COST BENEFIT ANALYSIS OF PHOTOVOLTAIC TECHNOLOGY ADOPTION AT REST AND SERVICE AREA FOR MALAYSIA HIGHWAY

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DEDICATION

This project report is dedicated to my lovely parents, who were always there for me and for their overwhelming support, encouragement, sacrifices and endless love. It is also dedicated to my beloved sisters and my supervisor.

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ABSTRACT

Photovoltaic technology is cleaner technology that's served the needs in reducing energy demand consumption. However, the demand for this technology is still weak due to its high cost of installation and maintenance. Besides that, rest and service areas (RSAs) are facilities that operate 24/7 consuming high energy demand. However, the combination of this technology for RSAs seems beneficial since it carries the benefits not only as part of alternative energy, but it will keep the whole environment from its footprint clean. Hence, this research aims to identify the cost-benefit analysis on PV technology, which assists decision-makers, stakeholders and highway concessionaires in selecting the best PV technology for RSAs. To achieve this aim, issues and challenges, types of PV technology and cost analysis have been investigated. Microsoft Excel and RETScreen Expert software have been used to evaluate the economic and environmental aspects. Five semi-structured interviews were conducted. All costs incurred were collected from manufacturers and governmental agencies. The study revealed that high initial cost of photovoltaic system, lack of public awareness and lack of government incentives are the key lever issues that hindering the prosperity of this technology in the Malaysian market. Besides that, it reveals that the total initial cost of monocrystalline and poly-crystalline PV system estimated to be (MYR 715400 and MYR 518500) respectively. The financial indicators for the monocrystalline PV system were found to be (MYR 1513182, 17.6% and 3.1) for (net present value, internal rate of return and benefit-cost ratio) respectively. While the poly-crystalline PV system were found to be (MYR 1440253, 21.5% and 3.8) for (net present value, internal rate of return and benefit- cost ratio) respectively. For the environmental analysis, monocrystalline and poly-crystalline reduce the GHG emission at Machap RSA by (25.6% and 22.3%), respectively. From this, concludes that poly-crystalline is more economical however it can be improved for monocrystalline providing more space area is being added up.

ABSTRAK

Teknologi fotovoltaik (PV) teknologi bersih yang memenuhi keperluan dalam mengurangkan penggunaan permintaan tenaga. Walau bagaimanapun, permintaan teknologi ini masih lemah disebabkan kos pemasangan dan penyelenggaraan yang tinggi. Selain itu, kawasan rehat dan rawat (R&R) adalah kemudahan yang beroperasi 24/7 menggunakan permintaan tenaga yang tinggi. Di samping itu, gabungan teknologi ini untuk R&R nampaknya memberi manfaat kerana ia membawa faedah bukan sahaja sebagai sebahagian daripada tenaga alternatif, tetapi ia akan memastikan seluruh alam sekitar bersih daripada jejaknya. Oleh itu, penyelidikan ini bertujuan untuk mengenal pasti analisis kos-faedah mengenai teknologi PV yang membantu pembuat keputusan, pihak berkepentingan dan pemegang konsesi lebuh raya dalam memilih teknologi PV yang terbaik untuk R&R. Untuk mencapai matlamat ini, isu dan cabaran, jenis teknologi PV dan analisis kos telah disiasat. Microsoft Excel dan perisian pakar RETScreen telah digunakan untuk menilai aspek ekonomi dan persekitaran. Lima wawancara separa berstruktur telah dijalankan. Semua kos yang ditanggung telah dikumpulkan daripada pengilang dan agensi kerajaan. Kajian menunjukkan bahawa kos awal sistem fotovoltaik yang tinggi, kekurangan kesedaran orang awam dan kekurangan insentif kerajaan adalah isu utama yang menghalang penggunaan teknologi ini secara meluas di pasaran Malaysia. Seterusnya, jumlah kos awal monokristalin adalah RM 715400 dan sistem PV polikristalin dianggarkan RM 518500. Penunjuk kewangan untuk sistem PV monokristalin didapati (RM 1513182, 17.6% dan 3.1) untuk setiap (nilai kini bersih, kadar pulangan dalaman dan nisbah manfaat-kos). Sementara itu sistem PV polikristalin didapati (RM 1440253, 21.5% dan 3.8) masing-masing untuk setiap (nilai semasa bersih, kadar pulangan dalaman dan nisbah kos faedah). Daripada ini, dapat disimpulkan bahawa polikristalin lebih ekonomik namun ia dapat diperbaiki untuk monokristalin yang menyediakan lebih banyak ruang yang mampu diperbesarkan lagi.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
A-Si	-	Amorphous Silicon
ASSC	-	Amorphous Silicon Solar Cell
BCR	-	Benefit to Cost Ratio
BEI	-	Building Energy Index
BIPV	-	Building Integrated Photovoltaic
BOS	-	Balance of System
CBA	-	Cost Benefit Analysis
CdTe	-	Cadmium Telluride
CTSC	-	Cadmium Telluride Solar Cell
CIGS	-	Copper Indium Gallium Selenium
DC	-	Direct Current
EPC	-	Engineering-Procurement-Contract
FDP	-	Fuel Diversification Policy
FGSCs	-	First Generation of Solar Cells
FiT	-	Feed in Tariff
GEF	-	Global Environment Facility
GHG	-	Greenhouse Gases
GW	-	Giga Watt
HOMER	-	Hybrid Optimization Model for Electric Renewable
HVAC	-	Heating-Ventilation-Air-Conditioning
IEA	-	International Energy Agency
IGS	-	Industry Research and Development Grant Scheme
IRR	-	Internal Rate of Return
JKR	-	Jabatan Kerja Raya
MECM	-	Ministry of Energy, Communication And Multimedia
MG	-	Mega Watt
MSC	-	Monocrystalline Solar Cell
NASA	-	National Aeronautics & Space Administration
NEPEs	-	Non-Financial Public Enterprises

NPV	-	Net Present Value
NREL	-	National Renewable Energy Laboratory
NSE	-	North-South Expressway
O&M	-	Operation & Maintenance
PBP	-	Project Payback Period
PCF	-	Prototype Carbon Fund
PSC	-	Polycrystalline Solar Cell
PSH	-	Prototype Solar House
PV	-	Photovoltaic
PVMC	-	Photovoltaic Monitoring Schemes
RE	-	Renewable Energy
REEEP	-	Renewable Energy and Energy Efficiency Partnership
RSA	-	Rest and Services Area
SDGs	-	Sustainable Development Goals
SEDA	-	Sustainable Energy Development Authority
SETs	-	Solar Energy Technologies
SGSCs	-	Second Generation of Solar Cells
SR	-	Solar Radiation
SSC	-	Silicon Solar Sells
TFSCs	-	Thin Film Solar Cells
TNR	-	Tenaga National Research
TW	-	Terra Watt
UiTM	-	University Technology Mara
UKM	-	University Kebangsaan Malaysia
UN	-	United Nation
UNEP	-	United Nation Environment Program
UTM	-	Universiti Teknologi Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Energy is a pivotal key for development and economic growth. Energy usage and demand is increasing while resources are decreasing which ergs the researchers to think seriously to secure a sustainable and green source of energy. Renewable energy is currently on the rise, especially in Malaysia. As sustainable and clean energy source, solar energy will not generate environmental pollution generated by conventional energy sources such as gas, oil and other fossil fuels during use (Hosseini *et al.*, 2013). One of the most important energy-saving measures is the development and use of renewable energy. Over the previous 30 years, several developed industrial nations and some developed nations had already tethered immense importance to solar technology development.

Malaysia, as an oil-producing nation, has long depended on fossil fuels to meet the electricity consumption of the region. Nonetheless, realizing that-relying on fossil fuel would have a negative impact on the environment and economies, the government of Malaysia has been exploring the efficiency of renewable energy (RE) resources since about the earliest 2000s. Different policies have been developed and enforced over the years to develop Malaysia's renewable energy sector. The Sustainable Energy Development Authority (SEDA) thereby intends to achieve 6% (985 MW) of solar power and 73% (21,4 GW) of solar power by 2015 and 2050, accordingly as shown in Figure 1.1 (W. Chen, 2012).

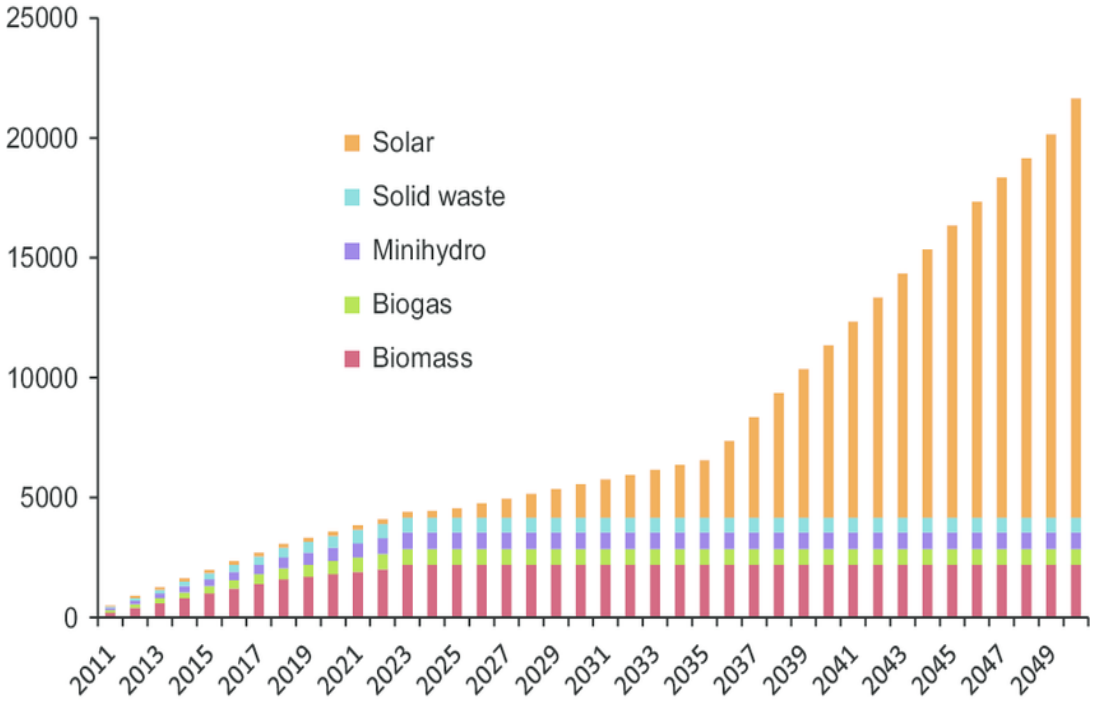

Figure 1.1 Solar energy target up to 2050 in Malaysia (W. Chen, 2012)

Malaysia is considered to be a tropical country with a lot of sunlight throughout the year, for example Malaysia got a lot of sunlight with an average of 4-8 hours of sunlight daily. (Mekhilef *et al.*, 2012). Therefore, PV technology can be applied as sustainable and green energy. PV technology is one of the applications of solar power. PV is a technology in which cells comprising solar PV materials which transform sun irradiance into direct current electricity (Saidur *et al.*, 2009). World power output in 2012 reached 17 Tera Watts (TW), which is less than the sun power the planet gets. The sun gives the planet a 3.4×10^4 TW usable power (Hosenuzzaman *et al.*, 2015).

A study by the National Renewable Energy Laboratory (NREL) revealed that The advantages of implementing PV technologies include reducing the overall cost of electricity, defending against increasing electrical power prices in the future, helping to reduce the impacts on the environment and achieving a good return on investment. Table 1.1 shows the most important benefits of PV technology.

Table 1.1 Photovoltaic technology benefits

Aspect	Benefits	Author
Environmental	Providing clean energy, reducing carbon emissions, decreasing air pollution, minimizing acid rain, utilizing sunray, reducing fossil fuel consumption, reducing global warming, and climate change.	(Basri *et al*., 2015), (Ramadhan & Naseeb, 2011), (Pauzi & Zakaria), (Saidur *et al*., 2009), (Mekhilef *et al.*, 2012), (Parida *et al.*, 2011), (Sampaio *et al*., 2019)
Financial	Long-term cost savings, lowers electricity bills, PV solar system has a long life.	

1.2 Problem Statement

Global energy demand is escalating at a skyrocketing pace due to increased population, greater industrial production and radical change in consumption patterns. Global energy demand is expected to increase by 30% by 2040.(IEA, 2017). It leads to increased demand for more efficient and renewable energy solutions, as well as cost-effective measures for sustained global growth. Malaysia, as an oil-producing nation, has long depended on fossil fuels to meet the electricity consumption of the region. Nonetheless, realizing that-relying on fossil fuel would have a negative impact on the environment and economies, the government of Malaysia has been exploring the efficiency of renewable energy (RE) resources since about the earliest 2000s. Different policies have been developed and enforced over the years to develop Malaysia's renewable energy sector. The Sustainable Energy Development Authority (SEDA) thereby intends to achieve 6% (985 MW) of solar power and 73% (21,4 GW) of solar power by 2015 and 2050, accordingly. as shown in Figure 1.1 (W. Chen, 2012).

Developing nations face huge difficulties in dealing with high demand for energy `(M. T. Islam *et al.*, 2014) and (Ahmed *et al.*, 2014). Like other developed Asian countries, Malaysia is dedicated to pursuing Sustainable Development Goals (SDGs) in all 17 indicators asserted by the UN by 2030 (UNDP), and leaders are actively outlining SDG development plans. Among the indicator's electricity supply to all residents at the country level and a decrease in total emissions (in terms of reducing GHG emissions) are the two main targets that the Malaysian government should fulfil. However, with rising urban sprawl and living standards of population in Malaysia, there is surety that human activities will rise dramatically, meaning mobility thru roadway networks.

The North-South Expressway is the longest expressway in Malaysia with the total length of 748 kilometers and contains a 24 Rest and Service Area (RSA). RSA is an important highway network facility that operates 24 hours a day and utilizes significant amount of energy for lighting, cooling, and restaurant activities. Due to the use of electricity, a noticeable amount of carbon is emitted from the RSA (Ramlia *et al.*, 2019). Facilities and building in RSA consider high energy consumption buildings (Rozana *et al.*, 2013). By promoting the photovoltaic technology at RSAs this will help to reduce the energy consumed from conventional methods, reduce the electricity bill and the emission of greenhouse gases (GHG). Yet, lack of awareness about PV technology benefits. As well as Stakeholders usually consider financial constraint as the main barrier for not implementing in PV technology. Therefore, a cost benefits analysis on PV technology is carried out in this study to give an approximate depiction to the decision maker, stakeholders and highway concessionaires while to adopt or not to adopt this technology in RSAs' facilities.

1.3 Research Aim and Objectives

The aim of this study is to propose the best type of Photovoltaic (PV) technology for Malaysia Highway Rest and Services Area in order to reduce the greenhouse gases (GHG) emission, cost and to create healthy environment for the future generation. Thus, to achieve this aim four objectives were adapted. The objectives of the research are:

1. To investigate the issues and challenges of Photovoltaic technology that has been implemented in Malaysia.

2. To compare the types of photovoltaic technology that are available in Malaysia based on its benefits.

3. To identify the cost analysis components of photovoltaic technology that are available in Malaysia.

4. To evaluate and propose the economic and environmental aspects for photovoltaic technology to be implemented at Malaysia Highway Rest and Service Areas.

1.4 Scope of the Study

The scope of this research is summarized as follow:

1. This research will focus on MACHAP rest and services area only.

2. The research will focus on photovoltaic (PV) only as a solar renewable energy.

3. The research will focus on fixed rooftop photovoltaic power generation.

4. The research will focus on the PV technologies that are available in the local market.

5. The data is obtained from manufacturers, sustainable energy development Malaysia (SEDA) and by conducting semi-structured interviews.

1.5 Significance of Study

Previous research highlighting the importance of PV's benefits, while some research regarding Rest and Services Areas (RSAs) focusing on the energy consumption investigation. However, there are non-research that focusing on the integration of these two concepts. Therefore, this study is perceived that the adoption of PV technologies in Malaysian RSAs will decrease the electricity bill and participate to reduce the country GHG emission. In order to acknowledge Malaysia in promoting clean energy to the world nations, it is important to identify the level of its acceptance and adoption. In addition to the fact that RSAs facilities are considered an open space facility that mostly single-story buildings, a relatively high ratio of ceiling-to-floor compared to other types of facilities with roughly similar floor area. The proportionally large rooftop area that does not serve any particular purpose. In most cases, deploying green technologies such as photovoltaic technology makes no alteration to the building design. Moreover, the output of this research also will identify its demand since it is an open space facility. With this, the performance of PV system is more beneficial, economical and individually improve the demand without being affected by the shading of surrounding building areas.

1.6 Brief Research Methodology

Research process is a framework for achieving the goal of study. This requires research design that relies on study nature. Research process requires a number of actions or measures that inevitably conduct research and the appropriate ordering of the actions (Kothari, 2004). The process is a step-by-step procedure of the designing, analysis, and project report as shown in Figure 1.2.

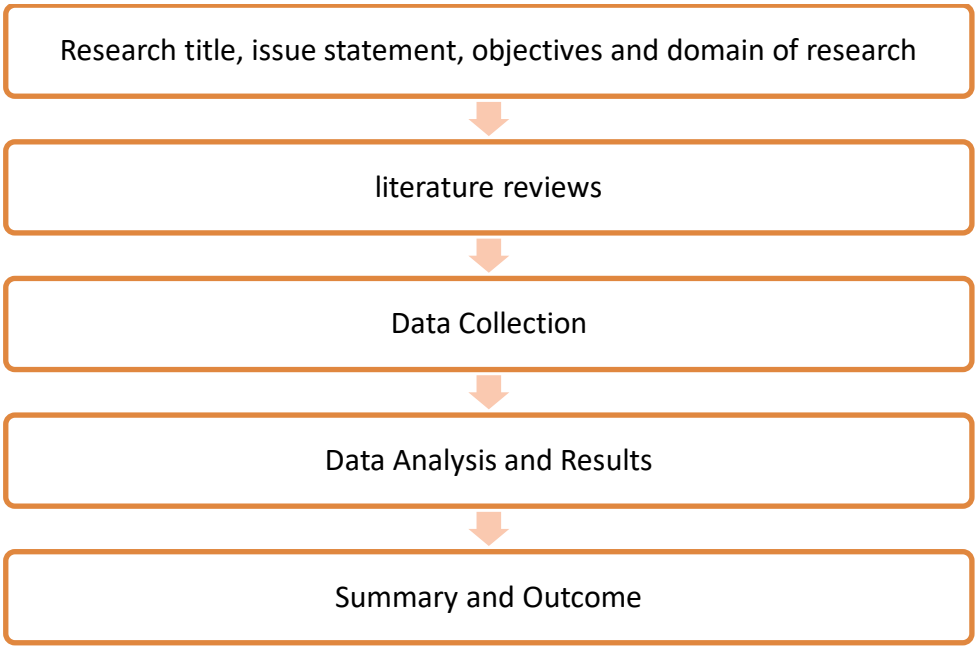

Figure 1.2 Flowchart methodology map

1.6.1 Identification of problems and scope of study

The primary stage is the understanding and gain deep perception on the research topic of problem thru; problem assertion, purpose and objectives as well as scope and limitations of study. Literature evaluations are achieved on previous research, journals, statistics, books, Malaysian enacted acts and newspaper.

1.6.2 Data Collection

Data collection is the preliminary level of a research project. it's been carried out thru consultation of previous research works from diverse sources (books, journals, thesis, electronic resources, governmental agency and manufacturing companies). It additionally counts on semi-structured interviews that discuss the problem and the topic with skilled experts within the area of research.

1.6.3 Data Analysis

At this level, collected data had been analysed doing content analysis, Microsoft Excel and RETScreen expert software. Data must be entered and screened in detail. Numerous parameters had been used for the evaluation. Quantitative information in form of tables, charts, graphs are generated as output to attract outcomes and explication.

1.6.4 Conclusion

At this level, the research can be organized on the basis of the study findings and the evaluation which have been finished. Furthermore, the problem of research, the implication of research and recommendation for future studies are also suggested here.

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