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# Bioenergy as a prospective energy source in the future

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**Abstract**

The issues of global warming and greenhouse gasses have raised the concern of the people and led to integrate ambitious of using bioenergy in many countries. In this paper, the issues of conventional energy are stated, and the different types of conventional energy resources are discussed including coal, petroleum and natural gas. The process of pulverized coal combustion (PCC) to generate electricity is also studied and discussed in this paper to have a better understanding of the process and the emission of greenhouse gas released from the use of coal to generate conventional energy. The reason of soil contamination and air pollution caused by the refinery process of petroleum is also discussed in this paper and several study cases of the social economic impact caused by the production of natural gas in development countries. Furthermore, the used of bioenergy and different type of bioenergy resource are discussed including biogas, algae biofuel, and biodiesel. The process of algae cultivation for algae biofuel and the study of toxic waste algae strains that can give a negative impact to the environment is studied to avoid harmful substances released to the environment. The potential algae application in different fields is also included to show the benefit of algae biofuel which is flexible and able to contribute to the global economic growth. Lastly, the advantages of using bioenergy are discussed including the mitigation of greenhouse gas emission, improve social economic growth, renewable energy resources and prevent prescribed burning of the forest.

Keywords :
Energy, Bioenergy, biogas production, biofuel production

## 1 Introduction

Energy is crucial to support the economic development worldwide, it is used in our daily lives and serve different purpose including industry, modern agriculture, and transportation which makes a better life quality for a human being (Liang et al., 2009). However, the increasing human population worldwide has led to the increasing demand of energy use, the emission of carbon dioxide ($CO_2$) released through the conventional energy generated can bring many environmental issues such as global warming, and climate change (Yilmaz et al., 2009). The non-renewable energy source such as fossil fuel and coal use to generate conventional energy for power supply have high efficiency of power output but the amount released of carbon dioxide ($CO_2$) and pollutant emissions are very high (Dong et al., 2018). Therefore, bioenergy was introduced in many countries since early 19 centuries to mitigate the environmental issues that caused by conventional energy, the concerned of environmental issues worldwide has led to the increasing demand of bioenergy use in many countries and estimate to reach 40 Mtoe (1675 PJ) of energy produced globally in the year of 2035 (Matzenberger et al., 2015).

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Bioenergy is a renewable energy that often produced from biomass which is an organic material to produce chemical energy and has fewer pollutants emission gas produced to conserve the environment and at the same time support the demand of energy needs for the people (Faaij et al., 2014). Consequently, the material uses to generate non-renewable energy such as fossil fuel and coal are depleting which caused many countries to put in a lot of effort to make social and technical changes and start generating bioenergy for power, industry and transportation use (Ulsrud, 2012). Although bioenergy brings many benefits to the environmental, it has some disadvantage and limitation to hold it back such as undeveloped infrastructure and complicated formula to produce (Algieri, 2014). To meet the increasing demand of energy supply in the future and global warming issues, it is required to improve the efficiency of bioenergy produced and develop new technology to reach zero greenhouse gas emission from bioenergy (Ahrens et al., 2017).

## 2 Conventional energy

Conventional energy is widely used in both developing and developed countries to help the economic growth and improve the life quality of the people, it often has high efficiency of power output and the resources used to generate conventional energy such as fossil fuels and coal which can be extracted easily as a natural resource some part of the world (Dong et al., 2018). Many develop-

ing countries in Asia including Malaysia, Indonesia, Philippines, Cambodia, and Vietnam highly depend on fossil fuel to generate energy for the transportation system and power supply as the fossil fuels are the cheapest and reliable energy resource among these countries (Bilgen, 2014). However, developed countries such as Australia, United States, and Germany are boosting the economy of the country by producing a huge amount of coal with 869 billion tons per year of coal produced to support 40% of the electricity production in the world. The different type of energy resources used to generate conventional energy and the problems are discussed in the following section.

## 2.1 Coal

Coal is used as one of the major energy resources in many countries, it provides heat and electricity for the household and uses in the process of gas and iron industry (Thomson, 2003). Thermal coal can use to generate electricity by crashing it into powder form and goes through process such as pulverized coal combustion (PCC) to generate a huge amount of electricity for the country, Figure 1 below has shown the process of coal that convert to electricity which can reach up to 400 thousand volts of electricity distribute to a wide range of household area. The world has consumed a large amount of coal each year and the amount has reached up to 3732 million tons of coal per year, China is the largest coal consumption country due to high population and urbanization have led to the increasing demand of electricity use in the country (Wang et al., 2019). Furthermore, the usage of coal in Poland is mainly for heat production, the technology of underground coal gasification (UCG) in Poland which is the ignition of coal to produce heat as an energy for the gasification process to convert fossil fuel into high-quality systemic gas, the gas produced by UCG is able to generate electricity and heat arises during the winter season (Burchart-Korol et al., 2016). Nowadays, coal can be used to produce liquid fuels for the transportation system by going through several processes including direct coal liquefaction (DCL) and coal to liquids (CTL) process, crude oil consist of hydrogen can be extracted from coal through DCL process and the oil extracted can be refined into synthetic gasoline and diesel for the transportation system. However, the burning of coal can emit a huge amount of greenhouse gases and pollutants such as carbon dioxide (CO2) and sulfur dioxide (SO2) which are toxic and harmful to the environment (Wang, 2011).

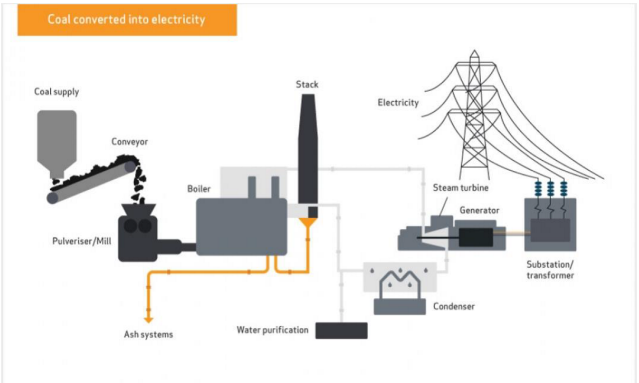


**Figure 1** The pulverized coal combustion (PCC) system uses to convert coal to electricity. Adapted from World Coal Association. Copyright 2013 by VGB Power Tech.

## 2.2 Petroleum

Petroleum is classified as a nonrenewable source also known as a fossil fuel consist of hydrocarbon chemical compound, the fossil fuel that extracted from the ground is required to go through a technical process called fractional distillation to separate the oil product including kerosene, diesel, and gasoline (The need project, 2018). Petroleum can be used in the transportation systems such as diesel and gasoline are widely used as an energy resource for the vehicles whereas Kerosene is commonly used to power the jet and rocket engines, it is also useful for lighting fuel in the past before the electricity is widely used for lighting (Al-Mofleh et al., 2010). Figure 2 has shown the consumption of petroleum is very high in many developing countries such as Malaysia and Thailand, the reason of high demand petrol needs for the energy resource use in the transport system is due to the electric vehicle and public transportation are not advance when compared to developed country such as United State thus, the residents highly depend on gasoline and diesel vehicle for their daily transportation system (Muangjai et al., 2017). The intensive use of diesel and gasoline vehicles can contribute greenhouse gas emission to impact the quality of local air, diesel engine vehicle contributes 15% more carbon dioxide ($CO_2$) per km used when compared to petrol vehicle as the diesel vehicle is more efficient compared to petrol vehicle (Hooftman et al., 2016). However, the production of oil in a refinery process emit greenhouse gasses and Volatile Organic Carbon (VOCs) which can cause serious air pollution issues, long term exposure of toxic air pollutants released from refineries such as benzene, toluene, ethylbenzene and xylene (BTEX) can cause blood production, nervous system and lymphatic system which are hazardous to human health (Correa et al., 2012). The toxic air pollutants generated from the refinery process can release to the atmosphere by several reasons including the leakage of refinery when cleaning and maintaining activities, sewage leakage and leak detection and repair (LDAR) program (Rao et al., 2005). Furthermore, the waste generated from the petroleum refinery include solid waste such as petroleum coke which consists of a high concentration of sulfur (120 ppm) is often sell to the retailer, the leakage of petroleum coke may occur during the transportation of petroleum coke to the ground and contaminate the soil eventually wash through soil by rainfall and contaminate the groundwater (Wang et al., 2019).

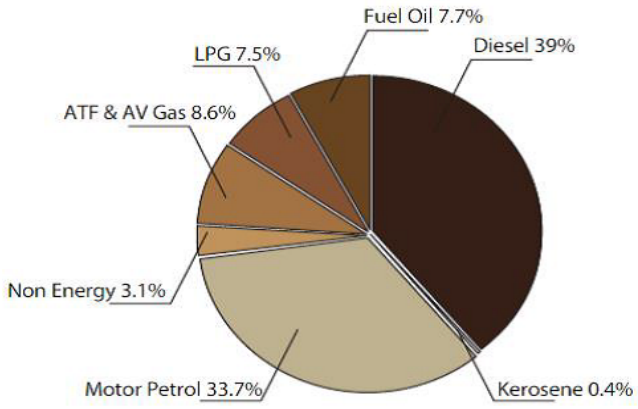


**Figure 2** The consumption of petroleum product in Malaysia. Al-Mofleh, A., Taib, S., Salah, W. A. (2010). Malaysian energy demand and emissions from the transportation sector. (Al-Mofleh et al., 2010)

## 2.3 Natural Gas

The petroleum resource use for conventional energy is depleting rapidly due to the increasing human population and the demand of natural resource worldwide, petroleum resource estimate to use up in the next 60 years at current rates of extraction (Brandt, 2011). Natural gas is one of the major energy resources for the transportation system and many households use for cooking, natural gas has a lower cost and able to last longer which estimate to use up in the next 90 years (Whelan and Wong, 2013). The use of natural gas for heavy-duty vehicles are widely spread in many countries which are driven by lower price of natural gas in the market compare to petrol, the use of natural gas for natural gas vehicles (NGV) contribute lower carbon emissions released to the

atmosphere at the same time it is able to maintain identical fuel efficiency of heavy-duty natural gas engine with 2780 Nm torque and the power output of 457 kW (Dunn et al., 2013). Despite lower carbon emission release by natural gas resource, a large amount of methane ($CH_4$) emissions can be released by natural gas vehicle (NGV) which can impact the air quality in many countries, the average methane ($CH_4$) emitted by NGVs in China is 0.44 ± 0.07 Tg which can cause serious air pollution in China (Hu et al., 2018). In addition, many developing countries such as Malaysia is more focusing on economic growth as Malaysia in one of the petrol producing country which export huge amount of natural gas and petrol fuel worldwide every years to boost the economy growth of the country which can cause faster depletion rate of natural gas (Chong et al., 2015).

# 3 Bioenergy

Bioenergy is a renewable energy resource generated by organic material and has fewer pollutants emission gas produced to conserve the environment at the same time to supply the energy demands of the people (Röder and Welfle, 2019). Bioenergy is widely used in many countries for the past decades and support up to 70 % of energy demand worldwide to slow down the depletion rate of non-renewable energy resources such as fossil fuel and coal (Scarlat and Dallemand, 2019). The use of bioenergy helps to mitigate climate change and other environmental issues, bioenergy can generate heat, electricity and transportation fuel which is economical and environmentally friendly (Mohr et al., 2019). However, bioenergy is facing the future challenge of sustainable crops cultivation for bioenergy production and the impact of economic growth of the country, the process of bioenergy production can be relatively complex and difficult to maintain (Gírio, 2019). The intensive cultivation of bioenergy crops can cause several environmental issues such as land degradation, water quality and the loss of biodiversity as the increase of bioenergy production to meet the increasing demand of energy requires more land for bioenergy crops growth (Pulighe et al., 2019). In the following section, several types of bioenergy are discussed including biogas, algae biofuel and biodiesel, the advantages bioenergy are also stated and discussed.

## 3.1 Biogas

Biogas is used to generate heat and electricity for household areas in many countries, the production of biogas is normally from the degradation of organic material such as agricultural waste (Scarlat et al., 2018). The improvement of today agriculture technology has developed the use of agricultural waste such as pig manure and corn straw as the biomass to produce biogas for the demand of energy supply (Ning et al., 2019). The utilize of algaculture waste to produce biogas can helps to reduce the impact of environmental issues including eutrophication, odor problem and water contamination due to the irrigation of crops that growth with pesticide and organic fertilizer used (Nasir et al., 2012). In Europe, the electricity generated is dominated by the production of biogas, biogas can generate electricity from landfill gas and sewage sludge which have the capacity to generate 3000 MW of electricity each year (Scarlat et al., 2018). Figure 3 has shown the increasing development of electricity generated by biogas in the European country, Germany which indicate biogas is leading the economy and energy production industry in Europe area (Scholwin and Nelles, 2013).

Conventional liquefied petroleum gas (LPG) fuel is commonly used for cooking in both restaurant and household area, the increasing of conventional LPG fuel price has impacted the economic concern of the people and led to the increase rate of using biogas for cooking (Patowary et al., 2019). Biodegradable solid waste such as kitchen food, sewage sludge, and animal waste can be decomposed and generate biogas that normally consists of 70% methane ($CH_4$), biogas has a good calorific value with the average of 5,000 kcal m-3 which can be ignited easily and use for heating and cooking (Abbasi et al., 2012). However, the process of increase methane in biogas production can be complex as the increasing amount of methane in biogas is limited due to several limits in chemical process thus, the effectiveness of biogas is restricted and more biogas is required to be generated to meet the increasing demand for energy use in the future (Wang et al., 2018).

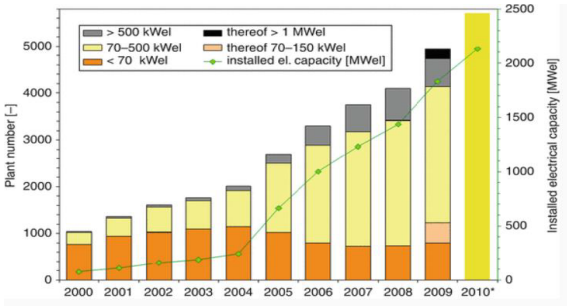


**Figure 3** Biogas for electricity generation in Germany. (Scholwin and Nelles, 2013)

## 3.2 Algae biofuels

Algae is widely used in the food production industry for the last few decades, many food productions such as chips, protein bar, and supplements consist of algae in today market due to the rich nutrient of Omega-3 can only be found in mainly fish and plants which is good for the health after consumed (Moejes and Moejes, 2017). Algae has the advantage of high oil fraction can be used as biofuel to replace conventional energy resource such as fossil fuel, Figure 4 below has shown the flow chart of potential algae application in different fields which can beneficial to the global economic growth (Johnson and Wen, 2009). One of the successful cases is the use of combination biofuel hydro-processed ester, fatty acid, and conventional jet fuel as the energy source of Singapore Airline's Airbus A350-900 which has carried 206 passengers flew from San Francisco to Singapore in the year 2017 and this succeed process has shown the potential development of algae-base jet fuel in the future. The cultivation of algae feedstock is simple to operate without the need of supervisor, but monitoring is required due to effectiveness and the environmental impacts of algae cultivation (Suganya et al., 2016; Ratnasari et al., 2022a). Although the cultivation of algae is simple to operate, it contains toxic waste algae strains which are hazardous to the environment (Davison, 2005). The effectiveness of algae cultivation can be affected by several limitations including unregular temperature, evaporation loss and carbon dioxide (CO2) released to the atmosphere, thus it is important to regularly monitor the process of algae cultivation (Lee and Lee, 2016). Figure 5 below has shown the different algae cultivation methods which indicate the importance of monitoring algae cultivation to avoid toxic substance to impact the environment (Adeniyi et al., 2018).

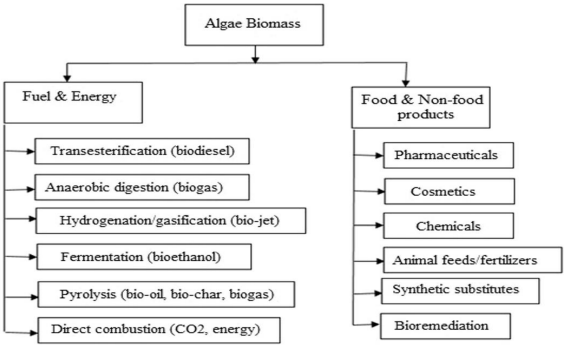


**Figure 4** The flow chart of algae biomass production (Adeniyi et al., 2018)


**Figure 5** The Algae cultivation methods. A) Natural, B) Artificial (flat plate photobioreactor), C) Tubular photobioreactor and D) Column photobioreactor (Adeniyi et al., 2018)

### 3.3 Biodiesel

Biodiesel is one of the major bioenergy resources generated by vegetable oil or animal fat, biodiesel is commonly used as an energy resource for many usages such as diesel engine and heating oil to mitigate the environmental issues as the released of carbon dioxide ($CO_2$) emission from biodiesel is significantly low compared to the use of conventional diesel fuel (Manaf et al., 2019). There are many types of vegetable oil can be used to produce biodiesel, the tree seed genus Cascabela (Apocynaceae) is widely used to produce biodiesel at Mexico and South America (Sánchez-Arreola et al., 2019). Cascabela (Apocynaceae) is grown in the dry forest and have a very dense population of Cascabela trees which can supply a huge amount of seeds for biodiesel production, Figure 6 below has shown a wide distribution of Cascabela in Mexico (Sánchez-Arreola et al., 2019). Cascabela seeds contain rich plant oil which is renewable and very suitable for producing biodiesel. Furthermore, soybean is another renewable energy resource for producing biodiesel, 86 million tons of soybean has been produced by 70% agriculture cropland in Brazil which makes Brazil the second largest biodiesel producer (da Silva César et al., 2019). Another major contribution to the resource of producing biodiesel is the palm oil and Indonesia is the largest palm oil producer which has produced 29 million tons of palm oil per year followed by Malaysia which has produced 19 million tons, huge amount of palm oil has grown which help to sustain the economy of the countries as palm oil is very low in price which can be converted to high-value products such as biodiesel and high quality cooking oil (Ahmad et al., 2019; Ratnasari et al., 2021; Ratnasari et al., 2022b).

**Figure 6** The distribution of Cascabela (Apocynaceae) in Mexico. Adapted from Sánchez-Arreola, E., Bach, H., Hernández, L. R. (2019). Biodiesel production from Cascabela ovata seed oil. Bioresource Technology Reports,100-220. Copyright 2019 by ScienceDirect.

## 4 The advantages of bioenergy

Bioenergy has several major advantages to the environment and social economy, one of the major advantages of using bioenergy is the mitigation of air pollution and greenhouse gas emission (Lee, 2017). Greenhouse gasses such as carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$) are commonly released to the atmosphere by the used of conventional energy, the used of bioenergy contribute significant low carbon dioxide ($CO_2$) emission released to the atmosphere which helps to mitigate the environmental issues caused by the impact of greenhouse gas emission (Algieri, 2014). Furthermore, bioenergy is a renewable natural resource which can supply the energy demand of the people in long term whereas conventional energy resource such as fossil fuel, coal, and natural gasses are non-renewable energy resource which is depleting rapidly due to the increasing human population worldwide (Alsaleh et al., 2017). In addition, the efficiency of bioenergy is usually high enough for the current state of energy demand, the biogas that is used for cooking and heating consists of a high amount of methane ($CH_4$) gas which is adequate for household use, biofuel and biodiesel are also efficient in generate electricity and use in diesel engine for transportation system (Buchholz et al., 2009). Moreover, the huge amount of bioenergy crops production can boost up the economic growth of the country, bioenergy resource such as animal manual, food waste, palm oil, and soybean feedstock are normally low price which can convert into a high-value product (Balat and Balat, 2009). Also, generate bioenergy can help to save the environment and the landfill, the disposal waste can be used to generate electricity or different source of bioenergy which can save the cost of designing huge area of landfills for the waste disposal (Escamilla-Alvarado et al., 2017). Besides, bioenergy production can be used by wood waste or small wood to generate biodiesel. Using of wood for the production of bioenergy is able to provide an alternative solution to prescribed burning of forest as prescribed burning for agriculture use is very common in some area which can increase the greenhouse gas emission and release toxic air pollutant which are hazardous to the environment and human health (Keller et al., 2018). However, bioenergy is still in the early stage of development and have higher potential of improvement compare to the conventional energy therefore, the efficiency of bioenergy produced have to be increased to meet the demand of increasing energy supply whereas greenhouse gasses such as carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$) generate from the bioenergy have to be reduced to reach zero emission of greenhouse gas to mitigate the environmental issues (Ahrens et al., 2017; Paredes-Sánchez et al., 2019).

## 5 Conclusion

In conclusion, the use of bioenergy brings a lot of benefits to the environment and the social economy of the countries. The resources of conventional energy are depleting rapidly due to the increasing demand for energy supply. Bioenergy resources such as biogas are suitable to replace natural gas to generate power and electricity due to the advantages of low carbon emission released during the process and the decompose of organic waste which can save the area of landfill use for the disposal waste. Algae biofuel and biodiesel are very efficient to generate electricity and used as the engine fuel for the transportation system, biofuel and biodiesel are friendly to the environment as it contributes fewer greenhouse gasses released to the atmosphere compared to petroleum and coal. Furthermore, the cost of the material to generate bioenergy is low for the price of feedstock compared to the resource of conventional energy such as petroleum and coal, the resource of bioenergy can be obtained from vegetable oil and organic waste materials which are renewable. Therefore, bioenergy is suitable to replace conventional energy to generate power and electricity for different application including transportation system, heating and cooking. Overall, the advantages of using bioenergy mentioned in this essay have clearly stated that bioenergy is a potential source of energy to meet the future demand for energy needs.

## Declaration of competing interest

The authors declare no known competing interests that could have influenced the work reported in this paper.

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