COST-BENEFIT ANALYSIS OF RENEWABLE ENERGY PILOT PROJECT FOR SUSTAINABLE TOURISM AT PHU KRADUENG NATIONAL PARK, THAILAND

ROYPIMJAI JAIMUN

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……
Miss Roypimjai Jaimun
Candidate

……
Assoc. Prof. Nathsuda Pumijumnong,
Ph.D. (Natural Science)
Major advisor

……
Mr. Usa Boonbumroong,
Ph.D. (Energy Technology)
Co-advisor

……
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

……
Lect. Ratchaphong Klinsrisuk,
Ph.D. (Urban Environmental Management)
Program Director
Master of Science Program in Technology of Environmental Management
Faculty of Environment and Resource Studies
Mahidol University

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for the degree of Master of Science (Technology of Environmental Management)
on
March 3, 2014

……
Miss Roypimjai Jaimun
Candidate

……
Asst. Prof. Patamaporn Sripadungtham,
Ph.D. (Electrical Engineering)
Chair

……
Assoc. Prof. Nathsuda Pumijumnong,
Ph.D. (Natural Science)
Member

……
Mr. Usa Boonbumroong,
Ph.D. (Energy Technology)
Member

……
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

……
Assoc. Prof. Kampanad Bhaktikul,
Ph.D. (Civil and Environmental Engineering)
Dean
Faculty of Environment and Resource Studies
Mahidol University

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ROYPIMJAI JAIMUN 5436526 ENTM/M

M.Sc. (TECHNOLOGY OF ENVIRONMENTAL MANAGEMENT)

THESIS ADVISORY COMMITTEE : NATHSUDA PUMIJUMNONG, Ph.D. (NATURAL SCIENCE), USA BOONBUMROONG, Ph.D. (ENERGY TECHNOLOGY)

ABSTRACT

The objectives of this study were to evaluate the Renewable Energy Pilot Project for Sustainable Tourism at Phu Kradueng National Park. The study was divided into three parts, namely 1) Environmental impacts which were gas emission, noise level and grease and oil in soil from diesel engine of vendors and project's diesel engine. 2) Net Present Value (NPV), Internal rate of Return (IRR) and Benefit Cost Ratio (B/C ratio) were used to analyze economic viable of the project. 3) Calculating suitable electricity change for vendors and water heater change for travelers which will make the project self-sustainable.

In summary, from the analysis on the impact on the environment, it was found that the project's diesel engine emitted carbon monoxide (CO) was less than that of the diesel engine at the stores; the measured sound pressure level was about 82 dBA at the location of the diesel engine which was higher than the acceptable level; the grease and oil contamination of the soil in the vicinity area of the store's diesel engine was around 0.08-0.10 % dry basis; in the vicinity area of the project's 48 kW diesel engine it was around 0.08 % dry basis. Therefore, it can be summarized that the project's diesel engine impacts on the environment much less than the store's diesel engine. In addition, from the cost-benefit analysis of the project, it was found that it was worth investment in the renewable energy project. Moreover, in the cases of the project received the budget support to purchase of the new equipment that the proper electricity rates for the stores were 7.62 Baht. In the case of the project did not receive any budget support to buy the new equipment that the stores were responsible to pay for the new equipment in a form of paying electricity rates to the National Park were 18.39 Baht and in a case that the Phu Kradueng Nation Park and the stores shared the cost for purchasing of the new equipment. The proper electricity rates for the stores were 11.01 Baht. The appropriate water heater rate was about 15 Baht per person per 5 minute.

KEY WORDS: COST-BENEFIT ANALYSIS / RENEWABLE ENERGY / DIESEL ENGINE / PHU KRADUENG NATIONAL PARK

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การวิเคราะห์โครงการต้นแบบพลังงานทดแทนเพื่อการท่องเที่ยวที่ยั่งยืน ณ อุทยานแห่งชาติภูกระดึง ประเทศไทย

COST-BENEFIT ANALYSIS OF RENEWABLE ENERGY PILOT PROJECT FOR SUSTAINABLE TOURISM AT PHU KRADUENG NATIONAL PARK, THAILAND

รอยพิมพ์ใจ ใจมั่น 5436526 ENTM/M

วท.ม. (เทคโนโลยีการบริหารสิ่งแวดล้อม)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์ : นาฏสุดา ภูมิจำนงค์ Ph.D. (Natural Science),
อุสาห์ บุญบำรุง Ph.D. (Energy Technology)

บทคัดย่อ

การศึกษามีวัตถุประสงค์เพื่อประเมินความคุ้มค่าในการลงทุนของโครงการต้นแบบพลังงานทดแทนเพื่อการท่องเที่ยวที่ยั่งยืน ณ อุทยานแห่งชาติภูกระดึง จังหวัดเลย การรวบรวมข้อมูลปฐมภูมิ ได้มาจากการใช้แบบสอบถาม เก็บตัวอย่างในพื้นที่และนำไปวิเคราะห์ผลในห้องปฏิบัติการ โดยผลการศึกษาแบ่งออกเป็น 3 ด้านคือ 1) การศึกษาผลกระทบทางสิ่งแวดล้อม ทำการเปรียบเทียบปริมาณก๊าซ ระดับความดังของเสียง และปริมาณคราบน้ำมันปนเปื้อนในดิน ของเครื่องยนต์ดีเซลที่ติดตั้งในร้านค้ากับเครื่องยนต์ดีเซลของโครงการ 2) การวิเคราะห์ความคุ้มค่าโครงการ วิธีการศึกษาที่ใช้คือ การวิเคราะห์ต้นทุน ผลตอบแทน และความคุ้มค่าทางเศรษฐศาสตร์และทางการเงินของโครงการ โดยใช้เกณฑ์ในการตัดสินใจความเหมาะสมของการลงทุน 3 เกณฑ์คือ มูลค่าปัจจุบันสุทธิ, อัตราผลตอบแทนภายใน และอัตราส่วนผลตอบแทนต่อต้นทุน 3) การหาอัตราค่าไฟฟ้าที่เหมาะสม โดยใช้วิธีวิเคราะห์มูลค่าปัจจุบันสุทธิ เลือกอัตราค่าไฟฟ้าที่ทำให้มูลค่าปัจจุบันสุทธิมีค่าเท่ากับศูนย์ การศึกษาครั้งนี้คำนวณในส่วนของอัตราค่าน้ำอุ่นที่เหมาะสมแสดงถึงผลตอบแทนที่อุทยานฯ จะได้รับจากโครงการ

ผลการศึกษาพบว่าเครื่องยนต์ดีเซลของโครงการ ปลดปล่อยปริมาณก๊าซคาร์บอนมอนอกไซด์ ต่ำกว่าเครื่องยนต์ดีเซลของร้านค้า ระดับความดังของเสียงเฉลี่ยที่วัดได้สูงสุด ณ ตำแหน่งที่ตั้งเครื่องยนต์เท่ากันที่ระดับ 82 เดซิเบลเอ ซึ่งสูงกว่าค่าระดับเสียงเฉลี่ยมาตรฐานที่กำหนดไว้ และปริมาณของคราบน้ำมันในดินจากเครื่องยนต์ของร้านค้ามีค่าน้ำมันในดินเฉลี่ย 0.08-0.10 กรัมต่อดิน 100 กรัมแห้ง สรุปได้ว่าเครื่องยนต์ดีเซลของโครงการ มีผลกระทบต่อสิ่งแวดล้อมน้อยกว่า การประเมินความคุ้มค่าทางเศรษฐศาสตร์ของโครงการสรุปได้ว่าการลงทุนติดตั้งระบบผลิตไฟฟ้าฯ คุ้มค่าในการลงทุน และการคำนวณหาอัตราค่าไฟฟ้าที่เหมาะสมสำหรับร้านค้าอยู่ที่ 7.62, 18.39 และ 11.01 บาทต่อหน่วย สำหรับกรณีได้รับเงินสนับสนุน, กรณีร้านค้าเป็นผู้รับผิดชอบค่าใช้จ่าย และกรณีแบ่งสัดส่วนในการรับภาระค่าใช้จ่ายเพื่อซื้ออุปกรณ์มาเปลี่ยนในปีที่ 10 ตามลำดับ และอัตราค่าน้ำอุ่นที่เหมาะสมอยู่ที่ 15 บาทต่อนักท่องเที่ยว 1 คนต่อ 5 นาที

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CHAPTER I
INTRODUCTION

1.1 Statement of the problems

There are major pollutions problems such as air pollution, smoke and oil contaminated in soil at the Phu Kradueng National Park due to the vendors and the staffs have been using diesel engine generators. These pollutions cause respiratory and lung diseases. The pollutant emitted from a diesel engine affects the global warming. Moreover, the diesel engine generates the sound pressure level that exceeds the World Health Organization standard when it is started. Additionally, it contributes the mental health of the staffs, the vendors and the tourists (1). As a results, the research and development of renewable and alternative energy is promoted by the government policy. The goal is to reduce the quantity of foreign fossil fuels import approximately 25 % at least within 10 years (2). In 1999, renewable energy has become an alternative way for reducing such a problem at the Phu Kradueng National Park by employing the integrated power system using solar cells, wind turbines and diesel generators to generate the energy in the Visitor Center areas (Wang-Kwang). In 2009, some equipment got deteriorated causing the reduction of the power distribution stability. In addition, this integrated power system project only covered the areas of the staff's and the traveler's houses but not included the areas of the stores. Moreover, the gasoline's price has increased continuously (3). For these reasons, the first renewable energy project at Phu Kradueng National Park for sustainable tourism in 2012 was initiated. The aim of the project was to supply electricity to cover the stores by installing additional solar cell systems, increasing bidirectional inverters, using Smart Microgrids, and installing the prepaid meter to study the demand of the power system at the Phu Kradueng National Park in terms of capacity and power.

This study focuses on a study of economic value of investing in the renewable energy project by increasing the integrated power system proportionally and the improvement of some other related parts. This study can also be guidance for

the development of the power systems to the other National Parks. The electricity rates were also calculated for the stores at the Phu Kradueng National Park. As a result, this project will support the integrated power system to be able to perpetually sustainable in supplying the system itself. Additionally, it is responded to the government policy for utilizing clean energy, fortifying the stability of the electricity production system, and thus increasing more power distribution.

1.2 Objectives

1.2.1 To analyze the environmental impacts in the renewable energy pilot project for the sustainable tourism at the Phu Kradueng National Park.

1.2.2 To assess the value of investing in the renewable energy pilot project for the sustainable tourism at the Phu Kradueng National Park.

1.2.3 To calculate the appropriate electricity rates for the stores in the Visitor Center areas at the Phu Kradueng National Park.

1.3 Scope of study

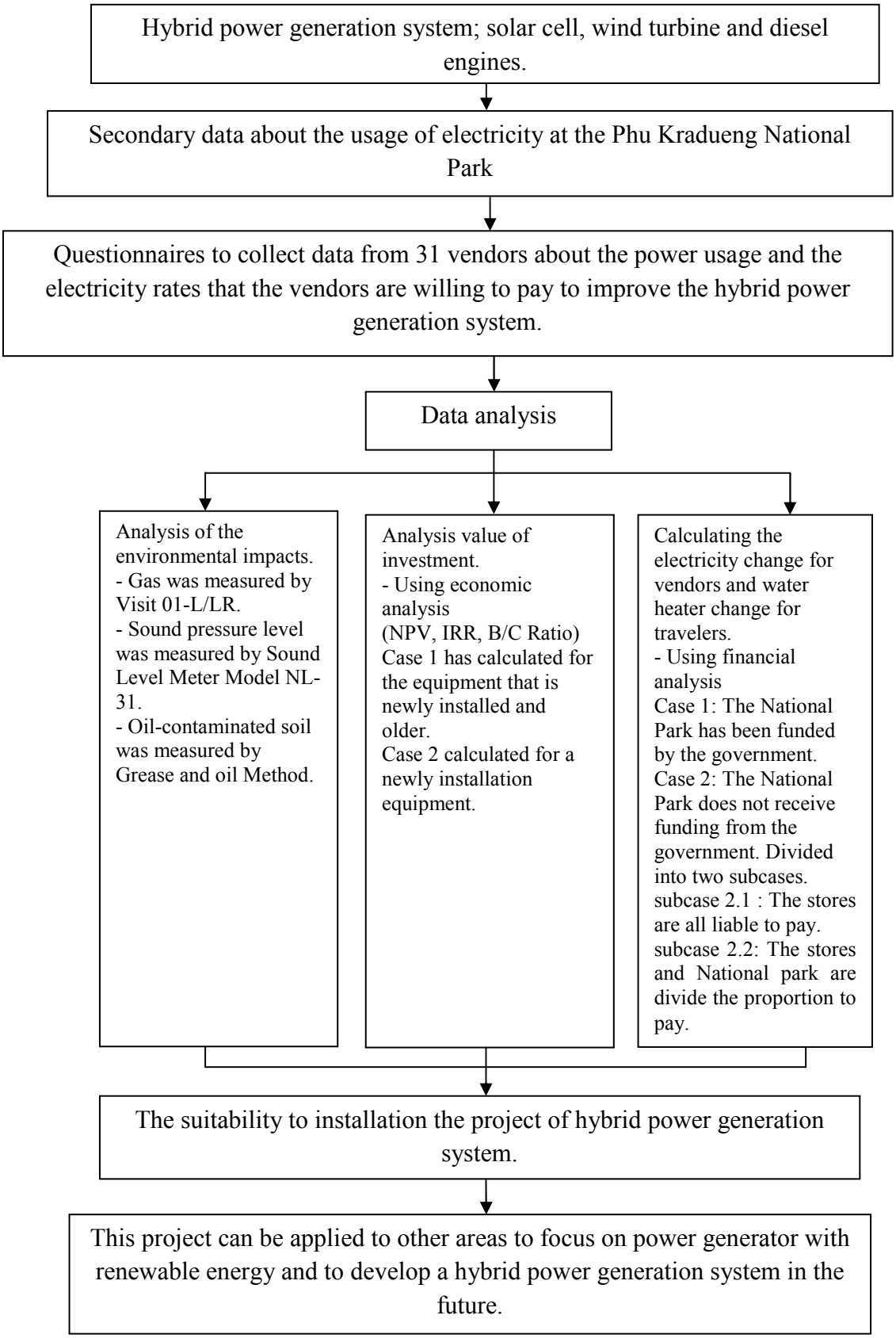
1.3.1 The areas of study are the stores, the staffs' and the travelers' residences in the Visitor Center area at the Phu Kradueng National Park in Loei province.

1.3.2 The assessment of investing value was divided into the economics assessment and the financial assessment. It was the analysis of costs and benefits of the project by focusing on the value of the renewable energy power system utilization as the primary system and the diesel engine as the backup system. This project covered for twenty years period.

1.3.3 The appropriate electricity rates were calculated based on the financial analysis by taking into an account for costs and benefits of the project such as the amount of electricity used at the stores, the hours of electricity used and how much the power can be generated. So the proper electricity rates for the stores were obtained.

1.3.4 The analysis of the environmental impacts was carried out by measuring the released of air pollutants, noise pollution and the amount of grease and oil in soil. These measurement quantities were measured from the vendor's diesel generators used at the stores and compared to the measurement quantity released from the project's diesel generators which was installed in 2012.

1.4 Conceptual framework of study



1.5 Expected Results

This project shows the analysis of the value of the investment, the payback period, the direct benefit and the indirect benefits of the renewable energy pilot project for the sustainable tourism at the Phu Kradueng National Park.

This hybrid electricity system developed for this project can be adapted and applied to the other National Parks that lack electricity. However, one must consider about the environment, geography and the other factors of each area in order to develop this hybrid power generation system in the future.

1.6 Definition

1.6.1 Hybrid power generation system

Hybrid power generation system in this project composed of the three power sources which are the solar cells systems, the wind turbines, and the diesel engines. The system was required to have the batteries energy storage system to supply the electrical load which has occurred since 2013.

1.6.2 The solar cells system

The solar cells system consists of the solar panels with the total maximum power 23.1 kW. It distributes the power to nine PV array through an inverter which connected to the distribution line of 3 kW. The original solar panels from the previous project were 7.5 kW. The new solar panels were installed with 17.18 kW in addition to the original solar panels. The new system can produce 34,857 kWh of energy per year, or 60 % of the electricity demand at the Phu Kradueng National Park. It was found that for the high season of tourisms at the Phu Kradueng Nation Park in 2010, the electrical load of the system reached averagely 50 kW. Electrical load is expected to reach 167 kWh in 2013. The maximum power is required to accommodate the demand for electricity usage.

1.6.3 Wind turbines

This study used a three-blade wind turbine for electricity 2.5 kW 1 unit mounted on hub height 18 meters. It can produce 1,687 kWh of energy per year, or 2.7 % of the electricity demand in 2013. Due to the wind turbine was already modified to be compatible with the AC system in 2010, thus, this project does not implement any additional wind turbine.

1.6.4 Diesel engines

Due to the electrical system's load has a maximum value of 25.5 kW at 6 pm., so we choose a system with 48 kW, 3 phases and 230/400 volt to replace the diesel generators. The control system parallels the source power with the bi-directional inverter to increase the ability of power distribution to the electrical load averagely 50 units per day. The system will also charge the battery as well as supply power directly in a case that the battery has no enough charges and unable to supply the power to the electrical load.

1.6.5 Value of economics

The value of economic analysis considers from three approaches; the Net present value (NPV), the internal rate of return (IRR) and the benefit-cost ratio (B/C ratio). The appropriate project must have a net present value of the investment project (NPV) more than 0. The internal rate of return is the highest rate of return or the discount rate that the project can pay back. It paid on the total return which equals to the total cost. The project's internal rate of return (IRR) equals to 0, is a rate that makes the net present value NPV = 0. The decision to accept or reject the project was considered the calculated internal rate of return (r) on the interest rate in the market. Generally, we will use the loan interest rate from a financial institution at the time of the decision. If the calculated internal rate of return (r) is higher than the interest rates, then the project is acceptable to invest. If the calculated internal rate of return (r) is lower than the interest rate, then the project is not acceptable to invest. The successful project must have the return on cost equal to or more than zero.

CHAPTER II
LITERATURE REVIEW

The review literature in this chapter was divided into 4 sections. The first section was about the general information of the Phu Kradueng National Park. Then in the second section, the power generation system at the Phu Kradueng National Park was described. Next the background theories used in the study such as economic valuation, cost-benefit analysis etc. were explained in the third section. And finally the last section was about the related research.

2.1 The Phu Kradueng National Park

The Phu Kradueng National Park is located in Tambon Sri Than, Phu Kradueng district, Loei province. It is one of the most abundance natural parks in Thailand. It was established as a conserved forest in 1943 and became the National Park on October 7, 1956. The park covers about 348.12 square kilometres. The Phu Kradueng is a mesa with approximately 400-1,200 meters above sea level surrounded by valleys. The highest point is about 1,316 meters above sea level. The Phu Kradueng National Park has many tourist attractions such as cliffs, waterfalls, and savanna-pine and wilderness areas.

The climate of the Phu Kradueng was influenced by southwest monsoon and northeast monsoon from April to October as it is a rainy season. The torrential rain period is from August until September and the average temperature is 26˚ C. The highest temperature is approximately 23˚-30˚ C in April. The lowest temperature is about 0˚-10˚ C in January, which was influenced by clouds and fog covering on the summit area. The average annual relative humidity is about 90 %. Additionally, the weather of hilltop is quite fluctuated. Also, due to the thick clouds and fog cover the hilltop area, thus, the weather there is cold throughout the year.

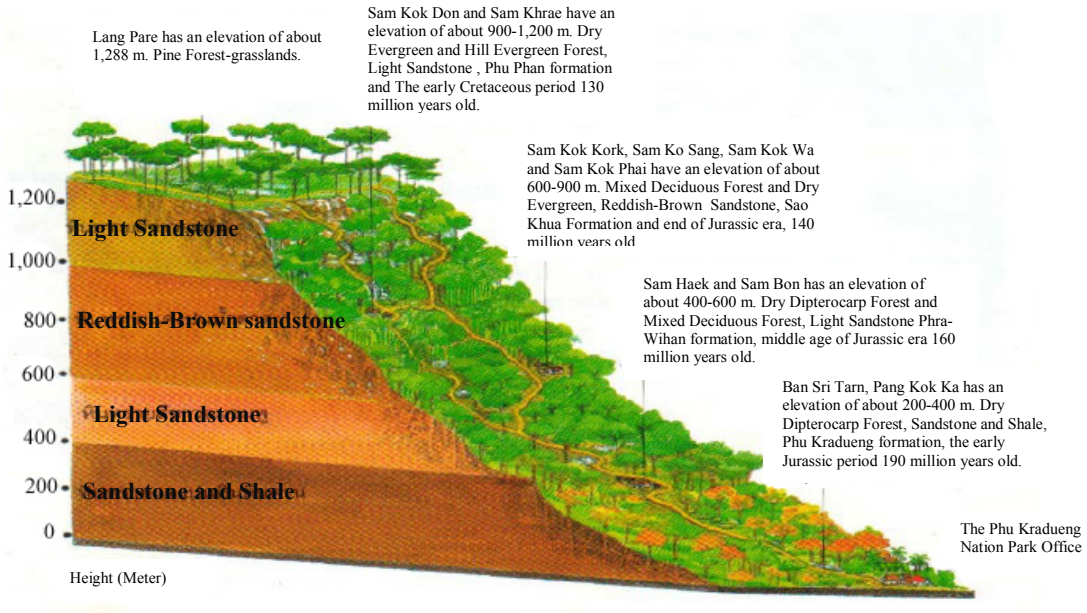


Figure 2-1 Displays the terrain of the Phu Kradueng from the foothill up to the hill top.

The facility details of the National Park located the Wang-Kwang tourist information center are shown in Table 2-1.

Table 2-1 The facility details at the Wang-Kwang tourist information center (4)

Sequence	Category	Number	Notation
1	Tourist's house	13	- Phu Kradueng National Park has many porters for service carrying tourists.
2	Row house	2	
3	Restroom	10	
4	Campsite	47 Rai	- The electric system around tourist information center come from solar-cell generators and wind turbine generators.
5	Dome tent (3)	50	
6	Dome tent (6)	20	
7	Cable tent (6)	40	
8	Canteen	28	- There is Pin phone system for service tourists.
9	Souvenir shop	3	
10	Electric system	6.00-10.00 pm	
11	Water supply	24 hr.	

The Phu Kradueng National Park allows tourists to access the pathway from 7 am - 2 pm because it usually takes about 4-5 hours by foot to walk up to the hilltop. The Phu Kradueng National Park is usually opened for visitors from October until May and is closed from June till the end of September due to the rainy season. However, during the shutdown period in the rainy season, some areas of the National park are still opened such as the Sri than tourist visitor center at the foothill areas and the Taad-Hong waterfalls. The numbers of tourists who visit the Phu Kradueng National Park from 2008 to 2012 are summarized and shown in Table 2-2.

Table 2-2 The number of tourist's statistic that come to visit at Phu Kradueng National Park in 2008-2012 (5)

Unit: Number of people

Month / **A.D.**	**2007/ 2008**	**2008/ 2009**	**2009/ 2010**	**2010/ 2011**	**2011/ 2012**	**Average**	**Percentage**
October	6,034	6,428	6,384	5,095	2,180	5,224	8.31
November	8,451	7,373	8,273	7,812	7,619	7,906	12.57
December	33,580	24,841	27,308	30,394	25,593	28,343	45.06
January	9,475	10,571	9,729	11,720	11,315	10,562	16.79
February	2,738	3,735	2,920	4,433	3,111	3,387	5.39
March	1,194	3,193	830	1,297	1,642	1,631	2.59
April	1,336	4,780	741	1,410	1,033	1,860	2.98
May	718	1,881	633	400	392	804.8	1.28
June	7	1,587	220	603	594	602.2	0.96
July	29	2,708	432	820	838	965.4	1.53
August	48	1,262	266	534	1,500	722	1.15
September	14	1,254	35	402	2,728	886.6	1.41
Total	63,624	69,613	57,771	64,920	58,545	62,895	100
Percentage Increasing/ Decreasing (%)		**9**	**-17**	**12**	**-10**		

It can be seen from the Table 2-2 that most tourists visit the Phu Kradueng in December around 45.06 %; whereas, fewer tourists about 0.96 % in June. Also, the

number of tourists decreases 17 % in 2010 compared to the numbers of visitors in 2009.

2.2 The Phu Kradueng National Park power generation system

Nowadays most of the shops at the Phu Kradueng National Park have been using the diesel generator to generate electricity. Though, the usage of the diesel generator has the major disadvantage that affects the shopkeepers, the National Park officers, and the tourists' health. The major disadvantage is that the diesel generator also creates the pollutions, mainly, the air pollution and the noise pollution.

2.2.1 Air pollution from the diesel generator

2.1.1.1 The sources of air pollution

Nilubol (1) stated that based on the operation of the diesel generator, the air pollution usually comes from its combustion systems as follows:

1) Fuel evaporation gas i.e. hydrocarbon (HC) evaporated from the other parts of the engine such as the tank and the carburetor. The quantity of evaporated gas depends on the temperature of atmosphere, the temperature of the engine and the evaporation ability of fuel. It could be compared with Reid Vapor Pressure (RVP). If RVP is high, the fuel has better evaporation ability. The proportion of HC emitted from the engine was approximately 20 % from this system. The diesel generator, of which the fuel has the boiling point higher than the temperature of the atmosphere, has no carburetor; thus, there is no hydrocarbon released from the evaporation step. By opening and closing the fuel tank too often will cause more fuel's evaporation, especially while the fuel tank is filling up. The volume of the evaporated fuel equals to the volume of the fuel being filled to the tank. For the carburetor when the engine is stopped, it will draw the heat from the engine. So the fuel in the carburetor will evaporate through the carburetor. As the engine gets hotter, the fuel will evaporate more. The fuel evaporation comes from both the fuel tank and the carburetor. Most of the fuel evaporation is mostly hydrocarbon, approximately 20 % of total pollutants released from the diesel engine.

2) Crank case, the pollution from crank case seeps in cylinder and piston downward to the crank case as the intake stroke and the compression stroke. These gases are generally referred to as the blow by gas. The blow by gas are often the hydrocarbon (HC) mixed with air about 85 % and also comes from the exhaust gases 15 %. These gases must be released from the crank case, otherwise it will damage to the engine due to the gases and the oil in the crank case get mixed and become sediment and its reactions as acid causing metal corrosion. The 4-stroke gasoline engine, HC was released from this system approximately 25 % of the total HC. For the diesel generator has only 1 % of the total HC released from the diesel engine.

3) Discharge of the exhaust system, the pollution from this system is the most dangerous and has quite abundant quantity. It is a result of the combustion of fuels and other chemicals such as either burned or unburned hydrocarbon, some carbon monoxide (CO) from the incomplete combustion process, some nitrogen oxide (NO_x) from the combustion of nitrogen with the high temperature of air, some sulfur dioxide (SO_2) and lead filled in gasoline. In addition, there is some black smoke known as a characteristic of the diesel generator. As a result, the quantities of pollutants depend on some variables of the generator for example electricity consumption rate, air and the condition of the combustion in the cylinders.

The sources of pollution and percentages of the difference sources i.e., the crank case: HC 25 %, particulates 25 %; the tank and the carburetor: HC 20 %; the exhaust system: HC 55 %, CO 99 %, SO_x 99 %, particulates 75 %. shows in Table 2-3 exhibits the difference in pollutant emissions. Individual engines, fuels including specific conditions of each engine results in the differences in the volume of pollutants emission from each engine. However, some theory describes differently about the sources of pollution in car and percentages of the pollutants emissions.

Table 2-3 The difference in pollutants (CO, HC and NO_x) (6)

Unit: part per million (ppm)

Origin of pollutants	**The 4-stroke gasoline engine car**			**Diesel**		
Pollution load (ppm)	CO	HC	NO_X	CO	HC	NO_X
Exhaust gas	100	55	100	100	99	100
Blow-by gas	-	25	-	-	1	-
Fuel evaporation gas	-	20	-	-	-	-

Note: CO= Carbon monoxide, HC= Hydrocarbon, NO_x= Nitrogen Oxide

2.2.1.2 Gas pollutants from the diesel generator

The major pollutants emitted from the diesel engine are nitrogen oxide (NO_x), solid particles (Smoke), hydrocarbon (HC) and carbon monoxide (CO). In addition, the most dangerous pollutants are the smell, the noise pollution and aldehyde.

1) Carbon monoxide (CO), comes from incomplete combustion of fuel. The CO production process in the diesel generator is resemblance to carbonize in the gasoline engine. If the combustion rate in the air increases and decreases rapidly, then there will be a lot of CO which is the smoke production process. The diesel engine's combustion normally uses more of the air quantity compared to the gasoline engine about 1.2-10 times. So the quantity of CO emitted from the diesel engine will be much less than the CO released from the gasoline engine. Carbon monoxide is quite dangerous gas that can do harm to every creature. Especially when we smell carbon monoxide, it will get into the circulatory system rapidly and bind to hemoglobin quickly. Additionally, CO has the ability for binding to hemoglobin much faster than oxygen about 300 times. Thus, hemoglobin will not be able to bring oxygen through cells and internal organs. If the brain cells lack oxygen only a short period of time, there will be some dizziness symptoms. If there is CO more than 100 ppm, it will be very dangerous for human. If the quantity of CO increases up to 800 ppm, then the person who inhales that much of CO will faint within 1 hour and probably die.

2) Hydrocarbon (HC), the diesel engine will release HC because the incomplete combustion. Though the quantity of HC emitted from the engine will be only a few for the same reason as CO emission. But it could be increased when combination of the air and the thick fuel touch with the cylinder block wall at low temperatures. So HC will not react to O_2 and therefore, there is no combustion. If some mixture is too thin, it will put out a fire and cause a lot of HC. The residual oil will not further burn in the combustion process and thus, more HC will be produced. The lubricating fuel in the cylinder block and the incomplete combustion cylinder is also the cause of emitting HC. Hydrocarbons are hazardous due to it can react and bind to nitrogen oxide and ozone to create smog which is dangerous to environment. It is difficult to describe how much nitrogen oxides being produced or in which cylinder due to the ratio of air and fuel varies complexly in the cylinder. In a case that the cylinder has a lot O_2, the combustion will be complete and fast. This also causes very high temperature in the cylinder and thus more of nitrogen oxide gets produced during this process. The combination of NO and NO_2 is quite hazardous. The oxide of nitrogen that is so harmful and dangerous. When people breathe this gas that bronchial mucosa and lungs are inflamed.

Smoke is produced from the core of fuel beam injected into the cylinder which is slow diffused and has high density. When spindle fuel contacts the high temperature in the cylinder as O_2 making the combustion faster, this will produce carbon aerosol and finally create black smoke. Meanwhile, the fuel contacts the cylinder, the cylinder block as well as the fuel droplets after injection, it creates black smoke. Black smoke can cause the lung tumor.

3) Sulfur dioxide (SO_2), occurs when there is some sulfur in the fuel. The diesel fuel has sulfur (S) about 0.5-1.0 % by weight as mandated by law after the distillation process. It is found that 0.3 % of fuel sulfur will release sulfur dioxide (SO_2), approximately 100 ppm. The combustion of the fuel that contains sulfur will release sulfur dioxide (SO_2) approximately 90 %. This is considered as poisonous gas with tangy smell. By touching the poisonous gas, there will be eyes irritation. By inhaling it, there will some inflammation the respiratory epithelial surface and effected to bronchial contraction. When sulfur dioxide exposes in the sun light, it will become sulfur trioxide (SO_3), which will turn into the sulfuric acid if SO_3 are mixed with the

water mist. The sulfuric acid causes the rain to become acid rain which is dangerous to the environment for example it causes the corrosion of lime stone structure and metal, it harms the forests and it causes the water resources become acid.

2.2.1.3 Impact of air pollution on human beings

Human get effects from air pollution by breathing. The respiratory system consists of nose, nasal membranes, mouth, neck, windpipe and larynx. SO_2 causes mucus, inflammatory phlegm, breathing discomfort and pneumonia. Moreover, NO_x and CO could infiltrate into alveolus and bind to hemoglobin producing Carboxyhaemoglobin (COHb). The COHb inhibits O_2 in purifying blood, which could be danger to life. The pollution impacts to humans were summarized in Table 2-4.

Table 2-4 Impact of air pollution on humans (7)

Pollutant	Quantity (ppm)	Symptom	Reference
SO_2 and Chemical aerosol	80-100 Average per year	Elder who are older than 50 to occur inflammation of respiratory tract and lungs.	Winklstein 1967
	SO_2 and chemical aerosol 130 for each		Douglas&Waller 1966
	SO_2 and chemical aerosol 130 for each		Lunn et al 1967
	SO_2 and chemical aerosol 130 for each		Petrilli et al 1969
	SO_2 Average 140-260 per 24 hr.		Carnow et al 1969
	SO_2 300-500 and less chemical aerosol		Brasser et al 1967
	SO_2 630 and chemical aerosol 300		Lawther 1958
CO	35 minutes per 8 hr.	Amnesia	Schulte 1963
	35 minutes per 8 hr.	Amblyopia	Me Farland et al 1904

Note: ppm= Part per million, SO_2= Sulfur dioxide, CO= Carbon monoxide

2.2.1.4 Impact of air pollution on plants

Plants can absorb air pollutants by inhaling the pollutants left on their leaves. The component of SO_2 will destroy chlorophyll and thus decrease the photosynthesis.

2.2.1.5 The standards for ambient air regulation. Table 2-5 displays the air pollution regulation by Pollution Control Department.

Table 2-5 Air pollution regulation by Pollution Control Department in 1992 (8)

Air Pollution regulation by Pollution Control Department in 1992	**Concentration of Gas (Part per million: ppm)**
Carbon monoxide (CO)	30
Nitrogen dioxide (NO_2)	0.17
Sulfur dioxide (SO_2)	0.30

2.2.2 Noise Pollution

2.2.2.1 The sources of noise pollution

1) Natural sound sources, most of natural sound such as thunder and thunderbolt, are not too loud to create much of noise pollution problem.

2) Man-made sound sources

- Stationary source such as noises from the factories with the diesel engines, drilling machines, night clubs, and construction sites.

- Mobile source for example noises from motor vehicles i.e., car, bus, motorcycle, boat, and plane etc.

2.2.2.2 Dangers of noise pollution

1) Dangers of noise pollution to humans, direct damages to the auditory nerve. The loud noise affects to hearing for 2 levels as of following.

- Temporary hearing threshold shift due to being exposed to the loud noise for a short period of time which causes temporary deafness. This temporary deafness is curable.

- Permanent hearing threshold shift because of being exposed to the loud noise for a long period of time continuously which causes the auditory

system deteriorated. For the first few times of being exposed to the loud noise, it sometimes will not be noticeable. However, if the person is exposed to the loud noise for very long time and more frequently, then that person will suffer from permanent hearing loss.

2) Dangers of noise pollution to general physical and mental health, the sound pressure level above 80 decibels will cause some disturbance and dangers to human. However, some people can bear with the loudness due to they get accustomed with this environment. The noise pollution can cause some damages as follows.

- Damages to physical body. If the person is exposed to extremely loud noise, it will cause deafness, expansion of the blood vessels, hypertension, muscular spasm, deterioration of the immune system and weakness.

- Damages to mental health. The annoyance from noise pollution can cause stress. The annoyance due to noise pollution can be categorized as follows.

- Loudness; the loud noises cause some nuisance. The sound level over 100 decibels is harmful; one should not be exposed to this sound level more than 2 hours.

- Pitch; the noise with frequency over 15,000 cycles per second causes more annoyance than the lower frequency noise at the same loudness.

- The intermittency and irregularity noise; which is the noise without rhythm, can create more annoyance than the continuous and unchanged noise.

- The sound source's direction; the sound comes from the same direction sources causes less annoyance than the noise comes from multi direction sound sources.

3) Danger of noise pollution to work habits, the excessively loud noise will decrease work efficiency of the workers. It could be described as follows.

- Low noises will not affect workers much though it can cause the workers to make mistakes and lead to some accident.

- Intermittent noises and high frequency noises affect the workers more than the continuous noise such as car braking noise from suddenly stop. These noises can make the worker feel unhappy as doing their jobs.

- In an extremely loud place, it will affect the ability of reading comprehension and/or memorizing any context.

4) Other dangers of noise pollution, noise pollution can cause hearing loss. It can also put the environment in danger such as traffic noise the cause annoyance to the residential areas, and extremely loud noises cause some disturbance to animals.

2.2.2.3 Sound pressure level standard and regulation

Standard and regulation of hearing defines the sound source and the impact of sound, sound pressure level, loudness and the duration of sound exposure. For the frequency and the distance from the noise source, it can be measured by installing the sound measurement device at some certain distance from the sound source according to the standard and regulation such as the measurement of sound pressure level emitted from the motorcycle's exhaust, the sound level meter must be 0.5 meters far from the exhaust.

In order to prevent the damages from noise pollution, the World Health Organization (WHO), the U.S.EPA, the World Bank and Japan have issued the standards of sound level that specify the sound levels which will not cause nuisance and affect people as shown in Table 2-6.

Table 2-6 The highest sound level that it causes no disturbance to human by WHO, World Bank, U.S.EPA and Japan (9)

Activities	Institute			
	The World Bank	WHO	U.S.EPA	Japan
1. Living (Outdoor building)				
- Daytime (7 am. – 10 pm.)	55 dBA	55 dBA	55 dBA	50 dBA
- Nighttime (10 pm. – 7 am.)	45 dBA	45 dBA	55 dBA	40 dBA
2. Living (Indoor building)				
- Daytime (7 am. – 10 pm.)	-	45 dBA	45 dBA	-
- Nighttime (10 pm. – 7 am.)	-	35 dBA	45 dBA	-
3. Commerce				
- Daytime (7 am. – 10 pm.)	65 dBA	70 dBA	-	60 dBA
- Nighttime (10 pm. – 7 am.)	55 dBA	70 dBA	-	50 dBA
4. Learning (nursing school)/quiescence				
- During class	-	35 dBA	-	-
- During activity	-	55 dBA	-	-
- Daytime (7 am. – 10 pm.)	-	-	-	45 dBA
- Nighttime (10 pm. – 7 am.)	-	-	-	35 dBA

2.2.3 The electricity generation system for the visitor center (Wang-Kwang) and Housings for authorities

King Mongkut's University of Technology Thonburi staffs have been checking the performance of the installation system by changing the expired battery and modifying the system to be a Pure AC Coupled Hybrid System from December of 2011 to January of 2012, which is the high season for tourism. The electrical load of the system was averagely 50 units per day. The electricity generation system by way of the renewable energy could generate an average of 30 units per day consisting of the electricity from the solar cells about 28 units per day, and the electricity from the wind turbine around 2 units per day. The diesel generator distributed the supplement

energy approximately 20 units per day. So for the high tourism season, it is necessary to have the diesel generator to dissipate supplement power.

After May of 2012, the electrical system load decreased to 29 units per day, which was lower than the designed electrical load. due to the National Park is closed. The capability of generating electricity from renewable energy was decreased to an average of 25 units per day due to the rainy season. However, the electrical generation system from renewable energy was still able to produce enough power for the electrical load by turning on the diesel generator from time to time. It is found that the improved power system during the first year of operation has met the requirement for the electricity system design. The electrical system at Tourist service center zone (Wang-Kwang) is more stable with 3 phase 230/400 volts, 50 Hz. It could provide electricity for 24 hours at the preserved national park and also public illumination system. The tourist lodges have electricity from 6 pm -10 pm. The efficiency of the electrical system was increased to 9 % from the original system. Also, the fuel consumption reduced averagely about 720 liters per month.

However, this project covers only the housing authorities and national park lodges travelers. It does not include 31 stores in the area. At the present, those stores are also affected from expensive fuel situation because the stores use the small diesel generators (3-5 kW) for generating electricity. In addition, they used gasoline for more than 1,600 liters per month. The operation of such system created loud noise and pollution directly affecting tourists and wildlife directly. Moreover, the Phu Kradueng National Park still has costs for supplying fuel to the diesel pump to service tourists more than 450 liters

The improvement of the power generating system and the power distribution system is to construct the hybrid system by means of the renewable energy at the Phu Kradueng National Park. The improved system can support the increased electricity load for the stores and the pumping system. It is operated by increasing the proportion of the renewable energy and the Smart Microgrids.

2.2.3.1 The hybrid power generation system

The research about the hybrid power generation system protocol utilizing the clean energy occurred in 2012. It was an independent power generation system by means of AC-coupled modular expandable hybrid system, which

was operated together with the alternator. There is a standard for data communication and operation control, of which the objective is to design to an easy-to-install structure and able to expand the additional system by installing more of the power generating systems with different control features.

In 2012, the power generating system at the Phu Kradueng National Park is the hybrid power generating and distributing system. The power is generated by ways of the hybrid system composed of the solar cell, the wind turbine and the battery. It could distribute electricity directly to the electrical load by using the grid-connected inverter and the bi-directional inverter. The battery and the bi-directional invert will adjust the power distributed from the system to match with the electrical load. This system has some advantages; it is easy to expand productivity and expand from a single-phase AC power to a three-phase system. When the electrical load has more power than the total power of the bi-directional inverter, the diesel engine will then supply the power to the electrical load.

The ratio of the renewable energy to the electrical load is 60 % for the electricity generating system in 2012. It decreased only 11 % when compared with increased electrical load such as the stores and the pump systems. This also affected the system that depends mainly on the diesel generator. In this research project, the improved system was design in order to increase the renewable energy and decrease the dependent on the diesel cost as well as increase the bi-directional inverter’s capacity for more electrical load distribution in the morning. Furthermore, it can decrease the diesel engine's operating hours and also provide more power to the stores so that they can service the tourists.

The designed hybrid system in this project composes of 3 resources; the solar systems, the wind turbines and the diesel engines with the battery energy storage system to supply power to the electrical loads that occur in 2013 approximately 167 units per day with maximum power 25.5 kW. The system was designed by using HOMERpro program. It is found that the proper power system to be applied at the Phu Kradueng National Park should consist of the solar system with 24.78 kW, the wind turbine with 2.5 kW the renewable energy sources, the battery subsystem with 240 kWh as the energy storage, and the diesel generator with 48 kW for supplying auxiliary power during the high electricity demand period. The designed

hybrid power system is a parallel hybrid power source and can be described as following.

1) The solar cell subsystem consists of the solar cells panels with maximum power of 24.78 kW. The maximum power dissipated through the grid-connected inverter is approximately 3 kW for 9 machines. The solar cells power comes from the original system around 7.5 kW and from the additional installation about 17.18 kW. The new system can produce 34,857 kWh of energy per year or 60 % of the electricity demand in 2013. It is expected that the demand for electricity during opening season is approximately 167 units per day in a case that every store has additional electrical appliances.

2) The wind turbine system composes of the three wind turbine blades with 2.5 kW mounted on an 18-meter hub height. It can produce power about 1,687 units per year or 2.7 % of the electricity demand in 2013. Due to the wind turbine system has already been improved to be compatible with the AC system in 2010, thus this project does not develop any further improvement.

3) The diesel generator system; due to the maximum electrical loads about 25.5 kW during 6 pm, so we chose the generator with 48 kW, 3 phase, 230/400 volts to replace the original expired diesel generators. The control system is done by paralleling the sources with the bi-direction inverter to increase the ability to supply the power to the electrical loads during the high demand period and also to charge a battery as well as directly supply power in a case that the battery charge cannot supply enough power to the electrical loads.

4) The battery subsystem consists of the 144 vented-type station lead-acid batteries with 1,000 ampere-hour each. The total energy of the system equals to 240 kWh which is enough to spare for one day. Since the battery system were already installed in 2010, so this project did not procure any further supply.

5) The six bi-directional inverters with 5 kW each connected as 2 sets of the 3 phase system parallel to each other to distribute the renewable energy to the electrical loads up to 30 kW. In a case that the maximum load less than 30 kW, it is not necessary to operate the diesel system. The inverters convert the DC voltage from the battery system to AC for supplying the electrical loads. Meanwhile, if the battery has insufficient energy to supply to loads, the inverters will recharge the

batteries. In 2010, the bi-directional inverters were installed for 3 units. In this project additional three inverters were installed. The total power from the new installation is about 15 kW. Based on the experience from the past, the inverters are very important part of the system. When the inverters were broken, it would affect the entire power system. As a result, it is necessary for this project to procure the additional reserved bi-directional for the stability of the power system.

6) The grid-connected inverter with 3 kW each for 10 units by connected to a photovoltaic system with 2.6 kW each. There are three original grid-connected inverter installed in 2010 and additional 6 units installed in this project. Due to security reasons in distributing power as well as the bi-directional inverter, it is necessary to procure an additional back-up inverter and grid-connected inverter with 3 kW. This power system is capable of supplying more power, which is increased from the solar system about 24.78 kW and from the wind turbine system around 2.5 kW. By integrating the grid-connected inverter with the bi-directional inverters, the hybrid system can support a maximum power of 56.5 kW.

7) The measurement and data collection system for a study of the operation of the system and assessment on technical and economic aspects of the project. Also, it can be used to improve the system's performance and to plan a utilization plan for maximum benefit. The measurement system can be connected to control and read the electrical measurement results from the devices in the system as well as the meteorological data. The measurement data are linked to the data base on the website. Since the measurement and data collection system was installed in 2013, this project only provided a monitor to display the operation of the system at the visitor center (Wang-Kwang).

8) The distribution system, due to the project has improved the production and the distribution of electricity to support the increased electrical load for the stores and the pumping system. Therefore, it is mandated to install the low voltage distribution system of 3 phases, 4 wires by burying the lines underground direct to the stores and the pumping system. The power cable NYY with a cross-sectional area not less than 25 square millimeters were used in order to prevent the voltage drop for more than 3 %. Furthermore, the signs were installed to indicate the power lines.

This hybrid system can provide the power (from the solar subsystem and the wind turbine) average about 100 units per day, around 70-90 units per day in the rainy and the winter season, and approximately 100-120 units per day in the summer which is the peak season for power distribution. In a case that the power is generated from the solar cell subsystem, the wind turbine system and the diesel generator, it is expected that the power distribution could reach 167 units per day which is sufficient to service the Phu Kradueng National Park in the opening season in 2013.

The original transmission line with 3 phases, 4 wires buried underground was suffered from the lightning surge occurred in the AC of the new project. To solve this problem, the lightning protection device was installed for more protection to the transmission lines and increase the power stability and safety as shown in Figure 2-2.

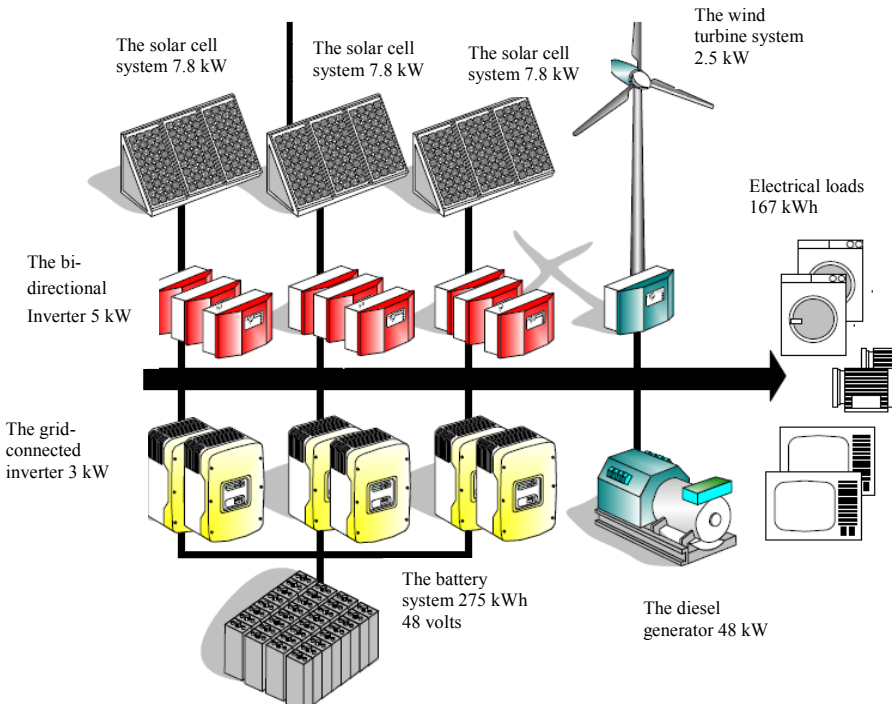


Figure 2-2 Components of the power system that used in The Phu Kradueng National Park in 2013 (10)

2.2.3.2 Smart Microgrids technology

Smart Microgrids are the electrical network employing the information technology and communications to manage and control the power generation and distribution. It can support the electrical network connection from the alternative energy resources or distributed generation (DG) and the utilization of assets for maximum benefit including the efficient, stable, and reliable service for the users through a smart meter.

At the present, the power distribution is a one-way direction from the manufacturer to the consumer through the distant transmission lines which causes a huge power loss. The hybrid system was implemented in this project by means of the intelligent electrical network technology. For rural villages, the power production distribution system with renewable energy (Mini-grid) was used. The power system will supply power to a multi- point transmission system or distribution system along the transmission line by connecting to AC grid system. The energy sources were scattered on each side of the island. This reduces load capacity of the power plant and dissipates energy to decrease the transmission loss.

This new system has changed the concept of power transmission from the original one. The original single direction power transmission line was changed into the bi-directional transmission line by using information technology to assist in communication and management. This way the consumers can access the energy consumption data at the time. In addition, the power management responds to the consumers' maximum satisfaction and the amount of money paid for electricity consumption including the amount of money and the quantity of electricity that consumers can save up. By gaining the access to the power consumption data, the consumers may be more aware of how to utilize the electricity and perhaps change the power consumption behavior.

2.3 Concepts and theories

In this project, the analysis of the hybrid power generating system was studied. It is necessary to evaluate and determine the project costs and social benefits, the feasibility and the value of investment in this project. Moreover, the data were

analyzed to determine the appropriate electricity rates for the stores. The concepts and theories used for this project can be explained as follows:

2.3.1 The concept of cost-benefit analysis

The worthiness analysis of project is a way to assess the value of investing based on the analysis of cost-benefit analysis (CBA) due to a monetary standard used to measure the financial assessment. Most of the expensed incurred in the period before the operation is performed and execution of the project. This study conducted a cost-benefit analysis which is divided into 2 categories; the economic analysis and the financial analysis.

2.3.1.1 The analysis of economic value

Boonlue (11) stated that the analysis of the economic project is the method to find the real value of costs and benefits of the project by cutting unproductive costs and expenses. If the market is perfectly competitive, then the market value is the price that reflects the real value of goods and services. But the market is not perfectly competitive in reality, thus, the price does not reflect the real value of goods and services. So, it is required to calculate the real price, or so-called the shadow price, which reflects the true opportunity cost of the inputs or goods for evaluation of the true costs and benefits of the project. This can group the product that cannot be traded in the global market (Non-Tradable Goods), such as local transportation including freight trains and freight road, construction, manufacture and supply of electricity. The shadow price of the product can be calculated by using the coefficient of adjustment or standard conversion factor with the following formula. In this research, the market price was changed to the economics value by calculating the coefficient of adjustment defined by Ahmed (12).

$$\text{Conversion Factor} = \frac{\text{Shadow Price}}{\text{Market Value}} \qquad [1]$$

The investment of the project at a particular time by expecting the benefits in the future must adjust the value of money at the same time for both the cost stream and the benefit stream prior to a comparison and an analysis to assess the

worthiness of the project. The most common method of adjustment is the discount rate which is the future value converted into a present value or equivalent.

1) The discount rate; the economic analysis the capital investment of the new project is the rate of return. That is the opportunity cost. For the discount rate used in the financial analysis that is the interest rate or the financial support rate, which was expected to receive from the investment. It is necessary to choose the appropriate discount rate.

The choice of discount rate comes from calculating the present value. This study used the rate of return on government bonds interest rate, which is the funding of the Phu Kradueng National Park. The discount rate used for calculating the economic value in this study is the rate of return 10 % from The Bureau of the Budget.

2.3.1.2 The analysis of financial value

The estimated cost of the project is the estimation of various values used in the project consisting of; The investment cost, which is the cost resulting from using resources to build infrastructure facilities for production. The operating and maintenance cost, which are expenses incurred while starting operations in order to the project can procede.

The estimated return of project comes in a form of the benefit of the project that can calculate as the financial value, such as revenues, which was in a form of the electricity bill. In considering the funding source, the project manager must anticipate capital needs in the future for example the equipment maintenance costs or the replacement in terms of money and time. Due to the lifetime of equipment is not all the same, the funding source can be divided into 2 phases: short-term and long-term funding sources. There are 2 kinds of funding source: the debt financing and the equity financing. In this project, we considered a possible source of funding comes from the Phu Kradueng National Park revenue or the issuance of government bonds.

The estimated cash flow of project must be used the statement of cash flows, which is the financial statement providing information about cash inflows and outflows of the project. That is come from the funding sources and an increased or decreased net cash during the operating activities, investing activities to be aware of the financial changes. After calculating the current return and the cost, we

can determine income and cost of the project annually. The difference between the current revenue and the expenditure in net cash flows or net benefit can be written as the following equation:

$$\text{Cash flow} = \text{benefit per year} - \text{expenditure per year} \quad [2]$$

Discount rate was analyzed for the financial worthiness that can be divided into 2 sessions: Bank of Thailand (13), the first investment requires the rate of return at 10 % and the second session is the interest rate of government bonds at 6 %.

2.3.2 Criteria for making a decision from the analysis of economic value

Makprang (14) stated that the financial analysis evaluates costs and benefits resulting from investment of project. It is useful to compare costs and benefits of that project. Due to the costs and benefits of the project occur in different periods of time throughout the project's duration. So it must be adjusted for the time value to ensure the benefit and costs. By assigning the current time, the financial analysis can be compared correctly to see whether the benefits are worth to invest or not. The criteria for decision making are:

2.3.2.1 The Net Present Value (NPV) is the difference between the present value of the returns from throughout project and the present value of cost to invest over the life of the project at a discount rate. That used the loan interest rate of financial institutions. The suitable project must have a net present value (NPV) is greater than zero, which can be written by the following formula.

$$\text{NPV}= \sum_{t=1}^{n} \frac{B_t}{(1+i)^t} - \left[\sum_{t=1}^{n} \frac{C_t}{(1+i)^t} + C_o \right] \qquad [3]$$

Assigned:

B_t = Benefit in each year order (t = 1, 2, 3,..., n)

C_t = Cost in each year order (t = 1, 2, 3,..., n)

C_0 = Expenditure for investment on the first year

t = Year order

i = Interest rate of loan

n = Life of project (years)

2.3.2.2 Internal Rate of Return (IRR) is rate of return or maximum discount rate that project can pay back. It was the project pay out that will have the project's total return equals to the total cost at IRR=0. That is rate to make NPV=0.

$$\text{IRR (r)}: \sum_{t=1}^{n} \frac{B_t}{(1+i)^t} - \left[\sum_{t=1}^{n} \frac{C_t}{(1+i)^t} + C_o \right] = 0 \qquad [4]$$

Assigned:

B_t = Benefit in each year order (t = 1, 2, 3,..., n)

C_t = Cost in each year order (t = 1, 2, 3,..., n)

C_0 = Expenditure for investment on the first year

t = Year order

i = Interest rate of loan

n = Life of project (years)

r = Internal rate of return was calculated

2.3.2.3 The Benefit-Cost Ratio (B/C Ratio) is a ratio between the present value of expected returns from the project and the present value of the cost that was paid over the lifetime of project at various ratios. The project was successful when benefit-cost ratio must be equal to or greater than zero, the formula is as following:

$$\text{B/C ratio} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t} + C_0} \qquad [5]$$

Assigned:

B_t = Benefit in each year order (t = 1, 2, 3,..., n)

C_t = Cost in each year order (t = 1, 2, 3,..., n)

C_0 = Expenditure for investment on the first year

t = Year order

i = Interest rate of loan

n = Life of project (years)

2.4 Related studies

Klaimukh (6) studied and evaluated the technology hybrid system with clean energy at the Tarutao National Park by installing the solar cell, the wind turbine and the diesel engine. There was a study about the environmental impact on economic value and gathering the factors that used for evaluating the technology. Delphi Technique was used from 12 expert persons. It is found that the electricity generating technology is appropriate for the environment by considering the air pollution, the noise pollution and the contamination of oil. The thesis evaluated appropriate social that the generation system has recognized from people in the area. This study found that the project was not worth the investment by looking at the 3 methods of investment decision criteria (NPV, IRR and B/C ratio). However, the willingness to pay of the users can be counted as additional benefit of the project. By collecting the opinions of the experts based on the analysis of economic value, it is found that the overall technology is appropriate for the area but the investment for installation is too high. The experts agreed about the evaluation of the project that should be considered in the following order; the potential energy sources in the area, the policy and the law, the technology selection, the economics value, the environmental impact and the suitability for the user.

Sereepaowong (3) studied the environmental impact and the economic feasibility for the project as well as the financial management company (RESCO). For example, the hybrid power system with renewable energy for communities lacks of electricity in Koh-jik village, Chanthaburi province. This area had trouble using electricity. Originally, this village used the diesel engine to generate electricity but the problem is the cost of fuel and oil transportation. It also contributed pollution. King Mongkut's university of Technology Thonburi's staffs installed the electricity generating system by ways of the renewable energy hybrid. The analysis of the cost of project found the original power system causes more pollution than the hybrid system For the economic feasibility of the project, it was found that it was worth the investment. But it was not worth on the financial of RESCO. The villagers were satisfied in the system and the management. It can be considered as a good pilot project on the development of the renewable energy to produce electricity for the other areas.

Nilubol (1) assessed the suitability of the hybrid power system with clean energy, in the aspects of environment impact, attitudes of consumers and value of economic by analysis of the variance, the difference of the average, the variance, and the percentage, the difference between the median, the mode and the inter-quartile range. This study is a survey research by studying about the diesel engine power system. For the environmental aspect, studied about air and noise pollution and the contamination of oil in soil. For the attitude of the consumers toward the hybrid systems, it was done by studying the attitudes of the tourists, the park officials and the shop owners at the Phu-Kradueng National Park. Questionnaires were used to collect the data. For the economic value analysis, the costs and benefits was analyzed by gathering information from the documents and related agencies. For the assessment of economic environment, the questionnaires were used to collect data and then analyzed by means of Contingent Valuation Method (CVM).

This study found that the power system with diesel engines causes the noise and the air pollution. In addition the contamination of oil in soil was found more than that of the hybrid power system with clean energy. This study surveyed the consumers' attitudes for 3 groups. It was found that the good attitude was toward the hybrid systems over the power system with the diesel engine. In terms of assessing the

value of investing for the 20-year project, it was found that it was not worth the investment because it costs more than the benefits. However, when the environmental benefit of this project was taken into account, it was worth for the investment. This project contributes the good impacts on the environment. For the technology assessment of the power system, there were important factors as follows: the potential of the energy resource, the compliance with the environmental laws and policies, the proper electricity generating technology, the value of investing, the environmental impact and the readiness of the power consumers.

Furthermore, the process of the economic value analysis of the electricity hybrid system was studied in order to be aware of the costs incurred and benefits expected whether it was worth to invest or not. They also mentioned about the consequences of the project and its effects that may arise if project were not implemented. As well as the cost that is needed in order to carry out this project and update more current data.

Ku, Yoo (15) studied about the willingness to accept the investment for the renewable energy, with a case study of South Korea. The South Korean government has set a target to reduce the use of energy sources by 11 % within 2030. This is the right policy for the investment in the renewable power consumption. Therefore, it is necessary to have a return on investment analysis of alternate energy based on willingness to pay of households. This study is an attempt to apply the method to analyze The Choice Experiment (CE) to evaluate the investment in the renewable energy in South Korea by considering various features. From previous model in a form of Multinomial logit (MNL), in this study the model Multinomial probit (MNP) was used. The MNP model analysis was way more interesting than the MNL because this model was more flexible. That is to say the MNP error is more flexible than the other models. Moreover, this method allows the researchers to release the tension about the assumption that all respondents have the same requirements for the estimation. The results demonstrate the value of the protected wildlife, the reduction of the pollution and the increased chances of employment in South Korea. On the other hand, the respondents did not give the value in modifying landscape, the MWTP monthly for maintenance around 1 % in terms of wildlife and air pollution. It was calculated at KRW approximately 6.85 (USD 0.0071) and KRW 8.40 (USD 0.0088), respectively.

The willingness to pay monthly in the rural areas, for the long term employment for additional workers at KRW 10.87 (USD 0.0113) as well as the willingness to pay in the city around KRW 135.1 billion (USD 140.7 million). The highest level was presented in the survey for plants that use the clean energy. From a comparison of clean energy crops, it is found that this clean energy crops will make revenues about 50 % of the improvement variety of species in the vicinity. This can reduce the air pollution by up to 100 % in a long term.

Prakash, Bhat (16) analyzed the energy, the economic and the environmental impacts of the renewable energy systems. The renewable energy power generation technology is assessed by compared to a range of indicators of sustainability using data obtained from the literature review. These indicators dictate the cost of the electricity generating system, the greenhouse gas emissions and the energy payback. It was found that all three parameters have the width of the range of each technology for grading the different sources of a new protocol. It has been proposed to link to the greenhouse effect, the energy payback and the cost of generating electricity from the renewable sources. In addition, the wind power and small water energy produced a sustainable energy source for electricity generation. The format of the value of the renewable energy sources from the electricity generation have been analyzed that could be viewed from FM (Figure of Merit) from the origin sources. The ability to support and the sources' lifetimes are different. It could be considered to assess the effects of greenhouse gas emissions and EPBT value of FM. The heat from solar PV and the small water power has the differences from 729 to 900, 12 to 360, 36 to 360 and 560 to 900, respectively. The ranges of FM systems are different due to the geography, the consideration of life, the ability to support of systems and the time for conducting research as well as the increase of the capacity, the reduction of the greenhouse effect and the EPBT significantly. This FM shows that the sustainability of electricity production by the wind turbines and the small hydro systems should be developed first. Then after that the solar thermal and solar PV systems can be further developed. The wind turbines and the small hydro system are the best systems for the sustainable development.

Jun, Lee, Park, Jeong, Shin (17) evaluated the renewable energy plan to reduce CO_2 in South Korea. The renewable energy source (for example, landfill gas,

wind energy, solar energy) is environment friendly and generates power in South Korea. It is intended to produce a new renewable energy technology. The purpose of this research was to study the effect of the economic, the environmental and the benefits of the renewable energy in the electricity generating system market of South Korea with the existing energy-economic model. This is so-called the alternative energy system in long term including the environmental databases and related technologies. In this study, the environmental impact and the economics of renewable energy technologies were carried out by using the wind power, the solar energy from LFG and the burning of rubbish. It was conducted by simulation to create a situation of choice LEAP. The model of LEAP resulted in changing the patterns of costs to produce electricity (average reference numbers in 2008-2020). A comparison of the existing power plant was created. The investment in production of electricity by burning garbage affected to the economic more than any other types of the renewable energy from 2020. The cost per unit of the electricity produced from burning waste was increased by 46 % in comparison with bituminous coal in the energy market of South Korea. The annual investment cost by electricity production in each form in 2020 is 1.68 ₡ per kWh (SC I), 8.68 ₡ per kWh (SC II), 4.88 ₡ per kWh (SC III), 0.89 ₡ per kWh (SC IV) and 5.31 ₡ per kWh (SC V), respectively.

Hafez, Bhattacharya (18) studied the proper planning and the design of the renewable energy by using micro-grid. The renewable energy sources have been recognized as an important alternative to the procurement plan for micro-grid. This study focuses on the planning, design, sizing and operation of hybrid renewable energy in a form of micro-grid with the goal to reduce the cost of operation by the consideration of environmental emissions. There were 4 different case studies: the diesel engine, the fully renewable energy, the renewable energy with the diesel engine, and the external grid-connected Micro grid. The designed system were compared and evaluated for their economic value, the performance of operation and emissions. The analysis used to determine the target breakeven point in the economics for the power distribution system including the micro-grid. The energy software HOMERpro has been used in this study known types of the renewable energy systems. The analysis shows that the diesel engine integrating with the micro-grid provided the cheapest net present cost and also emitted relatively low volume of greenhouse gas emissions

compared to that of released from the diesel engine or the micro-grid. Although, using renewable energy micro-grid barely emit carbon dioxide but the net present cost is quite high.

In summary, these literature reviews in this chapter provided the knowledge about the renewable energy. In this study, we focus on the renewable energy options, the break even points of investment, the assessment of the reasonable alternatives for each area, the impacts on economic and environmental when the alternative energy is utilized and the plan to implement the renewable energy for reducing the pollution in the future.

CHAPTER III
MATERIALS AND METHODS

3.1 The scope of the research

This study is an applied research to study and analyze the suitability of the renewable energy system protocol for the sustainable tourism at the Phu Kradueng National Park by comparing between the electricity generating system with the diesel engines used in the store and the new hybrid electricity generating system that was improved in 2012. This research includes the calculation to determine the proper electricity rates for the stores that utilize both systems of the electricity generating systems at the Phu Kradueng National Park. The analysis was divided into 3 aspects as following:

1) The study about the impacts of the project on the environment by measuring the quantity of the air pollutants and the noise level emitted from the diesel engines and the quantity of the oil contamination in soil. It was the comparison of the measurement results measured from the diesel engines at the stores with the results measured from the project's diesel engine at the power plant.

2) The analysis of the value of the project was done by mean of the economics analysis and the financial analysis as well as the costs and benefits of the project by using the data collected from some involved agencies. Then the costs and benefits analysis was used to make a decision whether it is worth for an investment by employing three criteria; the net present value (NPV), the internal rate of return (IRR), and the benefit-cost ratio (B/C ratio).

3) The calculation of the proper electricity rates by using the questionnaires to inquire the stores' electricity consumption data and the costs of the fuel to supply to the generators. The calculation results were also compared to the quantity of the power generated by the new hybrid power generating system in order to obtain the appropriate electricity rates for the stores. Moreover, the water heater rate

was calculated in order to get all the costs return for the water heater by the prepaid solar cell energy system in the year 10^{th} of the project.

3.2 Population and samples

3.2.1 The impacts on the environment

A comparison between the amount of the pollutants emitted from the project's diesel engines at the power plant and the amount of the pollutants released from the diesel engines at the stores at the Phu Kradueng National Park in 2012 was carried out and categorized into three aspects as follows:

3.2.1.1 The air pollution emitted from the diesel engines

The population and the samples were the quantity of carbon dioxides (CO_2), carbon monoxide (CO), nitrogen oxide (NO_x), hydrocarbon (HC) and sulfur dioxides (SO_2). These samples were emitted from the diesel engines at the stores and the project's diesel engine at the power plant.

3.2.1.2 The noise pollution from the diesel engines

The population and the samples were the sound pressure level emitted from the diesel engines at the stores and the project's diesel engine at the power plant.

3.2.1.3 The contamination of oil in soil caused by the diesel engines

The population and the samples was the factor of the contamination of grease and oil in soil due to the diesel engines at the stores and the project's diesel engine at the power plant.

3.2.2 The analysis of the investment worthiness

The financial data of the project were collected from the amount of the money invested in the project and the returns of the project. The analysis was done to cover a 20-year period.

3.2.3 The calculation of the appropriate electricity rates for the stores

The populations were the 31 stores' owners at the Wang-Kwang visitor center. The sample groups in this research were random by way of purposive sampling, which is the selection of the samples that agree with the objectives of the research (19). There 31 questionnaires used in this project to inquire the electricity consumption data, electrical appliance data, and the attitudes of the stores' owners at the Wang-Kwang visitor center.

3.3 Research Method

3.3.1 The impacts on the environment

The variables for this research were based on the Environmental Impact Statement which is the report about the main impacts on the environment for the operation of the system significantly which affects to human being (20). The variables can be considered for 3 aspects as follows:

3.3.1.1 The air pollution from the diesel engines

- Data collection, data were collected by measuring the amount of carbon dioxides (CO_2), carbon monoxide (CO), nitrogen oxide (NO_x), hydrocarbon (HC), and sulfur dioxides (SO_2) emitted from the project's diesel engine at the power plant and also from the diesel engines at the stores.

- Measurement devices, The Visit 01-L/LR device as shown in Figure 3-1 is the equipment for measuring the amount of the gases emitted from the project's diesel engine at the power plant and from the diesel engine at the stores.

Figure 3-1 Visit 01-L/LR

- Data analysis, the collected data i.e., CO_2, CO, NO_x, HC and SO_2, were analyzed to determine the differences between the air pollutants emitted from the project's diesel engine and the store's diesel engines.

- Statistics, the statistics used for the quantitative analysis of the amount of the pollutants emitted from the diesel engines is the determination of the differences of the averages of the gases emitted from the project's diesel generator and the store's diesel generator.

3.3.1.2 The noise pollution emitted from the diesel engine

- Data collection, sound pressure level emission from the project's diesel engine at the power plant and from the diesel engine at the stores were measured and recorded.

- Measurement device, We used sound level meter model NL-31 as shown in Figure 3-2 to measure the sound pressure level emitted from the project's diesel engine at the power plant and the diesel engine at the stores.

Figure 3-2 Sound Level Meter NL-31

- Data analysis, the sound pressure level measurement data emitted from the project's diesel engine at the power plant and from the diesel engine at the stores were analyzed to determine whether the differences of the measurement is significant or not.

- Statistics, the statistics used for the quantitative analysis of the sound pressure levels emission from the diesel engines is the determination of the differences of the averages of the sound pressure level released from the project's diesel engine at the power plant and from the diesel engine at the stores.

3.3.1.3 The contamination of oil in soil

- Data collection, the measurement of the grease and oil contamination from the project's diesel engines at the power plant and from the diesel engine as well as from the gasoline engines at the stores was carried out to collect the data.

- Measurement method, the method of the contamination measurement was performed by digging the soil for about 0-5 and 5-10 cm depth to collect the soil sample according to the method (21). After that the soil sample was tested to determine the contamination of grease and oil in the chemical laboratory by using grease and oil method.

- Data analysis, the results from the grease and oil contamination measurement were analyzed to determine whether there was any significant difference between the samples from the power plant area and the samples from the stores area.

- Statistics, the statistics used for the quantitative analysis of the contaminations of grease and oil is the determination of the differences of the averages of the grease and oil contamination from the samples at power plant area and from the samples from the diesel engine and the gasoline engine at the stores area.

3.3.2 The assessment of investment value

- Data collection, the assessment of investing value was divided into the economics assessment and the financial assessment. It was the analysis of costs and benefits of the project by focusing on the value of the renewable energy power system protocol. It was divided into 3 parts; the investment cost for 71.70 %, the replacement cost for 28 % and the maintenance cost for 0.30 %. The detail of the assessment was shown in Table 3-1

Table 3-1 Cost and benefit of the project

Cost	Benefit
Cost at the Phu Kradueng National Park	**1. Economical benefits**
Investment Cost	- returns from fuel savings
- the battery subsystem with 1,000 ampere-hour , total of 240 kW-hour	- returns from ice saving cost for the stores
- the solar cell system with 17.18 kW and the solar cell panels with 7.5 kW from the previous project	- returns from the expired equipment value at the year 10^{th} , 20^{th}
- the bi-directional inverter system with 5 kW, for 6 inverters	- returns from increasing units of electricity
- the grid-connected inverter system with 3 kW, for 10 inverters	**2. Financial benefits**
- the diesel engine system with 48 kW	- electricity rates from the stores
- DC breaker and fuse for the bi-directional inverter	
- surge protection system	
- motor/ pump	
- monitor	
- installation expense	
- equipment delivery expense	

Table 3-1 Cost and benefit of the project (cont.)

Cost	Benefit
- misc. expense	
- material expense	
- research assistant wages	
- KMUTT expense	
- project management expense	
- installation expense for the stores*	
Operating Cost	
- fuel expense	
Maintenance Cost	
- the equipment that were used for less than 20 years	

Note: */ For the store's installation equipment cost, it was an addition for calculating economical cost only, which the stores paid for this cost.

The study of the economics assessment was divided into 2 cases.

Case 1: In a case that all the equipments used are brand new.

The costs include the investment cost, the replacement cost and the maintenance cost.

The benefits can be in a form of the return from fuel savings, the return from ice saving cost of the stores, the return from the value of the expired equipments at the year 20^{th} and the return from increasing electricity units.

Case 2: In a case that some of the equipments used are brand new and some are the original ones from the previous project. The cost and the benefit can be in a form of the cost and the return from as well as in case 1.

The study of the financial assessment was divided into 2 cases.

Case 1: The financial analysis in the case that the project received the money support to replace the equipment operating less than 20 years.

Case 2: The financial analysis in a case that the project did not receive any money support to replace the equipment operating for less than 20 years. This can be divided into 2 subcases.

Subcase 2.1: The calculation of the proper electricity rates by which the Phu Kradueng National Park has enough money from the admission fee and the save-up fund that can cover the cost to replace the new equipment with less than 20 years of operating.

Subcase 2.2: The calculation of the proper electricity rates by dividing the proportion of expense to purchase the equipment with less than 20 years of operating. By which the stores will contribute some cost in a form of the electricity rates that they need to pay to the Phu Kradueng National Park. And the Phu Kradueng National Park will contribute the cost for purchasing the equipment with less than 20 years of operating.

The costs include the replacement cost, the operating cost and the maintenance cost.

The benefits can be in a form of the electricity rates that they must to pay to the Phu Kradueng National Park.

- Data analysis

1) The economics assessment of the project, the estimation of the economics cost of the project, the calculation of the economic value for the investment cost, the replacement cost and the maintenance cost, must take into account for the conversion factor by applying the conversion factor (CF) from the financial value. The World Bank assigned the conversion factor for Thailand to be 0.92 for the adjustment of the investment and the operating cost as shown in Table 3-2.

Table 3-2 Conversion factor defined by the World Bank in 1997 (12)

Cost	Conversion Factor
Land	1.00
Investment cost	0.88
Equipment	0.85
Operating , Maintenance cost and Misc. cost	0.92

2) The financial assessment of the project, the national park has issued the government bonds since the beginning of the project. So there is no additional expense

for the investment cost. There were only the operating cost and the maintenance cost of the project. The additional batteries were prepared as a spare without any cost. The analysis of the financial cost used the market price of the investment for the calculation without using any conversion factor. The calculation uses the project's cash flow at the Phu Kradueng National Park after the project was complete. In addition, there was a study about the equipment that operates for less than 20 years such as the batteries with maximum operating of 7 years. So the Phu Kradueng National Park must find the budget to buy the new batteries.

After that the financial data of the renewable energy project at the Phu Kradueng National Park was used to determine the criteria for making a decision for the investment according to the time adjustment principle. The assessment of cost and benefit or the difference between the cost and the benefit that occur in different period of time, were used in the calculation. The project covers for 20 years period. The discount rate used in this economics assessment was 10 %. According to the return rate specified by the Bureau of Budget, the calculation for discount rate of the financial analysis for this study was about 6 % for the government bond's interest rate (13). The criteria for making a decision from the analysis of economic value are as following:

The Net Present Value (NPV)

Assumption

H_0: if the NPV is more than 0, then this project is worth for investment.

H_1: if the NPV is less than or equals to 0, the project is not worth for investment.

The Internal Rate of Return (IRR)

Assumption

H_0: if r is more than 10%, then this project is worth for investment.

H_1: if r is less than 10%, then this project is not worth for investment.

The Benefit-Cost Ratio (B/C Ratio)

Assumption

H_0: if B/C ratio is more than or equals to 0, then this project is worth for investment.

H_1: if B/C ratio is less than 0, then this project is not worth for investment.

Payback period (PBP) can be calculated from equation [1]

$$\text{PBP} = \frac{\text{Investment cost}}{\text{Net return average per year}} \qquad [1]$$

Where Net cash per year = Receive cash flow per year – Cash flow payment per year

Pittayapak, Tippayawong, Jompakdee (22) in a case that the net return per year is not equal to the net benefit per year until the years that the net return equals to the investment cost. These years are the payback period.

The calculation was done by using Microsoft Excel to analyze NPV, IRR, B/C Ratio and PBP of the renewable energy protocol of the Phu Kradueng National Park. Then the calculation results will be used as the three criteria for making a decision that are the NPV more than 0, the IRR must be more than the interest rate and the B/C ratio must be equal or more than 0. If the calculation results pass all 3 criteria, then it can be summarized that the renewable energy protocol is worth for the investment.

3.3.3 Appropriate electricity rates for the stores

- Data collection, the questionnaires were used to inquire the data from 31 stores at the Wang-Kwang visitor center area.

- Data collection tool, questionnaires were used to collect quantitative data about the store information, the electricity consumption, the demand of electricity and the fuel cost to provide to the diesel generator. The detail of the questionnaire is in Appendix. Data collection tool to be used in the research to access the data base and the related research involving with the power generating system for designing the questionnaire. The questionnaires consist of 3 parts as follows:

Part 1 general information of the stores, the area of the stores, the types of the stores, the numbers of customers, and the operating hours. The data interpretation is based on (23) the class interval principle.

Part 2 general information about the electricity generating system, electrical appliances used at the store, the type of the generator used at the store. Also,

the information about the impact from the diesel generator, the satisfaction about power distribution and some comments about the installation additional power system are included in this part.

Part 3 attitude toward the renewable energy system at the Phu Kradueng National Park.

- Data analysis, the calculation to determine the appropriate electricity rate was done by the financial analysis can be divided into 2 cases.

Case 1: The project received the money support to replace the equipment operating less than 20 years. The calculation of the proper electricity rate takes into account for the operating cost and the maintenance cost by choosing the electricity rates that causes NPV equals 0.

Case 2: The project did not receive any money support to replace the equipment operating for less than 20 years. The calculation for the proper electricity rates will only include the operating cost and the maintenance cost. In this case the Phu Kradueng National Park and the store need to pay for purchasing the new equipment to replace the old one at the 10^{th} year. We chose the proper electricity rate and the admission fee that causes the NPV equals 0. This can be divided into 2 subcases.

Subcase 2.1 The calculation of the proper electricity rates by which the Phu Kradueng National Park has enough money from the admission fee and the save-up fund that can cover the cost to replace the new equipment with less than 20 years of operating.

Subcase 2.2 The calculation of the proper electricity rates by dividing the proportion of expense to purchase the equipment with less than 20 years of operating. By which the stores will contribute some cost in a form of the electricity rates that they need to pay to the Phu Kradueng National Park. And the Phu Kradueng National Park will contribute the cost for purchasing the equipment with less than 20 years of operating.

The calculation in the calculation of the proper electricity rates by dividing employs the proportion of electricity consumption of the stores together with the appropriate electricity rate in the case of calculation of the proper electricity rates by which the Phu Kradueng National Park has enough money from the admission

fee and the save-up fund to determine the most appropriate electricity rate. For the admission fee, it can be calculated by comparing the returns from electricity rates with the admission fee as well as the amount of tourist per year. The calculated admission fee can cover for the cost of purchasing the equipment with less than 20 years of operation.

This project also installed the water heater shower by way of solar cell energy at the male and the female shower at the visitor center (Wang-Kwang). Due to the water heater system is the prepaid solar cell system with the cost about 500,000 Baht, so in this research, the proper water heater rate is also calculated. This proper water heater rate has the payback period for 10 years which will be paid by the tourists and thus brings the revenue to the Phu Kradueng National Park.

CHAPTER IV
RESULTS AND DISCUSSIONS

The cost-benefit analysis was applied to the renewable energy protocol project for sustainable tourism at the Phu Kradueng National Park. The renewable energy project in 2012 is considered as the clean energy project to generate electricity by utilizing the solar cells and the wind turbine as the primary sources and the diesel engine as the secondary source. By performing the field experiment, then analyzing the data in the laboratory, and collecting the questionnaires, the results can be summarized and discussed as follows: the impacts on environment were studied by comparing the amount of air pollutants, noise level (sound pressure level) and the grease and oil contamination in soil, the cost-benefit analysis of the renewable energy protocol project for sustainable tourism at the Phu Kradueng National Park, the social assessment by way of the calculation for the appropriate electricity rates for the stores at the National Park and the calculation for the proper water heater rates for the tourists and discussions.

4.1 Results

The analysis of the environmental impacts measured at the store area and the power plant area in 16-17 August 2013. The sampling point were shown in Figure 4-1.

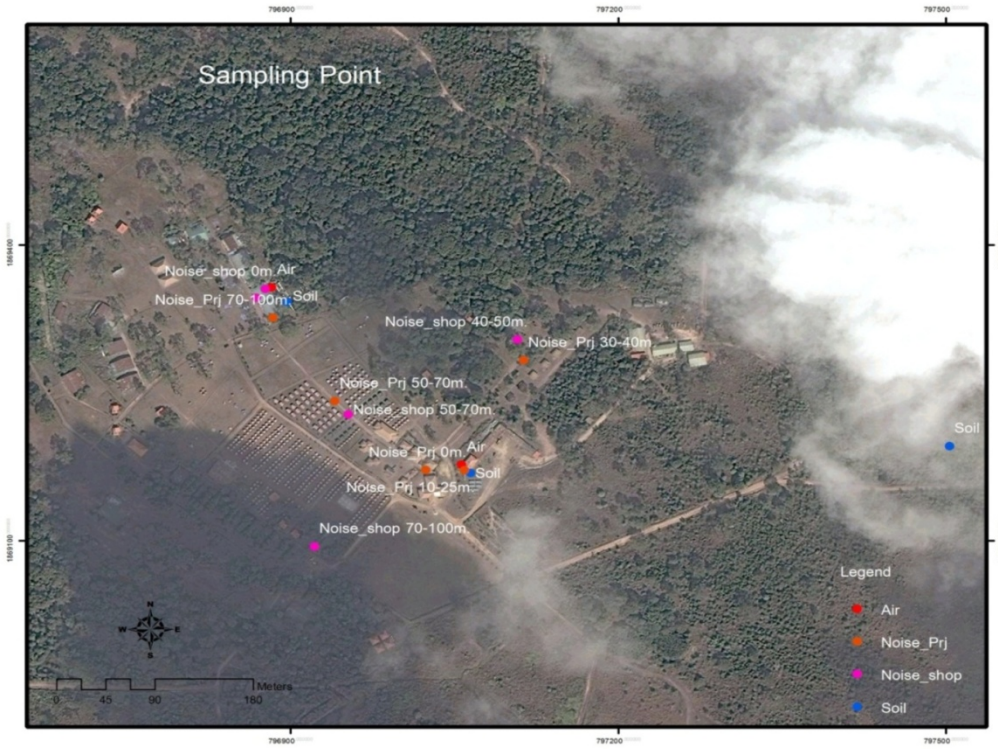


Figure 4-1 Sample locations for studying impacts on the environment at the Phu Kradueng National Park

4.1.1 The study about impacts on environment: The impacts on environment were studied by comparing the amount of air pollutants, noise level (sound pressure level) and the grease and oil contamination in soil.

4.1.1.1 Air pollution emitted from the diesel engines

The air pollutants emitted from the diesel engine at the store and from the project's diesel engine at the power plant, which was installed in 2012, were measured by the Visit 01-L/LR. The results were compared and displayed in Table 4-1 and Table 4-2, respectively.

Table 4-1 Measurement results of carbon dioxides (CO_2), carbon monoxide(CO), nitrogen monoxide(NO), nitrogen dioxides (NO_2), nitrogen oxide(NO_x) and sulfur dioxides (SO_2) emitted from the diesel engine at the stores.

Gas emission- at the end of- the engine's -exhaust.	**Air pollutants measurement results emitted from the 5 kW diesel engine (3 years of operation)**				
Gas	#1	#2	#3	# 4	Average
CO_2 (percent)	2	2.5	2.7	2.7	2.48
CO(ppm)	600	689	712	725	681.5
NO (ppm)	78	75	78	78	77.25
NO_2 (ppm)	-	-	-	-	-
NO_x (ppm)	79	77	82	82	80
SO_2 (ppm)	-	-	-	-	-

Source: from the study on 16 August, 2013

Note: ppm = part per million

According to Table 4-1, it was found that when operating the engine for a long period of time, the amounts of air pollutants i.e., carbon dioxides (CO_2), carbon monoxide (CO), nitrogen monoxide (NO) and nitrogen oxide (NO_x) were increased from when it was started. The air pollutants measurement results emitted from the project's diesel engine, which was installed in 2012, were shown in Table 4-2.

Table 4-2 Measurement results of carbon dioxides (CO_2), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxides (NO_2), nitrogen oxide (NO_x) and sulfur dioxides (SO_2) emitted from the project's diesel engine.

Gas emission- at the end of- the engine's -exhaust.	**Air pollutants measurement results emitted from the 48 kW project's diesel engine installed in 2012**				
Gas	#1	#2	#3	#4	Average
CO_2 (percent)	2.7	2.7	2.7	2.7	2.7
CO(ppm)	336	322	319	293	317.5
NO (ppm)	209	212	211	212	211
NO_2 (ppm)	-	-	-	-	-
NO_x (ppm)	217	221	222	222	220.5
SO_2 (ppm)	-	-	-	-	-

Source: from the study on 17 August, 2013

Note: ppm = part per million

From the results shown in Table 4-1 and 4-2, it was found that the average amounts of carbon dioxides (CO_2) emitted from the store's diesel engine and from the project's diesel engine were relatively closed. The average amounts of nitrogen monoxide (NO) and nitrogen oxide (NO_x) emitted from the project's diesel engine were higher than those emitted from the store's diesel engine due to the 48 kW project's diesel engine provided more power than the 5kW store's diesel engine. From the interview with the stores' owners, it was found that their diesel engines were shut down for quite some times due to the electricity distributed from the renewable energy project were enough to cover the stores' area. The air pollutant was measured from only one diesel engine, so the amount of the gas emission was less than that measured from the project's diesel engine which provided much more power. The new diesel engine was installed to be a secondary source which will only be turned on if the power from the solar cells and the wind turbine was not enough. The measured gases

were compared to the standard air ambient regulated by the Pollution Control Department as shown in Table 4-3.

Table 4-3 The average of air pollution emitted from the store diesel engine's exhaust and from the project diesel engine's exhaust compared to the standard air ambient.

The standard air ambient averaged in 1 hour (Pollution Control Dept., 1992)	**The average of air pollutants emitted from the store's diesel engine***	**The average of air pollutants emitted from the project's diesel engine installed in 2012***
Carbon monoxide (CO) = 30 ppm	175 ppm	12.25 ppm
Nitrogen dioxides (NO_2) = 0.17 ppm	0 ppm	0 ppm
Sulfur dioxides (SO_2) = 0.30 ppm	0 ppm	0 ppm

Source: from the study on 17 August, 2013

Note: ppm = part per million

*/ measured from 5 meters away from the exhaust's end

From Table 4-3, it can be seen that the average of carbon monoxide (CO) measured from the store's diesel engine by using the Visit 01-L/LR was 175 ppm, which was more than that of the project's diesel engine. The amount of CO exceeded the standard air ambient regulated by the Pollution Control Department that can affect the stores' owners, tourists and the National Park's staffs. Sengbangpla (7) stated that if a person inhales CO for about 35 minutes, it will cause blurred vision, inflammation of the respiratory system and amnesia.

4.1.1.2 Noise pollution from the diesel engine

The sound pressure levels emitted from the project's diesel engine and from the store's diesel engine were measured by the sound level meter NL-31. From Table 4-4, it can be seen that the maximum average sound pressure level was 82 dBA measured at the location of the 5 kW store's diesel engine. The further the distance of the receptor away from the diesel engine, the less sound pressure levels were detected.

Table 4-4 Sound pressure levels measurement of the 5 kW store's diesel engine (3 years of operation) which measured from the receptors at the stores.

Sound pressure levels / **Receptor locations**	**The distance from the diesel engine**	**The 5 kW store's diesel engine (3 years of operation)**	**Sound pressure level of background noise**
	meter (m)	**sound pressure level (decibel A: dBA)**	**sound pressure level (decibel A: dBA)**
At the location of the-diesel engine	0	82	51
At the stores	10-25	56	51
At the tourists' lodges	40-50	50	51
At the semi-permanent-tents	50-70	49	51
At the staffs' housing	70-100	49	51

Source: from the study on 16 August, 2013

The sound pressure levels measured from the project's diesel engine, which was installed in 2012. It was found that the maximum average sound pressure level was 82 dBA measured at the location of the 48 kW project's diesel engine. The further the distance of the receptor away from the diesel engine, the less sound pressure levels were detected. That were displayed in Table 4-5.

Table 4-5 Sound pressure levels measurement of the 48 kW project's diesel engine (installed in 2012) which measured from the receptors at the power plant.

Sound pressure levels / **Receptor locations**	**The distance from the diesel engine**	**The 48 kW Project's diesel engine (installed in 2012)**	**Sound pressure level of background noise**
	meter (m)	**sound pressure level (decibel A: dBA)**	**sound pressure level (decibel A: dBA)**
At the location of the-diesel engine	0	82	51
At the Wang-Kwang visitor center	10-25	50	51
At the tourists' lodges	30-40	50	51
At the semi-permanent - tents	50-70	49	51
At the stores	70-100	49	51

Source: from the study on 16 August, 2013

The sound pressure levels emitted from the store's diesel generator and from the project's diesel engines were compared to the acceptable sound pressure level regulated by the World Health Organization (WHO). The WHO has specified the acceptable averaged sound pressure level, which is 70 decibel A (dBA) for 24 hours (24). The averaged sound pressure level measured only at the location of the diesel engine was 82 dBA which was higher than the acceptable sound pressure level and was considered as noise pollution which affects the stores' owners, the tourists and the National Park's staffs by causing nuisance, stress and prone to neurosis symptoms.

4.1.1.3 Grease and oil contamination in soil

The measurement of grease and oil contamination was done by mean of Grease and Oil Method (FOG). Soil samples were collected by way of the

method introduced by Yaibuated (21). After that, the soil samples were sent to the laboratory for the analysis of grease and oil contamination. The soil samples were collected from the vicinity area of the 5 kW diesel engine (2 years of operation), from the 2 kW gasoline engine (2 years of operation) and from the 48 kW project's diesel engine installed in 2012. Additionally, this study included the measurement of the dirt bulk density to determine the dry dirt mass per volume unit (25) The soil sample were collected to get analyzed in the laboratory. The results were shown in Table 4-6.

Table 4-6 The Grease and oil contamination in soil in the vicinity areas of the diesel engine, the gasoline engine and the project's diesel engine as well as natural soil by way of Grease and Oil method (FOG).

The depth for drilling the ground (cm.)	**Soil in the vicinity area of the 5 kW diesel engine (2 years of operation)**	**Soil in the vicinity area of the 2 kW gasoline engine (2 years of operation)**	**Soil in the vicinity area of the 48 kW project's diesel engine**	**Natural soil**
0-5	0.10	0.08	0.08	0.05
5-10	0.09	0.04	0.08	0.06
Bulk density average	0.77	0.86	1.00	0.70

It can be seen from the results that the dirt collected from the vicinity areas of the small diesel engine gave higher value of the grease and oil contamination than that from the gasoline and the huge diesel engines. This is possibly due to the huge diesel engine was installed on the cement base and also had the tray for engine oil, so not much grease and oil was leaked into the soil. Moreover, the contamination depends on the other natural factors such as rain. When it was raining, the leakage oil in the dirt would be diffused, so the measurement result was decreased. Also, the method of engine installation affects the amount of the contamination. The engines installed on the cement base would yield small amount of contamination.The

stores wanted to avoid the engines' vibration so they have the engines located on the cement base.

4.1.2 The cost-benefit analysis of the renewable energy protocol project for sustainable tourism at the Phu Kradueng National Park.

The project covers for 20 years period with the discount rate of 10%. The costs for investment can be divided into 2 cases as follows.

Case1: The government was responsible for the total cost consisting of the investment cost, the replacement cost and the maintenance cost which was adjusted by the conversion factor of 0.92 in a case of installation the brand new equipment.

- Investment cost for the economic assessment, the true expenses were included in the calculation such as the expense for the battery subsystem with 1,000 ampere-hour, total of 240 kW-hour installed in 2010, the solar cell system with 17.18 kW, the bi-directional inverter system with 5 kW, for 6 inverters, the grid-connected inverter system with 3 kW and the installation expense for the stores. Though the stores' owners were responsible for the installation cost, this cost must be included in the calculation of the total cost of the project that can be shown in Table 4-7

Table 4-7 Case 1: Investment Cost

Item	Description	Net value (Baht)	Years of operation (year)
1	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	2,649,600	10
2	The solar cell system with 17.18 kW	1,106,392	20
3	The bi-directional inverter system with 5 kW, for 6 inverters	828,000	10
4	The grid-connected inverter system with 3 kW, for 10 inverters	276,000	10
5	The diesel engine system with 48 kW	874,000	20

Table 4-7 Case 1: Investment Cost (cont.)

Item	Description	Net value (Baht)	Years of operation (year)
6	DC breaker and fuse for the bi-directional inverter	110,400	20
7	Surge protection system	395,600	20
8	Motor/ pump	414,000	10
9	Monitor	92,000	10
10	Installation expense	368,000	
11	Equipment delivery expense	736,000	
12	Misc. expense	690,000	
13	Material expense	579,600	
14	Research assistant wages	331,200	
15	KMUTT expense	574,080	
16	Project management expense	299,920	
17	Installation expense for the stores	174,800	
	Total	**10,499,592**	

The cost for electrical wires, the equipment installation expense and the electrical switches expense was considered at the first year of the project. There were 25 small stores (49-98 square meters) needed to provide 6,000 Baht to have electrical wires in the store. For the 4 big stores (190-400 square meters), they had the cost for electrical wires for 10,000 Baht. The total cost was about 190,000 Baht. ((190,000*0.92) = 174,800 Baht)

- Replacement cost, the replacing the equipment with less than 20 years of operation were shown in Table 4-8.

Table 4-8 Case 1: Replacement cost

Item	Description	Years of operation (years)	Net value (Baht)
1	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	10	2,649,600
2	The bi-directional inverter system with 5 kW, for 6 inverters	10	828,000
3	The grid-connected inverter system with 3 kW, for 10 inverters	10	276,000
4	Motor/ pump	10	414,000
5	Monitor	10	92,000
	Total		**4,259,600**

- Maintenance Cost, the maintenance cost for the entire 20 years equals 682,520 Baht or 34,126 Baht per year that can be shown in Table 4-9.

Table 4-9 Case1: Maintenance Cost

Item	Description	Years of operation (year)	Maintenance cost rate (Baht)	Net value (Baht)	The value of maintenance the project (Baht/ year)
1	The solar cell system with 24.78 kW	20	0.10	1,106,392	1,106
2	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	10	0.20	2,649,600	5,299

Table 4-9 Case1: Maintenance Cost (cont.)

Item	Description	Years of operation (year)	Maintenance cost rate (Baht)	Net value (Baht)	The value of maintenance the project (Baht/ year)
3	The bi-directional inverter system with 5 kW, for 6 inverters	10	0.50	828,000	4,140
4	The grid-connected inverter system with 3 kW, for 10 inverters	10	0.50	276,000	1,380
5	The diesel engine system with 48 kW	20	2.20	874,000	19,200
6	DC breaker and fuse for the bi-directional inverter	20		110,400	1,000
7	Surge protection system	20		395,600	1,000
8	Motor/ pump	10		414,000	1,000
	Total			**6,653,992**	**34,126**

Note: O&M = 10$/yr/1 kW, $ = 32 Baht (the currency exchange in August 2013)

The benefit in assessment of economics can be devided into 4 value composes of;

1) The returns on fuel savings

For the renewable energy project for sustainable tourism at the Phu Kradueng National Park, it was found that the 48 kW diesel engine used the diesel fuel about 3,063 litre per year, the 29 stores used the diesel fuel to generate power and to supply the water pump system for 20,000 litre per year. The diesel fuel cost at the oil refinery on 2 October 2013 was 24.83 Baht perlitre and the benzene fuel cost at the

refinery on 2 October 2013 was 23.26 Baht perlitre. The cost for benzene fuel at Phu Kradueng district was (23.26+(0.57*0.92)) = 23.78 Baht perlitre. The detail were shown in Table 4-10.

Table 4-10 Returns on fuel savings

Item	Description	Count	Unit
1	The electricity generating diesel engine project	3,063	Litre/ year
2	The stores used the oil to generate electricity	12,800	Litre/ year
3	The quantity of diesel fuel used in previous project	3,600	Litre/ year
4	The quantity of diesel fuel in the previous pump system	3,600	Litre/ year
Total	The quantity of oil utilized in the previous project	20,000	Litre/ year
So	The amount of fuel saving	16,937	Litre/ year
6	The diesel fuel cost at the oil refinery	24.83*	Baht/ Litre
7	The gasoline fuel cost at the oil refinery	23.26*	Baht/ Litre
8	Oil transportation costs from Bangkok to the Phu Kradueng	0.57*	Baht/ Litre
9	Conversion factor	0.92	
10	Oil transportation cost deliver to the Phu Kradueng	15	Baht/ Litre
Thus,	**fuel saving costs**	**683,435.05**	**Bath/ year**

Thus, the renewable energy project for sustainable tourism at the Phu Kradueng National Park has saved the fuel cost for 20,000 – 3,063 = 16,937 litre per year or as the saving fuel cost for 16,937*(25.35+15) = 683,435.05 Baht per year.

2) The returns of ice saving cost for the stores

During the tourism season, the stores would purchase some ices for storing fresh food and for consumption. The cost for buying ice averagely about 4 days per week, 20 kilogram per day, 12 Baht per kilogram (adjusted by conversion factor 0.92, so the real cost was 11.04 Baht per kilogram), transportation cost 15 Baht per kilogram. There were 19 stores purchasing ice. Thus, the total cost for purchasing ice was 4,027,392 Baht per year. The calculation was carried out for the beginning of tourism season for 4 months. That can be shown in Table 4-11.

Table 4-11 Ice saving costs

Item	Description	Count	Unit
Before the project			
1	Stores need ice for fresh food storage and also for consumption	19	store
2	The day of purchasing ice (Mon., Wed., Fri., Sat.)	4	day/ week
3	The amount of ice to be purchased	20	Kilogram/ day
4	The cost of ice (adjusted by Conversion factor)	11.0400	Baht/ kilogram
5	Ice transportation	15	Baht/ kilogram
6	Total day of buying ice	64	day/ year
Total	Total cost for procurement of ice (before the project)	4,027,392	Baht/ year
After the project			
1	The day of purchasing ice (Fri., Sat.)	2	day/ week
2	Total day of buying ice	32	day/ year
Total	Total cost for procurement of ice (after the project)	2,013,696	Baht/ year
Thus	**Total cost savings for ice**	**2,013,696**	**Baht/ year**

After the renewable project was started, the total saving cost on ice was about 2,013,696 Baht per year.

3) The value of the expired equipment at the end of project period

The value of the expired equipment at the end of project period was 10% of the true value. It was found that the 48 kW diesel engine has the value at the 20th year about 87,400 Baht, the 1,000 ampere battery system at the end of life 10th year has the value about 264,960 Baht and also at the end of project 20th. Hence, the total value of the expired equipment was approximately 617,320 Baht.

4) The returns of the increased electricity units

Originally, the stores at the Wang-Kwang visitor center generated some electricity themselves to be used within the stores. It was found that the 22 stores had the 2 hp generators and the other two stores had the 5 hp generators. (1hp= 0.746 kW) The hours of operating the engines were from 6 pm-10 pm or about 4 hour per day. From the calculation for the 4 months during the beginning of the tourism season, it was found that the original units of electricity produced by the stores were about

19,226.32 unit per year. The renewable energy generated the electricity to distribute to the store for 20,914 unit per year. From the questionnaires, it was found that the stores' owners were willing to pay for electricity about 10 Baht per unit. So the value of the increased electricity unit equals to 15,779 Baht per year. The detail were shown in Table 4-12.

Table 4-12 Value of the increase electricity units

Item	Description	Count	Unit
1	Electricity generation	34,857	kWh
2	Electricity that the National Park consumed (40% of the total power generation)	13,942.8	kWh
3	Electricity that the stores consumed (60% of the total power generation)	20,914.2	kWh
4	Original: the stores had 2 hp engine	22	machine
5	Original: the stores had 5 hp engine	2	machine
6	The generator's capacity to produce electricity	40.284	kW
7	Duration of power distribution	4	hour/ day
8	Days of power distribution at the beginning of the tourism season for 4 months	120	day/ year
Total	Electricity that the stores generated	19,226.32	kWh/ yr.
9	The rates that the stores are willing to pay for electricity	10	Baht/ unit
10	Additional electricity generation	1,578	kWh
Thus	**The value of increased electricity unit**	**15,779**	**Baht/ year**

Note: 1 horsepower (hp)= 0.746 kW

The total cost for the renewable energy project for sustainable tourism at the Phu Kradueng National Park composed of:

Case 1:

Investment Cost= 10,499,592 Baht

Replacement Cost = 4,259,600 Baht

Maintenance Cost = 34,126 Baht per year

The total returns of the project consist of:

Returns on fuel cost saving= 683,435.05 Baht per year

Returns on ice cost saving = 2,013,696 Baht per year

Returns on the values of the expired equipment at the end of the project period= 352,360 Baht at the year 20^{th} and at the year 10^{th} has 264,960 Baht.

Returns on the increased electricity unit = 15,779 Baht per year

The results of Cost-Benefit analysis in a case of installation the brand new equipment can be shown in Table 4-13. From the cost-benefit analysis for case 1, it was found that the net present value (NPV) of the project equals 10,818,678; the B/C ratio equals 1.87, the IRR equals 24.13 and the PBP is 5.3 years. As a result, it was worth for the investment in this project because the NPV, the IRR and the B/C Ratio met the acceptable criteria.

Table 4-13 Case1: Cost-Benefit analysis (not include the environmental benefit and the cost for water heater by the prepaid solar cell energy system)

Year	Cost	O&M	Total Cost	Benefit	Net Cash Flow
0	10,499,592	0	10,499,592	0	-10,499,592
1		34,126	34,126	2,712,910	2,678,784
2		34,126	34,126	2,712,910	2,678,784
3		34,126	34,126	2,712,910	2,678,784
4		34,126	34,126	2,712,910	2,678,784
5		34,126	34,126	2,712,910	2,678,784
6		34,126	34,126	2,712,910	2,678,784
7		34,126	34,126	2,712,910	2,678,784
8		34,126	34,126	2,712,910	2,678,784
9		34,126	34,126	2,712,910	2,678,784
10	4,259,600	34,126	4,293,726	2,977,870	- 1,315,856
11		34,126	34,126	2,712,910	2,678,784
12		34,126	34,126	2,712,910	2,678,784
13		34,126	34,126	2,712,910	2,678,784
14		34,126	34,126	2,712,910	2,678,784
15		34,126	34,126	2,712,910	2,678,784
16		34,126	34,126	2,712,910	2,678,784
17		34,126	34,126	2,712,910	2,678,784
18		34,126	34,126	2,712,910	2,678,784
19		34,126	34,126	2,712,910	2,678,784
20		34,126	34,126	3,065,270	3,031,144

NPV = 10,818,678

IRR = 24.13

B/C Ratio = 1.87

Pay Back = 5.325

Case2: The government is responsible for the whole investment costs consisting of the investment cost, the replacement cost and the maintenance cost. The conversion factor to be used in the calculation was 0.92 (12). In this case, it would be

the calculation of the investment costs for installing the new equipment and for the active old equipment.

- Investment Cost, the calculation of the investment cost include 7.5 kW solar cells system from the previous project that were shown in Table 4-14

Table 4-14 Case 2: Investment cost

item	Description	Net value (Baht)	Years of operation (years)
1	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	2,649,600	10
2	The solar cell system with 17.18 kW and the solar cell panels with 7.5 kW from the previous project	1,485,892	20
3	The bi-directional inverter system with 5 kW, for 6 inverters	828,000	10
4	The grid-connected inverter system with 3 kW, for 10 inverters	276,000	10
5	The diesel engine system with 48 kW	874,000	20
6	DC breaker and fuse for the bi-directional inverter	110,400	20
7	Surge protection system	395,600	20
8	Motor/ pump	414,000	10
9	Monitor	92,000	10
10	Installation expense	368,000	
11	Equipment delivery expense	736,000	
12	Misc. expense	690,000	
13	Material expense	579,600	
14	Research assistant wages	331,200	
15	KMUTT expense	574,080	
16	Project management expense	299,920	
17	Installation expense for the stores	174,800	
	Total	**10,879,092**	

- Replacement Cost,the replacing the equipment with less than 20 years of operation were shown in Table 4-15

Table 4-15 Case 2: Replacement cost

Item	Description	Years of operation (years)	Net value (Baht)
1	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	10	2,649,600
2	The bi-directional inverter system with 5 kW, for 6 inverters	10	828,000
3	The grid-connected inverter system with 3 kW, for 10 inverters	10	276,000
4	Motor/ pump	10	414,000
5	Monitor	10	92,000
	Total		**4,259,600**

- Maintenance cost,the maintenance cost for the entire of 20 years was equal to 690,100 Baht or 34,505 Baht per year that can be seen in Table 4-16.

Table 4-16 Case 2: Maintenance cost

Item	Description	Years of operation (years)	Maintenance cost (Baht)	Net value (Baht)	Net value of project maintenance cost (Baht/ year)
1	The solar cell system with 24.78 kW	20	0.10	1,485,892	1,486

Table 4-16 Case 2: Maintenance cost (cont.)

Item	Description	Years of operation (years)	Maintenance cost (Baht)	Net value (Baht)	Net value of project maintenance cost (Baht/ year)
2	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	10	0.20	2,649,600	5,299
3	The bi-directional inverter system with 5 kW, for 6 inverters	10	0.50	828,000	4,140
4	The grid-connected inverter system with 3 kW, for 10 inverters	10	0.50	276,000	1,380
5	The diesel engine system with 48 kW	20	2.20	874,000	19,200
6	DC breaker and fuse for the bi-directional inverter	20		110,400	1,000
7	Surge protector	20		395,600	1,000
8	Motor/ pump	10		414,000	1,000
	Total			**7,033,492**	**34,505**

Note: O&M = 10$/yr/1 kW, $ = 32 Baht (currency exchange rate in August of 2013)

The total cost for the renewable energy project for sustainable tourism at the Phu Kradueng National Park composed of:

Case 2:

Investment Cost = 10,879,092 Baht

Replacement Cost at the end of 10^{th} year of the project = 4,259,600 Baht

Maintenance Cost = 34,505 Baht per year

The total returns of the project consist of:

Returns on fuel cost saving= 683,435.05 Baht per year

Returns on ice cost saving = 2,013,696 Baht per year

Returns on the values of the expired equipment at the end of the project period= 352,360 Baht at the year 20^{th} and at the year 10^{th} has 264,960 Baht.

Returns on the increased electricity unit = 15,779 Baht per year

The calculation of the investment costs for installing the new equipment and for the active old equipment. The analysis for case 2; It was found that the net present value (NPV) equals 10,435,947, the B/C ratio equals 1.81, the IRR equals 23.19 and the PBP is 5.6 years. Thus, it was worth to invest in this renewable energy project due to the NPV, the IRR, and the B/C ratio meet the acceptable criteria. The detail can be shown in Table 4-17

Table 4-17 Case2: Cost-Benefit analysis (not include the environmental benefit and the cost for water heater by the prepaid solar cell energy system)

Year	Cost	O&M	Total Cost	Benefit	Net Cash Flow
0	10,879,092	0	10,879,092	0	-10,879,092
1		34,505	34,505	2,712,910	2,678,405
2		34,505	34,505	2,712,910	2,678,405
3		34,505	34,505	2,712,910	2,678,405
4		34,505	34,505	2,712,910	2,678,405
5		34,505	34,505	2,712,910	2,678,405
6		34,505	34,505	2,712,910	2,678,405
7		34,505	34,505	2,712,910	2,678,405
8		34,505	34,505	2,712,910	2,678,405
9		34,505	34,505	2,712,910	2,678,405
10	4,259,600	34,505	4,294,105	2,977,870	- 1,316,235
11		34,505	34,505	2,712,910	2,678,405
12		34,505	34,505	2,712,910	2,678,405
13		34,505	34,505	2,712,910	2,678,405
14		34,505	34,505	2,712,910	2,678,405
15		34,505	34,505	2,712,910	2,678,405
16		34,505	34,505	2,712,910	2,678,405
17		34,505	34,505	2,712,910	2,678,405
18		34,505	34,505	2,712,910	2,678,405
19		34,505	34,505	2,712,910	2,678,405
20		34,505	34,505	3,065,270	3,030,765

NPV = 10,435,947

IRR = 23.19

B/C Ratio = 1.81

Pay Back = 5.57

4.1.3 The social assessment and the financial analysis to determine the appropriate electricity rates for the stores

4.1.3.1 The social assessment

The questionnaires were used as a research tool to inquire the information from the stores' owners about electricity consumption, the fuel cost for the generator. There were 31 stores at the Wang-Kwang visitor center. However, the two stores belong to the same owner. Thus, there were 29 questionnaires. The questionnaires were collected on 8-9 November 2013. The results can be described as follows:

1) Personal information, it was found that most of the stores' owners are female for 86.2%, average ages of 51-55 years around 20.7%, high school graduates around 48.3%. The average salary was about 32,500 Baht per month. The average expense was 10,000 Baht per month. There are 29 stores at the Wang-Kwang visitor center with the area around 49 square meters each. There are 10 souvenirs shops and 19 restaurants. The average number of customers was around 20 persons per day. The opening hours are from 6 am- 10 pm. They usually open for around 8 months in a year.

2) Information about electricity system, the information was divided as follows; information about electrical appliance, information about power generating system, information about impacts from the diesel engine, information about satisfaction toward electricity utilization and information about improvement of wires, as well as the information of public lighting system.

The electrical appliances used at the visitor center in 2012 were as following: fluorescent 18W for 19 counts, compact fluorescent 9W for 8 counts, compact fluorescent 11 W for 10 counts, compact fluorescent 18 W for 283 counts, compact fluorescent 13 W for 68 counts, 14-20" TV for 7 counts, 21" TV for 1 count, 20-21" flat screen TV for 2 counts, stereo 40, 120, 70/700, 1, 800W for 5counts, rice cookers for 3 counts, notebook for 3 counts, electronic kettle for 3 counts, electronic food processor for 1 count, electronic fruit juice maker 1 litre 300 W for 5 counts, electronic fruit juice maker 1.5 litre 350 W for 1 count, electronic fruit juice maker 2 litre 600 W for 4 counts and the battery chargers for 106 counts.

The information about electricity generating system, it was found that most of the engines were the gasoline engines (about 69 %). Most of the engines were 2 hp for 75.9 %, 5.50 hp for 20.7 %; one with the 4 hours per day of operation (85.7%) and consumefuel about 2 litre per day, the other one used fuel about 3 litre per pay and consume fuel for 3 litre per day.The fuel cost was about 40-120 Baht per day or 62.1 %. The engine repair mostly happens once a year or 55.2%. The expense for domestic power generation was approximately 2,961-4,720 Baht per month or 48.3%. From the information about the impacts of the system, it was found that the diesel engines cause noise pollution, air pollution, smog, smoke, tangy gases, etc. The expense was approximately 65.5%. It appears that the stores' owners were satisfied with 24 hours power supply. Though some electrical appliances were not permit to use for about 93.1%. The stores' owners were willing to have the improvement of domestic electrical wiring. Also, the stores' owners would like to have more lighting system installed for public area and pathways.

3) The customers' satisfaction, the information about customer's satisfaction, it appears that the current system needs to get improved by having the solar cells system and the wind turbines as the primary source and the diesel engine as the secondary source. Due to the cost for the hybrid renewable energy is quite high, the customer were willing to distribute to the cost by paying electricity rates at 10 Baht per unit for about 65.5%. 100% of the stores' owners agreed with have the new renewable energy installed and were willing to pay a deposit on the electricity meter. About the impact of the new renewable energy system, 100% of the stores' owners thought that the new project gave the positive impacts i.e., for the convenience of electricity usage about 69% and for environment/ eco- friendly about 31%.

4.1.3.2 The calculation for the appropriate electricity rates. Financial analysis to calculate the appropriate electricity rates by setting the electricity rate that makes the NPV equals to zero. The government bond interest was 6% specified by the Bank of Thailand. The analysis was divided into 2 cases as follows.

Case 1: the Phu Kradueng National Park received the support budget to purchase the equipment (less than 20 years of operation)

Case 2: the Phu Kradueng National Park did not receive the support budget to purchase the equipment (less than 20 years of operation). This can be divided into 2 subcases as following:

Subcase 2.1 the Phu Kradueng National Park did not receive the support budget to purchase the equipment (less than 20 years of operation). In this case the stores were responsible for providing the money to buy the new equipment in a form of paying the electricity rates to the Phu Kradueng National Park.

Subcase 2.2 the Phu Kradueng National Park did not receive the support budget to purchase the equipment (less than 20 years of operation). In this case the stores and the Phu Kradueng National Park would share the cost for purchasing the new equipment. (60% from the stores, 40% from the National Park) The stores would pay the electricity rates to the National Park; whereas, the National Park would receive the admission fee from the tourists. The calculation was done by dividing the proportions of cost for the stores and for the Phu Kradueng National Park.

- Replacement cost, the replacing the equipment with less than 20 years of operation were shown in Table 4-18.

Table 4-18 Case 1: Replacement Cost for the appropriate electricity rates

Item	Description	Years of operation (Year)	Net value (Baht)
1	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	10	2,880,000
2	The bi-directional inverter system with 5 kW, for 6 inverters	10	900,000
3	The grid-connected inverter system with 3 kW, for 10 inverters	10	300,000
4	Motor/ pump	10	450,000
5	Monitor	10	100,000
	Total		**4,630,000**

- Operating cost has the fuel for generation system amount 3,063 litre per year or net value 123,737 Baht per year that can be shown in Table 4-19.

Table 4-19 Case 1: Operating cost for the appropriate electricity rates

Item	Description	Amount (litre/ year)	Net value (Baht/ year)
1	The amount of fuel	3,063	123,737

Note: Diesel price at the oil refinery on 2 October 2013 was 24.8272 Baht/ litre (26); Diesel price at the Phu Kradueng district (24.8272+0.57+15) = 40.3972 Baht/ litre

- Maintenance cost, the maintenance cost for the whole 20 years project period was about 711,500 Baht or 35,575 Baht per year that were displayed in Table 4-20.

Table 4-20 Case1: Maintenance Cost for the appropriate electricity rates

Item	Description	Years of operation (year)	Maintenance rate (Baht)	Net value (Baht)	The value of maintenance the project (Baht/year)
1	The solar cell system with 24.78	20	0.10	1,615,100	1,615
2	The battery subsystem with 1,000 ampere-hour, total of 240 kW-hour	10	0.20	2,880,000	5,760
3	The bi-directional inverter system with 5 kW, for 6 inverters	10	0.50	900,000	4,500

Table 4-20 Case 1: Maintenance Cost for the appropriate electricity rates (cont.)

Item	Description	Years of operation (year)	Maintenance rate (Baht)	Net value (Baht)	The value of maintenance the project (Baht/year)
4	The grid-connected inverter system with 3 kW, for 10 inverters	10	0.50	300,000	1,500
5	The diesel engine system with 48 kW	20	2.02	950,000	19,200
6	DC breaker and fuse for the bi-directional inverter	20		120,000	1,000
7	Surge protection system	20		430,000	1,000
8	Motor/ pump	10		450,000	1,000
	Total			**7,645,100**	**35,575**

Note: O&M = 10$/yr/1kW, $ = 32 Baht (the currency exchange rate in August 2013)

The financial return, the appropriate electricity rates for the stores by setting NPV =0 and the total power generated was about 34,857 unit per year. The software HOMERpro was used for estimating the amount of the electricity generated from the system. The National Park consumed 40% of the total power or about 13,942.80 unit per year. The stores consumed 60% of the total power or about 20,914.20 unit per year.

The total cost of this renewable energy project composed of:

Replacement Cost = 4,630,000 Baht

Operating Cost = 123,737 Baht per year

Maintenance Cost= 35,575 Baht peryear

Thus, the total O&M Cost = 123,737 + 59,010 = 182,747 Baht per year.

From the analysis result in case 1, it can be seen that when the NPV equals zero, the electricity rate was about 7.6174 Baht per unit for this case. The appropriate electricity rate for the stores calculated by using Microsoft office excel was about 8 Baht per unit, which the National Park would get the returns about 159,172 Baht per year. The detail were shown in Table 4-21.

Table 4-21 The cost-benefit analysis for the whole 20 years of the project period. (Discount rate was 10%) Case 1: The National Park received the budget fund to purchase the new equipment (less than 20 years of operation).

Year	Cost	O&M	Total Cost	Benefit	Net Cash Flow
0	0	0	0	0	0
1		159,312	159,312	159,312	0
2		159,312	159,312	159,312	0
3		159,312	159,312	159,312	0
4		159,312	159,312	159,312	0
5		159,312	159,312	159,312	0
6		159,312	159,312	159,312	0
7		159,312	159,312	159,312	0
8		159,312	159,312	159,312	0
9		159,312	159,312	159,312	0
10	0	159,312	159,312	159,312	0
11		159,312	159,312	159,312	0
12		159,312	159,312	159,312	0
13		159,312	159,312	159,312	0
14		159,312	159,312	159,312	0
15		159,312	159,312	159,312	0
16		159,312	159,312	159,312	0
17		159,312	159,312	159,312	0
18		159,312	159,312	159,312	0
19		159,312	159,312	159,312	0
20		159,312	159,312	159,312	0

NPV= 0

The analysis result in subcase 2.1, it was found that when the NPV equals zero, the electricity rate was about 18.3950 Baht per unit for this case. The stores would pay for the cost for purchasing the new equipment. The appropriate electricity rate for the stores calculated by using Microsoft office excel was about 19 Baht per unit, which the National Park would get the returns about 408,011 Baht per year. That were shown in Table 4-22.

Table 4-22 The cost-benefit analysis for the whole 20 years of the project period. (Discount rate was 10%) subcase 2.1 the stores would pay the cost for purchasing the new equipment

Year	Cost	O&M	Total Cost	Benefit	Net Cash Flow
0	0	0	0	0	0
1		159,312	159,312	384,716	225,404
2		159,312	159,312	384,716	225,404
3		159,312	159,312	384,716	225,404
4		159,312	159,312	384,716	225,404
5		159,312	159,312	384,716	225,404
6		159,312	159,312	384,716	225,404
7		159,312	159,312	384,716	225,404
8		159,312	159,312	384,716	225,404
9		159,312	159,312	384,716	225,404
10	4,630,000	159,312	4,789,312	384,716	-4,404,596
11		159,312	159,312	384,716	225,404
12		159,312	159,312	384,716	225,404
13		159,312	159,312	384,716	225,404
14		159,312	159,312	384,716	225,404
15		159,312	159,312	384,716	225,404
16		159,312	159,312	384,716	225,404
17		159,312	159,312	384,716	225,404
18		159,312	159,312	384,716	225,404
19		159,312	159,312	384,716	225,404
20		159,312	159,312	384,716	225,404

NPV= 0

The calculation of the electricity rate of subcase 2.2, it was found that the National Park should collect electricity rates for (59.88%*18.39) = 11.01 Baht per unit. Also, the National Park should raise the admission fee for additional ((40.12%*408011)/62,895) = 2.60 Baht per tourist (at the present, the admission fee is 20 Baht per tourist). Thus, the appropriate admission fee should be 22.60 Baht per tourist so that the National Park will have enough fund to purchase the new battery at the year 10th. The detail can be shown in Table 4-23

Table 4-23 The cost-benefit analysis for the whole 20 years of the project period. (Discount rate was 10%) subcase2.2 the stores and the Phu Kradueng National Park would share the cost for purchasing the new equipment. (60% from the stores, 40% from the National Park)

Items	Amount
The store's cost for purchasing the battery in the year 10th	2,772,455 Baht
The National Park's cost for purchasing the battery in the year 10th	1,857,545 Baht
Total	4,630,000 Baht
Average tourists per year	62,895 Tourists
Stores' electricity consumption	59.88%
The National Park's electricity consumption	40.12%
The returns from the electricity rates from case 3.2.1	408,011 Baht/ year
Electricity rate of case 3.2.1	18.39 Baht

4.1.4 The calculation for proper water heater rate

The prepaid solar cells water heater has the total cost of 500,000 Baht (the operation period is 10 years). The government bond interest was at 6%. The calculation of the proper water heater rate is the calculation to find the returns of the water heater within 10 years. The factor of the 10 years period can be calculated from the following equation:

$$\sum_{t=10}^{n}\left(\frac{1}{(1+i)^{1}}\right)+\left(\frac{1}{(1+i)^{2}}\right)+\cdots+\left(\frac{1}{(1+i)^{10}}\right) \quad [1]$$

Where t = Year order

i = Interest rate of loan

n = Life of project (years)

From the calculation, the factor was about 5.63. Then the total cost of the prepaid solar cell water heater was 500,000/5.62 = 88,787.73 Baht per year. It was expected that the two water heater tanks can contain water for 300 litres each, which should be enough for 50 tourists per day and 1 tourists could be use water for 5 minute. If we took the number of the days using water heater only for the tourism season for 4 months (120 days), then the appropriate water heater rate should be (88,787.73/(50*120)) = 14.7980 Baht per person or approximately 15 Bath per person per 5 minute.

4.2 Discussions

The analyzed results of this project can be discussed as follows:

4.2.1 Impacts on environment

It was found that the average of carbon monoxide (CO) measured from the store's diesel engine was much higher than that of the project's diesel engine. It affects the stores' owners, the tourists, and the National Park's staffs such as Sengbangpla (7) if a person was exposed to CO for about 35 minutes aside from the exhaust gas, then that person would suffered from blurred vision, inflammation of respiratory system, and amnesia which agreed with the research done.

It can also be seen from this study that the project's diesel engine of the project has less impact of carbon monoxide (CO) and oil contamination than the diesel engine at the store. However, the options of having or not having the renewable energy project cannot be explicitly stated about which option would yield better

environmental impacts. For example, if we don't have the renewable project, then the 24 diesel engines at the stores must be operated, causing high CO pollutants. But if we only operate the renewable energy project, there will be some other impacts on the environment by the huge project's diesel engine.

4.2.2 Cost-Benefit analysis

From the cost-benefit analysis of the renewable energy project, it was found that this project is worth for the investment.

This project also support the reduction of energy came from fossil usage. It will decrease the pollution and decrease the dependent on fossil energy utilization. Additionally, it can be seen from the analysis result that the fuel cost was also reduced. At the end of this project, the fuel cost saving was about 683,435.05 Baht per year or 16,937 litre per year. In the future, the fuel price tends to be increase as well as the transportation cost, this will also affects the returns of the project. This study agrees with Sereepaowong (3) about "The integrated renewable energy system for the community that lacks electricity: the pilot project at Moo Ban Koh Jick".

Another benefit of this study is the ice cost saving at the Wang-Kwang visitor area. There are 19 restaurants that need ice to keep food fresh. Usually, the restaurants need to buy ice 4 days per week. After the renewable project has begun, the stores' owners only buy ice 2 days per week. So the cost saving on ice is considered as the returns of the project.

For the increased electricity units, it was found that the increased electricity units were about 1,578 kWh. By using the electricity rate of 10 Baht per unit that the stores' owner are willing to pay to the National Park, the net value of the electricity rate is increase to 15,779 Baht per year. From the analysis, it can be seen that the returns of 25%, 74%, and 1% came from the fuel cost saving, the ice cost saving and the increased electricity units, respectively. This project aims to provide the power system that can supply the power for the entire area the stores due to the previous system, it only cover the staffs' housing and the tourists' lodges. Thus, the returns on ice cost saving was larger than the other returns of the project. If we applied this project to different area, then the returns of the project will also changed.

4.2.3 Financial analysis for the calculation of the appropriate electricity rates for the stores.

The cost-benefit analysis was applied to the project by using the net present value (NPV) and the government bond interest at 6% as the indication of the worthiness of investment. From several assumptions that possibly occur such as whether the National Park received or does not receive the support budget for purchasing the new equipment (less than 20 years of operation). From the analysis results, it was found that the appropriate rates were at 8, 19 and 12 Baht which cause NPV equals 0. That indicates the National Park will obtain the returns of the project and able to purchase the equipment (less than 20 years of operation) which makes this project worth the investment.

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

The cost-benefit analysis of the renewable energy pilot project for sustainable tourism at the Phu Kradueng National Park aims to assess the value of investment and to calculate the appropriate electricity charge for the stores in the Wang-Kwang visitor center areas. It is expected that this pilot project can also be applied to the other national parks that lack electricity. Additionally, the development of the hybrid power generation system can be adapted to be compatible with environment, geography and other factors for applying to the other national parks. The calculation to determine appropriate electricity rate can help the Phu Kradueng National Park so that the park can manage electricity utilization in the future. This study was divided into 3 aspects.

1) The impacts on the environment by the measurement of the amount of the air pollutants using the Visit 01-L/LR. The quantity of carbon dioxides (CO_2), carbon monoxide (CO), nitrogen monoxide (NO), and nitrogen oxide (NO_x) emitted from the 5 kW store's diesel engine and from the project's diesel engine were measured. It was found that the diesel engine at the store had been turned off for long time due to the renewable energy project can supply enough electricity to the stores. The measurement of the air pollutants was only done for one engine. The measurement of the noise pollution was done by sound pressure level measurement using the sound level meter NL-31. The sound pressure measurement was measured at the distance 0, 10-25, 40-50, 50-70 and 70-100 meters away from the sound source i.e. the 5 kW store's diesel engine. In additional, the sound pressure was measured at the distance 0, 10-25, 30-40, 50-70 and 70-100 meters away from the 48 kW project's diesel engine. The reason for choosing the measurement only from the 5 kW store's diesel engine was that most stores did not turn on the engine for long period of time due to the renewable energy distributed from the renewable energy project improved in 2012 was enough to cover the stores. Hence, the measurement results from the

store's diesel engine represented the whole diesel engines from all stores. The measurement of grease and oil contamination in soil was carried out by collecting the soil sample around the area of the 5 kW diesel generator at the store. It was found from interviewing the stores' owners that there was grease and oil leaking into the soil where the diesel engines were operated. There was also grease and oil leaking into the dirt where the 2 kW gasoline engine at the store was operated. Due to there were the diesel and the gasoline engines, so we also studied about the amount of grease and oil contamination in soil caused by different kinds of engines. The dirt samples were collected from the area nearby the 48 kW project's diesel engine and from the other areas of the park to be analyzed in the chemistry lab by way of grease and oil method (FOG) to determine the amount of the grease and oil contamination. The analysis results collected from the diesel engine at the store and from the project's diesel engine at the visitor center were compared. The dirt samples were collected in August of 2013.

2) Cost and benefit data of the project was collected and analyzed. The analysis was divided into two cases as follows.

2.1 The calculation to determine the cost of the new equipment installed in this project

2.2 The calculation to determine the cost of the new equipment installed in this project and the cost of the equipment installed in the original project. In this case the new equipments were operating with the old equipments.

This analysis was used as the criteria for making a decision about the worthiness of the project. The three criteria were NPV, IRR, and B/C ratio as well as the payback period of the project.

3) Financial analysis to calculate the appropriate electricity rates by setting the electricity rate that makes the NPV equals to zero. The analysis was divided into 3 cases as follows.

3.1 The Phu Kradueng National Park received the support budget to purchase the equipment (less than 20 years of operation).

3.2 The Phu Kradueng National Park did not receive the support budget to purchase the equipment (less than 20 years of operation). In this

case the stores were responsible for providing the money to buy the new equipment in a form of paying the electricity rates to the Phu Kradueng National Park.

3.3 Phu Kradueng National Park did not receive the support budget to purchase the equipment (less than 20 years of operation). In this case the stores and the Phu Kradueng National Park would share the cost for purchasing the new equipment. The stores would pay the electricity rates to the National Park; whereas, the National Park would receive the admission fee from the tourists. The calculation was done by dividing the proportions of cost for the stores and for the Phu Kradueng National Park.

Furthermore, this research also calculated the appropriate water heater rate. The appropriate water heater rate was used in the cost-benefit analysis of the water heater shower facility by way of the prepaid solar cell system which was also installed in this project.

5.1 Conclusions

5.1.1 The study of the impacts on environment

The average of the carbon monoxide (CO) emitted from the 5 kW store's diesel engine (3 years of operation) was 175 ppm. This amount was much more than the average CO emitted from the project's diesel engine installed in 2012, which as 12.25 ppm. The average CO emission from the store's diesel engine exceeded the acceptable level of CO measured at 5 meters away from the exhaust specified by the Pollution Control Department.

The sound pressure levels measured from the store's diesel generator and from the project's diesel engines were compared to the acceptable sound pressure level specified by the World Health Organization (WHO). The WHO has set the acceptable averaged sound pressure level, which is 70 decibel-A (dBA) for 24 hours (24). The averaged sound pressure level measured at the distance near the diesel engines was 82 dBA which was higher than the acceptable sound pressure level. However, the sound pressure levels were decreased for further distance at least 10 meters away from the diesel engines.

For the bulk density measurement of the soil and the grease and oil contamination, it was found that the soil density collected from the vicinity area of the diesel engine was about 0.77 grams per cubic centimeters with the grease and oil contamination about 0.10 % dry basis. The soil density collected from the vicinity area of the gasoline engine was approximately 0.86 gram per cubic centimeters with the grease and oil contamination about 0.08 % dry basis. The soil density collected from the vicinity area of the gigantic diesel engine was around 1.00 gram per cubic centimeters with the grease and oil contamination around 0.08 % dry basis. The soil density collected from other areas far from the engines was about 0.70 gram per cubic centimeters with the grease and oil contamination around 0.05 % dry basis. Thus, the utilization of the diesel generators causes the grease and oil contamination in soil problem.

5.1.2 The cost-benefit analysis

For a case of investment for the brand new equipment, it was found that the net present value of the project was about 10,818,678 Baht; the internal rate of return was about 24.13 %; the benefit-cost ratio was around 1.87; and the payback period was 5.3 years. Thus, it was worth to invest in this renewable energy project. In a case of investment for integrating the brand new equipment with the old equipment, it was found that the net present value was approximately 10,435,947 Baht; the benefit-cost ratio was 1.81; the internal rate of return was about 23.19 % and the payback period was around 5.6 years. Hence, it was worth to invest this project because the net present value, the internal rate of return, and the benefit-cost ratio met the requirements that can be summarized in Table 5-1.

Table 5-1 The value of the worth of investment

	The brand new equipment	**The new equipment and for the active old equipment**
NPV	10,818,678	10,435,947
IRR	24.13%	23.19%
B/C Ratio	1.87	1.81
Pay Back Period	5.32 year	5.57 year

5.1.3 The calculation for the appropriate electricity rates

Based on the financial analysis, it was found that:

5.1.3.1 The project received the budget support to purchase the equipment (for less than 20 years of operation), the appropriate electricity rates was 7.62 Baht per unit.

5.1.3.2 The project did not receive any budget support to buy the equipment (for less than 20 years of operation), the stores were responsible to pay for the equipment in a form of paying electricity rates to the National Park. The appropriate electricity rate was 18.39 Baht per unit. And In a case that the Phu Kradueng Nation Park and the stores shared the cost for purchasing the new equipment. The proper electricity rate for the store was 11.01 Baht per unit. Meanwhile, the National Park's appropriate admission fee should be increased for 2.60 Baht per tourist. The appropriate electricity rates for the store can be summarized in Table 5-2.

Table 5-2 The appropriate electricity rates for the stores

	Received the budget fund to purchase the new equipment	**The stores would pay the cost**	**The stores and the Phu Kradueng National Park would share the cost**
The appropriate electricity rate	7.6174 Baht/ unit	18.3950 Baht/ unit	11.01 Baht/ unit
Admission fee for additional			2.60 Baht/ tourist

5.1.4 The calculation for the proper water heater rates

The calculation for the proper water heater rate was the calculation for the returns from the water heater facility within 10 years period of utilizing the prepaid solar cell water heater shower system. It was found that the appropriate rate for water heater was about 14.7980 Baht per tourist.

In summary, from the analysis on the impacts on environment, it was found that the project's diesel engine emitted carbon monoxide (CO) less than that of the diesel engine at the stores; the measured sound pressure level was about 82 dBA which higher that the acceptable level; the grease and oil contamination of the soil in the vicinity area of the store's diesel engine was around 0.08- 0.10 % dry basis; the grease and oil contamination of the soil in the vicinity area of the project's 48 kW diesel engine was around 0.08 % dry basis. So it can be summarized that the project's diesel engine impacts environment much less than the store's diesel engine.

In addition, from the cost-benefit analysis of the project, it was found that it was worth for investment in the renewable energy project. Moreover, the proper electricity rates for the stores were 7.61, 18.39 and 11.01 Baht per unit for the cases of the project received the budget support to purchase the equipment, the project did not receive any budget support to buy the equipment that the stores were responsible to pay for the equipment in a form of paying electricity rates to the National Park and In a case that the Phu Kradueng Nation Park and the stores shared the cost for purchasing the new equipment, respectively. The appropriate water heater rate was about 15 Baht per tourist.

5.2 Recommendations

There are some recommendations for future research as follows:

5.2.1 The returns for the investment

This research studied about the cost-benefit analysis which concerns mainly on the benefit that the stores can obtain. It will be very useful for future research to analyze the cost-benefit analysis for different aspects to display the true value of the returns for the investment at the Wang-Kwang visitor center, the Phu Kradueng National Park.

5.2.2 Water pollution

This research analyzed the impacts on environment i.e., the air pollution, the noise pollution, and the grease and oil contamination at the vicinity area of the

stores' diesel engines and the project's diesel engine at the Phu Kradueng National Park. Additionally, we found that there is some water canals behind the stores closed to the diesel engines. The stores' owners mentioned that the grease and oil also leak into the water canals which can cause water pollution. So it is recommended for future research to study about impact on water pollution.

5.2.3 Air pollution

The measuring the released of air pollutants were measured from the vendor's diesel generators used at the stores and the project's diesel generators. In this study were measured by the Visit 01-L/LR that could not measure nitrogen dioxide (NO_2) and sulfur dioxides (SO_2). For future research to study about the quantity of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) that's more comprehensive on air pollution.

5.2.4 The indirect benefit

The cost-benefit analysis of this renewable energy project for sustainable tourism at the Phu Kradueng National Park still does not cover all parameters in term of the returns of the project. The assessment on the environmental return was not included, so the analysis of the returns of the project was possibly lower that it should be. The example of the indirect benefit is the saving on the cost of medical care, the stores' owners are happy about the cost saving from using the diesel engines, as well as the tourists. Thus, it is recommended for future study to include the assessment on the environment in the cost-benefit analysis.

5.2.5 The hybrid power generation systems in 2013/2014

The park officer's interview was inquired on 4th March 2014. After the hybrid power generation systems operating for 1 year, in October the system could supply enough energy to demand (energy from the solar subsystem and the wind turbine system in daytime and energy from the battery subsystem at nighttime). As for the project's diesel engine was turned on only for maintenance. In the high season (November to February) the energy was generated from the solar cell subsystem, the wind turbine system and the diesel engine. It could provide to demand also. The solar

cell subsystem and the wind turbine system supplied energy at daytime. The diesel engine was turned on only for 2 hours per day at 8 pm- 10 pm. After 10 pm the battery subsystem, that changed energy around 90 % - 100 % of its capacity at daytime, supplied energy until morning. The stores' energy demands were different for each store because of tourists who entered. The store's diesel engines were not turned on because the hybrid power generation system could provide enough energy. The rate of electricity fee was 10 Baht per unit. The stores were equipped 6 cu.ft. refrigerators as agreed in the meeting and some stores added televisions, DVD players and food processors. In October the stores were not necessary to buy ice but in the high season they bought ice 2 times per week. The ice consumption cost could be saved as predicted

The after installation data verification must be emphasized. In order to track the project’s results for improving and developing the hybrid power generation systems in the future.

REFERENCES

(1) Nilubol D. Technology assessment for electricity generation from hybrid clean energy: phukradueng national park loei province [thesis of science program in technology of environmental management]. Nakhon Pathom: Mahidol University; 2001.

(2) Ministry of energy. Alternative energy policy [internet]. 2008 [cited 2012 Nov 20]. Available from: http://www.energy.go.th.

(3) Sereepaowong S. Hybrid electrification system for off-grid rural community: ko-chik village pilot project [thesis of science program in technology of environmental management]. Nakhon Pathom: Mahidol University; 2005.

(4) The national education and research. Strategic plan for the phu kradueng national park management plan [internet]. 2004 [cited 2012 Nov 19]. Available from: http://www.dnp.go.th/nprd/plan/data/ne/Phu_Kradueng_NP_Plan.pdf.

(5) Research studies database of park. Phu kradueng tourism statistics [internet]. 2012. [cited 2012 Nov 23]. Available from: http://www.dnp.go.th.

(6) Klaimukh T. The technology assessment of PV/wind/diesel hybrid system: a case study at tarutao marine national park [thesis of science program in technology of environmental management]. Nakhon Prathom: Mahidlol University; 2001.

(7) Sengbangpla P. The exhaust from the engine and control. Bangkok: Chulalongkorn publisher; 1994.

(8) Pollution control department. The standard air ambient [internet]. 1992 [cited 2012 Nov 21]. Available from: http://www.pcd.go.th/info_serv/reg_std_airsnd01.html.

(9) Nonsung S, Tulyasatearn S. The noise pollution [internet]. 2004 [cited 2012 Nov 21]. Available from: http://www.tei.or.th/cef/nonoise/nonoise_knowledge_4detail.html.

(10) Pilot plant development and training institute King Mongkut's University of Technology. Phu kradueng national park for sustainable tourism. Bangkok: King Mongkut's University of Technology. 2012.

(11) Boonlue M. The worth in economics in energy power by wind turbine [thesis of economics]. Bangkok: Srinakharinwirot University; 2011.

(12) Ahmed S. Shadow prices for economic appraisal of project. Washington: The World Bank publisher; 1997.

(13) Bank of Thailand. The government bond interest [internet]. 2013 [cited 2013 Sep 14]. Available from: http://www.bot.or.th.

(14) Makprang S. The cost-benefit analysis of pile wood business: a case study at boon-chu pile shop singburee province [research exercise in current economics issues]. Chiangmai: Chiangmai University; 2002.

(15) Ku SJ, Yoo SH. Willingness to pay for renewable energy investment in Korea: a choice experiment study. Renewable and Sustainable Energy Reviews 2010;14:2196-201.

(16) Prakash VR, Bhat IK. Economics and environmental impacts of renewable energy systems. Renewable and Sustainable Energy Reviews 2009;13:2716-21.

(17) Jun SY, Lee SM, Park JW, Jeong SJ, Shin HC. The assessment of renewable energy planning on CO_2 abatement in South Korea. Renewable Energy 2010;35:471-77.

(18) Hafez O, Bhattacharya K. Optimal planning and design of a renewable energy based supply system for microgrid. Renewable Energy 2012;45:7-15.

(19) Panpinit S. Social science research techniques. 3rded. Bangkok: Witayapat; 2006.

(20) Friesema HP, Culhane PJ. Social impacts, politics and the environmental impact statement process [internet]. 1976 [cited 2013 Jun 5]. Available from: http://heinonline.org/HOL/LandingPage?collection=journals&handle=hein.journals/narj16&div=27&id=&page=.

(21) Yaibuated N, Somboon W, Kanchanakul N. The study of soil properties which may be associated with toxicity in Bangkok. Bangkok: Chulalongkorn publisher; 1979.

(22) Pittayapak A, Tippayawong N, Jompakdee W. Mechanical extraction of vegetable oils for local use: an economic analysis. Naresuan University journal 2003;11(3):9-20.

(23) Best JW. Research in Education. New Jersey: Prentice-Hall. 1977.

(24) Birgitta B, Thomas L, Dietrich HS. Guidelines for community noise [internet]. 1995 [cited 2013 Jul 17]. Available from: http://www.who.int/docstore/peh /noise/Comnoise-1.pdf.

(25) Munkwomdee S. Bulk density [internet]. [cited 2013 Sep 25]. Available from: http://www.vijai-rid.com/bulk%20density.html.

APPENDIX

แบบสอบถามโครงการปรับปรุงระบบผลิตไฟฟ้าแบบผสมผสานด้วยพลังงานสะอาด

(อุทยานแห่งชาติภูกระดึง : ต้นแบบอุทยานแห่งชาติพลังงานทดแทน

เพื่อการท่องเที่ยวที่ยั่งยืน)

วันที่เก็บข้อมูล……..…….รหัสแบบสอบถาม.....

โปรดใส่เครื่องหมาย √ ลงใน □ ที่ต้องการเลือก และเขียนคำอธิบายในช่องว่าง

ส่วนที่ 1 ข้อมูลส่วนบุคคล

1. เพศ □ ชาย □ หญิง

อายุ…….ปี

การศึกษาสูงสุด

□ ประถมศึกษา □ มัธยมศึกษาตอนต้น

□ มัธยมศึกษาตอนปลาย/ปวช. □ อนุปริญญา/ปวส.

□ ปริญญาตรี □ ปริญญาโท

□ ปริญญาเอก □ อื่นๆ (ระบุ).....

การประกอบอาชีพในปัจจุบัน

□ ข้าราชการ/รัฐวิสาหกิจ □ พนักงานเอกชน

□ นักเรียน/นักศึกษา □ รับจ้าง

□ ธุรกิจส่วนตัว □ แม่บ้าน

□ ค้าขาย□ อื่น ๆ (ระบุ)……..

รายได้เฉลี่ยรวมทั้งครัวเรือนโดยประมาณ ……บาท/เดือน

ค่าใช้จ่ายเฉลี่ยรวมทั้งครัวเรือนโดยประมาณ.....บาท/เดือน

จำนวนสมาชิกที่อาศัยอยู่ภายในร้านค้า..... คน เป็นชาย..... คน หญิง.....คน

ขนาดพื้นที่ของร้าน.....ตารางเมตร

ประเภทของการให้บริการ

□ ร้านขายของที่ระลึก.....

☐ ร้านอาหารตามสั่ง.....

☐ อื่นๆ (ระบุ).....

จำนวนผู้มาใช้บริการ.....คน/วัน .....คน/เดือน .....คน/ปี

ช่วงเวลาที่เปิดให้บริการในแต่ละวัน..... น. ถึง..... น.

ระยะเวลาที่เปิดให้บริการตลอดทั้งปี ..... เดือน/ปี

รายได้เฉลี่ย..... บาท/วัน ..... บาท/ปี

ส่วนที่ 2 ข้อมูลเกี่ยวกับระบบไฟฟ้า

1. เครื่องใช้ไฟฟ้าและเวลาการใช้งานในปัจจุบัน

ประเภท	ขนาด	จำนวน	ช่วงเวลาใช้งาน
1.หลอดไฟฟ้า ☐ หลอดไส้ ☐ หลอดฟลูออเรสเซนต์ ☐ หลอดตะเกียบ ☐ หลอดคอมแพค	 วัตต์ วัตต์ วัตต์ วัตต์		
2. พัดลม ☐ ติดผนัง ☐ ตั้งพื้น ☐ ตั้งโต๊ะ ☐ ติดเพดาน	 นิ้ว นิ้ว นิ้ว นิ้ว		
3.โทรทัศน์ ☐ ขาวดำ ☐ สี ทั่วไป ☐ สีจอแบน	 นิ้ว นิ้ว นิ้ว		
4. เครื่องเล่นดีวีดี	วัตต์		
5. เครื่องเล่นวีซีดี	วัตต์		
6.เครื่องเสียง	วัตต์		
7. หม้อหุงข้าว (ความจุ)	ลิตร		

8. เครื่องคอมพิวเตอร์ (ขนาดจอ)	นิ้ว		
9. กระติกน้ำร้อน (ความจุ)	ลิตร		
10.เตารีด ☐ ธรรมดา ☐ ไอน้ำขนาดเล็ก ☐ ไอน้ำขนาดใหญ่	 วัตต์ วัตต์ วัตต์		
11.เครื่องซักผ้า ☐ แบบกึ่งอัตโนมัติ ☐ แบบอัตโนมัติ	 กก. กก.		
12.เครื่องปิ้งขนมปัง	วัตต์		
13.เครื่องบดอาหาร ☐ ขนาดเล็ก ☐ ขนาดกลาง ☐ ขนาดใหญ่	 วัตต์ วัตต์ วัตต์		
14.ตู้เย็น(ขนาดความจุ)	คิว		
15.เครื่องปั่นผลไม้	ลิตร		
16.เครื่องเป่าผม/เครื่องหนีบผม	วัตต์		
17.กระทะไฟฟ้า ☐ ขนาดเล็ก ☐ ขนาดกลาง ☐ ขนาดใหญ่	 วัตต์ วัตต์ วัตต์		
18.ไมโครเวฟ (ความจุ)	ลิตร		
19.ที่ชาร์จไฟโทรศัพท์มือถือ	วัตต์		
20.ที่ชาร์จไฟวิทยุสื่อสาร	วัตต์		

2. ระบบผลิตไฟฟ้าด้วยเครื่องยนต์ที่ใช้งานในปัจจุบัน

2.1 ประเภทของเครื่องยนต์ (ดีเซล/เบนซิน) …….

2.2 ยี่ห้อเครื่องยนต์ …… ขนาด …… แรงม้า

2.3 ยี่ห้อเครื่องกำเนิดไฟฟ้า …….. ขนาด …….. กิโลวัตต์

2.4 ช่วงระยะเวลาใช้งาน ……น. - …… น. รวมใช้งานวันละ …… ชั่วโมง

2.5 ปริมาณน้ำมันที่ใช้ต่อวัน …….. ลิตร คิดเป็นเงิน..... บาท/วัน

2.6 ความถี่ในการซ่อมระบบผลิตไฟฟ้าด้วยเครื่องยนต์โดยประมาณ …….. เดือน/ครั้ง

2.7 ค่าใช้จ่ายเกี่ยวกับการผลิตไฟฟ้าของครอบครัวท่านในปัจจุบัน คิดเป็น ……. บาทต่อเดือน

3. ท่านคิดว่าระบบการผลิตไฟฟ้าเครื่องยนต์ที่ใช้งานในปัจจุบัน ก่อให้เกิดผลกระทบต่อตัวท่านและอุทยานแห่งชาติภูกระดึงอย่างไร

☐ 3.1 ไม่ก่อให้เกิดผลกระทบ

☐ 3.2 ก่อให้เกิดผลกระทบในด้านบวก ดังนี้

ได้รับความสะดวกสบายในการใช้ไฟฟ้า

☐ รักษาสิ่งแวดล้อม

☐ เสียค่าใช้จ่ายต่ำ

☐ 3.3 ก่อให้เกิดผลกระทบในด้านลบ ดังนี้

เสียงดังจากเครื่องยนต์ดีเซล เครื่องกำเนิดไฟฟ้า

มลภาวะทางอากาศ หมอก ควัน เขม่า ฝุ่นละออง

กลิ่นก๊าซและกลิ่นน้ำมันเผาไหม้ฟุ้งกระจาย

ค่าใช้จ่ายสูง

4. ท่านพึงพอใจกับการจ่ายพลังงานไฟฟ้าของโครงการรูปแบบใด

☐ ท่านสามารถใช้ไฟฟ้าได้ตลอด 24 ชั่วโมง แต่มีการห้ามนำเครื่องใช้ไฟฟ้าบางชนิดเข้ามาใช้งาน เช่น เครื่องปรับอากาศ เป็นต้น

☐ ท่านสามารถใช้ไฟฟ้าเครื่องใช้ไฟฟ้าได้ทุกชนิด แต่ต้องมีการจัดระยะเวลาในการจ่ายไฟฟ้า เช่น ระหว่างเวลา 05.00 – 08.00 น. และ18.00 – 22.00 น. เป็นต้น

5. เพื่อความปลอดภัยในชีวิตและทรัพย์สินของท่าน ท่านยินดีจะปรับปรุงระบบการเดินสายไฟฟ้าภายในบ้านของท่านให้เป็นไปตามมาตรฐานการไฟฟ้าส่วนภูมิภาคหรือไม่

☐ ยินดี ☐ ไม่ยินดี

6. ท่านคิดว่าควรติดตั้งระบบไฟฟ้าแสงสว่างและอุปกรณ์สาธารณะฟรี บริเวณใดบ้าง

(ตอบได้มากกว่า 1 ข้อ)

☐ ทางเดิน ☐ ห้องน้ำ

☐ ร้านค้า ☐ บ้านพัก

☐ ที่ทำการอุทยาน ☐ ห้องพยาบาล

☐ อื่น ๆ (ระบุ).....

ส่วนที่ 3 ทัศนคติต่อระบบผลิตไฟฟ้า

1. ท่านคิดว่าระบบผลิตไฟฟ้าเดิมที่ใช้อยู่ในปัจจุบัน ดีหรือไม่

☐ ดีอยู่แล้ว เพราะ.....

☐ ไม่ดี เพราะ.....

ข้อเสนอแนะ

.....

.....

2. ท่านอยากให้มีระบบผลิตไฟฟ้าแบบใหม่หรือไม่

☐ อยาก เพราะ.....

☐ ไม่อยาก เพราะ.....

3. ท่านคิดว่าระบบผลิตไฟฟ้าที่เหมาะสมของอุทยานแห่งชาติภูกระดึงคือ

☐ ควรเปลี่ยนมาใช้ระบบผลิตไฟฟ้าจากโซลาร์เซลล์และกังหันลมเท่านั้น โดยไม่จำเป็นต้องใช้เครื่องยนต์ปั่นไฟอีก

☐ ควรใช้ไฟฟ้าจากเครื่องยนต์ปั่นไฟแยกตามร้านค้าเหมือนปัจจุบัน

☐ ควรใช้ไฟฟ้าจากเครื่องยนต์ปั่นไฟแบบรวมเพียงเครื่องเดียว

☐ ควรใช้ไฟฟ้าจากระบบผลิตไฟฟ้าจากโซลาร์เซลล์และกังหันลมเป็นหลัก แต่ก็ควรมีเครื่องปั่นไฟสำรองไว้ด้วย เพื่อใช้ผลิตไฟฟ้าแทนโซลาร์เซลล์และกังหันลม เฉพาะในช่วงที่โซลาร์เซลล์และกังหันลมผลิตไฟฟ้าไม่ได้ เช่น ช่วงที่ไม่มีแสงแดดติดต่อกันหลายวัน หรือช่วงที่ไม่มีลมพัดแรง

☐ อื่น ๆ (ระบุ)…….

4. จากการที่รัฐได้มีแผนการติดตั้งระบบผลิตไฟฟ้าด้วยโซลาร์เซลล์และกังหันลมที่อุทยานแห่งชาติภูกระดึงนี้ ต้องใช้งบประมาณค่อนข้างสูง เพื่อดำเนินการดูแลระบบและรักษาระบบนี้ ในฐานะที่ท่านได้รับผลประโยชน์จากระบบนี้ ท่านคิดว่าจำนวนเงินที่เหมาะสมที่ท่านสามารถจ่ายได้ คือ ……....บาท/หน่วย

5. ท่านเห็นด้วยหรือไม่กับการติดตั้งระบบผลิตไฟฟ้าจากโซลาร์เซลล์ กังหันลม และเครื่องยนต์ดีเซล

☐ เห็นด้วย เพราะ…….....……

☐ ไม่เห็นด้วย เพราะ…….....……...

6. ท่านยินดีจ่ายค่ามัดจำมิเตอร์ไฟฟ้า เพื่อบันทึกปริมาณการใช้ไฟฟ้าหรือไม่

☐ ยินดี เพราะ…….....…

☐ ไม่ยินดี เพราะ…….....……...

7. ท่านคิดว่าการติดตั้งระบบผลิตไฟฟ้าด้วยโซลาร์เซลล์และกังหันลมบนอุทยานแห่งชาติภูกระดึงก่อให้เกิดผลกระทบต่อตัวท่านและชุมชนอย่างไรบ้าง

☐ 7.1 ไม่ก่อให้เกิดผลกระทบ

☐ 7.2 ก่อให้เกิดผลกระทบในด้านบวก ดังนี้

ได้รับความสะดวกสบายในการใช้ไฟฟ้า

รักษาสิ่งแวดล้อม

☐ 7.3 ก่อให้เกิดผลกระทบในด้านลบ ดังนี้

เสียงดังจากเครื่องยนต์ดีเซล เครื่องกำเนิดไฟฟ้า

มลภาวะทางอากาศ หมอก ควัน เขม่า ฝุ่นละลอง

กลิ่นก๊าซและกลิ่นน้ำมันเผาไหม้ฟุ้งกระจาย

ค่าใช้จ่ายเพิ่มมากขึ้น

8. คาดการณ์แนวโน้มการท่องเที่ยวและธุรกิจร้านค้าบนอุทยานแห่งชาติภูกระดึง คิดว่าจะเป็นอย่างไร พร้อมเหตุผล

……

……

……

9. ท่านคิดว่ารูปแบบการขึ้นมาเที่ยวบนภูกระดึงจะเปลี่ยนไปจากที่เป็นอยู่หรือไม่

เปลี่ยนไป เพราะ

.....

เปลี่ยนเป็นอย่างไร (อธิบาย)…….....….....

……...

ไม่เปลี่ยน เพราะ

.....

การเปลี่ยนแปลงจะมีผลกระทบกับความต้องการใช้พลังงานเพิ่มขึ้นหรือไม่ และร้านค้าจะได้รับผลกระทบอย่างไรกับการเปลี่ยนแปลงดังกล่าว

□ มีผลกระทบ อย่างไร

(ระบุ).....

□ ไม่มีผลกระทบ อย่างไร

(ระบุ).....

10. ท่านมีข้อเสนอแนะอื่นๆ เกี่ยวกับการจัดการระบบผลิตไฟฟ้าแบบผสมผสานบนอุทยานแห่งชาติภูกระดึงให้มีประสิทธิภาพ และให้เกิดประโยชน์กับชุมชนอย่างยั่งยืนอย่างไร

……

……

(ขอขอบคุณค่ะ)

BIOGRAPHY

NAME	Miss Roypimjai Jaimun
DATE OF BIRTH	8th July 1988
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Kasetsart University, 2006-2009 Bachelor of Science (Agricultural Economics) Mahidol University, 2011-2013 Master of Science (Technology of Environmental Management)
ADDRESS	2/22 Soi.Preamsombud 1 Prachasongkrock Rd., Dindang Bangkok, Thailand 10400
E-MAIL	roypimjai.j@gmail.com
PUBLICATION / PRESENTATION	Cost-benefit analysis of renewable energy pilot project for sustainable tourism at Phu Kradueng National Park, Thailand. The proceedings in the 10th National Kasetsart University Kamphaeng Saen Conference. Conference on 7 December 2013 at Kasetsart University Kamphaeng Saen Campus.