018)	- On shore large (Nextera Energy, 2018) - On shore small (ibid.) - Off shore (ibid.)	- Microhydro=up to 100kW of power. " As a general rule, there are 9.8 kW available from each cubic meter per second of water falling through 1 meter. The greater the drop, or "head," the lesser the flow of water required to achieve the same electricity" (Pascal, 2007).	- 100kW to 1MW (Richter, 2016)

Appendix B: Interview & Focus Group Questions

B.1 Interview questions for FFC

Interview conducted in Thai

English

1. Why did you decide to install a rooftop solar system?
2. How was the Electricity Authority involved with the installation of your solar cells?
3. What is your average the electricity consumption and cost each month?
4. What appliances consume the majority of electricity in your organization?
5. How effective have the solar cells been so far?
6. Approximately how much money have you saved after installing the solar rooftop?
7. What was the cost of installation?
8. How long does it takes for solar cell to worth its price?
9. What is the life time of solar cell is approximately?
10. Why electricity authority decided to choose solar cell?
11. Do you know anywhere else that use the same method?
12. How much electricity do the solar cells produce?
13. Do you depend on other types of electricity besides solar?
14. How do you maintain your solar system?

Thai

1. ทำไมบ้านทานตะวันถึงตัดสินใจติดตั้งแผงโซล่าเซลล์บนหลังคา
2. การไฟฟ้ามีส่วนร่วมกับการสำรวจและติดตั้งแผงโซล่าเซลล์ที่บ้านทานตะวันอย่างไร
3. ปริมาณการใช้ไฟฟ้า และค่าไฟต่อเดือนประมาณเท่าไหร่
4. ปกติใช้ไฟ้ฟ้ามากในส่วนไหน
5. หลังจากการติดตั้งแผงโซล่าเซลล์ การใช้ไฟฟ้ามีประสิทธิภาพเป็นอย่างไร
6. หลังติดตั้งแล้วประหยัดเงินขึ้นประมาณเท่าไหร่
7. ค่าติดตั้งเท่าไหร่
8. ต้องใช้เวลากี่ปีถึงจะคุ้มทุนการติดตั้ง
9. แผงโซล่าเซลล์มีอายุการใช้งานประมาณกี่ปี
10. ทำไมการไฟฟ้าถึงเลือกใช้แผงโซล่าเซลล์
11. มีสถานที่ใดอีกบ้าง ที่มีการนำแผงโซล่าเซลล์มาใช้
12. แผงโซล่าเซลล์สามารถผลิตไฟฟ้าได้ทั้งหมดเท่าไหร่
13. ตอนนี้ทางบ้านยังใช้ไฟฟ้าจากทางการไฟฟ้าอยู่ไหม
14. มีการดูแลแผงโซล่าเซลล์ที่ติดตั้งอย่างไรบ้าง

B.2 Interview questions for Dr. Suthee Traivivatana

Interview conducted in Thai

English

1. How have energy alternative options been funded previously?
2. Is alternative energy possible and suitable for use in Nong Khai, Thailand based on:
   a. Price
   b. Installation
   c. Size
   d. The amount of electricity
   e. Lifetime
3. Do you have any recommendation for Sarnelli House's problems?

Thai

1. ในช่วงระยะเวลาที่ผ่านมาพลังงานทดแทนได้รับการสนับสนุนได้อย่างไรบ้าง

2. ขอคำแนะนำเกี่ยวกับพลังงานทางเลือกแต่ละประเภท ความเหมาะสมและความเป็นไปได้ ที่ใช้ในบริเวณนั้นในไทย ตัวเลือกใดน่าสนใจมากที่สุด
    a. ราคา
    b. การติดตั้ง
    c. ขนาด
    d. ปริมาณไฟ คิดว่าครอบคลุมการใช้ไฟฟ้าแบบไหนบ้าง
    e. อายุการใช้งาน
3. มีคำแนะนำสำหรับการแก้ปัญหาที่เกิดขึ้นที่บ้านซาเนลลี่ไหม

B.3 Interview Questions for Ms. Wimon Thammawong and Mr.Wittawat Savangnam

Interview conducted in Thai

English

1. Please tell us about the energy disruptions.
2. How is the electricity restored?
3. Do villagers also experience these disruptions?
4. What causes the power disruptions?
5. Do Pi Si Thong and Don Wai experience the same outages?
6. Have you ever asked the Electric Authority to permanently fix the problem?
7. Where do you gain the idea of using solar cells?
8. Are you planning to install solar cells in all houses?
9. Does the Sarnelli House have an Energy Management system?
10. What are the activities during night time?
11. How much do your emergency lights cost?
12. How much areas do the Sarnelli House have?
13. Do you think of other renewable energies that is not solar cell?
14. How do you deal with waste?
15. Do you use biogas?
16. Is Nong Khai windy?
17. Does Nong Khai have a lot of rain?
18. Do you use a power generator here?

Thai

1. ช่วยอธิบายเกี่ยวกับปัญหาไฟฟ้าขัดข้องได้หรือไม่
2. มีขั้นตอนอย่างไรบ้างจึงจะสามารถใช้งานไฟฟ้าได้ดังเดิมหลังจากไฟดับ
3. ผู้อยู่อาศัยในบริเวณใกล้เคียงได้รับผลกระทบจากปัญหาไฟฟ้าดับหรือไม่
4. อะไรเป็นเหตุให้เกิดไฟฟ้าดับ
5. บ้านไผ่สีทอง และบ้านดอนหวายได้รับผลกระทบจากไฟฟ้าดับพร้อมกันหรือไม่
6. เคยมีการร้องขอให้ทางการไฟฟ้าส่วนภูมิภาคมาแก้ไขปัญหาหรือไม่
7. ได้ไอเดียที่จะนำโซล่าร์เซลล์มาใช้จากไหน
8. มีความคิดที่จะติดตั้งโซลาร์เซลล์สำหรับบ้านทุกหลังเลยหรือไม่
9. ซาเนลลี่มีการจัดการลดการใช้พลังงานหรือไม่
10. กิจวัตรที่ผู้อยู่อาศัยทำในช่วงกลางคืนของแต่ละวันมีอะไรบ้าง
11. ไฟฟ้าสำรองฉุกเฉินที่กำลังใช้อยู่มีราคาเท่าใด
12. ซาเนลลี่มีพื้นที่ใช้สอยทั้งหมดเท่าใด
13. มีไอเดียเกี่ยวกับพลังงานทดแทนประเภทอื่นนอกจากโซลาร์เซลล์หรือไม่
14. มีการจัดการเกี่ยวกับขยะ และเศษอาหารอย่างไร
15. มีการใช้ก๊าซธรรมชาติหรือไม่
16. กำลังลมในหนองคายมีมากน้อยเพียงใด

17. จังหวัดหนองคายมีฝนตกมากน้อยเพียงใด
18. มีการใช้เครื่องปั่นไฟฟ้าหรือไม่

B.4 Interview questions for Fr. Shea

Interview conducted in English

English

1. Please tell us a little about how Sarnelli house got started.
2. How frequently do power outages occur?
3. What is the duration of the electricity outages?
4. What is your energy source?
    a. Is it fossil fuel based, are you connected to a grid, or purchase from a grid?
5. What would be your budget for a renewable energy implementation?
6. Who provides funding to Sarnelli and would they be interested in implementing a renewable energy project?
7. Have there been previous attempts to fix this problem?
8. How do the power outages affect the Sarnelli staff and residents?
9. How do you currently address power outages?
10. Is there anyone with technical skills or interested in learning the technical skills to maintain the alternative energy option.
11. What is your current energy consumption per day, per month, and year?
12. What is the average energy costs per day, month and year?
    a. How much energy do you need to run efficiently?
13. What renewable energies do you believe may be beneficial to this orphanage?
    a. Are there any that would not be viable?

Thai

1. ช่วยเล่าถึงจุดเริ่มต้นของบ้านซาเนลลี่ได้หรือไม่
2. ปัญหาไฟฟ้าดับเกิดขึ้นบ่อยแค่ไหน
3. ปัญหาไฟฟ้าดับที่เกิดขึ้น กินเวลามากน้อยเพียงใด
4. คุณใช้พลังงานประเภทใดเป็นหลัก
    a. ใช่พลังงานน้ำมันปิโตรเลียมหรือไม่, เป็นการต่อตรง หรือซื้อจากแหล่งจ่ายพลังงาน
5. อยากทราบเงินทุนที่มีสำหรับการติดตั้งพลังงานทดแทน
6. ใครเป็นผู้สนับสนุนด้านเงินทุนให้กับทางซาเนลลี่ และผู้สนับสนุนมีความสนใจด้านพลังงานทดแทนหรือไม่
7. จนปัจจุบันได้มีการทดลองแก้ไขปัญหาดังกล่าวหรือยัง
8. ปัญหาไฟฟ้าขัดข้องมีผลกระทบต่อทางมูลนิธิ และผู้อยู่อาศัยอย่างไรบ้าง
9. ในปัจจุบันมีการแก้ไขปัญหาไฟฟ้าดับอย่างไรบ้าง
10. มีใครที่มีความสามารถในด้านการช่างเพื่อมาทำหน้าที่บำรุงรักษาระบบพลังงานทดแทนบ้าง
11. มีการใช้พลังงานมากน้อยเพียงใดใน 1 วัน/ เดือน/ ปี
12. พลังงานเฉลี่ยที่ใช้ใน 1 วัน/ เดือน/ ปี มีปริมาณเท่าใด
    a. ต้องใช้พลังงานเท่าใดจึงจะเพียงพอ
13. พลังงานทดแทนประเภทใดบ้างที่คุณคิดว่าจะเป็นประโยชน์กับซาเนลลี่
    a. และประเภทใดที่คิดว่าไม่สามารถนำมาใช้ได้

B.5 Interview questions for Fr. Ole

Interview conducted in Thai

English

1. Please tell us a little about how you became involved with Sarnelli House.
2. How often does the Sarnelli House experience power disruptions?

3. How is the electricity is connected between Pi Si Thong and Don Whai?
4. Do you have an Energy Management System?
5. What do you think about implementing solar cells here?
6. How do the water pumps at Sarnelli use electricity?
7. Do children use a lot of electricity?

Thai

1. ช่วยบอกเล่าเรื่องราวที่ทำให้คุณมามีส่วนร่วมกับซาเนลลี่
2. ปัญหาไฟฟ้าดับที่ซาเนลลี่เกิดขึ้นมากน้อยเพียงใด
3. ระบบจ่ายไฟฟ้าระหว่างบ้านไผ่สีทอง และบ้านดอนหวายมีการเชื่อมต่อกันแบบใด
4. ที่นี่มีการจัดการลดการใช้พลังงานหรือไม่
5. มีความคิดเห็นอย่างไรสำหรับการติดตั้งโซลาร์เซลล์ที่ซาเนลลี่
6. ปั๊มน้ำที่ซาเนลลี่ใช้พลังงานไฟฟ้าอย่างไร
7. เด็กๆที่ซาเนลลี่ใช้พลังงานมากน้อยเพียงใด

B.6 Interview questions for Ms. Kate Introna and Mr. Brian O'Riordan

Interview conducted in English

English

1. How many kids are currently at Sarnelli House?
2. Please explain what the orphanage does when the power goes out.
3. When was the last time you had a power outage?
4. How does the rainy season affect electricity?
5. Are you aware of how the power is restored?
6. Have there been previous attempts to solve this issue?
7. From your understanding, is this whole area on the same grid?
8. If the power is lost in one village, is it also off in the other?
9. Does the farm require any electricity?
10. Aajaan Pat has told us that you have already looked at a little bit of solar energy, is that true?
11. Why would you wish to install solar panels?
12. Do you have a budget for solar project?
13. Would you be interested in having solar energy and storing it?

Thai

1. มีจำนวนเด็กที่อาศัยที่ซาเนลลี่ทั้งหมดกี่คน
2. ช่วยอธิบายว่าทางมูลนิธิทำอย่างไรเมื่อไฟฟ้าดับ
3. ครั้งล่าสุดที่ไฟฟ้าดับคือเมื่อใด
4. ฤดูฝนมีผลกระทบต่อไฟฟ้าที่ซาเนลลี่อย่างไรบ้าง
5. ทราบหรือไม่ว่าพลังงานไฟฟ้ากลับมาเป็นปกติได้อย่างไรหลังจากเกิดไฟฟ้าดับ
6. เคยมีความพยายามที่จะแก้ไขปัญหาดังกล่าวหรือไม่
7. พื้นที่โดยรอบซาเนลลี่ทั้งหมดมีการจ่ายไฟที่เชื่อมถึงกันหรือไม่
8. เมื่อเกิดไฟฟ้าดับที่หมู่บ้านหนึ่ง จะมีผลกระทบต่อบริเวณข้างเคียงหรือไม่
9. ฟาร์มของทางซาเนลลี่มีการใช้ไฟฟ้าหรือไม่
10. อาจารย์พัตได้เล่าว่าพวกคุณได้หาข้อมูลด้านโซลาร์เซลล์มาบ้างแล้ว เป็นข้อเท็จจริงหรือไม่
11. ทำไมถึงคิดที่จะติดตั้งโซลาร์เซลล์
12. คุณมีเงินทุนสำหรับโครงการโซลาร์เซลล์หรือไม่
13. คุณมีความสนใจที่จะสำรองพลังงานที่ได้รับจากโซลาร์เซลล์ด้วยแบตเตอรี่หรือไม่

B.7 Interview questions for PEA Representatives

Interview conducted in Thai

English

1. What is the most common energy source in Nong Khai?
2. Do you have alternative options available? If so, what are they?
3. Do you have maintenance and upgrade services?
4. Are these areas connected to the same electrical grid?
5. What is the main cause of the power outages in the community where Sarnelli House located?
6. What controllable factors cause these problems?
7. What uncontrollable problems cause these factors?

Thai

1. อะไรคือแหล่งพลังงานที่ใช้มากที่สุดในจังหวัดหนองคาย
2. มีพลังงานทางเลือกแบบไหนที่เป็นไปได้บ้างไหม อะไรบ้าง
3. มีบริการบำรุงรักษา หรือการปรับเปลี่ยนอุปกรณ์บ้างไหม
4. พื้นที่โดยรอบมีการเชื่อมต่อระบบไฟฟ้าแบบเช่อมถึงกันหรือไม่
5. อะไรคือปัญหาหลักของปัญหาไฟฟ้าขัดข้องในพื้นที่บริเวณซาเนลลี่เฮ้า
6. ตัวแปรควบคุมของปัญหานี้
7. อะไรคือปัญหาที่ไม่สามารถควบคุมได้

B.8 Interview questions for Solar Panel Companies

Interviews conducted in Thai

English

1. Which type of components (including panels, batteries, inverters, etc.) are mostly used in Thailand? Why?
2. From our scale of 80,000 and 100,000 kWh electricity usage per year ,which kind of solar panel, battery, and inverter should be used?
3. Do you have a maintenance plan? If not, how would the buyer maintain the solar system?
4. Do you have service offices in Nong Khai? If not, what is the closest one?
5. How much is the estimated installation cost for a project at the scale of Sarnelli House?
6. Are there any factors other than consumption needed to calculate the number of necessary solar panels?
7. Do the solar panels include insurance and/or warranty? How long?
8. Do you offer different mounting systems?
9. Sarnelli House is set up in two separate villages, could you accommodate for that?
10. Based on the information given, what is the cheapest combination to fulfill this necessity?
11. Based on the information given, what is an affordable combination to fulfill this necessity with batteries?
12. What are all the solar components you sell? Which ones do you believe are essential?
13. Do you have a financing system? Loans?
14. Would you be able to give us a quote? What would be the process for three different estimates?
15. Do we need a permission from the government/authority to install a solar system?

Thai

1. ส่วนประกอบประเภทใดในระบบโซลาร์เซลล์ (แผงโซลาร์, แบตเตอรี่, อินเวอร์เตอร์,อื่นๆ)ที่มีการใช้มากที่สุดในประเทศไทย และเพราะอะไร
2. จากปริมาณการใช้ไฟฟ้าประมาณ 80,000 - 100,000 kWh ต่อปี, ประเภทของแผงโซลาร์, แบตเตอรี่,และอินเวอร์เตอร์ที่เหมาะสมคือประเภทใด
3. มีแผนการบำรุงรักษาไหมหลักจากติดตั้ง ทำเองได้ไหม

4. มีบริการหรือสำนักงานที่หนองคายไหม ถ้าไม่มี ที่ไหนใกล้ที่สุด
5. โดยพื้นที่ของซาเนลลี่ คิดว่าจะมีค่าใช้จ่ายในการติดตั้งโซลาร์เซลล์มากเพียงใด
6. มีปัจจัยอื่นนอกจากปริมาณไฟที่ใช้คำนวณจำนวนแผงโซล่าเซลล์ไหม
7. มีประกันแผงให้ไหม นานเท่าไหร่
8. ตัวฐานรองมีรูปแบบอื่นไหม เช่น หมุนตามแสงแดด
9. สถานสงเคราะห์มี2หมู่บ้าน ต้องติดแยกไหม หรือ ติดที่เดียวแล้วเดินสายได้ อันไหนประหยัดเงินกว่า
10. ระบบที่ถูกที่สุดราคาประมาณเท่าไหร่ ที่สามารถครอบคลุมเครื่องใช้ไฟฟ้าในบ้านได้
11. ถ้าเพิ่มแบตเตอรี่เข้าไปในระบบจากคำถามข้อก่อนหน้า ต้องเพิ่มเงินอีกกี่บาท
12. บริษัทมีขายอุปกรณ์หรือวัสดุอะไรบ้าง แล้วสิ่งไหนที่สำคัญที่สุด?
13. มีระบบผ่อนไหม
14. ขอตัวอย่าง3แบบที่เป็นไปได้ในการติดตั้ง
15. การติดตั้งโซลาร์เซลล์ต้องขออนุญาตจากทางรัฐบาลหรือไม่

B.9 Focus Group Questions for Our Lady of Refuge Residents

Focus Group conducted in Thai

English

1. At what time do you normally do homework?
2. What activities do you do at night time?
3. What do you currently do when you do not have electricity?
4. What activities do you need electricity for?
5. How often do you believe you lose power?
6. Do they teach you about renewable energies in your schooling?
7. Do you think there is a kind of renewable energy that would be helpful here?

Thai

1. ทำการบ้านเวลาใด
2. มีกิจวัตรอะไรบ้างที่ทำในเวลากลางคืน
3. มีการแก้ปัญหาแบบใดบ้าง ขณะเกิดไฟฟ้าขัดข้อง
4. กิจกรรมอะไรบ้างที่ต้องการไฟฟ้า
5. ปัญหาไฟฟ้าขัดข้องเกิดขึ้นบ่อยแค่ไหน
6. มีการให้ความรู้ด้านพลังงานทดแทนในโรงเรียนบ้างไหม
7. มีไอเดียเกี่ยวกับพลังงานทางเลือกที่จะเป็นประโยชน์ต่อที่นี่บ้างไหม

Appendix C: Energy Breakdown Spreadsheet

Electricity costs

	Nong Khai Redemptorist Projects	St. Patrick's Boys Home	Sarnelli House	Viengkhuk Children Hospice	Outreach Program	House of Hope	Nazareth Girls Home	Jan and Oscar	Farm	Charleen (guest house)	Gary and Janet	Total
2018												
Electricity	105,063	76,843	105,942	71,528		76,844	123,059	76,845	108,644	105,059	36,320.75	886,147.75
TOTAL	105,063	76,843	105,942	71,528	0	76,844	123,059	76,845	108,644	105,059	36,320.75	886,147.75
DIFF	-8,684.25	-9,378	-8,645.5	-445	0.0	-9,380	-10,186.5	19,130	16,628.5	-9,174.5	-4,850.75	-24,986.0
2017												
Electricity	113,747.25	86,221	114,587.5	71,973		86,224	133,245.5	57,715	92,015.5	114,233.5	41,171.5	911,133.75
TOTAL	113,747.25	86,221	114,587.5	71,973	0.0	86,224	133,245.5	57,715	92,015.5	114,233.5	41,171.5	911,133.75
DIFF	21,413	81,710	21,342.75	20,979	0.0	21,032	24,413.25	-7,478	18,583	21,898.25	6,583.5	230,476.75
2016												
Electricity	92,334.25	4,511	93,244.75	50,994	0	65,192	108,832.25	65,193	73,432.5	92,335.25	34,588	680,657
TOTAL	92,334.25	4,511	93,244.75	50,994	0	65,192	108,832.25	65,193	73,432.5	92,335.25	34,588	680,657
DIFF	-3,175.25	(61,985.5)	(5,969.25)	13,975	0	(1,304.5)	5,412.75	58,389	-44,140	(4,216.25)	34,588	-8,426
2015												
Electricity	95,509.5	66,496.5	99,214	37,019	0	66,496.5	103,419.5	6,804	117,572.5	96,551.5		689,083
TOTAL	95,509.5	66,496.5	99,214	37,019	0	66,496.5	103,419.5	6,804	117,572.5	96,551.5		689,083
DIFF	-10,889.4	3,403.5	(9,305.1)	113	0	3,402.89	(5,120.29)	(56,296)	38,291.27	(9,844.75)		(46,244.88)
2014												
Electricity	106,398.9	63,093	108,519.1	36,906		63,093.61	108,539.79	63,100	79,281.23	106,396.25		735,327.88
TOTAL	106,398.9	63,093	108,519.1	36,906	0	63,093.61	108,539.79	63,100	79,281.23	106,396.25		735,327.88
DIFF	6,745.4	-6,331	6,053.6	-2,015	0	-6,335.39	8,892.29	-6,327	27,287.23	6,747.75		34,717.88
2013												
Electricity	99,653.5	69,424	102,465.5	38,921		69,429	99,647.5	69,427	51,994	99,648.5		700,610
TOTAL	99,653.5	69,424	102,465.5	38,921	0	69,429	99,648	69,427	51,994	99,648.5		700,610.0

savings on utilities from the previous year

greater expenditure on utilities than the previous year

filled boxes represent lowest (green) to greatest (red) spending on electricity

Appendix D: PEA Breakdown of Cost per kWh

D.1 PEA Document of Electricity Costs

การไฟฟ้าส่วนภูมิภาค
PROVINCIAL ELECTRICITY AUTHORITY

อัตราค่าไฟฟ้าจำแนกตามกิจการไฟฟ้า

ประเภทที่ 1 บ้านอยู่อาศัย

สำหรับการใช้ไฟฟ้ากับบ้านเรือนที่อยู่อาศัย รวมทั้งวัด สำนักสงฆ์ และสถานประกอบศาสนกิจของทุกศาสนา ตลอดจนบริเวณที่เกี่ยวข้อง โดยต่อผ่านเครื่องวัดไฟฟ้าเครื่องเดียว

1.1 อัตราปกติ

การใช้ไฟฟ้า	อัตราค่าไฟฟ้าจริง				การอุดหนุนค่าไฟฟ้า		อัตราค่าไฟฟ้าที่เรียกเก็บ	
	ระบบผลิตไฟฟ้า (บาท/หน่วย)	ระบบส่ง (บาท/หน่วย)	ระบบจำหน่าย (บาท/หน่วย)	ค่าบริการ (บาท/เดือน)	ระบบจำหน่าย (บาท/หน่วย)	ค่าบริการ (บาท/เดือน)	ค่าพลังงานไฟฟ้า (บาท/หน่วย)	ค่าบริการ (บาท/เดือน)
1.1.1 ใช้พลังงานไฟฟ้าไม่เกิน 150 หน่วยต่อเดือน								
ค่าบริการรายเดือน				40.90		-32.71		8.19
หน่วยที่ 0 – 15	2.9955	0.2818	0.4849		-1.4134		2.3488	
หน่วยที่ 16 – 25	2.9955	0.2818	0.4849		-0.7740		2.9882	
หน่วยที่ 26 – 35	2.9955	0.2818	0.4849		-0.5217		3.2405	
หน่วยที่ 36 – 100	2.9955	0.2818	0.4849		-0.1385		3.6237	
หน่วยที่ 101 – 150	2.9955	0.2818	0.4849		-0.0451		3.7171	
หน่วยที่ 151 – 400	2.9955	0.2818	0.4849		0.4596		4.2218	
หน่วยที่ 401 เป็นต้นไป	2.9955	0.2818	0.4849		0.6595		4.4217	
1.1.2 ใช้พลังงานไฟฟ้าเกิน 150 หน่วยต่อเดือน								
ค่าบริการรายเดือน				38.22		-		38.22
หน่วยที่ 0 - 150	2.9955	0.2818	0.4849		- 0.5138		3.2484	
หน่วยที่ 151 – 400	2.9955	0.2818	0.4849		0.4596		4.2218	
หน่วยที่ 401 เป็นต้นไป	2.9955	0.2818	0.4849		0.6595		4.4217	

1.2 อัตราตามช่วงเวลาของการใช้ (Time of Use Rate : TOU)

ระดับแรงดัน	อัตราค่าไฟฟ้าจริง					การอุดหนุนค่าไฟฟ้า		อัตราค่าไฟฟ้าที่เรียกเก็บ		
	ระบบผลิตไฟฟ้า (บาท/หน่วย)		ระบบส่ง (บาท/หน่วย)	ระบบจำหน่าย (บาท/หน่วย)	ค่าบริการ (บาท/เดือน)	ระบบจำหน่าย (บาท/หน่วย)	ค่าบริการ (บาท/เดือน)	ค่าพลังงานไฟฟ้า (บาท/หน่วย)		ค่าบริการ (บาท/เดือน)
	Peak	Off Peak	Peak	Peak		Peak		Peak	Off Peak	
22 กิโลโวลท์ขึ้นไป	3.4781	2.6037	0.7058	0.9296	312.24	-	-	5.1135	2.6037	312.24
ต่ำกว่า 22 กิโลโวลท์	3.5816	2.6369	0.7481	1.9384	38.22	- 0.4699	-	5.7982	2.6369	38.22

หมายเหตุ 1. ผู้ใช้ไฟฟ้าที่ติดตั้งเครื่องวัดไฟฟ้าไม่เกิน 5 แอมป์ 220 โวลท์ 1 เฟส 2 สาย จะจัดเข้าประเภทที่ 1.1.1 แต่หากใช้ไฟฟ้าเกิน 150 หน่วยติดต่อกัน 3 เดือน ในเดือนถัดไปจะจัดเข้าประเภทที่ 1.1.2 และเมื่อใดมีการใช้ไฟฟ้าไม่เกิน 150 หน่วย ติดต่อกัน 3 เดือน ในเดือนถัดไปจะจัดเข้าประเภทที่ 1.1.1

2. ผู้ใช้ไฟฟ้าที่ติดตั้งเครื่องวัดไฟฟ้าเกิน 5 แอมป์ 220 โวลท์ 1 เฟส 2 สาย จะจัดเข้าประเภทที่ 1.1.2

3. ผู้ใช้ไฟฟ้าประเภทที่ 1.1.1 ที่ใช้ไฟฟ้าไม่เกิน 50 หน่วยต่อเดือนทุกราย ยังคงได้รับสิทธิค่าไฟฟ้าฟรีถึงค่าไฟฟ้าประจำเดือนธันวาคม 2558 และตั้งแต่ค่าไฟฟ้าประจำเดือนมกราคม 2559 เป็นต้นไป ผู้ใช้ไฟฟ้าประเภทที่ 1.1.1 ที่ได้รับสิทธิค่าไฟฟ้าฟรี จะต้องไม่เป็นนิติบุคคลและมีการใช้ไฟฟ้าไม่เกิน 50 หน่วยต่อเดือน ติดต่อกันเป็นระยะเวลาไม่น้อยกว่า 3 เดือน นับถึงเดือนปัจจุบัน

4. ประเภทที่ 1.2 กรณีติดตั้งเครื่องวัดไฟฟ้าทางด้านแรงต่ำของหม้อแปลงซึ่งเป็นสมบัติของผู้ใช้ไฟฟ้า ให้คำนวณหน่วยคิดเงินเพิ่มขึ้นอีกร้อยละ 2 เพื่อครอบคลุมการสูญเสียในหม้อแปลงไฟฟ้าซึ่งมิได้วัดรวมไว้ด้วย

5. ประเภทที่ 1.2 เป็นอัตราเลือก ทั้งนี้ ผู้ใช้ไฟฟ้าจะต้องชำระค่าใช้จ่ายตามที่การไฟฟ้าส่วนภูมิภาคกำหนด และหากเลือกใช้ไปแล้วไม่น้อยกว่า 12 เดือน สามารถแจ้งความประสงค์ขอเปลี่ยนไปใช้อัตราประเภทที่ 1.1 ได้

D.2 English Translation of D.1

Electricity usage	Actual Electricity Consumption				Electricity subsidies		Payment to PEA	
	Electric Production system (baht/kWh)	Transmission system (baht/kWh)	Selling System (baht/kWh)	Service Charge (baht/kWh)	Selling System (baht/kWh)	Service Charge (baht/month)	Energy charge (baht/kWh)	Service Charge (baht/month)
1.1 not exceeding 150 kWh per month								
Monthly amount				40.9		-32.17		8.19
unit 0-15	2.995	0.2818	0.4849		-1.4134		2.3488	
unit 16-25	2.995	0.2818	0.4849		-0.774		2.9882	
unit 26-35	2.995	0.2818	0.4849		-0.5217		3.2405	
unit 36-100	2.995	0.2818	0.4849		-0.1385		3.6237	
unit 101-150	2.995	0.2818	0.4849		-0.0451		3.7171	
unit 151-400	2.995	0.2818	0.4849		0.4596		4.2218	
unit 401+++	2.995	0.2818	0.4849		0.6595		4.4217	
1.2 exceeding 150 kWh per month								
Monthly amount				38.22		-		38.22
unit 0-150	2.995	0.2818	0.4849		-0.5138		3.2484	
unit 151-400	2.995	0.2818	0.4849		0.4596		4.2218	
unit 401+++	2.995	0.2818	0.4849		0.6595		4.4217	

Appendix E: Solar Panel Company Comparison

	Solar Gen (Wattana Wanish Co. Ltd.)	**Electric Industries & Equipment Club Limited**	**SCG Satit Chaikittikorn - Technical sales manager, Solar business**	**Thai Solar Future**	**Kitjarak Solar Energy Co. Ltd.**	**Amorn**
Solar panel	Polycrystalline	Monocrystalline Weight: 7-8 kg	weight: 15 kg with installation weight 18-19 kg	Solartron company polycrystalline	Monocrystalline	25 kg/ panel 750 kg total
Size of panel	size: 2 x 1 m	size: 2 x 1 m	size: 2 x 1 m 76 cells = 2 sq.m		size: 32 sq.m. for 15 panels	2 x 1 m
Number of panel	Recommend 16 panels	Recommend 10 panels	Recommend 8 panels	recommend 24 panels	Recommend 15 panels	30 panels
weight per panel	15 kg/sq.m	7-8 Kg	15 kg/sq.m not exceeding 20kg	320 watts 24 panels	-	25 kg 330 watts
Price per panel		1K for 55,000 baht	8panels	1K for 40,000+++ baht		
Component material	Polycrystalline	monocrystalline	monocrystalline	Polycrytalline	Monocrystalline	
Performance (kW)	300 watt/panel 16 panels = 4.8 kW/hr 4.8 kW/hr x 4 hr = 19.2 kW/day	330 watt/panel 10 panel = 3.3 kW/hr 3.3 kW/hr x 4 hr = 13.2 kW/day (**4 hrs from average sunlight during noon that solar panel efficiently work)	330 watts/ panel 8 panel = 2750 watts/hr (2500 x 1.1 safety factor) 2750 watts = 10 kW/day	320 watts/ panel 24 panels x 320 watts = 7.6 kW/day (He calculate for me)	350 watts 15 panels x 350 watts= 5.25 kW/hr	30 panel x 4900 =
Insurance/Warranty	Solar panel = 10 years Linear power warranty = 25 years	Insurance system = one year Inverter = 5 years Solar panel = 10 year	Solar panel = 10 years (for body) = 25 years (for performance) Equipment in system = 5 years Leaking insurance = 5 years	Solar panel =25 year inverter = 5 year system = 2 years		System = 1 year solar การติดตั้ง1ปี ค่าซ่อม 15000ต่อครั้ง
system	On grid system	On grid system	On grid system	On-grid system	On-grid system	On grid system
Remark	http://www.solargen.co.th/th/product/294781/product-294781?category_id=46820	Recommend to install on rooftop because no need to pay for the structure	Moving mounting system for solar farm	7-8 years return on investment save 3000 ++ baht/month	http://www.kitjarak.com	
Total price of solar panel	265,000 baht for all equipments (not include installation cost) Price include - solar panel - inverter - Breaker - Surge protection - Fuse - AC	550,000 baht for whole system (40 watts but recommend 10 Kwatts) Hybrid inverter (if you want to install battery) Controller - Breaker - Lightning protecter (surge) Electric meter - measure electricity get into the system		300,000 - 350,000 baht installation panel all equipments	approximately 300,000 baht for whole system	228,470 baht breaker = 15,000 baht AC = 25,000 baht
Battery type		Dry battery (rarely require to fill up the water) Wet battery	Not selling battery	Not able to give info.		Change hybrid-off grid system for 10k 10000x(10x8)= 80000 option breaker 15000 electrical wire & [illegible]
Number of battery		recommend 6 batteries				
Size of battery		200 amp 12v				
Price per battery		Dry - 14,580 baht per battery Wet - 8,500 baht per battery				
Mounting system		Hybrid system				
Insurance/Warranty		No, usage up to 2 years and change - Dry Up to 2-3 years, no more - Wet				
Installation cost		55,000 include everything				80,000 baht
Maintenance condition		No need because the rain is going to wash all the dust				
Maintenance cost		-				10,000 baht / time
Return on investment		4-5 years				
Amortization		No, pay full amount at once	pay full			
Payment		Pay half price before installation 50% Pay other half after installation - After the product arrived at the site 30% - After finishing all installation 20%				
Installation time		around 15 days				

Appendix F: Amorn Electronic Quotes

F.1 10 kW Quote without Battery

บริษัท อมรศูนย์รวมอะไหล่อีเล็คโทรนิคส์ จำกัด
AMORN ELECTRONIC CENTER SPARE CO.,LTD
17/18-19 หมู่ที่ 6 ต.บางกระทึก อ.สามพราน จ.นครปฐม 73210
โทรศัพท์ : (662)482-1320-5. โทรสาร : (662) 482-1337-8
Home Page : www.amorngroup.com

วันที่ 8/2/2019

Quotation

บริษัท มูลนิธิสถานสงเคราะห์เด็กSarnelli

เรียน คุณเอ็ม energyforsarnelli@gmail.com **Tel.** 089-4044204

No.	Bar Code	Description	จำนวน หน่วย	ราคาต่อหน่วย บาท	ราคารวมVat บาท
1	2000001837276	แผงโซลาร์เซลล์ 330 watt 24V Poly-crystalline	32	4,900	156,800
2	2000001763810	Growatt กริดอินเวอร์เตอร์ 10000UE 3-Phase (SSC)	1	85,000	85,000
3	2000001702055	BaanSolar Alu Standard Rail 4200mm VP-FZ-R4201	16	1,200	19,200
4	2000001702109	BaanSolar Mid Clamp 40mm VP-FZM-41	60	45	2,700
5	2000001702147	BaanSolar Hook/Metal Sheet VP-FZM-014	64	90	5,760
6	2000001702086	BaanSolar End Clamp Adjustable 30/40/45/50mm VP-FZ-AE	12	50	600
7	2000001702079	BaanSolar Alu Standard Rail Splice Kit VP-FZ-SK	10	100	1,000
8	2000001727744	สาย Cable Solar Panel 6sq. mm. @10M (เมตรละ 69 บาท)	2	6,900	13,800
9	2000001730775	ขั้วต่อสายโซล่าเซลล์ MC4 Connector-TUV	12	90	1,080
				Total	**285,940.00**

หมายเหตุ : **ยืนใบเสนอราคาถึงวันที่ 28.2.2019**
อุปกรณ์ตู้คอลโทรล 15,000บาท
ค่าติดตั้ง 80,000 บาท

บริษัทหวังเป็นอย่างยิ่งว่า จะได้รับการพิจารณาจากท่าน

ขอแสดงความนับถือ
อุบลวรรณ เดชอุป
Product Sale
Tel.094-415-5997

F.2 10 kW Quote With Battery

บริษัท อมรศูนย์รวมอะไหล่อีเล็คโทรนิคส์ จำกัด
AMORN ELECTRONIC CENTER SPARE CO.,LTD
17/18-19 หมู่ที่ 6 ต.บางกระทึก อ.สามพราน จ.นครปฐม 73210
โทรศัพท์ : (662)482-1320-5. โทรสาร : (662) 482-1337-8
Home Page : www.amorngroup.com

วันที่ 8/2/2019

Quotation

บริษัท มูลนิธิสถานสงเคราะห์เด็กSarnelli

เรียน คุณเอ็ม energyforsarnelli@gmail.com **Tel.** 089-4044204

No.	Bar Code	Description	จำนวน หน่วย	ราคาต่อหน่วย บาท	ราคารวมVat บาท
1	2000001837276	แผงโซลาร์เซลล์ 330 watt 24V Poly-crystalline	32	4,900	156,800
2		INFINIS Hibrid On-Grid 10K 3-Phase	1	160,000	160,000
3	2000001822944	แบตเตอรี่เจล Deep Cycle รุ่น TGEL 12V 200Ah	8	12,250	98,000
4	2000001702055	BaanSolar Alu Standard Rail 4200mm VP-FZ-R4201	16	1,200	19,200
5	2000001702109	BaanSolar Mid Clamp 40mm VP-FZM-41	60	45	2,700
6	2000001702147	BaanSolar Hook/Metal Sheet VP-FZM-014	64	90	5,760
7	2000001702086	BaanSolar End Clamp Adjustable 30/40/45/50mm VP-FZ-AE	12	50	600
8	2000001702079	BaanSolar Alu Standard Rail Splice Kit VP-FZ-SK	10	100	1,000
9	2000001727744	สาย Cable Solar Panel 6sq. mm. @10M (เมตรละ 69 บาท)	2	6,900	13,800
10	2000001730775	ขั้วต่อสายโซล่าเซลล์ MC4 Connector-TUV	12	90	1,080
				Total	**458,940.00**

หมายเหตุ : **ยืนใบเสนอราคาถึงวันที่ 28.2.2019**
อุปกรณ์ตู้คอลโทรล 15,000บาท
ค่าติดตั้ง 80,000 บาท

บริษัทหวังเป็นอย่างยิ่งว่า จะได้รับการพิจารณาจากท่าน

ขอแสดงความนับถือ
อุบลวรรณ เดชอูป
Product Sale
Tel.094-415-5997

F.3 5 kW Quote without Battery

บริษัท อมรศูนย์รวมอะไหล่อีเล็คโทรนิคส์ จำกัด
AMORN ELECTRONIC CENTER SPARE CO.,LTD
17/18-19 หมู่ที่ 6 ต.บางกระทึก อ.สามพราน จ.นครปฐม 73210
โทรศัพท์ : (662)482-1320-5. โทรสาร : (662) 482-1337-8
Home Page : www.amorngroup.com

วันที่ 14/2/2019

Quotation

บริษัท มูลนิธิสถานสงเคราะห์เด็กSarnelli

เรียน คุณเอ็ม energyforsarnelli@gmail.com **Tel.** 089-4044204

No.	Bar Code	Description	จำนวน หน่วย	ราคาต่อหน่วย บาท	ราคารวมVat บาท
1	2000001841143	อินเวอร์เตอร์ Senergy singer phase 5K	1	29,000	29,000
2	2000001837276	แผงโซลาร์เซลล์ 330 watt 24V Poly-crystalline	16	4,900	78,400
3	2000001702055	BaanSolar Alu Standard Rail 4200mm VP-FZ-R4201	6	1,200	7,200
4	2000001702154	BaanSolar Hook/กระเบื้องลอนคู่/ M10-200	24	250	6,000
5	2000001702109	BaanSolar Mid Clamp 40mm VP-FZM-41	22	45	990
6	2000001702079	BaanSolar Alu Standard Rail Splice Kit VP-FZ-SK	4	100	400
7	2000001702086	BaanSolar End Clamp Adjustable 30/40/45/50mm VP-FZ-AE	4	50	200
				Total	122,190.00

หมายเหตุ : **ยืนใบเสนอราคาถึงวันที่ 28.2.2019**

อุปกรณ์ตู้คอลโทรล 15,000 บาท

ประมาณการค่าติดตั้ง 8บาท/ Watt 40,000 บาท

บริษัทหวังเป็นอย่างยิ่งว่า จะได้รับการพิจารณาจากท่าน

ขอแสดงความนับถือ
อุบลวรรณ เดชอูป
Product Sale
Tel.094-415-5997

F.4 5 kW Quote with Battery

บริษัท อมรศูนย์รวมอะไหล่อีเล็คโทรนิคส์ จำกัด
AMORN ELECTRONIC CENTER SPARE CO.,LTD
17/18-19 หมู่ที่ 6 ต.บางกระทึก อ.สามพราน จ.นครปฐม 73210
โทรศัพท์ : (662)482-1320-5. โทรสาร : (662) 482-1337-8
Home Page : www.amorngroup.com

วันที่ 14/2/2019

Quotation

บริษัท มูลนิธิสถานสงเคราะห์เด็กSarnelli

เรียน คุณเอ็ม energyforsarnelli@gmail.com **Tel.** 089-4044204

No.	Bar Code	Description	จำนวน หน่วย	ราคาต่อหน่วย บาท	ราคารวมVat บาท
1		อินเวอร์เตอร์ ไฮบริด รุ่น Solax On Grid 5kw S-Phase	1	95,000	95,000
2	2000001837276	แผงโซลาร์เซลล์ 330 watt 24V Poly-crystalline	16	4,900	78,400
3	2000001822944	แบตเตอรี่เจล Deep Cycle รุ่น TGEL 12V 200Ah	4	12,900	51,600
4	2000001702055	BaanSolar Alu Standard Rail 4200mm VP-FZ-R4201	6	1,200	7,200
5	2000001702154	BaanSolar Hook/กระเบื้องลอนคู่/ M10-200	24	250	6,000
6	2000001702109	BaanSolar Mid Clamp 40mm VP-FZM-41	22	45	990
7	2000001702079	BaanSolar Alu Standard Rail Splice Kit VP-FZ-SK	4	100	400
8	2000001702086	BaanSolar End Clamp Adjustable 30/40/45/50mm VP-FZ-AE	4	50	200
				Total	239,790.00

หมายเหตุ : **ยืนใบเสนอราคาถึงวันที่ 28.2.2019**

อุปกรณ์ตู้คอลโทรล 15,000 บาท

ประมาณการค่าติดตั้ง 8บาท/ Watt 40,000 บาท

บริษัทหวังเป็นอย่างยิ่งว่า จะได้รับการพิจารณาจากท่าน

ขอแสดงความนับถือ
อุบลวรรณ เดชอุป
Product Sale
Tel.094-415-5997

Appendix G: Calculations

G.1 Calculation of kWh consumed per day

kWh each day	Charge by PEA
First 150	7.0101
Next 250	7.9835
Over 400	8.1834
monthly fee	38.22

Charge by PEA in 2018=	886,148.00
886148=	150*7.0101*12+250*7.9835*12+**X***12+38.22*12
X=	**8642**
	(150+250+8642)*12
kWh consumed in 2018=	108504
kWh consumed daily in 2018=	**297**

G.2 Estimations of kWh consumed per house

FARM

Household equipment	Amount of equipment	Watts per hour	Operating time	Electricity usage per day (Watt/day)	
Water Pump	2	3,000	3	18,480	
Fertilizer maker (Granulator)	1	5,000	1	6,600	
Total				25,080	Watts
				25.08	KiloWatts

GARY AND JANET

Household equipment	Amount of equipment	Watts per hour	Operating time	Electricity usage per day (Watt/day)	
Water Pump	1	3,000	2	5,280	
Lights	8	60	3	1,267	
Refrigerator	1	1,000	5	5,280	
Total				11,827	Watts
				11.83	KiloWatts

GUEST HOUSE

Household equipment	Amount of equipment	Watts per hour	Operating time	Electricity usage per day (Watt/day)	
Water Pump	1	3,000	1	3,960	
AC	8	1,100	3	27,104	
Lights	21	60	4	5,544	
Refrigerator	3	1,000	5	15,840	
Total				52,448	Watts
				52.45	KiloWatts

HOUSE OF HOPE

Household equipment	Amount of equipment	Watts per hour	Operating time	Electricity usage per day (Watt/day)	
Water Pumps	1	3,000	4	10,560	
Refrigerator	3	1,000	5	15,840	
Lights	9	60	4	1,901	
AC	4	1,100	2	7,744	
Total				36,045	Watts
				36.04	KiloWatts

JAN AND OSCAR					
Household equipment	**Amount of equipment**	**Watts per hour**	**Operating time**	**Electricity usage per day (Watt/day)**	
Water Pumps	1	3,000	2	5,280	
Refrigerator	4	1,000	5	21,120	
Lights	15	60	4	3,168	
AC	1	1,100	2	1,936	
Total				31,504	Watts
				31.50	KiloWatts

NAZARETH HOUSE					
Household equipment	**Amount of equipment**	**Watts per hour**	**Operating time**	**Electricity usage per day (Watt/day)**	
Water Pump	1	3,000	2	5,280	
AC	2	1,100	2	4,840	
Lights	35	60	3	5,544	
Refrigerator	7	1,000	5	36,960	
Computer	2	400	2	1,408	
Total				54,032	Watts
				54.03	KiloWatts

OFFICE					
Household equipment	**Amount of equipment**	**Watts per hour**	**Operating time**	**Electricity usage per day (Watt/day)**	
Water Pump	1	3,000	1	3,960	
AC	2	1,100	2	3,872	
Lights	13	60	3	2,059	
Refrigerator	1	1,000	5	5,280	
Computer	8	400	2	5,632	
Total				20,803	Watts
				20.80	KiloWatts

LADY OF REFUGE					
Household equipment	**Amount of equipment**	**Watts per hour**	**Operating time**	**Electricity usage per day (Watt/day)**	
Water Pump	1	3,000	2	6,600	
Lights	50	60	3	7,920	
Refrigerator	3	1,000	5	15,840	
Total				30,360	Watts
				30.36	KiloWatts

SARNELLI HOUSE					
Household equipment	**Amount of equipment**	**Watts per hour**	**Operating time**	**Electricity usage per day (Watt/day)**	
Water Pump	1	3,000	2	5,280	
Lights	11	60	2	1,452	
Refrigerator	5	1,000	5	26,400	
Total				33,132	Watts
				33.13	KiloWatts

ST PATRICK'S					
Household equipment	**Amount of equipment**	**Watts per hour**	**Operating time**	**Electricity usage per day (Watt/day)**	
Water Pumps	0	3,000	0	0	
Refrigerator	1	1,000	5	5,280	
Lights	14	60	4	2,957	
AC	1	1,100	2	1,936	
Total				10,173	Watts
				10.17	KiloWatts

Appendix H: Recommendation Data

H.1 Large-scale

House	kWh / day	kWh / day during peak	Current cost	System Suggeste	kW covered	Coverage Ratio	Savings baht/year	ROI
Farm	25	16	108,644	5kW	21	0.84	62,000	5
Water Pumps	65	29	439,539	10kW	42	0.6461538462	124,000	5
Office + Guest	73	24	210,122	5kW	21	0.2876712329	62,000	11
Pi Si Tong	77	12	230,532	5kW	21	0.2727272727	62,000	5
Pi Si Tong w/ Battery	77	12	230,532	10kW	42	0.5454545455	124,000	5
Everything	300	65	886,147	80kW	300	1	886147	17

We used the total cost of electricity for the year to calculate the average kWh consumed at Sarnelli House every day. Using the formula from the PEA, we solved for the total kWh used in a year. We divided that number by 365 days of the year and calculated that the complex uses about 300 kWh every day. From there we used the information we collected by surveying the complex and counting the appliances at each house. We found the average watts each appliance uses to calculate how many kWh each house uses every day. We assumed that without a battery, the solar panel would work for 5 hours of the day. For the farm and the office, we assumed the total kWh consumed were during 8 hours of the day. We then took five eighths of the total kWh used every day to get the kWh used during peak hours. For House of Hope and the guest house we assumed that the same number of kWh would be used each hour. To find the kWh during peak hours we divide 5 peak hours by 24 total hours of kWh. For the rest of the houses and buildings we assumed that during the day about half of the electricity of other houses would be used since the kids would not be home. To find the kWh for these houses we divided 5 peak hours by 24 total hours and then divided that in half again to account for the children not being home.

To decide which system to recommend, we calculated the kWh that could be produced in a day. If a 5 kW system produces 5 kWh every hour, then if it runs for five hours a day, it will produce 25 kWh a day. However, the system is only about 85 percent efficient, therefore it will produce closer to 21 kWh a day; a 10 kW system will produce about 42 kWh per day. We used this numbers to decide which system would work best for each house and which would produce the lowest amount of waste without a battery.

To calculate the coverage ratio, we took the number of kWh covered by the recommended system and divided it by the total kWh used in a day for that location. We then took the coverage ratio and multiplied it by the cost of electricity from 2018 for that location to calculate the yearly savings from implementation of the system. Finally, to calculate the return on investment (ROI), we took the total cost of implementing the given system and divided that by the yearly savings.

H.2 Small-scale

Item	Product Name	Company/ Representative seller	Product Website	Properties	Cost (Baht)	Cost (USD)
Solar reading lamp	Anpress® Flexible Gooseneck Style 4-LED Mini Solar Table Lamp / PC USB Charger LED Portable Lamp / Solar Bulbs Light / Solar Indoor Reading lighting (White)	Anpress/ Amazon	https://www.amazon.com/dp/B00WQRQXTC/ref=psdc_1063292_t2_B01NAO7TJH	- 3 watts consumption - A battery is built-in (nonremovable) - 4 white LED light bulbs	740	23.48
	KK.BOL Solar Desk Lamp Three Levels Dimmable Led Table Lamp	KK.BOL/ Amazon	https://www.amazon.com/dp/B071LQF5KB/ref=psdc_1063292_t1_B01NAO7TJH	- Maximum consumption = 6W - 1500 AH lithium battery - Can be charged by both solar and USB charger - 2W solar panel	818	25.99
	Solar lantern XML-C23-6	XML Solar	https://www.xml-solar.com/product/419/	- 1.7W Polycrystalline solar panel - 2600 mAH battery - Fully charged in 8-10 hrs. - USB charging available	735	23.36
Item	**Product Name**	**Company/ Representative seller**	**Product Website**	**Properties**	**Cost (Baht)**	**Cost (USD)**
Solar fan	Amata solar fan 16 inches	Amata Solar/ Lazada	https://www.lazada.co.th/products/fan-set-0216-inches-i273044407-s432457222.html?spm=a2o4m.seller.list.20.7cae6b0ca2HFzF&mp=1	- 20W solar panel - 9Ah battery - At least 6 hrs. of charging	5100	163
	XML 14 inches solar fan	XML Solar	https://www.xml-solar.com/product/290/	- 30W polycrystalline solar panel - 9Ah battery - 4-5 hrs. working	3800	122
Item	**Product Name**	**Company/ Representative seller**	**Product Website**	**Properties**	**Cost (Baht)**	**Cost (USD)**
Solar motion activated outdoor light	Solar motion sensor 40 LED wall light	Lazada	https://www.lazada.co.th/products/led-solar-motion-sensor-light-40-led-i279984676-s452837189.html?spm=a2o4m.searchlistbrand.list.4.28d944b2SB7U3f&search=1	- 5 Watt power consumption - 6-8 hrs. charging time - LED light - lithium battery 3.7V/1200MA	860	27.5
	Solar Motion Sensor Light Outdoor, Super Bright 28 Led Security Light Waterproof Motion Activated Wall Lights (2 Pack)	Amazon	https://www.amazon.com/Neloodony-Outdoor-Security-Waterproof-Activated/dp/B073VJ8N2Y	- 8-10 hrs. light power - 6-8 hrs. charge time - 0.55W solar panel - Li-ion battery: 3.7V 1200mAh	843 for 2-pack 422 each	26.99 for 2-pack (13.5 each)
	12W Automatic Battery Powered Motion Led Sensor Light Detector	Sresky	https://www.alibaba.com/product-detail/12W-Automatic-Battery-Powered-Motion-Led_1718099217.html?spm=a2700.7735675.normalList.5.QRKWwl&s=p	Place of Origin: Guangdong, China (Mainland) Brand Name: Sresky Model Number: SSL-02 Sensor Light Type: Solar Lamp Led: 20 w Battery: 26400mAh Certification: CE.ROHS,FCC Resistance: IP68 Solar panel: 15w Rechargeable battery: Li-ion battery LED brand: EPISTAR Led Sensor Light: 2000LM Sensor Light Detector: 1 year warranty	63-4650	US $2-149 / Pieces