IDENTIFICATION AND EVALUATION OF THE CRITICAL SUCCESS FACTORS FOR SOLAR ENERGY PROJECT IN MALAYSIA USING ANALYTIC HIERARCHY PROCESS (AHP)

KOGILA VANI D/O MOKAN

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Faculty of Technology Management and Business
Universiti Tun Hussein Onn Malaysia

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged

Student : ……
KOGILA VANI D/O MOKAN

Date : 28 JANUARY 2021

Supervisor : ……
TS.DR.LEE TE CHUAN

Date : 28 JANUARY 2021

Co Supervisor : ……
MADAM ROHAIZAN BINTI RAMLAN

Date : 28 JANUARY 2021

DEDICATION

To my beloved parents, Mr. Mokan and Mrs. Punithavathy, my brother, Mr. Ravikumar, my supervisor, Dr. Lee Te Chuan, my co supervisor, Madam Rohaizan and all my friends,

Thank you for your unlimited support, motivation, encouragement and guidance and inspiration throughout this meaningful research journey.

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ABSTRACT

Energy sources is an essential part for all living things in the world. Malaysia is a gifted country with renewable energy sources which will never run out and constantly recharged by nature. Solar energy is one of the potential renewable energy sources in Malaysia that could generated sustainable power sources directly from sun. The problems that encourage conduct this research are import of fossil fuel that put a lot of burden on Malaysia's economy, environmental issue, lack of awareness among public, lack of publication of critical success factors (CSFs) of solar energy project and methodology gap. In order to address these issues, this research aimed to identify the CSFs for solar energy project in local context, analysed the CSFs importance in solar energy project in Malaysia using analytic hierarchy process (AHP) method and evaluated the ranking of CSFs based on AHP result. Total 6 main CSFs namely economic, environment, technology, organization and management, government and social factor and 27 sub-factor were proposed in this research to develop AHP model. Besides, the data for this research were collected via online survey questionnaire from 73 solar energy companies in Klang Valley with 52% return rate of valid questionnaires. The collected data were analysed using Expert Choice software of AHP to rank the CSFs from most important factors. The finding revealed that environment factor (0.206) ranked as first priorities CSF followed by technology factor (0.195), economic factor (0.168), government factor (0.155), organization and management factor (0.142) and social factor (0.134) respectively. Moreover, reduce carbon dioxide emission (0.079), government policies (0.073), financial perspective (0.061), financial support (0.055) and reduce air pollution (0.048) were the priority ranking order of the top 5 sub-factor that identified in this research. Besides, the finding achieved in this research provide guideline for solar energy industry in Malaysia to manage and increase the quality of solar energy project successfully. Plus, the assessment of AHP model in this research served a better idea and knowledge for future researcher since the AHP model purpose in this research is new in local context.

ABSTRAK

Sumber tenaga diperlukan bagi semua kehidupan di dunia ini. Malaysia ialah sebuah negara yang dikurniakan dengan pelbagai sumber tenaga boleh diperbaharui yang tidak akan habis dan sentiasa diperbaharui semula oleh alam semula jadi. Tenaga suria berpotensi sebagai salah satu tenaga boleh diperbaharui di Malaysia yang mejana sumber tenaga secara langsung dari matahari. Masalah yang mendorong membuat kajian ini adalah pengimportan bahan bakar fosil yang membebankan ekonomi Malaysia, isu alam sekitar, kurang kesedaran di kalangan masyarakat, kekurangan kajian lepas tentang faktor kejayaan kritikal (CSFs) dalam projek tenaga suria serta jurang metodologi. Masalah ini ditangani dalam kajian ini dengan mengenal pasti CSFs dalam konteks tempatan, menganalisis kepentingan CSFs dalam mengusahakan projeck tenaga suria dengan mengunakan kaedah Analytical Hierarchy Process (AHP) dan menilai turutan CSFs berdasarkan keputusan AHP tersebut. Sejumlah, 6 faktor utama iaitu ekonomi, persekitaran, teknologi, organisasi dan pengurusan, kerajaan dan sosial serta 27 sub faktor telah digunakan dalam kajian ini untuk membina model AHP. Seterusnya, data kajian ini dikumpulkan melalui soal selidik atas talian daripada 73 syarikat tenaga suria di Lembah Klang dengan kadar pulangan 52% soal selidik yang sah. Data yang dikumpulkan telah dianalisis menggunakkan perisian Expert Choice untuk menilai kedudukan CSF dari keutamanya. Keputusan menunjukkan persekitaran (0.206) adalah faktor utama diikuti dengan faktor teknologi (0.195), factor ekonomi (0.168), faktor kerajaan (0.155) faktor organisasi dan pengurusan (0.142) dan faktor social (0.134). Selain itu, mengurangkan kadar pengeluaran karbon dioksida (0.079), dasar kerajaan (0.073), perspektif kewangan (0.061), sokongan kewangan (0.055) dan mengurangkan pencemaran udara (0.048), adalah urutan kedudukan bagi 5 sub faktor utama dalam kajian ini. Justeru, pencapaian kajian ini akan menjadi garis panduan kepada syarikat tenaga suria di Malaysia untuk mengurus dan meningkatkan kualiti projek tenaga suria dengan jayanya. AHP model kajian ini adalah baru dalam konteks tempatan di mana akan menambahkan pengetahuan penyelidik masa hadapan.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AC	-	Alternating Current
AHP	-	Analytic Hierarchy Process
ANN	-	Artificial Neural Networks
ASEAN	-	Association of South- east Asian Nations
A-Si	-	Amorphous silicon solar cell
BEER	-	Building energy efficiency retrofit
CdTe	-	Cadmium telluride solar cell
CI	-	Consistency Index
CIGS	-	Copper indium gallium selenide
CI (G) S	-	Copper indium gallium selenide solar cells
CPV	-	Concentrator photovoltaics
CR	-	Consistency Ratio
CSFs	-	Critical Success Factors
CSP	-	Concentrated solar power
DC	-	Direct Current
DEA	-	Data Envelopment Analysis
DSSC	-	Dye-sensitized solar cell
DMU 1	-	Decision making unit 1
FAHP	-	Fuzzy Analytic Hierarchy Process
FiT	-	Feed-in Tariff
GaAs	-	Gallium arsenide germanium solar cell
GDP	-	Gross Domestic Product
GEF	-	Global Environment Facility
GHG	-	Green House Gases

GITA	-	Green Income Tax Exemption
GoM	-	Government of Malaysia
GSCM	-	Green Supply Chain Management
IRENA	-	International Renewable Energy Agency
ISPSs	-	Institutional Solar Photovoltaic Systems
Ktoe	-	Kilo tonnes of oil equivalent
kW	-	kilowatt
LSS	-	Large Scale Solar
LSC	-	Luminescent solar concentrator cell
MBIPV	-	Malaysian Building Integrated Photovoltaic
MCDM	-	Multi-Criteria Decision Making
MESTECC	-	Minister of Energy, Science, Technology, Environment and Climate Change
Mida	-	Malaysia Investment Development Authority
MIDF	-	Malaysian Industrial Development Finance Berhad
MJ	-	Multijuction Solar Cell
Mono-Si	-	Monocrystalline solar cell
MW	-	Megawatts
NDP	-	National Depletion Policy
NEM	-	Net Energy Metering
NEP	-	National Energy Policy
NPP	-	National Petroleum Policy
NSM	-	National Solar Mission
PV	-	Photovoltaic
PVPSs	-	Photovoltaic Pumping Systems
R&D	-	Research and Development
REPG	-	Renewable Energy Power Generation
RER	-	Renewable Energy Resources

RETs	-	Renewable Energy Technologies
RI	-	Random Index
SEDA	-	Sustainable Energy Development Authority
SESB	-	Sabah Electricity Sdn Bhd
SREP	-	Small Renewable Energy Power Programme
SWHs	-	Solar Water Heaters
TFSC	-	Thin Film Solar Cell
TNB	-	Tenaga Nasional Berhad
TSE	-	Total Survey Error

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction

Energy sources is an essential part for all living things in the world. There are many natural resources world widely, some are non-renewable energy and some are renewable energy. Non- renewable energy is also known as conventional energy which extracted from limited resources that will be end one day. Conventional energy used various type of sources to generate energy such as fossil fuel, natural gas, nuclear energy and hydroelectric energy (Monin *et al.*, 2018). Nowadays, most of the energy generated are from fossil fuel sources and it full fill three forth of global energy demand (Destek & Aslan, 2017). Fossil fuel composed namely to coal, oil and gas (Covert *et al.*, 2016).

Furthermore, fossil fuel such as coal are reserve in various parts of the world especially in China and America are the largest manufacturer and user of coal (Abas *et al.*, 2015). The main usage of coal is to generate electricity and produce synthetic fuel for industrial and transport sector (Elizabeth *et al.*, 2013). While, oil is in liquid phase which are used in transportation sector and easy to handle because of that oil are well developed in world market especially petroleum (Koyama, 2017). Natural gas is an energy sources that was discovered in Sylhet at 1995 which use to generate energy (Monin *et al.*, 2018). Few decades ago, natural gas is most popular and ancient Chinese used it to convert sea water into salt (Abas *et al.*, 2015). Natural gas also known as cleanest sources of energy among the fossil fuels which supply through pipelines (Koyama, 2017).

Besides, fossil fuels is limit in nature and it's combustion contributes to environmental problem through producing carbon dioxide, greenhouse gases and climate change (Covert *et al.*, 2016). Due to that, renewable energy sources which is environmental friendly are consider as alternative to produce energy (Büyüközkan *et al.*, 2016). Renewable energy is a sustainable power sources which are constantly recharged by nature. The energy is obtained from non-stop or repetitive currents recurring in the natural environment that will never run out (Khan *et al.*, 2018). Renewable energy also alluded as a clean energy which derived from natural resources that constantly renewed (Shinn, 2018). In short, it can be said that renewable energy can re-establish themselves over a brief time frame and do not reduce.

Moreover, there are several types of renewable power sources such as solar energy, wind energy, biomass energy and tidal power. Solar energy is radiant light and heat from the sun which turn into electricity. Solar energy has the highest probability to provide clean, safe and reliable power than other renewable energy. Surplus power for local utilities also can supported by installing solar panel array on houses. According to Tiwari & Sahota (2016) there are two kind of solar energy which are passive solar and active solar. Passive solar energy access to thermal energy from sun directly and indirectly. While active solar energy is generating electrical energy by using the sun's electromagnetic radiation.

Next is, wind energy. Wind energy is the motion of air in atmosphere to collect energy (Kalmikov, 2017). Wind energy also known as kinetic energy that exchange into mechanical or electrical power. The wind turbine is utilized to create electricity that can diminish the expenses of production and maintenance (Panwar *et al.*, 2011) . Meanwhile, biomass energy consists of all type of organic matter from fuel wood to marine vegetable which convert into useful form of energy (Khan *et al.*, 2015). Baskar *et al.*, (2012) mention that biomass energy or bioenergy consists of solid, liquid, gaseous fuel, electrical energy or beneficial chemical product derived from organic substances. Lastly, tidal power also a renewable energy which used to depict the energy produced from power in sea tidal currents. Tidal currents are strongest where the water section is quickened around headlands, over reefs or in river (Alrikabi, 2014).

Renewable energy also has a lot of benefits and important especially for the environment. First, environment benefits where renewable energy technologies are clean sources of energy which have a lower environment compare to conventional energy technologies (Sani *et al.*, 2019). Renewable energy would not cause of any

environmental pollution problems and its advantages is by one-time investment we can derive energy for plenty a long time without affecting the surroundings. Second, energy for our upcoming generation which mean renewable energy will not end while other energy sources are limited and will be run down someday. Third, job and economy benefits where majority of renewable energy investments are used up on materials and group of workers to increase and maintain the conveniences in place of imports high price energy (Bulavskaya & Reynès, 2018).

Furthermore, Can Şener *et al.*, (2018) mentioned multiple benefits of renewable energy sources such as increase energy security, sustainable economic growth and pollution reduction, reduce water footprint, lower wastewater and lower solid waste pollution. Based on Renewable 2018 Global Status Report, the renewable power capacity increases world widely in year 2017 as well by reduces costs, rises in investment and advances in enabling technologies. Solar energy also being consider to satisfy energy demand in Malaysia. Energy demand in Malaysia increase along with economy growth and solar energy take into account more than other renewable energy sources because of it 'plug and play" features while other resources require mechanical support such as generators and chemical support (Solangi *et al.*, 2015).

Moreover, renewable energy projects also offer eco-friendly benefits rather than providing electricity. There are numerous type of renewable energy project that can be performed such as wind projects, solar projects, bagasse power projects, thermal power projects and waste heat recovery power projects (Maqbool *et al.*, 2018). The type of renewable energy project of a country is decided based on their countries' available resources. Malaysia is a country have a tropical climate that could provide access to solar energy sources along the year. Regarding to that, solar power projects have been potential in Malaysia and be considered in this research. The current study is conducted to identify, analyse and evaluate CSFs for solar energy projects in Malaysia using AHP approach.

1.2 Research Background

Energy sources are one of the most important things for the development of financial system and social growth in a country. Although energy not regarded as affluence as it used to be but it has end up a compulsion in our everyday life. As a developing

country, Malaysia's prosperity depends on having access to reliable and secure supplies of energy (Yatim *et al.*, 2016). The main energy sources of Malaysia are depend on non-renewable energy includes coal, natural gases and fuel-oil (Samsudin *et al.*, 2016). However, as mention earlier non-renewable energy are the limited sources and not capable to meet Malaysia's future energy requirement.

Government of Malaysia realized the possibility of renewable energy as an another choice to ensure the sustainability of power sources because Malaysia is the gifted country with huge amount of renewable energy sources which includes biomass, hydro, wind, solar, small hydro and ocean (Syahril *et al.*, 2016). In Malaysia, renewable energy consider as a fifth sources of energy and also introduced as the fifth fuel strategy in the energy-mix under the 8th Malaysia Plan in 2001 (Kardooni *et al.*, 2015). The purpose of the policy was to encourage integration of renewable resources for power generation and reduce dependency on non-renewable energy.

Malaysia is a tropical country with hot weather throughout the year with solar radiance of 1400 to 1900 kWh/m^2 per year. (Bakhtyar *et al.*, 2014). Alam *et al.*, (2016) also mentioned that Malaysia has a higher opportunities to explore solar energy due to the tropical-humid climate all over the year and Malaysia has an outstanding capacity for electricity generation from solar energy. Among the Association of South- east Asian Nations (ASEAN) countries, Malaysia is the largest electricity consumer and expecting the demand of electricity will reach 23, 099 MW in 2020 (Ahmad & Tahar, 2014). Table 1.1 show the total electricity consume in Malaysia from year 2000 to year 2018.

Table 1.1: Statistic of final electricity consumption

Year	Final Electricity Consumption (ktoe)					
	Agriculture	Commercial	Transport	Industrial	Residential	Total
2000	0	1478	4	2805	975	5262
2001	0	1579	3	2930	1081	5593
2002	0	1698	4	3059	1161	5922
2003	0	1818	5	3242	1248	6313
2004	0	1979	5	3340	1319	6643
2005	0	2172	5	3371	1395	6943
2006	5	2272	5	3475	1514	7271
2007	16	2480	4	3587	1598	7685
2008	19	2598	15	3687	1668	7987
2009	21	2743	12	3719	1792	8287
2010	24	3020	18	3994	1937	8993
2011	26	3172	18	4045	1974	9235
2012	30	3325	21	4509	2126	10011

Table 1.1: (Continued)

2013	32	3466	21	4809	2262	10590
2014	36	3566	22	5072	2346	11042
2015	41	3663	23	5200	2471	11398
2016	47	3817	29	5822	2679	12394
2017	50	3762	39	6145	2610	12606
2018	53	3958	41	6547	2553	13152

Table 1.1 derived from Suruhanjaya Tenaga website which clearly shown that the electricity usage in Malaysia raises constantly from year 2000 to 2018. Industrial sector contributes to the high consumption of electricity every year follow by commercial, residential, transport and agriculture sector. This also support by Bakhtyar *et al.*, (2014) who mentioned that Malaysia's electricity demand has significant increased due to industrialization as well increase in population. Solangi *et al.*, (2015) highlights that Malaysia's Vision 2020 targets to achieve fully industrialized Malaysia by 2020 and energy usage of country also one of the main part of the objective.

Furthermore, there are two types of solar energy sources which are PV Solar system and Solar Thermal system (Rajput, 2017). Solar PV is a system which converts light energy into electricity through semiconductor devices known as solar cells. While, solar thermal system form heat energy from sun for a wide range of application (Asif, 2017). According to Baharum *et al.*, (2018) in Malaysia prioritize are more given to solar PV technology by the authorities because solar PV is the only technology that are eligible for tariff payment. Figure 1.1 show the image of solar PV panel. The lifetime of a solar panel is 25 years while other minor component in solar panel such as converter and batteries have lifetime about 5 to 15 years only (Azman *et al.*, 2011).

Figure 1.1: Solar PV Panel (Azman *et al.*, 2011).

Moreover, Malaysian Building Integrated Photovoltaic Technology Application Project (MBIPV) was launched in 2005 followed by SURIA 1000 programme in 2006 and SURIA for Developers Programme in 2007 (Baharum *et al.*, 2018). The project is collectively supported by the Government of Malaysia (GoM) authorities, the Global Environment Facility (GEF) and some private sectors. There had been numerous demonstration PV projects in diverse sectors which includes housing and buildings project. Malaysia's government also introduced Feed-in Tariff (FiT) Scheme as a medium to improve renewable energy in Malaysia and obtained significant changes in solar PV (Baharum *et al.*, 2018).

Plus, Sustainable Energy Development Authority of Malaysia (SEDA) identifies that the market for solar energy has shown the maximum growth in comparison to different renewable energy technology. According to SEDA portal till Sept 30, 2013, solar PV had the highest percent for approved programs or 192 MV of set up ability compared with other renewable energy. 2,279 applications with an installed capacity of 24.2 MW has been approved by SEDA Malaysia and 592 applications with set up capacity of 8.98 MW have started out operations. Furthermore, Malaysia Investment Development Authority (Mida) chief government officer Datuk Azman Mahmud also pointed out that the Malaysian Solar PV Roadmap 2030 would be established to drive our country's solar PV industry ahead. He also mentions that

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