END-OF-LIFE SOLAR PANEL RECYCLING DECISIONS FOR MALAYSIA

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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END-OF-LIFE SOLAR PANEL RECYCLING DECISIONS FOR MALAYSIA

This report is submitted in accordance with requirements of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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2023

DECLARATION

I hereby, declared this report entitled "End-of-Life Solar Panel Recycling Decisions for Malaysia" is the result of my own research except as cited in references.

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Author's Name : LIM JIE XIANG

Date : 24 January 2023

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the prerequisite for Degree of Manufacturing Engineering (Hons). The name of the supervisory is as follow:

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ABSTRAK

Penggunaan meluas bahan api fosil, seperti arang batu sebagai penjanaan kuasa utama, telah terbukti memberi kesan negatif kepada dunia. Tenaga suria, sumber tenaga yang boleh diakses terbesar di dunia dan kini berkembang pesat di seluruh dunia. Pada penghujung tahun 2017, kapasiti PV terpasang global adalah sekitar 400 GW, dan diramalkan meningkat kepada 4500 GW menjelang 2050. Malaysia kini memperluaskan penggunaan tenaga boleh diperbaharui (terutamanya pada tenaga solar), melalui beberapa skim dan satu daripada ini dipanggil Solar Skala Besar (LSS). Dengan peningkatan dalam penggunaan panel solar, sisa yang terhasil juga diunjurkan akan meningkat secara berterusan. Keputusan kitar semula panel solar EoL di Malaysia hanyalah dalam keadaan awal dan belum matang, dengan kajian terdahulu yang terhad mengenai kaedah untuk memilih lokasi kitar semula yang mengambil kira elemen rantaian bekalan yang berkekalan boleh dicapai pada masa ini. Oleh itu, adalah perlu untuk mengenal pasti dan mencadangkan lokasi yang berkemungkinan untuk dijadikan sebagai pusat kitar semula panel solar yang mengambil kira elemen rantaian bekalan berkekalan di Malaysia secepat mungkin untuk mengelakkan sejumlah besar sisa panel solar berakhir di kawasan tanah dan menyebabkan pencemaran kepada alam sekitar. Kaedah pusat graviti, kerumitan rantaian bekalan, analisis rantaian bekalan jejak karbon, Proses Hierarki Analitik, dan algoritma K-Means digunakan dalam kajian ini. Dalam kajian ini, sebuah pangkalan data mengenai maklumat 454 ladang LSS dan Bukan LSS telah dibangunkan. Selain itu, kaedah pemodelan graviti diguna pakai untuk mengenal pasti lokasi titik tengah geografi untuk pusat kitar semula panel solar di Malaysia. Seterusnya, kerumitan rantaian bekalan dan penilaian rantaian bekalan jejak karbon telah digunakan untuk menentukan alternatif yang paling ideal daripada tiga alternatif yang dicadangkan untuk mengangkut sisa ke pusat pengumpulan atau kitar semula masing-masing berdasarkan atribut berbeza yang dipertimbangkan. Keputusan lokasi kitar semula kemudiannya diputuskan oleh AHP (di mana alternatif C dicadangkan). Gabungan pendekatan ini diklasifikasikan sebagai penilaian rantaian bekalan logistik dalam kajian ini. Kajian ini kemudiannya diteruskan dengan pengoptimuman

pengelompokan, di mana penilaian pengoptimuman pengelompokan untuk ladang LSS dan ladang keseluruhan tanpa sebarang batasan segmentasi geografi telah dijalankan melalui algoritma k-means. Kluster optimum yang dicadangkan untuk ladang LSS dan keseluruhan ladang masing-masing adalah 8 dan 20 kluster. Kajian ini mencadangkan semua langkah penting dalam menentukan lokasi dan kelompok kitar semula untuk ladang solar di Malaysia. Oleh itu, ini boleh menjadi rujukan kepada pihak berkuasa mengenai keputusan kitar semula yang mempertimbangkan rantaian bekalan yang mampan.

ABSTRACT

The widespread use of fossil fuels, such as coal as the primary power generation, has been proved to have an adverse impact on the globe. Solar energy, the world's greatest readily accessible energetic resource and is now growing rapidly in the use of this renewable energy worldwide. At the end of 2017, the volume of the global mounted PV was around 400 GW, and is predicted to increase to 4500 GW by 2050. Malaysia is now expanding its use of renewable energy (particularly on solar energy), through several schemes and one of these is called Large Scale Solar (LSS). With the increase in the use of solar panels, the waste created after the EoL solar panels was also projected to rise steadily. The recycling decisions of EoL solar panels in Malaysia is just in an initial and immature state, with limited previous study regarding the method for selecting the recycling locations that considering the sustainable supply chain elements is reachable presently. Hence, it is necessary to identify and propose the possible location for EoL solar panel recycling centres that take into account the sustainable supply chain element in Malaysia as soon as possible to avoid the vast number of solar panel waste ending up in land-fields and causing pollution to the environment. The centre-of-gravity method, supply chain complexity, carbon footprint supply chain analysis, Analytical Hierarchy Process, and K-Means algorithm was applied in this study. In this study, a database regarding the information of the 454 LSS and Non-LSS farms was developed. Moreover, the gravity modelling method is adopted to identify the geographic midpoint location for the solar panel recycling centres in Malaysia. Next, the supply chain complexity and carbon footprint supply chain assessment was applied to determine the most ideal alternative from three alternatives proposed for transporting the waste to respective collection or recycling centres based on different attributes considered. The recycling location decisions is then decided by AHP (where alternative C was suggested). The combination of these approaches was classified as logistic supply chain assessment in this study. The study is then continued with the clustering optimisation, where the assessment of the clustering optimisation for LSS farm and overall farm without any geographic segmentation limitations was carried out via the k-means algorithm. The optimum clusters proposed for LSS farm and overall farm were 8 and 20 clusters respectively. This study proposed all of the important steps in deciding the recycling locations and clusters for solar farms in Malaysia. Therefore, this can be a reference to the authorities on recycling decisions that consider the sustainable supply chain.

DEDICATION

This paper is dedicated to:

My appreciated father, Lim Oon Heng

My beloved mother, Khoo Sok Cheng

My much-loved sister, Lim Yi Wen

for providing me cooperation, encouragement, moral support, understandings and also money

Thanks So Much & Love All Of You Forever

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PV	-	Photovoltaic
TWyr	-	Terawatt-Years
KW	-	Kilowatt
MW	-	Megawatt
GW	-	Gigawatt
TW	-	Terawatt
FiT	-	Feed-in Tariff
LSS	-	Large-Scale-Solar
EoL	-	End-of-Life
OECD	-	Organisation for Economic Cooperation and Development
IRENA	-	International Renewable Energy Agency
SEDA	-	Sustainable Energy Development Authority
mono-Si	-	monocrystalline silicon
poly-Si	-	polycrystalline silicon
PERC	-	Passivated Emitter and Rear Cell
TFSC	-	Thin-Film solar cell
CdTe	-	Cadmium Telluride
CIGS	-	Copper Indium Gallium Selenide
a-Si	-	amorphous silicon
WEEE	-	Waste Electrical and Electronic Equipment
SEIA	-	Solar Energy Industries Association
SO_2	-	Sulfur Dioxide
CO_2	-	Carbon Dioxide
CH_4	-	Methane

CHAPTER 1

INTRODUCTION

1.1 Research Background

Green energy and clean energy are regularly associated with renewable energy, however there are several fundamental variations between the three types of energy (Gielen et al., 2019). Renewable energy originates from recyclable sources where the sources or processes will be renewed on a regular basis, clean energy originates from sources that do not discharge pollutants, and green energy originates from natural sources. Solar energy, wind energy, and hydroelectric power are the instances of renewable energy sources. The widespread use of fossil fuels has been proved to have a negative impact on the globe, follow-on in higher global temperatures, more intense weather phenomenon, and the destruction of ecosystems (IEA, 2021). The increase of renewable and green energy generation is fuelled by continual improvements in capture and storage technology and stability, as well as the worldwide drive toward Net Zero. As a result, renewable energy is becoming increasingly vital as a solution for the future of humanity's primary power needs.

Solar panels are also known as solar electric panels, or photo-voltaic (PV). The main purpose of solar panels is to utilize the sunlight energy to generate direct current electricity (Akorede, 2022). The benefits of practicing solar energy as well as other available renewable energy to generate energy is that of its less impact towards the environment or more eco-friendly than the traditional energy. Solar energy, which reaches the earth's surface every year in the amount of 79,000 TWyr, is the world's greatest readily attainable energetic resource and the origin of most other (particularly fossil) available sources of energy. As of 2021, the capacity generated from solar energy is valued at 1.25 TW globally (Adib et al., 2021). This is composed of Solar Photovoltaic (PV) 760 GW, solar thermal 500 GW, and Concentrated Solar

Power (CSP) 6 GW. This amounts to a yearly energy generation of around 0.24 TWyr, or about 0.08 percent of the solar probable that may be exploited on an annual basis.

Since 2010, the international weighted mean levelized cost of electricity engendered by utility-scale solar photovoltaics (PV) has decreased by 85 percent until (M. Perez & Perez, 2022). Moreover, solar energy can achieve 100 percent of the extent of global primary energy demand for 12x over although be confronted to certain limitations such as efficiency and suitable plant. Solar power can look up to contribute as much as 27x over towards global energy demand if an entirely electrified future is becoming real. Humans had overlooked energy conversion efficiency since humans were focused on the amount of energy available. The efficiency of solar energy in 2021 will be around 20 percent and it is likely to escalate in the future based on a published article on 2021 (M. J. Perez et al., 2021). The 30-year exploitable solar reserves, based on current estimates, total 8,300 TWyr30, or nearly 12 times world primary demand over that electricity period.

The global average cost of solar photovoltaic (PV) electricity generated in 2019 has decreased by 73 percent since 2010 at the rate of USD 0.053/kWh or RM 0.23/kWh (Agency, 2020). This is due to the sheer rapid rate of innovation, which has poured competitive pressure into the energy industry. In terms of cumulative capacity, Asia Pacific held a 58.9% share of the worldwide solar PV market in 2020, and this percentage is predicted to rise to 59.8% in 2030, according to the Global Data's latest report in 2021 (Global Data Energy, 2021). China, United States, Japan, Germany, and India are the top five countries in the worldwide solar PV market. India is predicted to surpass Japan and Germany as the third-largest solar PV market in terms of accumulative volume by 2030. On the other hand, since 2019, Vietnam has spot a noteworthy growth in solar PV volume. The government's attractive Feed-in Tariff (FiT) has sparked significant interest in solar PV generation in Vietnam among domestic and international generating enterprises.

In 2020, the volume of renewable energy installed in the Asia-Pacific region is 517 GW, in which solar energy contributed 215 GW (Global Data Energy, 2021). It is expected that the volume of renewable energy installed in the Asia-Pacific area in 2025 will be up to 815 GW, in which solar energy is likely to contribute about 382 GW, according to a report. Table 1.1 below illustrates the solar energy capacity in some of the Asia countries from 2014 to 2018 (Ludin et al., 2021). From the table, the topmost three Asia countries that have the highest solar energy capacity in 2014 are China, Japan, and India with the capacity of 28,402 MW, 23,339

MW, and 2,518 MW, respectively. Meanwhile in 2018, the three Asia countries that have the highest solar energy capacity are also China, Japan, and India with the significant increase in capacity to 175,032 MW, 55,500 MW, and 27,098 MW correspondingly (Frischknecht et al., 2015).

Table 1.1: Solar Energy capacity in some of the Asia country from 2014 to 2018 (Ludin et al., 2021)

Countries	Total Solar Energy Capacity (MW)				
	2014	2015	2016	2017	2018
China	28,402	43,552	77,802	130,816	175,032
Japan	23,339	34,150	42,040	49,040	55,500
India	3518	5396	9647	17,873	27,098
South Korea	2481	3613	4502	5835	7862
Thailand	1304	1425	2451	2702	2725
Chinese Taipei	620	842	1245	1768	2618
Philippines	23	165	759	886	886
Malaysia	166	229	279	317	438
Kazakhstan	5	57	57	59	209
Singapore	26	46	97	116	150
Vietnam	5	5	5	8	106
Indonesia	42	51	58	59	60
Cambodia	9	12	18	28	28
North Korea	5	8	10	11	11
Brunei Darussalam	1	1	1	1	1
Total	59,946	89,552	138,971	209,519	272,724

Malaysia is now expanding its use of renewable energy, following the lead of countries with high renewable energy capability, particularly those in northeast Asia such as Japan, the Republic of Korea, and Taiwan (Bajracharya & Bhattarai, 2016). For instance, Japan has improved its energy efficiency measures by liberalizing its electricity and gas markets and committing to a 25 percent reduction in CO_2 emissions by 2030 from 2013 baseline emissions (Frischknecht et al., 2015). Malaysia by now started a scheme called Large Scale Solar (LSS). The goal of this effort is to build large-scale solar power facilities in which each of these facilities have the capacity between 1 to 30 MW (Rödl and Partner, 2022). The Malaysian Energy Commission, which in Malay "*Suruhanjaya Tenaga"* (ST) is implementing the program in collaboration with "*Tenaga Nasional"*, a Western Malaysian electrical company. With the increase in the usage of solar energy in Malaysia, the huge quantity of the first batch of end-of-life solar panel waste generated will soon be encountered in the next decade. So, proper, and systematic solar panel recycling management must be established and implemented just before the first batch of solar panel waste arrives.

The Malaysian government has set a forceful aim of boosting the proportion of renewable energy (RE) within the country's energy mix. Malaysia's main power generation sources have been coal, natural gas, and large hydro (Sharvini et al., 2018). Renewable energy has gone a long way in Malaysia from the time when the Four Fuel Diversification Strategy was introduced in 1980, with the goal of harmonising the usage of oil, gas, coal, and hydro in the energy mix (Hannan et al., 2018). Malaysia has committed to diminish its involvement of Greenhouse Gas (GHG) emissions to its Gross Domestic Product (GDP) by 45 percent by 2030 in contrast to 2005 (Mah et al., 2019).

1.2 Problem Statement

At the end of 2017, the global installed PV capacity was around 400 GW, with the capacity predicted to increase to 4500 GW by 2050 (Chowdhury et al., 2020). However, every coin has two sides. With a 25-year mean panel lifetime, global solar panels waste is estimated to reach 4 percent to 14 percent of total produced capacity by 2030, growing up to more than 80 percent, which is around 78 million tons by 2050 (IRENA and IEA-PVPS, 2016). As a result, in the coming decades, PV panel disposal will become a key environmental concern. Eventually, there will be a lot of chances to investigate the disposal and recycling of PV panels that are no longer in use. High quality solar panels may reach a life cycle between 30 to 40 years (Vekony, 2021). The users may experience a reduction of 20% in power capacity during the life of the PV panels which, a maximum of 10% drop between 10 to 12 years of PV panels used, and 20% reduction when reaching 25 years of use. This data is guaranteed by most of the manufacturers. In reality, some of the solar panels' power capacity will only reduce between 6 to 8% after 25 years.

The rate of usage of solar panels in Malaysia is estimated to increase in the future as the Malaysia government is aiming to achieve a total of 31% from all sources of renewable energy out of the total electricity generated by 2025 (Shukla, 2022). The rapid growth in the usage of solar energy via solar panel to generate electricity in Malaysia is extremely uplifting. Nevertheless, with the escalation in the employment of solar panels, the waste created after the EoL solar panels will also rise steadily. The recycling management of EoL solar panels in Malaysia is just in an initial and immature state. There are numerous studies or even research have been published regarding the recycling technology for the used solar panels. However, limited previous study or research have been conducted presently regarding the suggested locations for the recycling centre worldwide, and Malaysia particularly. One of the obstacles that lead to this problem is that there is a lack of an integrated information database for the solar farms in Malaysia currently. This data is tremendously crucial in order to calculate, determine, and thus propose the ideal recycling centre within the entire Malaysia to speed up the solar panels recycling rate in this country.

After that, there are no previous studies that identify and propose the possible location of end-of-life solar panel recycling centres in Malaysia that consider the sustainable supply chain element. An effective logistic path (in terms of time and economics) to transport the used solar panels to recycling centres is able to determined by considering this element. Furthermore, there are limited studies that are conducted regarding the optimisation towards the recycling facility in Malaysia. This needs to be conducted as soon as possible to avoid the vast number of solar panel waste ending up in land-fields and causing pollution to the environment.

1.3 Objectives

The following are the objectives of this study:

i. To determine the profile and locations of solar farms in Malaysia.

ii. To propose the suitable recycling locations for solar farms by assessing supply chain complexity and carbon footprint.

iii. To optimise the recycling facility clusters for EoL solar panels.

1.4 Scopes

This study focuses on the EoL solar panel recycling management in Malaysia, which has not proposed the technology on the recycling methods. Next, the quantity and capacity of the solar panels installed in the private residential area are not included in this study. Moreover, this study takes into account the solar farm that has the detailed information for each solar farm. This study excluded the households used solar panels. Only Large-Scale-Solar (LSS) farms and other declared large solar farms are identified in this study.

1.5 Importance of Study

It is believed that the shortest distance in the transportation of the scrapped solar panels from the solar farm in all the regions across Malaysia to the respective recycling centres will be determined and set on. As a result, the transportation duration can speed up and thus reduce the transportation costs. Besides that, the potential location of end-of-life solar panel recycling centres in Malaysia can be discovered. This includes the northern region, Central region, eastern coasts region, southern region, east Malaysia region (Sabah and Sarawak), and the clustering optimisation without the restriction of the geographic segmentation for all the solar farms in Malaysia. All of the important steps in deciding the recycling locations and clusters are suggested in this study. Therefore, this can be an input to the authorities on recycling decisions that consider the sustainable supply chain.

1.6 Organization of Report

The structure of this report first begins with Chapter 1, Introduction. This chapter discusses the backdrop of the title of study which is EoL solar panel recycling management. Next is illustrated by the problem statement of the study. The objectives and scope of this study are stated afterward. The importance of the study is also revealed. Next is followed by Chapter 2, Literature Review. This chapter will focus on the searching of the past research topic from journals, books, internet resources etc. After that, continued with Chapter 3, Methodology. The preliminary research, LSS farm in Malaysia, and the distribution of EoL solar panel waste will be discussed. The results analysis of the location of EoL solar panel recycling centres in Malaysia and the most suitable distribution of EoL solar panel waste will be presented in Chapter 4, Results and Discussion. Lastly, the recommendations and conclusion on this study will be presented in Chapter 5.

1.7 Summary

In this chapter, the problem statement, objectives, as well as the scopes of this study have been identified and stated. It is important to propose the location of EoL solar panel recycling centres in Malaysia as quickly as possible to avoid burdening the environment due to the first batch of the mass retired solar panels is just around the corner.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews a comprehensive and general literature from the previous study that correlated with the topic of this study. The research is gathered from all the resources available such as online journals, articles, books, and etc.

2.1 Solar Energy

The world's energy demand is expanding rapidly as a result of population growth and industrialization, and thus lead to the depletion of the world's available resources such as fossil fuels (Shafiee & Topal, 2009). As a result, one of the most crucial tasks of the twenty-first century is avoiding an energy crisis (Kannan & Vakeesan, 2016). Because energy demand is proportional to economic growth, therefore it rises in lockstep with it. However, many countries continue to rely on non-renewable energy sources, which could contribute to climate change and, as a result, heavy natural disasters that harm the planet's ecosystems (Schou, 2000). For the sake of the future of the globe, it is consequently critical to use environmentally favourable energy sources or in other words, renewable energy (Alanne & Saari, 2006).

Because of various factors, solar energy can be the best renewable energy source option for the world in future. Primarily, solar energy is the most plentiful renewable energy source; the sun emits it at an amount of 3.81023 kW, of which the earth intercepts around 1.81014 kW (Panwar et al., 2011). Solar energy smash on earth in a variety of forms, including heat and light. Solar energy may meet world energy demand sufficiently, according to studies, because it is abundant in nature and a costless source of energy (Nathan S. Lewis, 2007).

Moreover, because it is non-limited and has a higher production efficiency than other energy sources, it is a potential origin of energy for the planet (Nozik, 1978). Furthermore, the usage and stalking of solar energy has no harmful consequences on ecosystems that preserve natural balance for the welfare of living creatures (Kannan & Vakeesan, 2016). Additionally, because solar systems are easily inexpensive and adaptable, they may be effectively used in settlement systems, industrial operations, and houses (Kannan & Vakeesan, 2016).

2.1.1 Global Solar Energy Production

Currently, the main global energy system is still highly reliant on unrenewable energy, particularly on fossil fuels with over 80 percent of the total global energy supply. This then results in countless drawbacks that have been produced, especially regarding the ecosystem of industry and the environment. For example, aggravating the greenhouse effects, the imbalance in supply and demand in the global energy market (Li et al., 2019), the risk of oil reserve depletion, etc. The worldwide temperature has escalated by around 1.0 °C over pre-industrial levels because of the vast quantity of carbon dioxide released by burning fossil fuels (Xiao et al., 2019). If carbon excretion remains to rise at this current speed, the temperature is anticipated to climb by 1.5 degrees Celsius between 2030 and 2052 (Fawzy et al., 2020). Meanwhile, the adverse and spillover effects of global warming, such as rising sea levels, jeopardise the daily lives and economic activities of around one billion people. (Wang et al., 2021). Gratefully, the utilisation rate of renewable energy such as solar energy keeps increasing year by year globally with the aim to gradually cast off the highly relied on unrenewable energy gradually.

Figure 2.1 below indicates the solar energy generation capacity from 2010 to 2020 globally (Jaganmohan, 2022). In 2010, the total solar energy produced was recorded at 21,400 MW. Although the total solar energy generated in 2012 is marginally descent to 36,478 MW from 36,600 MW in 2011. However, global solar energy generation are bounce back after that and rise gradually after that. In 2019, the total solar energy generated is 140 GW, which accounted for nearly 3% of the electricity produced in the world. The total solar energy produced in 2020 is recorded at the highest rate with roughly 178,000 MW or 178 GW, this has posed a significant improvement from 21,400 MW in 2010. Renewable energy accounts for 29% of international electricity generation by the end of 2020. In 2020, more than 256 GW of volume was added, with wind and solar PV accounting for over 10% of total installed renewable power capacity (André et al., 2021).

From that, China became the country that produces the most solar energy in the world. In 2019, China have installed over 30.1 GW of solar capacity and the total installed solar capacity in that country has reached 205.2 GW (Masson et al., 2020). With the Chinese market accounting for 27% of total worldwide PV installations, this is then allow China to maintain its market leadership in solar energy. Next, the United States (U.S) with the installed capacity of 13.3 GW in 2019 and 75.9 GW altogether is the second country in the world that generates the most solar energy. After that, India with the installed capacity of 10.1 GW in 2019 and 42.9 GW cumulatively is behind China and U.S. This is followed by Japan and Vietnam with the installed capacity of 7 GW and 4.8 GW in 2019.

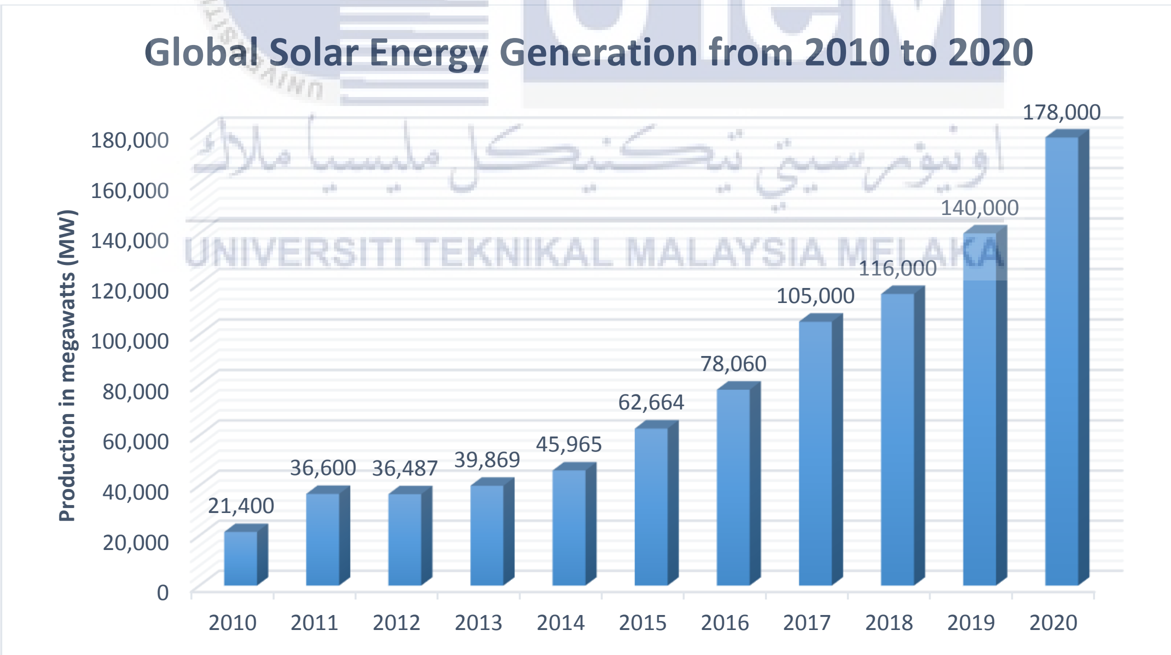


Figure 2.1: Solar Energy Generation Capacity from 2010 to 2020 Globally (Jaganmohan, 2022)

Additionally, Figure 2.2 below reveals the projection of market share of solar panels by technology type for 2014, 2020, and 2030 (Chowdhury et al., 2020). The silicon based solar panels are the absolute predominance types of solar panels if compared to thin film and other types of technology with approximately 92% of market share in 2014. Nonetheless, the market share of silicon based solar panels was diminished to 73.30% in 2020 and is expected to continue to reduce to 44.80% by 2030 (IRENA and IEA-PVPS, 2016). At the same time, the market share for the other types of solar panel technology is predicted to grow steadily from 1% in 2014 to 44.10% in 2030.

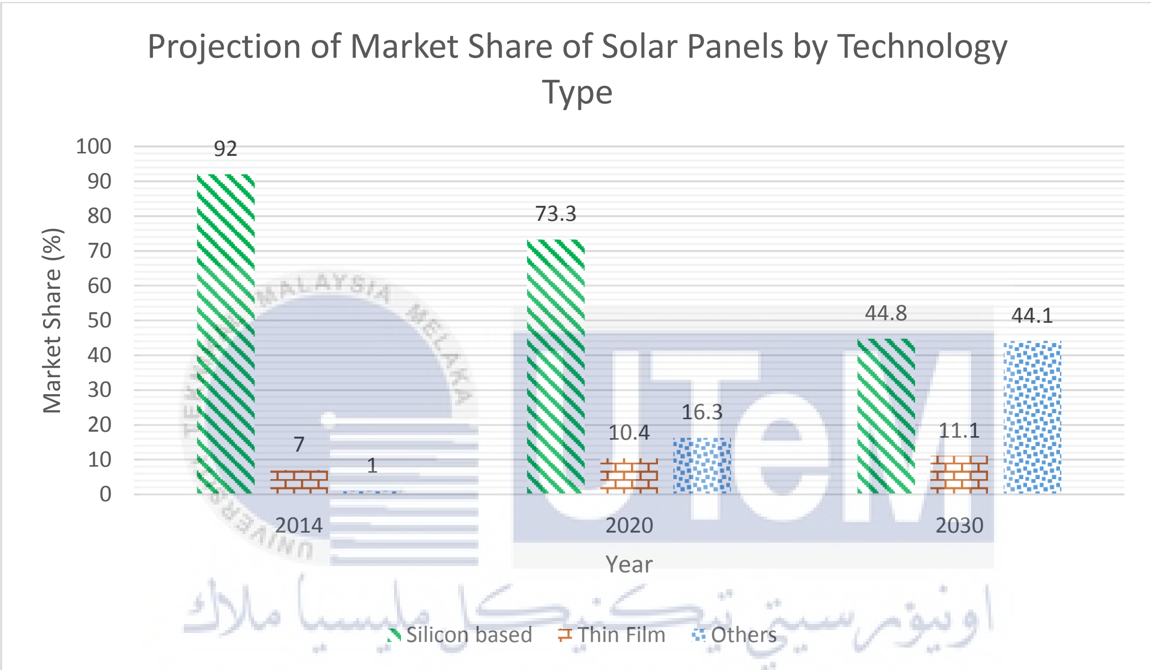


Figure 2.2: Projection of market share of solar panels by technology type (Chowdhury et al., 2020)

2.2 Projections of Solar Panel Installation Globally

Based on Wood Mackenzie, it is forecast that the total solar panels mounted in China, U.S, India and Japan in 2024 is 368.9 GW, 149.2 GW, 105.4 GW, and 82.3 GW correspondingly (Edmond, 2022). Figure 2.3 below illustrates the prediction of the global cumulative electricity capacity generated by solar power from 2015 to 2050 (IEA, 2014). From that, the global cumulative electricity capacity generated by solar power is expected to reach 1,720 GW by 2030, 4,050 GW by 2040, and 4,675 GW by 2050 based on the International Energy Agency (IEA). It is forecast that there will be a steady increase of the use of solar energy across the country in the world from years to years. India, Africa, Middle East and some non-Organisation for Economic Cooperation and Development region (OECD) are expected to have a significant growth in adopting and developing solar energy throughout these few decades (IEA, 2014).

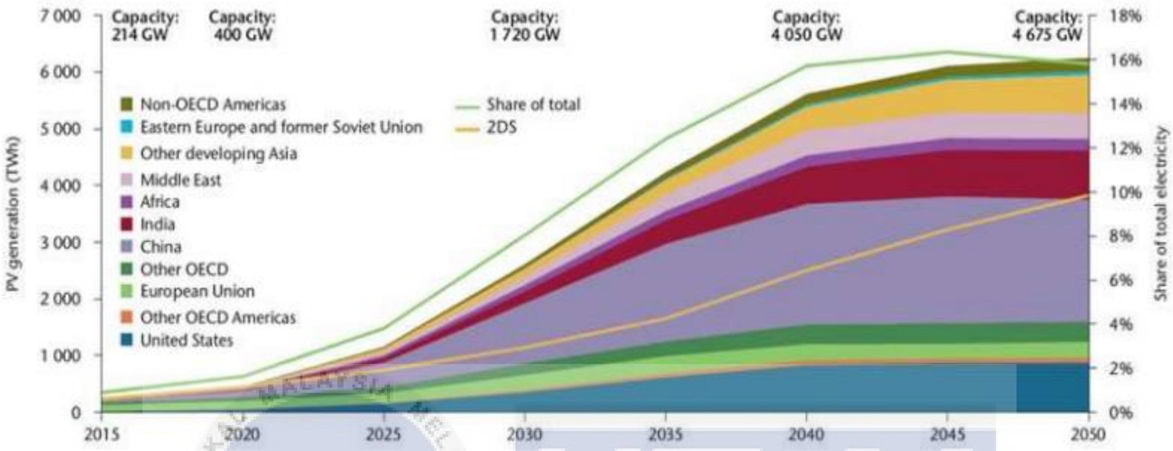


Figure 2.3: Prediction of the global cumulative of electricity generated till 2050 (IEA, 2014)

2.2.1 Forecast of Solar Panel Waste

The solar panels waste will certainly rise as time passes in correspondence to the expansion of the use of solar panels in most of the country. Because solar technology produces electricity in a cost-effective and ecologically beneficial manner, solar deployment stakeholders have to apply environmental procedure and rules, including accountable EoL management methods. A skeleton that encourages the early creation of EoL management will help to accelerate the development of complete policies (Komoto & Lee, 2018). The average lifetime of a solar panel is estimated to last for 27.8 years, which is in the most ideal conditions (refer Table 2.1). Nevertheless, a small portion of the panels may reach its life cycle earlier because of certain accidents. For instance, damage of panels while installation or transportation, technical failure, physical failure, and unpredictable environmental factors and accidents.

Hence, Figure 2.4 below illustrates an analysis on the forecast of the global quantity of solar panels waste in the year of 2050 have been carried out by IEA PVPS Task12 and IRENA (IRENA and IEA-PVPS, 2016). Based on the analysis, the PV module waste is expected to reach 43 500 tonnes by 2016 under the regular-loss scenario, rising to 1.7 million tonnes by 2030. By 2050, the increase will be even more dramatic, reaching almost 60 million tonnes. In the end of 2016, the early-loss scenario anticipates substantially larger entire PV waste flow, with 250 000 tonnes alone. Since the early-loss scenario predicts a greater ratio of early PV panel breakdown than the regular-loss scenario, this estimation would climb to 8 million tonnes by 2030 and 78 million tonnes by 2050.

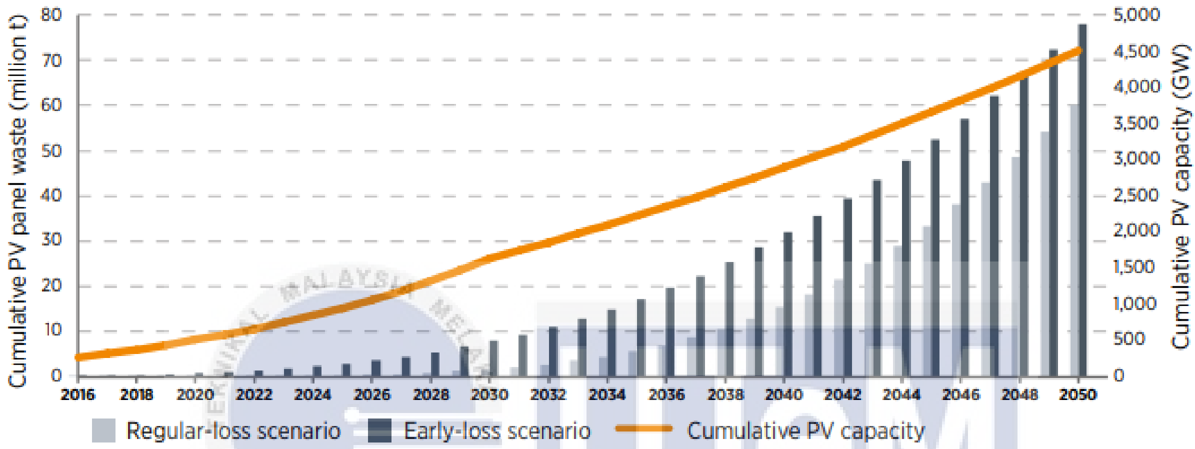


Figure 2.4: Forecast of the global quantity of solar panels waste until 2050 (IRENA and IEA-PVPS, 2016)

2.3 Lifetime of Solar Panel

Table 2.1 below shows the lists of several research of the prediction on the lifetime of solar panel. Based on the researches gather in Table 2.1 below, most of the projection on the lifespan of solar panels is around 30 years. Hence, it is adequate that the mean lifespan of solar panels is set at 27.8 years or equivalent to 27 years in this research.

Table 2.1: Several research of the prediction on the lifetime of solar panel

Title	Authors	Solar Panel Lifetime (years)
Comprehensive Guide to Solar Panel Types	(McBride, 2021)	25
Recycling of photovoltaic panels by physical operations	(Granata et al., 2014)	25-30
The Opportunities of Solar Panel Recycling	(Vekony, 2021)	30
End-Of-Life Management: Solar Photovoltaic Panels	IRENA and IEA-PVPS. (2016)	30
End of Life Management Solar PV Panels	(Weckend et al., 2016)	30
Hydrogels beads for cooling solar panels: Experimental study	(Abdo et al., 2020)	25-30
Environmental impacts of recycling crystalline silicon (c-SI) and cadmium telluride (CDTE) solar panels	(Maani et al., 2020)	25
Reverse logistics network design for waste solar photovoltaic panels: A case study of New South Wales councils in Australia	(Islam et al., 2021)	20-30
Average lifetime of solar panel		27.8 or equal to 27

2.4 Types of Solar Energy Technologies

Solar energy is one of the renewable, clean energy that is produced from the sun which is present in the form of heat and light. As of 2022, there are divided into two main technologies available in the world which are photovoltaic solar technology and solar thermal technology (Singh, 2013). For photovoltaic solar technology, it refers to the technology that alters the sunlight energy to the electricity energy via the aids of panels composed from semiconductor cells. For instance, monocrystalline silicon solar panel (mono-Si), polycrystalline silicon solar panel (poly-Si), Passivated Emitter and Rear Cell panel (PERC), and Thin-Film solar cell panel (TFSC) are categorised under this technology (Singh, 2013). Meanwhile, solar thermal technology alters the sunlight energy into heat energy and then converts into mechanical energy before turning into electrical energy. Concentrated Solar Power (CSP) is the example of solar power that utilised this technology.

2.4.1 Types of Solar Panel

Currently, monocrystalline silicon solar panel (mono-Si), polycrystalline silicon solar panel (poly-Si), Passivated Emitter and Rear Cell panel (PERC), and Thin-Film solar panel are the four main types of solar panels that are commonly utilised by the market (McBride, 2021). Mono-Si solar cell are composed from a sole pure silicon crystal, which makes it become the most space-efficient and durable than the other three types of solar panel. The cost of this type of panel is slightly expensive than the other three types of solar panel due to masses of the silicon being wasted in order to fabricate a single monocrystalline cell. The appearance of this type of solar panel is in dark black (McBride, 2021). This is due to the light interacting with pure silicon crystal.

Next, poly-Si are composed from a variety of the fragments of silicon crystal and these silicon crystals are then melted and poured into a mould before cut into wafer shaped (McBride, 2021). This type of panel is more economical due to the absent of any kind of wastage and much simple cell manufacturing process. But, the efficiency of this type of panel is lower than mono-Si, because the impurity of this panel is higher than mono-Si type solar panel or lower purity in other words. Low heat resistance also makes this type of panel less efficient in high temperature environments. Poly-Si panels often appear in blue colour.

PERC can be known as the enhancement version of the mono-Si solar panel. A rear cell is added in this type of panel to capture the light that comes from reflection, which raises the absorption rate of the solar radiation. A passivation layer is added in the rear external of the solar cell to reflect the light waves that are over 1,180 nm, which is not able for the silicon wafer to absorb and thus lower the temperature in the rear cell (McBride, 2021). PERC is perfect for compact locations due to it can capture extra solar energy with a smaller physical footprint. PERC panels are marginally more expensive than normal panels due to the further materials required, but have a lower average fee per watt due to its efficiency.

Furthermore, Thin-Film solar panels are made by depositing one or more layers of extremely tiny layers that are flexible (Singh, 2013). Because it does not require a frame backing, each panel is lightweight and simple to install. Thin-film panels, unlike crystalline silicon panels, can be customised in size correspondingly. This type of panel is less efficient than silicon-based solar panels. Thin-film solar panels can be manufactured by vary of materials. For instance, Cadmium telluride (CdTe), copper indium gallium selenide (CIGS), and amorphous thin-film silicon (a-Si). Table 2.2 below summarised the properties of the four types of solar panel.

Table 2.2: Solar Panel Types and its Properties

Types / Properties	PERC	mono-Si	poly-Si	Thin-Film
Cost	Highest	High	Intermediate	Lowest
Efficiency	Highest	High	Intermediate	Lowest
Made From	Single pure silicon crystal	Single pure silicon crystal	Vary of the fragments of silicon crystal	Thin layers of photovoltaic material
Appearance	Black	Black	Blue	Black, blue, or grey (Vary on the type)
Space Consumption	Least	Less	Intermediate	More
Temperature Coefficient	N/A	-0.3 to -0.5% /°C	-0.3 to -0.5% /°C	-0.2% /°C

CdTe, the most popular type in thin-film solar panels. To capture the sunlight, a layer of CdTe is sandwiched between two crystal clear conducting layers, with a glass layer on top for safeguard (McBride, 2021). Moreover, four components are sandwiched between two conductive layers in a CIGS solar panel (i.e. glass, plastic, aluminium or steel). To capture electrical currents, front and back electrodes are used. For a-Si, although it contains silicon, a-Si is not formed up of solid silicon wafers. Instead, a-Si is made up of non-crystalline silicon that is applied to glass, plastic, or metal.

From this, it can be divided into two varieties of solar panel based which are silicon based and thin-film based. Mono-Si, poly-Si, and PERC are categorised in the types of silicon based and Thin-Film solar panels are categorised under the thin-film based (Vekony, 2021). The composition of these two based of solar panel are listed in below:

- Silicon based solar panels are composed of 76% glass, 10% plastic, 8% aluminium, 5% silicon, and 1% metals.
- Thin-film based solar panels composed of 89% of glass, 4% plastic, 6% aluminium, and 1% metals.

Next, Table 2.3 below states the efficiency for several types of solar panel collected from different articles and resources. From this table, an average on the efficiency of different types of solar panel have been made. The PERC has an average efficiency of 21.75%, which is the most efficient type of solar panel compared to the other types. Furthermore, the average efficiency for mono-Si, and poly-Si types of solar panel is 20.12%, and 16.88% correspondingly. The types of solar panel that have the lowest efficiency is a-Si with 9.1% of average efficiency.

Table 2.3: Solar Panel Types and its Efficiency

Solar Panel Type	Authors and Correspond Efficiency						Average Efficiency
	(McBride, 2021)	(Nexamp, 2021)	(Gaglia et al., 2017)	(GreenMatch, 2022)	(Svarc, 2022)	(Pakere et al., 2017)	
PERC	5% more than mono-Si	N/A	N/A	N/A	17-20%	N/A	21.75%
mono-Si	≥20%	>20%	14-19%	±20%	16.5-19%	25.3-27.6%	20.12%
poly-Si	15-17%	15-17%	14-19%	±15%	15-18%	21.30%	16.88%
CIGS	13-15%	13-15%	N/A	N/A	N/A	22.6-23.3%	16.98%
CdTe	9-11%	9-11%	N/A	N/A	N/A	22.10%	14.03%
a-Si	6-8%	6-8%	7-11%	7-10%	N/A	14%	9.1%

Moreover, Table 2.4 below displays the cost per watt for several types of solar panel. From this table, an average on the cost per watt for different types of solar panel have been made. The PERC type of solar panel has an average cost per watt of $0.49 or RM 2.15, which is the lowest among the other types of solar panel. The average cost per watt for mono-Si, and poly-Si types of solar panel is $1.25 or RM 5.50, and $0.9 or RM 3.96 respectively.

Table 2.4: Cost per Watt for Each Types of Solar Panel

Types of Solar Panel	Authors and Correspond Cost per Watt				Average Cost per Watt
	(McBride, 2021)	(Nexamp, 2021)	(Flannery, 2022)	(Brill and Pelchen, 2022)	
PERC	$0.32-0.65	N/A	N/A	N/A	$0.49
mono-Si	$1-1.50	$1-1.50	$1-1.50	$1-1.50	$1.25
poly-Si	$0.70-1	$0.90-1	$0.70-1	$0.90-1	$0.9
CIGS	$0.60-0.70	*$0.50-1	*$1-1.50	*$1-1.50	$0.98
CdTe	$0.50-0.60	*$0.50-1	*$1-1.50	*$1-1.50	$0.95
a-Si	$0.43-0.50	*$0.50-1	*$1-1.50	*$1-1.50	$1.18

Note:

The cost per watt listed above is excluding the installation and labour cost.

*The figures is the range for all types of the Thin-Film solar panel

Table 2.5 below shows the average solar panel mass per wattage for several brands of solar panel in the market (McBride, 2021). All the solar panels that were selected for this comparison have the capacity of 250 watt 60-cell solar panels. The highest average mass per wattage is Waaree Solar 250W, with 0.09 kg. Meanwhile, the lowest average mass per wattage is Canadian solar CS6K, with 0.0728 kg. On the other hand, Table 2.6 below also displays the other average solar panel mass per wattage for several brands of solar panel in the market (McBride, 2021). All the solar panels that were selected for this comparison have the capacity of 300 watt 72-cell solar panels. For this category, the highest average mass per wattage is Canadian solar Dymond Series, with 0.0917 kg. Meanwhile, the lowest average mass per wattage is Vikram Solar Eldora Grand Series, with 0.0733 kg.

Table 2.5: Mass per Watt for Selected Types of 250 watt 60-cell solar panels (McBride, 2021)

Solar Panel capacity (250 watt 60-cell solar panels)	Dimensions (mm) (height × width × depth)	Solar Panel mass (kg)	Average Solar Panel mass per wattage (kg)
Canadian solar CS6K	1650 X 992 X 40	18.2	0.0728
Vikram Solar Eldora Neo Series	1640 X 992 X 40	18.5	0.074
Waaree Solar 250W	1640 X 990 X 40	22.5	0.09
Trina Honey Series	1650 X 992 X 35	18.5	0.074
Jinko Solar Panels 255W	1650 X 992 X 40	19	0.0745

Table 2.6: Mass per Watt for Selected Types of 300 watt 72-cell solar panels (McBride, 2021)

Solar Panel capacity (300 watt 72-cell solar panels)	Dimensions (mm) (height × width × depth)	Solar Panel mass (kg)	Average Solar Panel mass per wattage (kg)
Canadian solar Dymond Series	1968 X 992 X 58	27.5	0.0917
Vikram Solar Eldora Grand Series	1955 X 991 X 40	22	0.0733
Waaree Solar Aditya Series	1960 X 990 X 40	22.5	0.075
Trina Tall Max Series	1956 X 992 X 40	22.5	0.075
Jinko Solar Panels	1956 X 992 X 40	26.5	0.088

Common industrial solar cells wattage that has been adopted is rated for around 350 watts per panel (LOW CARBON ENERGY, 2020). The mass of the 350 watt 72-cell solar panels come in various ranges from 22 kg to 32.2 kg. Moreover, the range of variation of the mass average per wattage is from 0.0629 to 0.0663. From Table 2.7, it is reasonable to assume that the average mass per 1 wattage for 350 watt 72-cell solar panels is 0.06492 kg on average. This value is then being adopted to calculate the weight of solar panels for each solar plant for this study. Note that the weight of solar panels calculated for each solar plant for this study is just estimated only based on the research cases.

Table 2.7: Mass per Watt for Selected Types of 350 watt 72-cell solar panels

Solar Panel capacity (350 watt 72-cell solar panels)	Dimensions (mm) (height × width × depth)	Solar Panel mass (kg)	Solar Panel average mass per 1 wattage (Solar Panel capacity)	Source
REC Solar's TwinPeak REC350TP2S 72	2005 X 1001 X 30	22	0.0629	(Panels, 2020)
Hyundai HiSS350RI 350W 4BB Solar Panel	1960 X 998 X 40	22.9	0.0654	(Module, 2017)
Hyundai HiS-S350TI 350 Watt Solar Panel	1960 X 998 X 50	23.2	0.0663	(Solar Electric Supply, 2013)
Axitec AC-350M/156-72S	1956 X 992 X 40	23	0.0657	(Axitec, 2022)
Jinko solar JKM350M-72-V	1956 X 992 X 40	22.5	0.0643	(Jinko, 2008)
Average mass per 1 wattage (Solar Panel capacity)			0.06492	

2.4.2 Solar Panel Configurations and Conversion System

A single unit of solar panel is composed of several solar modules and numerous solar cells. Hence, the actual magnitude and mass of a solar panel rely on the cell configuration and the type of the wattage of the solar panel (McBride, 2021). The standard dimension of a solar cell is about 6” × 6” or 156 mm × 156 mm, and 40 mm in thickness. The common size of cell configuration available in the market nowadays is 60-cell, 72-cell, and 96-cell. The common dimension (in Width × Length) for 60-cell, 72-cell, and 96-cell solar panels is 33” × 66”, 39” × 77”, and 41.5” × 62.6” respectively (Patel, 2022). In order to achieve higher voltage output, select the configuration panel with a higher cell. Meanwhile, the common type of the wattage of the solar panel is 250-watt to 400-watt solar panels. For instance, a 4 KW system can be built up by sixteen 250-watt solar panels.

1 KW solar panel systems are able to produce 5,000 watts of electricity and require approximately 70 square feet of space (Ong et al., 2013). Based on the technologies employed, 5 to 13 acres is required to produce 1 MW of electricity or approximately 10 sq. metre area for a 1 kW solar capacity. However, there are three factors in general that will affect the overall capacity produced by the solar panels. These issues are geographical location, type of solar panel selected, and the installation parameters.

2.4.3 Size and Trend of Solar Cell

As of 2022, there are numerous sizes of solar cells available in the market. Figure 2.5 below illustrates the current and future projection for global market shares of solar cells by size (Co.KG, 2021). The years counted in this global market share of solar cell by size is from 2019 to 2024. From the table below, it is clearly shown that the favourite size of solar cell being adopted in 2019 is 156.75 mm, which this cell is recorded for approximately 80% out of hundreds of the market shares.

Next, the 158.75 mm size of solar cell became the most widely installed solar cell in 2020 with over 40% of the global market shares. However, the 166 mm size of solar cell overtook the most widely installed solar cell in 2021 with over 40% of the global market shares. It is expected that the global share of the 166 mm size of solar cell will descent year by year and it is likely to be replaced by the solar cell with the size of 182 mm and 210 mm starting from 2022 to 2024 (Co.KG, 2021).

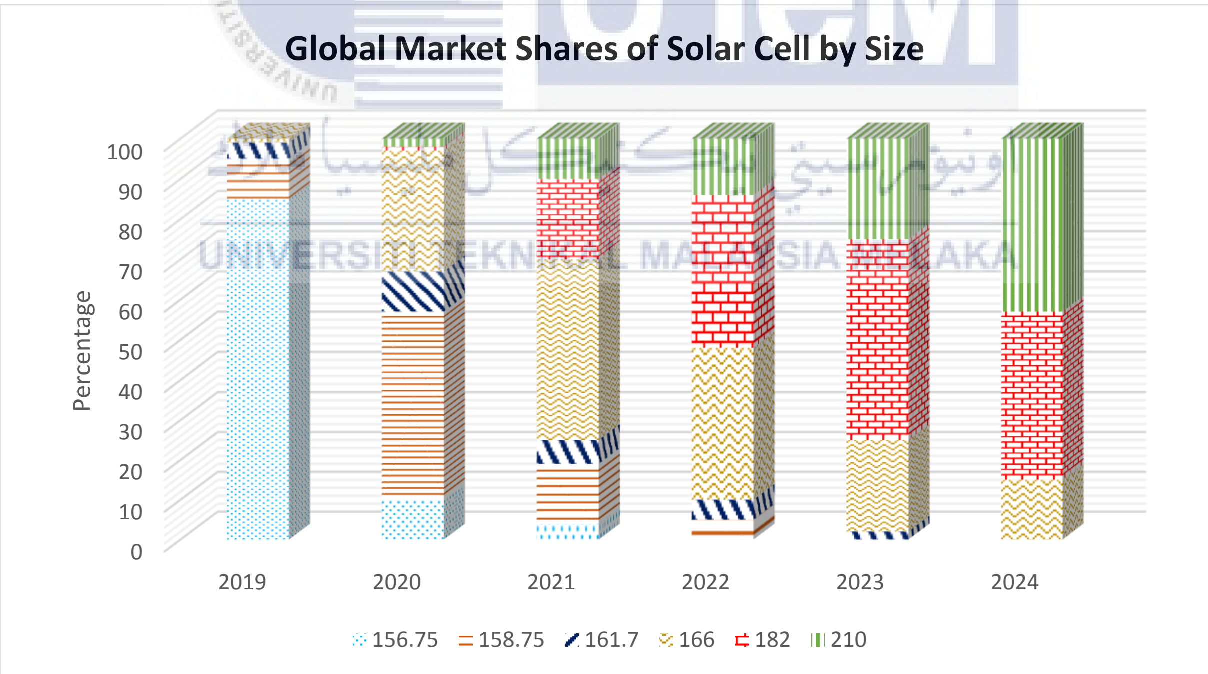


Figure 2.5: Current and Future Projection for Global Market Shares of Solar Cell by Size (Co.KG, 2021)

2.4.4 Causes of Solar panels Damage

There are abundant causes that will lead to the failure of the solar panel. For instance, electrical equipment, poor design, grounding issues, transportation, and etc. (Lunardi et al., 2018). Figure 2.6 below illustrates the causes that lead to failure of the solar panel. Optical failure is claimed to be the most causes that lead to failure of the solar panel from the output of the result, which accounted for about 20% of the total causes (Chowdhury et al., 2020). Next, power loss as well as junction box and cables both become the second most causes that lead to failure of the solar panel with the proportion of 19% respectively. Glass breakage and defect cell interconnect is also one of the major reasons that lead to failure of the solar panel. Both of these causes accounted for 10% of the rate correspondingly (Chowdhury et al., 2020). These early failures on solar panels will shorten the lifetime of the solar panel and become the waste earlier than expected. These early solar panel waste will burden most of the country especially in Malaysia as the EoL solar panel recycling management is still in an initial development stage.

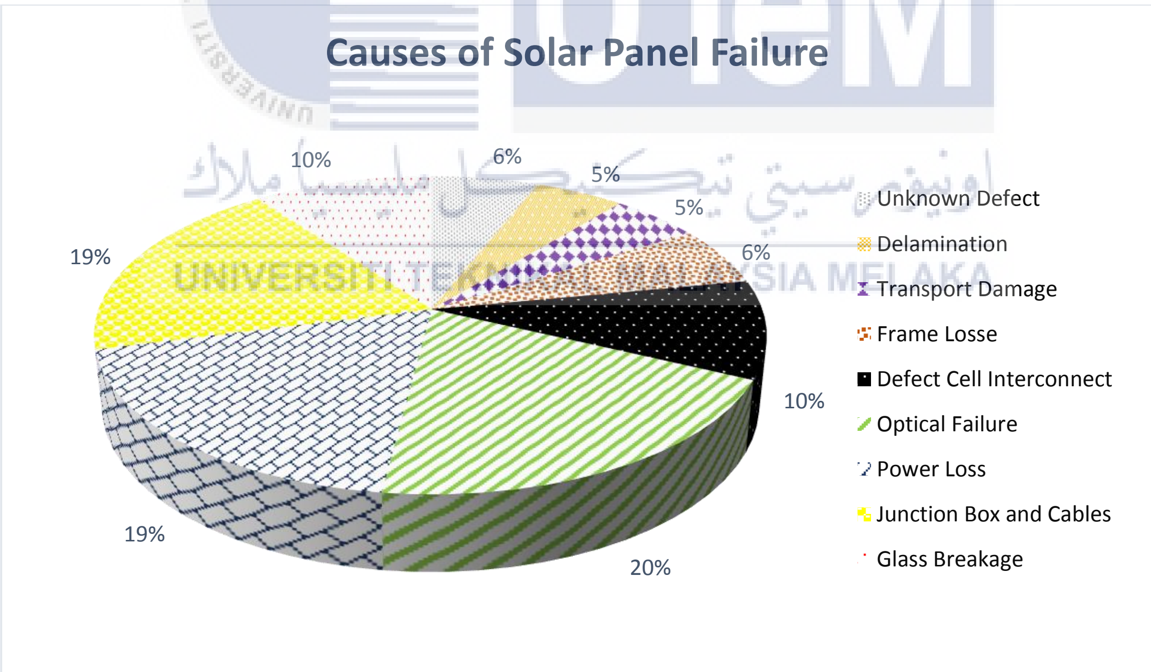


Figure 2.6: Causes that lead to failure of the solar panel (Chowdhury et al., 2020)

2.4.5 Challenge of the Solar Panels

Solar energy as one of the clean, renewable, yet sustainable energy is a popular energy generation alternative for most of the countries towards the reduction or replacement of relying unrenewable energy such as fossil fuels as the primary energy generation source (IRENA and IEA-PVPS, 2016). This should benefit the environment of this planet as solar energy produces the energy without generating the carbon footprint. Nonetheless, the lifetime of the solar panels is shorter than predicted and most vital, extremely high expenditures in recycling these panels has resulted in the EoL of the solar panels ending up in landfill. In long terms, this will burden the environment as the panels contain some toxic materials such as lead and cadmium which will leach out and thus pollute the land and create new environmental hazards.

According to the IRENA official forecasts, approximately 78 million tonnes of solar panels waste in total will be produced in 2050 (IRENA and IEA-PVPS, 2016). Please note that this figure does not include those panels that require early replacement due to all kinds of reasons. Figure 2.7 below indicates the forecast for the solar panels lifetime under several conditions. This forecast pinpoints the lifetime of the solar panels is 30 years, starting in 2020. Starting from the most ideal condition, the panels are not experiencing any failure and reach its end-of-life in 2050, based on a weight-to-power proportion of 90 tonnes per MW, roughly 315,000 metric tonnes of left-over panels will be produced in 2050.

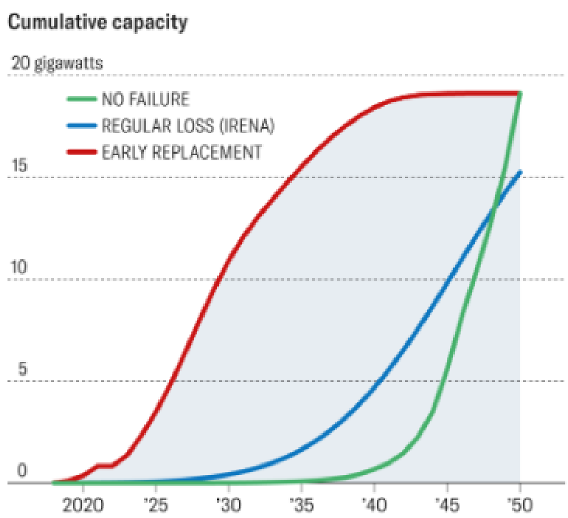


Figure 2.7: Forecast for the solar panels lifetime under several conditions (IRENA and IEA-PVPS, 2016)

On the other hand, if the early replacement on panels occurs, it is estimated that humans will face roughly 315,000 metric tonnes of used panels around 2040, which is much earlier than 2050 (Duran et al., 2021). This situation will pose a disadvantage or threat towards the industry which is currently confronted with inadequate recycling knowledge and methodology of solar panels. Up to now, First Solar is the only U.S. panel manufacturer that has a recycling programme in place, which solely applies to the company's own products. Recycling one panel currently costs $20–$30 or RM 88 to132. Meanwhile, it would only cost $1–$2 or RM 4.40 to 8.80 to send that same panel to a landfill.

Nonetheless, the direct expense of recycling is only one element of the overall EoL burden. Panels are large, delicate pieces of equipment that are usually put on the roofs of homes (Atasu et al., 2021). Detaching and removing these panels requires specialised work to avoid shattering the panels before reaching the truck. Due to the solar panels having minuscule levels of heavy metals (cadmium, lead, etc.), some governments may designate solar panels as hazardous waste. This categorization comes with a plethora of expensive restrictions, such as the fact that hazardous waste can only be transported during particular hours and along specific routes. Solar panel recycling capacity must be constructed as part of a comprehensive end-of-life ecosystem that also includes uninstallation, transportation, and proper solar waste storage facilities (IRENA and IEA-PVPS, 2016). Government subsidies are likely to be the only method to develop capacity quickly enough to meet the scale of the growing trash crisis. The cost of developing solar end-of-life infrastructure is an unavoidable element of the R&D bundle that comes with green energy support.

2.5 Recent End-of-Life (EoL) Solar Panel Management in Different Regions

Differ regions or even countries have varying processes, approaches, regulations, and many more in handling and managing the used solar panels. This is due to each country needs to accommodate its distinct circumstances in order to select the most appropriate methods in managing and disposing of the huge amount of used solar panels in each country or region (Komoto & Lee, 2018). For instance, the recycling technology of the country, the rate of utilisation of the solar panels in the particular country, policy of each of the governments, etc.

Sub-chapter below will discuss the current EoL solar panels management methodology in some regions such as Europe, U.S, Japan, China, and South Korea.

2.5.1 Europe

In Europe, as early as 2012, an order which named "Waste Electrical and Electronic Equipment" (WEEE) mandated the recycling of the used solar panels after reaching its EoL or early damage (European Union, 2012). The aims of this directive consist of gathering, retrieval, and reusing targets for waste from the used solar or PV panels, which is categorised as the electrical and electronic equipment waste across Europe. Besides that, the regulation also states that the manufacturers have to be responsible for its own goods when it becomes waste.

All European Union (EU) participant states have incorporated the PV requirements into national legislation, forcing every single producers that supply PV panels in the EU whether to operate its own take-back and recycling systems or engage in producer compliance schemes starting from 2012 onwards (European Union, 2012). Thus, this can avoid the used electrical waste (solar panels) ending up in landfill. A variety of European R&D programmes are motivating the enhancement of reusing skills for the various solar technology relations, in accordance with the WEEE Directive (Komoto & Lee, 2018). These approaches aim to reduce recycling expenses while also increasing income sources from subordinate raw materials recovered through recycling.

2.5.2 United State (U.S)

Currently, general waste regulations are the only regulations that apply towards the EoL solar panels gathering and recycling in the U.S (Curtis et al., 2021). This is due to there are no tenable regulations regarding the recycling management of the EoL solar panels in the federal government of the U.S. As of 2021, there are a total of four states in the U.S that have enacted the regulations related to the recycling of the used solar panels.

First is the Washington D.C, all solar panel manufacturers are affected by Extended Producer Responsibility (EPR) law, which was executed in Washington (Washington State Legislature, 2017). The government of Washington approved Senate Bill 5939 in July 2017, which alters state renewable energy structure tax incentives and mandates a PV module takeback and recovering programme. Manufacturers must submit product stewardship ideas that detail how it will fund the takeback and reprocessing programme, as well as allow for the return of PV modules at places throughout the state, according to the law. Effective from July 1, 2023, the regulation will mandate solar modules makers to fund the takeback, or reusing of PV modules sold in or into the state after July 1, 2017, at no cost to the customer. After January 1, 2021, companies that do not offer a recycling programme will be unable to retail solar panels.

Furthermore, California also established a legislation that allows EoL Solar panels to be managed as universal hazardous waste, which went into effect in January 2021 (Curtis et al., 2021). The universal waste law in California provides for less severe handling, shipping, and storage regulations for modules being recycled or disposed of, and forbids the use of heat and chemical treatment and recycling methods (Komoto & Lee, 2018). Next, an act was passed in 2019 in New Jersey and North Carolina to investigate EoL PV module governance methods in order to guide future ordinance in its respective states. Both California and Hawaii have proposed (pending) measures that would establish consultative bodies to evaluate and recommend EoL policies for PV modules in each respective state. A measure has been presented in Rhode Island that, if passed, would establish a Photovoltaic Module Stewardship and Takeback Scheme.

Several Solar panel manufacturers have offered to collect and recycle end-of-life PV modules on a voluntary basis (SEIA, 2016). For example, First Solar maintains commercial-scale recycling plants in Ohio, Germany, and Malaysia for its CdTe Solar panel products. The Solar Energy Industries Association of the United States (SEIA) maintains a corporate social responsibility body that monitors progress in PV recycling, and in September 2016, it declared the creation of a National PV Recycling Plan.

SEIA has made it easier for buyers to choose a cost-effective and ecologically responsible EoL organisation option for its PV merchandises by launching this programme that sums the services offered by recycling vendors and Solar panel makers (SEIA, 2016). The Solar panel Recycling Working Group of SEIA will choose Preferred Recycling Partners who will provide exclusive benefits to SEIA members while making its own general services open to all fascinated groups. SEIA is also developing dynamic waste management solutions in order to eliminate landfills throughout the sector. This comprises the national recycling network initiative, which will provide a portal for system owners and customers to learn how to responsibly recycle its own solar panels, as well as invest in research and development to improve recycling technology.

2.5.3 Japan

As EoL PV panels are not subject to any unique restrictions in Japan, these waste must be handled according to the Waste Management and Public Cleansing Act (Komoto & Lee, 2018). The law defines wastes, as well as the responsibilities of industrial waste generators and handlers, as well as the components of industrial waste management, such as landfill disposal. The Ministry of Economy, Trade and Industry (METI) and the Ministry of Environment (MOE) collaborated to analyse how to deal with EoL renewable energy tools like solar panels. A guideline for endorsing a system for collecting, recycling, and correct treatment was devised in June 2015, and it covered technology R&D, ecologically friendly designs, and instructions for dismantling apparatus, carriage, and curing, as well as user awareness.

The first edition of a guideline advocating effective EoL curing for PV panels, including reusing, was issued in April 2016 based on this roadmap (MOE, 2016). The guideline provides fundamental information on decommissioning, carriage, recycling, and industrial waste discarding, as well as pertinent legislation and regulations. The roadmap and guideline are likely to prompt additional discussion of policies related to the EoL management of solar panels waste. The goal of these R&D projects is to create feasible PV recycling methods. This will be accomplished through developing inexpensive recycling technologies and researching the best ways for removal, collecting, and sorting.

2.5.4 China

Alike most of the country, China does not own a legislation enactment also regarding the EoL solar panels management at this time (Komoto & Lee, 2018). But, related technology research has begun, and the Twelfth 5-Year Plan's National High-tech R&D Programme for solar panels Recycling and Safety Disposal Research has presented recommendations on policy and technological R&D (Zhang et al., 2016). Special legislation and regulations for EoL PV panel recycling, as well as targets for recycling amounts and the implementation of relevant economic structures, are among the policy recommendations. On the technological and R&D front, for c-Si and thin-film PV panels, the focus is on emerging and demonstrating high-efficiency, reasonable cost, and low-energy-utilisation recovery methods and methodologies.

Directions for enhancing the EoL management of waste solar modules are outlined in the Thirteenth 5-Year Plan for 2016-2020 (MOST, 2016). The critical guidelines or focuses in this plan are including the recycling technology for Thin-film based solar panels such as CdTe and CIGS. Experimental demonstration and critical equipment development for large-scale crystalline silicon PV module recycling that is efficient, low-cost, and low-energy. Mobile platform development for MW-scale crystalline silicon - based solar panel recycling on-site. Policy and the standard parameters for recycling.

2.5.5 South Korea

Currently, South Korea also does not have legislations on handling the EoL solar panels waste within the country (Komoto & Lee, 2018). As an approach to enhance Solar panel recycling, a paper titled "2015 energy information and policy support initiatives" advocated adding an act authorising the relay of panels waste disposal to the current "Act on the Promotion of the Development, Use, and Diffusion of New and Renewable Energy" (Kang et al., 2015). Adding laws covering PV waste to the current renewable energy law, rather than creating a separate law expressly for solar waste, would be more efficient, according to the analysis.

Two new solar panel recycling operations were launched in 2016 (Komoto & Lee, 2018). One is a research and development project aimed at illustrate recycling approach by building a recycling facility with a volume of 2 tonnes per day, with the goal of reclaiming unharmed wafers from solar waste modules with a yield of over 70 percent in order to reduce the amount of electricity used to manufacture new PV panels. The other project is a non-R&D initiative to create a Solar panel recycling centre in Korea to manage PV waste modules. Table 2.8 below summarizes the End-of-Life (EoL) Solar Panel Management in selected countries (Komoto & Lee, 2018).

Table 2.8: Summarize of the End-of-Life (EoL) Solar Panel Management in different country (Komoto & Lee, 2018)

Country/ Organization	End-of-Life (EoL) Solar Panel Management	
	Approaches	Regulations
European Union	All European Union (EU) participant states have incorporated the PV requirements into national legislation, forcing all producers that supply PV panels in the EU whether to operate its own take-back and recycling structures or engage in producer compliance schemes starting from 2012 onwards.	2012 Waste Electrical and Electronic Equipment (WEEE)
U.S	Manufacturers must submit product stewardship ideas that detail how it will fund the takeback and recycling programme, as well as allow for the return of PV modules at places throughout the state.	Extended Producer Responsibility (EPR) law in Washington
	Less severe handling, shipping, and storage regulations for modules being recycled or disposed of, and prohibits the use of heat and chemical treatment and recycling methods.	Universal Hazardous Waste in California
	To investigate EoL PV module management methods in order to guide future regulation in its relevant states.	A legislation in New Jersey and North Carolina
Japan	The legislation outlines wastes, duties of industrial waste generators and handlers, and components of industrial waste management, including landfill disposal.	The Waste Management and Public Cleansing Act

China	The Twelfth 5-Year Plan's National High-tech R&D Programme for solar panels Recycling and Safety Disposal Research has presented recommendations on policy and technological R&D (Zhang et al., 2016). Special legislation and regulations for EoL PV panel recycling, as well as targets for recycling rates and the implementation of relevant financial structures, are among the policy recommendations.	N/A
South Korea	As an approach to enhance Solar panel recycling, a paper titled "2015 energy information and policy support initiatives" advocated adding an act mandating the relay of panels waste disposal to the current "Act on the Promotion of the Development, Use, and Diffusion of New and Renewable Energy".	N/A

2.6 General EoL Solar Panel Recycling Management

Discarded solar panels EoL management provides chances for each of the three Rs (Reduce, Reuse, and Recycle) of sustainable waste management. Recycling systems and its associated regulatory frameworks for EoL solar panels management are relatively new additions to the 3Rs (Komoto & Lee, 2018). Recycling systems and the associated regulatory frameworks for PV end-of-life management are relatively new additions to the 3Rs. In terms of environmental implications and resource efficiency, EoL management with material recovery is superior to disposal for managing EoL PV systems (Ravikumar et al., 2016).

When recycling procedures are effectual, recycling is able to decrease waste, waste-related emissions, and also has the probability to reduce energy use and emissions associated with the manufacture of virgin materials (Komoto & Lee, 2018). This could be especially important for high-impurity raw materials (such as semiconductor originator material), which frequently need energy-intensive pre-treatment to obtain required cleanliness levels. Recycling of resource-constrained metals used in solar panels is also critical for long-term resource management.

Solar panels recycling systems have been investigated and developed extensively over the last decade, but still have yet to be fully commercialised or to achieve substantial ranks of material retrieval, at least for the most common PV technology family, crystalline-based solar panels (Komoto & Lee, 2018). Backing for technological R&D can boost technology performance and increase the value of recycled materials. It is indeed important to consider how the restored materials can be reused as materials in addition to material recovery from discarded panels. Material recycling frequently falls short of the quality standards required to maximise its value. Success in technological R&D, on the other hand, may be able to bridge this gap, allowing for more efficient and effective raw material and component recovery.

Generally, solar module glass, cable, and aluminium frames are recyclable and are often being detached from the solar panels (Ravikumar et al., 2016). These materials usually account for most of the weight of a solar panel yet the least value in the panels. After separating the recyclable components from the panels, the left-over materials end-up in landfills. But, the application of the recycled glass is limited as the glass contains metals. As of the end of 2020, valuable materials such as silicon, copper, and silver are not being recycled by some countries such as the U.S (Wesoff et al., 2022).

Currently, monocrystalline silicon solar cell (mono-Si), polycrystalline silicon solar cell (poly-Si), Passivated Emitter and Rear Cell (PERC), and Thin-Film solar cell (TFSC) are the four main types of solar panels that dominant the solar panels market globally (Komoto & Lee, 2018). From that, mono-Si and poly-Si solar cells are the most commonly used types of solar panels technology. However, the process in manufacturing these panels will affect the environment. For instance, the mass consumption of electrical and water energy to produce the panels, emission of hazardous gases, and hazardous by-products created.

Fluorine, chlorine, nitrate, isopropanol, SO_2, CO_2, and respirable silica particles and solvents are among the pollutants emitted during the manufacturing of silicon solar panels (Komoto & Lee, 2018). Moreover, depending on their positioning and efficiency, crystalline solar panels yield 9-17 times the energy used to manufacture it over the course of a lifetime. Clean energy payback takes one to four years, subject to the type of PV technology used. Solar energy reduces emissions by roughly 8 pounds of sulphur dioxide, 5 pounds of nitrogen oxides, and over 1,400 pounds of carbon dioxide per 1,000 kWh produced. Recycling solar panels instead of utilising new materials will save 1/3 of the energy under the European Photovoltaic Industry Association (Life Cycle Assessment, 2022).

2.7 Solar Panels Recycling Approaches

The life cycle or lifetime of solar panels is about 30 years (Vekony, 2021). High quality solar panels may reach a life cycle between 30 to 40 years. The users may experience a reduction of 20% in power capacity during the life of the PV panels which, a maximum of 10% drop between 10 to 12 years of PV panels used, and 20% reduction when come to 25 years of use. These data are promised by the majority of the manufacturers. In reality, some of the solar panels' power capacity only reduce between 6 to 8% after 25 years (Vekony, 2021). After 30 years of the lifetime, the solar panels should be dismantled and recycled over again instead of buried in the landfills.

Presently, solar panel waste is classified as the general waste in most of the country. But, EU countries are classified as e-waste (European Union, 2012). Solar cell manufacturers are required by act to encounter severe regulatory and recycling criteria in order to warrant that solar panels will not become a liability on the surroundings. Indeed, if recycling facilities are not implemented, landfills will contain 60 million tonnes of PV panel trash by 2050. Because all solar cells include a fixed amount of hazardous substances, this would be a non-renewable energy source.

At this time, among all the studies that related to the recycling of solar panels that have been published was mainly concentrated on both the extraction of silicon and the recycling of the rare materials (Xu et al., 2018). The types of recycling process for used solar panels are currently divided into three different categories which is component restoration, separation of modules, and the abstraction of rare materials from the components (e.g., silicon). The overall recycling methods for silicon based and thin-film based solar panels was illustrated in Figure 2.8.

There is absent of component separation or material recycling involved in replacement of components process, with the purposes to refurbish systems and avoid circuit group electrical short. Next, the physical separation process does not include separating out any specific kind of substance, but rather the mechanical separation of shattered panels (Xu et al., 2018). Examples of operation that can be performed in this procedure include chemical, thermal, and organic solvent treatment. Meanwhile, there are several techniques that can be used to extract silicon and other rare materials from the component parts, such as hydrometallurgy, wet mechanical treatment, chemical procedure, and cement-based thermal insulation system.

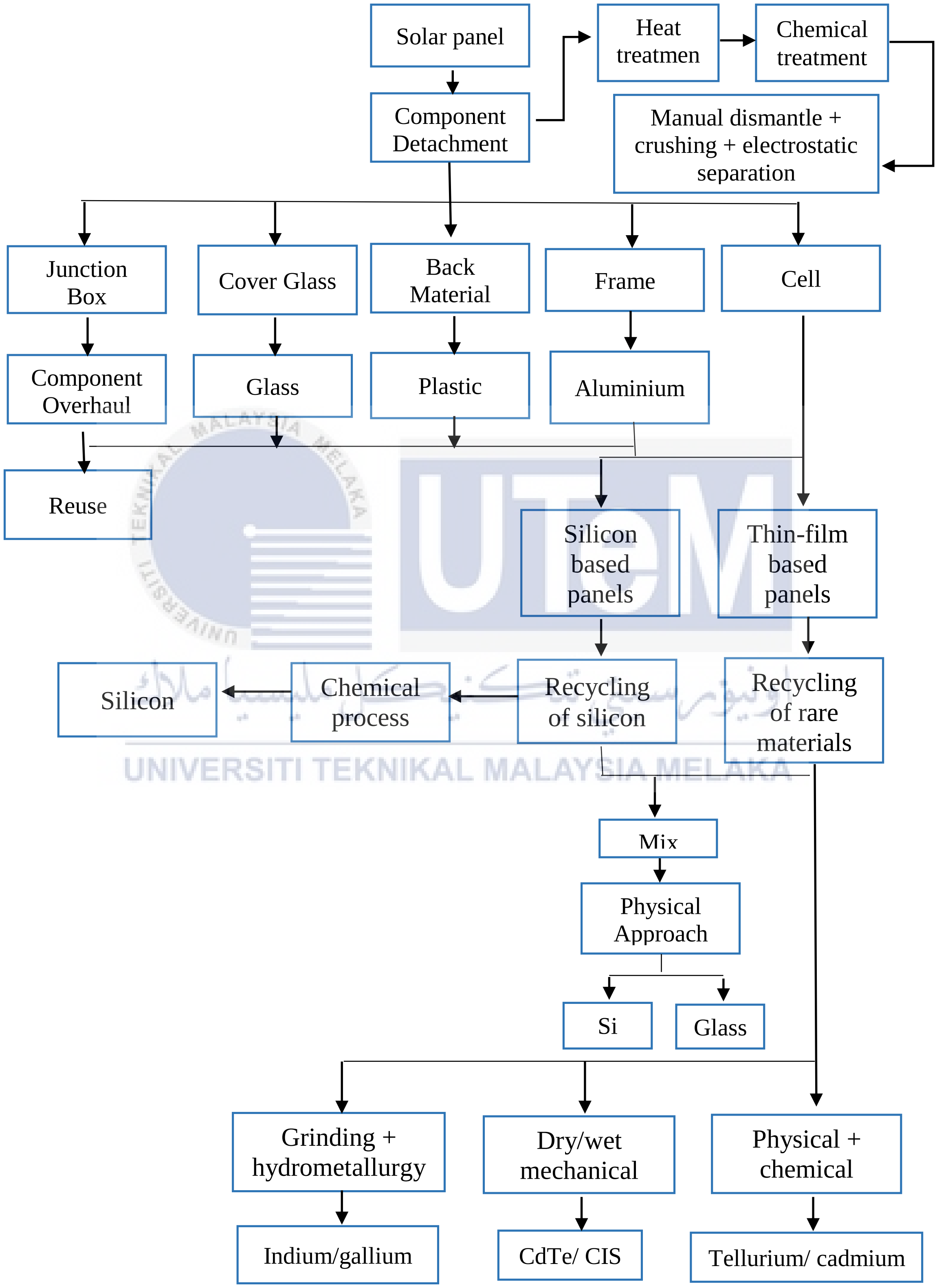


Figure 2.8: Overall recycling methods for silicon and thin-film based panels (Xu et al., 2018)

There are in total two main bases of solar panels which are silicon based and thin-film based, which both require different recycling processes (Lunardi et al., 2018). Both varieties, silicon and thin-film based solar panels, can be reused through different industrial methods. Although silicon-based panels are currently more common, this does not rule out the prospect of significant worth in thin-film-based cell materials in the future. The recycling process for both silicon and thin-film based are as below (Vekony, 2021):

2.7.1 Silicon Based PV Panels Recycling Process

The recycling process for silicon based solar panels are as follow (Xu et al., 2018) (Vekony, 2021):

1. Collecting wastes.
2. Disassembling the solar panel to detach aluminium and glass (almost 95% of glass can be reprocessed, all external metal parts are recycled for re-mouldings cell frames)
3. To assist the cell elements stick together, the remaining materials are heated to 500°C in a thermal processing centre.
4. Due to the supreme heat, the enclosing plastic vaporised, leaving the silicon cells available for further processing. (The plastic is employed as an origin of heat for further thermal processing.)
5. After the thermal treatment, the green hardware is physically separated.
6. The vast majority of the cells (about 80%) can be reused, with the remaining being polished further.
7. Acid is used to etch silicon wafers, which are little silicon particles.
8. Broken wafers are melted and reused to create new silicon modules, resulting in a silicon material recycling rate of 85 percent.

2.7.2 Thin-Film Based PV Panels Recycling Process

The recycling process for thin-film based solar panels are as follow (Xu et al., 2018) (Vekony, 2021):

1. The first step is to shred the solar panels.
2. A hammer mill is used to make sure that no particles are larger than 4-5mm, which is the size at which the lamination that holds the interior components together fractures and may be removed.
3. To separate solid and liquid material, a rotating screw is utilised, which the solid parts keeps spinning inside a tube while the liquid drips into a container. Because, unlike silicon-based PV panels, the residual component is made up of both solid and liquid material.
4. Liquids go through a precipitation and dewatering procedure to ensure purity.
5. The final product undergoes metal processing to thoroughly separate the individual semiconductor components.
6. The final procedure is dependent on the panel manufacturing technology utilised; nonetheless, 95% of the semiconductor material is reused on average.
7. Solid matter is contaminated by interlayer materials, which are lighter in mass and can be eliminated via a vibrating exterior.
8. The substance next goes through a rinsing process. The only thing remaining is pure glass, with 90% of the glass elements salvaged for remanufacturing.

2.8 Future Benefits of Solar Waste Management

A sophisticated solar panel recovery system will be required to cope with the huge capacities of PV modules that will be discarded in the next few years. PV recovery would not only create more green jobs, but it will also generate an estimated £11 billion in recoverable value by 2050, which is comparable to RM 60 billion (Vekony, 2021). This infusion will enable the production of 2 billion solar panels without the need to invest in raw materials. This means that only recovering previously used materials will be enough to generate 630 GW of electricity.

2.9 Identify the Total Output of a Solar Panel System

Solar cells and the wattage of the solar system determined the actual magnitude and mass of a solar panel. The more the solar cell, the larger and the heavier the solar panel is (Howell, 2022). The examples of calculation below shows the calculation for the total output of a solar panel system (KW) and the energy of solar panel produced per day (KWh) respectively.

The total output of a solar panel system (KW) = wattage of respective solar panel (W) × the total quantity of solar panels used

The energy of solar panel produced per day (KWh) = wattage of respective solar panel (W) × the total quantity of solar panels used × peak sun hours

2.10 Current and Future Renewable Energy Electricity Generation in Malaysia

Currently, RE contributes around 18% of the total energy output in Malaysia. The government of Malaysia is aiming to raise the generation of RE in Malaysia by 31% and 40% through 2025 and 2035 correspondingly under the energy transition plan until 2040. In 2025, 26% out of 31% of RE generation will come from Peninsular and 32% out of 40% of RE generation will come from Peninsular in 2035. By 2035, the energy supply from all installed capacity for RE is expected to grow from 8,700 MW (in 2020) to 18,000 MW (Abdullah, 2022). Hence, when compared to 2005, carbon emission intensity from the power industry is expected to drop by 45 percent in 2030 and another 60 percent in 2035 (MIDA, 2022).

2.10.1 Solar Potential in Malaysia

Malaysia monthly solar irradiation is predictable in between 400-600 MJ/m^2 (Mekhilef et al., 2012). This amount indicate that Malaysia are having highest potential in developing solar energy due to Malaysia are geographically situated nearby the equator that experiencing hot and sunny weather all year around. Between November to March which is the season of North-East monsoon, the solar irradiation is higher where the wind originates from the South China Sea that first passes the east coast of Malaysia and leaves from the west coast of Malaysia. Meanwhile, between May to September which is the South-West monsoon season, the solar irradiation is lower where the wind blows back from Sumatera Island and moves towards the west coast of Malaysia.

Figure 2.9 below shows the solar energy volume generated in Malaysia from 2011 to 2020 (Müller, 2021). In 2011, Malaysia produced only 1 MW of solar energy because Malaysia is at the start-up phase in developing the solar industry. After that, the solar energy capacity generated in Malaysia is increasing steadily year by year. As of 2020, the net installed solar energy capacity achieved 1,493 MW, which is nearly double of the capacity compared to 2019, which is 882 MW. The solar energy generation in Malaysia is expected to growth up to 6,500 MW (Ahmad et al., 2011).

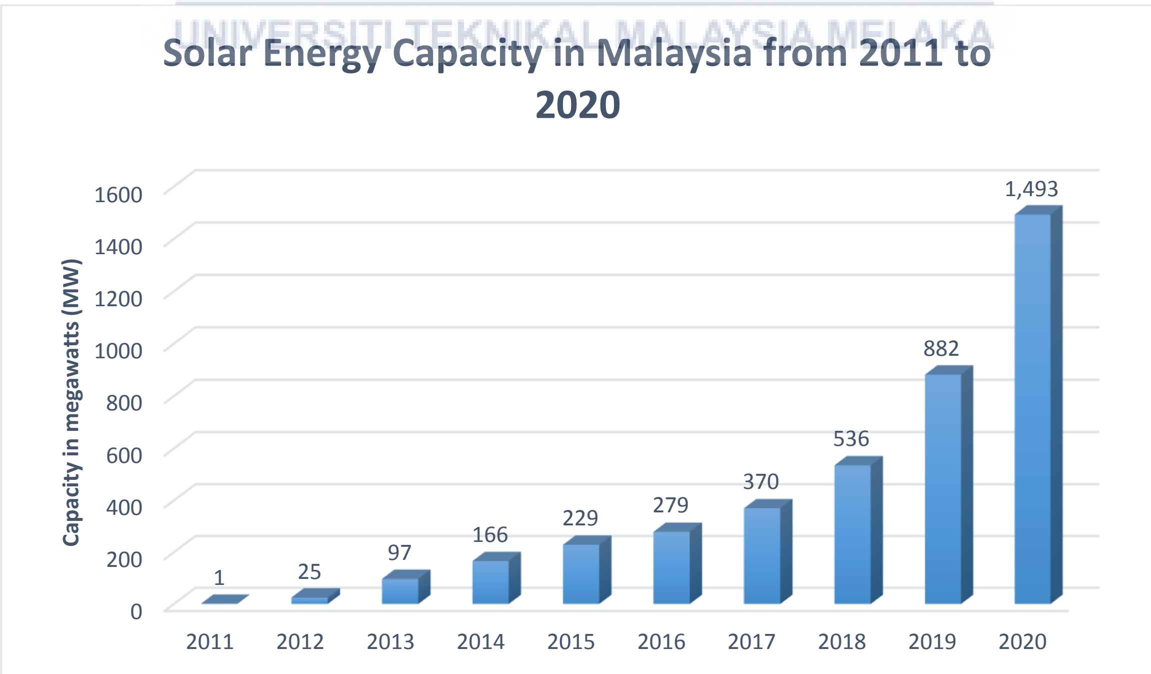


Figure 2.9: Solar Energy Capacity Generated in Malaysia from 2011 to 2020 (Müller, 2021)

2.10.2 Projection of Solar Panel Waste in Malaysia

The numbers of the used solar panels in Malaysia in the next few decades seem to sharply increase as the trend of green energy becomes more vital year by year. The solar panel waste in Malaysia for 2016 and 2020 is recorded at 20 tons and 100 tons respectively. Hence, the forecast of the solar panel waste in Malaysia for 2030, 2040, and 2050 is 2,000 tons, 30,000 tons, and 190,000 tons correspondingly (Vekony, 2021). An enormous quantity of solar panel waste is about to strike the nation if the recycling management of the EoL solar panel is not speed-up.

2.11 Policy

Renewable energy is progressively making its mark in Malaysia, improving or bettering renewable energy utilisation one step at a time by focusing on distinct factors (Vaka et al., 2020). These fundamentals, entail a mixture of policies and initiatives aimed at growing the country's economy. Some essential policies and programmes have been formed to accomplish the defined targets, and new methods are now being implemented to deliver RE to future generations. These policies are described in detail further down.

2.11.1 Malaysia National Renewable Energy Policy

The government of Malaysian is currently concentrating on the development of "fifth fuel" as a renewable energy resource (Business Monitor International, 2008). The initial goal was to generate 5% of power through renewable energy by 2005, which equated to 500-600 MW of installed volume, and the strategy began in 2001. This strategy was supported by fiscal incentives such as investment tax credits and the Small Renewable Energy Program (SREP), which helped small-scale renewable energy producing plants connect to the national grid. The SREP agreed to sell power generated from renewable projects up to 10 MW to Tenaga Nasional Berhad (TNB) for a 21-year licensing deal.

The Malaysian government launched several of vision policy to reach the 2019 targets by executing a few plans and building schemes to make renewable energy available to everybody (SEDA, 2019). SEDA Malaysia's key goal is to achieve a 20% RE capacity mix by 2025 through extended Net Energy Metering and Solar Leasing, Large Scale Solar Programme 3 (LSS3), Non-Solar RE Projects, and a RE facilitation plan. There are six in total of the main considerations for any RE policy which is, highlighting current market failures, assigning long-term sustainability; encouraging new firms; understanding the importance of the environment as a contributor to economic growth, advancing human capital resources in R&D technologies, and improving policy consistency (SEDA, 2019). Table 2.9 below illustrates the objective, strategies, and action plan of the National RE policy (Vaka et al., 2020).

Table 2.9: The objective, strategies, and action plan of the National RE policy (Vaka et al., 2020)

Objectives	Strategies	Action Plan Required
RE will contribute to increasing the domestic power generation mix by 2025.	Create a regulatory structure that is appropriate.	To construct the critical institutional structures, straightforward acts are required.
By 2025, boost the growth of RE generation cost.	Create a favourable atmosphere for the growth of the RE industry.	Measures to encourage and promote the growth and development of RE industries.
By 2025, the cost of producing RE will be reasonably predictable.	To promote RE businesses, expand human capital development.	
By 2025, the initiative will have protected the ecosystem for future generations.	Improve RE R&D activities for the country's economic growth.	
By 2025, raise awareness of RE's contribution and relevance.	Create and develop a renewable energy advocacy programme.	

2.11.2 Renewable Energy Act of 2011

This Renewable Energy Act of 2011 is accountable for the start of RE production and other connected topics, as well as the establishment and implementation of a unique tariff structure (Vaka et al., 2020). This Act covers a variety of topics and stages in the process of achieving renewable energy. On December 1st, 2011, Malaysia passed a mandatory renewable energy act, implementing a feed-in tariffs (FIT) system with yearly installed capacity restrictions until 2030. This act is intended to attract the attentiveness of various governments and financial agencies in order to economically and potentially support renewable energy and develop Malaysian RE resources. Some of the issues that show a critical character in the expansion of RE and the structure that contributes to the growth of RE are initial, FiT structure, joining, purchase, and supply of RE, information gathering powers, RE fund, FiT, execution, general and savings, and transitional (SEDA, 2019).

2.11.3 National Green Technology Policy

The National Green Technology Policy put in place a proper plan that focused on attaining energy independence and limiting climate change, which is one of the country's rising assets for economic success (Vaka et al., 2020). Green technology, according to the government, is the finest alternative for influencing the country's low-carbon economy, which is endorsed by the majority of countries. Malaysia's government has chosen to join the rest of the world in decreasing greenhouse gas emissions, thereby lessening the severity of climate change and boosting the country's economic growth. Furthermore, green technology policy is primarily based on four key aspects which are energy, environment, economy, and social. Table 2.10 below displays four key aspects that affect the National Green Technology Policy. Four foundations and five strategic thrusts underpin the new National Green Technology Policy. This strategy was implemented to diminish environmental deterioration, achieve zero or low greenhouse gas productions, reduce the consumption of energy and natural resources, and endorse the use of renewable resources (Foo, 2015).

Table 2.10: Four key aspects that affect the National Green Technology Policy (Vaka et al., 2020)

Energy	Environment	Economy	Social
Request for energy self-sufficiency.	The natural environment should be preserved and improved.	To use any technology to help the country's economic progress.	To improve everyone's quality of life.
To increase the efficiency of use.	Assist in lowering the severity rate.	By enacting a few policies.	

2.11.4 Sustainable Energy Development Authority Act of 2011

The Malaysian government's Sustainable Energy Development Authority (SEDA) is accountable for promoting and implementing sustainable energy (IRENA, 2019). The key objective of this Act is to consume or create adequate energy to meet existing demands without compromising the needs of future generations, which includes renewable energy. Furthermore, the national green technology strategy focuses primarily on a wide range of industries, including energy, construction, waste management, and carriage. The entire energy consumption of each sector was gathered, and it was discovered that residential and industry consume 33% and 30% more energy, respectively, than commercial (23%) and transportation (15%).

2.11.5 Financial Support to Encourage Small and Medium (SME) Scale Industries to Utilize Renewable Energy

The Government of Malaysia should take steps to assist small and medium-sized business (SME) from promotion through commercialization, whether through grants, subsidies, or credits (SEDA, 2020). These small firms can effortlessly access countryside areas, ensuring the potential development of renewable energy. The government of Malaysia might introduce a slew of new plans and incentives to help small and medium-sized businesses produce renewable energy, which currently falls short of international requirements. For instance, all partnerships in the solar sector must be on board in order for Malaysia's PV market to grow.

(a) Combination of solar energy with PV as part of the government's ambition to support solar energy as a realistic form of RE by installing lower-cost solar PV on all government facilities For instance, schools, hospitals, and universities.

(b) In terms of PV service providers, the Malaysian PV industry must establish a high standard of customer care, such as distribution, in order to attract greater participation in the global PV market.

(c) Implementing the green finance system and encouraging banks to provide money to solar energy projects.

2.11.6 Loans Available to Small and Large Scale Industries to Utilize and Supply Green Technology

The Green Technologies Financing Scheme (GTFS) was established by the Malaysian government to assist and launch green technology. The major goal of this programme is to promote and expand the use of green technologies and supplies (Vaka et al., 2020). Meanwhile, the government assists green technology producers and users by granting financial credits of up to 60% through the Credit Guarantee Corporation (CGC) and promising to cover the 2% interest/profit rates. Malaysia's Ministry of Energy and Green Technology, as well as the Ministry of Water, were involved in this scheme.

2.12 Malaysia in Monitoring Renewable Energy

The major bodies for monitoring overall energy production from renewable sources are the Sustainability Energy Development Authority (SEDA) and the Energy Commission. SEDA Malaysia uses its database that called PV Monitoring System (PVMS) to track PV performance based on irradiance on a regular basis (SEDA, 2020). Furthermore, the performance of PV systems at over 129 sites across Malaysia was documented on a daily and monthly basis (PVMS, 2020). According to the most recent news, the Malaysian government has launched a National PV Monitoring Performance Database as an endeavour to track the performance and reliability of chosen grid-connected solar panel systems. At this moment, Malaysia is monitoring 150 grid-connected solar panel systems with a capacity of 1 MW in real time. Later, using this data as a guidance, national energy strategies and schemes will be established and organised.

2.13 Initiative Taken by Government of Malaysia

In order to reduce electricity prices and CO2 emissions, Malaysia's government is concentrating on renewable energy and energy efficiency. Malaysian Renewable Energy (RE) supports the ministry's solar PV project, which will use the Net Energy Metering (NEM) system to capture excess energy.

2.13.1 Net Energy Metering (NEM)

The Ministry of Energy and Natural Resources (KeTSA) implemented the NEM scheme, which was regulated by the Energy Commission (EC) and implemented by the Sustainable Energy Development Authority (SEDA). According to SEDA, NEM is a solar photovoltaic (PV) programme introduced by the Prime Minister as a successor for the FiT scheme in the 2018 budget (Vaka et al., 2020). The electricity generated by solar PV systems will be utilised first, with any excess being exported to the grid. The users is then can sell the excess electricity to the local Distribution Licensee such as TNB (Peninsular Malaysia), SESB (Sabah), and Sarawak Energy (Sarawak) at the Energy Commission-determined premium rate. This scheme is applied to all TNB and SESB consumers, including residential, industrial, and commercial clients.

As of January 1, 2019, 11 MW of energy had been saved using this scheme, with the government aiming for a 20% reduction by 2030. The new Net Energy Metering 3.0 plan (NEM 3.0) was launched by KeTSA on December 29, 2020, in response to an enormous reaction from the PV industry and in an effort to expand the use of solar energy. From 2021 to 2023, the NEM 3.0 will be in place, with an overall share of up to 800 MW. Table 2.11 below lists the benefits and drawbacks of the NEM scheme (SEDA, 2016), (IRENA, 2019).

Table 2.11: Benefits and drawbacks of NEM scheme (SEDA, 2016), (IRENA, 2019)

Benefits	Drawbacks
Inspiring everyone to do its part in renewable energy generation, which has the ability to tackle the nation's energy security and climate issues	Because of its delayed adoption, the NEM has become a challenge.
Reducing the emission of greenhouse gases	NEM is the abundant electricity sold to distribution licences at a low displacement cost.
NEM also serves as a buffer against future increases in electricity tariffs.	
An addition of a battery or energy storage structure to the PV structure to improve self-consumption capability	
The certified NEM program holders have the ability to generate electricity from their PV system in the event of a grid failure.	

2.13.2 Large Scale Solar (LSS) Project

Electricity produced from a solar power station at a scale high enough to be characterised as utility-scale or large-scale is referred to as Large-Scale Solar (LSS) (Vaka et al., 2020). The main goal of LSS is to increase the amount of electricity supplied by solar PV and solar farms. Companies interested in constructing a LSS project in Malaysia will have to go through a bidding route set up by the Energy Commission (EC) (Vaka et al., 2020). EC has been conducting competitive bidding for LSS since 2016, with a total capacity of 434 MW available for Peninsular Malaysia at a levelized price of 39.95 to 44.95 Sen/kWh. In the first round of the LSS bidding competition, the incumbent utility company won 50 MW, and the Sepang LSS plant was successfully commissioned in November 2018. The EC's second round of LSS bidding gives a total of 563 MW, with a third round in 2019 likely to provide 500 MW (Abdullah et al., 2019).

The licence to build the Large-Scale Solar project is only given to the shortlisted companies. In February 2019, the commission also began the third cycle of the LSS initiative to boost renewable energy generation (Vaka et al., 2020). The first two LSS project cycles resulted in a total installed volume of 958 MW for the government. In order to encourage more industry participation in LSS, incentives must be implemented. Figure 2.10 below shows the overall capacity awarded by EC in the first and second rounds of LSS bidding in Peninsular Malaysia (goleman, daniel; boyatzis, Richard; Mckee, 2019). Perlis has the highest sun irradiation among all the states in Malaysia, making it one of a suitable candidate for solar energy harvesting.

Figure 2.10: LSS capacity awarded by EC in Peninsular Malaysia (goleman, daniel; boyatzis, Richard; Mckee, 2019)

2.13.3 Self-Consumption (SELCO)

Self-consumption (SELCO), in which the electricity produced by solar panels is used solely for personal purposes and any additional electricity is not permitted to be sent back to the grid. Because of the rising cost of electricity, the core purpose of this programme is to save more energy (SEDA, 2019). The government of Malaysia has taken steps to assist individuals, businesses, and industries in installing clean solar panels in order to lower its electricity costs correspondingly.

2.13.4 Feed-in tariff (FiT)

The feed-in tariff (FiT) programme, which began in 2004, aims to boost renewable energy investments. Malaysia has had a Feed-in Tariff (FiT) for solar PV since 2011, but it has now been replaced by a net metering programme (Vaka et al., 2020). FiT rates vary depending on the technology and capacity installed. This program's primary goal is to temporarily sell clean energy to the distribution licence. Furthermore, the length of time is determined by the renewable energy and technology practiced. Solar PV technology, for example, has a 21-year life expectancy. Every kWh of electricity that users generate will be compensated by the consumer or the government, ensuring that the particular users will recoup its investment in technology.

The government has taken initiative to promote and encourage all individuals, businesses, and manufacturers to fully employ resources in order to achieve a greener and more sustainable energy (SEDA, 2020). SEDA Malaysia is working closely with all state governments, associations, agencies, and other organisations to implement sustainable energy programmes connected to solar PV projects. The state government has tasked SEDA Malaysia with implementing the RE and EE efforts, and the company has already completed two solar PV installations as part of the smart Selangor programme. The low Carbon Building Facilitation Program and the solar PV Installation Facilitation Program are the two most essential efforts.

The main goals of the low-carbon facilitation plan are to prioritise the development of an energy management scheme, raise awareness, develop human capital volume in energy management, reduce the cost of a building's annual utility bill, and recognise the potential for energy and greenhouse gas savings (SEDA, 2020). The 50 kWp installed volume of Grid Connected Photovoltaic (GCPV) to produce EE and connected to the power supply to the building common area is the focus of the solar PV installation facilitation programme.

2.14 Centre of Gravity in Gravity Modelling Method

An optimal and proper location waste processing centre has to be easy for the transportation of the waste as the processing centre is crucial in the recycling network (Sultan et al., 2018). The centre-of-gravity method has been adopted in this study in order to recognise the suitable spot for the EoL solar panel waste recycling centre within Malaysia. The centre of gravity system is a method for computing geographic coordinates for a single new facility with a shorter distance and at the most economical cost. It is a method that takes into account the following inputs which is markets, the volume of goods transported, and the cost of transport (Ng et al., 2003). This optimal location identification technique has the advantages of simple calculation, taking into account current facilities, and cost economics.

The formula proposed by (Chase et al., 1998) to calculate the centre of gravity is apply in this research paper. As illustrated in Figure 2.11, each latitude and longitude in the spherical coordinate system is transformed into the Cartesian coordinates (X, Y, Z) in order to calculate the precise distance. The weightage is then multiplied by the X, Y, and Z coordinates, and the result is appended. The location where the line crosses the earth's surface is the geographic midpoint. A line might be drawn from the earth's focal point out to these new X, Y, and Z values. The midpoint's latitude and longitude are calculated using this surface point. Notable is the assumption that the earth is a perfect spherical rather than an oblate spheroid.

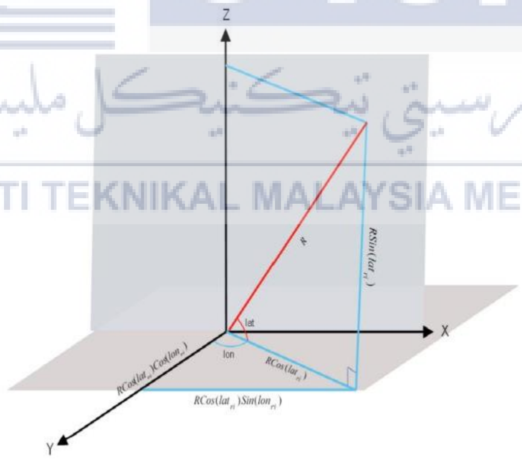


Figure 2.11: System Conversion of Spherical coordinate into Cartesian coordinates (Chase et al., 1998)

2.15 The Supply Chain Complexity Assessment

The waste distribution channel complexity index is determined by factoring in transportation distance and waste volume generated across the whole supply chain network

(Sultan et al., 2018). The number of individual excursions required to collect waste from a spot, as measured by the parameter H, is the number of trips required if the waste could be calm in a single visit. Figure 2.12 below shows the supply chain complexity is thought to be proportional to waste mass and travel distance, with the circle signifying the amount of waste in each point (M1, M2, M3, M4, and M5) and the line denoting the distance travelled from the waste source close proximity to the recycling centre (D1, D2, D3, D4, and D5).

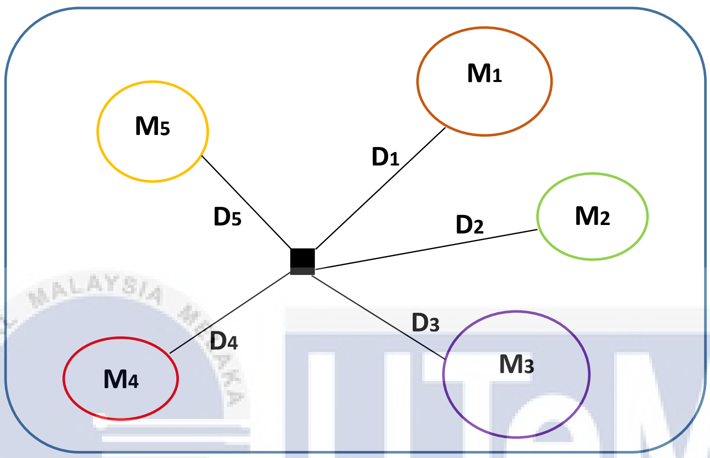


Figure 2.12: Supply Chain Complexity Concept Diagram (Sultan et al., 2018)

2.16 Carbon Footprint Weighted Sum Method

The weighted sum method was employed in this carbon footprint supply chain assessment. In weighted sum method, the shortest travelling route of the travelled waste from each solar plant to the collection centre or recycling centre would be determined which would also consider the minimal cumulative value of total distance travelled and greenhouse gas (GHG) emission as criterion. According to recommendations made by the Department for Environment Food & Rural Affairs in the UK, GHG emission conversion factors are employed in accordance with the number and nature of vehicles used (Department for Environment Food & Rural Affairs, 2016). In Table 2.12 below, the conversion factors are displayed. Employing the distance-based approach for transportation compliant with the Greenhouse Gas Protocol, the specific distance and greenhouse gas emissions are measured (GHG Protocol, 2016). Before the entire amount of waste could be delivered, a variety of vehicles were still feasible.

Table 2.12: GHG Emission and Conversion Factors per-vehicle-per-tonne-km (Department for Environment Food & Rural Affairs, 2016)

Vehicle and Body Type	Gross Vehicle Weight (tonne)	Waste Capacity (tonne)	$kgCO_2e$ per tonne-km			
			CO_2	N_2O	CH_4	Total
Heavy Duty Truck, (Firm)	>3.5-7.5	2.00	0.55235	0.00632	0.00025	0.55892
Heavy Duty Truck, (Firm)	>7.5-17	5.00	0.36321	0.00416	0.00017	0.36754
Heavy Duty Truck, (Firm)	>17	9.00	0.16905	0.00194	0.00008	0.17107
Heavy Duty Truck, (Articulated)	>3.5-33	12.35	0.14413	0.00165	0.00003	0.14581
Heavy Duty Truck, (Articulated)	>33	18.50	0.08054	0.00092	0.00002	0.08148
Van, Class I, Diesel	<1.4	0.64	0.64610	0.00790	0.000066	0.65407
Large Ferry Freight	N/A	N/A	0.38434	0.00286	0.00015	0.38735

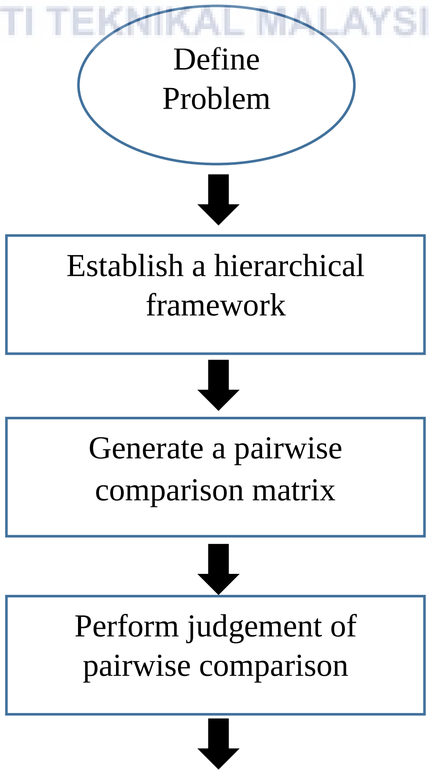
2.17 The Recycling Locations Decision by Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is one of the helpful tools that can be applied during the selection stage. The AHP is a strong and adaptable weighted scoring decision making technique that developed at the Wharton School of Business to assist people in setting priorities and choosing the optimum solution (Saaty, 1980). Multi-criteria decision making has been resolved through AHP in both academic and industrial application. AHP has been employed in practically all decision-making applications, and it is primarily used in the selection and evaluation of prospects, particularly in the fields of engineering, personal, and sociological sectors (Vaidya et al., 2006). Implementing AHP typically relies on the expertise and knowledge of users or experts to identify the variables influencing the decision-making process (Ho, 2008) (Dweiri & Al-Oqla, 2006). There are a total of 20 industrial expert judgments involved as determinants of the variable weights in this study.

The first step in applying AHP is to formulate the decision problem as a hierarchy structure, with the top level representing the general objectives or aim, the middle levels representing the criteria and sub-criteria, and the bottom level representing the option alternatives. Participants are asked to set up a pairwise comparison matrix at each hierarchy and compare one another using a pairwise comparison rating scale (1-9) once a hierarchy framework has been built, as illustrated in Table 2.13 (Hajeeh & Al-Othman, 2005). The relevance of each comparison matrix is then determined by using the eigenvector approach to solve each comparison matrix in the synthesis of priority stage (Cheng et al., 2007). Moreover, develop the overall priority ranking based on the value calculated and select the best alternative. These concepts can be further developed as depicted in Figure 2.13 (Hambali et al., 2008).

Table 2.13: Fundamental Pairwise Comparisons Rating Scale (Hajeeh & Al-Othman, 2005)

Scale	Definition
1	Equally important
3	Variable A is slightly more important than variable B
5	Variable A is more important than variable B
7	Variable A is more important than variable B
9	Variable A is absolutely more important than variable B
2,4,6,8	Value between the two closest numbers



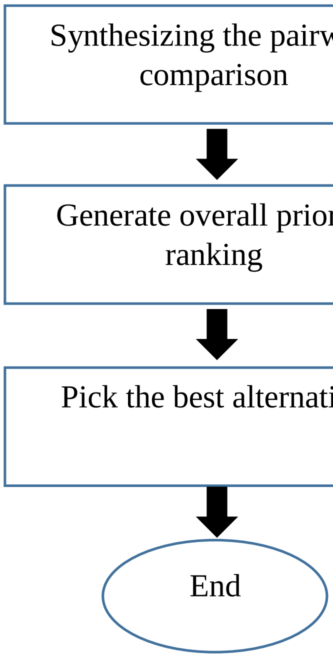


Figure 2.13: Step in Applying AHP (Hambali et al., 2008)

2.18 Geospatial Clustering Approach

Depending on the geospatial segmentation of the location based on region or state as in the previous section, the centre-of-gravity approach was utilised to locate the recycling centre. Under this scenario, it's likely that the solar plant will be situated near or at the state or region's border, which could put it closer to the recycling facility for a different state or region. As a result, finding additional different clustering option away from the region or state constraints will enable better waste supply chain management. To overcome this kind of challenge, a clustering algorithm is necessary.

2.18.1 K-Means Clustering Algorithm

Connectivity models, density-based clustering, distribution models, and centroid models are just a few of the several kinds of clustering models that are accessible (P. Tan & Steinbach, 2006). These models and associated properties are depicted in Table 2.14. For the location clustering, K-Means, which is based on centroid models, would be preferred to utilise in this research. With the implementation of the clustering algorithm, this may involve a thorough allocation and planning based on several council or local government requirements, yet it could be more reliable than the earlier methodology because the closest distances among the solar plant without any border restrictions are now taken into account.

Table 2.14: Several Kinds of Clustering Models (P. Tan & Steinbach, 2006)

Clustering Models	Instance of the Models	Justification of the Models
Connectivity	Hierarchical	These algorithms create models based on connectedness over distance rather than offering a single way to divide the data set.
Density-Based Clustering	DBSCAN	It may have difficulty in distinguishing neighbouring clusters and this algorithm predicts that clusters have a similar density.
Distribution	Expectation-maximization Algorithm	The modelling of clusters is achieved using statistical distributions (i.e. multivariate normal distributions). These methods place an additional load on the user because there might not be a clear-cut mathematical model for many real data sets.
Centroid	K-Means Algorithm	The algorithms allocate each element to the closest centroid for each cluster, which is represented by a single mean vector for each cluster.

One well-known division technique for clustering is the K-means algorithm (Arora et al., 2016). The K-means clustering algorithm divides the data into groups based according to how near the solar plant and recycling facility are to one another in terms of Euclidean distance. It divides a collection of locations into an initial number of clusters as an input parameter. In order to build clusters, the object's mean value is set as a similarity parameter. The cluster mean or centre is created through the picking of clusters at random. Other objects are grouped together based on resemblance. This algorithm determines the separation between each location and the centroid of each cluster. The fundamental steps in k-means are as below (Geetha et al., 2009).

1. 1 Determine the number of k-th cluster in a given supply chain boundary to manage the used solar panels.
2. Randomly create k clusters and identify respective centres, or simply create k random points and use those as the cluster centres.
3. Determine the closest cluster centre for each point.
4. Recalculate the new cluster centres, and
5. Continue with step 3 until a convergence requirement is reached or the cluster centres remain the same.

2.19 Summary

The recycling rate of the used solar panel in worldwide is increasingly more vital as the prediction on the global solar energy generated, the global cumulative of electricity capacity generated by solar power, and the forecast of the global quantity of solar panels waste is reported to rise drastically until 2050 according to an analysis made by (IRENA and IEA-PVPS, 2016). Malaysia, as one of the countries that is suitable to develop solar energy, started this investment before this and is currently further expanding this renewable energy with several schemes. With the growth in the quantity of the solar panels usage, the capacity of EoL solar panels waste is also predicted to rise to 190,000 tons in 2050. Hence, it is necessary for Malaysia to identify and propose the solar panel recycling centres within this country to avoid the mass amount of solar panels waste end-up in landfills. The methods that are going to be applied in this study included Centre-of-Gravity Method, Supply Chain Complexity, Weighted Sum Method, Analytical Hierarchy Process (AHP), and K-Means Clustering Algorithm.

CHAPTER 3

METHODOLOGY

This chapter will present a detailed flow chart regarding the steps in constructing the end-of-life solar panel recycling management by conducting two different clustering alternatives in Malaysia. For the first clustering alternative, the centre-of-gravity approach is utilised in this study in order to recognise the suitable spot for the EoL solar panel waste recycling centre according to each region allocated within Malaysia. Furthermore, the supply chain complexity and weighted sum method (considered total transportation distance and total carbon footprint) was applied to determine the most ideal alternative from several alternatives for transporting the waste to respective collection or recycling centres based on different attributes considered. Meanwhile, K-means clustering algorithm was the second clustering alternative employed in this study. The related equations for both approaches is also being recognised throughout this chapter.

3.1 Process Flow Chart

Figure 3.1 below displays the process flow chart for this study. This study starts with the bottomless literature review of the related articles, journals, conferences papers and etc. Next, gather and list all the locations of the LSS farm within Malaysia. Furthermore, by utilising the centre-of-gravity method to identify the midpoint location for the solar panel recycling centres according to each region allocated in Malaysia. All the locations identified must be in an area that is optimal for waste carriage purposes. Another clustering alternative, K-means algorithm is then carried out to optimise the clusters, which will permit for a better management of the waste supply chain (no border restriction). A proper and varied planning is needed due to different local council requirements. Lastly, proposed all the locations of the recycling centres obtained.

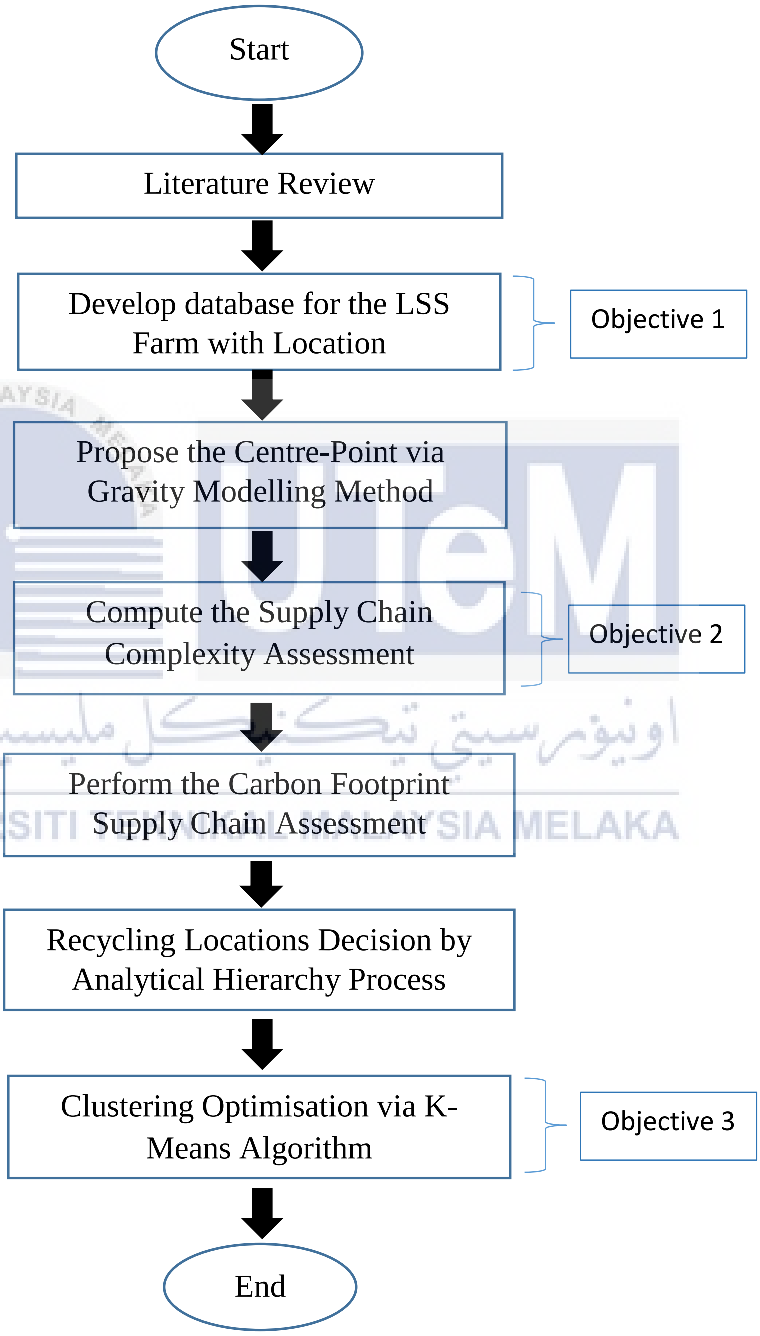


Figure 3.1: Flowchart of the Research

3.2 Propose the Centre-Point via Gravity Modelling Method

In order to obtain the proposed locations for recycling facilities, the locations in the form of latitude and longitude coordinates for the solar plant are identified initially and are then altered into radians as shown in equations 1 and 2 below. Next, these radian forms of latitude and longitude coordinates are then converted into the Cartesian coordinate system via the equations 3, 4, and 5 as below. Table 3.1 below illustrates the justification of the alphabet for equations 1 to 5.

$$(1)\ lat_{ri} = \frac{lat_i\,\pi}{180}$$

$$(2)\ lon_{ri} = \frac{lon_i\,\pi}{180}$$

$$(3)\ X_i = R\cos(lat_{ri})\sin(lon_{ri})$$

$$(4)\ Y_i = R\cos(lat_{ri})\cos(lon_{ri})$$

$$(5)\ Z_i = R\sin(lat_{ri})$$

Table 3.1: Justification on the alphabet for equations 1 to 5

Number	Alphabet in Equation	Explanation
1.	lat_{ri}	Radian form for latitude of i-th location
2.	lon_{ri}	Radian form for longitude of i-th location
3.	lat_i	Degree form for latitude of i-th location
4.	lon_i	Degree form for longitude of i-th location
5.	X_i	X-axis in Cartesian form for i-th location
6.	Y_i	Y-axis in Cartesian form for i-th location
7.	Z_i	Z-axis in Cartesian form for i-th location
8.	R	Radius of earth

The calculation were assigned based on two various scenarios, which is considering all solar farm as similarly vital, and weightage were assigned based on the volume of generated wastes. Each solar plant's waste production volume was measured and documented and weighted in the computation. Theoretically, the recycling centre should be located nearer to the solar plant that produces the higher volume of waste.

According to this method, it is advocated that the recycling centre is located in the center of all the solar farms by taking into account the quantity of the waste created by each farm. According to a paper published by (Chase et al., 1998). It evaluates latitude and longitude data and converts it to Cartesian coordinates which reveal the central position for the waste processing centre. As a result, the weighted Cartesian coordinates of X, Y, and Z were calculated using equations 6, 7, and 8 shown below. The coordinate data was then transformed to latitude and longitude for a plan projection. Table 3.2 below states the explanation towards the alphabet for equations 6, 7, and 8.

$$(6)\ X_c = \sum_{i=1}^{j} \left[\frac{\sum_k^n x_k (M_k)}{\sum_k^n M_k} \right]_{ui}$$

$$(7)\ Y_c = \sum_{i=1}^{j} \left[\frac{\sum_k^n y_k (M_k)}{\sum_k^n M_k} \right]_{ui}$$

$$(8)\ Z_c = \sum_{i=1}^{j} \left[\frac{\sum_k^n z_k (M_k)}{\sum_k^n M_k} \right]_{ui}$$

Table 3.2: Explanation towards the alphabet for equations 6, 7, and 8

Number	Alphabet in Equation	Explanation
1.	X_c	The centre-of-gravity in X coordinate
2.	Y_c	The centre-of-gravity in Y coordinate
3.	Z_c	The centre-of-gravity in Z coordinate
4.	x_k	X coordinate from k-th location
5.	y_k	Y coordinate from k-th location
6.	z_k	Z coordinate from k-th location
7.	M_k	Weightage mass of solar panel wastes relocated to the recycling centre
8.	ui	Year of study

* The k-th location will differ depending on accumulated years of study.

Equations 9 to 11 were used to shift the Cartesian coordinates for the midpoint or centre of gravity of the solar plant back to the form of latitude and longitude. Equations 12 and 13 were implemented to convert the final midpoint latitude and longitude from radians to degrees. Table 3.3 below displays the justification on the alphabet for equations 9 to 13.

$$(9) \qquad Lon = Arc\tan(x, y)$$

$$(10) \qquad \text{Hyp} = \sqrt{x^2 + y^2}$$

$$(11) \qquad Lat = Arc\tan(Hyp, y)$$

$$(12) \qquad Lat_m = \frac{Lat\,(180)}{\pi}$$

$$(13) \qquad Lon_m = \frac{Lon\,(180)}{\pi}$$

Table 3.3: Justification on the alphabet for equations 9 to 13

Number	Alphabet in Equation	Explanation
1.	Lon	Radian form of midpoint of longitudinal coordinate
2.	Lat	Radian form of midpoint of latitudinal coordinate
3.	Hyp	Radian form of hypotenuse of Cartesian coordinates
4.	Lat_m	Degree form of midpoint of latitudinal coordinate
5.	Lon_m	Degree form of midpoint of longitudinal coordinate

The general phases in applying the centre of gravity techniques is start with determine the amount of items waste transferred from the solar farm to the recycling centre (which location will be looked for) for each period. Follow by opening the map and choose a starting point (0.0). Lastly, create a coordinate system with the recycling centre locations as the starting point.

3.3 The Supply Chain Complexity Assessment

The solar farm was used as a collecting point in this study. If there have increase in the collection of locations, these would need to be handled as separate circles in the analysis. Equation 14 is used to model supply chain complexity, and it was taken from Dahmus and Gutowski's design complexity model (Dahmus & Gutowski, 2007). A similar approach is utilised in this study to assess the problems of the waste reverse supply chain (i.e., taking carriage distance and waste capacity into account) at a specific supply chain network between waste resource locations and recycling centres. The complexity of item distribution in the supply chain network will be represented overall mathematically here. Equation 14 was used to describe the supply chain's complexity H_s, with K = -1 resulting in a positive integer as the response. Table 3.4 below states the explanation on the alphabet for equations 14, 15, and 16.

$$(14) \quad H_s = K \sum_{i=1}^{M} W_i D_i \log W_i D_i$$

Where;

$$(15) \quad W_i = \frac{M_i}{M_{total}}$$

$$(16) \quad D_i = \frac{L_i}{R}$$

Table 3.4: Explanation on the alphabet for equations 14, 15, and 16

Number	Alphabet in Equation	Explanation
1.	W_i	Mass fraction of waste in a solar farm in term of whole supply chain
2.	M_i	Actual weight of the waste in kilogram (kg)
3.	M_{total}	Total mass of the waste in the supply chain (in kg)
4.	D_i	Distance scale of the waste source to the recycling centre
5.	L_i	Transport distance of the item (in km)
6.	R	Longest distance in the supply chain (in this research which was set as 1700 km for the Malaysia)

Moreover, a component excision concept as stated in equation 17 was adopted in this study, with K = -1 resulting in a positive integer (Sultan et al., 2018). C_i as the component weight fraction which is illustrated in equations 18. M_i represents the actual weight of the component in kilogram (kg), while M_{total} indicates the total weight of the assembled solar panels. The binary excision applied to retrieve a component was expressed by the base of two logarithms.

$$(17) \quad H_m = K \sum_{i=1}^{M} C_i \log C_i$$

Where;

$$(18) \quad C_i = \frac{M_i}{M_{total}}$$

3.4 The Carbon Footprint Supply Chain Assessment

Since the weighted sum method is the most well-known and uncomplicated multi-criteria decision analysis (MCDA) method, it is utilised to determine the best alternatives (Naidu et al., 2014). When dependent or conflicting variables affect the decision maker's aims, people may use this strategy. By using the instance of two criteria utilised in this research (total distance travelled and greenhouse gas), the formulation that may be employed with stages to redefine initial data to the normalised score of alternatives. To calculate the normalised score of the alternatives in the criteria, equation 19 was utilised. In order to attain normalised weights for the criteria, equation 20 was used. To enable mathematical calculation among the criteria utilising different units, normalisation is mandatory. Equation 21 was employed to attain the optimal alternative for the minutest function of optimised criteria. Description of the alphabet for equations 19 to 21 are presented in Table 3.5 further down.

$$NS_{ij} = \frac{S_{ij}}{\sum_{i=1}^{n} S_{ij}} \quad (19)$$

$$NW_j = \frac{W_j}{\sum_{j=1}^{m} W_j} \quad (20)$$

$$F_i = \sum_{j=1}^{m} NW_j \times NS_{ij} \quad (21)$$

Table 3.5: Description on the alphabet for equations 19 to 21

Number	Alphabet in Equation	Explanation
1.	i	Alternative
2.	j	Criteria
3.	NS_{ij}	Normalised Score of Alternative i in Criteria j
4.	S_{ij}	Score of Alternative i in Criteria j
5.	NW_j	Normalised Weight of Criteria j
6.	W_j	Weight of Criteria j
7.	F_i	Final score of Alternative i

3.5 Recycling Locations Decision by Analytic Hierarchy Process

The Analytical Hierarchy Process (AHP) procedure for this study is as follows:

For a matrix of pairwise element: $\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$

1) Sum the values in each row of the pairwise matrix as shown in Equation 22.

$$C\ ij = \sum_{i=1}^{n} C\ ij \qquad (22)$$

Where:

n= Number of items

i= Row of pairwise matrix

$C\ ij$= The entry in the i row and the j column of pairwise matrix

2) Divide each element in the matrix by its row with the sum of the pairwise matrix total to generate a normalized pairwise matrix as illustrated in Equation 23.

$$X\ ij = \frac{C\ ij}{\sum_{i=1}^{n} C\ ij}\ ;\ \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix} \qquad (23)$$

Where:

n= Number of items

i= Row of matrix

$X\ ij$= The entry in the i row and the j column of normalized pairwise matrix

$C\ ij$= The entry in the i row and the j column of pairwise matrix

3) Divide the sum of the normalized column of the matrix by the number of variables used (n) to generate the weighted matrix which is priorities vector as displayed in Equation 24.

$$(24) \qquad Wj = \frac{\sum_{j=1}^{n} X\, ij}{n}; \begin{bmatrix} W_{11} \\ W_{12} \\ W_{13} \end{bmatrix}$$

n= Number of items

j= Column of matrix

Wj= The entry in the j column of weighted matrix

3.6 Clustering Optimisation via K-Means Clustering Algorithm

The waste detail that is, the coordinates and volume of the waste is crucial for identifying the best clusters for recycling centres. In this instance, it was determined that the problem evaluation pertains to Malaysia with the number of solar plants (n) and an identified quantity of waste, scattered in spherical coordinates (later were converted to Cartesian coordinates). Next, the number of solar plants (n) were grouped to form clusters, (k). Equation 25 shows the example of the number of solar plant in each cluster can be described as below.

$$(25) \qquad \sum_{j=1}^{k} n_j = n$$

Let X be the binary matrix, such that:

$$X_{ij} = \begin{cases} 1 & if\ solar\ plant\ i\ is\ allocated\ to\ cluster\ j, \\ 0 & otherwise \end{cases}$$

The solar plant C_1, C_2,..., should be positioned in the (x, y) plane. The aim is to determine X that reduces

$$(26) \qquad \sum_{j=1}^{k} \sum_{i=1}^{n} Distance_{ij} \times X_{ij}$$

$$(27) \qquad \sum_{j=1}^{k} X_{ij} = 1$$

$$(28) \qquad \sum_{i=1}^{n} d_i X_{ij} < C_{max}$$

$$(29) \qquad \sum_{i=1}^{n} d_i X_{ij} > C_{min}$$

Depending on where the $Distance_{ij}$ indicates how close the solar plant i is to the cluster j (i.e. distance of travel between i and j). The main function (Equation 26) is to reduce the total distances that solar plants must traverse to reach the cluster centre. Equation 27's constraint guarantees that only one cluster j is given to each solar plant i. The restriction (Equations 28 and 29) is to keep the cluster's total waste, C_{max} and C_{min}, within the operating range of the cluster's maximum and minimum operating capacities. In this problem, C_{max} is assumed to be 20,000 tonne, which was based on the capacity of the worldwide recycling facility that is currently in operation. A 300 tonne minimum operating capacity, C_{min} was established as in Equations 29.

The distance between the solar plant and the collecting or recycling centre is computed utilising Euclidean distance ($distance_{ij}$) as presented in Equation 30, where i denote the solar plant and j represent the number of clusters. The minimal number of clusters could serve as the initial number of clusters (e.g. 1 clusters).

$$(30) \qquad Distance_{ij} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$$

K-means algorithm could be applied to estimate the ideal number of clusters among the 454 solar plant located within the entire Malaysia. The following are the steps in computing clusters:

1. Apply Equations 3 to 5 to convert all of the longitudinal and latitude data into Euclid form so that the distance between the solar plant and collecting or recycling centre can be calculated.
2. Choose K, the initial cluster number, from the smallest cluster number (k = 1).
3. Employ Equation 25 to calculate distances between each cluster point and all other points.

4. Allocate each plant to the cluster with the closest mean, then use the centre of gravity formula to evaluate the cluster centres.
5. Apply Equation 14 to calculate the overall supply chain complexity for clusters.
6. Repeat from step 3 (recalculating distances and reallocating cases to clusters until there is no change) until the algorithm converges.
7. Compute the overall waste produced by each group.
8. If the cumulative waste for each group is less than or equal to 20,000 tonnes (the processing capacity of the waste centre) and more than or equal to 300 tonnes (the lowest tolerable operating capacity of the waste centre), then halt; otherwise, increase the number of clusters (k = k +1) and proceed to step (3).

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter begins with database development of the solar plant in Malaysia (LSS and Non-LSS plant). The recycling locations on several illustrative scenarios via the gravity modelling method was presented. Next, section 4.3 displays the supply chain complexity assessment for all the three scenarios in order to identify the least complex supply chain. Furthermore, section 4.4 illustrates the carbon footprint supply chain assessment by weighted sum analysis. A decision making tool, AHP was utilized to determine the best decision afterward. Moreover, K-Means clustering algorithm as the clustering optimisation was also utilised and included in this chapter to determine the optimal locations for recycling centres without the limit of the state's border for LSS and Non-LSS solar plant in Malaysia. The gravity modelling method and supply chain complexity assessment for different periods of solar panels waste was also included in this study.

4.1 Identification of the Solar Plant in Malaysia

4.1.1 Determine LSS Plant

Since the first bidding process began in 2016, the EC of Malaysia has conducted four bidding processes to allocate the license to the selected company to build, operate, and own the solar plant within the states of Malaysia (excluding Sarawak) as of 2022. For the first round of the LSS bidding, there are 19 companies which are shortlisted by the EC of Malaysia to build the LSS solar plant under five capacity packages offered (Suruhanjaya Tenaga, 2017). Next, 41 companies are being shortlisted in the second round of the LSS bidding under five volume packages offered (Bidders et al., 2019). Meanwhile, there are only five companies which are qualified through EC to develop the LSS solar plant in the third round of the LSS bidding (Energy Commission Malaysia, 2020). Furthermore, a number of 30 companies are being shortlisted in the fourth round of the LSS bidding under two capacity packages offered (Energy Commission, 2021).

Hence, there are in total 95 companies that were awarded to develop the LSS solar plant by EC of Malaysia within the four round of bidding processes. However, there will be only 89 companies that will be taken into account or considerations to perform the various analyses in this study (**refer Appendices A**). There are several reasons that cause the eliminations of the six companies, where one of the companies that have been awarded with the LSS project initially has been revoked by EC of Malaysia (JETRO, 2021). Meanwhile, the other five companies are also excluded in this study due to the lack of detailed information about these solar plants. The list of companies that was precluded in this study was displayed in **Appendices B**.

4.1.2 Recognise Non-LSS Plant

Besides the LSS scheme that is conducted by the government of Malaysia, there are numerous solar farms that are built, and operated by the public (i.e. private, and private company) with varying capacities. For this study, there are 365 Non-LSS plants that has been successfully identified within the entire Malaysia (**refer Appendices C**). This makes the overall number of the solar plant that will be included in the several analyses that will be presented in the following sections become 454 in total. The analyses include; Centre-of-Gravity Approach, Supply Chain Complexity Measure, Weighted Sum Method, and K-Means Clustering Algorithm.

4.1.3 End-of-Life Solar Panels Waste Analysis

Figure 4.1 displays the cumulative installed solar capacity (in MW) trend as of 2022 together with the foresight of future solar panels waste up to 2051. The earliest solar panels being installed among the 454 solar plants was in 2007 (0.45 MW capacity) and is predicted to be discarded in 2034 will produce 29 tonnes of waste. This figure is then estimated to rise drastically to over 191,379 tonnes at the year of 2051, where the total cumulative capacity of over 2,947 MW. Among the time frame, 2050 will receive the most solar panel waste thanks to the planned capacity installed in the single year of 2023 was the largest from 2007 to 2024. Note that there are in total 45 out of 454 solar plants with an unidentified year of operation and hence are being excluded in this analysis.

Table 4.1 indicates the operating year of the solar farm. Table 4.2 below illustrates the numbers of solar plants located in each state. Selangor, with 114 solar plants was the state with the most solar plant within Malaysia. On the other hand, Perak was the state which generated the highest solar capacity of Malaysia. Table 4.3 shows the distribution of capacity weightages by LSS and Non-LSS. It shows obviously that LSS has significantly more weightages than Non-LSS and requires more attention.

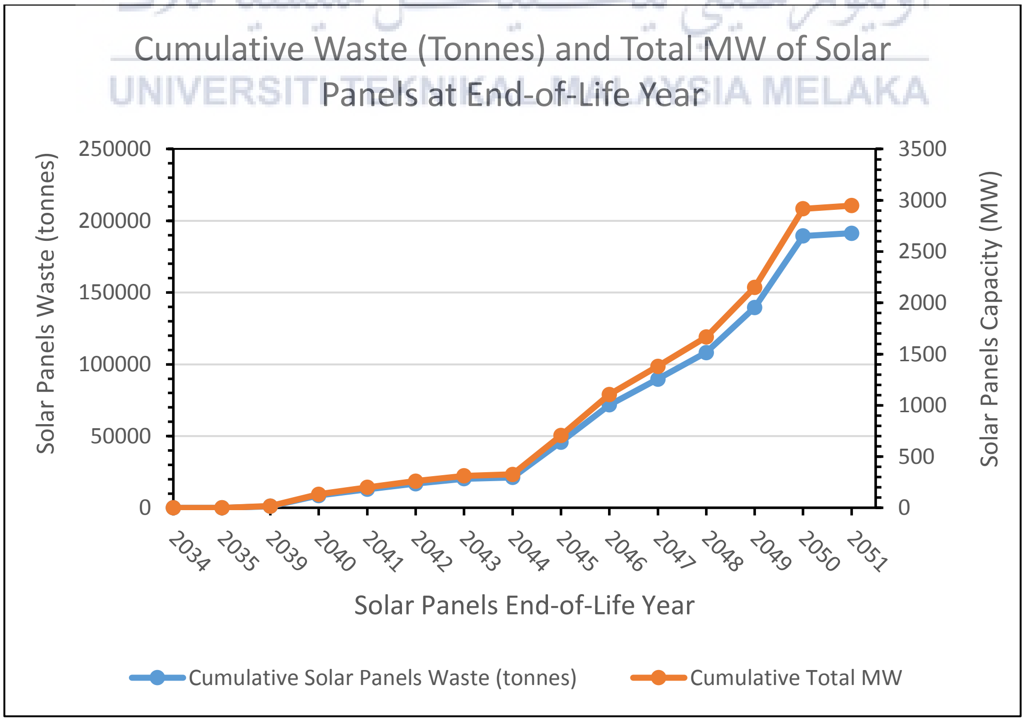


Figure 4.1: Cumulative Installed Solar Capacity and Foresight of Solar Panels Waste

Table 4.1: Operating Year of Solar Farm

Year	Average lifetime of solar panel (27)	Total number of farm	Solar Panels Waste (tonnes)	Cumulative Solar Panels Waste (tonnes)	Total MW	Cumulative Total MW	Percentage (%)
2007	2034	1	29.214	29.214	0.450	0.450	0.014
2008	2035	1	5.843	35.057	0.090	0.540	0.003
2012	2039	19	1,086.112	1,121.170	16.730	17.270	0.520
2013	2040	43	7,495.014	8,616.180	115.450	132.720	3.587
2014	2041	60	4,376.257	12,992.440	67.410	200.130	2.095
2015	2042	95	3,926.362	16,918.800	60.480	260.610	1.879
2016	2043	89	3,371.945	20,290.750	51.940	312.550	1.614
2017	2044	5	913.554	21,204.300	14.072	326.622	0.437
2018	2045	18	24,640.126	45,844.430	379.546	706.168	11.793
2019	2046	15	25,985.528	71,829.960	400.270	1,106.440	12.437
2020	2047	17	17,868.646	89,698.600	275.241	1,381.680	8.552
2021	2048	9	18,467.143	108,165.740	284.460	1,666.140	8.839
2022	2049	11	31,468.672	139,634.420	484.730	2,150.870	15.062
2023	2050	25	49,797.535	189,431.950	767.060	2,917.930	23.834
2024	2051	1	1,947.600	191,379.550	30.000	2,947.930	0.932
N/A	N/A	45	17,552.161	208,931.710	270.366	3,218.300	8.401
TOTAL		454	208,931.711		3218.295		100

Table 4.2: List of Solar Farm Locations by States

States/ Federal Territory	Total number of farm	Total MW	Percentage (%)
Perlis	14	100.501	3.123
Kedah	45	528.670	16.427
Pulau Pinang	45	134.984	4.194
Perak	46	653.720	20.313
Kuala Lumpur	8	3.832	0.119
Selangor	114	391.622	12.169
Negeri Sembilan	27	116.840	3.630
Melaka	12	74.230	2.307
Johor	34	152.590	4.741
Kelantan	13	108.290	3.365
Terengganu	18	386.080	11.996
Pahang	16	334.316	10.388
Sabah	59	177.060	5.502
Sarawak	3	55.560	1.726
TOTAL	454	3218.295	100

Table 4.3: Capacity Weightages by LSS and Non-LSS

	Total MW	Percentage (%)
LSS	2203.824	68.48
Non-LSS	1014.471	31.52
TOTAL	3218.295	100

4.2 The Gravity Modelling Method for Proposing Recycling Locations

Based on geospatial clustering, a number of possible recycling centre scenarios were taken into consideration: (1) new proposed recycling facility for the entire Malaysia, (2) new recycling centres in every region of Malaysia (including Northern, Central, Southern, East Coast, Sabah, and Sarawak) with multiple collection centres, (3) new recycling centres with each one collection centres in Peninsular, Sabah, and Sarawak. Calculations were performed by MATLAB and equations 1-13. The weightage was the quantity of waste produced by a particular solar farm or company.

From the calculations, the geographic midpoint obtained are as follows. For the northern region (include state of Perlis, Kedah, Pulau Pinang, and Perak), the initial geographic midpoint attained in latitude and longitude was 5.160298, 100.695788 (in Selama, Perak) and is then relocated to 5.170386839719077, 100.70602548935739, respectively pinpointed the location as Selama, Perak due to the ease of transportation concern. Figure 4.2 displays the geographic midpoint for the northern region on google map. Next, for the central region (consist of federal territory of Kuala Lumpur, Putrajaya, and state of Selangor), the early geographic midpoint obtained in latitude and longitude was 3.0658, 101.553948 (Kampung Kebun Bunga, Shah Alam, Selangor), where located at the residential area, and hence is then moved to 3.0588761161638907, 101.54917179728511 Section 21, Shah Alam, Selangor. The proposed location for the recycling centre in central region on map was presented in Figure 4.3.

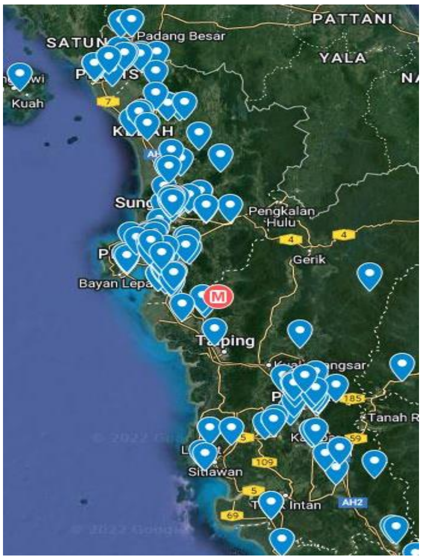


Figure 4.2: The geographic midpoint for northern region

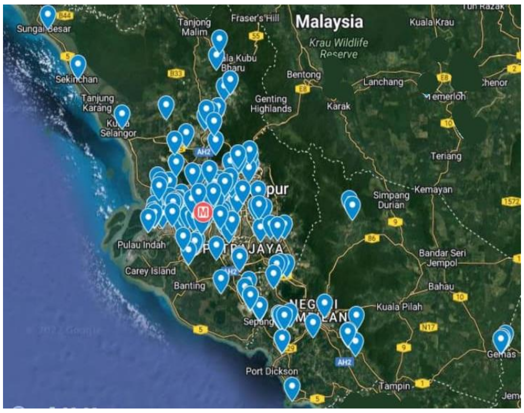


Figure 4.3: The geographic midpoint for central region

Furthermore, the geographic centre gained for the southern region (include state of Negeri Sembilan, Melaka, and Johor) was 2.100978, 102.907785 (Sri Medan, Johor) in latitude and longitude initially, it is then repositioned to 2.088761, 102.923824 in Sri Medan, Johor also due to the transportation concern. Figure 4.4 shows the suggested geographic midpoint of the southern region on map. Meanwhile, the early geographic midpoint obtained in latitude and longitude was 4.572295, 103.156094 (Al-Muktafi Billah Shah, Terengganu) for east coast region (consist of state of Kelantan, Terengganu, and Pahang) and due to the ease of transportation factor, the geographic midpoint was shifted to Al-Muktafi Billah Shah, Terengganu also with the latitude and longitude in 4.5640212882407, 103.19339696357626. The recommended recycling location for the east coast region in map was presented in Figure 4.5.

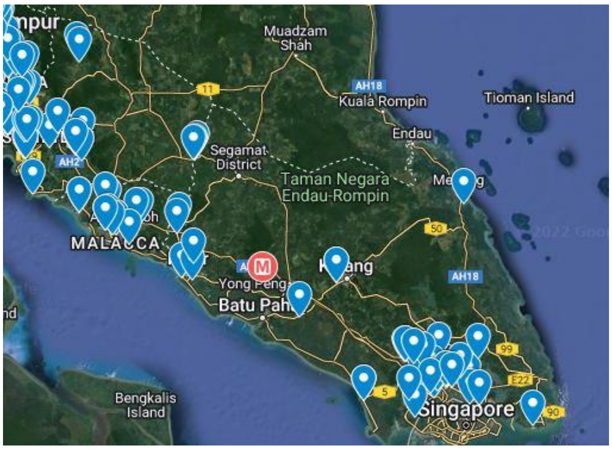


Figure 4.4: The geographic midpoint for southern region

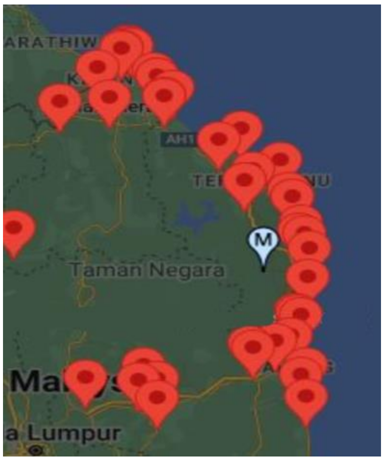


Figure 4.5: The geographic midpoint for east coast region

The geographic centre obtained within the solar farm in peninsular Malaysia was in (Ulu Jelai, Pahang) with the latitude and longitude of 4.369493, 101.746201 initially, the location is then relocated to 4.360006251573142, 101.65859141132695 where in Ulu Jelai, Pahang as well due to transportation concern. Figure 4.6 unveiled the geographic midpoint for peninsular Malaysia on google map. For the state of Sabah and federal territory of Labuan exclusively, the geographic midpoint obtained is in Ranau, Sabah with the latitude and longitude 5.981374, 116.728505 (refer Figure 4.7). The initial geographic midpoint attained within Sarawak solely was 1.305532, 111.89419 in latitude and longitude (Lubok Antu, Sarawak), the geographic centre is then repositioned to Engkilili, Sarawak with the latitude and longitude in 1.277259, 111.628823 because of the carriage reason. The recycling location for Sarawak on google map was exhibited in Figure 4.8.

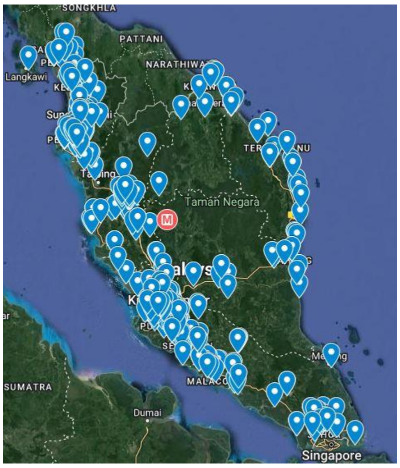


Figure 4.6: The geographic midpoint for peninsular Malaysia

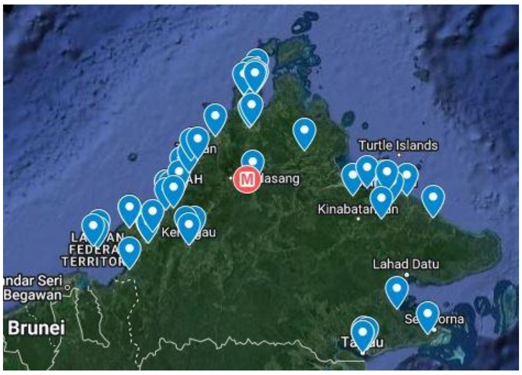


Figure 4.7: The geographic midpoint for Sabah

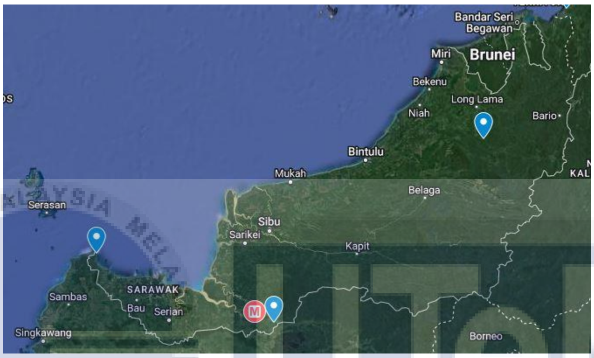


Figure 4.8: The geographic midpoint for Sarawak

The output for the geographic centre gained within the entire Malaysia was 4.420203326618889, 102.45651064604682 in latitude and longitude (Hulu Tembeling, Pahang). The suggested recycling location obtained for the entire Malaysia was shown in Figure 4.9. The final recycling centre obtained through the geographic midpoint calculation was 4.3601099401218075, 102.41071131232034 in latitude and longitude (Kuala Tahan, Pahang), where it was calculated based on the eight geographic midpoint location that listed in the above explanations, and was shown in Figure 4.10.

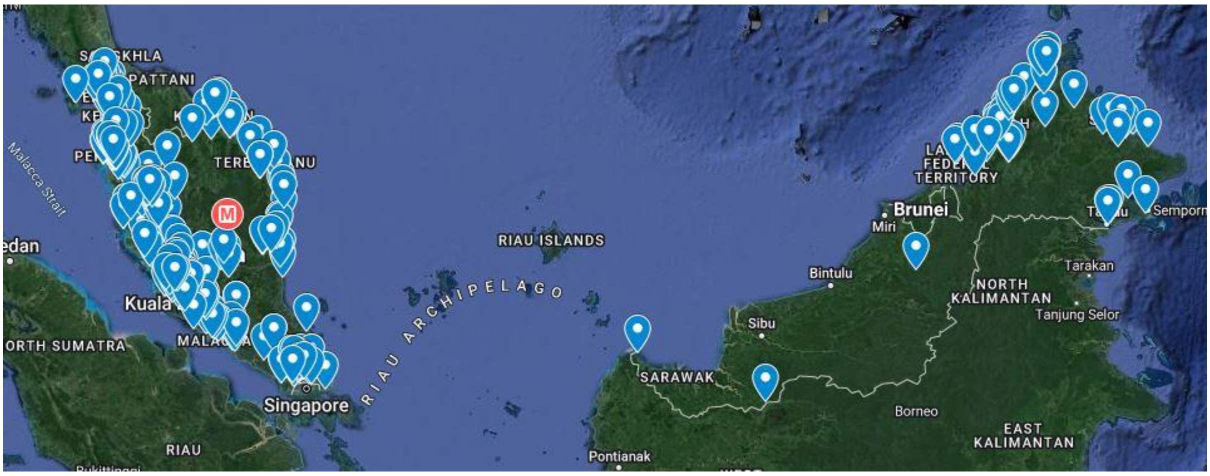


Figure 4.9: The geographic midpoint for entire Malaysia

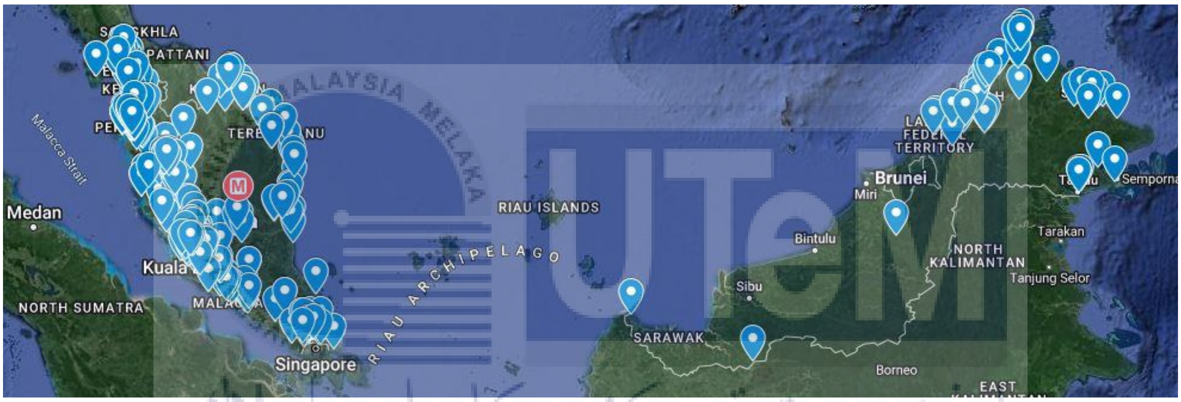


Figure 4.10: The geographic midpoint based on the eight proposed geographic midpoint

The results of the location determination for options A, B, and C are presented in Table 4.4. All 454 solar plant/companies in Malaysia were classified into categories A, B, and C, while regional evaluation categories B1, B2, B3, B4, B5, B6, and C1 were used (i.e. Northern, Central, Southern, East Coast, Sabah, Sarawak and Peninsular Malaysia). The Supply Chain Complexity Assessment was employed to ensure the best option, and the results were compared with the Carbon Footprint Supply Chain Assessment.

4.3 Supply Chain Complexity Assessment

A number of clustering possibilities were subjected to a supply chain complexity assessment, which was mostly based on the scenarios from Table 4.4. First of all, the score for scenario A's complexity was recorded as 2.42. Since there was no clustering at this time, this scenarios may be regarded as starting points. Thus, the location of the recycling centre was the only factor that affected the score. After the clustering was complete, the supply chain complexity was dramatically decreased, with scores of 1.11 and 0.64 for 6 and 4 clusters, correspondingly. In this supply chain complexity analysis, the lower the score obtained, the better the alternative was. Table 4.5 displays the results summary for the supply chain complexity analysis.

Table 4.4: Alternative clustering for proposed recycling centre

Alternative	Classification	Recycling Facility	Number of Solar Farm	Proposed Location based on Centre of Gravity Method
A	The Entire Malaysia	New Proposed Recycling Center (Whole Malaysia)	454	Hulu Tembeling, Pahang (4.420203326618889, 102.45651064604682)
B	By Region of Malaysia:	6 collection centres at every Malaysia region and with one recycling centre at Kuala Tahan		Kuala Tahan, Pahang (4.3601099401218075, 102.41071131232034)
B_1	Northern	1	150	Selama, Perak (5.170386839719077, 100.70602548935739)
B_2	Central	1	122	Shah Alam, Selangor (3.0588761161638907, 101.54917179728511)
B_3	Southern	1	73	Sri Medan, Johor (2.088761, 102.923824)
B_4	East Coast	1	47	Al-Muktafi Billah Shah, Terengganu (4.5640212882407, 103.19339696357626)
B_5	Sabah	1	59	Ranau, Sabah (5.981374, 116.728505)
B_6	Sarawak	1	3	Engkilili, Sarawak (1.277259, 111.628823)

C	By Malaysia:	3 collection centres at Malaysia and with one recycling centre at Kuala Tahan		Kuala Tahan, Pahang (4.3601099401218075, 102.41071131232034)
C_1	Peninsular	1	392	Ulu Jelai, Pahang (4.360006251573142, 101.65859141132695)
C_2	East M'sia (Sabah)	1	59	Ranau, Sabah (5.981374, 116.728505)
C_3	East M'sia (Sarawak)	1	3	Engkilili, Sarawak (1.277259, 111.628823)

Table 4.5: Supply chain complexity for solar panels waste in Malaysia

Alternative	Classification	Number of Solar Farm	Waste Volume (Tonne)	Clusters	Supply Chain Complexity Index	Final Rank
A	The Entire Malaysia	454	208931.711	No	2.42	3
B_{Region}				6	1.11	2
$C_{Malaysia}$				3	0.64	1

In Table 4.6, which was calculated, the internal complexities for each integration cluster in B_{Region} (B1, B2, B3, B4, B5, and B6) is shown. The complexity for B5 (Sabah) was the highest in the cluster B with 0.92; this was because the Solar Plant within the state were vastly distributed throughout the state and the travel distances between each solar power plant and Sabah's recycling centre were arbitrary. The score gained for internal clusters complexity for region B1-Northern, B2-Central, B3-Southern, B4-East Coast, and B6-Sarawak were 0.60, 0.26, 0.68, 0.60, 0.92, and 0.32 accordingly.

Meanwhile, Table 4.7 below displays the internal complexities for respective integration clusters in $C_{Malaysia}$ (C1, C2, and C3). Among each integration cluster in $C_{Malaysia}$, C1 (Peninsular) scores the highest complexity index in this cluster with 1.57. The lowest complexity score achieved in this cluster was 0.32 via C3 (Sarawak). This indicates that by working in a regional cluster method and successfully coordinating the waste supply within that specific region, the complexity index of Malaysia can be reduced.

Table 4.6: Cluster internal supply chain complexity for Alternative B

Alternative	Classification	Number of Solar Farm	Waste Volume (Tonne)	Clusters	Supply Chain Complexity
B_1	Northern	150	92 048.445	No	0.60
B_2	Central	122	25 672.874		0.26
B_3	Southern	73	22 310.407		0.68
B_4	East Coast	47	53 798.295		0.60
B_5	Sabah	59	11 494.735		0.92
B_6	Sarawak	3	3 606.955		0.32

Table 4.7: Cluster internal supply chain complexity for Alternative C

Alternative	Classification	Number of Solar Farm	Waste Volume (Tonne)	Clusters	Supply Chain Complexity
C_1	Peninsular	392	193830.021		1.57
C_2	Sabah	59	11 494.735	No	0.92
C_3	Sarawak	3	3 606.955		0.32

Besides that, Table 4.8 below demonstrates one of the instances of calculation for alternative $C_{Malaysia}$. Results show that the total complexity index summations from three clusters in this cluster was 0.64. Where this value makes it became the optimal alternative for this assessment as the least complexity index was preferred for this assessment. Moreover, internal complexity computation for C_3 was presented in Table 4.9. The outcomes from this calculation was essential for the computation of the cluster internal supply chain complexity.

Table 4.8: Example of supply chain complexity calculation for Alternative C

Clusters	Waste (Tonne)	W_i	Distance to Recycling Centre (km)	D_i	WiD_i	$\log WiD_i$	$WiD_i \log WiD_i$
Peninsular	193830.021	0.927	198	0.116	0.108	-3.210	0.346
Sabah	11494.735	0.055	1645	0.967	0.053	-4.231	0.225
Sarawak	3606.955	0.017	1044	0.614	0.010	-6.559	0.069
							0.641

Table 4.9: Example of internal complexity calculation for C_3

Solar Farm	Waste (Tonne)	W_i	Distance to Recycling Centre (km)	D_i	W_iD_i	$\log W_iD_i$	$W_iD_i \log W_iD_i$
1	3 246	0.899	47.1	0.027	0.024	-5.325	0.132
2	180.478	0.050	349	0.205	0.010	-6.606	0.067
3	180.478	0.050	700	0.411	0.020	-5.602	0.115
H_s							0.315

Alternatives A (the entirety of Malaysia), C1 (Peninsular), C2 (Sabah), C3 (Sarawak), and $C_{Malaysia}$'s (Combination of C1, C2, C3) clustering and supply chain complexity scores are reflected in the set of alternatives shown in Figure 4.11. The supply chain complexity analysis for alternative A (in which each company would forward its waste to a single planned recycling centre) was found to be 2.42. As expected, when the solar plant were split into three different clusters (i.e. Peninsular, Sabah, and Sarawak), the value was drastically decreased to 0.64. In this scenario, the clusters of solar plants were able to coordinate the waste collection among themselves before transporting the waste to the recycling facility, as in the alternative $C_{Malaysia}$.

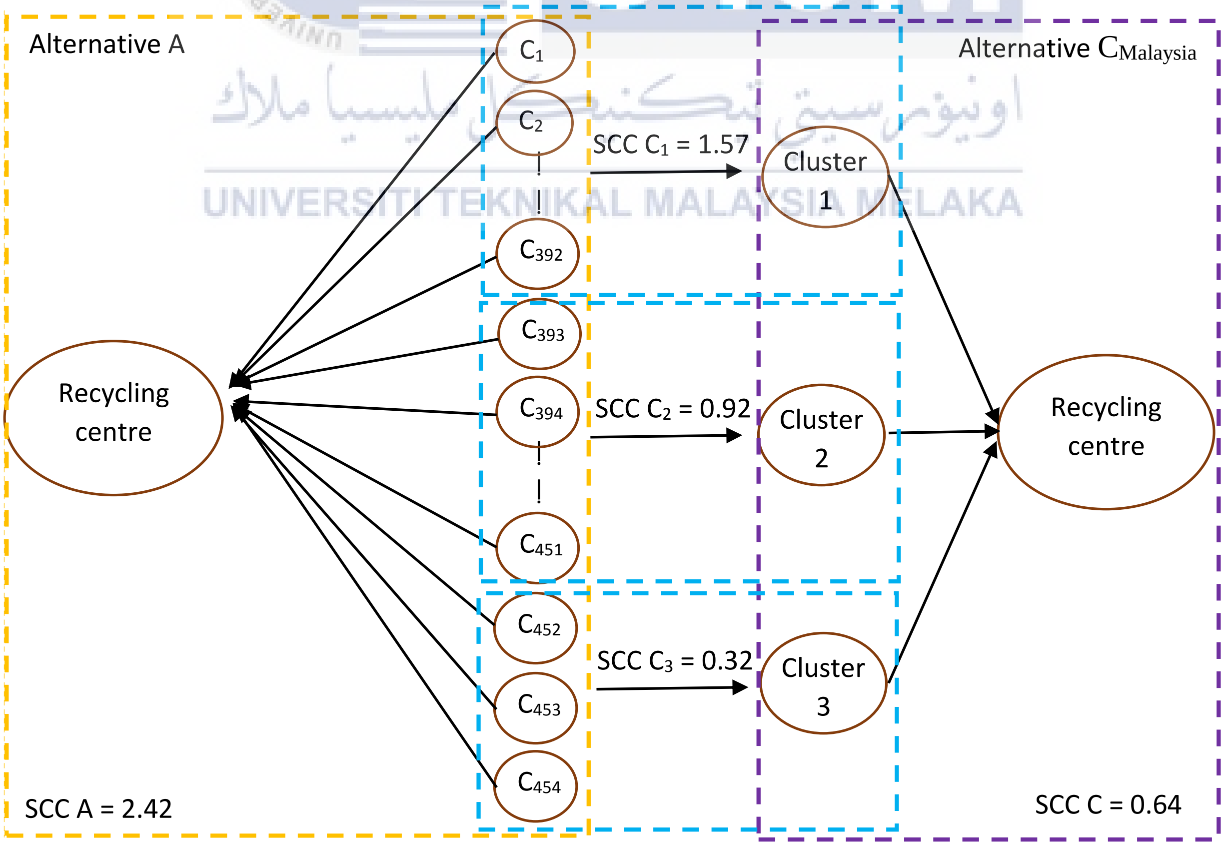


Figure 4.11: Various Clustering Alternatives to Minimize Supply Chain Complexity

It is important to note that the supply chain complexity measure was used to determine the internal complexity for each cluster, with complexity scores for clusters C1, C2, and C3 being 1.57, 0.92, and 0.32, correspondingly. Cluster C1 obtained the highest score for supply chain complexity. This was based on the principle that all solar plant in peninsular should transfer its waste to a single centre in West Malaysia or the peninsular for recycling. Table 4.8 and 4.9 contain examples of calculations for alternative clusters $C_{Malaysia}$ (three clusters) and C2 (internal cluster's supply chain complexity) accordingly.

As previously stated, the alternative with the lowest supply chain complexity score among the alternatives was selected as the best approach. Overall, the cluster $C_{Malaysia}$, which had three clusters and a score of 0.31, had the least supply chain complexity. In order to confirm the lowest transportation emissions and route distance, this result could be compared to the carbon footprint supply chain assessment in the upcoming section 4.4.

4.4 Carbon Footprint Supply Chain Assessment

The outcomes from the section 4.3 with the least supply chain complexity were re-evaluated in this carbon footprint supply chain assessment by using the weighted sum approach. This method verifies that the results of the rechecking of the supply chain complexity findings were represented in the reduced overall transportation gas emissions and cost in terms of transportation distance and greenhouse gas/carbon footprint. On the basis of the final scenarios as shown in Table 4.5, the values for both qualities were determined.

To enable mathematical operation, these values were later normalised. The attributes in this case were given equal weight because the weighted sum method calls for weight to be allocated to the attributes. Since the intention was to minimize the function of the variables, each attribute was then multiplied by weight to yield the final scores of the weighted decision matrix. The outputs were then sorted in ascending order. Table 4.10 presents the treatments for the final positioning. Alternative B, C, and A were published in ascending order as the final scores. This shows that option B, which had the lowest overall score, was the optimal path that reduced both the overall commuting distance and the GHG emission.

Table 4.10: Multi-Objective Optimisation by Weighted Sum Method Calculation

Alternative	Decision Matrix (Criteria)		Normalised Decision Matrix		Normalised Weights		Weighted Decision Matrix		Final Score	Final Rank
	Total Transportation Distance (TTD) (km)	Total Carbon Footprint (TCF) (kgCO2e)	TTD	TCF	TTD	TCF	TTD	TCF		
A	243357.1	278841	0.5682	0.4593			0.2841	0.2296	0.5138	3
B	56131	188950	0.1310	0.3112	0.5	0.5	0.0655	0.1556	0.2211	1
C	128761.9	139253	0.3006	0.2294			0.1503	0.1147	0.2650	2

According to the analysis, the Complexity Supply Chain measure can be used to evaluate the complexity of both intra- and inter-cluster supply chains. This would provide stakeholders with a clear perspective when planning significant supply chains for recycling centre locations. The weighted sum approach could be used to determine the outcome of the supply chain complexity method in order to shorten transportation distances and reduce gas emissions. However for this research paper, the final suggested alternative via utilised both the supply chain complexity analysis and carbon footprint supply chain assessment are differ.

The supply chain complexity analysis recommended that alternative C was the optimal choice in terms of the solar panels waste accounted for by each solar plant and the shortest transportation distance for carrying the waste to the proposed recycling centre (geographical distraction) as seen in Table 4.5. Meanwhile, alternative B was the outcome obtained via the weighted sum approach. This method takes into consideration the transportation distance and greenhouse gas/carbon emission from the respective solar plant to the suggested collection centre or recycling centre. This circumstance explained that the differ the criteria considered in a certain method, the differ the alternative might be selected. Due to there being two different alternatives was recommended by two varying techniques, which did not come with a consensus. Hence, the final alternative was decided through the Analytic Hierarchy Process (AHP) as presented in section 4.5 below.

4.5 Recycling Locations Decision via Analytic Hierarchy Process

A decision making tool, AHP was utilized to select the best decision since there was not a single alternative that has been proposed through the both approachs in the above section. The first step in AHP is to determine the priorities for alternative A, B, and C in supply chain complexity assessment and carbon footprint supply chain assessment correspondingly. Next, complete the pairwise comparison matrix where it will display the preferences for the three alternatives for each criteria. Moreover, sum the columns in the pairwise comparison matrix (synthesizing the judgements) and then divide the elements by the column totals. Sum each row and divide by the total numbers of elements in each row.

Hence, the priority vector for the alternatives with respect to both criteria was obtained. The priorities can refer to the final score attained in Table 4.5 and 4.10 respectively for supply chain complexity and carbon footprint supply chain. Table 4.11 presents a summary of priorities vectors for alternative A, B, and C for the supply chain complexity and carbon footprint supply chain correspondingly. In this study, the lower the score obtained, the better the alternative is. Through Table 4.11, it was undoubtedly that the alternative C was the best option under supply chain complexity criteria and the alternative B was the best choice in carbon footprint supply chain criteria.

Table 4.11: Summary of Priorities Vector for alternative A, B, and C for the supply chain complexity and carbon footprint supply chain

Criteria / Alternatives	Supply Chain Complexity Assessment	Carbon Footprint Supply Chain Assessment
A	0.5740	0.5138
B	0.2701	0.2211
C	0.1557	0.2650

On the other hand, 20 industrial experts took part in this analysis by providing its judgments of preference on the priorities of the two criteria (supply chain complexity method and carbon footprint supply chain) in terms of the overall goal via online survey from Google Form. The details of the 20 industrial experts are displayed in **Appendices D**. After that, it was continued with the calculation of pairwise comparison matrix for the two criteria and this step is repeated 20 times. Subsequently, sums all of the priorities for each criteria and divides it with the numbers of experts that get involved in this analysis. Hence, the priorities obtained for the two criteria (supply chain complexity method and carbon footprint supply chain) was 0.52 and 0.48 respectively. An overall priority ranking can be carried out after obtaining the priorities vector for alternative A, B, and C for the supply chain complexity and weighted sum approach, and the priorities for the two criteria. The final AHP ranking for this study was presented in the following Table 4.12. From the result obtained by AHP analysis, the best alternative to transport the used solar panels to the collection or recycling centre was alternative C with 0.21, and is followed by alternative B (0.25), and alternative A (0.54).

Table 4.12: Final AHP Ranking

Final Rank	Alternative	Overall Priority
1	C	0.2085
2	B	0.2464
3	A	0.5449

4.6 Summary of Logistic Supply Chain Assessment

The logistic supply chain assessment for this study begins with the gravity modelling analysis. The Centre-of-Gravity method have been adopted in this gravity modelling analysis in order to recognise the geographic midpoint for the EoL solar panel waste collection or recycling centre by regions within Malaysia (i.e. Northern region, southern region). Eight geographic midpoint locations were obtained based on this technique. Next, the Supply Chain Complexity algorithm was employed to compute the supply chain complexity index for three different alternatives formed hinge on distance to centre and the quantity of waste. Alternative C was the best option proposed from this analysis.

Moreover, it is then compared with the Carbon Footprint Supply Chain Assessment via Weighted Sum Method where this method considered the factors of the Total Transportation Distance (TTD) and Total Carbon Footprint (TCF). The optimal alternative suggested by this method was alternative B. Since there was not a single alternative that was recommended by both the analyses, hence a decision making technique called Analytic Hierarchy Process (AHP) was carried out in this study. Through the judgments of preference (from industrial experts) and the computations, alternative C was the most optimal option to adopt for this logistic supply chain assessment. Table 4.13 below illustrates the rank for each approach and the final rank of AHP.

Table 4.13: Rank for Each Approach and the Final Rank of AHP

Alternative	Rank		
	Supply Chain Complexity Assessment	Carbon Footprint Supply Chain Assessment	AHP
A	3	3	3
B	2	1	2
C	1	2	1

4.7 Comparison between Mean and Judgement from Industrial Experts for Normalised Weights in Multi-Objective Optimisation

The algorithm utilised was the same as in section 4.4 above. The weighted sum approach was adopted in order to compute the final score for the carbon footprint supply chain assessment. The changes in the parameter utilised for normalised weights makes this analysis somewhat dissimilar from the carbon footprint supply chain assessment that have been done in section 4.4. For the previous calculation in section 4.4, the normalised weights were equally distributed (0.5 for both TTD and TCF). However, the comparison has been carried out in this section to analyse the outcomes by adopting the equally distributed normalised weights and judgement from the 20 industrial experts on both TTD and TCF as the parameter for normalised weights, this analysis is named new carbon footprint supply chain.

From the judgement on both criteria TTD and criteria TCF from 20 industrial experts through online survey tools, Google form. There are in total eight experts indicating that TTD was more crucial than TCF, where this group has a weightage of 0.73. Next, three out of twenty experts have a different opinion where they rated that TCF is significant than TTD, this group accounted for 0.27 of weightage. Meanwhile, the remaining nine experts rated both TTD and TCF as equally significant. Table 4.14 below displays the outcomes for carbon footprint supply chain assessment by implementing the preferences from experts as the normalised weights. The new priorities vector for the carbon footprint supply chain and the new carbon footprint supply chain was illustrated in Table 4.15.

Table 4.14: Multi-Objective Optimisation based on the judgement from experts

Alternative	Decision Matrix (Criteria)		Normalised Decision Matrix		Normalised Weights		Weighted Decision Matrix		Final Score	Final Rank
	Total Transportation Distance (TTD) (km)	Total Carbon Footprint (TCF) (kgCO2e)	TTD	TCF	TTD	TCF	TTD	TCF		
A	243357.1	278841	0.5682	0.4593			0.4147	0.1240	0.5387	3
B	56131	188950	0.1310	0.3112	0.73	0.27	0.0956	0.0840	0.1796	1
C	128761.9	139253	0.3006	0.2294			0.2194	0.0619	0.2813	2

Table 4.15: Comparison of Priorities Vector between carbon footprint supply chain and new carbon footprint supply chain

Carbon Footprint Supply Chain Assessment	New Carbon Footprint Supply Chain Assessment
0.5138	0.5387
0.2211	0.1796
0.2650	0.2813

From the results obtained in Table 4.14 and 4.15, it shown obviously that the priority vector attained for each three alternatives has altered correspondingly. Where alternative B with the reduction of 0.5 was the highest alteration compared to both the alternative A and C in the new carbon footprint supply chain. However, the final rank for the carbon footprint supply chain with respect to two different normalised weights have maintained the unchanged. Therefore, it can be summarised that the divergence between normalised weights via equally distributed and preference from the 20 industrial experts was marginal insignificant. Table 4.16 below shows the comparison of AHP ranking by referring to the carbon footprint supply chain and new carbon footprint supply chain.

Table 4.16: Comparison of Final AHP Ranking and new AHP Ranking

Final AHP Ranking			New AHP Ranking		
Final Rank	Alternative	Overall Priority	Final Rank	Alternative	Overall Priority
1	C	0.2085	1	C	0.2164
2	B	0.2464	2	B	0.2264
3	A	0.5449	3	A	0.5569

The results displayed in Table 4.16 undoubtedly depicted that the new final rank for each three alternatives remained as same as the final rank where the normalised weights was determined via equally distributed although there were faintly changes in the overall priority for each alternative. However, the disparity between alternative C and B was narrowed down from 0.04 to only 0.01. Thus, it can be summarised that the divergence between normalised weights via equally distributed and preference from the 20 industrial experts on the outcomes for AHP ranking was insignificant.

4.8 Clustering Optimisation by K-means Clustering Algorithm

4.8.1 Clustering Optimisation for LSS Solar Plant

With the aid of the processing application MATLAB, 89 LSS solar plants within Malaysia were evaluated. Based on the recycling plant's present operating capacity, the processing limit for each cluster (recycling plant) was imposed at a maximum of 20,000 tonnes and a minimum of 300 tonnes annually (Mahmoudi et al., 2020). The outcomes were compiled in Table 4.17. Only k = 8 first met the conditions while the rest of the cluster (k = 1 to k = 7) surpassed the capacity of the recycling centre. Consequently, in order to manage a total of 108,734.9 tonnes of waste produced, Malaysia needs to assign the 89 LSS solar plants into eight clusters.

When all the requirements were satisfied at eight clusters, the distribution of the LSS solar plant is revealed in Figure 4.12 below. The LSS solar plant were positioned at the closest processing facilities. Besides that, centroids for each cluster were also tabulated along with the outcome of the analysis. The coordinate of these eight recycling centres are presented in the following Table 4.18.

For each scenario, the supply chain complexity of the clusters was evaluated according to Table 4.17, and the findings are displayed in Figure 4.13. Based on the tabulated results, the overall supply chain complexity for one cluster to eight clusters was in between 0.48 to 0.79. The lowest complexity index recorded was of 0.48 (for four clusters), meanwhile the highest complexity index noted was 0.79 (for eight clusters). In the beginning, the index was recorded at 0.55 and declined to 0.48 (four clusters). However, it then bounced back to 0.59 (five clusters) and kept falling to 0.50 (seven clusters) before rising slightly to 0.79 (eight clusters).

Table 4.17: Information on Different Number of Clusters for LSS

Clusters	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8
Cluster 1	108734.9	105157.8	59488	54308	27971	3577.1	14542	15509
Cluster 2		3577.1	3577.1	3577.1	3577.1	28939	3577.1	3577
Cluster 3			45670	21893	29316	19608	27971	19034
Cluster 4				28957	17946	14542	9866.7	18695
Cluster 5					29925	16700	3403.9	17613
Cluster 6						25369	31448	4933
Cluster 7							17926	14542
Cluster 8								14832

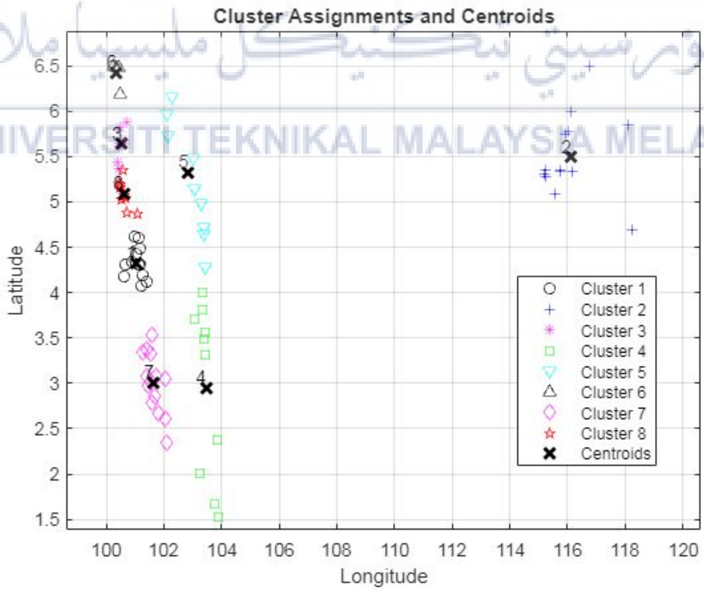


Figure 4.12: Distribution of LSS Solar Plant and Clusters when K=8

Table 4.18: Location of Recycling Centres for Eight Clusters

Cluster	Coordinate (Latitude, Longitude)	Location
1	4.32801, 101.041	Tanjung Tualang, Perak
2	5.49668, 116.123	Papar, Sabah
3	5.64394, 100.548	Sungai Petani, Kedah
4	2.94816, 103.4207	Pekan, Pahang
5	5.32733, 102.844	Sungai Tong, Terengganu
6	6.42587, 100.352	Kepelu, Kedah
7	3.0084, 101.649	Puchong, Selangor
8	5.08857, 100.618	Beriah, Perak

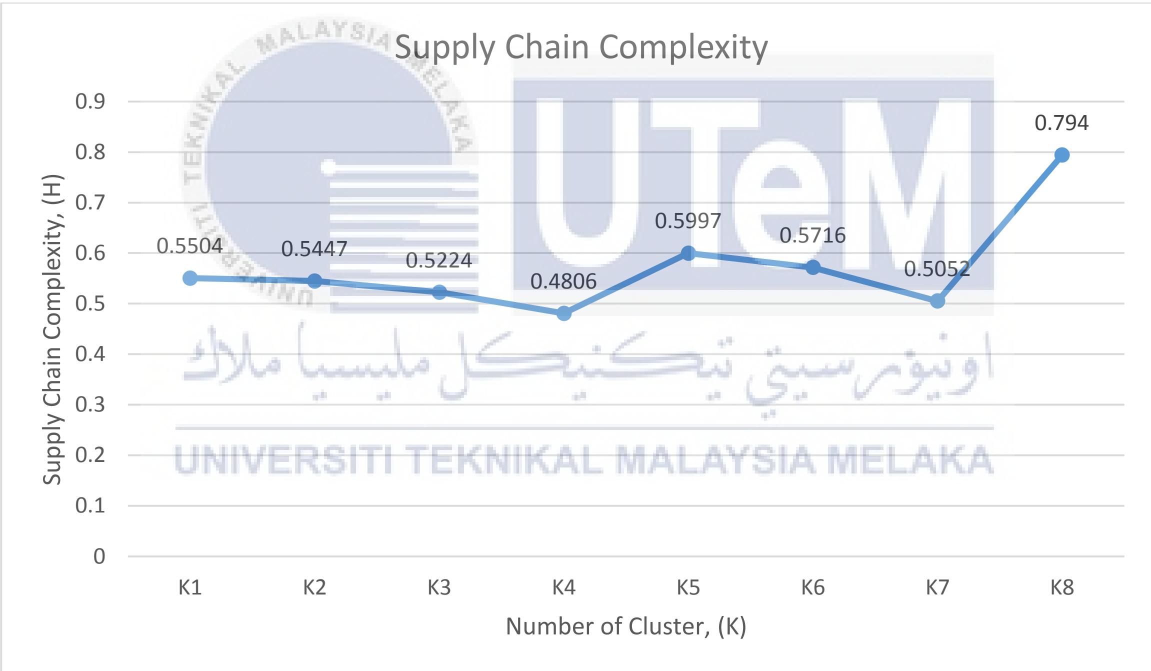


Figure 4.13: Supply Chain Complexity of LSS on 8 Clusters

4.8.2 Clustering Optimisation for LSS and Non-LSS Solar Plant

The steps of analysis for this section are same with the section above, the dissimilar is that this section is focused on 454 solar plants (both LSS and Non-LSS) in Malaysia via the aids of processing software, MATLAB. The processing limit for each cluster (recycling plant) was set at a maximum of 20,000 tonnes and a minimum of 300 tonnes annually based on the recycling plant's existing operational capability. Table 4.19 contains a compilation of the results. Only k = 20 initially meets the requirements, while the other members of the cluster (k = 1 to k = 19) exceed the recycling center's capacity. Therefore, Malaysia had to divide the 454 solar plants into 20 clusters in order to manage the 158,788.13 tonnes of waste that were created overall.

Figure 4.14 below shows how the solar plant was distributed once all the requirements had been met at 20 clusters. The closest processing facilities were where the solar plant was situated. Furthermore, centroids for each cluster were also presented along with the outcome of the analysis. The coordinate of these 20 recycling centres are presented in the following Table 4.20.

According to Table 4.19, the supply chain complexity of the clusters was assessed for each scenario, and the results are shown in Figure 4.15. The supply chain's total complexity fluctuated along with the clusters, according to the tabulated results. Based on the tabulated results, the overall supply chain complexity for one cluster to eight clusters was in between 1.05 to 0.12. The maximum complexity index stated was 1.05 (for seven clusters), while the lowest complexity index noted was 0.12 (for one cluster). Initially, the index was recorded at 0.12 and remains up and down afterward till 20 clusters with the supply chain complexity index of 0.58. This figure was the intermediary value for the overall supply chain complexity index.

Table 4.19: Information on Different Number of Clusters for LSS and Non-LSS

Clusters	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12	K=13	K=14	K=15	K=16	K=17	K=18	K=19	K=20
Cluster 1	158788	147311	11340	38702	38362	52913	34520	25354	7487.7	38994	2050.5	24224	7420.6	17338	14002	34549	12818	23821	7420.6	14002
Cluster 2		11477	67021	11340	2187.7	2050.5	5456.9	2741.3	3416.2	3560.3	29663	2050.5	2145.3	2243	2050.5	3262.3	3560.3	2145.3	5540.8	1513
Cluster 3			80427	69325	9152.4	2741.3	64534	8967.9	2604.1	29043	29043	38994	21175	38994	6151.7	20914	6151.7	21111	537.3	7421
Cluster 4				39421	33446	45146	5883.2	2.050.5	13849	3262.3	2604.1	29663	11106	21132	6822.6	137.2	7420.6	7420.6	18053	5501
Cluster 5					75641	6685.5	11106	44657	35047	2604.1	38994	6685.5	6151.7	537.3	1102.2	1513.2	4144.5	3318.6	24224	2604
Cluster 6						49252	29663	29043	5456.9	39289	7487.7	11106	24224	1173.3	17486	3560.3	22443	8576.6	2604.1	3262
Cluster 7							7624.9	39289	37019	24865	3262.3	7420.6	8576.6	2604.1	11106	7420.6	38506	610.8	1670.6	2464
Cluster 8								6685.5	29043	2050.5	11106	8581.6	1358.8	6151.7	38506	29663	3262.3	537.3	34549	17333
Cluster 9									24865	6151.7	6151.7	21170	2050.5	5420.9	2604.1	11106	2604.1	15173	2193.6	15173
Cluster 10										8967.9	3560.3	137.16	38994	7420.6	29663	24224	16420	18966	10192	4501
Cluster 11											24865	6151.7	29663	18053	7917	1294.7	4803.7	5540.8	3455.7	18053
Cluster 12												2604.1	2604.1	4919.6	5973	537.3	537.3	1513.2	2223.7	537
Cluster 13													3318.6	8576.6	412.5	5540.8	1513.2	21760	4803.7	5421
Cluster 14														24224	4736.6	5055.3	2623.4	1358.8	17295	10218
Cluster 15															10256	7543.5	16343	5420.9	1173.3	4804
Cluster 16																2467	10218	16446	12533	3560

Cluster 17	[redacted]	5420.9	2464.5	5055.3	19377
Cluster 18	[redacted]		2604.1	1513.2	5526
Cluster 19	[redacted]			3750.3	16924
Cluster 20	[redacted]				594

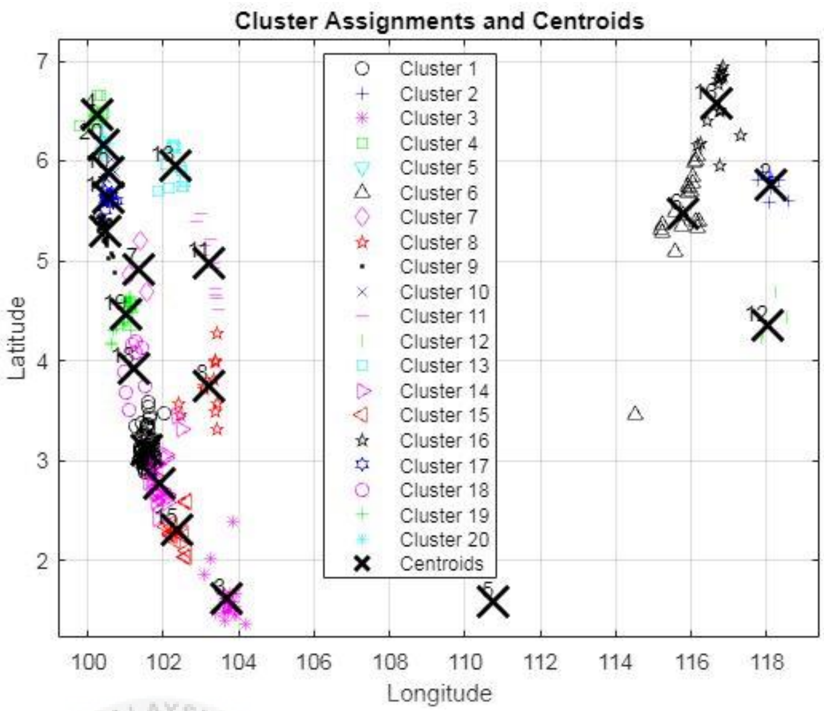


Figure 4.14: Distribution of LSS and Non-LSS Solar Plant and Clusters when K=20

Table 4.20: Location of Recycling Centres for 20 Clusters

Cluster	Coordinate (Latitude, Longitude)	Location
1	3.1038,101.55	Shah Alam, Selangor
2	5.76519, 118.196402	Sandakan, Sabah
3	1.61381, 103.672	Senai, Johor
4	6.46511, 100.223	Kangar, Perlis
5	1.549004, 110.8003	Sebangan, Sarawak
6	5.46522, 115.783	Bongawan, Sabah
7	4.91791, 101.34	Sungai Siput, Perak
8	3.74932, 103.19	Kuantan, Pahang
9	5.30309, 100.446	Simpang Ampat, Pulau Pinang
10	5.88522, 100.552	Pendang, Kedah
11	4.98079, 103.211	Penghulu Diman, Ajil, Terengganu
12	4.35175, 118.032	Tawau, Sabah
13	5.9514, 102.314	Mahligai, Melor, Kelantan
14	2.77192, 101.882	Labu, Negeri Sembilan
15	2.30598, 102.38	Air Panas, Malacca
16	6.57482, 116.687	Kota Marudu, Sabah
17	5.63256, 100.55	Sungai Petani, Kedah
18	3.92758, 101.218	Durian Sebatang, Perak
19	4.45877, 101.026	Batu Gajah, Perak
20	6.16691, 100.412	Langgar, Kedah

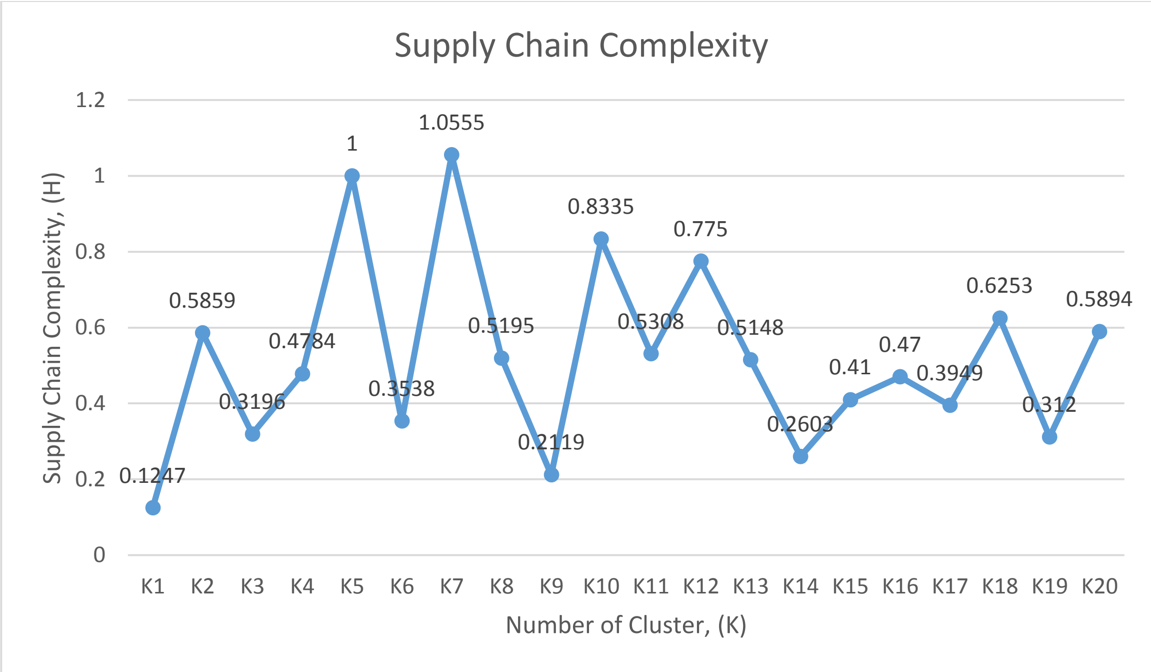


Figure 4.15: Supply Chain Complexity of LSS and Non-LSS on 20 Clusters

4.9 Summary of Clustering Optimisation

A vector quantisation clustering technique, or K-means algorithm, which does not directly use pairwise distances between data points was employed in this clustering optimisation analysis. Since the total of squared deviations from the centroid is equal to the sum of the pairwise squared Euclidean distances divided by the number of points, it equates to continually assigning points to the nearest centroid and using only that distance in Euclidean space. This would be the exclusive method in which the K-Means technique could be used to optimise clusters. The study could be advanced in the future by using a new strategy to employ the algorithm, particularly the strategy that takes real distances into account for multiple iterations before the optimisation result converges.

There are two clustering optimisation analyses that have been carried out by the K-means algorithm in this study. For LSS plant analysis, the number of clusters proposed to manage the 108,734.9 tonnes of waste produced with respect to the capacity of a recycling facility was eight clusters. On the other hand, the amount of clusters proposed to engage the 158,788.13 tonnes of waste produced for Non-LSS plant analysis was 20 clusters.

4.10 Gravity Modelling and Supply Chain Complexity Assessment for Different Period of Solar Panels Waste

According to the operating year of the solar farm that developed and listed at Table 4.1, the shifts of recycling location for Malaysia in the future was possible to calculate. The solar panels waste distribution and shifts of centre-of-gravity within three periods of study (i.e. start, middle, and end), with an interval of five years each period was plotted on map and presented in Figure 4.16 to 4.18 below. The icon (M) in blueish displays the estimated centre of gravity for each period, while the red marker denotes the position of solar farms. For the start period of this analysis, it included the EoL of solar farms in the year of 2034 to 2041 in Malaysia (which are 124 solar farms). Next, the 222 solar farms that reached its EoL between the years of 2042 to 2046 were counted in the middle period. Furthermore, the 63 solar farms that will reach its EoL between the years of 2047 to 2051 were assigned in the end period. However, there are in total 45 solar farms that were omitted in this assessment due to the undetermined commence operation date (COD).

Figure 4.16: Waste distribution and centre-of-gravity shifts at start phase (2034-2041)

Figure 4.17: Waste distribution and centre-of-gravity shifts at middle phase (2042-2046)

Figure 4.18: Waste distribution and centre-of-gravity shifts at end phase (2047-2051)

As a result of changes in the overall quantity of waste produced between 2034 and 2051, as well as newly discovered solar farms during that time interval, the recycling location will vary. Given that it might not be financially wise to establish multiple centres for different years, or to continually alter locations according to waste volume and the number of solar farms, this creates a dilemma in deciding the placement of recycling centres. Table 4.21 below illustrates the recycling centres suggested within the three periods of study.

Table 4.21: The suggested recycling centres within the three periods of study

Phase	Original midpoint location	Relocated midpoint location	Reason
Start	3.371669, 102.275859 (Perak, Pahang)	3.3904821169298893, 102.28315885734074 (Perak, Pahang)	Ease of transportation
Middle	4.560727, 103.337489 (Ketengah Jaya, Terengganu)	-	-
End	4.475728, 102.17558 (Kechau, Pahang)	4.420467164994652, 102.06390170380655 (Kuala Lipis, Pahang)	Ease of transportation

Alongside with the changes in centre-of-gravity, a new supply chain complexity index for the three periods was computed in this assessment. By taking into account the numerous potential pathways to recycling centres, supply chain complexity analysis is used to determine the degree of complexity. Figure 4.19 displays the changes of recycling centres within the three periods of time in a map. Equation 14 was implemented to assess the supply chain complexity index, and the results show an undulation over the timeframe as shown in Figure 4.20.

Figure 4.19: Alterations of recycling centre within the timeframe

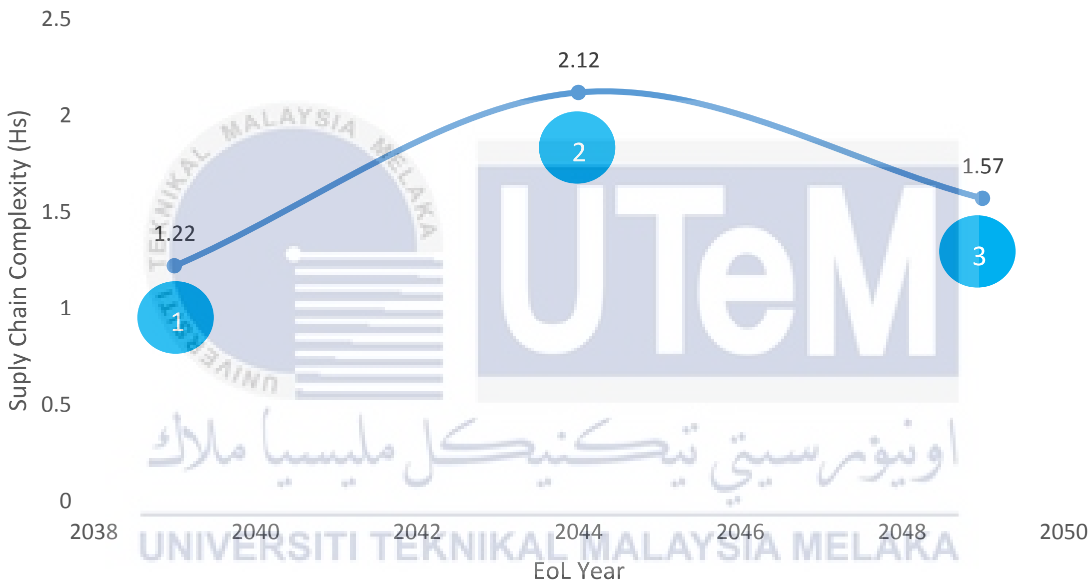


Figure 4.20: Shifts of the supply chain complexity

The main reasons that contributed to the highest complexity index achieved in the middle period (2.12) was because of the increase of EoL solar farms from east Malaysia, which include Sabah and Sarawak. This was due to the high complexity in transportation of the used solar panels from these areas which are imperfect in roadway infrastructure, particularly in outback areas. This escalates the challenging or difficulty in transporting the solar panels to recommended recycling centres. Next, the increase in the quantities of EoL solar farms within this timeframe also contributed to the high complexity index obtained in this middle period. Hence, it can be stated that with the rise in quantities of EoL solar farms from east Malaysia and peninsular, the complexity index for EoL solar panels supply chain will also increase.

Aside from the supply chain complexity assessment for the route, the complexity in detaching solar panels that used the theory of material separation was evaluated, and the model is depicted in equation 17. The capacity of solar farms and the complexity of material separation in solar panels are correlated in Figure 4.21.

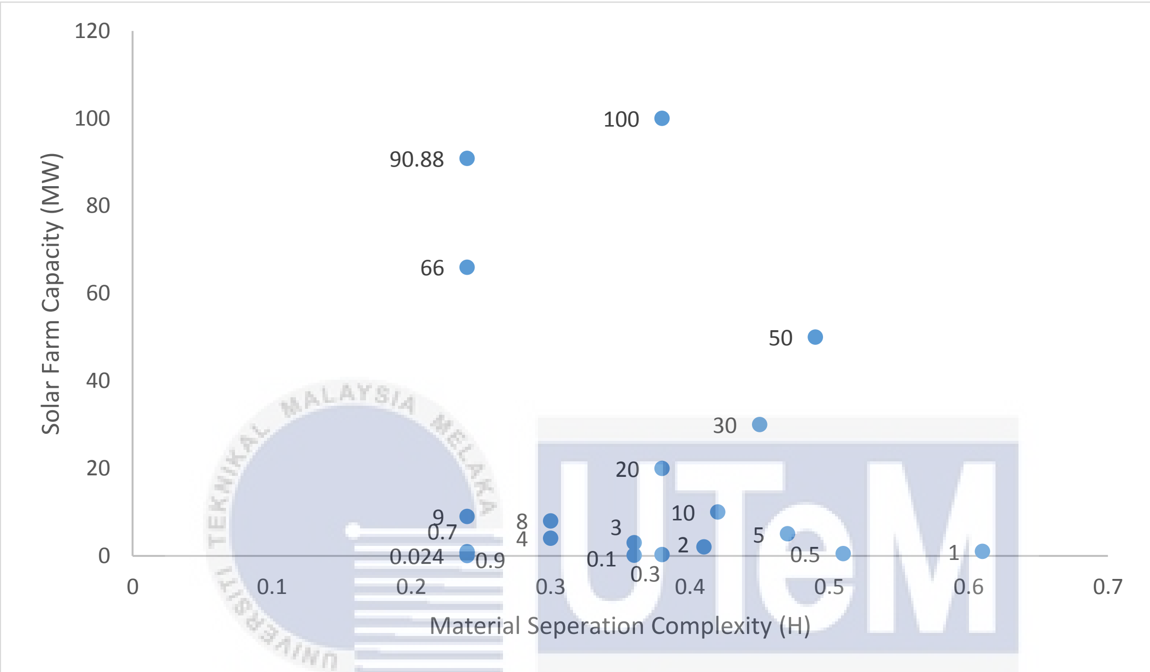


Figure 4.21: Relationship of material separation complexity and solar farm capacities

The complexity index for solar farms with capacities ranging from 0.024 MW to 100 MW is from 0.24 to 0.61. With the exception of the 1MW capacity, the complexity of the capacity of solar farms is rather minimal. This is because the majority of the solar farms capacity in Malaysia at this time were held under this group of capacity. So, the complexity index for 1 MW was slightly higher than the other group of solar farm capacity. A useful indicator and trend for dismantle is the decrease in complexity from the earlier 1 MW solar farm capacity to the current 2 MW and above solar farm capacity.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In conclusion, the analyses created and applied in this study were as follow: the gravity modelling assessment to determine the recycling centre using the centre-of-gravity approach, the assessment of the supply chain's complexity, the assessment of the carbon footprint supply chain by the weighted sum technique, the recycling locations decision via AHP (for logistic supply chain assessment), and the assessment of the clustering optimisation by applying the k-means algorithm. As the outcomes, several solar panels waste recycling facilities locations and one out of three alternatives has been proposed as the best alternative under logistic supply chain assessment (alternative C). Meanwhile, the optimised number of clusters for LSS farm (8 clusters) and Non-LSS farm (20 clusters) has been suggested through clustering optimisation assessment.

Besides that, a comparison between the differences in normalised weights by equally distributed mean and preference from 20 industrial experts in carbon footprint supply chain assessment has been conducted and the results indicate that the divergence was marginal insignificant. Thus, it does not affect the final ranking for AHP where the preferences alternative are the same with the mean and preference from 20 industrial experts in normalised weights, which is alternative C, B, and A in sequence. Furthermore, the solar panels waste is expected to reach its maximum supply chain complexity index (2.12) between the years of 2042 to 2046 according to the supply chain complexity assessment for the EoL solar panels waste in three different periods. This study has taken into account the sustainable supply chain element through carbon footprint supply chain assessment to consider the alternative that has the least environmental effect towards nature.

Initially, there was insufficient data to complete this study regarding the locations of the solar plants, the volume of waste produced, and other crucial solar plant details. These limited the ability to analyse the recycling location more deeply. Nevertheless, through the continuous research from the journals, published research papers, and the authorities' websites, these limitations were successfully resolved. Moreover, there was time taken in research, study, and implementing the suitable methods in this study, some of the analyses required trial and error. By figuring out the quantity of waste and the locations where waste could be recycled in this study, advancement towards a new stage of research was made possible, where a deeper comprehension of the decision tool and its components was carried out. The related parties would be advised by having this strategy to consider sustainability issues like carbon footprint and greenhouse gas emissions from transportation in addition to the logistics issue.

There was surely space for improvement in this study, both in terms of the methods employed and the proportion of solar plants involved. In the future, if the credible statistics are accessible, other aspects might be taken into account. Moreover, the capacity of the recycling centre can be updated by the researchers for the other cases. This can raise the trustworthiness of the future study. Other than that, the additional locations analysis method or even clustering approach that is not applied in this study could be considered in the future in order to increase the reliability of the location of the recycling centre proposed.

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APPENDICES

Appendice A

No.	Company	Coordinates (Latitude, Longitude)	Location	State	Acres	MW	Total Mass (Kg)	Expected Households powered	CO2 offsetting	Investment costs	Start using	Source
1	SBU Power Sdn Bhd	6.47489582050546, 100.35291582560248	UniMAP Pauh Campus, Arau, Perlis	Perlis	20	3.996	259420.32	-	-	-	3/3/2018	(Suruhan jaya Tenaga, 2017)
2	Consortium Tesdec Services Sdn Bhd & Suria Infiniti Sdn Bhd (Ladang Solar Tesdec)	4.7161544040726735, 103.39738859641201	Mukim Sura, Dungun, Terengganu	Terengganu	4 hectare = 9.88422	3.5	227220	-	-	20 million	2019	(Suruhan jaya Tenaga, 2017)
3	Revenue Vantage Sdn Bhd (Cypark Resources Bhd)	3.0502677461375955, 102.06795706828932	Jelebu, Negeri Sembilan	Negeri Sembilan	-	3	194760	-	-	21.63 million	Sep-18	(Suruhan jaya Tenaga, 2017)

4	Consortium Greenviro Solutions Sdn Bhd & PLB Terang Sdn Bhd	5.1981188660976425, 100.4295626519634	(Lot 1340, Jalan Byram, 14300 Nibong Tebal, Pulau Pinang)	Pulau Pinang	20.2 hectare= 49.91529	20	1298400	12,400	-	-	30/11/2018	(Suruhanjaya Tenaga, 2017)
5	Consortium Zelleco Engineering Sdn Bhd & Pengkalan Bumijaya Sdn Bhd & Amled Illumination (M) Sdn Bhd	1.6719528846346638, 103.74042765471374	(PTD 10277, MUKIM ULU SUNGAI JOHOR, KOTA TINGGI, JOHOR DARUL TAKZIM)	Johor	-	29	1882680	-	10,765	-	2019	(Suruhanjaya Tenaga, 2017)
6	Eastern Pacific GD Solar Sdn Bhd	4.276503732908513, 103.44013177140899	(LOT 6217 MUKIM TELUK KALONG, KEMAMAN, TERENGGANU)	Terengganu	28 hectare= 69.1895	18.5	1201020	-	-	86 million	23/3/2018	(Suruhanjaya Tenaga, 2017)

7	HNG Capital Sdn Bhd (Leader Solar Energy)	5.613243365978265, 100.45235950017471	(Lot 2 Mukim Daerah Darul Aman, Sungai Pasir, 08000 Sungai Petani, Kedah)	Kedah	49 hectare= 121.082 acre	29	1882680	11,000	40,000 tonnes annually	180 million	11/10/2018	(Suruhanjaya Tenaga, 2017)
8	Selasih Mentari Sdn Bhd	2.6648828766507946, 101.81890229048116	Ladang Tanah Merah, Negeri Sembilan	Negeri Sembilan	-	8	519360	-	-	53.38 million	2018	(Suruhanjaya Tenaga, 2017)
9	IL Solar Sdn Bhd	6.475625996204388, 100.4283978933121	(Solarvest Bukit Kayu Hitam (12MWp), 06050 Bukit Kayu Hitam, Kedah)	Kedah	-	10	649200	2,600 daily	35 tonnes daily	-	22/12/2017	(Suruhanjaya Tenaga, 2017)

10	Tenaga Nasional Bhd	2.78296073 3566444, 101.612457 89645895	(Mukim Tanjung 12, Kuala Langat, Selangor)	Sela ngor	98 hectar es= 242.1 63 acres	50	32460 00	-	76,000 tonnes	-	Nov-18	(Suruhan jaya Tenaga, 2017)
11	Consortium UiTM Property Management Sdn Bhd & BJ Power Co. Ltd & Perwira Al-Shura Consulting Engineers Sdn Bhd	3.71389620 6253904, 103.081643 99855428	(UiTM Solar Park I, Jalan Gambang , 26300 Gambang , Pahang)	Paha ng	110 hectar es= 290 acres	50	32460 00	22,000	-	277.9 million	Apr-19	(Suruhan jaya Tenaga, 2017)
12	Mudajaya Group Bhd (Mudajaya 49 MW Sungai Siput Large Scale Solar Power Plant)	4.87175978 4157295, 101.077229 69450265	Sungai Siput, Kuala Kangsar, Perak	Pera k	94.3 hectar es= 233.0 204 acres	49	31810 80	-	50,000 tonnes annually	306 Million	27/11/20 18	(Suruhan jaya Tenaga, 2017)
13	Gading Kencana Sdn Bhd	4.08082043 5995956, 101.244141 55397568	(Kampun g Batu Empat, 35500 Bidor, Perak)	Pera k	98 acres	30	19476 00	20,000	800,000 tonnes a year	214 Million	Nov-18	(Suruhan jaya Tenaga, 2017)

14	Consortium Synergy Generated Sdn Bhd & Scomi Group Bhd & Lembaga Tabung Angkatan Tentera (Strong Elegance Sdn. Bhd)	5.649589770990508, 100.57085260736497	Sungai Petani, Kuala Muda, Kedah	Kedah	-	30	1947600	-	-	-	2018	(Suruhanjaya Tenaga, 2017)
15	Solar Management (Chembong) Sdn Bhd Mattan Engineering Sdn	2.6050572125557947, 102.06765456327221	(Jln Seremban - Tampin, Kampung Anak Ayer Kundor, 71300 Pedas, Negeri Sembilan)	Negeri Sembilan	200 acres	50	3246000	--	-	-	30/1/2019	(Suruhanjaya Tenaga, 2017)
16	Sabah Energy Corporation Sdn Bhd	5.352181113465075, 115.24137605047109	Kampung Tanjung Kubong, Wilayah Persekut	Sabah	-	5	324600	-	-	-	2018	(Suruhanjaya Tenaga, 2017)

			uan Labuan, Sabah									
17	RUSB-BTS Joint Consortium	6.495243943065044, 116.75693219922559	Kota Marudu, Sabah	Sabah	-	5.9	383028	-	-	-	2018	(Suruhanjaya Tenaga, 2017)
18	Beau Energy East Sdn Bhd	5.351101703805977, 115.73492728522216	Beaufort, Sabah	Sabah	-	6	389520	-	-	-	2018	(Suruhanjaya Tenaga, 2017)
19	Ditrolic Sdn Bhd & Integrated Logistics Solutions Sdn Bhd	3.02183682702476, 101.56179709791415	Klang, Selangor	Selangor	-	3	194760	-	-	-	2018	(Bidders et al., 2019)
20	Fairview Equity Project Sdn Bhd	2.3782740020288875, 103.851344526735	(LOT 2158 & 2159 JALAN META, MUKIM MERSING,JOHOR)	Johor	-	5	324600	-	-	-	Oct-20	(Bidders et al., 2019)
21	Jentayu Solar Sdn Bhd	6.183663198288962, 100.47230790129663	(Pokok Sena Solar PV Plant)	Kedah	25 acres	5.99	388870.8	-	-	-	Oct-19	(Bidders et al., 2019)

22	Scope Marine Sdn Bhd (Batu Rakit Solar Power Plant (5MWac))	5.478990763365366, 103.0039254877613	(Kawasan Industri Batu Rakit, Kuala Terengganu, Terengganu)	Terengganu	16 acres	5	324600	-	5,716 tonnes per year	-	30/9/2020	(Bidders et al., 2019)
23	Asia Meranti Sdn Bhd & Atlantic Blue Sdn Bhd & Ocean Solar Energy Sdn Bhd	4.884520527217419, 100.6913762413494	(34400 Kamunting, Perak)	Perak	-	9.9	642708	-	-	-	3/11/2019	(Bidders et al., 2019)
24	Asia Meranti Sdn Bhd & Atlantic Blue Sdn Bhd & Ocean Solar Energy Sdn Bhd	4.427880855544101, 101.0372267339329	Kinta, Perak	Perak	-	9.99	648550.8	-	-	-	2019	(Bidders et al., 2019)
25	Asia Meranti Sdn Bhd & Atlantic Blue Sdn Bhd & Ocean Solar Energy Sdn Bhd	4.480934486876898, 101.15578282992867	(Kampar) Kinta, Perak	Perak	-	9.99	648550.8	-	-	-	2019	(Bidders et al., 2019)

26	Coral Power Sdn Bhd	4.181619069087294, 100.62815526248765	Manjung, Perak	Perak	75 acre	9.99	648550.8	-	-	62 million	2020	(Bidders et al., 2019)
27	Fairview Equity Project Sdn Bhd	2.0134283110612956, 103.26401884207795	(LOT 4465,4469,4470,4471,4472,4482 &4483; MUKIM KLUANG,JOHOR)	Johor	-	9.99	648550.8	-	-	-	Sep-20	(Bidders et al., 2019)
28	Ikram Greentech Sdn Bhd & Icon Energy Solutions Sdn Bhd & KIP Management Sdn Bhd	2.341327967262262, 102.08197391138931	(3961, Jalan Tunas Baru Seksyen 2/4, Taman Perindustrian Masjid Tanah, 78300 Masjid Tanah, Melaka)	Melaka	-	6.8	441456	-	-	-	Dec-20	(Bidders et al., 2019)
29	Maju Solar Sdn Bhd & Kara Power	5.822788521293066,	Kuala Muda, Kedah	Kedah	-	9.9	642708	-	-	-	2019	(Bidders et al., 2019)

	Engineering Sdn Bhd	100.468503 3993527										
30	Wawasan Dengkil Sdn Bhd & Pristine Multi-Vision (M) Sdn Bhd	2.86300401 23933957, 101.679508 80523895	(Solarvest floating solar farm Dengkil, Selangor 12.995MWp)	Selangor	53 acres	9.98	647901.6	5,851	11,548	-	2020	(Bidders et al., 2019)
31	BGMC Corp Sdn Bhd & Bras Venture Bhd (LSS PV 30MWac KUALA MUDA KEDAH)	not sure 5.64955423 2841943, 100.570896 1526282	Kuala Muda, Kedah	Kedah	-	30	1947600	-	-	RM300 to RM400 million	2021	(Bidders et al., 2019)
32	(Redsol solar farm) Fumase (Malaysia) Sdn Bhd & Scatec Solar Malaysia B.V.	5.04779951 7772156, 100.646913 54991952	(Lot 7948, Jalan Alor Pongsu, Bukit Merah, 34310 Bagan Serai, Perak)	Perak	-	30	1947600	21,000	44,000	-	Oct-20	(Bidders et al., 2019)
33	(Cypark Viva Sik solar farm) Gaya	5.88496404 53589975,	Sik, Kedah	Kedah	100	30	1947600	11,305 annually	45,905 tonnes annually	-	1/1/2022	(Bidders et al., 2019)

	Dunia Sdn Bhd & Enertra Sdn Bhd & Ambang Fiesta Sdn Bhd	100.717358 51244961										
34	Greencells Majulia Joint Venture (Majulia Sdn Bhd & Greencells Gmbh)	3.31961517 4822434, 103.423681 10783087	Mukim Bebar, Pekan, Pahang	Pahang	-	30	1947600	16,560	51,242 tonnes a year	-	Jun-21	(Bidders et al., 2019)
35	Hasilwan (M) Sdn Bhd & Idiqa Holding Sdn Bhd	5.72922666 8623755, 102.164409 77240468	Machang, Kelantan	Kelantan	-	30	1947600	-	-	-	2020	(Bidders et al., 2019)
36	Kenyir Solar Park Sdn Bhd & Gunkul Engineering Public Co Ltd	4.652096, 103.382388	(Kawasan Tok Arun, Mukim Kuala Paka, Daerah Dungun, Terengganu)	Terengganu	-	29.99	1946950.8	-	-	-	Dec-20	(Bidders et al., 2019)

37	(KBJ HECMY Sdn Bhd) Konsortium Beseri Jaya Sdn Bhd & Hanwha Energy Corporation Singapore Pte Ltd	6.496603954734139, 100.24834918304443	LSS3 BKS30 LARGE SCALE SOLAR FARM BUKIT KETERI (Kampung Perawah, Chuping)	Perlis	-	30	1947600	15,000	-	220 million	2020	(Bidders et al., 2019)
38	Leader Energy Sdn Bhd (Solar Farm - Leader Solar Energy II (Bkt. Selambau))	5.6508418841791865, 100.61750962376311	(Lot 5 Pekan Bukit Selambau 08010 Bukit Selambau Kedah Darul Aman)	Kedah	29.124 acres	20	1298400	-	-	118.4 million	11/2/2020	(Bidders et al., 2019)
39	Danau Tok Uban (Cove Suria) solar farm Nippon Bumijaya Sdn Bhd & B&Z Mechanical & Electrical Sdn Bhd	6.1646, 102.2829	Danau Tok Uban, Kelantan (previously Empangan Kelinchi)	Kelantan	40 hec= 98.8422 acres	30	1947600	46,480	96,600 tonnes annually	225 million	2022	(Bidders et al., 2019)

40	RE Gebeng Sdn Bhd	4.003128561218487, 103.3596967008959	Kuantan, Pahang	Pahang	-	29.916	1942146.72	12,000	-	-	22/1/2020	(Bidders et al., 2019)
41	Tenaga Nasional Bhd	5.672140589590176, 100.62403706740598	Bukit Selambau, Kuala Muda, Kedah	Kedah	50 hectare = 123.553 acre	30	1947600	-	-	180 million	8/9/2020	(Bidders et al., 2019)
42	(UiTM Solar Park II) UiTM Property Management Sdn Bhd	1.5284087387744927, 103.87576354924775	(PT 204761, Jalan Purnama, Bandar Baru Seri Alam, 81750 Masai, Johor)	Johor	112 acres	25	1623000	-	28,000 tonnes per year	125 million	2/12/2020	(Bidders et al., 2019)
43	(Woodford Solar 1) Gaya Belian Sdn Bhd & Constant Energy International Services Limited & Stone EPC (Sabah) Sdn Bhd &	5.348257988767762, 115.73919819318115	Beaufort, Sabah	Sabah	-	5	324600	1,077	7,182 tonnes per year	-	2019	(Bidders et al., 2019)

	Ixowave (Pty) Ltd											
44	ib vogt GmbH & Coara Solar Sdn Bhd	4.977728380468988, 103.31947633822456	(Lot 14366, Jalan FELDA Rantau Abang 1, 21610 Marang, Terengganu)	Terengganu	245 hectares= 605.408 acres	100	6492000	-	>170,000 tonnes per annum	-	2022	(Energy Commission Malaysia, 2020)
45	(Cypark Suria Merchang Sdn Bhd) Cypark Resources Berhad & Impian Bumiria Sdn Bhd	5.145, 103.0819 (approximate)	Marang, Terengganu Merchang	Terengganu	-	100	6492000	-	-	-	2022	(Energy Commission Malaysia, 2020)
46	JKH Renewables Sdn Bhd & Solarpack Asia Sdn Bhd (Solarpack Suria Sungai Petani)	5.650382223607079, 100.60941661441814	(Off Jalan Kuala Muda / Sg Division, K621, Kampung Patani Para,	Kedah	-	90.88	5899929.6	-	-	-	2021	(Energy Commission Malaysia, 2020)

			08010 Sungai Petani, Kedah)									
47	(Kerian Solar) ENGIE Energie Services S.A & TTL Energy Sdn Bhd	5.07223260879721, 100.63730921344971	(3JCP+VW, 34400 Bagan Serai, Perak)	Perak	-	100	6492000	11,800	139,000 tonnes annually	-	5/8/2022	(Energy Commission Malaysia, 2020)
48	(LSS3 Pekan Sdn Bhd) Konsortium Beseri Jaya Sdn Bhd & Hanwha Energy Corporation Singapore Pte. Ltd.	3.5644025956003347, 103.42772478973133	(41, Jln Kampung Tanjung Selangor, 26600 Pekan, Pahang) Pekan, Pahang	Pahang	-	100	6492000	-	-	-	2021	(Energy Commission Malaysia, 2020)

49	Ditrolic Sdn Bhd & Integrated Logistics Solutions Sdn Bhd	2.97156721 45074787, 101.471248 63353847	Klang, Selangor	Sela ngor	-	5.99	38887 0.8	-	-	-	-	(Bidders et al., 2019)
50	Hong Seng Assembly Sdn Bhd	5.44365885 4939997, 100.387863 78221162	Seberang Perai Utara, Pulau Pinang	Pula u Pina ng	-	1	64920	-	-	-	-	(Bidders et al., 2019)
51	Naza Power Sdn Bhd & Komitmen Mantap Sdn Bhd	5.96605546 7729569, 102.080054 45687894	Pasir Mas, Kelantan	Kela ntan	-	9.99	64855 0.8	-	-	-	-	(Bidders et al., 2019)
52	Naza Properties Sdn Bhd & Kara Power Engineering Sdn Bhd	3.33275037 37213124, 101.555275 36391602	Rawang, Selangor	Sela ngor	-	9	58428 0	-	-	-	-	(Bidders et al., 2019)
53	Sun Energy Ventures Sdn Bhd & Baywa R.E. Solar Pte Ltd	3.08017398 3317546, 101.388881 00859609	Klang, Selangor	Sela ngor	-	9.972	64738 2.24	-	-	-	-	(Bidders et al., 2019)
54	Danau Tok Uban (Cypark) solar farm Revenue	6.1646, 102.2829	Danau Tok Uban, Kelantan (previous	Kela ntan	40 hec= 98.84 22 acres	30	19476 00	-	-	225 million	2024 (schedul ed)	(Bidders et al., 2019)

	Vantage Sdn Bhd & Cypark Renewable Energy Sdn Bhd		ly Empangan Terip)									
55	BP Energy Sdn Bhd	4.68606610 17115355, 118.225057 1233191	Kampung Dasar, Kunak, Sabah	Sabah	-	5	324600	-	-	-	scheduled 6/2023	(Bidders et al., 2019)
56	Greenviro Solutions Sdn Bhd	5.28289892 8622935, 115.230807 02625566	Labuan	Sabah	-	1	64920	-	-	-	-	(Bidders et al., 2019)
57	GV Bumisinar Sdn Bhd & Amled Solar Sdn Bhd	5.75002311 3038899, 115.917733 84782032	Papar, Sabah	Sabah	-	2.3	149316	-	-	-	-	(Bidders et al., 2019)
58	Nusantara Megamas - Natural Majestic Consortium (Nusantara Megamas Sdn Bhd & Natural Majestic Sdn Bhd)	5.99525889 5125117, 116.107381 74359972	Kota Kinabalu, Sabah	Sabah	-	2.6	168792	-	-	-	-	(Bidders et al., 2019)

59	Sabah Electricity Sdn Bhd	5.34133434076882, 115.74311754768738	Beaufort, Sabah	Sabah	-	5	324600	-	-	-	-	(Bidders et al., 2019)
60	Suria Capital Holding Berhad & Suria Capital Engineering Services Sdn Bhd & Raps Solutions Sdn Bhd	5.772507681008804, 116.02557882884156	Kawang, Papar, Sabah	Sabah	-	2	129840	-	-	10.682 million	-	(Bidders et al., 2019)
61	TTL Energy Sdn Bhd	5.082536100171969, 115.55441723568264	Sipitang, Sabah	Sabah	-	5	324600	-	-	-	-	(Bidders et al., 2019)
62	GV Bumisinar Sdn Bhd & Amled Solar Sdn Bhd	5.33539815778347, 116.15473283191524	Keningau, Sabah	Sabah	-	7.7	499884	-	-	-	-	(Bidders et al., 2019)
63	(Jetama Sdn Bhd) Sabah Development Energy Sdn Bhd & Symbior Solar Siam Ltd	5.305150128249871, 115.19620952238867	(Kampung Bukit Kalam) Labuan	Sabah	42 acres	10	649200	-	-	-	Jun-23	(Bidders et al., 2019)

64	Sun Energy Ventures Sdn Bhd & Baywa R.E. Solar Pte Ltd	5.845613228917599, 118.09020405519443	Sandakan, Sabah	Sabah	-	10	649200	-	-	-	-	(Bidders et al., 2019)
65	Advancecon Solar Sdn Bhd	3.0840905838358372, 101.74420284342635	Kuala Langat, Selangor	Selangor	-	26	1687920	-	-	-	30/11/2023	(Energy Commission, 2021)
66	Atlantic Blue Sdn Bhd	4.310809528221132, 100.66885690282486	Manjung, Perak	Perak	-	25	1623000	-	-	-	31-Dec-22	(Energy Commission, 2021)
67	Atlantic Blue Sdn Bhd	3.33871877781264, 101.26067397069288	Kuala Selangor, Selangor	Selangor	-	13	843960	-	-	-	31-Dec-22	(Energy Commission, 2021)
68	Atlantic Blue Sdn Bhd	4.310809528221132, 100.66885690282486	Manjung, Perak	Perak	-	12	779040	-	-	-	31-Oct-23	(Energy Commission, 2021)
69	Bakateam Services Sdn Bhd (Samaiden Sdn Bhd)	5.371256996856192, 100.44550500433633	Seberang Perai Tengah, Pulau Pinang	Pulau Pinang	-	15	973800	-	-	-	2023	(Energy Commission, 2021)
70	Greenviro Solutions Sdn Bhd (Samaiden Sdn Bhd)	5.157636236617876, 100.49984388136609	Lot 1478, Mukim 8, Nibong Tebal,	Pulau Pinang	-	10	649200	-	-	-	2023	(Energy Commission, 2021)

			Seberang Perai Selatan, Pulau Pinang									
71	Grooveland Sdn Bhd	4.345244006389716, 100.91866586679924	Mukim Bota, Perak	Perak	-	17.36	1127011.2	-	-	-	2023	(Energy Commission, 2021)
72	(Solar Citra Sdn Bhd) MK Land Resources Sdn Bhd	5.027179849934064, 100.54319863477184	Kerian, Perak	Perak	-	10.95	710874	-	-	-	31/12/2023	(Energy Commission, 2021)
73	Nexuscorp group Sdn Bhd	3.3683079218989054, 101.41630004835966	Bestari Jaya, Selangor	Selangor	-	29.99	1946950.8	-	-	-	9/3/2023	(Energy Commission, 2021)
74	PB Green Farm Sdn Bhd & Mass Team Industries (M) Sdn Bhd	4.122601320681388, 101.42092801065863	Batang Padang, Perak	Perak	-	10	649200	-	-	-	2023	(Energy Commission, 2021)
75	(Energy ES Sdn Bhd) Savelite Engineering Sdn Bhd & Frasers Construction (M) Sdn Bhd	5.352743568331462, 100.57293475439086	Kulim, Kedah	Kedah	-	20.76	1347739.2	-	-	-	2023	(Energy Commission, 2021)

	& Moderntent Development Sdn Bhd											
76	(Teja 1 Sdn Bhd) Taiping Solar Sdn Bhd	4.303436720784526, 101.13351172875697	Kampar, Perak	Perak	-	15	973800	-	-	-	14/12/2022	(Energy Commission, 2021)
77	(Kellie Energy Sdn Bhd) Taiping Solar Sdn Bhd	4.603538721480447, 101.14905511556184	Kinta, Perak	Perak	-	15	973800	-	-	-	14/12/2022	(Energy Commission, 2021)
78	(Teja 2 Sdn Bhd) Taiping Solar Sdn Bhd	4.303436720784526, 101.13351172875697	Kampar, Perak	Perak	-	10	649200	-	-	--	14/6/2023	(Energy Commission, 2021)
79	Tan Chong Motor Assemblies Sdn Bhd & APM Shock Absorbers Sdn Bhd & TCIM Sdn Bhd	3.5367, 101.5949 (approximate)	Kawasan Kolam Takungan Air Serendah, Hulu Selangor, Selangor	Selangor	-	20	1298400	-	-	-	31-Dec-23	(Energy Commission, 2021)
80	Asiabina Properties Sdn Bhd	4.614571489973356, 101.00360796938236	Perak	Perak	-	50	3246000	-	-	-	2023	(Energy Commission, 2021)

81	Classic Solar Farm Sdn Bhd	6.498500, 100.258000	Chuping, Perlis	Perlis	-	50	3246000	-	78,450 tonnes per year	175 million	2023	(Energy Commission, 2021)
82	Gopeng Berhad	4.308500, 101.153700	Mukim Teja, Daerah Kampar, Perak	Perak	-	50	3246000	-	-	200 million	31/12/2023	(Energy Commission, 2021)
83	JAKS Solar Power Sdn Bhd partnered with Qhazanah Sabah Sdn Bhd (QSSB) (JAKS Solar Nibong Tebal Sdn Bhd)	5.184903255324606, 100.46582610548718	Seberang Perai, Pulau Pinang	Pulau Pinang	-	50	3246000	-	-	-	2023	(Energy Commission, 2021)
84	Perbadanan Kemajuan Negeri Pahang & Kumpulan Powernet Berhad (PKNP KPower Suria Sdn Bhd)	3.492100, 103.389500	Pekan, Pahang	Pahang	-	50	3246000	-	-	-	31/12/2023	(Energy Commission, 2021)

85	Ragawang Corporation Sdn Bhd	3.812600, 103.325600	Pahang	Pahang	-	50	3246000	-	-	-	2023	(Energy Commission, 2021)
86	Ranhill Utilities Berhad (Ranhill Solar I Sdn Bhd)	4.197500, 101.259300	Batang Padang, Perak	Perak	-	50	3246000	-	-	-	31/12/2023	(Energy Commission, 2021)
87	Sharp Ventures Sdn Bhd	3.083900, 101.408200	Mukim Kapar, Daerah Klang, Selangor	Selangor	-	50	3246000	-	-	185 million	2023	(Energy Commission, 2021)
88	TNB Renewables Sdn Bhd (TNB Bukit Selambau Solar Dua Sdn Bhd)	5.674178001454808, 100.62396524099935	Bukit Selambau, Kedah	Kedah	-	50	3246000	-	-	-	31/12/2023	(Energy Commission, 2021)
89	Uzma Environergy Sdn Bhd (Uzma Kuala Muda Sdn Bhd)	5.644600, 100.489000	Kuala Muda, Kedah	Kedah	-	50	3246000	-	-	-	31/12/2023	(Energy Commission, 2021)

Appendice B

No	Company	Cause	Location	Coordinates	State	Acres	Capacity	Total Mass (Kg)	Operation Date	Source
1	ATK Development Sdn Bhd & Suria Takbir Construction Sdn Bhd	Lack of Information	-	-	-	-	15	973800	2023	(Energy Commission, 2021)
2	ATK Development Sdn Bhd & Suria Takbir Construction Sdn Bhd	Lack of Information	-	-	-	-	13	843960	2023	(Energy Commission, 2021)
3	Fusion Trend Sdn Bhd	Lack of Information	-	-	-	-	13	843960	2023	(Energy Commission, 2021)
4	PB Green Farm Sdn Bhd & Mass Team Industries (M) Sdn Bhd	Lack of Information	-	-	-	-	15	973800	Dec-23	(Energy Commission, 2021)
5	Tesdec Services Sdn Bhd	Lack of Information	-	-	-	-	17	1103640	2023	(Energy Commission, 2021)
6	Consortium Malakoff Corp Bhd & DRB-Hicom Environmental Services Sdn Bhd	Revoked by EC	Tanjung Malim, Perak	-	-	-	50	3246000	-	(JETRO, 2021)

Appendice C

No.	Company	Coordinates (Latitude, Longitude)	Location	Acres	MW	Total Mass (Kg)	Expected Households powered	CO2 offsetting	Investment costs	Start using	Source
1	Tadau Energy Sdn. Bhd.	6.907865262039166, 116.81696145392395	Kudat, Sabah	17.72 acres	2	129840	-	-	-	16/9/2017	(Mark et al., 2017)
2	Tadau Energy Sdn. Bhd.	6.944826509928434, 116.83091080831544	Jln Bak Bak, 89050 Kudat, Sabah	170.105 acres	48	3116160	-	-	-	26/9/2018	(Hamzi et al., 2017)
3	Quantum Solar Park (Melaka)Sdn. Bhd (ItraMAS Corporation Sdn & Scatec)	2.2915501209781675, 102.36387185719023	(77200 Bemban, Malacca)	180 acres	50	3246000	31,000	70,000 tonnes a year	-	May-19	(Soalan, 2017)
4	EVN Vision Sdn Bhd	5.511434956600263, 100.43604606685501	(Lot 1552, Seberang Perai Utara, Pulau Pinang)	4.029	1	64920	-	-	-	8/12/2016	(Maros & Juniar, 2017)
5	Cypark Resources Bhd Selasih Mentari Sdn Bhd (Kuala Sawah Solar Power Plant)	2.635395172163805, 101.93945986378455	Kuala Sawah, Rantau, Negeri Sembilan	21	3.3	214236	7,000	-	65 million	Oct-13	(The Star, 2014)
6	Gading Kencana Sdn Bhd	2.292734343565037,	Kompleks Hijau Solar, Jalan Solar 1,	17.17 Acres	8	519360	-	-	84 Million	23/12/2014	(Kencana, 2016)

		102.3427063 4897457	Bandar Hijau, Hang Tuah Jaya, 75450 Ayer Keroh, Melaka								
7	Synergy Generated Sdn. Bhd.	5.384120972 716331, 102.8608474 5610431	(21500 Sungai Tong, Terengganu)	20 acres	5	324600	-	-	-	28/11/2 014	(Synergy , 2020)
8	IRM Solar Sdn. Bhd. Bhd.	6.651755599 6011835, 100.2614146 2807509	(Titi Tinggi, 02100 Padang Besar, Perlis)	-	5	324600	-	-	-	13/8/20 16	(IRM, 2016)
9	Scatec Solar & Quantum Solar Park (LSS GURUN KEDAH)	5.864314130 28935, 100.5351105 2784586	Jln Kampung Paya Mat Insun, 06700 Pendang, Kedah	180 acres	50	3246000	30,000	70,000 tons per year	-	Dec-18	(Soalan, 2017)
10	(Merchang Quantum Solar PV Park) Itramas Corp. Sdn Bhd	4.929437924 233656, 103.3405216 6882609	(Mukim Merchang, Marang, Terengganu, 21610)	205 acres	50	3246000	93,000	188,000	-	31/5/20 19	(Soalan, 2017)
11	Cypark AIPV PILOT PROJECT (Kuala Perlis Solar Power Plant (Cypark))	6.409703072 817442, 100.1376660 7471518	Kg Wai, Kuala Perlis, Perlis	26.68 acres	1.07 5	69789	-	-	>80 million	2020	(Star, 2015)
12	Cypark SEPRI DAM FLOATING	2.659527040 0633355,	Empangan Sepri, Negeri Sembilan	1 acres	0.27	17528.4	-	-	-	Dec-16	(Future, 2018)

	SOLAR PV POWER PLANT	102.0944126 9163025									
13	Pekat Kuala Penyu Solar Power Plant (ST 25)	5.494741122 088385, 115.5560605 0836266	89800 Kuala Penyu, Sabah	-	1.7	110364	-	-	-	2016	(Pekat, 2022)
14	Pekat Tok Bali, Kelantan Solar Power Plant	5.897620, 102.474039	Tok Bali, Kelantan	3 acres	1	64920	-	-	-	2020	(Pekat, 2022)
15	TTL Energy	5.751900243 170369, 115.9174924 7192158	Jalan Perkuburan Kg. Laut, 89600 Papar, Sabah	-	1	64920	-	-	-	2016	(Energy, 2022)
16	Amcorp Properties Berhad	2.597247487 881804, 102.6223085 3238772	73400 Gemas, Negeri Sembilan	34 acres	10.25	665430	3,315	25,000 tonnes every	-	Jan-14	(Green et al., 2014)
17	Scatec Solar	4.929676531 166616, 103.3405150 3170853	Kampung Jambu Bongkok, 21610 Marang, Terengganu	-	66	4284720	31,000	70,000 tonnes per year	-	31/5/2019	(Scatec, 2019)
18	PLB Green Solar Sdn Bhd & Samaiden Sdn Bhd	5.197932821 422416, 100.4296546 1340917	Lot 1340, Jalan Byram, 14300 Nibong Tebal, Pulau Pinang	56.4 acres	20	1298400	12,000	-	105 million	2018	(Greenviro, 2020)
19	EDRA Solar Sdn Bhd	5.588949437 700493,	PT 7651 Bandar, 09300	104-hectare=	50	3246000	-	-	-	2019	(Soalan, 2017)

		100.6487008 50545	Kuala Ketil, Kedah	256.9 9 acres							
20	Kumpulan Melaka Berhad	2.339587148 8280413, 102.2167124 4897851	KMB 5mwp Solar Farm, Melaka World Solar Valley, Rumbia 78000 Alor Gajah, Melaka	-	5	324600	-	-	46 Million	2013	(BERHAD, 2019)
21	Success Signet Sdn Bhd (Solarfarm)	5.633302904 010033, 100.5287391 6784233	Kampung Sungai Pasir Kechil, 08000 Sungai Petani, Kedah	-	1.75	113610	-	-	-	2013	(PLUS, 2022)
22	Maxgreen2 Solar Power Plant	5.600213323 37689, 100.4976651 9322264	08000 Sungai Petani, Kedah	-	1	64920	-	-	-	Jan-16	(BizMalay, 2022)
23	Pulau Kapas Solar PV Hybrid Station	5.217610548 637917, 103.2618919 2309711	Pulau Kapas, Kuala Terengganu, Terengganu	2	0.45	29214	-	-	-	4/6/2007	(Energy Commission of Malaysia, 2016)
24	Unicity Management Sdn Bhd	6.376642159 774543, 100.2247730 9519907	Jalan Long Boh, 01000 Kangar, Perlis	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
25	Sunnyside Solar (BSL eco energy)	5.910310767 530864,	K154, Kampung Kilang Besar,	87,120 sq	1	64920	420 per month	-	-	2016	(BSL, 2022)

	(Sunnyside Innovations Sdn. Bhd)	100.4936626 9667827	06700 Pendang, Kedah	ft= 2 acres							
26	(My Angkasa Solar) The Malaysian National Co-operative Movement's (Angkasa)	6.011197374 607634, 100.6161034 4641277	Kampung Baharu Siam, 06700 Pendang, Kedah	1.2-hectare= 2.96 acres	0.15	9738	-	-	9 million	1/1/2018	(My, 2018)
27	KLASIK AKTIF SDN BHD	5.362626476 3393845, 100.4054848 8831477	Kawasan Perusahaan Perai 3, 13600 Perai, Penang	-	0.18	11685.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)
28	ISFSB (Integrate Solar Farm Sdn. Bhd)	4.498497269 135177, 101.1642932 7495192	31600 Kampung Kepayang, Perak	-	0.5	32460	-	-	-	2015	(Energy Commission of Malaysia, 2016)
29	Majuperak Solar Power Plant	4.497737062 403165, 101.1634912 7699402	Sebahagian Lot 312366 Mukim Sungai Raya Daerah Kinta 31600 Perak	-	0.5	32460	-	-	-	2015	(Energy Commission of Malaysia, 2016)
30	SISB (Solar Interactive Sdn. Bhd) Vsolar Group Bhd & Genbayu	4.497907453 636236, 101.1642976 5745443	31600 Kampung Kepayang, Perak	300	0.5	32460	-	-	-	2015	(Miranville, 2020)

	Gemilang Sdn Bhd										
31	MATAHARI KENCANA SOLAR FARM, (BSL eco energy)	3.7466353922371205, 101.5026028364681	Matahari Kencana Solar Farm, Tanjung Malim	3	1	64920	420 per month	-	-	2014	(BSL, 2022)
32	Bagan Datoh Solar Power Plant	3.886756717978678, 100.94912185434657	Lorong 5, Taman Seri Iskandar, 36400 Hutan Melintang, Perak	-	2.5	162300	-	-	-	2013	(Energy Commission of Malaysia, 2016)
33	Bagan Datoh Solar Farm Sdn. Bhd. (nearby with bagan datoh solar power plant)	3.888630830086773, 100.94936779626923	36400 Hutan Melintang, Perak	-	2.5	162300	-	-	-	2015	(Energy Commission of Malaysia, 2016)
34	TNB Energy Services Sdn Bhd (Stesen Solar Hibrid RPS KEMAR)	5.2016376015569366, 101.39587939352866	RPS Kemar, Gerik, Perak	-	0.85	55182	-	-	-	30/11/2012	(Aziz & Shamsudin, 2013)

35	Ceria Suriamas Sdn Bhd	3.1120087155937974, 101.630175907287	4, Jalan 19/1, Seksyen 19, 46300 Petaling Jaya, Selangor	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
36	WIBAWA HARMONI SDN BHD	3.0543352288424788, 101.50890292271455	Seksyen 16, 40200 Shah Alam, Selangor	-	0.99	64270.8	-	-	-	1/12/2012	(Energy Commission of Malaysia, 2016)
37	SunEdison Long Term Parking Solar Power Station (10 MW KLIA Solar Power Plant) (SunEdison Satellite Building Solar Power Station)	2.757727857402495, 101.6993926351095	Taxi & Bus Holding Area, Jalan KLIA 1, Kuala Lumpur International Airport, 43900 Sepang, Selangor	-	19	1233480	-	-	200 million	1/8/2013	(Star, 2014)
38	Fortune 11 Sdn. Bhd. (SunEdison (MALAYSIA) Solar Engineering Sdn. Bhd.)	2.7791747256747925, 101.71249048929315	43900 Sepang, Selangor (Sepang Solar Panel (SunEdison))	36	5	324600	-	-	-	2013	(Energy Commission of Malaysia, 2016)

39	Solarcity Malaysia Sdn Bhd (Evergreen Fibreboard Bhd)	1.8579734754410937, 103.09376474869728	Kawasan Perindustrian Parit Raja, 86400 Parit Raja, Johor	-	7	454440	-	-	-	1/7/2022	(Tay, 2022)
40	Voltages Renewables Snd Bhd (Voltage Renewables S/B Solar Power Plant (Petronas)) (Petronas 10 MW Gebeng Solar Power Plant)	3.9951604881434313, 103.36859228120153	(Pusat Perkhidmatan Gebeng, 26100 Balok, Pahang)	-	10.02	650498.4	-	-	-	24/11/2013	(Petronas, 2022)
41	Mattan Engineering Sdn (SOLAR MANAGEMENT (PEDAS ONE) SDN BHD) (BIPV)	2.609336645459781, 102.06550230830453	Sjk (t) Ladang Chembong, Jln Seremban - Tampin, Kawasan Perindustrian Chembong, 71300 Pedas, Negeri Sembilan	-	1	64920	-	-	-	1/10/2015	(MATTAN, 2017)
42	Pajam Solar Power Plant (Cypark) Cypark Resources Bhd	2.835834889243324, 101.8467642865072	71700 Mantin, Negeri Sembilan	32.5 hectare= 80 acres	13	843960	-	-	-	8/1/2013	(theborneopost, 2012)

43	Mudajaya Corporation Berhad (Special Universal Sdn Bhd.)	3.976668483119513, 103.38999195825222	Jalan Gebeng 1/11, Kawasan Industri Gebeng, 26100 Balok, Pahang	-	10	649200	-	-	-	1/1/2014	(Energy Commission of Malaysia, 2016)
44	Pekat Solar Sdn Bhd & MFP Solar Sdn Bhd	3.7423554526494764, 101.51767536564248	Proton's Tanjung Malim plant	23	12	779040	-	-	33.1 million	1/5/2021	(Pekat, 2022)
45	Pekat Solar Sdn Bhd	5.228500712019075, 100.4544060831831	(720 Persiaran Cassia Selatan 1, Kawasan Perindustrian, Batu Kawan, 14100, Penang)	-	1.5	97380	-	-	-	24 September 2020	(Pekat, 2022)
46	Pekat Solar Sdn Bhd	2.662509751388509, 101.82522143713119	(Ladang Tanah Merah A3 Division, Bukit Pelanduk, 71960 Port Dickson, Negeri Sembilan)	-	1	64920	-	-	-	11/7/2019	(Pekat, 2022)
47	ZMan Technologies (Ennesa Power) (UPM agri Solar Power Plant)	2.982986704387655, 101.65025262849441	Jalan Suria Puchong 2, Puchong Gateway, 47110 Puchong, Selangor	7.5	2	129840	-	-	-	1/4/2015	(ENNESA, 2017)

48	ZMan Technologies (Ennesa Power)	2.9839484795515343, 101.64846315804262	Jalan Suria Puchong 2, Puchong Gateway, 47110 Puchong, Selangor	3.5 acres	1	64920	-	-	-	2017	(ENNESA, 2017)
49	ENGIE Services Malaysia Sdn Bhd	3.0586590027287537, 101.48504387381686	Mycron Steel CRC Sdn Bhd (Lot 717, Jalan Sungai Rasau, Seksyen 16, 40200 Shah Alam, Selangor) and Melewar Steel Tube Sdn Bhd (Seksyen 15, 40200 Shah Alam, Selangor)	-	3.2	207744	-	2,000 tons per year	-	2021	(ENGIE, 2020)
50	1MWp BIPV Rooftop solar farm Atlantic Blue Sdn Bhd (Atlantic Blue Sdn Bhd - 1MWp Solar PV Plant)	6.176214628973888, 100.52944729667885	Taman Desa Ilmu, 06400 Pokok Sena, Kedah	-	1	64920	-	-	-	2014	(Ansori, 2015)
51	BSL eco energy	3.1714057573369154,	Jalan Sultan Yahya Petra, Kampung	1.62	1	64920	420 per month	-	-	2017	(BSL, 2022)

		101.7199976 0177196	Datuk Keramat, 54100 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur (UTM Kuala Lumpur)								
52	SURE SUPPLY SDN BHD, SELANGOR (BSL eco energy)	3.197444407 954762, 101.7160389 1931602	NO.2A-1, Jalan Perusahaan Tengah, Kawasan Perusahaan Pkns, 53200 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur	-	0.072	4674.24	30	-	-	2017	(BSL, 2022)
53	EVERGREEN GOLDYEAR SDN BHD	3.006432870 829859, 101.3756725 443439	Kawasan Perindustrian Selat Klang Utara, 42000 Port Klang, Selangor	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
54	Petronas Solar PV	3.157726843 56232, 101.7121748 988813	Suria KLCC	2.22	0.69	44794.8	250	360 tonnes annually	-	2013	(Petronas, 2022)

55	M+ PETRONAS (MMHE)	1.4562587798851736, 103.88377947732697	PLO 3, Jalan Pekeliling, Malaysia Heavy Marine Engineering, 81700 Pasir Gudang, Johor	10.11	8.3	538836	-	-	-		2021	(Petronas, 2022)
56	M+ PETRONAS (UTP)	4.383617055975329, 100.97122095243749	Persiaran UTP, 32610 Seri Iskandar, Perak	-	7.3	473916	-	-	-		2021	(Petronas, 2022)
57	M+ PETRONAS (PRPC) Sdn Bhd Phase 1	1.354477888630119, 104.17193137392862	81600 Pengerang, Johor	-	49.73	3228471.6	-	-	-		2022	(Petronas, 2022)
58	Tan Chong Motor Holdings Bhd	3.363900, 101.602900	a lake in Serendah, Selangor	-	20	1298400	-	-	-		2023	(C. M. H. Tan, 2021)
59	BBP Solar Farm	5.653804033571247, 100.57460955408882	Geran 33590, Lot3222, Mukim Sungai Petani District of, 08000 Sungai Petani, Kedah	-	2.78	180477.6	-	-	-		-	(Energy Commission of Malaysia, 2016)
60	plus xnergy	2.691400, 101.750500	Sepang, Selangor	-	9.98	647901.6	-	-	-		2013	(PLUS, 2022)
61	Hulu Terengganu Solar Energy harvesting	5.053885882509014, 103.03437720698099	Jalan Lenjang - Pengkalan Ajal, 21700 Kuala Berang, Terengganu	-	2.78	180477.6	-	-	-		-	(Energy Commission of Malaysia, 2016)

62	TNB Store Yard & Parking	5.620734742595458, 100.48696198008798	Jalan Enam, Jalan Bakar Arang, 08000 Sungai Petani, Kedah	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
63	LABEL CONQUEST SDN BHD	5.324616040677497, 100.45718561125791	2343, Jalan Iks Bkt Minyak 1, Taman Iks Bukit Minyak, 14100 Bukit Mertajam, Pulau Pinang	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
64	TNB Power Generation Sdn Bhd (TNB Genco)	4.167058934677508, 100.64315937378412	Sultan Azlan Shah Power Station (SJSAS), Manjung Perak	175 hectares= 432.434 acres	100	6492000	-	-	-	-	(AZALEA, 2022)
65	SOLAR ULU YAM	3.453058823436479, 101.6461134184602	PT 1366,SOLAR BELAKANG KILANG JOREX, Kampung Baharu Tambahan Hulu Yam Lama, 44200 Batang Kali, Selangor	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
66	26MWac LSSPV Plant	2.9155147555907055,	SKVE, Kampung	-	26	1687920	-	-	-	-	(Energy Commiss

		101.5286396 8941398	Sungai Jarom, 42600 Jenjarom, Selangor								ion of Malaysia , 2016)
67	Bukit Palong Solar Power Plant (Cypark) Cypark Resources Bhd	2.583729000 3272075, 101.8292265 7561261	KM 2, Jalan Lukut-Sepang, Lukut, 71010 Port Dickson, Negeri Sembilan	14.22 hectar es= 35.13 acres	5	324600	-	-	-	-	(theborn eopost, 2012)
68	Rimba Terjun Solar Power Plant (Cypark) Cypark Resources Bhd	1.473200241 5146992, 103.3931355 0343701	Jalan Kukup, Kampung Tengah, 82000 Pontian, Johor	-	2.78	180477.6	-	-	-	-	(Energy Commiss ion of Malaysia , 2016)
69	Lubukan Hybrid Solar Power Plant	5.722556751 5874936, 118.1149059 3479046	Pusat Bandar Sandakan, Sandakan, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commiss ion of Malaysia , 2016)
70	Semayang Hybrid Solar Power Plant	5.727759675 270466, 118.1278052 702456	Pusat Bandar Sandakan, Sandakan, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commiss ion of Malaysia , 2016)
71	Tanjung Batu Hybrid Solar Power Plant	5.800465674 097294, 118.1581013 6757855	Pusat Bandar Sandakan, Sandakan, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commiss ion of Malaysia , 2016)

72	Mumiang Hybrid Solar Power Plant	5.807751310004169, 118.32362981528959	Sandakan, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
73	Sepinong Hybrid Solar Power Plant	5.74872209893232, 118.1838948726645	Pusat Bandar Sandakan, Sandakan, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
74	Tundun Buhangin Hybrid Solar Power Plant	5.593318818198963, 118.58802371411598	Kinabatangan, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
75	Stesen Solar Hibrid Sugut, Beluran Sabah.	6.2635603046148995, 117.30093126288654	Jalan Nangoh Paitan Kanibungan, 89100 Kota Marudu, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
76	Tawau power station	4.2820651249692965, 117.8878040604908	Lembaga Letrik Sabah, Jalan Kuhara, 91000 Tawau, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
77	Frontier	5.946000895701496, 116.77989048107185	Lot no 063014719, Kampung Nalapak, 89300 Ranau, Sabah	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)

78	Trina Solar Company Ltd floating solar photovoltaic (FPV)	1.147222, 111.873889	Batang Ai Hydroelectric Plant	191.12 Ha= 472.26 acres	50	3246000	-	-	-	2022/2023	(theborneopost, 2022)
79	Solar Power Plant Telok Melano, Sarawak Energy Berhad	2.0045996230250984, 109.6450820283409	Lundu, Sarawak	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
80	Long Keseh Solar Farm	3.451914098355384, 114.51206407072813	Long Keseh, Baram, Sarawak	-	2.78	180477.6	-	-	-	-	(Energy Commission of Malaysia, 2016)
81	Pekat Solar Sdn Bhd	3.112631298188979, 101.42869176368406	Ideal Quality, Klang (Subsidiary Of Kossan Group)	-	2.6	168792	-	-	-	-	(Pekat, 2022)
82	Pekat Solar Sdn Bhd	5.703851758391979, 100.45999191973529	Teh Ah Yau Rubber Factory, (Semeling, 08100 Bedong, Kedah)	-	1	64920	-	-	-	-	(Pekat, 2022)
83	Pekat Solar Sdn Bhd	3.072102903482819, 101.6063412263947	Sunway Pyramid, Petaling Jaya	-	1	64920	-	-	-	-	(Pekat, 2022)

84	Pekat Solar Sdn Bhd	1.3972356910193937, 103.6285947705067	(Pusat Komersial Sunway Marketplace, Persiaran Medini 5, Sunway, 79250 Nusajaya, Johor)	-	3	194760	-	-	-	-	(Pekat, 2022)
85	Pekat Solar Sdn Bhd	3.0250928560000703, 101.56559202908046	(2, Persiaran Kuala Langat, Seksyen 27, 40400 Shah Alam, Selangor)	-	4.2	272664	-	-	-	-	(Pekat, 2022)
86	Pekat Solar Sdn Bhd	3.072144770937236, 101.47139209667607	(No. 2, Lengkok Keluli 2, Bukit Raja Prime Industrial Park, 41720, 41050 Klang, Selangor)	-	2.4	155808	-	-	-	-	(Pekat, 2022)
87	Pekat Solar Sdn Bhd	5.2293465645755814, 100.45654811017098	(Plot 301A, Persiaran Cassia Selatan 1, 14110 Simpang Ampat, Pulau Pinang)	-	1	64920		-	-	-	(Pekat, 2022)

88	Pekat Solar Sdn Bhd	2.23388028110989, 102.2498570678415	(3, Jalan Perindustrian Bachang Baru 3, Taman Bachang Baru, Batu Berendam, 75350 Melaka)	-	1.1	71412	-	-	-	-	(Pekat, 2022)
89	Itramas Corp. Sdn Bhd	5.4353981688008295, 100.30417267259075	St. Nicholas' Home, George Town, Pulau Pinang (No. 4, Jalan Bagan Jermal, 10250 George Town, Pulau Pinang)	-	0.024	1558.08	-	-	-	-	(itramas, 2022)
90	BP Energy Sdn Bhd	3.273799188242398, 101.4892718543467	KL-Kuala Selangor Expressway (LATAR)	-	0.4	25968	-	-	-	-	(Energy Commission of Malaysia, 2016)
91	MAJUPERAK Holdings Berhad (Majuperak-United Solar JV Sdn Bhd (MUJV))	4.364300470453223, 100.96048678949697	MAJLIS DAERAH PERAK TENGAH, KOMPLEKS MDPT, SERI ISKANDAR, 32600 Bota, Perak	1,500sqm	2.78	180477.6	-	3,000 tonnes	-	Apr-21	(Star, 2022)

92	M+ PETRONAS	6.128577442 29414, 100.3424833 2332295	Tesco (Lotus's) Mergong, Bandar Baru Mergong, Alor Setar, Kedah	-	1.05	68166	-	-	-	-	(Petronas , 2022)
93	M+ PETRONAS	2.982442485 31835, 101.6174636 7669818	Tesco Extra (Lotus's Extra) Bukit Puchong, Bandar Bukit, Puchong, Selangor	-	2.78	180477.6	-	-	-	-	(Petronas , 2022)
94	Ace Pixel Sdn. Bhd.	2.728187723 9599073, 101.7179418 0493175	Sebahagian Lot No. H.S(D) 07435, PT 19, Mas Cargo Complex, Zone B Free Commercial Zone, Southern Support Zone, Kuala Lumpur International Airport, 64000 Sepang, Selangor.	-	0.4	25968	-	-	-	2014	(Energy Commiss ion of Malaysia , 2016)

95	Acidchem International Sdn. Bhd.	5.371317868880391, 100.39616859230553	Sebahagian Lot PT 3176, Mukim 1, Daerah Seberang Perai Tengah, 13600 Pulau Pinang	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
96	Alliance Contract Manufacturing Sdn. Bhd.	5.405738410091878, 100.39442131349705	Sebahagian Lot PT 2815, Mukim 01, 13700 Daerah Seberang Perai Tengah, Pulau Pinang	-	0.42	27266.4	-	-	-	2014	(Energy Commission of Malaysia, 2016)
97	Alpha Automation (Selangor) Sdn. Bhd	3.0878477436899767, 101.57669305656736	5, Jalan Pemberita U1/49, Kawasan Perindustrian Temasya, 40150 Shah Alam, Selangor	-	0.18	11685.6	-	-	-	2012	(Energy Commission of Malaysia, 2016)
98	Am Rich Constructions & Development Sdn. Bhd.	2.7019272583317466, 101.9804195286008	No. 45, 1, Jalan BPS4, Bandar Prima Senawang, 70450 Seremban,	-	0.09	5842.8	-	-	-	2015	(Energy Commission of Malaysia, 2016)

			Negeri Sembilan								
99	Ambang Fiesta Sdn. Bhd.	6.400971878240375, 100.14323756434666	Sebahagian Lot PT 4564, Mukim Kuala Perlis, 02000 Kangar, Perlis	-	5	324600	-	-	-	2012	(Energy Commission of Malaysia, 2016)
100	Ambang Fiesta Sdn. Bhd.	6.4014560747504925, 100.14391310556911	Lot PT 4564 (2889), Mukim Kuala Perlis, 02000 Kangar, Perlis	-	1	64920	-	-	-	2013	(Energy Commission of Malaysia, 2016)
101	Aneka Retail (M) Sdn. Bhd.	5.817681769227923, 100.48318299009378	Sebahagian Lot 10239, Mukim Bandar Gurun, Daerah Kuala Muda,08300 Kedah	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
102	APM Springs Sdn. Bhd.	3.002788355565096, 101.40484755419875	Sebahagian Lot 29709 Seksyen 20, Kg. Baru Pandamaran, Bandar Port Swettenham, Daerah Klang, 42009 Selangor	-	0.42	27266.4	-	-	-	2016	(Energy Commission of Malaysia, 2016)

103	Aquaponics Energy Garden Sdn. Bhd.	5.643614554193621, 100.52068543154392	Lot 3508, Mukim Kuala Muda, Daerah Sungai Petani,08000 Kedah	-	0.43	27915.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)
104	Aquaponics Solar Farm Sdn. Bhd.	5.649335801676297, 100.49713138424583	Lot 3499, Mukim Kuala Muda, Daerah Sungai Petani, 08000 Kedah	-	0.34	22072.8	-	-	-	2013	(Energy Commission of Malaysia, 2016)
105	Aspen Moments Sdn. Bhd.	5.455015286985698, 100.42567161556266	No. Lot 603 Mukim 16 Daerah Seberang Perai Utara 13800 Seberang Prai	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
106	AT Engineering Solution Sdn. Bhd.	5.293828530020646, 100.2868468678418	Sebahagian Lot 124600, Mukim 12, Daerah Barat Daya, 11900 Pulau Pinang	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
107	AT Precision Tooling Sdn. Bhd.	5.302877686371718, 100.28762320342416	Sebahagian No. Lot 12340, Mukim 12, 11900 Daerah Barat Daya, Pulau Pinang	-	0.3	19476	-	-	-	2016	(Energy Commission of Malaysia, 2016)

108	Aten Sdn. Bhd	2.8591582895659586, 101.67864023900546	Lot 6090, 28 1/2 Mile Salak Road, Mukim Dengkil, Daerah Sepang, 43800 Selangor	-	0.51	33109.2	-	-	-	2015	(Energy Commission of Malaysia, 2016)
109	Autokit Design Technologies (M) Sdn. Bhd.	5.279035253290994, 100.45004153771283	Sebahagian PT 5890, Mukim 13, Daerah Seberang Perai Selatan, 14100 Pulau Pinang	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
110	Azminas Sdn. Bhd	3.128477633039517, 101.38751934007473	No. Lot 42366, Mukim Kapar, Daerah Klang, 42200 Selangor	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
111	Beyond Solaris Sdn. Bhd.	3.7396663852295453, 103.06382528741061	Lot 74366 Mukim Gambang Daerah Kuantan 26300 Pahang	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
112	Bhan Guang Trading Sdn. Bhd.	5.3550319270801445, 100.44762936109488	Lot 10051, Mukim 07, Daerah Seberang Perai	-	0.12	7790.4	-	-	-	2016	(Energy Commission of

			Tengah, 14000 Pulau Pinang								Malaysia , 2016)
113	Bina Puri Norwest Sdn. Bhd.	3.1789972378407048, 101.64686920226698	Lot 1621, Jalan Prima Pelangi 6, Taman Bukit Prima Pelangi, Mukim Batu, 51200 Kuala Lumpur	-	0.3	19476	-	-	-	2014	(Energy Commission of Malaysia , 2016)
114	Binawani Sdn. Bhd.	3.1922966096570162, 101.67526605406603	Plaza Tol Batu, Km 3.0, Lebuhraya Duta-Ulu Kelang, Off Jalan Kuching, 51200 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur	-	0.41	26617.2	-	-	-	2016	(Energy Commission of Malaysia , 2016)
115	Biosun Energy Sdn. Bhd.	4.16330080776984, 101.19542651093228	Sebahagian Lot 1788, Mukim Batang Padang, Daerah Batang Padang, 35400 Perak	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia , 2016)
116	Broadway Victory Sdn. Bhd.	3.003458397820549,	Lot PT 4236, H.S.(M) 6267, Mukim	-	0.99	64270.8	-	-	-	2012	(Energy Commission of

		101.3759501 2551144	Kapar, Selat Kelang Utara, Selangor									Malaysia , 2016)
11 7	Candela Green Energy Sdn. Bhd.	4.625958711 558237, 103.4189773 5193109	No. Lot 17631, Kampung Bharu Gong Samak, Mukim Kuala Paka, 23100 Dungun, Terengganu	-	0.18	11685.6	-	-	-		2014	(Energy Commiss ion of Malaysia , 2016)
11 8	Cathayana Ecotech Sdn. Bhd.	3.811324909 5293154, 103.3257190 270171	Lot 1048 Sek 28-1053, Mukim Lorong Tun Ismail 5, Daerah Kuantan, 25000 Pahang	-	0.09	5842.8	-	-	-		2015	(Energy Commiss ion of Malaysia , 2016)
11 9	CEL Logistics Sdn. Bhd.	1.564924423 7009343, 103.7110779 9667811	Lot PTD 149225, Mukim Tebrau, Daerah Johor Bahru, 81300 Johor	-	0.43	27915.6	-	-	-		2016	(Energy Commiss ion of Malaysia , 2016)
12 0	Cemara Angsana Sdn. Bhd.	2.587069351 6462904, 102.6132383 2977979	Sebahagian No. Lot Hs(D) 10045, PT 3980, Mukim	-	5.76	373939.2	-	-	-		2013	(Energy Commiss ion of Malaysia , 2016)

			Gemas, Daerah Tampin, 73400 Negeri Sembilan								
121	Cheng Hua Engineering Works Sdn. Bhd.	3.0049976400699174, 101.47728221017003	P.T. 66271, Mukim Klang, 41200 Klang, Selangor	-	0.18	11685.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)
122	Chiat Hin Envelope Manufacturer Sdn. Bhd.	5.357642301762949, 100.40217118318333	Sebahagian Lot 2831, Mukim 01, Daerah Seberang Perai Tengah, 13600 Pulau Pinang	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
123	Chung Hwa High School	2.039791753268857, 102.55414472735828	Chung Hwa High School, Sebahagian Lot 3517, Mukim Bandar Maharani, Daerah Muar, 84000 Johor	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
124	Cine Art Communication Sdn. Bhd.	4.634785978705943, 101.14872992096748	Lot 305012, Mukim Hulu Kinta, Daerah Kinta, 31150 Perak	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)

125	Pesaka Technologies Sdn. Bhd.	4.680258625105165, 101.5464718760449	Sungai Brooke, Mukim Lojing, Daerah Gua Musang, Kelantan	-	0.1	6492	-	-	-		2016	(Energy Commission of Malaysia, 2016)
126	Renewable Power Sdn. Bhd.	3.5906763826173003, 101.60633315127178	Sungai Kerling, Kompartment 52 & 53, Hutan Simpan Gading, Mukim Kerling, Daerah Hulu Selangor. Selangor	-	4	259680	-	-	-		2013	(Energy Commission of Malaysia, 2016)
127	Dato' Ir. Dr. Dennis Ganendra	3.0427871730405114, 101.43970133189731	Sebahagian Lot P.T. 17562, Mukim Klang, Daerah Klang, 40350 Selangor	-	0.81	52585.2	-	-	-		2012	(Energy Commission of Malaysia, 2016)
128	Dato' Ir. Dr. Dennis Ganendra	3.4721422012302314, 102.00830465152642	Sebahagian Lot No. 3861, 3862 & 3863, Mukim Sabai, Daerah Bentong, 28600 Pahang	-	0.99	64270.8	-	-	-		2013	(Energy Commission of Malaysia, 2016)

129	Dekad Aliran Suria Sdn. Bhd.	6.363583347044564, 100.42186265221488	Sebahagian Lot 722 Mukim Husba Daerah Kubang Pasu 06000 Kedah	-	0.8	51936	-	-	-	2016	(Energy Commission of Malaysia, 2016)
130	Delloyd Holdings (M) Sdn. Bhd.	2.9999552959476534, 101.49310353225837	No. Lot 2592, Mukim Klang, Daerah Klang, 41200 Selangor	-	0.84	54532.8	-	-	-	2015	(Energy Commission of Malaysia, 2016)
131	Dexon Electrical Engineering Sdn. Bhd.	3.020564155745332, 101.624874448379	Sebahagian Lot 41580, Mukim Pekan Penaga, Daerah Petaling, 47610 Selangor	-	0.42	27266.4	-	-	-	2016	(Energy Commission of Malaysia, 2016)
132	Dickow Sdn. Bhd.	5.301683757460091, 100.45095638314041	Plot 361, Bukit Minyak, Mukim 13, Daerah Tengah, 14100 Seberang Perai Tengah, Pulau Pinang	-	0.42	27266.4	-	-	-	2014	(Energy Commission of Malaysia, 2016)
133	E&W Venturetech Sdn. Bhd.	3.1367621514004247, 101.53040732494534	Sebahagian Lot 3764, Mukim Sungai Buluh, Daerah	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)

			Petaling, 40150 Selangor								
134	Eagletech Industries Sdn. Bhd.	3.0251640368184596, 101.76699712798371	Lot PT 7645, Mukim Cheras Daerah Cheras 43200 Selangor	-	0.18	11685.6	-	-	-	2014	(Energy Commission of Malaysia, 2016)
135	Eco Integrated Sdn. Bhd.	2.581609743265623, 102.60973366287732	Sebahagian Lot 1497, Mukim Gemas, Daerah Tampin, 73400 Gemas, Negeri Sembilan	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
136	Eco Meridian Sdn. Bhd.	5.31326291969891, 100.27766857155036	Sebahagian Lot 71413 Mukim 12, Daerah Barat Daya 11900 Pulau Pinang	-	0.7	45444	-	-	-	2016	(Energy Commission of Malaysia, 2016)
137	Ecosensa Technologies Sdn. Bhd.	5.691060703989082, 101.84872687795186	Lot 561, Mukim Jeli, Daerah Jeli, 17700 Kelantan	-	0.1	6492	-	-	-	2015	(Energy Commission of Malaysia, 2016)
138	EH Solar Farm Sdn. Bhd.	6.180575643971124, 100.47306998387023	Lot 999 (40), Mukim Bandar Pokok Sena, Daerah Pokok Sena,	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)

			06400 Kedah								
139	Elegant Group Sdn. Bhd.	3.0526747068442863, 101.67125064317216	Sebahagian Lot PT 303, Mukim Damansara, Daerah Petaling Jaya, 47620 Selangor	-	0.14	9088.8	-	-	-	2015	(Energy Commission of Malaysia, 2016)
140	Emerald Esteem Sdn. Bhd.	3.0323799254264237, 101.37728223900538	Sebahagian PT 230, Mukim Bandar Sultan Suleiman, 42000 Klang, Selangor	-	0.99	64270.8	-	-	-	2013	(Energy Commission of Malaysia, 2016)
141	Energenetic Sdn. Bhd	2.670862271170375, 101.85608827420218	Lot PT 12681 Mukim Bandar Sri Sendayan Daerah Seremban 71900 Negeri Sembilan	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
142	Epic Solartech Sdn. Bhd.	3.1774220385782357, 101.45420171303816	Lot 7878 Mukim Bukit Raja Daerah Petaling 40000 Selangor	-	0.3	19476	-	-	-	2016	(Energy Commission of Malaysia, 2016)

143	Equity Global Stocks Sdn. Bhd.	2.2664423246758574, 102.54123937199903	Lot 1926, Mukim Tangkak Daerah Tangkak 84900 Johor	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
144	Everise Taskforce Sdn. Bhd.	3.066455608116689, 101.53852867469743	Lot 3, Jalan Keluli 15/16, eksyen 15, Bandar Shah Alam, Daerah Petaling, 40200 Selangor	-	0.43	27915.6	-	-	-	2014	(Energy Commission of Malaysia, 2016)
145	Exotic Access Sdn. Bhd.	3.0106822907163395, 101.3710164355104	Lot PT 4180, Hs(D) 6214, Mukim Kapar, Selat Kelang Utara, 42000 Selangor	-	0.5	32460	-	-	-	2012	(Energy Commission of Malaysia, 2016)
146	Fairview Equity Project Sdn. Bhd.	2.013428240974911, 103.26398738054937	Lot 5193, 5194, 5195, 5196 Dan 5197, Mukim Kluang, Daerah Kluang, 86000 Johor	-	2	129840	-	-	-	2014	(Energy Commission of Malaysia, 2016)
147	Feedimo Sdn. Bhd.	5.3610103183925135,	Sebahagian Lot 625 & 626, Mukim	-	0.18	11685.6	-	-	-	2016	(Energy Commission of

		100.4712314 2959857	12, Daerah Seberang Perai Tengah, 14000 Pulau Pinang								Malaysia , 2016)
14 8	Fitent Sdn. Bhd.	4.475084028 643671, 101.0548996 3152897	Lot 300645, Mukim Sungai Terap, 31000 Daerah Kinta, Perak	-	0.43	27915.6	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)
14 9	Gaya Dunia Sdn. Bhd. (Fasa I - Solar)	2.584945821 6925907, 101.8308830 7524278	Tapak Pelupusan Bukit Palong, Lot No. 4730, Mukim Lukut, Daerah Port Dickson, 71000 Negeri Sembilan	-	3	194760	-	-	-	2013	(Energy Commiss ion of Malaysia , 2016)
15 0	Gen Master Manufacturing Sdn. Bhd.	4.507216782 708104, 101.1465381 6271615	Lot PT214903, Mukim Sungai Raia, Daerah Kinta, 31300 Perak	-	0.18	11685.6	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)
15 1	General Environmental Solution Sdn. Bhd.	2.256697054 216249, 102.2013083 8673019	Sebahagian Lot 1997 Mukim Tanjong Minyak Daerah Melaka	-	0.17	11036.4	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)

			Tengah 75260 Melaka								
152	Genetic Solar Sdn. Bhd.	4.559903859058704, 101.24593296864396	Sebahagian Lot Hs (D) 203820, PT 7498, Mukim Sungai Raya, Daerah Kinta, 31300 Perak	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
153	Getsol Sdn. Bhd.	6.460231604676996, 100.35178393177569	Universiti Malaysia Perlis, Lot 20265, Mukim Padang Siding, Daerah Arau, 02600 Perlis	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
154	GF Technology Sdn. Bhd.	5.3054032781096385, 100.28823576523922	Sebahagian No. Lot 16041 (Plot 108) Mukim 12, Daerah Barat Daya 11900 Pulau Pinang	-	0.33	21423.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
155	Goldust Growth Sdn. Bhd.	3.0984219720131594, 101.63131319859984	Lot PT 249 Seksyen 32, Mukim Bandar Petaling Jaya, Daerah	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)

			Petaling, 46100 Selangor								
156	Green Catalyst Sdn. Bhd.	3.030112613784791, 102.07868801966303	Sebahagian Lot 7681, Mukim Glami Lemi, Daerah Jelebu, 71650 Negeri Sembilan	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)
157	Gubahan Ceria Sdn. Bhd.	2.5818637256542676, 102.60597907734049	Sebahagian No. Lot Hs(D) 10045, PT 3980, Mukim Gemas, Daerah Tampin, 73400 Negeri Sembilan	-	4.5	292140	-	-	-	2013	(Energy Commission of Malaysia, 2016)
158	Hartamas Mentari Sdn. Bhd.	2.998919111226737, 101.62197203316629	Lot 8, Mukim Pekan Puchong Perdana, Daerah Petaling, 47100 Selangor	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
159	HBH Global Energy Sdn. Bhd.	6.465705041096119, 100.28673027773944	Sebahagian Lot 20159 Jalan Guar Nangka Mata Ayer Mukim	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)

			Padang Siding Daerah Perlis 02500 Perlis								
160	Herbalnet (Malaysia) Sdn. Bhd.	5.646161924104809, 100.49421304010205	Sebahagian Lot 52 & 53 Bandar Sungai Petani Daerah Kuala Muda 08000 Kedah	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
161	HBH Global Energy Sdn. Bhd.	2.3638372644770396, 102.19988829550842	Lot 58 Mukim Kelemak Daerah Alor Gajah, 78000 Alor Gajah, Melaka	-	0.17	11036.4	-	-	-	2014	(Energy Commission of Malaysia, 2016)
162	Herbalnet (Malaysia) Sdn. Bhd.	3.1431934778135853, 101.51075743173647	Lot 61771 Mukim Bandar Glenmarie Daerah Petaling 40150 Selangor	-	0.41	26617.2	-	-	-	2016	(Energy Commission of Malaysia, 2016)
163	Hong Seng Motor Sdn. Bhd.	5.430226554179169, 100.38423034870131	Lot 3420, Mukim 16, Daerah Seberang Perai Utara, 13800 Pulau Pinang	-	0.17	11036.4	-	-	-	2015	(Energy Commission of Malaysia, 2016)

164	Hong Seng Power Sdn. Bhd.	5.437851350443509, 100.41751651299444	Sebahagian Lot 10088, Mukim 16 Daerah Seberang Perai Utara 13800 Butterworth Pulau Pinang	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
165	IB Sofa Sdn. Bhd.	2.9674656750873822, 101.83846695558697	Lot 23792, Pekan Semenyih, 43500 Daerah Ulu Langat, Selangor	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
166	Ikatan Hemat Sdn. Bhd.	3.4456974181190745, 102.34335193773893	Lot 239, Mukim Mentakab, Daerah Temerloh, 28400 Temerloh, Pahang	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
167	Indawan Enterprise Sdn. Bhd.	6.241391062586749, 100.4188344296367	Sebahagian No. Lot 2772, Bandar Jitra, Kubang Pasu, Kedah	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
168	Infra Masyhur Sdn. Bhd	2.69344201401616652, 101.75084095623076	Lot 47946, Mukim Dengkil, 63300	-	0.34	22072.8	-	-	-	2013	(Energy Commission of

			Daerah Sepang, Selangor								Malaysia , 2016)
169	Integrated Logistics Solutions Sdn. Bhd.	6.147400994944078, 102.29217045588804	Sebahagian Lot PT 678 Jalan Padang Tembak, Pengkalan Chepa, Mukim Panchor, Daerah Kota Bharu, 16100 Kelantan	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia , 2016)
170	Integrated Logistics Solutions Sdn. Bhd.	3.0221137170411163, 101.56195289852108	Lot PT 599 Pekan Hicom 40400 Daerah Petaling Selangor	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia , 2016)
171	Ire-Tex Packaging Sdn. Bhd.	5.414767273721655, 100.55640617596121	Lot Plot 49 Bandar Kulim Daerah Kulim, 09000 Kedah	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia , 2016)
172	Iskandar Regional Development Authority (Irda)	1.482733900024893, 103.71835662594376	No. Lot PTD 124161, Mukim Pulai, Daerah Johor Bahru, 79200 Johor	-	0.21	13633.2	-	-	-	2013	(Energy Commission of Malaysia , 2016)

173	Ivory Dazzle Sdn. Bhd.	3.0333009661643575, 101.44255087292929	Sebahagian Lot PT 17562, Hs(D) 43148, Mukim Klang, Daerah Klang, 40350 Selangor	-	0.99	64270.8	-	-	-	2013	(Energy Commission of Malaysia, 2016)
174	Jayadev A/L K.K. Pillai	5.897552961620242, 102.47401242864453	Sebahagian Lot PT2421, PT2422 Mukim Semarak, Tok Bali, Daerah Pasir Putih 46400 Kelantan	-	1	64920	-	-	-	2013	(Energy Commission of Malaysia, 2016)
175	Jefi Aquatech Respurces Sdn. Bhd.	5.288526727265049, 100.44831440168514	Plot 314A (PT 988), Mukim 13, Daerah Seberang Prai Tengah, 14100 Pulau Pinang	-	0.18	11685.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)
176	Jishan Pack Sdn. Bhd	5.173905338305314, 100.49344564388376	Lot 4281, Jalan Bukit Panchor, Mukim 07, Daerah Seberang Prai	-	0.18	11685.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)

			Selatan, 14300 Pulau Pinang								
177	Justpack Sdn. Bhd.	4.598616601724909, 101.07710963437995	Lot 203660 Mukim Hulu Kinta Daerah Kinta 31560 Perak	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
178	K.J. Hock Hin Sdn. Bhd.	6.122434868805692, 100.33808782361801	Sebahagian Lot PT 4093, Pulau Jeragan, Mukim Bandar Alor Setar, Daerah Kota Setar, 05150 Kedah	-	0.28	18177.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
179	Kandis Energy Solaris Sdn. Bhd.	5.9419439648610295, 102.44950599282878	Sebahagian Lot PT 8281 Kg Gong Nibong Hilir Mukim Telong, Daerah Jajahan Bachok, 16070 Kelantan	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
180	Kayangan Megajaya Sdn. Bhd.	3.0534040428178746, 101.50736074511073	Lot No. 606, Seksyen 16, Mukim Shah Alam, 40000 Daerah	-	0.5	32460	-	-	-	2012	(Energy Commission of Malaysia, 2016)

			Petaling, Selangor								
181	Kayel Rubber Products Sdn. Bhd.	5.3521158447348425, 100.39862582816575	Lot 395, Lorong Perusahaan 8, Kawasan Perusahaan Perai, 13600 Perai, Pulau Pinang	-	0.41	26617.2	-	-	-	2015	(Energy Commission of Malaysia, 2016)
182	Kemuning Sumikin Bussan Sdn. Bhd.	2.910110831337097, 101.51840265194197	No. Lot 793, Mukim Telok Panglima Garang, Daerah Kuala Langat, 42600 Selangor	-	1.01	65569.2	-	-	-	2012	(Energy Commission of Malaysia, 2016)
183	Kimmark Manufacturing Sdn. Bhd.	3.0305729685669633, 101.73626547841087	Lot 1808, 12 1/2 Mile Sungei Besi Cheras Road, Pekan Ceras, 43300 Daerah Hulu Langat, Selangor	-	0.42	27266.4	-	-	-	2015	(Energy Commission of Malaysia, 2016)
184	Kombinasi Bumi Solar Sdn. Bhd.	3.0525545469015154, 101.4589255045693	Sebahagian Lot PT 57355 (HSD 57947), Mukim Klang,	-	0.31	20125.2	-	-	-	2014	(Energy Commission of Malaysia, 2016)

			Daerah Klang, Selangor									
185	Kombinasi Bumi Solar Sdn. Bhd.	2.8805107336859446, 101.49656134149454	Lot 2493, Sungai Jarom, Mukim Telok Panglima Garang, 42700 Kuala Langat, Selangor	-	1.01	65569.2	-	-	-		2014	(Energy Commission of Malaysia, 2016)
186	Komitmen Mantap Sdn. Bhd.	6.128115211603564, 102.23762621870793	Sebahagian Lot PT 952, Mukim Kubang Ketam, 16150 Pasir Mas, Kelantan	-	4	259680	-	-	-		2014	(Energy Commission of Malaysia, 2016)
187	Kompass Murni Sdn. Bhd.	2.0244413252265168, 102.59880563045672	No. Lot 2000, Mukim Jorak, Daerah Muar, 84000 Johor	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia, 2016)
188	Kuala Berang Power Solution Sdn. Bhd.	5.053873924785471, 103.03435749344129	Sebahagian Lot PT13251 Dan PT 13250, Mukim Kuala Berang, Daerah Hulu Terengganu,	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia, 2016)

			21700 Terengganu								
189	Kualiti Alam Sdn. Bhd.	2.662482299207124, 101.8252388975955	Lot 6638, Mukim Jimah, 71960 Daerah Port Dickson, Negeri Sembilan	-	0.15	9738	-	-	-	2014	(Energy Commission of Malaysia, 2016)
190	KUB-Berjaya Energy Sdn. Bhd.	3.0239780410954205, 101.53979070944409	No. Lot 25, 36 Dan 37, Mukim Sungai Tinggi, Daerah Hulu Selangor, 40400 Selangor	-	0.13	8439.6		-	-	2012	(Energy Commission of Malaysia, 2016)
191	Kurnia Majuria Sdn. Bhd.	3.0069763724399947, 101.37535044970272	Sebahagian Lot PT 4244, Mukim Kapar, Daerah Klang, 42000 Selangor	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
192	Leaf Solar Sdn. Bhd.	5.404388197690753, 100.5693135397604	Sebahagian Lot PT 2486, Mukim Bandar Kulim, Daerah Kulim, 09000 Kedah	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)

193	Lembaga Pengelola SJKC Sungai Way	3.0879080508980183, 101.62114803661053	Lot 5150, Jln SS 9A/1, Seri Setia, 47300 Petaling Jaya, Selangor	-	0.18	11685.6	-	-	-	2014	(Energy Commission of Malaysia, 2016)
194	Lembaga Pengelola SMJK Katholik Petaling Jaya	3.1076357475411323, 101.65199813330506	Sebahagian HSD 175755, Bandar Petaling Jaya 46000 Daerah Petaling, Selangor	-	0.18	11685.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)
195	Lembaga Pengurus SJK (C) Yuk Chai	3.117606792797537, 101.60680037607301	Sebahagian Lot PT 1885, Mukim Sungai Buloh, Daerah Petaling, 47301 Selangor	-	0.11	7141.2	-	-	-	2016	(Energy Commission of Malaysia, 2016)
196	Leong Bee & Soo Bee Sdn. Bhd.	5.408458187571918, 100.33138137780186	Lot 143 & Lot 145, Seksyen 11E, Bandar George Town Daerah Timur Laut 10300 George Town, Pulau Pinang	-	0.33	21423.6	-	-	-	2014	(Energy Commission of Malaysia, 2016)

197	LGH Construction Sdn. Bhd.	6.093067561118043, 100.31215981928591	Lot 707, 141, 142 Mukim Bandar Kuala Kedah Daerah Kota Setar, 06600 Kedah	-	0.43	27915.6	-	-	-		2015	(Energy Commission of Malaysia, 2016)
198	Lim Choo Soo	2.2643859932665, 102.21044577761452	PT6424 & PT6425, Jalan Tanjung Minyak, Mukim Cheng, 75250 Melaka Pindah, Melaka	-	0.95	61674	-	-	-		2013	(Energy Commission of Malaysia, 2016)
199	Lim Seng Plastic Sdn. Bhd.	4.5300933843554505, 101.05629371200664	Sebahagian Lot 203381, 203382, 203383, 203384 Dan 189654, Hulu Kinta, Daerah Kinta, 31500 Perak	-	0.18	11685.6	-	-	-		2016	(Energy Commission of Malaysia, 2016)

200	Macglo Steel Service Centre Sdn. Bhd.	2.9926862688494142, 101.51561178318215	Lot 3801 & Lot 104015, Batu 6 1/4, Jalan Klinik, Seksyen 32, Bukit Kemuning, 40460 Shah Alam, Selangor	-	0.47	30512.4	-	-	-		2012	(Energy Commission of Malaysia, 2016)
201	Mahendran Surya Innovations Sdn. Bhd.	3.251200, 101.593000	Lot 830, Mukim Batu Daerah Gombak 47000 Selangor	-	0.42	27266.4	-	-	-		2016	(Energy Commission of Malaysia, 2016)
202	Malaysian Green Technology Corporation	2.95741128188597, 101.75141087015095	No. 2, Jalan 9/10, Persiaran Usahawan, Seksyen 9, Bandar Baru Bangi, 43650 Kajang, Selangor	-	0.09	5842.8	-	-	-		2008	(Energy Commission of Malaysia, 2016)
203	Mara Incorporated Sdn. Bhd.	5.79997739354066, 102.56711209803458	Lot 003385, Mukim Kampung Raja, Daerah Besut,	-	0.18	11685.6	-	-	-		2014	(Energy Commission of Malaysia, 2016)

			22200 Terengganu									
204	Maran Road Sawmill Sdn. Bhd.	3.4594993432417005, 102.46415445046826	Lot 3887, Mukim Perak, Daerah Temerloh, 28000 Pahang	-	0.5	32460	-	-	-		2014	(Energy Commission of Malaysia, 2016)
205	Matahari Suria Sdn. Bhd.	3.2178450331763977, 101.71476659125958	Sebahagian Lot 4582, Mukim Setapak, Kuala Lumpur, 54100 Kuala Lumpur	-	1	64920	-	-	-		2016	(Energy Commission of Malaysia, 2016)
206	Maximum Progress Sdn. Bhd.	3.056180186441187, 101.52335010016445	Lot PT2121, Mukim Bandar Shah Alam, Daerah Petaling, 40200 Selangor	-	0.43	27915.6	-	-	-		2015	(Energy Commission of Malaysia, 2016)
207	Metex Steel Sdn. Bhd.	2.8398655138352646, 101.82290962834108	Lot 19033, 19034,19035 Dan19055, Mukim Setul, Daerah Seremban, 71800 Negeri Sembilan	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia, 2016)
208	Micron (M) Sdn. Bhd.	3.04213739154318,	Sebahagian Lot 38172, Mukim	-	0.18	11685.6	-	-	-		2016	(Energy Commission of

		101.5420399332337	Pekan Baru Hicom, Daerah Petaling, 40000 Selangor									Malaysia, 2016)
209	Micron Concept Engineering Sdn. Bhd.	3.061265603374826, 101.53579770042666	Lot PT 2, Seksyen 16 Bandar Shah Alam Daerah Petaling, 40200 Selangor	-	0.18	11685.6	-	-	-		2015	(Energy Commission of Malaysia, 2016)
210	MIE Corporate Holdings Sdn. Bhd.	3.011038086200257, 101.61544319680368	No. Lot 39536 Mukim Petaling 47100 Puchong	-	0.2	12984	-	-	-		2014	(Energy Commission of Malaysia, 2016)
211	MIE Corporate Holdings Sdn. Bhd.	4.512382901695513, 103.44408183105362	Sebahagian Lot PT 13662, Mukim Kertih, Daerah Kemaman, 24300 Terengganu.	-	1	64920	-	-	-		2016	(Energy Commission of Malaysia, 2016)
212	Milleon Extruder Sdn. Bhd.	3.349829185525043, 101.57674579736491	Lot 946, Sungei Chu, Mukim Serendah, 48000 Daerah Hulu	-	0.5	32460	-	-	-		2014	(Energy Commission of Malaysia, 2016)

			Selangor, Selangor								
213	Minda Bumijaya Sdn. Bhd.	3.0411459383622534, 101.45071239790332	Sebahagian Lot PT 57351 Mukim Klang 40460 Klang	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
214	Mitsutoyo Marketing Sdn. Bhd.	2.2422918777527143, 102.53118745434762	Lot PT 16035, Mukim Tangkak, Daerah Ledang, 84900 Johor	-	0.4	25968	-	-	-	2015	(Energy Commission of Malaysia, 2016)
215	Modern Oriental Sdn. Bhd.	5.334091738838214, 100.4691706629942	Sebahagian Pt 10 Dan Lot 541 Mukim 13 Seberang Perai Tengah 14000 Seberang Prai	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
216	MP Solar Energy Sdn. Bhd.	4.524092751940678, 101.13268149296628	No. Lot 312366, Mukim Simpang Pulai Daerah Kinta 31300 Perak	-	0.5	32460	-	-	-	2015	(Energy Commission of Malaysia, 2016)
217	Mujur Satria Sdn. Bhd.	3.03902032905870 63, 101.44387193900542	Sebahagian Lot 17562, Mukim Klang, Daerah	-	0.99	64270.8	-	-	-	2012	(Energy Commission of

			Klang, 40350 Selangor								Malaysia , 2016)
218	Munsang Plantation Sdn. Bhd.	4.579010488007275, 101.04783964133904	Lot 216444 Kawasan Perindustrian Pengkalan 2 Pusing 31500, Ipoh, Perak	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia , 2016)
219	MyWindow Portal Sdn. Bhd.	5.740465158837262, 102.50883053821964	Lot 2114, Batu 55, Mukim Jabi, 22000 Daerah Besut, Terengganu	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia , 2016)
220	Nationgate Solution (M) Sdn. Bhd.	5.378871800088222, 100.38650878133579	Sebahagian No. Pt76, Mukim 01, 13600 Daerah Seberang Prai Tengah, Pulau Pinang	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia , 2016)
221	New Hoong Fatt Auto Supplies Sdn. Bhd.	3.187435355084366, 101.67691037010714	Sebahagian Lot 16474 Mukim Batu Kuala Lumpur 51200 Kuala Lumpur	-	0.18	11685.6	-	-	-	2014	(Energy Commission of Malaysia , 2016)
222	Ngai Cheong Metal Industries Sdn. Bhd.	2.9546483433360584, 101.64119075691535	Lot 4072, Taman Perindustrian Meranti	-	0.18	11685.6	-	-	-	2016	(Energy Commission of

			Perdana, Mukim Dengkil, Dengkil, 43800 Selangor								Malaysia , 2016)
223	Novel Energy Sdn. Bhd.	3.042500368355421, 101.44192298348302	Sebahagian Lot 22205 Mukim Klang Daerah Klang Selangor	-	0.35	22722	-	-	-	2015	(Energy Commission of Malaysia , 2016)
224	Nyloc Fasteners Sdn. Bhd	3.204078584179091, 101.67298274028667	16503 Batu Kuala Lumpur 51200	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia , 2016)
225	Ong Ah Hwa	3.7608975259579513, 103.22230660133111	Lot 74369 Mukim Kuala Kuantan Daerah Kuantan 26300 Pahang	-	1	64920	-	-	-	2013	(Energy Commission of Malaysia , 2016)
226	Onostatic Sdn. Bhd.	2.990398007062791, 101.3544842562373	Sebahagian Lot PT 90869, Mukim Klang, Daerah Klang, 42900 Selangor	-	0.16	10387.2	-	-	-	2016	(Energy Commission of Malaysia , 2016)
227	Oryza Tech Sdn. Bhd	6.1400321944768095, 100.35271320987191	Sebahagian Lot PT 755, Mukim Bandar Alor	-	0.27	17528.4	-	-	-	2016	(Energy Commission of

			Setar, Daerah Kota Setar, 05150 Alor Setar, Kedah								Malaysia, 2016)
228	Oto Vending Sdn. Bhd.	5.313630265231495, 100.46268816599425	Lot 31080, Mukim 14, Seberang Perai Tengah, 14000 Pulau Pinang	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
229	Outreach Green Sdn. Bhd.	6.467219340741781, 100.27918848432957	Sebahagian Lot 20159, Jalan Guar Nangka Mata Ayer, Mukim Padang Siding, Daerah Perlis, 02500 Perlis	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
230	Pantas Lestari Sdn. Bhd.	3.0231252117111733, 101.54657719667608	PT 17562, Mukim Klang, Daerah Klang, 40350 Selangor	-	0.43	27915.6	-	-	-	2014	(Energy Commission of Malaysia, 2016)
231	Pedoman Sentosa Sdn. Bhd.	6.128057171230494, 100.34105601876001	Sebahagian Lot 56 Mukim Mergong, Daerah Kota Setar, 05150 Kedah	-	0.17	11036.4	-	-	-	2016	(Energy Commission of Malaysia, 2016)

232	Pembinaan Eastern Aluminium Sdn. Bhd.	1.5149749509915431, 103.7320513779268	Lot PTD 102958, Mukim Senai, 81400 Daerah Kulaijaya, Johor	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
233	PEPS-JV (M) Sdn. Bhd.	3.4317276975100297, 101.62434062551122	Lot 1403, 1406 & 1409, Batu 29, Jalan Kuala Kubu, Muki Hulu Yam, 44300 Daerah Hulu Selangor, Selangor	-	2	129840	-	-	-	2013	(Energy Commission of Malaysia, 2016)
234	Perpetual Ingenuity Sdn. Bhd.	2.337086438128238, 102.08063286784136	No. Lot 6675 Mukim Sungei Baru Tengah Daerah Alor Gajah Melaka	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
235	Persistcom Sdn. Bhd.	4.195864665180112, 101.25944334127887	Lot 6369 Mukim Batang Padang Batang Padang 35000, Tapah, Perak	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
236	Planet Sonata Sdn. Bhd	5.393805532993387, 100.40045679407059	Lot 5369, HSD 42086 Mukim 01 Daerah Seberang Perai	-	0.11	7141.2	-	-	-	2014	(Energy Commission of Malaysia, 2016)

			Tengah 13700 Seberang Prai								
237	Powerlator Sdn. Bhd.	3.0011902527733385, 101.55980737072157	Lot 22205, Mukim Klang Daerah Klang 40400 Selangor	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
238	PS Green Energy Sdn. Bhd.	5.053719607922687, 103.03378815475465	No. Lot 3431 Mukim Kuala Berang 21700 Hulu Terengganu	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
239	PSJ Transport Sdn. Bhd.	5.308595765363823, 100.47695442501123	Sebahagian No. Lot 1675 Mukim 14, Seberang Perai Tengah 14000 Pulau Pinang	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
240	Pusat Dialisis Marjina Sdn. Bhd.	6.182386825513328, 100.55403447747497	Sebahagian Lot PT 2299, Mukim Gajah Mati, Daerah Pokok Sena, 06400 Kedah	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
241	Qube Solar System Sdn. Bhd.	5.209610168582265, 100.50724786305001	Sebahagian Lot 457 Mukim 12 Daerah Seberang Perai	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)

			Selatan 14200 Seberang Prai Pulau Pinang								
242	Ralco Compounding Sdn. Bhd.	2.8328389136693843, 101.8090240255116	Sebahagian Lot 758 Mukim Nilai, Daerah Seremban, 71800 Negeri Sembilan	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
243	Reko Heights Development Sdn. Bhd.	2.9685116927606696, 101.78952124433462	Sebahagian Lot 14990, Mukim Semenyih, Daerah Ulu Langat, 43000 Selangor	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
244	Rentak Raya Sdn. Bhd.	1.4731528752524974, 103.39312950585277	Tapak Pelupusan Rimba Terjun, Lot PTD 12068, Mukim Rimba Terjun, 82000 Daerah Pontian, Johor	-	2	129840	-	-	-	2012	(Energy Commission of Malaysia, 2016)
245	Revenue Vantage Sdn. Bhd.	6.40966695692701, 100.13766539817169	Sebahagian Lot 4564 Mukim Kuala Perlis Daerah	-	1.08	70113.6	-	-	-	2015	(Energy Commission of

			Kangar 02000 Perlis								Malaysia , 2016)
246	Revision Solar Sdn. Bhd.	5.372570289167602, 100.40368284212403	Lot 2584 (Pt 3195), Mukim 01Daerah Seberang Perai Tengah 13600 Pulau Pinang	-	0.18	11685.6	-	-	-	2013	(Energy Commission of Malaysia , 2016)
247	Rovski Industries Sdn. Bhd.	3.05148755228036, 101.59510486784072	Lot 561, Sungai Penaga Mukim Damansara, Daerah Petaling 47610 Subang Jaya	-	0.18	11685.6	-	-	-	2014	(Energy Commission of Malaysia , 2016)
248	Rumpun Tiara Development Sdn. Bhd.	3.308961779215324, 102.47134596811753	24437 Bera Triang 28200, Pahang	-	0.1	6492	-	-	-	2015	(Energy Commission of Malaysia , 2016)
249	Sage Majestic Sdn. Bhd.	2.8966827457465976, 101.5960204660761	Lot 23570, Mukim Dengkil, Daerah Sepang, 63000 Selangor	-	0.18	11685.6	-	-	-	2014	(Energy Commission of Malaysia , 2016)
250	Sai Kim Enterprise Sdn. Bhd.	3.5055920657834996, 101.10330996016795	Pt11175 Jalan Parit 5, Sekinchan Sabak Bernam 45400	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia , 2016)

251	Saluran Megajaya Sdn. Bhd.	3.059709749422683, 101.43107355204253	Sebahagian Lot PT 4213, Mukim Kapar, Daerah Klang, 42000 Selangor	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
252	Saujana Nagamas Sdn. Bhd.	3.053355214996003, 101.50894647478935	Lot 626 Dan 627, Jalan Gudang 16/9, Seksyen 16, 40000 Shah Alam, Selangor	-	0.99	64270.8	-	-	-	2012	(Energy Commission of Malaysia, 2016)
253	See Hau Global Sdn. Bhd.	1.576106941024404, 103.83509921709833	Sebahagian Lot 184, Mukim Plentong, 81800 Daerah Johor Bahru, Johor	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
254	Sendang Jaya Sdn. Bhd.	3.673031439380768, 100.99752028874474	Lot 11022 Mukim Pancang Bendena Sabak Bernam	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
255	Setanding Estetika Sdn. Bhd.	1.6640482510427839, 103.92230761337092	Lot 1118 Mukim Hulu Sungai Johor Daerah Kota Tinggi 81900 Johor	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)

256	Shah Alam Auto Parts Sdn. Bhd.	2.1895688884770603, 102.3095988400508	Lot 339, Mukim Kandang, 75460 Melaka Tengah, Melaka Bandaraya Bersejarah	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
257	Shaw & Sons (Kuala Lumpur) Sdn. Bhd.	3.048340215103778, 101.44742206028906	Sebahagian Lot 40734, Mukim Bandar Klang, Daerah Klang, 41400 Selangor	-	0.3	19476	-	-	-	2014	(Energy Commission of Malaysia, 2016)
258	Shea Fatt Hardware (M) Sdn. Bhd.	2.1036795632898233, 102.60721886784174	Sebahagian PTD 1504 Mukim Sungai Terap Daerah Muar, 84300 Johor	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
259	Shen Yong Engineering Works Sdn. Bhd.	2.2348252983790133, 102.23356644760067	3910 & 3905 Tanjong Minyak Melaka Tengah 75250	-	0.43	27915.6	-	-	-	2014	(Energy Commission of Malaysia, 2016)

260	Silverstar Pavilion Sdn. Bhd.	2.7578480226108137, 101.69903437103702	Sebahagian Pt 86, Jalan KLIA1, Lapangan Terbang Antarabangsa Sepang, 64000 Sepang, Selangor	-	10	649200	-	-	-	2013	(Energy Commission of Malaysia, 2016)
261	Sin Sentech Resources Sdn. Bhd.	5.337162796136294, 100.42277953225951	Sebahagian Lot PT 32, Mukim 1, Daerah Seberang Perai Tengah, 13600 Pulau Pinang	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
262	Smart Goldenway Sdn. Bhd.	3.108556238303836, 101.59035677337793	No. Lot 9579 Mukim Damansara Petaling 47301 Petaling Jaya	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
263	SMF Engineering Sdn. Bhd.	3.4530419687809673, 101.64610541100261	Lot PT 1366 Mukim Ulu Yam Daerah Hulu Selangor 44300 Selangor	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)
264	Solar Management (Chembong) Sdn. Bhd.	2.6026511316141416, 102.06429983785118	Lot PT 2540, Mukim Pedas, 71300 Rembau,	-	2.01	130489.2	-	-	-	2013	(Energy Commission of

			Negeri Sembilan								Malaysia , 2016)
265	Solar Management (Pedas Two)	2.602679998111555, 102.0644485678411	Lot 927, Mukim Chembong, 71300 Rembau, Negeri Sembilan	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia , 2016)
266	Solar System & Power Sdn. Bhd.	2.9822333994590995, 101.65014145677195	Site A, Sebahagian No. Lot 13854 Mukim Puchong Daerah Petaling 43400 Seri Kembangan, Selangor	-	2.02	131138.4	-	-	-	2015	(Energy Commission of Malaysia , 2016)
267	Solarco Holdings Sdn. Bhd.	5.365132003659187, 100.5595296474416	Sebahagian Lot A12, Mukim Kulim, Daerah Kulim, 09000 Kedah	-	0.49	31810.8	-	-	-	2014	(Energy Commission of Malaysia , 2016)
268	Solarcorp Sdn. Bhd.	2.25540303779171, 102.19977378482872	Lot 11220, 11221, 11222 Dan 11223 Mukim Tanjong Minyak, 75250 Daera Melaka	-	0.43	27915.6	-	-	-	2014	(Energy Commission of Malaysia , 2016)

			Tengah, Melaka								
269	Solplus Sdn. Bhd.	4.5410885306566176, 101.15058890439818	Sebahagian Lot 7499, Mukim Sungai Raya, Daerah Kinta, 31300 Perak	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
270	Solra Sdn. Bhd.	5.592795218223039, 100.76107602982302	Sebahagian Lot 222, Mukim Tawar, Daerah Baling, 09100 Kedah	-	0.48	31161.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)
271	Springfield Power Sdn. Bhd	3.0342502183941744, 101.74806061858237	Lot 4842, Batu 13, Jalan Sungai Besi, 43300 Cheras, Selangor	-	0.78	50637.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
272	Sri Kerdau Commodities Sdn. Bhd.	3.564135402046535, 102.38482389473253	Sebahagian Pt 1353 Mukim Kerdau Daerah Temerloh 28010 Pahang	-	0.27	17528.4	-	-	-	2016	(Energy Commission of Malaysia, 2016)
273	Star Media Group Berhad	3.1271005145587543, 101.64553045806282	Lot 64219, Mukim Damansara, 40150 Daerah	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)

			Petaling, Selangor								
274	Starken AAC Sdn. Bhd.	3.084889372902142, 101.69011951704302	Sebahagian Lot 16047, Mukim Bandar Serendah, Daerah Ulu Selangor, 42900 Selangor	-	1.43	92835.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
275	Sterling Fiesta Sdn. Bhd.	2.572936344307282, 102.09024445887822	Sebahagian Empangan Batu Hampar @ Sepri Mukim Sepri Daerah Rembau 71300 Negeri Sembilan	-	0.27	17528.4	-	-	-	2016	(Energy Commission of Malaysia, 2016)
276	Suluk Damai Sdn. Bhd.	2.661511352710342, 101.83843536536874	Lot PT 1062 Mukim Bandar Sri Sendayan Daerah Seremban 71950 Negeri Sembilan	-	0.36	23371.2	-	-	-	2015	(Energy Commission of Malaysia, 2016)

277	Sumber Elektron Sdn. Bhd.	2.6063856983299103, 102.06241987400921	Sebahagian Lot PT 2540, Ladang Chembong, Mukim Pedas, Daerah Rembau, 47301 Negeri Sembilan	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)
278	Sun Seng Fatt Sdn. Bhd.	4.593484710934545, 101.07038921072267	Sebahagian Lot 7498, Mukim Sungai Raya, Daerah Kinta, 31300 Perak	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
279	Sun Solartech Sdn. Bhd.	5.742531642270737, 102.5122423795263	No. Lot 2114, Blok 31, Batu 55, Mukim Jabi, Daerah Besut, 22000 Terengganu	-	0.5	32460	-	-	-	2015	(Energy Commission of Malaysia, 2016)
280	Sunrise Prima Sdn. Bhd.	2.98008635500009713, 101.54480160342312	Lot 26, Pt 56366, Mukim Klang, Daerah Klang,	-	0.42	27266.4	-	-	-	2013	(Energy Commission of Malaysia, 2016)

			40460 Selangor								
281	Suntech Energy Sdn. Bhd.	5.3583019586137075, 100.47245816688984	Sebahagian Lot 892, Mukim 15, Daerah Seberang Perai Tengah, 14000 Pulau Pinang	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)
282	Suntech Energy Sdn. Bhd.	2.8006067969221173, 101.79927329640613	Lot 732 Pekan Nilai 71800 Daerah Seremban Negeri Sembilan	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
283	Superspan Sdn. Bhd.	2.92560335728756, 101.47926409667613	Lot 2116, Batu 9, Telok, Mukim Teluk Panglima Garang, 42500 Daerah Kuala Langat, Selangor	-	1.5	97380	-	-	-	2014	(Energy Commission of Malaysia, 2016)
284	Synergy Must Sdn. Bhd.	2.7281157313163344, 101.71799576968849	Sebahagian Lot No. H.S(D) 07435, Pt 9, Mas Cargo Complex, Zone B	-	2.01	130489.2	-	-	-	2014	(Energy Commission of Malaysia, 2016)

			Free Commercial Zone, Southern Support Zone, Kuala Lumpur International Airport, 64000 Sepang, Selangor								
285	Synergy Solar Development Sdn. Bhd.	1.5784308731516632, 103.64261535434878	Plo 49, No. 23, Jalan Persiaran Teknologi, Taman Teknologi Johor, 81400 Skudai, Johor	-	1.37	88940.4	-	-	-	2013	(Energy Commission of Malaysia, 2016)
286	Synergy Solar Development Sdn. Bhd.	1.5354019307444324, 103.7794273038971	Plo 191, Jalan Angkasa Mas 15, Kawasan Perindustrian Tebrau II, 81100 Johor Bahru, Johor	-	0.09	5842.8	-	-	-	2012	(Energy Commission of Malaysia, 2016)
287	Synergy Solar Development Sdn. Bhd.	1.537699845413537, 103.76916944645602	Plo 228, Kawasan Perindustrian Tebrau II, 81100 Johor Bahru, Johor	-	0.17	11036.4	-	-	-	2012	(Energy Commission of Malaysia, 2016)

288	Synergy Solar Development Sdn. Bhd.	1.451909198949016, 103.92728745434906	Plo 742, Jalan Keluli 12, Kawasan Perindustrian Pasir Gudang, 81700 Pasir Gudang, Johor	-	0.17	11036.4	-	-	-	2012	(Energy Commission of Malaysia, 2016)
289	Synergy Solar Development Sdn. Bhd.	1.6231983245031523, 103.66634332943286	Sebahagian Lot PTD 37443, Jalan Perindustrian 3, Senai Industrial Park, 81400 Senai, Johor	-	0.17	11036.4	-	-	-	2014	(Energy Commission of Malaysia, 2016)
290	Synergy Solar Development Sdn. Bhd.	1.5383946134639281, 103.76970057669776	PLO 227, Kawasan Perindustrian Tebrau Ii, 81100 Johor Bahru, Johor	-	0.17	11036.4	-	-	-	2012	(Energy Commission of Malaysia, 2016)
291	Synergy Solar Development Sdn. Bhd.	1.6552591514545079, 103.58104624534806	Lot PTD 43009, Mukim Senai-Kulai, 81400 Daerah Johor Bahru, Johor	-	0.17	11036.4	-	-	-	2014	(Energy Commission of Malaysia, 2016)
292	Synergy Solar Development Sdn. Bhd.	1.654617980969586, 103.58331173774809	Lot PTD 43022, Mukim Senai-Kulai, 81400 Daerah	-	0.17	11036.4	-	-	-	2014	(Energy Commission of

			Johor Bahru, Johor								Malaysia , 2016)
293	Synergy Solar Development Sdn. Bhd.	1.6545796965932174, 103.58336885259128	Lot PTD 43023, Mukim Senai-Kulai, 81400 Daerah Johor Bahru, Johor	-	0.17	11036.4	-	-	-	2014	(Energy Commission of Malaysia , 2016)
294	Synergy Solar Development Sdn. Bhd.	1.6406288657056265, 103.62105029723932	Lot PTD 87634 (Plo 19), Mukim Kulai, Daerah Kulaijaya, 81400 Johor	-	0.42	27266.4	-	-	-	2014	(Energy Commission of Malaysia , 2016)
295	SYW Industry Sdn. Bhd.	4.575246757484975, 101.05411387859209	Sebahagian Lot 312248 Mukim Hulu Kinta Daerah Kinta, 31450 Perak	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia , 2016)
296	Tai Chong Marine Engineering Sdn. Bhd.	4.570651039613223, 101.05160598744439	Sebahagian Lot 111936 Mukim Hulu Kinta Daerah Kinta, 31450 Perak	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia , 2016)
297	Takumi Briquette	1.5073952737823886,	Lot 18066, Blok 5 Taman Melati	-	0.18	11685.6	-	-	-	2015	(Energy Commission of

	Industries Sdn. Bhd.	103.7007985 9734271	Tampoi Tebrau Johor Bahru 81200									Malaysia , 2016)
29 8	Tan Cheng Siang	3.152020926 1477583, 101.5714128 9918886	Di Atas Bumbung Pan Engineering Sdn. Bhd., Lot 12, Mukim Sungai Buluh, Daerah Petaling, 47810 Selangor	-	0.16	10387.2	-	-	-		2013	(Energy Commiss ion of Malaysia , 2016)
29 9	Tan Chong Motor Assemblies Sdn. Bhd.	3.354135844 4248988, 101.5590671 5561528	Sebahagian Lot 29120, Seksyen 20, Bandar Serendah, Daerah Ulu Selangor, 48000 Selangor	-	1	64920	-	-	-		2016	(Energy Commiss ion of Malaysia , 2016)
30 0	Tan Vait Leong	5.593732278 577998, 100.6497920 6948325	Sebahagian Lot 222, Kawasan Perindustrian Kuala Ketil, Mukim Tawar, 09100 Baling, Kedah	-	0.5	32460	-	-	-		2013	(Energy Commiss ion of Malaysia , 2016)

301	Tanda Hebat Sdn. Bhd.	3.1143665479616818, 101.39772120872034	Sebahagian Lot PT 4231, Mukim Kapar, Daerah Klang, 42000 Selangor	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)
302	Tanjung Suci Sdn. Bhd.	3.111711535492633, 101.6266794861527	Sebahagian Lot 24, Mukim Bandar Petaling Jaya, Daerah Petaling, 46300 Selangor	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
303	Temasek Cekap Sdn. Bhd.	5.644838169654095, 100.48723080979318	Sebahagian No. Lot 24871, Bandar Sg. Petani, 08000 Daerah Kuala Muda, Kedah	-	0.18	11685.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
304	Tenaga Ubah Sdn. Bhd.	4.315985940040887, 100.76561115717826	Sebahagian Lot 13044, Mukim Sitiawan, Daerah Manjung, 32400 Perak	-	0.28	18177.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
305	Tenaga Ziad Ariff Sdn. Bhd.	6.1356069320941735,	Sebahagian Lot 1314, Mukim	-	0.3	19476	-	-	-	2016	(Energy Commission of

		102.3042641 7395101	Panchor, Daerah Kota Bharu 16100 Kelantan								Malaysia , 2016)
30 6	Teong Huat Medical Sdn. Bhd.	5.294008450 017239, 100.4457345 0979102	Sebahagian Lot No. H.S(D) 14898 Pt 2938, Mukim 11, Daerah Seberang Prai Tengah, 13700 Pulau Pinang	-	0.18	11685.6	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)
30 7	Tew Peng Hwee	3.041097890 242574, 101.4509591 1601774	Sebahagian Lot 22202 (P.T. 17562), Mukim Klang, Daerah Klang, 40350 Selangor	-	0.72	46742.4	-	-	-	2012	(Energy Commiss ion of Malaysia , 2016)
30 8	Thamilmukilan A/L Puspanadan	6.123792081 189672, 102.2362400 0841521	Sebahagian Pt 117, Mukim Kota Bharu, 15000 Kelantan	-	0.62	40250.4	-	-	-	2013	(Energy Commiss ion of Malaysia , 2016)
30 9	The Methodist Church in Malaysia	2.421559821 223757, 101.8661578 678413	Sebahagian Lot PT 7417, Mukim Pasir Panjang, 71050 Port Dickson,	-	0.16	10387.2	-	-	-	2014	(Energy Commiss ion of Malaysia , 2016)

			Negeri Sembilan								
310	Thean Hin Chan Food Industries Sdn. Bhd.	6.65663732914319, 100.31031353024066	Sebahagian Lot 5o72, Mukim Titi Tinggi, Daerah Perlis, 02100 Perlis	-	0.9	58428	-	-	-	2016	(Energy Commission of Malaysia, 2016)
311	Thumbprints Utd. Sdn. Bhd.	3.312766753050053, 101.58862079667597	Sebahagian Lot PT 10346 Mukim Rawang, Daerah Gombak 48000 Selangor	-	0.5	32460	-	-	-	2014	(Energy Commission of Malaysia, 2016)
312	Trisen Manufacturing Sdn. Bhd.	2.9612053265358074, 101.81365879073196	Sebahagian Lot 1816 Mukim Labu, Daerah Sepang 43900 Selangor	-	0.27	17528.4	-	-	-	2016	(Energy Commission of Malaysia, 2016)
313	TS Solartech Sdn. Bhd.	5.295587162252734, 100.44120791017104	Sebahagian Lot 1002 Mukim 13 Seberang Perai Tengah 14000 Seberang Prai	-	1.18	76605.6	-	-	-	2014	(Energy Commission of Malaysia, 2016)
314	TS Worldwide Warehousing Sdn. Bhd.	3.043048817257513, 101.44100062274251	Sebahagian Lot P.T 126749, Mukim	-	0.18	11685.6	-	-	-	2014	(Energy Commission of

			Klang, 41200 Klang, Selangor								Malaysia , 2016)
315	TSI Dinamik Sdn. Bhd.	6.446177583604244, 100.2060973620134	Sebahagian Lot 2682, Kg. Binjal, Mukim Utan Aji, 01000 Kangar, Perlis	-	0.27	17528.4	-	-	-	2016	(Energy Commission of Malaysia , 2016)
316	TST Machinery & Automation Sdn. Bhd.	2.99992209165444, 101.61081074548643	32, Jalan Utama 1/7, Taman Perindustrian Puchong Utama, 47100 Puchong, Selangor	-	0.13	8439.6	-	-	-	2015	(Energy Commission of Malaysia , 2016)
317	Tuck Sun & Co (Malaysia) Sdn. Bhd.	3.0079272763269467, 101.44059732026798	142454 Klang Klang 42000	-	0.25	16230	-	-	-	2016	(Energy Commission of Malaysia , 2016)
318	TVE Tenaga Sdn. Bhd.	1.530968298915798, 103.79777898133663	No. 89-01, Jalan Rosmerah 3/1, Taman Johor Jaya, Johor, 81100 Johor Bahru	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia , 2016)

319	Twelve Stranddna Sdn. Bhd.	5.207840487536404, 100.5006863366415	No. Lot 670, Sg Bakap Mukim Seberang Perai Selatan Daerah Jawi 14200 Pulau Pinang	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
320	TWT Hardware Sdn. Bhd.	3.2494845208139815, 101.44870916784059	Lot 11250, Mukim Ijok, Daerah Kuala Selangor, 42300 Selangor	-	0.43	27915.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
321	Uchi Optoelectronic (M) Sdn. Bhd.	5.349458878234967, 100.39524172551265	Sebahagian Lot PT 3048, Mukim 01 Daerah Seberang Perai Tengah 13600 Pulau Pinang	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
322	Upaya Jayamas Sdn. Bhd.	3.05721586863272, 101.57558004451585	P.T. No. 249, Mukim Damansara, Daerah Petaling, 47600 Selangor	-	0.5	32460	-	-	-	2013	(Energy Commission of Malaysia, 2016)

323	Uptown System Sdn. Bhd.	2.7282121813983298, 101.71792066784096	Sebahagian Lot No. H.S(D) 07435, Pt 19, Mas Cargo Complex, Zone B Free Commercial Zone, Southern Support Zone, Kuala Lumpur International Airport, 64000 Sepang, Selangor	-	2.47	160352.4	-	-	-	2014	(Energy Commission of Malaysia, 2016)
324	Urban Aquaponics Sdn. Bhd.	6.062867072730258, 100.38367539807312	Sebahagian Lot 1 (Pt 4604), Mukim Kota Setar, Daerah Kuala Kedah, 05400 Kedah	-	0.43	27915.6	-	-	-	2013	(Energy Commission of Malaysia, 2016)
325	Vafe System Sdn. Bhd.	4.6161445944290795, 101.10134181179215	Lot 305014 Mukim Hulu Kinta Daerah Kinta 31200 Perak	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)
326	Velocity Renewable & Green Energy	5.62895845863481, 100.4974035718	Lot PT 24091 Mukim Bandar Sungai Petani Daerah	-	0.18	11685.6	-	-	-	2015	(Energy Commission of

	Tech Sdn. Bhd.		Kuala Muda 08000 Sungai Petani									Malaysia , 2016)
327	Viz Urbana Sdn. Bhd.	1.471110117562522, 103.59995099088346	Sebahagian Lot 15 Mukim Jelutong, Daerah Johor Bahru 79200 Johor	-	0.1	6492	-	-	-		2014	(Energy Commission of Malaysia , 2016)
328	Wangco Incorporated Sdn. Bhd.	3.076658607744336, 101.58381126306438	Lot PT 11741, Mukim Damansara, Daerah Subang Jaya, 47500 Selangor	-	0.18	11685.6	-	-	-		2015	(Energy Commission of Malaysia , 2016)
329	Weng Siang Sdn. Bhd.	5.3913069208887645, 100.39882213775844	Lot 520, Mukim 13 Seberang Prai Tengah 13700	-	0.43	27915.6	-	-	-		2015	(Energy Commission of Malaysia , 2016)
330	WT Plastic Products Sdn. Bhd.	3.096484414824354, 101.3915535610937	Sebahagian PT 50841, Mukim Kapar, Daerah Klang, 42200 Selangor	-	0.14	9088.8	-	-	-		2013	(Energy Commission of Malaysia , 2016)
331	Yanta Plastic Industry Sdn. Bhd.	5.319689740272172, 100.44850932087843	Sebahagian Lot 541 Dan Lot PT10, Mukim 13,	-	0.34	22072.8	-	-	-		2016	(Energy Commission of

			Daerah Seberang Perai Tengah, 14000 Pulau Pinang								Malaysia , 2016)
332	Yiqi Sdn. Bhd.	3.074690521694713, 101.53294947001082	Lot PT 104, Pekan Baru Subang, 40100 Daerah Petaling, Selangor	-	0.18	11685.6	-	-	-	2014	(Energy Commission of Malaysia , 2016)
333	Zinklite Corporation (M) Sdn. Bhd.	6.349735862876096, 99.79864960413224	Sebahagian PT 751 Mukim Bohor Daerah Langkawi 07000 Kedah	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia , 2016)
334	Api Api Energy Sdn. Bhd.	6.760852771146216, 116.72636239061815	No. Lot 055028192, Mukim Kota Kinabalu, Daerah Kudat, 89800 Sabah	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia , 2016)
335	Asiatic Eco Forest Sdn. Bhd.	4.286302593106882, 117.89433253578709	CL105112301, 91000 Tawau, Sabah	-	0.34	22072.8	-	-	-	2015	(Energy Commission of Malaysia , 2016)
336	Borneo Starcruise Sdn. Bhd.	5.979405902662167, 116.07087676663102	Sebahagian NT023037078, Mukim Kg Manggis,	-	0.18	11685.6	-	-	-	2016	(Energy Commission of

			Daerah Papar, 89600 Sabah									Malaysia , 2016)
337	Cahaya Metro Sdn. Bhd.	5.732749042694028, 115.96595727314256	Lot Cl 025088877, Mukim Bongawan, 89709 Papar, Sabah	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia , 2016)
338	Diamond Uptown Sdn. Bhd.	6.872201692945686, 116.76520515606911	Sebahagian Lot 1555, Mukim Kudat, Daerah Kudat, 89100 Sabah	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia , 2016)
339	Digital Awan Sdn. Bhd.	5.3912434396233415, 116.20645271009008	Sebahagian Lot PT 2129, Mukim Kampung Binaong, Daerah Keningau, 89007 Sabah	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia , 2016)
340	Energy Bay Sdn. Bhd.	5.672400737582566, 115.92048031998652	Lot Nt 043099341, Daerah Tuaran, Kg. Pogunlawid, 89600 Tuaran, Sabah	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia , 2016)

341	Evergreen Technology (M) Sdn. Bhd.	5.8084776346878835, 117.78864960344917	Sebahagian Lot 075510799, Mile 27, Jalan Labuk, Mukim Sungai Manuel, 90000 Daerah Sandakan, Sabah	-	1	64920	-	-	-		2015	(Energy Commission of Malaysia, 2016)
342	Firma Odesi Sdn. Bhd	5.888729267961632, 117.92386315250138	Lot 075405417, Mile 16, Jalan Labuk, Mukim Gum-Gum, 90000 Daerah Sandakan, 90000 Sandakan, Sabah	-	1	64920	-	-	-		2016	(Energy Commission of Malaysia, 2016)
343	Genertech Construction Sdn. Bhd.	6.1644251853753875, 116.18458300011967	Sebahagian Lot Nt043225636, Mukim Tuaran, Daerah Kampung Lok Batik, Jalan Sulaman, 89200 Tuaran, Sabah	-	0.43	27915.6	-	-	-		2016	(Energy Commission of Malaysia, 2016)

344	Green Leadership Sdn. Bhd.	5.385934979131329, 116.11442514866785	Sebahagian Lot Cl 135348051, Cl 13531-280, Batu 5 1/2, Mukim Nabawan, Daerah Keningau, 89000 Sabah	-	2	129840	-	-	-	2014	(Energy Commission of Malaysia, 2016)
345	GV Bumisinar Sdn. Bhd.	6.8431215090946145, 116.82824424507493	Sebahagian Lot 053051737, Mukim Kg Liman Limawan, Daerah Kudat, 89050 Sabah	-	0.6	38952	-	-	-	2015	(Energy Commission of Malaysia, 2016)
346	Inovasi Kurnia Sdn. Bhd.	6.399663524606172, 116.40693404565357	Nt 3598 Kampung Kota Peladok, Jalan Tamau Kota Belud 89150	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
347	KL Timber Sdn. Bhd.	5.323777495592503, 116.15130364599146	Sebahagian Lot 135319452 Mukim Pampang Daerah Keningau,	-	0.85	55182	-	-	-	2016	(Energy Commission of Malaysia, 2016)

			89000 Sabah								
348	Lok Kawi Plastic Industries Sdn. Bhd.	5.841263076391669, 116.04695512366602	Lot 64, Lok Kawi, Daerah Papar, 88100 Kota Kinabalu, Sabah	-	0.18	11685.6	-	-	-	2015	(Energy Commission of Malaysia, 2016)
349	Marudu Engineering Sdn. Bhd.	6.835121169887537, 116.79676999004516	Sebahagian Lot No. Nt 15445 (L.A.312-61), Mukim Kampung Rorongkom, Daerah Kudat, 00000 Sabah	-	1	64920	-	-	-	2014	(Energy Commission of Malaysia, 2016)
350	Marudu Power Sdn. Bhd.	6.5090426935515175, 116.76875921600536	Sebahagian Nt 224027678 Kg Goshen, Bandau 89100 Kudat, Sabah	-	1	64920	-	-	-	2016	(Energy Commission of Malaysia, 2016)
351	Microvest Power Ventures Sdn. Bhd.	6.813006470914797, 116.69870548411838	Nt053029217 Kampung Tambuluran Kudat 89050	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
352	Mutiara Desaru Sdn. Bhd.	5.69332227800214,	Sebahagian Lot Nt 1614 Mukim	-	0.42	27266.4	-	-	-	2016	(Energy Commission of

		115.9892555 6258011	Kg. Sempudu Daerah Papar, 89600 Sabah								Malaysia , 2016)
35 3	NK Energy Sdn. Bhd.	6.845472518 57625, 116.8035675 3467375	Sebahagian Lot 109, Daerah Kudat, 89050 Sabah	-	0.99	64270.8	-	-	-	2016	(Energy Commiss ion of Malaysia , 2016)
35 4	North-East Destiny Sdn. Bhd.	6.043167130 005589, 116.1480808 3041402	5th Floor, 1 Borneo Hypermall, Jalan Sulaman, 88400 Kota Kinabalu, Sabah	-	0.41	26617.2	-	-	-	2016	(Energy Commiss ion of Malaysia , 2016)
35 5	Powernet Venture Sdn. Bhd.	4.437495931 597555, 118.5332129 2682851	Sebahagian Lot 115, Mukim Pegagau, Daerah Semporna, 91308 Sabah	-	1	64920	-	-	-	2016	(Energy Commiss ion of Malaysia , 2016)
35 6	Sabakekal Sdn. Bhd.	5.845101558 3843855, 118.1253819 0208708	Lot No. 2 Batu 1 1/2 Jalan Buli Sim Sim Sandakan 90000, Sabah	-	1	64920	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)

357	Sibuga Energy Sdn. Bhd.	5.585620370264456, 118.06598195163605	Sebahagian Lot Cl 075349647, Daerah Sandakan, 90000 Sabah	-	0.99	64270.8	-	-	-	2016	(Energy Commission of Malaysia, 2016)
358	SMR Aquaculture Sdn. Bhd.	4.278026099693475, 117.92421020751567	Lot Cl. 105510870, Mukim Mas Mas Kalumpang, 91000 Daerah Tawau, Sabah	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
359	Sri Sabawak Energy Sdn. Bhd.	6.162511389426343, 116.1650504128565	Sebahagian Lot Nt 043196587 Mukim Kampung Laya-Laya 89200 Tuaran	-	1	64920	-	-	-	2015	(Energy Commission of Malaysia, 2016)
360	Sunwide Resources Sdn. Bhd.	4.247111857378974, 117.88045869379819	Sebahagian Lot 105556509, Mukim Tawau, Daerah Tawau, 91000 Sabah	-	0.43	27915.6	-	-	-	2016	(Energy Commission of Malaysia, 2016)
361	SW7 Sdn. Bhd.	5.495159247947412,	Sebahagian Lot Nt 183308214	-	1	64920	-	-	-	2016	(Energy Commission of

		115.5550164 212468	Mukim Kampong Tamu Kayol 89740 Kuala Penyu								Malaysia , 2016)
36 2	Tenaga Solar Beaufort Sdn. Bhd.	5.453411124 40641, 115.7874691 422357	Lot B1170494 Kg Mawao Membakut Beaufort 89800	-	1	64920	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)
36 3	Tiong Cheong Bricks Sdn. Bhd.	6.174904441 6771905, 116.2326786 794175	2762 Tuaran Tuaran 89207 Sabah	-	0.69	44794.8	-	-	-	2014	(Energy Commiss ion of Malaysia , 2016)
36 4	TR Energy Sdn. Bhd.	6.832765726 975019, 116.8101406 8546409	Lot 172, Daerah Kudat, 89050 Sabah	-	0.99	64270.8	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)
36 5	Vista Serijuta Sdn. Bhd	4.244958921 755028, 117.8798523 2827666	Sebahagian Lot No. 10200111 Sabah Ports Sdn. Bhd. 91000 Tawau	-	0.34	22072.8	-	-	-	2015	(Energy Commiss ion of Malaysia , 2016)

Appendice D

No.	Name	Name Of Organization	Position
1	Shafirul Azriq Bin Shariffudin	Cohu Malaysia Sdn. Bhd.	Senior Engineer
2	Mohamad Azril Bin Mohamad Noor	UEM Edgenta	Senior Manager
3	Zulfadhli	CTRM	Head Of Department
4	Masruddin Rahmat	Malaysian Refining Company Sdn Bhd	Culture And Behaviour Executive
5	Athira Suraya	Ericsson	Engineer
6	Muhammad Ilham Bin Abdul Rahim	Flextronic Sdn Bhd	Manufacturing Engineer
7	Mohd Irwan Shah Bin Mohd Rabu	CTRM Ac Sdn. Bhd.	Executive
8	Ts Dr Muhammad Azfar Bin Abdullah	AM Grand Management	Managing Director
9	Mohd Shafihan Bin Mohd Said	Teras Teknologi Sdn Bhd	Executive
10	Yoong Qi Hanh	Infineon	Resource Planner
11	Akmal Haziq	Meiban Technologies Sdn.Bhd	Product Engineer
12	Ong Kang Wei	AMD	Engineer
13	Lai Mom Wei	Infineon	Engineer
14	Gunawan Mohd Jais	Infineon Technologies Sdn Bhd	Project Manager
15	Wong Zhi Wei	Infineon	Industrial Engineer
16	Pang Yu Yang	Infineon	Industrial Engineer
17	Chan Chin Xsien	Toyota	Sales Advisor
18	Lee Sze Nee	Teguh Harian	Account Executive Officer
19	Hor Jin Yi	Infineon	Engineer
20	Ch'ng Li Shan	Keysight	Customer Service