Biofuel Production and Diffusion toward Sustainability: Case of South Africa

Satoshi Watanabe

Abstract

This study examines the social and economic effects on producing biofuels with case study of biofuel production in South Africa. Producing and diffusing renewable energies like biofuel can contribute not only to achieve mitigations of greenhouse gases (GHGs) but also to enhance economic benefits like job creation, and further to establish sustainable development in local communities of developing countries. On the other hands, production of biofuels can affect other environmental damage, economic inefficiency, or expanding social inequality. This study surveyed to current situations of world biofuel markets and examined the effects of biofuel production to economic and social sustainability with case study of biofuel in South Africa.

Key words: Biofuel, Sustainability, Economic and Social Effects, South Africa

1. Introduction

Renewable energies such as solar and wind power generations, bioenergies can contribute to mitigate greenhouse gases (GHGs), as well as to provide economic development through creating new jobs, business or industries on domestic or regional economy, or social inclusions by conservation of environments and local community through utilizing local natural resources. In this way, it is common sense that developments of renewable energies are important to achieve a sustainability of the world, however, it is a big issue that commercialization of solar or wind power energies caused to new issues such as inefficiency or instability of their power generations and environmental or social problems like utilization of lands or environmental destruction of the areas near their power plants.

Likewise, biofuel production and diffusion as are substitute to fossil fuel are expected to contribute to environmental conservation such as mitigation of GHGs, economic development by creation of new business or jobs, or social inclusions through utilizing local resource like biomass. However, booming and declining the world biofuel market caused to new

problems like instability of world's agricultural markets.

This study examines relationship between biofuel production and sustainability. The contents of this paper are as follows; chapter 2 explains current trends of biofuel market in the world, and some issues to sustainability on producing biofuel, and also shows the framework of the social and economic effect on producing biofuel; chapter 3 examines the effects of biofuel production on sustainability in South Africa; and chapter 4 remarks conclusions in this study.

2. Current Trends of Biofuel Market

2.1. World Trends of Biofuel Production

Quantities of biofuel production in the world are increasing since 2007. Figure 1 shows trend of biofuel production in the world, and that the quantities of 2017 increased about 2.2 times compared to value in 2007. And share of U.S in the world are increasing from 39.3% of 2007 to 43.4% of 2017, while Brazil, which being the second largest country on producing biofuel, declined the share from 33.2% of 2007 to 21.9% of 2017. And quantities of Middle East and Africa countries are slightly 45 thousands ton oil equivalent (TOE), and the share in the world is only 0.05% in 2017.

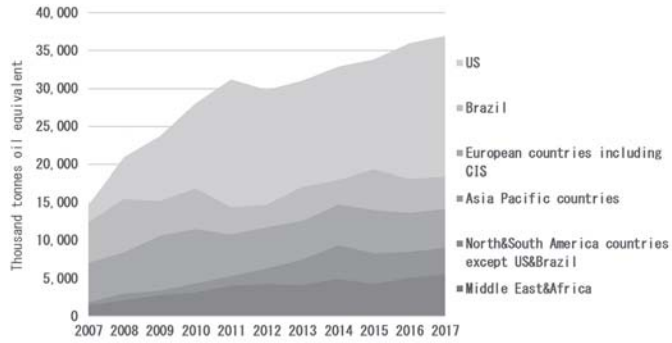

Figure 1　Trend of Biofuel Production by Regions
(2007–2017, unit: 1,000-t oil equivalents)

(source) Author's creation based on [1]BP (2018).

Table 1 shows the trend of biofuel production by countries since 2007 to 2017, the quantities of Asia countries such as Indonesia, China and Thailand, and European countries such as France, Netherland and Spain are increasing rapidly, however the quantities of Germany, which the third largest countries of biofuel production, is only less than one-tenth. In this way, the share of U.S. and Brazil on producing biofuel in the world market account

Table 1 Trend od Biofuel Production by Countries (2007–2017, unit: 1,000-t oil equivalents)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
US	14,709	20,934	23,761	28,044	31,184	29,808	31,057	32,890	33,849	35,986	36,936
Brazil	12,427	15,486	15,227	16,866	14,403	14,739	17,114	18,005	19,332	18,168	18,465
Germany	3,243	2,805	2,834	3,022	2,967	3,031	2,770	3,460	3,191	3,228	3,293
Argentina	173	635	1,055	1,670	2,234	2,295	2,014	2,644	2,038	2,828	3,131
France	1,153	2,064	2,408	2,353	1,935	2,145	2,306	2,573	2,559	2,405	2,224
Indonesia	217	530	469	723	1,110	1,397	1,750	3,110	1,314	2,238	2,326
China	982	1,194	1,224	1,584	1,970	2,103	2,346	2,609	2,653	1,811	2,147
Thailand	148	525	656	700	765	1,054	1,330	1,490	1,603	1,610	1,846
Netherlands	82	78	242	391	674	1,276	1,495	1,980	1,816	1,477	1,658
Spain	378	384	1,001	1,312	851	620	749	1,030	1,122	1,200	1,541
Cnada	502	543	761	787	899	1,004	1,059	1,188	1,142	1,197	1,239
Rests of World	3,415	4,931	6,256	6,454	6,688	7,376	8,425	9,030	9,247	9,335	9,315
Total World	37,429	50,109	55,894	63,906	65,680	66,848	72,415	80,009	79,866	81,483	84,121

(source) Author's creation based on [1]BP (2018).

for about two-third.

2.2. World Trends of Biofuel Consumption

Trend of quantities of biofuel consumption in the world is similar to that of biofuel production. Figure 2 shows trend of biofuel consumption by region since 2007, and the quantities of consumption are increasing on every country or regions. World consumption of biofuel is increasing from 994 thousand baller per day (BPD) in 2007 to 2,299 thousand BPD in 2016. In this trend, U.S shares about half of worldwide consumption since 2007. Otherwise, Brazil shared about 25% in the world, but recently the share of European countries catches up to that of Brazil.

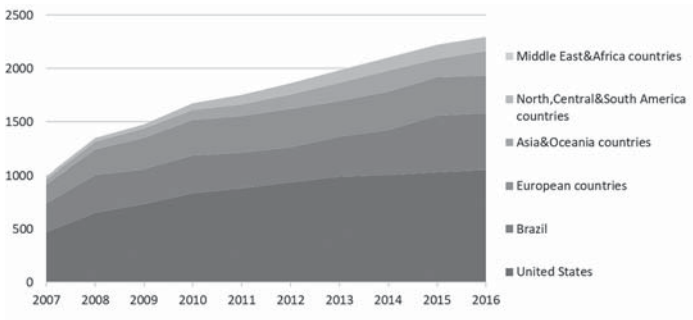

Figure 2 Trend of Biofuel Consumptions by Regions (2007–2016, unit: Thousands baller per day)

(source) Author's creation based on [2]USEIA website.

Table 2　Trend of Biofuel Consumption by Countries (2007–2016, unit: Thousands baller per day)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
United States	472.07	649.75	733.67	834.00	881.63	938.87	991.17	1005.44	1033.79	1055.27
Brazil	268.48	355.65	323.78	348.66	326.09	321.88	370.43	418.22	527.12	523.00
China	34.77	43.60	52.40	52.35	56.89	65.56	84.55	88.01	70.88	76.77
France	34.97	55.92	59.64	58.80	58.86	65.22	64.69	70.34	71.00	73.22
Germany	75.88	66.36	67.65	75.52	74.36	77.34	71.42	73.08	68.57	68.50
Canada	21.63	25.94	26.86	33.31	47.25	52.40	57.05	58.23	56.52	55.87
Indonesia	0.58	0.60	1.03	3.79	6.17	11.55	18.06	27.57	14.82	51.83
Thailand	4.81	12.12	18.37	18.94	18.78	24.11	34.44	38.48	41.74	43.31
Argentina	0.00	0.35	0.51	12.38	18.10	21.50	25.00	29.65	32.04	34.25
Spain	10.04	14.99	25.76	34.75	41.10	49.81	22.49	23.74	24.02	28.19
Rest of the World	70.65	123.00	166.90	201.39	222.14	233.57	245.41	273.17	283.27	289.56
Total	993.88	1348.28	1476.55	1673.88	1751.37	1861.82	1984.70	2105.91	222.76	2299.77

(source) Author's creation based on [2]USEIA website.

Table 2 shows trend of biofuel consumption by countries since 2007, developing countries such as Indonesia, Thailand, or Argentina is increasing rapidly. Furthermore, France and Spain increased gradually since 2007. However, as it is similar to be world's production of biofuel, the share of biofuel consumptions in U.S. and Brazil account for about 60–70% since 2007.

2.3. Trends of Biofuel Prices

As shown in 2.1 and 2.2, biofuel market in the world changed to increasing production

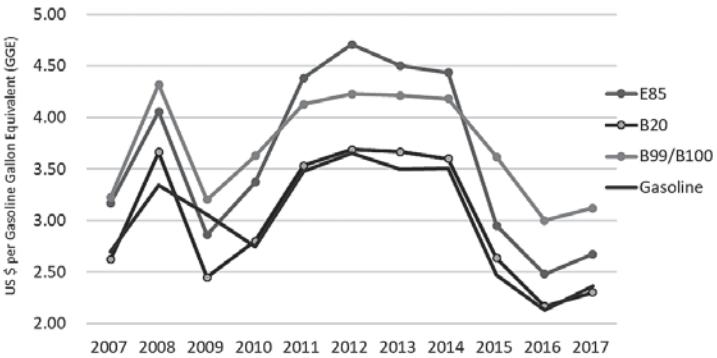

Figure 3　Trends of U.S Retail Biofuel and Gasoline Prices (2007–2017, unit: US dollar of Gasoline Gallon Equivalent)

(source) Author's creation based on [4]USDoE website.

(notes) E85 is an ethanol fuel blend of 85% ethanol fuel and 15% other fuel. B99/100 is a high-level biofuel blend consisting of up to 99 or 100 percent biodiesel.

and consumption, however, supply structure of biofuel in the world market is oligopoly by U.S. and Brazil. Generally, oligopoly market price tends to be higher, because oligopoly suppliers get profits through sustaining high-level price.

Figure 3 shows trends of U.S. retail biofuel and gasoline since 2007. The price rising occurred in 2008 and during 2010–2012, and these were caused by rising crude oil and oil products price in the world. On the other hands, declining oil price after 2013 induced to falling these biofuel price, as the results, production of biofuels was stagnant in the world ([3]JPEC, 2016).

2.4. Issues of Biofuel Production and Diffusion on Sustainability

Sustainability is defined by [5]World Commission on Environment and Development (1987), generally so called by Brundtland Report, as "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Especially, this concept is understood as the achievement of sustainability is the situation of balanced development which achieved the conservation of environment, economic development, and social inclusion in the international society such as Earth Summit on Rio de Janeiro of Brazil in 1992.

Biofuel production and diffusion contributes to improving environmental damage such as mitigation of global warming, economic growth such as development of new industry and job creation ([6]Moschini et, al, 2012). However, biofuel production faces to some issues for achievement of sustainability. First is that biofuel can mitigate emissions of GHGs through this consumption but can increase to burden of energy consumption through this production, because the production requires to a large electric energy for extraction process from crops such as corn and soybean. If their energy is supplied from fossil fuel, biofuel production causes to increase GHGs ([7]Nakano et, al, 2016). Second is that production of biofuel from agriproducts for foods can occur to threatens to competition between production of the fuel and food supply ([8]Richardson et, al, 2010). In fact, booming of biofuel production from food crops in United States and Brazil during 2008–2009 induced to inflation of food price, and to shortage of food supply in the world ([9]IEA, 2017).

Biofuel are three kinds of by what's from origin; biofuels from foods such corn and sugarcane is called by first generation fuels; biofuels from food wastes, residuals of crops and wood chips are called by second generation fuels; and biofuel from algae is called by third generation fuel ([10]Washizu et, al, 2015). Research and development of biofuel production technologies has been conducted to commercializing the business ([11]Acien et, al, 2013). Advantages of biofuel from algae are higher environmental conservation effects

like mitigating GHGs through harvesting cultures and more effective economic or social improvements like job creations than those of the first or second generation biofuel ([8]Richardson et, al, 2010).

However, for achieving their effects, it is necessary to be scale-up of cultivation, harvests, and extraction of biofuel from algae ([12]Lam and Lee, 2013). Moreover, their initial and running cost to be higher than those of the other biofuels ([13]Collet et, al, 2013). To overcome their issues, process of utilizing residuals as fertilizer on agricultural production after extraction of the fuels are included in production process of algal fuel ([11]Acien et, al, 2013). These combinations between biofuel production and utilization of the residuals can contribute to environmental improvement through mitigation of GHGs by cultivation of algae and substitution to non-fossil fuel, economic growth through creation of new industries as algae-energies or organic agriculture business, and social inclusion by job creation to low-middle income labors in rural economy ([7]Nakano et, al, 2016).

3. Biofuel Production in South Africa and Sustainability

3.1. Current Situation of Biofuel Production in South Africa

Republic of South Africa (in below, refer as South Africa) is the largest economic scale in African countries, and is one of BRICS countries which newly industrial countries.

The total primary energy supply of South Africa in 2014 is 5,915 Petajoule (PJ) and is dominated by renewable energy sources have a share of 10.9% or 648 PJ ([9]IEA, 2017). Almost of the total energy supply by renewable energy is shared by biofuels (98.6%). Figure 4 shows trend of bioenergy supply since 1990 to 2013, at once quantities of bioenergy

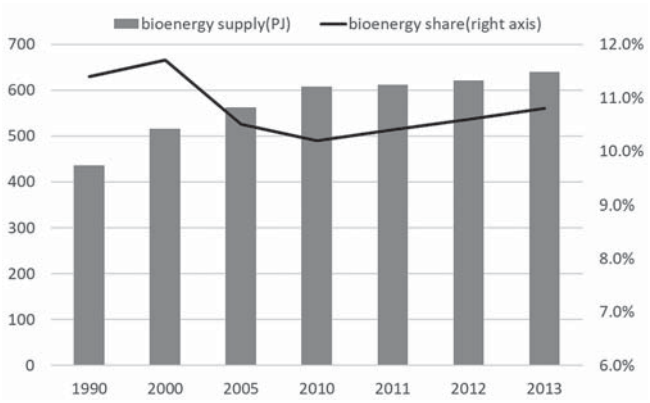

Figure 4　Trend of Bioenergy Supply in South Africa
(Source) Author's creation based on [9]IEA (2017)

supply decreased during 1990s to 2010 because main primary energy supply moved to fossil fuel by economic growth, but after 2010, share of bioenergy to energy supply is gradually increasing. Almost of this bioenergy supply is used by used in traditional ways such as cooking, heating or open fire ([9]IEA, 2017).

On the other hands, bioenergy consumption in South Africa increased rapidly after 2014 (shows Figure 5). Average growth ratio by year of bioenergy consumption in whole world increased by about 5.7% during 2009–2016, while in South Africa, for only three years during 2014–2016, bioenergy consumption increased about 570%.

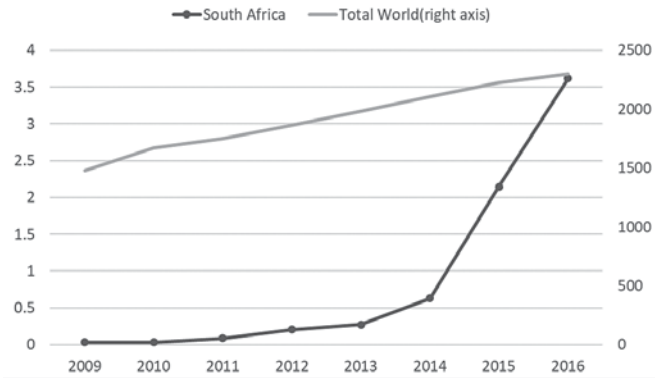

Figure 5 Trend of Biofuel Consumptions in South Africa (2007–2016, unit: Thousands baller per day)
(source) Author's creation based on [2]USEIA website.

3.2. Policies of Biofuel Production and Diffusion in South Africa

Table 3 is summarized about main policies for stimulating and supporting biofuel production and diffusion in South Africa. South Africa government published the Industrial Biofuels Strategy (IBS) to stimulate a biofuels industry in December 2007. Also, in 2009, they conducted to feed-in-tariff (FIT) to support diffusion of whole renewable energies. Furthermore, in March 2011, two important policies for stimulating biofuel production and diffusion were published; the Renewable Energy Independent Power Producer Programme (REIPPP) and the first Industrial Policy Action Plan (IPAP) ([14]Thapelo and von Blottnitz, 2012).

Table 3　Main Policies regarding Biofuel Production and Diffusion in South Africa

Date	Main Policies	Contents e.t.c.
Dec, 2007	the Industrial Biofuels Strategy (IBS)	Policy framework to stimulate a biofuels industry in South Africa (DME, 2007)
Mar, 2011	the Renewable Energy Independent Power Producer Programme (REIPPP)	Public procurement programme of onshore wind, solar PV, solar thermal, biomass solid, biogas, landfill gas and small hydro plants
Mar, 2011	the first Industrial Policy Action Plan (IPAP)	Revitalizing Politic Plan of Biofuel industry such as mandatory blending and a price support incentive mechanism for biofuels producers
Jan, 2014	the Draft Position Paper on the South African Biofuels Regulatory Framework	proposing an incentive of a guaranteed return on assets (ROA) of 15% for biofuels manufacturers

(Source) Author's creation based on [9]IEA (2017)

REIPPP replaced FIT, is a public procurement programme that price of procurement is established by the auctions for each technology and is guaranteed during twenty years. As the results, construction and supply of large-scale renewable energy capacity of more than 5MW were held by 3,625MW from 2011 to 2015 ([9]IEA, 2017).

IPAP consist of mandatory blending and fuel tax exemption to biodiesel or bioethanol ([14]Thapelo and von Blottnitz, 2012). Also, the Draft Position Paper on the South African Biofuels Regulatory Framework was published by Department of Energy (DoE) in 2014, which proposed a guaranteed return on assets of 15% for biofuels producers ([9]IEA, 2017).

3.3. Biofuel Production and Issues of Sustainability in South Africa

As mentioned in 3.2., South Africa government conducted to policies or incentive programme for stimulating biofuel production or supporting their diffusion. Quantities of biofuel production expanded gradually, while the share of bioenergy to primary energy supply did not increase as up and down to around 10%. However, bioenergy consumption in South Africa raised rapidly after 2014 by stimulating to bioenergy industry such as mandatory blending of biofuel and price incentive.

Bioenergy in South Africa can be evaluated as the consumption was induced, and the production was supported by some policy incentives of South Africa government. On the other hands, almost of the total primary energy supply of renewable energy is covered by energy from biofuels, and most of the bioenergy consumed in South Africa comes from solid biofuels, furthermore, mostly being used in traditional ways like cooking, heating or open

fire (IEA, 2017). And rising bioenergy consumption did not contribute to growth of bioenergy industry because share of bioenergy to total primary energy supply was not almost increasing.

Achievement of sustainability through biofuel production is necessary not only to induce technology development like biofuel from algae but also to diffuse environmental conservation, economic growth, and social inclusion. For example, mitigation GHGs with biofuel production is not only its effect on the consumption but those on production process. Or industrial development is diffused to bioenergy industry, as well as to other related industries. By those diffusion, it is possible to develop industries in rural areas such as agriculture, and to create new job to low-middle income workers.

First generation's biofuel production has some issues on burden to environmental damage or competition to food supply. So that third generation's biofuel from algae can contribute to overcome these issues on sustainability through utilizing residuals and efficient extraction.

4. Conclusions

This study examined relationship between biofuel production and sustainability. Main conclusions of this paper are as follows; firstly, world biofuel market was instable situation by effect of oligopoly markets with two large biofuel producer countries and by impact of world oil market. These can be obstacles to sustainability of world society or economy with biofuel production; secondly, biofuel production and diffusion can provide sustainable development with mitigation GHGs, creation new industries and business, and job creation, however the production and diffusion occur to other environmental damage such as increasing fossil fuel consumption or economic inefficiencies such as higher production or supply cost; and thirdly, in case of South Africa, several policies or economic incentive induced to growth of biofuel market, however growth of biofuel industry was not provided. And so that achievement of sustainability through biofuel production is necessary not only to induce technology development like biofuel from algae but also to diffuse environmental conservation, economic growth, and social inclusion.

Finally, future researches of this study are as follows; firstly, it is necessary to establish sustainable business model of biofuel production and diffusion. To do so, we need to explore to achieve both environmental conservation such as mitigation of GHGs and energy saving, economic efficiency through cost saving and benefit optimization, and social inclusion such as job creation; and secondly, we explore to suitable business based on environmental, economic, and social situation in South Africa. The business is necessary to be possible to improve some social problems such as environmental damage, energy loss, economic in

efficiency, and social inequality.

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