PRODUCTION OF SUSTAINABLE METHANOL FROM PLASTIC WASTES BY GREEN ENERGY TO OPTIMIZE LANDFILL AREA

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2022

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RESEARCH REPORT SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SAFETY, HEALTH AND ENVIRONMENT ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2022

UNIVERSITY OF MALAYA

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ABSTRACT

The fundamental element required to produce methanol is syngas. Many researchers have carried out in depth experiment on using plastic wastes to draw syngas which can be turned into methanol. Howbeit, the process of making this alternate fuel should be taken into consideration in order to attain sustainability. Exploiting the plastic wastes into a pyrolysis system that converts into methanol could reduce the expansion of landfill problem while contributing to alternate fuel. However this does not make the whole system sustainable unless the electricity required to operate is drawn from renewable source. In this paper, a thorough study showed on the possibilities of making the methanol production sustainable by substituting the raw material into plastic. Besides, the obsolete concept of energy storage system will be presented explaining how it could contribute to sustainable methanol production. On the other hand, based on the data collected from other research papers, the total amount of methanol that can be produced from the plastic wastes generated daily will be calculated. The propagation of plastic weightage to produce 1 litter of methanol was attained from an experiment conducted at a R & D chemical located at Kajang. From this calculation, a presumption were showed on the geographical layout that about 1/3 of the landfill area were saved. There are innumerable landfills been operating in Malaysia. Thus to explain the land reduction at landfill, Pulau Burung Landfill, Penang will be taken as an example to demonstrate by inserting the boundary coordinates of the overall location along with reduced landfill area location using polygon features in the GQIS software. The overall land and optimized land will be exemplified from the geographical image obtained from QGIS software. Considering this

approach will be elucidated on how it greatly affect the Malaysia's economic and environment.

Keywords: landfill, methanol production, plastic wastes, pyrolysis system, sustainable development,

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ABSTRAK

Unsur asas yang diperlukan untuk menghasilkan metanol ialah syngas. Ramai penyelidik telah melakukan eksperimen ke atas bahan plastik untuk cuba mengambil syngas untuk ditukarkan kepada metanol. Walaubagaimanapun, kaedah menghasilkan bahan api alternatif ini harus dikaji semula untuk mencapai kelestarian yang dikehendaki. Pengeksploitasian sisa plastik ke dalam system pyrolysis yang akan menukarkan metanol boleh mengurangkan masalah pengembangan tapak pelupusan sampah dalam masa yang sama menyumbang kepada perkembangan bahan api alternatif. Namun , ini tidak bermaksud bahawa kesuluruhan sistem ini menjadi lestari kecuali jika sumber tenaga elektrik untuk menjana sistem ini diambil daripada sumber semula-jadi . Dalam kajian ini , cara menjadikan plastik yang sedia ada ditukar untuk menjadi sebuah sistem yang lestari dijelaskan. Kaedah sistem penyimpanan tenaga akan dibentangkan unutk menjelaskan jenis yang ada seperti sistem simpanan tenaga elektrokimia , sistem simpanan haba , sistem simpanan roda tenaga , sistem simpanan tenaga udara mampan , dan lain-lain dan cara ia boleh menyumbang kepada cara penghasilan metanol secara lestari . Pada masa yang sama , berdasarkan data yang telah dikumpul daripada penyelidik lain , jumlah metanol yang boleh dihasilkan daripada sumber plastik yang dilupuskan dalam tempoh masa sehari boleh dikira. Daripada pengiraan ini , sebuah anggaran tentang berapa banyak tapak pelupusan sampah boleh dikurangan dari pengembangan boleh ditunjukkan berdasarkan perisian QGIS. Terdapat banyak tapak pelupusan sampah yang sedang beroperasi di Malaysia. Oleh yang demikian , untuk memperlahankan pengembangan tapak pelupusan sampah ini , tapak pelupusan sampah di Pulau Burung , Pulau Pinang harus dicontohi . Mereka mengunakkan kaedah menanda koordinat untuk menunjukkan

batas untuk tapak pulupusan sampah tersebut. Gambar tanah keseluruhan dan tanah yang diggunakkan akan diambil daripada gambar satelit yang akan diambil dari perisan QGIS.

Keywords: pembangunan lestari, pengeluaran methanol, sisa plastik, system pyrolysis, tapak pelupusan sampah

ACKNOWLEDGEMENTS

I would like to express my special thanks of gratitude to my supervisor Associate Professor Dr. Nasrin Aghamohammadi for guiding me throughout this research project. I perceived no hesitation from my supervisor during our individual supervision besides the busy schedule attending other students and classes. The guidelines given were lucid and efficacy for my research project. Not to forget my parents, who had persistently persuaded me to give the best. All the financial and motivational support by my parents and husband are much appreciated. Besides, I would like to extend my gratitude to my fellow classmates and friends who shared some of their work experiences which helped in my research report. I am extremely grateful to have these kind-hearted and helpful people around to complete my research report successfully. Finally, I apologize all other unnamed who helped me in various ways to complete my research report.

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LIST OF SYMBOLS AND ABBREVIATIONS

CAES	:	Compressed air energy storage
CO2	:	Carbon Dioxide
Cu	:	Copper
EC	:	Electrocatalysis
GHG	:	Green house gas
HDPE	:	High density polyethylene
LDPE	:	Low density polyethylene
PET	:	Polyethylene terephthalate
PETE	:	Polyethylene terephthalate
PP	:	Polypropylene
PS	:	Polysterene
PVC	:	Polyvinyl chloride
SDG	:	Sustainable development goal
TC	:	Thermocatalysis
QGIS	:	Quantum Geographic Information System
ZnO	:	Zinc oxide

CHAPTER 1: INTRODUCTION

1.1 Background

Methanol production is been on market for a long time. The raw materials used to produce the methanol are oil, coal and biomass. Though the introduction of methanol to the world has been a great leap from escaping the scarcity of oil and gas, the production is not seem to be environmentally sustainable. There are many ways of drawing methanol such as direct synthesis, indirect synthesis, hydrogenation and many more. Howbeit the method conducted, by substituting the raw material would create a big change to the environment. In the end, CO2 is needed to produce synthesis gas that can be convert it into methanol. To capture the CO2, it is not necessary to burn the oil, coal and biomass, instead the CO2 can be captured from heating the plastic wastes. This system is called pyrolysis where the plastics will be heated with absence of oxygen to produce synthetic gas which will be passed through a catalyst at a specific temperature and pressure to produce methanol. In order to generate the heat needed to operate the pyrolysis system, a large amount of electricity is required. In Malaysia, electricity is generated 40% from burning coal which leads to carbon emission. Thus, exploitation of renewable energy such as wind will be utilized to generate power and store it in energy storage system such as compressed air system. The compressed air will be released at high velocity to run the generator that generates the electricity which will be used to operate the pyrolysis system. This system is completely sustainable since the operating source is from renewable energy and the end product can be used as alternate fuel as the fossil fuel sources and depleting in the world. With this approach, the existing plastic wastes can brought down and the landfill area will be reduced for plastic dumping. Despite of reduction, reuse, and recycle practices, the landfill expansion is still being unavoidable in Malaysia (Ibrahim Mohammed et al., 2019).

1.2 Problem Statement

The world is revolutionising very quick without realizing the disaster caused by excessive usage of resources without sustaining it well. The consequences of this is either depletion of resources or unconstrained wastes of the resources which effects the living world. The concept of sustainable development in Industry 4.0 was introduced to the world, focussing on innovative technology without compromising economic, social, and environmental. Methanol production via pyrolysis system been studied and conducted for many years, though it may not sound familiar to many since further improvisation and research been carried out still. The research on pyrolysis methanol was done by many researchers in a small lab scale which some of them successfully attained less than 20g of sample. Many prototypes currently being built for bigger scale methanol producing pyrolysis system. Kasmuri et al. (2019) has expounded the theory of using bio methanol from sugarcane bagasse as a new renewable energy source. Forgetting the fact that the raw material stated earlier to produce bio-methanol is demarcated depending on the quantity of consumers. Thus, the production of bio methanol might fluctuate subject to the availability of the sugarcane bagasse. However, we could still set forth the methanol as renewable energy source by substituting the raw material to plastic wastes. As we are all aware that plastic wastes are scattered all around the world. There are innumerable of innovative actions have been taken to avoid single use plastic to mitigate plastic wastes generation. It requires serious action to eliminate the plastic wastes produced from all these decades that have been accumulated at landfills. This issue exacerbated during this pandemic season for the past 2 to 3 years as a consequence of online food orders which escalates the food packages, face mask and sanitizer usage. From cities to remote areas, plastic wastes are scattered around in form of face mask, drinking bottles, sanitizer bottles, straws, food packages and other sort of single use plastic products. It has been brought to attention that; Malaysia is one of the highest plastic consumers in Southeast Asia. Ever since China stopped purchasing plastic wastes in the year 2018, Malaysia be fitted for plastic wastes trafficking (Muslim, 2021). Besides that, the imported plastic wastes from developed countries are not recycled on account of expensive and complex process by some of the corporate companies and ends up at landfills. Channelling this plastic wastes to pyrolysis system converting it into methanol production would be a great leap to obliterate plastic wastes around. Be that as it may, this approach will not be professed as sustainable development by reason of the electrical energy source used to operate the pyrolysis system. According to (Haiges et al., 2017), 88.4% of electrical energy is form burning fossil fuels in Malaysia. To be specific, 53.3% from natural gas, 30.5% from coal, 2.8% from fuel oil and 1.8% from diesel. Burning the fossil fuel give rise to emission of GHG to atmosphere Howbeit, if the electricity used to operate the system is drawn from renewable energy or an energy storage system, it would make the whole methanol production process sustainable. As methanol can be used as an alternate fuel, the demand for it will be high. Thus, more plastic wastes will be used in the process of making methanol. By doing so, the existing plastic wastes can be reduced, and the landfills will be only used for organic wastes such as food, paper, and woods. As we are aware that the organic wastes decompose within 2-3 weeks, expansion of landfills will no longer be required. In contrary, the fossil fuel resources cannot be replenished in short period of time as we have resources only for the next 40 years, said by Millennium Alliance for Humanity and the Biosphere (MAHB). Therefore, an alternate fuel will be introduced to the world which will be produced sustainably while diminishing the plastic wastes at landfills. By doing so the plastics that have ended up at landfills will be decreased and the area of landfills will be optimized for organic waste dumping .

1.3 Research Question

To optimize the landfill area, few questions has to be acknowledged to depict a better view of the problem. For instance:

1. What kind of plastics are dumped at Malaysia's landfills in a day?
2. Does using plastic wastes in pyrolysis to produce methanol helps to reduce landfill areas?

1.4 Objective

1) To specify the opportunity of plastic wastes reduction by channelling it into a sustainable approach of methanol production using renewable energy source.
2) To show the reduction of landfill areas by utilizing the plastic wastes into pyrolysis system.

1.5 Conceptual Framework

A conceptual framework was constructed based on the literature review of the paper on how to attain sustainability in the process of producing methanol. The figure 1.1 depicts the possibility manoeuvres in achieving sustainability.

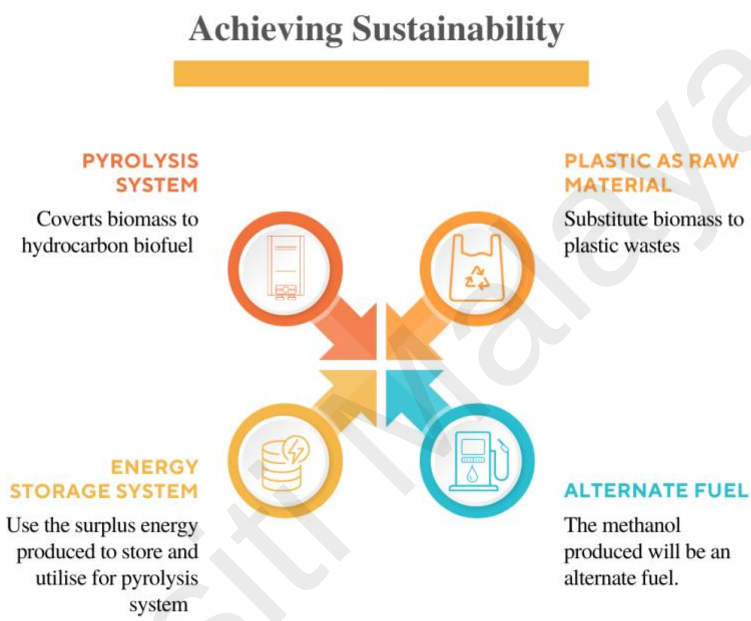


Figure 1.1 Conceptual Framework 1

CHAPTER 2: LITERATURE REVIEW

2.1 Plastic Background

Plastics are mainly made from petroleum bases such as crude oil, natural gas, cellulose, coal and etc. The first ever plastic was made in 1862 by Alexander Parkes and named it as Parkesine. Though it was not a successful invention back then since the potential of the plastic was not shown clearly. Improvisation was made on plastic manufacturing by many after the first invention by Alexander (Krosofsky, 2021). Followed by that, the proliferation of different composition of plastics were invented and introduced in the market. The vital purpose of plastic production was the claim of the material to be flexible, hence easily moulded into various shapes. It was also said to be light in weight which brings us the most crucial part which made the production of plastic essential, the convenience for users to carry it around. On the other hand, the production cost is cheaper compared to any other material. The table 2.1 shows the timeline of various type of plastic invention up to date.

Table 2.1 History of Plastic 1

1907	• Synthetic plastic called Bakelite was invented by Dr.Leo Bakeland
1920	• Polymers were found by Hermann Staudinger
1933	• Polyethylene, Polystyrene, Nylon were invented during the world war II
1950	• High Density Polyethylene were used to make milk bottles and to make other consumer products
1960	• Synthetic fibre, kevlar, thermoplastics were introduced
1970	• Biobased and biodegradable plastics were produced for environmental conservation

2.1.1 How Is It Made?

Plastics can be divided into two; synthetic type and bio-based type. The synthetic plastics are basically made from petrol base materials whereas the bio based plastics are made from renewable sources such as corns, bacteria, vegetables fats and oils. The synthetic plastics are mostly preferred ascribe to the fact that the process is not complex. A technique of plastic making is portrayed below.

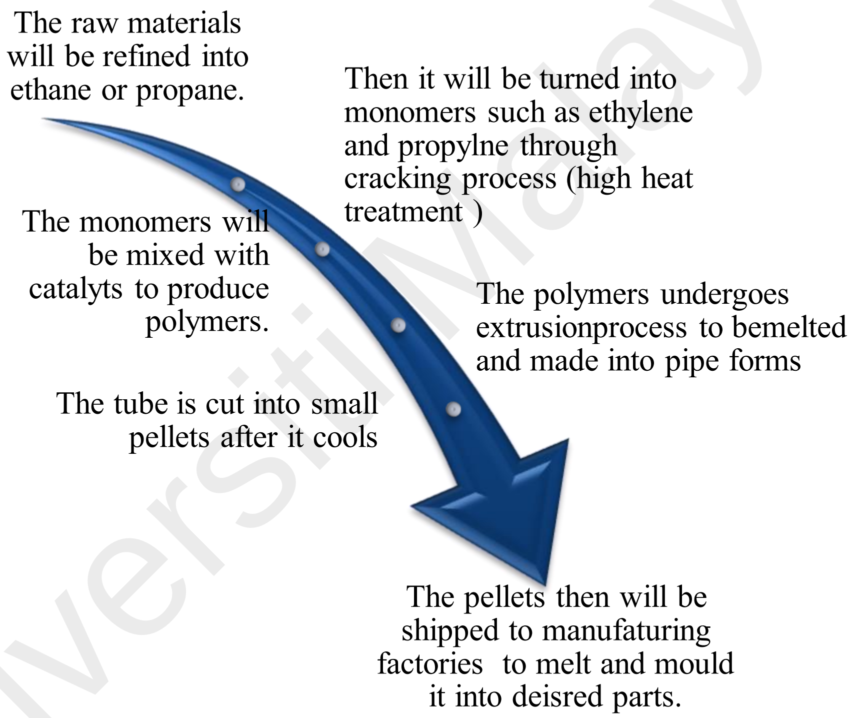


Figure 2.1 Process Of Plastic Making 1

There are innumerable of plastic types as mentioned earlier. The key point of improvisation made on plastic materials over the time was to befitted according to the application of it. Certain plastic material may not seem well suited for all the applications as the properties of the polymers varies. Some application may require high temperature withstand, shock proof, harder and other strong qualities. Thus, to accommodate this issue, the plastic material were composited with several other materials in order to customise the properties. The mechanical properties of the plastics changes together with the chemical properties. Thus far, all the existing plastic types out there has its own advantages and disadvantages. Gleaned from that, the application of the plastics were decided. The table 2.2 shows the types of plastic available heretofore along with the advantages and applications of it.

Table 2.2 Plastic properties 1

Type of Synthetic Polymers	Advantages	Application
PET or PETE	• Hard • Flexible • Absorbs odours and flavours from foods and drinks	Beverage bottles, food packaging, electrical parts, etc
HDPE	• Rigid • Does not transmit any chemical into foods and drinks	Grocery bags from markets, harder drinking bottles, piping, toys, etc
PVC	• Resistant towards flame • Flexibility Lightweight	Blister wrap, window and door frames, blood bags, medical tubing, drainage pipes, electric wire and cable.
LDPE	• Durable • Flexible	Packaging films, mineral bottles, soft tubing, carrier bags, moulded materials of laboratory equipment, etc
PP	• Resistant to high temperature • Hard • Flexible	Microwaveable trays, disposable cups and bowls, drinking bottles and straws.
PS	• Hard • Brittle	Food packing container, yoghurt pots, storage box

2.1.2 Disadvantages Of Plastics

Like any other materials, plastics are can only be recycled few times before it loses its quality and integrity (Miller, 2020). There are some types of plastics that can't be recycled. Plastics that are used once also known as single use plastics end up no where else but either in landfills or oceans . As the number of populations escalates the single use plastics also increases which leads to plastic pollution. Though there are plastics that can be recycled, the recycling process of plastics consumes immense energy which indirectly contributes to GHG emission. Besides that, when compared to organic items the duration of plastic to decompose takes a longer period of time. Miller (2020) has stated that some plastics would not completely decompose but on the other hand transmute into nano plastic which causes harm to human, animals and marine lives. As we can see in table 2.3, PVC type of plastics are the type that will never decompose.

Table 2.3 Decomposibility of Plastics 1

2.1.3 Plastic Wastes

Plastic pollution has been an issue for decades that has been addressed over this period of time , but a solution has yet to be found to completely obliterate the issue. The generation of plastic wastes in worldwide is quite impractical to mitigate since somehow each and every one of us are utilizing or retaining having products being made from plastics in our everyday life. For instance, plastic bottles, groceries packed in plastics, products with plastic labelling, coffee stirrers, straws and many more.

According to Al Rayaan (2021) ,the consumption of individual plastic globally are 33.5% of polyethylene (PE), 19.5% of polypropylene (PP), 16.5% of polyvinylchloride (PVC), 8.5% of polystyrene (PS), 5.5% of polyethylene terephthalate (PET) and polyurethane (PU), 3.5% of styrene copolymers (ABS, SAN, etc) and the remaining 13 % of thermosetting plastics, alloys, blends and more. Programme (2018) stated in the UN Environment Programme Report that nearly 1 million plastic drinking bottles are purchased every minute globally. This leads to difficulty in mitigation of plastic waste because as stated before plastic is the most common item that we find in our daily life, it is incorporated in nearly everything from our drinking bottles to kitchen ware due to its affordability and its convenience in our lives. In early 1950's the production of plastic was minimal hence making it easier to be controlled and managed .

However, in the 1990's the plastic wastes have proliferated three times in two decades. At current state of affair, we are responsible for 300 million tonnes of plastic waste generated in a year . The landfills are currently filled to the brim with plastic wastes and this does not include the another major part of it that winds up in the ocean . Despite knowing the repercussion of over usage of plastic, the production of plastic made items are still on going in many industries. The reverberations of plastics to the environment is not unprecedented as the medias have always been advertising about global warming, marine lives crisis and pollutions caused by plastics. Plastics are manufactured from refining the crude oil or natural gas which approximately emits 400 tonnes of GHG to the environment (OECD, 2018). This GHG is the main cause for the global warming and sea level rise. The amount of plastic wastes generated by only the Asian countries are hitting about 121 Mt (Liang et al., 2021). On top of this, Asian countries are importing plastic wastes from countries like, Germany, USA, Japan and etc for treatment and disposal purpose. Malaysia's Minister of Energy, Technology, Science, Climate Change, and Environment stated in her interview in National Geographic " no developing nation should be dumping side for the developed world"(PARKER, 2018). The figure 2.1 below shows some of the major loacations of the landfills in Malaysia that are still been operating. Such as Wilayah Persekutuan, Shah Alam, Jeram, Bukit Tagar, Tanjung Dua Belas, Persiaran Lestari, Kuang, Kubang, Dengkil, Teluk Mengkudu, Tanjung Langsat and Perlis.

Figure 2.2 Major Landfills 1

The plastic wastes does not only causes expansion of landfill, and ocean pollution but also causes soil pollution. Plastics that wind up at open dumping site breaks down to microplastics due to the sun's radiation. Based on the studies conducted by (Tun et al., 2021), the presence of microplastic in the soil has brought a shock. The microplastics that are present in the soil reduces the fertility of the soil, water holding capacity and changes the soil porosity. The provenance of microplastic in soil is mainly due to sludge usage, application of mulching film, wastewater irrigation, landfills, and atmospheric deposition (Yu et al., 2020).

In year 2020 and 2021, the plastic pollution proliferates badly due to the pandemic season in the health sector and public health security. As of August 23, 2021, approximately 212 million people worldwide were infected with the COVID-19 virus, with the Americas (47.6%) and Asia (31.22%) having the most confirmed cases, followed by Europe (17.26%) followed (Peng et al., 2021). The amount of plastic medical waste is increasing significantly due to an increase in hospitalizations and virus testing as shown in Figure 2.2. Many single-use plastics (SUP) laws have been repealed or withheld to support the huge demand for personal protective equipment (PPE, including face masks, gloves and face shields). In addition, due to self-isolation, social distancing and restrictions on public gatherings, reliance on online shopping, which contains a lot of plastic in packaging, is increasing at an unprecedented rate.

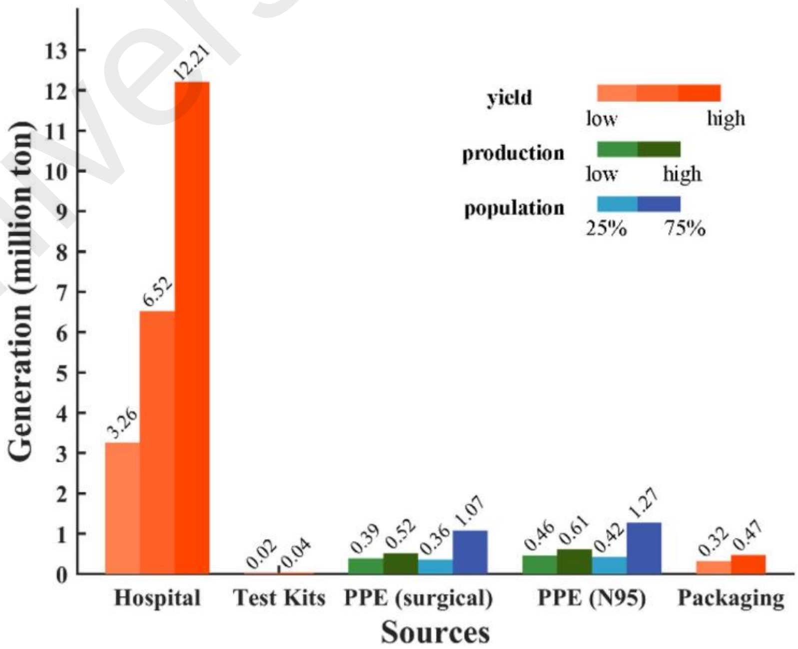


Figure 2.3 Sources of Plastic Pollution 1

Among the countries facing this issues such as India, Cambodia, Indonesia, Laos, Philippines , and Vietnam, Cambodia was stated the highest in presence of microplastic in the soil which is 218,182 pieces/kg. The microplastic can also be found in the ocean as ocean became the biggest plastic waste dumping site. Looking into the UN Environment Programme Report, plastic wastes are carried by the river to the ocean. The rivers stated below in table 2.3 carries approximately 90% of the plastic wastes that leads to the ocean. By the year 2050, we will be having more plastics in the ocean than fish if no actions are taken to combat this issue. According to (Ferraro & Failler, 2020), the macro, micro and nanoplastics threatens the health of the marine biosphere. Plastic waste traps and kills marine life. The fragmented plastic fragments are ingested by marine life and incorporated into the food chain. Marine plastics accumulate toxins and contain diverse microbial communities. Plastic debris is concentrated around shorelines and in “convergence zones” known as gyres, which persist for hundreds of years.

Table 2.4 Plastics Lead to Ocean 1

Name Of River	**Plastic Weightage (Tonnes)**
Chang Jiang (Yangtze River)	1,469,481
Indus	164,332
Hai He	91,858
Huang He (Yellow River)	124,249
Nile	84,792
Meghna,Ganges	72,844
Amur	38,267
Zhujiang (Pearl River)	52,958
Niger	35,196
Mekong	33,431

2.1.4 Plastic Waste Management in Malaysia

Malaysia has been tracking global trends in total plastic waste and single-use plastic consumption and has been the world's largest importer of plastic waste since 2017 as mentioned earlier. These factors create a number of serious problems for the country's waste management system. In Malaysia, most municipal solid waste is typically disposed of in both sanitary and unsanitary landfills, and there is very little recyclable plastic in Malaysi. In some jurisdictions, used plastics are sorted at their source and collected by private waste contractors paid for by the city council (Chen et al., 2021). However, these amounts are very small compared to the total amount of plastic contained in waste. Data on the total amount and type of plastic are scarce, but recyclable plastics are also shipped directly to consumers through industry-specific plastic recyclers, landfill collectors and charities and garbage stores. Industrial plastic waste in the form of industrial waste has a homogeneous and pure nature, making it much easier to recycle before consumption. In Malaysia, most states and territories support municipal solid waste collection by roadside or on-site (Chen et al., 2021). Although there is a scavenger and manual sorting of some recyclable materials (mainly plastics and metals) that have market value in landfills or other sources, the amount of recyclable materials that are sorted out in landfills is very small. The quality, quantity and form of collection, sorting and processing in Malaysia vary considerably. Even within the same municipality, communities with private gates (common in Malaysia) can organize their own household waste collection. Due to the dispersed nature of the Malaysian waste management system, there are currently no comprehensive data sets that describe trends, particularly detailed data on the proportion of each type of plastic from generation to recycling or landfill (Chen et al., 2021)

2.2 Methanol Production From Plastic Pyrolysis System

Methanol retains total energy of 22.7 MJ/kg whereas the normal petrol has 44 MJ/kg energy (Mancusi et al., 2021). Methanol holds half of the energy content of gasoline which makes it to be a good alternate fuel in near future. There are innumerable publications on the research of the methanol production. The key particle for methanol production is the CO2. Van-Dal and Bouallou (2013) has shared their idea of capturing the carbon dioxide from the surrounding and hydrogenate it to produce methanol. However, for a vast production of fuel grade methanol, extracting the CO2 from atmosphere would not suffice for large scale production. An alternate way of producing CO2 will be burning the wastes. As mentioned earlier, plastic wastes are ubiquitous around the world. Utilising the plastic as the main source of fuel to heat to capture CO2 will reduce the existing plastic wastes. In the pyrolysis system, it is proven that the plastics can be turned into aromatics, olefins, and paraffin (Ali et al., 2021). The carbon dioxide captured from heating the plastic wastes can be converted into crude oil with catalytic reactor. The table 2.5 shows the required temperature for heating the specific plastics and the weightage of crude oil and synthetic gas produced (Hussin et al., 2021).

Table 2.5 Biproducts of Plastic 1

Type of Plastic	Reactor	Pyrolysis Tempera-ture (°C)	Catalyst	Crude Oil(wt%)	Solid Residue (wt%)	Gas (wt%)
PE PP PS PET Mixed	Parr mini bench top	500	None	93 95 71 15 90	0 5 27 53 5	7 5 2 32 5
PE	Activated carbon bed	515–795	None	88–96	5.5	2
LDPE	Fixed-bed tubular flow reactor	425	HZSM-5 SiO_2-Al_2O_3			
HDPE	Continuous reactor	520	HZSM-5			
PET	Fixed bed	500	-	23.1	0	76.9

Focusing on the production of the methanol, the key concept here is the chemical reaction takes place between the carbon dioxide and other gasses along with catalysts. It can be attained in many ways. For instance, Mancusi et al. (2021) has elucidated chemical looping combustion of solid fuels that reacts with Cu/ZnO along with alumina catalyst to produce methanol. The ZnO reduces the poisoning of Cu and also to neutralize the acidity of alumina to produce dimethyl ether. Besides that, in the study of Chein et al. (2021), another way of methanol production was analysed. Either CO2 hydrogenation or syngas that generated from biogas will be sent through an isothermal reactor. It is also stated that isothermal reactor has higher methanol yield than adiabatic reactor. Khademi et al. (2021) highlighted on methane tri-reforming reaction as one of a way to produce synthetic gas which could be turned into methanol. The best operating temperature to obtain high CH4 conversion is 950 degree Celsius (Khademi et al., 2021). On the other hand, Cui et al. (2022) study shows, methanol synthesis and distillation process can produce pilot scale green methanol which is approximately 22, 236 tonnes per year and has been proven in dynamic modelling.

Besides the varies type of process, the type of catalysts used in the methanol production also plays a major role in attaining high purity of methanol. Izquierdo et al. (2013) research was based on five different types of Ni based catalysts that were prepared by inductively coupled plasma-atomic emission spectrometry (ICP-AES), temperature programmed reduction (TPR), N_2 adsorption–desorption isotherms, H_2-pulse chemisorptions, X-ray photoelectron spectroscopy (XPS) and SEM. The preparation of the catalysts were elucidated in detail by Izquierdo et al. (2012) in his book volume 37. Ballotin et al. (2020)'s innovative idea of using a solid acid catalyst of different nano structures in esterification to produce methanol. The experiment of hydrogenation of ethyl formate to methanol using various types of catalyst was conducted by (Zhang et al., 2021).

There are innumerable of articles and journals have elucidated pertaining methanol production. Some of the articles have highlighted their lab scale methanol production systems. The results of the product yield is analysed and shown in the figure 2.3 at the bottom.

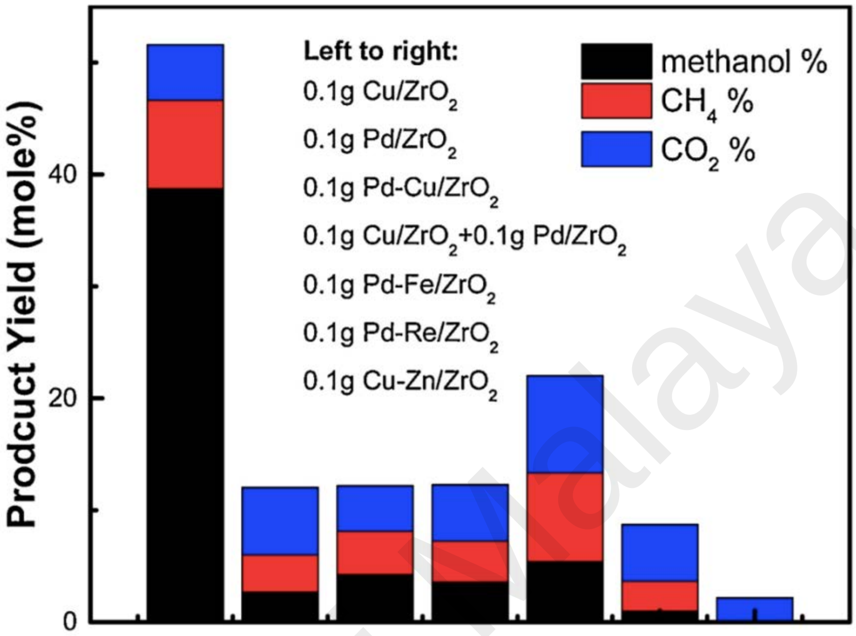


Figure 2.4 Yield Product 1

2.3 Other Approach on Sustainable Methanol Production

Bhardwaj et al. (2021) have explained on conversion of C02 into methanol using a variety of materials such as microparticles and nanoparticles. Some of the efficient materials used to convert CO2 to methanol are porphyrins, which have unique properties. Porphyrins used as nanoreactors have a large core size, large pyrrole subunits, and improved structure, size, intermolecular connectivity, and binding, resulting in a high degree of efficiency for the production of methanol from CO2 which will be a catalyst (Bhardwaj et al., 2021). In addition, biochar-based catalysts such as broadleaf tree biochars and crabshell biochars, and other biochar catalysts synthesized from agricultural waste such as corn cobs, pine and rice husks, are present in several inorganic species. Has been regarded as a better catalyst. Nanomaterials are also widely used for carbon recovery and conversion to many valuable products, including methanol. However, the main problem with using these materials for CO2 conversion is the high cost of synthesis.

On the other hand, Guzmán et al. (2021) explained about how Electrocatalysis (EC) and thermocatalysis (TC) can be used to convert CO2 to methanol which seem a promising technologies for carbon capture and utilization. The process of converting this CO2 to ethanol was analyzed in terms of technical, environmental and economic feasibility in the paper. The catalytic efficiency to the same catalyst mentioned earlier which are (CuO/ZnO/Al2O3) was evaluated in both the EC process and the TC process. The paper proved this particular approach can reduce CO2 to produce methanol.

2.4 Suggestions On Sustainable System

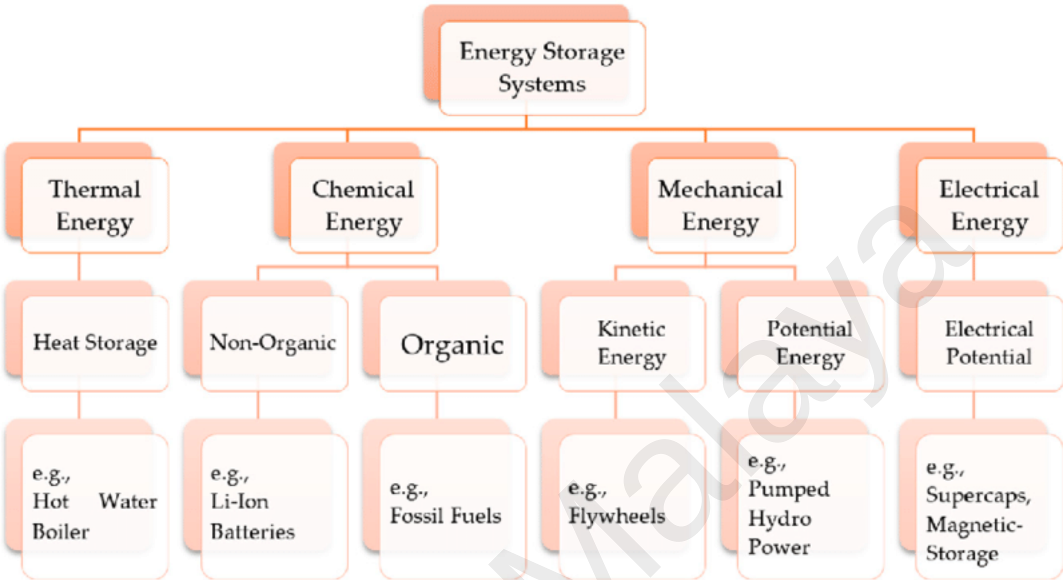
The world would have been primitive without the invention of power. Literally everything seem to be functionless without electrical energy as nothing could be operated without power. The demand of the energy has been proliferated in the 21st century due to the technology advancement. This is ascribed to the fact that the 63% of global electricity is generated from coal and natural gas (Zhao et al., 2021). Approximately 80% of carbon dioxide is generated from coal power plants. Cergibozan (2022) has stated in the research paper, the overall energy consumption worldwide can leverage more than 30% between the year 2018 to 2050. We require electricity is all the industries; tourism industry, transportation industry, manufacturing, health care and etc. As for the methanol production using the pyrolysis system also requires electrical energy to operate. Howbeit, as mention earlier in Malaysia the source of energy is mainly from coal and other polluting sources. Though the pyrolysis system uses plastic wastes to produce synthetic gas that can turned into methanol, this system will not be classified as green production since the electricity drawn to operate the system is from non-renewable energy. In order to make the entire plastic pyrolysis system sustainable, renewable energy such as, solar, hydro or wind shall be used to generate electricity for the system. Another way of making it sustainable would be utilizing electricity from energy storage system.

2.4.1 Energy Storage System

The first energy storage system was found 2,200 years ago near Baghdad, Iraq. It was the first functioning fuel cells. The fuel cell was 16mm long and about 8 inch. During discovery, the pot was covered by asphalt, a copper foil-wrapped tube was found inside. A thin ramrod of iron was clamped to the down lid. It passed through the centre tube of copper without touching the walls. The operation of this ancient battery basically illustrates the introduction of vinegar or grapefruit juice fermented in a jar. These acids allow the migration flow of electrons from the copper tube of iron ramrod when the two metals were connected at one end, generating a current of low intensity. Experiments have shown that this battery could generate between 1.5 and 2 volts. (Danila, 2010). Along the years there were numerous types of energy storage were discovered. Koohi-Fayegh and Rosen (2020) have highlighted some of the energy storage system that have been in use thus far, for instance electrochemical energy storage, thermal energy storage, flywheel energy storage, compressed air energy storage, pumped energy storage, magnetic energy storage, hydrogen energy storage, and redox flow battery.

The types of available energy storage systems along with examples were shown in the table 2.2 below.

Table 2.6 Types of Energy Storage 1



The most convenient and easy build of mechanical energy storage that can be used for the methanol producing pyrolysis system would be CAES system. The full cycle of normal operation of diabatic CAES consists of two processes: the charging and discharging process (King et al., 2021). During the charging process, electricity from the grid is used to power a turbine or a motor that drives a series of turbines and compress the air into a large underground cavity as the compression heat is removed into the environment. Later, during the unloading process, the high-pressure air in the storage chamber is mixed with gas and burned to power a turbine or series of turbines. This work is used to drive generators, and the electricity generated is fed to the grid or to consumers. CAES system can be used not only for operating the pyrolysis, but also so for the plastic shredding process, circulation pup operation and other sub parts of the pyrolysis system. Executing this idea will attain the SDG 12 goal, by developing sustainability in technology.

2.5 Summary of Literature Review

Emanate from all the research articles on plastic wastes, it was brought to attention that the plastic waste management handled by Malaysia is still substandard and creates an impediment on achieving SDG goal 13 climate action. There are many articles related to plastic wastes in Malaysia where the repercussions have been emphasized. Yet, the efforts taken to encounter the issues does not substitute the severity and requires different approach on tackling the issue. Instead of solely focusing on restricting the plastic usage, further research should be carried out on how to exploit the plastic wastes generated in other industries. There plenty of research has been done in new sustainable development and technology. However, we failed to interconnect the use of available sources to our convenience which would also be conducive to sustain the environment. It was brought to attention that the energy storage systems, methanol production, pyrolysis system all have been discovered and invented few decades ago. Much research been carried through on advancement and further modification on those discovery. Perhaps, intertwining these two approaches, plastic wastes in pyrolysis systems and energy storage system would set forth of new sustainable development.

CHAPTER 3: METHODOLOGY

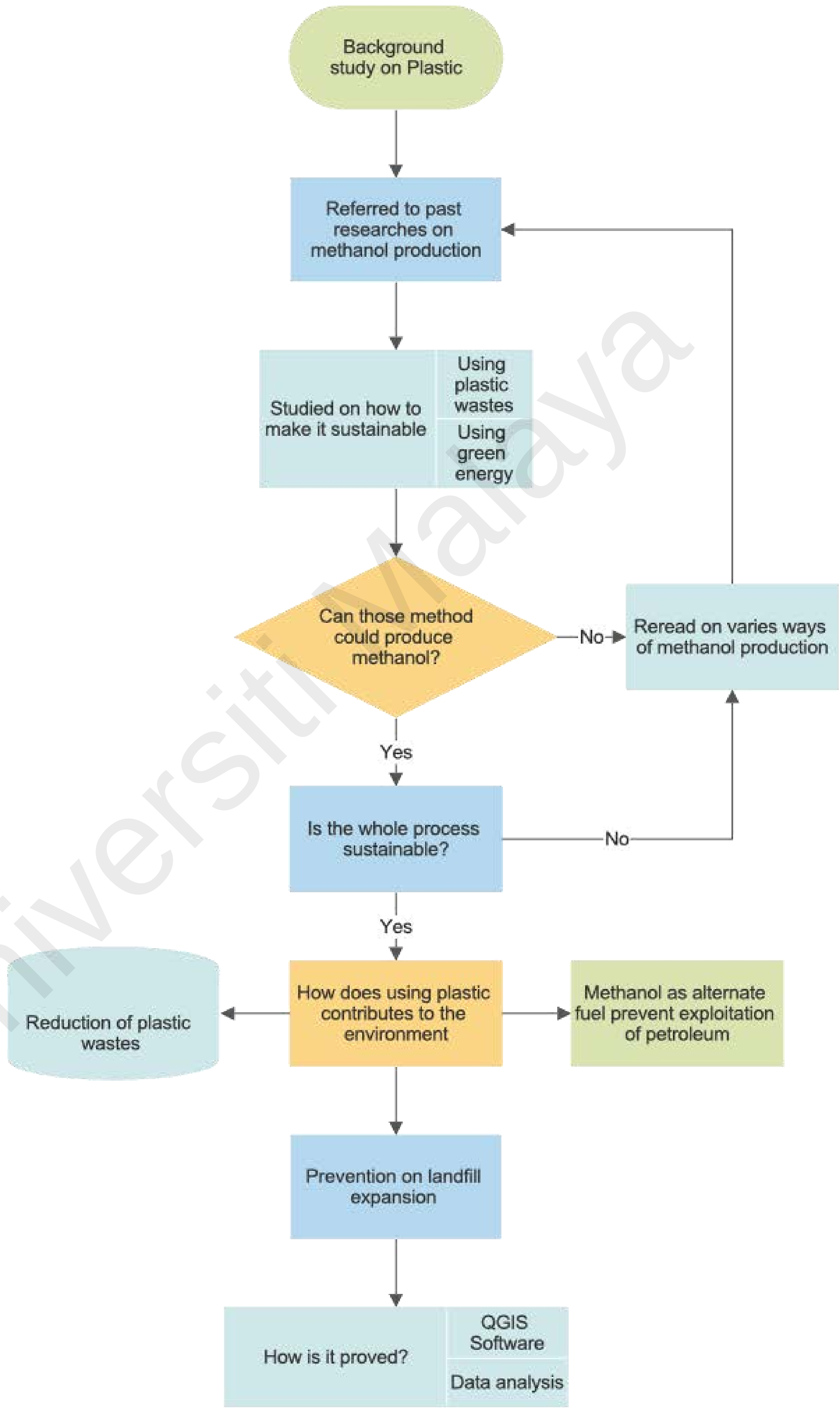
3.1 Introduction

The title was selected based on the idea captured from workplace where a pilot scale plastic pyrolysis prototype was being built. Intrigued to find out how this project could benefit the environment, thus decided to further study on this background. Carried out thorough study on the plastic pollution and ways that could obliterate the existing plastic wastes. Besides, electrical energy sources in Malaysia was brought to attention to show how it is classified as non-sustainable system just because the energy is drawn from the electric grid. Based on the study carried out in introduction, the problem statement of the research was highlighted. In term with the problem statement, the objectives of the researches were identified. Background study on past research papers pertaining the pyrolysis system were delineated. In addition, the plastic wastes pollution issues in Malaysia was also brought to attention. Not to forget, in effort of making the system sustainable, existing sustainable energy systems were also briefly explained. The methods and steps taken to carry out this research were explained using Perth charts and flow charts. Brief explanation on how the data was derived and the software were used to obtain the objectives of the research paper were explained. The methodology has briefly stated in the flowchart below for better comprehension.

3.2 Pulau Burung Landfill, Malaysia

The 62.4ha area of Pulau Burung Landfill is located in Penang Malaysia. About 33ha of the land receives approximately 1800 tonnes of municipal and non-hazardous wastes on daily basis. Almost half a tonnes of municipal wastes are collected from the island whereas the remaining wastes are from the mainland. In the year 1992, the Pulau Burung Landfill commenced the semi aerobic operation complying to level II sanitary landfill standards. It was upgraded to level III in year 2001 by controlled tipping of recirculation with circulation of leachate. However, the area used in the Pulau Burung Landfill is been keep expanding due to scarce of land for the wastes dumping.

3.2.1 Project Flowchart



3.3 Data Collection

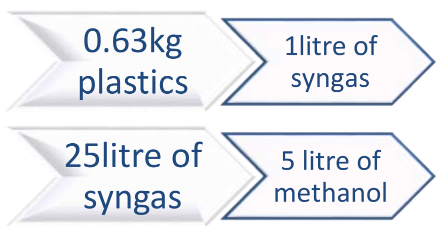
3.3.1 Plastics Wastes Generation

Several Research papers were thoroughly studied on plastic wastes generation globally and in Malaysia. Firstly, the history of plastics, how it was made, what are the types of polymers are manufactured and the properties of the polymers were studied. The decomposability of different types of plastics were highlighted. Then, another area of research on plastic wastes management in Malaysia were elucidated. The data on total weightage of plastic wastes produced in Malaysia were extracted from multiple research papers. Together with the information of the industries that produces plastic wastes were tabulated.

3.3.2 Methanol Production

An in depth review was done on existing research of methanol production. The methods of producing the methanol were studied well and chose to focus in only one method in this research paper. That one method of producing methanol chose to further the study was, pyrolysis system. The raw materials used in the pyrolysis systems were well studied. Analysed the differences of catalysts used in this system to check on how it effects the change of raw material. The yield product of the plastic pyrolysis were graphed in chapter to for better understanding. As shown in table 3.1, the experimental data was collected on the quantity of the plastics required to burn to attain 1 litre of synthetic gas which then weighs the methanol produced.

Table 3.1 Propogation of Methanol 1



3.3.3 Energy Storage System

Research were conducted on how the energy production approach, the quantitative data of energy usage in Malaysia and the affects towards environment. Explained on how the energy intertwines with the pyrolysis system and makes it unsustainable. To take measures about this issue, the energy storage systems that have been discovered heretofore been portrayed clearly comprising types of energy storage systems and examples related to the systems. An in depth interpretation was given on how the selected energy storage system benefits in the production of methanol using pyrolysis system.

3.4 Quantum Geographic Information System Software

The geographic information system (GIS) software version 3.8 is used to analyse information and export graphical maps for better illustration purpose. Due to unfamiliarity of the software, it required few days to assimilate on familiarity and use the software according to the analyzation required for this project. There is innumerable version of this software, howbeit version 3.8 was used to conduct the data analysis. The key point required to utilize this software is by determining the location coordinates accurately. For detailed polygon plot on the specific land requires boundary coordinates. The graphical map obtained from this software were saved as jpeg file and attached in the report for explanation purposes.

3.5 Data Analysis

A scrupulous analysis were conducted on all the existing sanitary landfills around Malaysia. It was brough to attention that there are more than 100 landfills in Malaysia are still operating. Using QGIS software, the latitude and longitude coordinates of all the major landfills in Malaysia were highlighted in red as shown in figure 2.1. The most recent existing data on plastic wastes weightage at landfills in Malaysia were derived from Journal of Cleaner Production by (Ooi et al., 2021). The total weightage of plastic wastes generated daily from all the industries in Malaysia were drawn from the table 3.1 below.

Table 3.2 Plastic Wastes Weightage 1

MSW	MSW component	Household (tonnes/day)	Institutional(tonnes/day)	Commercial(tonnes/day)	Industry (tonnes/day)	Total
PLASTIC	PET	722	275	601	160	1757
	HDPE	1166	340	656	390	2552
	PVC	174	35	58	386	653
	LDPE	1384	356	702	322	2763
	PP	363	135	268	30	797
	PS	577	212	389	415	1594
	OTHER	64	10	69	18	161

Based on this data, the amount of methanol that can be produced from plastic wastes generated daily will be calculated as shown in the equation below. Referring to the experimental data from a sustainable energy plant that is located at Kajang, 0.63 kg of plastic is required to produce 1 litre of synthetic gas. To produce 1 litres of methanol, 5 litres of synthetic gas is required. Therefore, 0.63 kg of plastic multiply with 5 litres of synthetic gas will deliver the total amount of plastic wastes required to burn to produce 1 litres of methanol which will be 3.15 kg. From the table 3.1, the total weightage of plastic wastes produced daily was 10277 tonnes. The value was multiplied by 1000 as conversion to kg then divided with 3.15kg of plastics to calculate the total amount of methanol that can be produced from the plastic wastes generated daily in Malaysia.

Total amount of methanol, $\ell = \frac{(10{,}277 \text{ tonnes x } 1000)}{3.15\text{kg}}$

= 3.26 megalitre of methanol

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Reduction of Landfill Area

Based Ooi et al. (2021) data on the plastic wastes weightage produced daily, it sums up to a total of 10,277 tones/day. Mentioned on the propagation of the experimental calculations of methanol production in chapter 3.4, the Table 4.1 shows the minimum plastic wastes quantity required to produce 5 liters of methanol. From this data, we can derive that an approximation of 3.26 megalitres of methanol can be produced daily utilising the plastic wastes generated in Malaysia daily.

Table 4.1 Propogation 1

By channelling the plastic wastes into pyrolysis system that can heat the materials and produce synthetic gas that is transformed to methanol, we could skip the dumping of plastic wastes at landfills. The current issue we are facing now is recycling of plastic requires a big sum of money and the process is complex. Thus, to escape from this issues, the organisations and bodies handling solid wastes refuse to proceed with recycling process and dumps at landfills. If we could scale up the pyrolysis system that could undertake the great masses of plastics into the systems, Malaysia will the leading country in methanol production as an alternate fuel owing to the fact that the raw materials used for the methanol production in the pyrolysis system will be overflowing. To expose to view of the reduction of landfill area, a geographical image were illustrated using QGIS software on a specific landfill area. The highlighted area in figure 4.2 below in light yellow indicates the total 624000 metre square area stated by Azme and Murshed (2018) of Pulau Burung landfill, Pinang and the darker shade yellow indicates the minimised landfill area based on assumption.

Figure 4.1 Minimised Landfills 1

The landfill area of 1/3 can be saved if the plastic wastes generated is deviated into the plastic pyrolysis system to produce methanol. Other wastes, such as organic and selected inorganic wastes that ends up at the landfills takes a decade or lesser to decompose. Thus the expansion of the landfills will not be drastic as the used landfill area of organic wastes will be cleared within few weeks of months due to its quick decomposability feature. However, as for plastic wastes, though the quantity does not vary much from others wastes, the decomposition period takes minimum of 20 years and maximum can go up to few hundred years. Thus, to clear the existing land allocated for plastic wastes is futile as it takes longer period to decompose. Leaving with no other options left, the landfill area to dump plastic wastes has to be expanded to receive the new batch plastic wastes every day. As mentioned in the objective, utilising plastic wastes in converting it into methanol will help to optimize the landfill area for only organic wastes and other wastes that requires less than 10 years to decompose.

4.2 Production of Sustainable Methanol

Burning an amount of 10,277 tones of plastic wastes on daily basis use up surfeit amount of electricity. Despite having multiple available energy storage system ideas, the CAES would be most well fitted to implement as it has the least energy loss compared to other systems. Though to build a large scale CAES system requires ample of space, it can be erected at bottom of the ground. There are multiple projects been operating and new upcoming projects are going on for the larger scale CAES which is evolving technology for large-scale long-term electrical energy storage that can help power systems meet their decarburization goals. CAES facilities often use large underground storage facilities to provide high throughput systems. This leads to saving up lands for electrical grid construction, transformers and subsidiary plant to support main energy plant. The Figure 4.2 shows the example of larger scale CAES system flow.

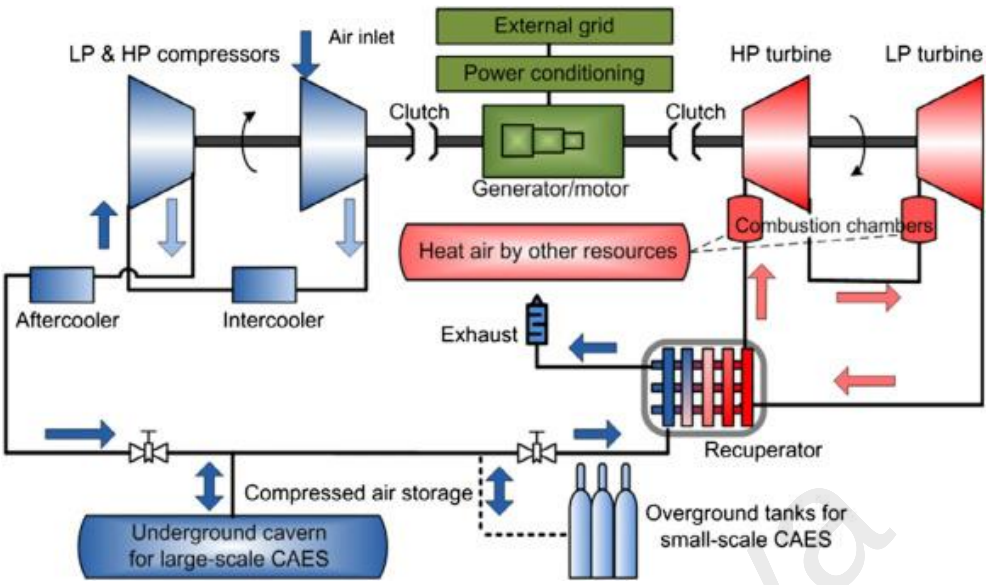


Figure 4.2 CAES System Layout 1

This CAES system can be used to operate the pyrolysis system for required time period to process the plastic wastes into methanol instead of utilising the energy source directly from the electric grid. As the quantity of plastic wastes generation is superfluity, the system may have to run continuously to retain the operation of methanol production. If the electricity is dependant from the electric grid where the main source of production is from burning coal, it would make the approach of methanol production non sustainable. It is totally inefficacious towards protecting the environment by using plastics to turn into methanol but using coal as medium of electricity which contributes to carbon emission. Thus, CAES system can be said to be a renewable energy or green energy sources in future electricity networks with good shelf life, capacity and power for sustainable technology.

4.3 Economic and Environment

Methanol is professed to be an alternate fuel for cars, ships, trucks, fuel cells, boilers and etc. Our economy is depending on various sector. Regardless of how, fuel is necessary and vital in most of the sectors. It somehow requires the presence of fuel to move forward. For instance, tourism involves transportation which requires fuel, manufacturing industry requires raw materials to be transported, huge plants requires fuel to operate and more in line. When Malaysia is filled with plastics and been importing plastic wastes from other developed countries, we have surfeit amount of raw materials for the pyrolysis system. High in raw material results in high volume of methanol production. Presuming that, when the production of methanol is high, the price per litter will be inexpensive. Introducing inexpensive fuel will sustain economical living standard as all the products including consumable and non-consumable will be low priced. Vice versa, the low cost fuel will escalate the need of more fuel as the consumption and utilisation will be increased drastically. This will lead us to dig up the old plastic on the landfills, abandoned plastic wastes around the coastal area and purchase more plastic wastes to keep pace with the methanol demand. The higher the demand of methanol, the lesser the plastic wastes around the world.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

The advancement of technology indeed plays a major role in developing countries such as our country, Malaysia. Howbeit, technology should be improvised concerning not only to ease the burden of human beings but without neglecting the environmental constraints. Introducing plastic pyrolysis producing methanol in Malaysia, indeed a great leap in substituting gasoline product. But what would be the exploit if the energy used to operate the system is polluting the environment. We may reduce the plastic pollution by utilising it in methanol conversion while producing GHG emission in running the system through non-renewable energy. In order to attain sustainability in a machinery system, the energy source holds a big part in achieving it. Though energy storage system is still practised by some small scale industries in Malaysia, it should be taken into consideration by our Energy Commission to implement the energy storage system nationwide. Operating the plastic pyrolysis system turning into methanol using energy storage system will not only reduce the landfill area expansion but also avoids oil and gas refinery. This alone will bring an enormous effect on achieving the SDG Goal 7 Affordable and Clean Energy and SDG Goal 13 Climate Action.

For further study, a research on how to sustain the energy storage system without utilising the electricity from the grid should be carried out. By doing so, we may not require multiple transformers and grids around Malaysia and depend solely on the Energy Storage System.

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