Biofuel From Biomass Waste
– Status and Prospects in China –

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1. Predicament of fossil fuels – two major contradictions between energy and environment

1.1. Overview

China remained the most largest energy consumer of the world since overtaking the United States for the first time in 2007, which is due to the rapid development of national economy in recent years. Figure 1 shows the changes of the primary energy consumption of China, the US and the world in the last ten years. It is found that the primary energy consumption of China increased by 38.8 % from 2,361.4 to 3,278.2 million tonnes oil equivalent during 2008-2017. In 2017, China accounted for 24.3 % of global energy consumption. It is a consensus that energy is absolutely the lifeblood of national economy. Fossil fuels not only provides essential power for industrial development but also bring serious environmental pollution. Nowadays, there are two major contradictions concerning energy and environment as shown in Figure 2.

One is the contradiction between the growing energy consumption and great shortage of fossil fuels. Another is the contradiction between the serious environmental issue due to over consumption of fossil fuels and the increasingly strict demands of the public concerning environmental quality. The burning of coal and oil brings plenty of atmospheric pollutants such as CO, SO_2, NO_x, particulate matters and greenhouse gases (mainly CO_2) leading to acid rain, photochemical smog, haze and global warming, which have raised a lot of environmental and social concerns. These factors lead to a move towards renewable, sustainable and cleaner energy sources, especially producing biofuel from biomass waste.

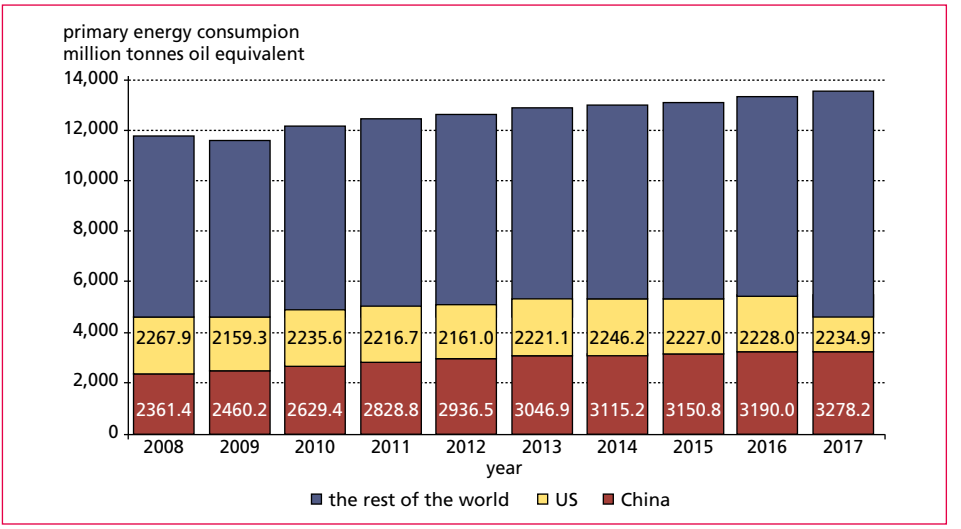

Figure 1: The primary energy consumption of China, the US and the world

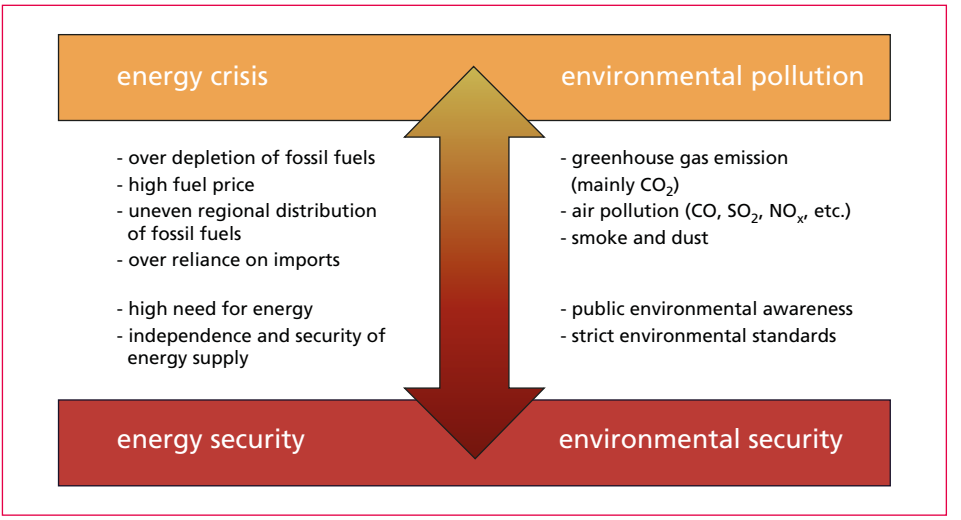

Figure 2: Two major contradictions concerning energy and environment

1.2. Energy supply, trade and consumption in China

1.2.1. Proved oil and coal reserves and energy trade

In recent decades, especially since the explosion of global energy crisis in 1970s, the development of the society has been greatly limited by energy shortage. According to BP Statistical Review of World Energy 2018 [1], global proved reserves of oil and coal in 2017 are 1,696.6 billion barrels and 1,035.0 billion tonnes, which are only sufficient to meet 50.2 and 134 years of global production at 2017 levels, respectively. Especially, in China the proved reserves are only 25.7 billion barrels (oil) and 138.8 billion tonnes (coal), which could only meet 18.3 and 39 years of national fuel consumption. China accounts for only 1.5 % of global oil reserves. Figure 3 and 4 show the distribution of proved oil and coal reserves of different countries and regions in 2017. It should be noted that most of fossil fuels are in the hands of a few countries. The proved oil reserves of Middle East reaches 813.5 billion barrels and accounts for 47.6 % of the world. However, the Asian-Pacific region where China located on is the most poor-in-oil region in the world, accounting for only 2.8 % of global oil reserves. China accounts for 13.4 % of global coal reserves, which seems to be a high value. However, taking the huge population base of China into consideration, the coal is also not abundant. The extremely uneven distribution of fossil fuels around the world has exacerbated energy shortages. More and more countries greatly depend on fuel import, which greatly threaten national energy security as fuel supply is often used for the political bargaining chip. It was reported that China's oil import dependency ratio rose to 68 % in 2017, the highest in its history [1]. Figure 5 presents the major trade movements of oil of the world in 2017.

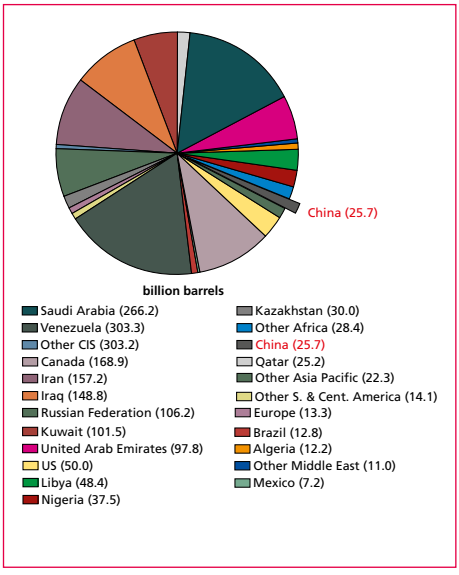

Figure 3: Distribution of proved oil reserves of different countries and regions in 2017

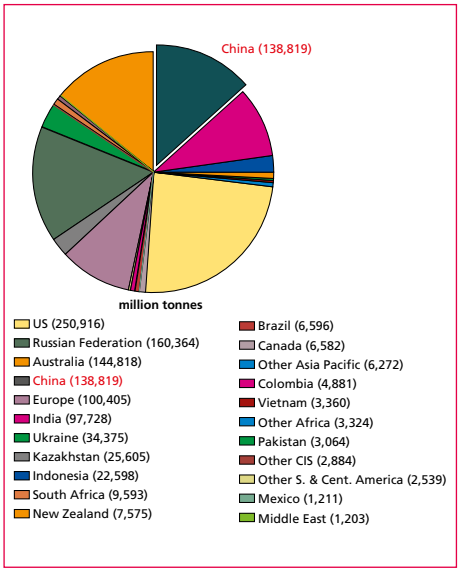

Figure 4: Distribution of proved coal reserves of different countries and regions in 2017

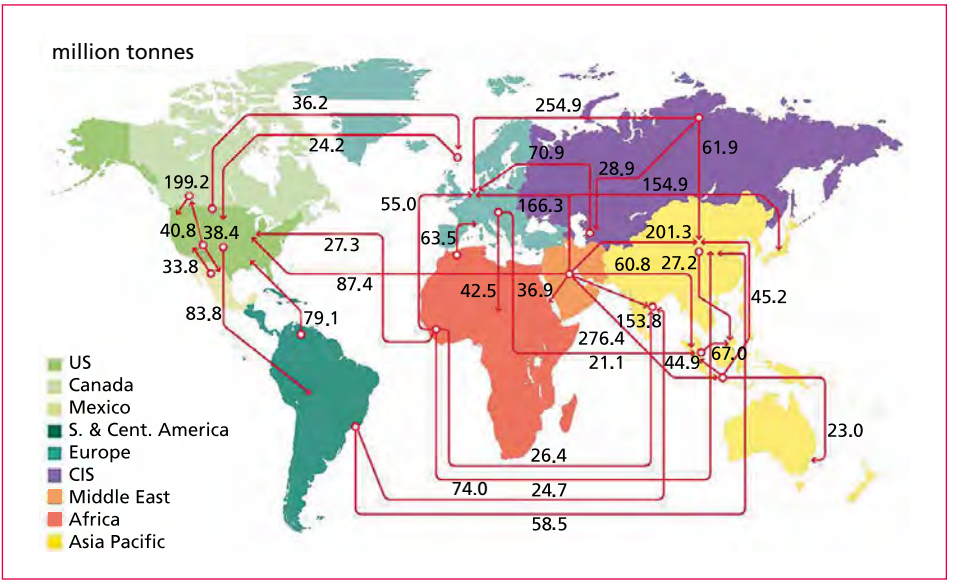

Figure 5: Major trade movements of oil in the world in 2017

Source: BP Statistical Review of World Energy 2018, 2018. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

1.2.2. Fuel production

The production of oil, natural gas and coal of China from 2007 to 2017 are summarized in Figure 6. It is found that the annual production of coal in China always remains a high level during the past ten years. In 2017, the production of coal in China reached 1,747.2 million tonnes oil equivalent, which accounted for 46.4 % of the whole world.

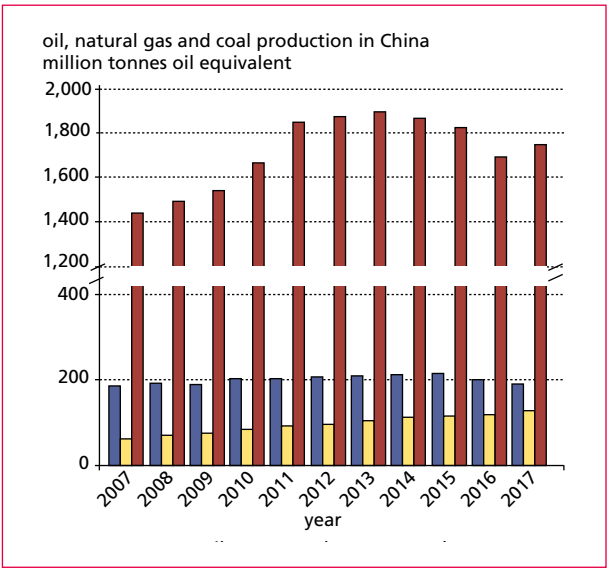

Figure 6:

Oil, natural gas and coal production in China from 2007 to 2017 (million tonnes oil equivalent)

China was still the world's largest coal producer. While the production of oil and natural gas of China were 191.5 million tonnes and 128.3 million tonnes oil equivalent respectively, which only accounted for 4.4 % and 4.1 % of the world. In 2017, coal and natural gas production of China increased by 3.6 % and 8.5 %, but oil production decreased by 3.8 %. Meanwhile, oil, natural gas and coal production of the world grew by 0.5 %, 4.0 % and 3.2 %, respectively. The US produced 631.6 million tonnes oil equivalent of natural gas and 571.0 million tonnes oil and was the greatest producer of natural gas and oil of the world.

1.2.3. Fuel consumption

In recent years, with the continuous optimization and adjustment of energy mix, the primary energy consumption of China is undergoing profound changes. Figure 7 presents the primary energy consumption mix of China in 2017. It is found that the oil, natural gas, coal, nuclear energy, hydroelectricity and renewables consumption were 679.5, 228.5, 1,938.3, 61.3, 262.7 and 107.9 million tonnes oil equivalent and accounted for 20.7 %, 7.0 %, 59.1 %, 1.9 %, 8.0 % and 3.3 % of the total primary energy consumption of China respectively. The coal and oil remained the main energy sources. Although coal is still the dominant fuel, its share of total primary energy consumption exhibits a clear downward trend from 70.0 % to 59.1 % the lowest on record.

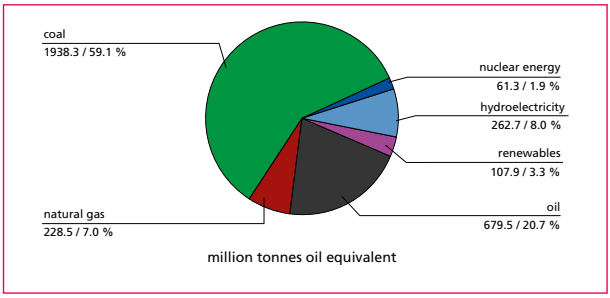

Figure 7:

The primary energy consumption mix of China in 2017 (note: renewables refer to wind, geothermal, solar, biomass and waste)

2. Biofuel from biomass waste – an answer to renewable energy

2.1. Urgent demand for developing biofuel

Independent and secure energy supply is the key to ensuring the steady economic development. The three times of oil shocks during 1973-1990 had a significant impact on global economic development and also prompted the huge change of energy mix of the world. The fuel importing countries were compelled to seek alternative of

fossil fuels and develop energy-saving technology. Against this backdrop, renewables development enter in a new era. In 2017, renewables (not including hydroelectricity) consumption of the world increased by 17.0 % and China accounted for 36.0 % of global renewables consumption growth. China's renewables consumption reached 21.9 % of the global total. In China, solar consumption grew the fastest (+76 %), followed by biomass (+25 %) and wind (+21 %) in 2017. Hydroelectricity also plays an important role in energy supply of China (Figure 7). Now China already surpassed the US and became the greatest renewables producer of the world. Nevertheless, there is still a long way to replace fossil fuels completely. The solar conversion efficiency is still not satisfactory. The hydroelectricity and wind are greatly limited by geographical and natural conditions. It is an urgent task to seek another easily available, renewable and sustainable alternative of fossil fuels.

2.2. Biofuel production from biomass waste

2.2.1. Overview

For the past few years, biofuel produced from biomass waste attracts more and more attention and is regarded as an answer to alternative of fossil fuels [3]. As shown in Figure 8, biomass waste that can be used for producing biofuel includes food waste, municipal waste, sewage sludge, livestock manure, agricultural wastes, energy crops, edible as well as non-edible oilseeds, various aquatic plants identified as bio-oil sources, etc. These biomass waste could be used for producing biogas, bioethanol, biodiesel, biohydrogen via anaerobic digestion, pyrolysis, gasification, etc. Biomass waste is a renewable resource that could be sustainably developed in the future. In a broad sense, biomass refer to all the matter that can be obtained from photosynthesis. They store biomass power in the form of glucose or starch molecules, oleaginous, cellulose, and lignocellulose. They are almost inexhaustible. For example, lignocellulose biomass is the most abundant renewable resource in the world, with an annual production estimated at about 50 billion tonnes. Municipal solid waste (MSW) is also a huge waste stream that contains abundant biomass energy. Figure 9 shows the total amount of collected and disposed MSW in China during 2003-2016. According to China Statistical Yearbook 2017 of National Bureau of Statistics of China, a total amount of collected and disposed MSW in 2016 was about 203.6 million tonnes in China [2]. It was reported that the organic fraction accounted for about 50 % (by weight) of MSW [4]. According to this ratio, organic waste in MSW may reach about 100 million tonnes in China.

Above all, biomass waste appears to have formidably positive environmental properties resulting in no net releases of carbon dioxide [5, 6]. Biofuels from biomass are considered to be carbon neutral because all CO_2 released during biofuel combustion is offset by carbon fixation during plant growth as shown in Figure 10.

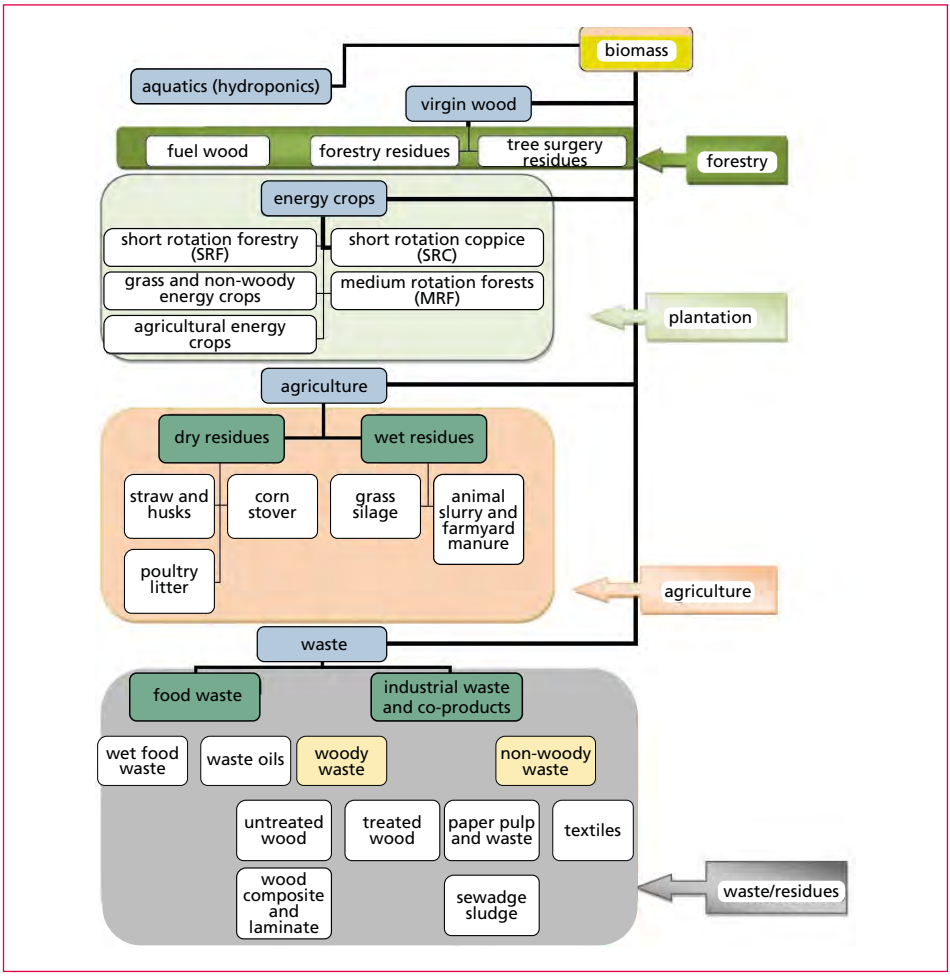

Figure 8: Sources of biomass for biofuel production

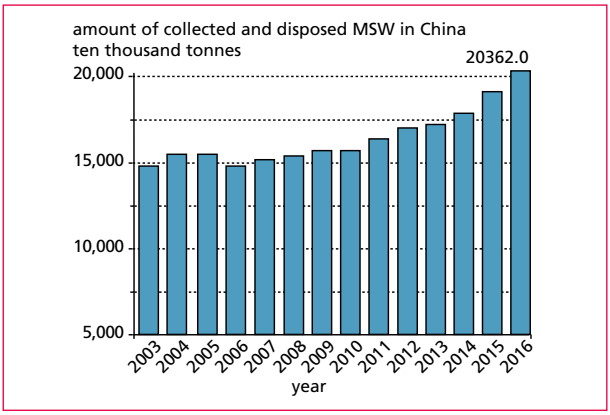

Figure 9:

Total amount of collected and disposed MSW in China during 2003-2016

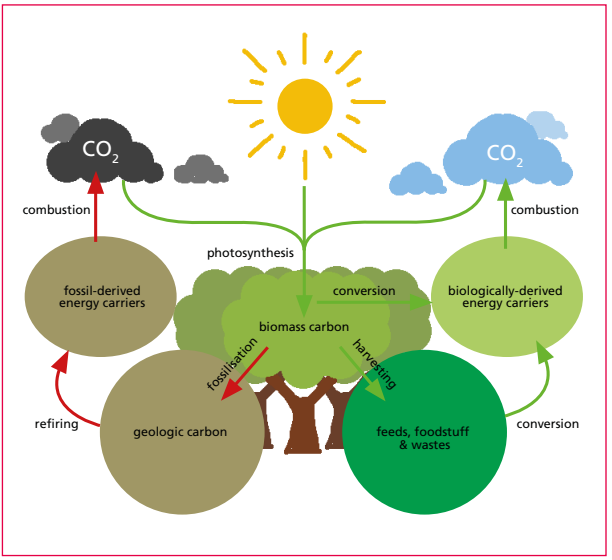

Figure 10:

Interconversion of various biomass and energy forms in the carbon cycle

Source: Srirangan, K.; Akawi, L.; Moo-Young, M.; Chou, C.P.: Towards sustainable production of clean energy carriers from biomass resources, Applied energy 100, 2012, pp. 172-186

Source: World BioenergyAssociation: Certification Criteria for Sustainable Biomass for Energy. WBA Position Paper, 2010

In recent years, biofuel production shows a clear growth trend and is gradually replacing the use of fossil fuels in transportation. In the past fifteen years (2000-2014), global liquid biofuels (bioethanol, biodiesel and hydrogenated vegetable oil, etc.) production obtained a 7.4-folds increase from 18.0 to 127 billion litres [7]. In 2015, 133 billion litres liquid biofuels were produced. Among liquid biofuels, the share of bioethanol production reached 62 % followed by biodiesel production (24 %). Figure 11 shows the annual production of liquid biofuels of different regions during 2000-2013 [7]. It was found that Americas (predominantly Brazil and the US) produced 89.8 billion litres of liquid biofuels and contributed 76.1 % of the world production in 2013.

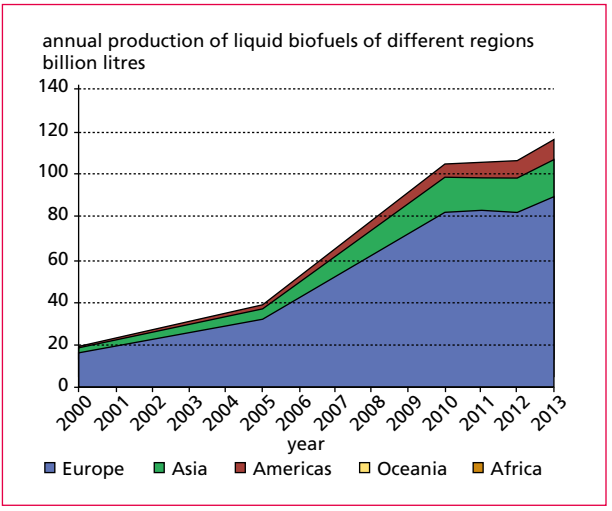

Figure 11:

Annual production of liquid biofuels of different regions during 2000-2013

2.2.2. Bioethanol

Figure 12 presents the annual production of bioethanol of different regions during 2000-2013. It was found that the global bioethanol production increased by 456.8 % from 13.2 billion litres in 2000 to 73.5 billion litres in 2013. Americas produced 64.0 billion litres of bioethanol and contributed 87.1 % of the global production in 2013. Figure 13 shows the bioethanol production of top 10 countries in 2015. The US was the greatest bioethanol producer. 85.8 % of global bioethanol was produced in USA and Brazil. Although China is the third largest bioethanol producer, its production was only 2.8 billion litres and accounted for 2.8 % of the world in 2015.

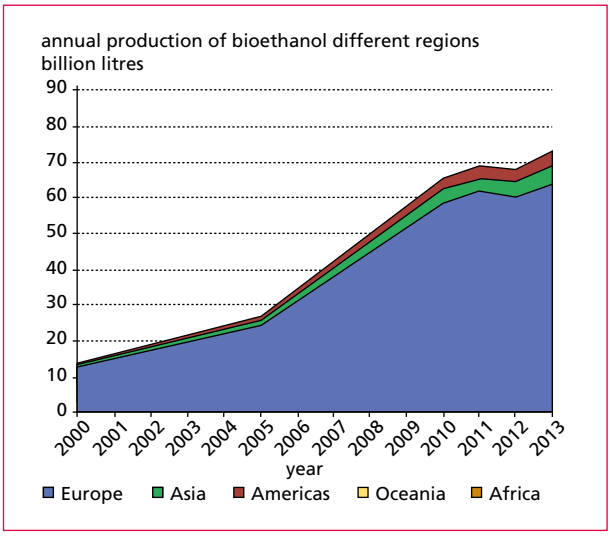

Figure 12:

Annual production of bioethanol of different regions during 2000-2013

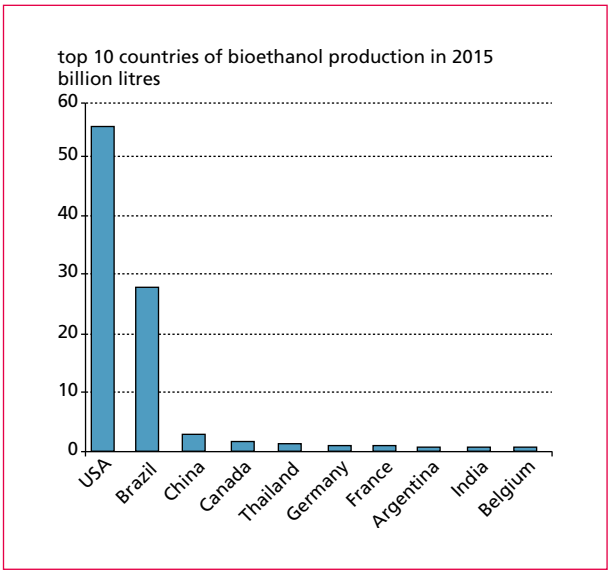

Figure 13:

Top 10 countries of bioethanol production in 2015

2.2.3. Biodiesel

Figure 14 presents the annual production of biodiesel of different regions during 2000-2013. It was found that the global biodiesel production increased by 3,340.5 % from 0.84 billion litres in 2000 to 28.9 billion litres in 2013. Europe and Americas produced 12.5 and 11.0 billion litres of biodiesel and contributed 43.3 % and 38.1 % of the global production in 2013 respectively. Figure 15 shows the biodiesel production of the top ten countries in 2015. The US and Brazil again topped the list of countries producing the most biodiesel and their share of global biodiesel production reached 15.9 % and 13.6 %. However, the development of biodiesel technology in China appears unsatisfactory and its biodiesel production was not among top ten countries.

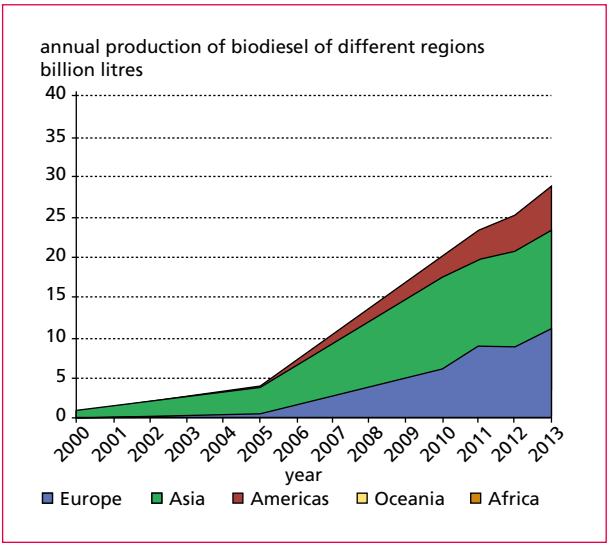

Figure 14:

Annual production of biodiesel of different regions during 2000-2013

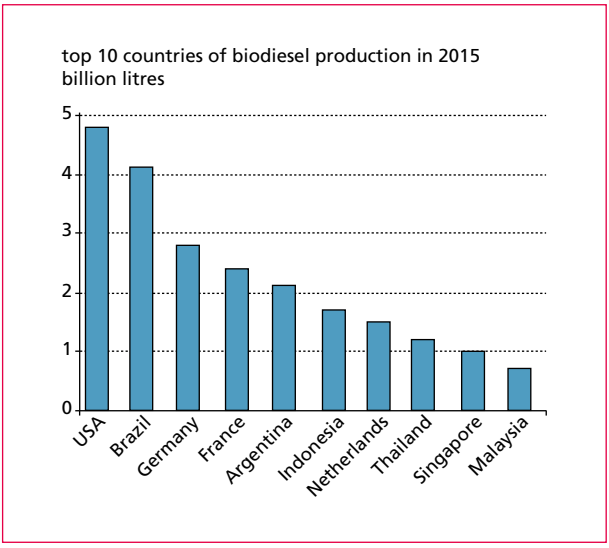

Figure 15:

Top 10 countries of biodiesel production in 2015

2.2.4. Biogas

Figure 16 presents the annual production of biogas of different regions during 2000-2013. It was found that the global biogas production increased by 3.6 times from 0.28 EJ (13.2 billion m^3) in 2000 to 1.28 EJ (59.0 billion m^3) in 2013. Europe and Asia produced 0.57 and 0.40 EJ of biogas and contributed 44.5 % and 31.3 % of the global production in 2013 respectively. Figure 17 shows the biogas production of top 10 countries in 2013. China, Germany and the US topped the list of countries producing the most biogas and their share of global biogas production reached 25.8 %, 22.7 % and 21.1 % respectively. China produced 15.2 billion m^3 of biogas and was the greatest biogas producer of the world owing to the extensive application of anaerobic technology in biomass waste treatment.

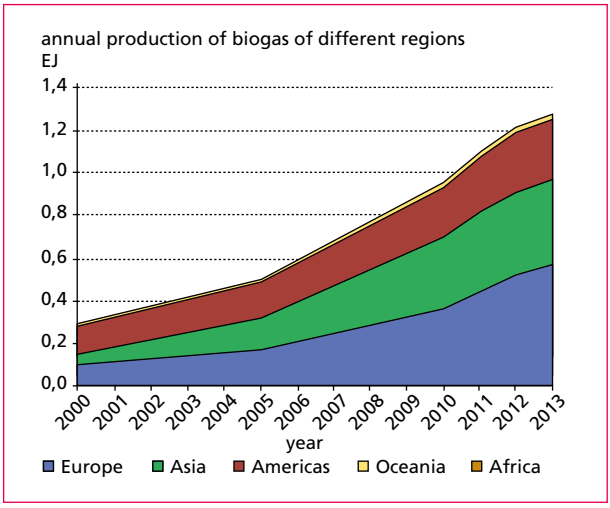

Figure 16:

Annual production of biogas of different regions during 2000-2013

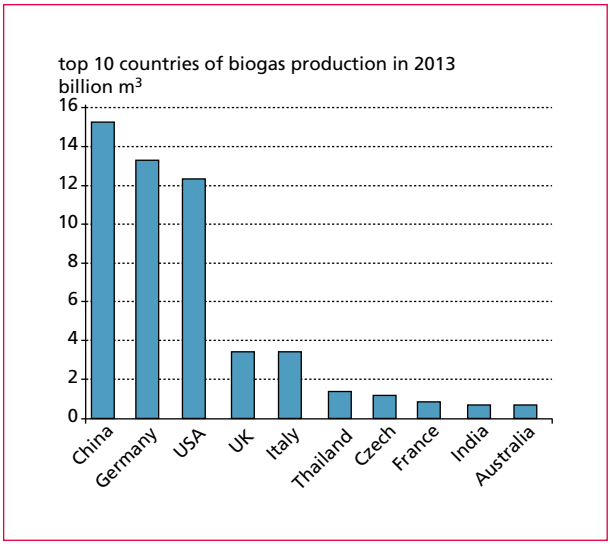

Figure 17:

Top 10 countries of biogas production in 2013

3. Conclusions

Although the fact that fossil fuels predominate energy consumption would not change in a short period, biofuel generated from biomass waste will predictably play an increasingly important role in addressing the long-term challenges of environment safety and energy security, especially in the developing countries or rural areas, where energy may be not sufficient.

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