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THE USE AND FUTURE OF BIOFUELS

Abstract:

Being one of the most primary inputs of everyday life and the industrial world, energy has been used in various ways since the first existence of human beings. When we look at the types of energy used today, we can see that the mainly used types of fuels are fossil based. CO2 is emitted as a result of the combustion of fossil-based fuels. The increasing amounts of CO2 in the atmosphere create a greenhouse effect.

Biofuels have been becoming prevalent rapidly because of constantly gaining economic value and concordantly having less negative effects on the environment. All plant and animal based substances with carbohydrate compounds as main components are biofuel resources.

This study includes an examination of the different kinds of biofuels and their effects regarding environmental-related aspects.

Keywords:

biofuels, energy, environment

JEL Classification: Q40, Q49, Q42

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1. INTRODUCTION

Being one of the most primary inputs of everyday life and the industrial world, energy has been used in various ways since the first existence of human beings. When we look at the types of energy used, we can see that the mainly used types of fuels are fossil based. CO_2 is emitted as a result of the combustion of fossil-based fuels. The increasing amounts of CO_2 in the atmosphere create a greenhouse effect. As it can be seen in Figure 1, 22% of the greenhouse gas emissions that occur in the European Union are caused by the emissions from the transportation sector (EEA, 2012).

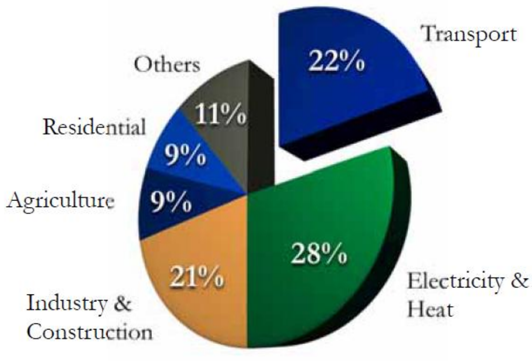

Figure 1. Greenhouse gas emissions in the European Union by sector

The Kyoto Protocol was adopted in 1997 by 30 industrialized countries in Kyoto, Japan in order to achieve a decrease in carbon dioxide (CO_2) emissions that create a greenhouse effect in global warming. On May 8, 2003, the EU commission issued the directive 2003/30/EC, which encourages biofuel production for use in the transportation sector. Especially after the adoption of the Kyoto Protocol, governments have had to take stricter precautions regarding emissions. As a result of these precautions, automotive manufacturers have been continuously working on developing vehicles and engines that are able to provide a decrease in emissions. The European Union (EU) has issued and put the Euro norms into effect. EU standards of exhaust emissions for passenger cars are presented in Table 1. It can be seen that as an outcome of the decisions taken by the EU, it is necessary for vehicle manufacturers to further decrease the exhaust emission values in the forthcoming years (Aydogan, 2011).

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Table 1. EU emission standards (for passenger vehicles, g/km)

	Date	CO	HC	HC+NOx	NOx	PM
Diesel						
Euro 1	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	0.14 (0.18)
Euro 2, IDI	1996.01	1.0	-	0.7	-	0.08
Euro 2, DI	1996.01a	1.0	-	0.9	-	0.10
Euro 3	2000.01	0.64	-	0.56	0.50	0.05
Euro 4	2005.01	0.50	-	0.30	0.25	0.025
Euro 5	2009.09b	0.50	-	0.23	0.18	0.005e
Euro 6	2014.09	0.50	-	0.17	0.08	0.005e
Gasoline						
Euro 1	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-
Euro 2	1996.01	2.2	-	0.5	-	-
Euro 3	2000.01	2.30	0.20	-	0.15	-
Euro 4	2005.01	1.0	0.10	-	0.08	-
Euro 5	2009.09b	1.0	0.10c	-	0.06	0.005d,e
Euro 6	2014.09	1.0	0.10c	-	0.06	0.005d,e

Today, vehicle manufacturers are trying to decrease the exhaust emissions produced by diesel-engine vehicles down within legal limits by using systems such as high-pressure fuel injection, multi-stage injection, three way catalytic converter, exhaust gas recycling, particle filters and injection start control through diesel engine management with an effort to meet the Euro norms. In addition to the reduction of harmful exhaust gas emissions, the reduction of CO_2 emissions is an important target of legislative forces. Due to the effect of CO_2 emissions on global warming, and the fact that fossil based fuel is a limited resource, a reduction of fuel consumption is an important development target for the upcoming years.

Another way to decrease exhaust emissions is the use of alternative fuels. The fastest developing type of alternative fuels is biofuels. Biofuels are made of different types of plants, which take CO_2 gas from the atmosphere during their growth. In this way, plants reduce the content of the greenhouse gas in the atmosphere and convert CO_2 into oxygen. Of course, there are CO_2-emissions produced during agricultural processes and the production of biofuels, but in a total balance of CO_2 gas, biofuels show an advantages behaviour.

A review of the scientific works conducted in recent years shows that the number of studies on alternative fuels has increased. The numbers of the studies conducted on biodiesel and ethanol emissions by year are presented in Figure 2 (EIA, 2013).

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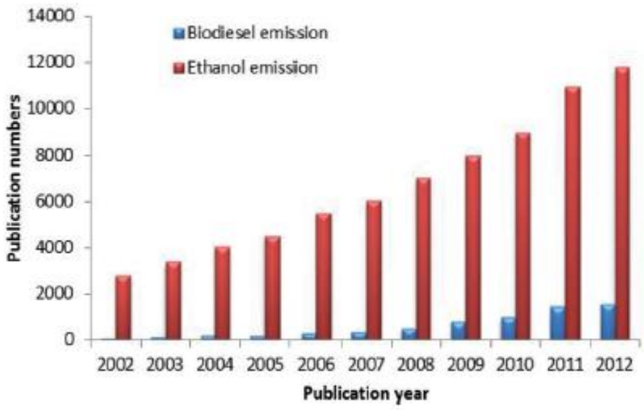

Figure 2. Variation of the number of studies on biodiesel and ethanol emissions by year

2. BIOFUELS

Biofuels have been becoming prevalent rapidly because of constantly gaining economic value and concordantly having less negative effects on the environment. All plant and animal based substances with carbohydrate compounds as main components are biofuel resources. Wood, oilseed plants, carbohydrate plants (potatoes, wheat, corn, beet etc.), fiber plants (linen, hemp, sorghum, etc.), protein plants (green peas, beans, etc.), and herbal wastes (twig, stem, straw, root, crust, etc.) constitute the plant biofuel resources. Herbal biomass occurs as the result of a process through which green plants convert solar energy into chemical energy and store this obtained chemical energy. Social, economic and environmental effects of biofuels are presented in Figure 3 (EEA, 2012).

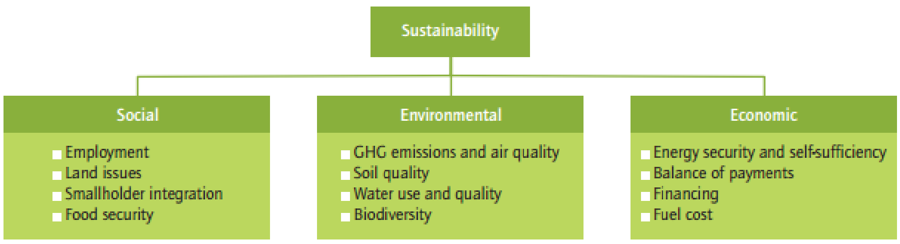

Figure 3. Social, economic and environmental effects of biofuels

Global biofuel production has started to increase in recent years. Figure 4 shows an estimation of global biofuel consumption. In the figure it can be seen that the global biofuel consumption, which was 18 *megaton of oil equivalent* (Mtoe) in 2004, is estimated to be 140 Mtoe in 2030 (EIA, 2013).

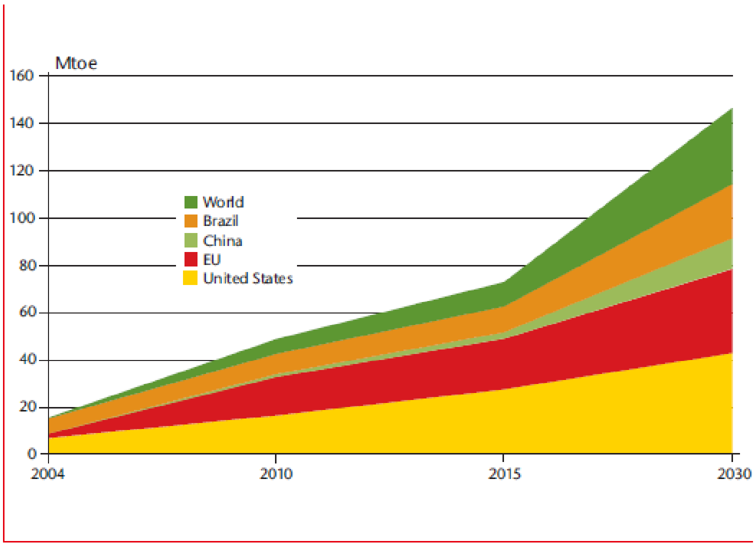

Figure 4. Estimation for global biofuel consumption

Biofuels are examined in four categories depending on the type of production and raw material selection:

First Generation Biofuels (2000-2010): Biodiesel, which is defined as a fatty acid methyl ester that can be used in internal combustion engines without requiring any modifications on the engine design, and bioethanol, which is produced from sources containing sugar and starch, are listed in this group. Bioethyl tertiary butyl ether, which is an ethanol derivative used as a gasoline additive, and biogas are other first generation biofuels. Agricultural products are utilized, as well as inputs from the food industry are also used in biodiesel and bioethanol production. Side-products are used for producing biogas.

Second Generation Biofuels (2010-2030): Fuels that can be used in flexible fuel vehicles or heat-electricity generation that are obtained through biomass conversion technologies, such as biomethanol and biohydrogen and biomass liquid fuel technology products (Fischer-Tropsch diesel and Fischer-Tropsch gasoline) are listed in this group.

Third Generation Biofuels (after 2030): One of the main goals of third generation biofuels, which are also named as “Advanced Fuels”, is biofuel production using genetically altered plants containing higher amounts of oil and cellulose and algae through a shift from lignocellulosic sources to cellulosic sources and the use of integrated biorefinery technologies.

Fourth Generation Biofuels (after 2030): Fourth Generation Biofuels will be produced from genetically optimized raw materials. Carbon monoxide in the pipe and exhaust gas of the biofuel will not be released to the atmosphere through being held by carbon holding and storing technologies. For such biofuels, which are also known as “Carbon Negative Biofuels”, extensive studies will be conducted on improving carbon holding and storing capacities within the scope of clean coal technology. In addition, it is aimed to remove carbon dioxide by using certain microorganisms to transform it into substances like sugar and consequently to fuels like ethanol and hydrogen (Demirbas, 2011).

Table 2. Classification of biofuels based on their generation technologies

Generation	Feedstocks	Examples
First-generation biofuels	Sugar, starch, vegetable oils, or animal fats	Bioalcohols, vegetable oil, biodiesel, biosyngas, biogas
Second generation biofuels	Non food crops, wheat straw, corn, wood, solid waste, energy crop	Bioalcohols, bio-oil, bio-DMF, biohydrogen, bio-Fischer–Tropsch diesel
Third generation biofuels	Algae	Vegetable oil, biodiesel
Fourth generation biofuels	Vegetable oil, biodiesel	Biogasoline

2.1. Biodiesel

Biodiesel is a fatty acid methyl ester which is derived from vegetable oils and animal fats, waste oils and residues in compliance with EN 14214 standards. Esterification technology is used in biodiesel production. The oil sources that can be used in biodiesel production are (Singh and Gu, 2010):

- Vegetable oils: Sunflower, soybean, rape, safflower, cotton and palm oils
- Recycled oils: By-products of the vegetable oil industry (Soapstock, waste oil)
- Urban waste and industrial waste-based recycled oils: Brown grease, Black grease
- Animal Fats: Tallow, fish oils and poultry oils
- Waste vegetable oils: Yellow grease and
- Algae.

Biodiesel can be used as fuel in engines either directly (B100) or through blending with diesel fuel at certain ratios (B20, B50, etc.). Biodiesel can be used in current diesel engines without requiring any modifications on the engine design. Countries that have a high biodiesel production potentials are given in Table 3. As the table shows, Malaysia comes first in terms of its biodiesel production potential (Aytav and Kocar, 2013).

Important characteristics of biodiesel are as follows (Demirbas, 2009):

- It is obtained from renewable raw material sources
- Decreases the dependence on petroleum products
- Considerably decreases emissions
- Does not contain sulfur
- Has good lubricant properties and increases the lubricant effect when blended with diesel fuel
- Has safe transportation, storage and easy usage properties due to its high ignition temperature
- Has a calorific value close to that of diesel fuel and a higher cetane number than diesel fuel
- The use of biodiesel fuel causes a decrease in the amount of PM, CO and HC existing in exhaust gases

Table 3. Countries with the highest biodiesel production potential

Country	Feedstocks
Malaysia	14.54
Indonesia	7.60
Argentina	5.36
USA	3.21
Brazil	2.57
Netherlands	2.50
Germany	2.02
Philippines	1.23
Belgium	1.21
Spain	1.07

2.2. Bioethanol

Bioethanol is a biofuel that can be obtained through the fermentation of plants containing sugar and starch or the acidic hydrolysis of cellulosic sources. Plants like sugar beet, sugar cane, corn, wheat and potato, wood-like plants such as stem, straw and bark, agricultural wastes and molasses, a byproduct of sugar production, can be used as raw material for bioethanol production.

It is more convenient to use bioethanol in gasoline engines owing to its high octane number. However, bioethanol has a considerably low cetane number. For this reason, its use in diesel engines has certain limitations. Important characteristics of bioethanol can be listed as follows (Demirbas, 2004):

- It is obtained from renewable raw material sources.
- Decreases the dependence on petroleum products
- Considerably decreases emissions
- Increases the octane number of the fuel
- It facilitates the more efficient and cleaner combustion of gasoline because of its oxygen content.

2.3. Methanol

Although methanol has a high octane number, it has a very low cetane number. For this reason, there are certain problems regarding its use in diesel engines. Methanol can easily be used in Otto engines. However, its use in diesel engines is only possible through the use of spark plugs or by blending methanol with diesel fuel at certain ratios (Serra and Zilberman, 2013).

2.4. Hydrogen

Hydrogen, which is the lightest element in nature, was discovered in 1766 by British scientist Sir Cavendish. Hydrogen is a colorless, odorless, flavorless and clear gas which is represented by the symbol "H" in the periodic table. Its atomic weight is 1.00797 kg/kmol and its atomic number is 1. Because of its low weight, it rarely occurs in a free state in nature. Hydrogen, which is an invisible and odorless gas, is observed in compounds with other elements in nature. Its density at 0 ^{o}C is 0.08987 kg/m^{3}.

Hydrogen has a considerably high combustion temperature and it does not have a poisonous effect. The only outcome of hydrogen combustion is water vapor. Hydrogen is an element which is highly difficult to condensate. It transforms into liquid phase at a temperature of approximately 20 Kelvin and at a pressure of 2 bars. Hydrogen is a considerably good thermal conductor (Govinda et all. 2011).

2.5. Biogas

Biogas is a gas mixture which occurs as the result of the decomposition of animal and plant wastes in an oxygen-free environment. Biogas contains 60-70% methane (CH_4), 30-40% carbon dioxide (CO_2), 0-2% hydrogen sulfide (H_2S) and a very small amount of nitrogen (N_2) and hydrogen (H_2). The term ‘biogas’ basically refers to the production of usable gasses from organic wastes. Since obtaining biogas depends on the decomposition of organic substances, plant wastes and animal manures can be used as the basic material for biogas production. Today, biogas production is utilized for heating a single residence, producing electricity using a generator etc (Serra and Zilberman, 2013).

2.6. Butanol

Butanol is the most complex of all alcohol fuels. As its $CH_3CH_2CH_2CH_2OH$ structure shows, butanol is a 4-carbon alcohol. Butanol is more poisonous compared to some other alcohols like methanol and ethanol. Butanol has a boiling point of 118 ^oC and a melting point of -89 ^oC. Butanol is commonly used as a solvent. It is also a candidate to be used as fuel. Butanol can be produced through the fermentation of agricultural products or from crude oil. It can be used as fuel in internal combustion engines operating with gasoline without performing any modifications on the engine. Butanol has higher energy content and a lower vapor pressure compared to ethanol and methanol.

4. FUEL PROPERTIES

The stoichiometric air-fuel ratios of biofuels are presented in Table 4. The cetane and octane numbers, lower calorific values and liter prices of these fuels can be seen in Table 5 (Pacini et al., 2013)

Table 4. The stoichiometric air-fuel ratios of selected biofuels

Gasoline has an air fuel ratio of	14.7 : 1
Natural Gas has an air fuel ratio of	17.2 : 1
Bio-Ethanol has an air fuel ratio of	9 : 1
Methanol has an air fuel ratio of	6.4 : 1
Hydrogen has an air fuel ratio of	34: 1
Diesel has an air fuel ratio of	14.6 : 1
Methane has an air fuel ratio of	17.4 : 1
Biogas has an air fuel ratio of	10: 1
Biodiesel has an air fuel ratio of:	12-13:1
Bio Ethanol (22 % mix) has an air fuel ratio of (as it is an oxygenated fuel as compared to Gasoline)	12.7 : 1
E85 has an air fuel ratio of	9.765

Table 5. The cetane and octane numbers, lower calorific values and liter prices.

	Cetane number	Heat value Lower Mj/kg	Octane Number	$/lt
Diesel Fuel	55	48		0,317
Aspir (safflower)	47,5	40,64		
CNG		52 000 Kj/kg		$4.3/Mio. BTU
Biogas		52 000		
LPG		46 000	95	0,318
petrol		48 000	98	0,343
Jatropha	51,6	37,2		0,75
Biodiesel from microalgae	71	41		8,7
ethanol	9	27	109	0,422
Methanol		19,85	110	0,171
Hydrogen		120 Mj/kg	130	
Bütanol	17-25	34 MJ/Kg		
Rapeseed	53	37		0,71
soybean	50	39		0,686
sunflower	49	33,5		0,75
Fisher tropsch		41,49 mj/kg		0,70

5. CONCLUSIONS

Due to their positive effects on exhaust gas emissions, especially on the reduction of the greenhouse gas (CO_2) emissions, biofuels show a great potential in present and the future. The development of second, third and fourth generation of biofuels will increase the efficiency in production and reduce the drawbacks, e.g. the influence of biofuel industry on food-production.
A broad variety of different types of biofuel enables the development of fuels with specified characteristics according to the requirements of engine exhaust gas after treatment technology.

Figure 5 includes a comparison of total CO_2 emissions of different types of energy sources for a standard mid-class personal car (Hirz, 2011). The CO_2 emissions are considered as well to tank emissions, which occur through the provision of fuel (or electric energy) and as tank to wheel emissions, which are influenced by the efficiency of the combustion engine. In case of electric vehicles, the well to tank emissions are defined by the type of electricity generation. It is visible, that conventional fuel (gasoline & diesel) shows a moderately well to tank CO_2 emission behaviour, whereas the main share occurs during operation of the engines in the car (tank to wheel emissions). Cars with hybrid propulsion systems show a similar behaviour, but a slightly reduced tank to wheel emission due to the increased drivetrain efficiency. Electric driven vehicles do not produce any tank to wheel emission, but the total CO_2 emission balance is directly influenced by the technology for producing electricity, e.g. a considerable share of coal-fired power stations has a big negative effect on the CO_2 emissions, as it can be seen in the German electricity mix. In contrast, the Austrian Ökostrom mix is based on 100 % electricity from renewable resources, which leads to a significantly reduced output of total CO_2 emissions.

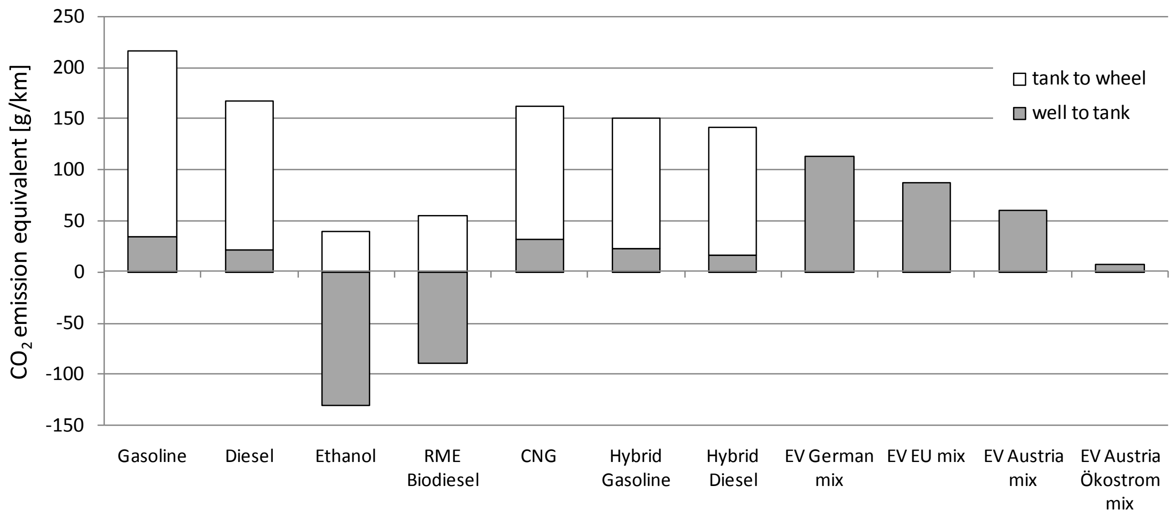

Figure 5: Comparison of total CO_2 emissions of different types of energy sources for a standard mid-class personal car

Finally, the diagram shows the CO_2 emission characteristics of 2 types of biofuel, ethanol and biodiesel. The negative well to tank emissions, which occur during the cultivation of plants and the production of fuel leads to a significantly reduction of the total CO_2 balance. Even considering the first generation of biofuels, which is not as effective as the following generations will be, the reduction of greenhouse gas emissions is a striking argument. The diagram shows the lowest total CO_2 output for cars driven by biofuels, with only one exception, the electric car, which is supplied by sustainable Ökostrom. In this way, biofuel shows a high potential as a fuel for future mobility concepts.

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