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BIOFUELS: AN ALTERNATIVE TO OIL?[1]

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Abstract

Oil dominates our world energetic mix and this aspect is especially visible in the transportation sector with over 90% of the fuel supply being represented by oil. Due to the geographic concentration of oil reserves, assuring energetic security becomes a challenge for countries short of resources. Biofuels are liquid or gaseous fuels derived from biomass. Energy crops can be specially harvested for this purpose and thus a renewable resource is available. Due to climate change considerations, biofuels use can reduce GHG emissions. Originating from agricultural feedstocks biofuels can offer an alternative market for these commodities. Governments have developed biofuels instruments, such as blending mandates, in order to improve their energetic security, replace oil and maintain the agricultural feedstock prices. The present paper analyzes the opportunity of using biofuels regarding their sustainability, competitiveness and their potential to improve energetic security.

Keywords: biofuels, oil, energetic security, sustainability, blending mandates

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1. Aspects regarding biofuels

The concept of biofuels refers to liquid or gaseous fuels obtained through the transformation of biomass.[2] Being produced from organic materials derived from biomass distinguishes them from oil, which is the main fuel that they aim to replace by their deployment. Through biomass we can understand biodegradable matter from agriculture, forestry, related industries or industrial and municipal waste.[3] Energy crops from plants, trees or herbaceous biomass can be harvested with the aim of obtaining energy.[4]

Biomass has been used for thousand of years in order to produce energy mainly through the use of wood and charcoal. Biofuels are related mainly with the transportation system and we can track their origins along with the development of automobile industry dating back to the 19th century. Back then different types of technologies were developed in order to propel the automobile with various energy sources such as coal, electricity or gasoline. In the end the internal combustion engine, build by Nikolaus Otto proved to be the most viable option by the beginning of the 20th century.[5] Testimonies from this period mention the fact that alcohol-based fuels were also used for fuelling. Ford T model for this matter was capable of running with ethanol.[6] Also in 1929, Rudolph Diesel used vegetal oil for the ignition of his diesel engine. However he noticed that the use of biofuels had some negative consequences upon the engine such as

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[2] International Energy Agency, *Technology Roadmap Biofuels for Transport*, 2011, [http://www.iea.org/publications/freepublications/publication/biofuels_roadmap.pdf], 10 October 2014

[3] Virginie Doumax, *The past and future of biofuels*, 2010, [http://www.irefeurope.org/en/sites/default/files/4part_energy%20police_small.pdf], 10 October 2014.

[4] World Energy Council, *Biofuels: Policies, Standards and Technologies*, 2010, [http://www.worldenergy.org/wp-content/uploads/2012/10/PUB_Biofuels_Policies_Standards_and_Technologies_2010_WEC.pdf], 10 October2014.

[5] D. Rajagopal, D. Zilberman, "Review of Environmental, Economic and Policy Aspects of Biofuels", *The World Bank, Policy Research Working Paper Series*, n° 4341, September 2007 *apud* Doumax, *op. cit.*

[6] C. Dimitri, A. Effland, "Fuelling the Automobile: An Economic Exploration of Early Adoption of Gasoline over Ethanol", *Journal of Agricultural and Food Industrial Organization*, vol. 5, 2007, *apud* Doumax, *op.cit.*

reduced atomization, a lower heating value, pump wear and carbon/coke deposits over the long run.[7]

The use of biofuels in the transportation field remained limited due to economic considerations, as alcohol-based fuels proved to be more expansive than gasoline. In the United States alcohol taxation and high corn prices restricted the adoption of biofuels.[8] In Germany with governmental support an ethanol market was developed at the beginning of the century but it lasted only for a few years as ethanol prices proved to be too high.[9] Besides fuel price, the network development in the US for oil distribution, which occurred before the development of the auto industry favored the use of gasoline. In contrast, there was no distribution system for grain commodities to facilitate ethanol processing.[10] We can also identify in the US at the beginning of the century upon until 1917 a period characterized by high farm prices. Due to price and infrastructure oil proved to be the first choice in the automobile fuel industry.[11]

It was not until the seventies that biofuels were to be reconsidered as an alternative fuel to gasoline and this was due to the oil crisis. A number of countries began to develop biofuel programs, but they were not substantial and were influenced by oil prices. Brazil, a heavily dependent oil country, developed a program where bioethanol was mixed with gasoline. However the main reason for implementing this measure was not the substitution of oil, but the need to balance the demand and production on the international sugar market. Being a major sugar exporter, Brazil needed an instrument in order to reduce the price volatility on the market which was affecting its export revenues.[12] The program aimed at reducing oil dependence while also developing an industry and lowering unemployment.[13] We can observe that the renewed interest in the biofuel use did not occur purely on energetic security reasons but also from economic ones such as trade imbalances and unemployment.

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[7] World Energy Council, *op.cit.*
[8] Dimitri, *op.cit.*
[9] Doumax, *op.cit.*
[10] Dimitri, *op.cit*
[11] Doumax, *op.cit.*
[12] World Energy Council, *op.cit*.
[13] Doumax, *op.cit.*

However in the mid eighties oil prices dropped and the interest for finding alternatives to oil declined. At the beginning of this century interest for the biofuel industry resumed, driven by actors such as the United States or the European Union which implemented measures in order to develop biofuel production.

Currently, governments are motivated in their actions by the fear of oil price escalations, greenhouse gasses and the overproduction present in the farming sector which lowers commodities prices. Policy makers aim in the same time to enhance energy security, combat climate change and to create new markets for the agricultural sector.[14]

2. Biofuels types and technologies

When we approach technologies, we can distinguish between conventional and advanced technologies. Conventional technologies have been scientifically proven and allow their deployment at an industrial level. Products of these technologies are known as first generation biofuels and among them we can find ethanol from sugar or starch, biodiesel from vegetable oils and biogas resulted from anaerobic digestion. Feedstocks used for first generation biofuels include sugarcane, sugar beet, corn, wheat or oil crops such as rape, soybean and palm oil. Regarding advanced technologies they are not yet found at the maturity stage. The products of these technologies are called second and third generation of biofuels. They include hydrotreated vegetable oil (HVO), biofuels resulted from lignocellulosic biomass such as cellulosic-ethanol, diesel resulted from the conversion of biomass in liquid (BtL), bio-synthetic gas (bio-SG) and also algae based biofuels.[15] The main distinction between the two technologies is the nature of the feedstocks used. For the first generation of biofuels we can find food crops which can be subject to competition between food and energy and can lead to cereals commodities price escalation while in the advanced technologies biofuels we can find feedstocks that are not among food crops.[16]

[14] *Ibidem*.
[15] International Energy Agency, *op.cit.*
[16] World Energy Council, *op.cit.*

In the category of first generation of biofuels we can find bioethanol which is obtained by fermenting biomass with a high content of carbohydrates. It can be obtained from sugar or starch, but the future generation of biofuels will allow it being obtained from cellulose and hemicelluloses.[17] Sugar ethanol is obtained through the fermentation of sucrose from sugarcane, sugar beet or sweet sorghum.

Secondary products resulting from the process such as dried distiller's grains with soluble (DDGS) or fructose enhance the overall economic performance of the process. Sugar and starch prices have an important share in the final costs of this type of biofuels.[18] Ethanol can be a substitute for oil in gasoline. It can be either blended in low proportions like the E10, or even replace gasoline in high proportions such as the E85.[19] Biodiesel is obtained from raw vegetable oils which are converted to biodiesel by the help of methanol or ethanol. From the biodiesel production process secondary products also result such as protein meal or glycerine which contributes to the economics of the process. Similar to ethanol production costs are sensitive to feedstocks prices.[20] Biodiesel can be used either as an additive in order to reduce the engine's emissions or as fuel.[21] Biogas is obtained through the anaerobic digestion of organic wastes or energy crops. It is used for generating heat and electricity, but by removing the CO_2 and hydrogen sulfide (S_s0) results biomethane which can be used as a fuel for vehicles.[22]

Passing to the advanced technologies, we find the production of bioethanol from lignocellulose through the biochemical conversion of cellulose and hemicellulose components of biomass into fermentable sugars.[23] In the next phase the sugar is fermented in ethanol similar to

[17] *Ibidem.*

[18] International Energy Agency, *op.cit.*

[19] Doumax, *op.cit*.

[20] International Energy Agency, *op.cit.*

[21] World Energy Council, *op.cit*.

[22] International Energy Agency, *op.cit.*

[23] International Energy Agency, *From 1st- to 2nd-generation Biofuel Technologies: An Overview of Current Industry and RD&D activities*, OECD/IEA, Paris, 2008, [http://www.iea.org/publications/freepublications/publication/2nd_Biofuel_Gen.pdf], 12.10.2014

conventional biofuels. In contrast to conventional one, advanced ethanol performs better in terms of GHG emissions, land requirements and energy balance.[24] They will be able to be blended in any proportion with their fossil counterparts. We can identify in this category the hydrotreated vegetable oil (HVO) and the biomass-to-liquid-diesel (BtL). HVO is obtained through hydrogenating vegetable oils and animal fats while for BtL in the first stage biomass in converted into syngas and then the syngas is catalytically converted in hydrocarbon liquids.[25]

Regarding the raw materials needed for producing biofuels we can highlight the potential al algae.

High productivity per hectare, usage of non-arable land and also various sources of water such as saline or wastewater represent potential advantages for using this resource.[26] Micro-algae are 16 times per hectare more productive as palm oil harvests and even to 100 times higher than land vegetable oil crops. Also they require up to 99% less water. Due to the fact that they absorb CO_2, algae crops can be injected with the carbon dioxide resulted from the fossil plants emissions thus creating a synergy between the two industries.[27] The fact that they can be grown on non-arable land such as ponds or even in the sea eliminates the competition for land.[28] The conversion process is similar to other vegetable oils conversion. In order for algae to be successful they have to be harvest in high quantities at a low price.[29] From algae crops, biodiesel can be produced for vehicles but also for airplanes thus an alternative for kerosene becomes available.[30]

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[24] *Ibidem.*

[25] International Energy Agency, *Technology Roadmap Biofuels for Transport*, 2011, [http://www.iea.org/publications/freepublications/publication/biofuels_roadmap.pdf], 10 October 2014

[26] A. Darzins, P. Pienkos and L. Edye, *Current status and potential for algal biofuels production*, a report to IEA Bioenergy Task 39, 2010, *apud* International Energy Agency, *op.cit*.

[27] International Energy Agency, *From 1st- to 2nd-generation Biofuel Technologies: An Overview of Current Industry and RD&D activities*, OECD/IEA, Paris, 2008, [http://www.iea.org/publications/freepublications/publication/2nd_Biofuel_Gen.pdf], 12.10.2014

[28] World Energy Council, *op.cit*.

[29] International Energy Agency, *op.cit.*

[30] World Energy Council, *op.cit.*

However, for the moment the costs for algae crops are quite high varying between 0.75-5 $/l without taking into account the conversion costs to biofuels. Space availability, sunshine presence, crops contamination and production scaling remain the main challenges for algae biofuels development.[31]

Biofuels can replace fossil fuels up to a point but there are differences regarding their properties. Biofuels present a lower energetic content, thus requiring higher volumes of fuel. Ethanol has two thirds of the energetic content of oil while biodiesel has about 90% of the energetic content of fossil diesel.[32] Differences occur also in the engines combustion due to fuel flux, phase transformation, and heat exchange. Ethanol can be used to supply engines with spark ignition, having similar properties to gasoline in terms of auto-ignitiability. Due to the fact that small engines are with spark ignition, ethanol is adequate for this kind of vehicles.

In contrast to fossil fuels, ethanol has a lower viscosity, wider flammability and a lower flash point. Ethanol use provides a more efficient combustion but it also reduces the power of the engine, because it runs at lower temperature.[33] Ethanol is not that flexible as biodiesel when it comes to blending it other fuels. In can be blended with gasoline up to 10-15%, point from which gasoline engines are no longer compatible, the limit being also known as the *blending wall*.[34] Beyond that limit there is the need to use flexible fuel vehicles, which have a propulsion control calibrated to handle the high content of oxygen from ethanol.[35] These engines can run with ethanol in high shares up to 85% (E85) or fully on ethanol (E100).[36]

In the case of biodiesel it can be blended with fossil diesel or substitute it, without the need of modifying the engine, especially when the blended volumes are reduced. Current diesel engines can run with biodiesel in shares up to 20% (B20). As in the case of ethanol, biodiesel presents a lower

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[31] Darzins, *op.cit.*

[32] Rob Bailey, *The Trouble with Biofuels: Costs and consequences of Expanding Biofuel use in the United Kingdom, Energy Environment and Resources 2013/01*, 2013, [http://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/0413pp_biofuels.pdf], 15.10.2014

[33] World Energy Council, *op.cit.*

[34] Darzins, *op.cit*.

[35] US Department of Energy, *Alternative Fuels Data Center – Flexible Fuel Vehicles*, 2014, [http://www.afdc.energy.gov/vehicles/flexible_fuel.html], 12.10.2014.

[36] World Energy Council, *op.cit*.

energetic content, due to the fact that the oxygen does not have the energetic value of the hydrocarbon molecules. However the oxygen from the biodiesel increases the efficiency of the combustion. Another aspect concerning biodiesel is its chemical and biological degradability. Biodiesel reacts quickly to water, temperature variation, oxygen and microbial action, which can change its composition in the matter of months. Due to this fact, biodiesel proves itself difficult to store over long periods of time [37] thus lowering its flexibility in contrast to fossil diesel.

3. Biofuels deployment in the transport energy market

Currently, we can observe a growing demand for biofuels use at global level mainly through the development of governmental programs. These programs aim at providing solutions to a series of challenges such as energetic security, agricultural commodities prices, rural development and greenhouse gases emissions reductions. Over 50 states have developed programs to enhance production and use of biofules in the transport sector. The main instrument applied for the development of the biofuels industry is represented by the *blending mandates*. These stipulate the volumes of biofules that must be found in the transport fuels.[38] Therefore fuel producers must acquire biofuels in order to mix them with the conventional fuels. These mandates create an artificial market for biofuels, by the governments but not at their expense.[39] The costs are past directly to the fuel producers and on to the consumers. In contrast, traditional instruments such as tax credit or governmental subsidies offer a degree of transparency to the tax payer contribution.[40] Also we can observe the fact that the financial effort is not supported by all contributors but only by the ones from the transport

[37] *Ibidem*.

[38] International Energy Agency, *Technology Roadmap Biofuels for Transport*, 2011, [http://www.iea.org/publications/freepublications/publication/biofuels_roadmap.pdf], 10 October 2014.

[39] Anna Rauch, Michael Thone, *Biofuels – At What Cost? Mandating ethanol and biodiesel consumption in Germany*, 2012, [http://www.iisd.org/gsi/sites/default/files/bf_awc_germany.pdf] , 15 October 2014.

[40] *Ibidem.*

sector. Blending mandates are not flexible because they can not adapt to market evolutions. This is due to the fact that they link oil and biofuel use. When oil prices are moderate and biofuels crops are high, the consumer can not opt exclusively for oil. Only in the adverse situation when oil prices are high and biofuels crops prices low, is there a benefit for the consumers.[41] Given the fact that the first generation of biofuel uses food crops the blending mandates create a connection between the energy transport market and the food market which can have adverse effects to cereal prices. This is because cereals become substitutable to oil. By sustaining biofuels, governments are creating a growing demand for agricultural commodities which will increase food prices. Although the second generation of biofuels aims at using non-agricultural commodities there will still be a competition for the production factors involved in agriculture such as land, water and fertilizers.[42] For the farmers the fact that they grow agricultural or energetic crops does not matter as long as commodities prices are high. Also high cereal prices will impact the costs of raising animals and the end the price of meat.[43]

Through enhancing the consumption of biofuels, governments aim in reducing the price volatility present in the fuel market. However biofuels price can also be volatile, due to the fact that the feedstocks represent an important share, up to 45-70%, in the production costs.[44] In the case cereals price escalation occur, biofuels price will also escalate. This can also occur due to meteorological events, such as the example of Brazil where due to low sugarcane harvests and high sugar price on the market, the government decided to reduce the minim ethanol share in gasoline from 25% to 20%.[45]

Polices aimed at developing biofuels use, present also a social component, namely rural development. It offers farmers the possibility of diversifying and growing their revenues by harvesting energetic crops. This

[41] Chris Charles, et al; *Biofuels – At What Costs? A review of costs and benefits of EU biofuel policies,* 2013, [http://www.iisd.org/gsi/sites/default/files/biofuels_subsidies_eu_review.pdf], 15 October 2014.

[42] Bailey, *op.cit*.

[43] Charles, *op.cit*.

[44] International Energy Agency, *op.cit*.

[45] International Energy Agency, *World Energy Outlook*, 2012, [http://www.iea.org/publications/freepublications/publication/WEO2012_free.pdf], 10 October 2014.

measure is also intended to maintain food prices stable. Jobs are created in the area of harvesting, processing and distributing biofuels. Refineries can be developed in rural areas for biofuel processing. Farmers can also produce their own fuel for their vehicles.[46] These policies open the possibility of signing long-term contracts with fuel producers which can secure farmers revenues.[47] However such measures create dependencies between farmers, the biofuel industry on one side and the governmental budgets on the other. Due to this created market, private investments are made into the sector. Such measures once adopted prove themselves difficult to revise due to the stakeholders involved. On the other hand the food and beverage industry is negatively affected by biofuel policies.[48] This aspect must also be linked with the fact that for certain regions, agriculture plays a dominant role in their economy and this kind of measures can also have an electoral purpose.[49] Such an example is provided by Al Gore, who recognized that his affinity for the agricultural states of Tennessee and Iowa and also the presidential elections played an important role in his decision to sustain biofuels use.[50]

A third aspect for which biofuels are promoted by governmental programs is represented by greenhouse gases emissions. Given the fact that about 20% of the global GHG emissions originate from the transportation sector, it is considered that biofuels use can help limit these externalities.[51] It is considered that during the burning of biofuels it is released in the atmosphere the CO_2 that was initially stocked by plants through the photosynthesis process when the crops have grown. Thus the GHG balance is considered to be null. However this aspect does not take into consideration emissions that occur due to the use of fertilizers, machinery use, biofuel refineries and indirect emissions from deforestation and land conversion.[52]

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[46] World Energy Council, *op.cit*.
[47] FAO. (2008). The State of Food and Agriculture, *Biofuels: prospects, risks and opportunities*. Rome: FAO, 2008, *apud* Charles, *op.cit*.
[48] Bailey, *op.cit.*
[49] Nicolas D. Loris, *The Ethanol Mandate: Don't Mend It, End It*, 2013, [http://thf_media.s3.amazonaws.com/2013/pdf/bg2811.pdf], 16.10.2014.
[50] "Al Gore's Ethanol Epiphany," The Wall Street Journal, November 27, 2010, *apud* Loris, *op.cit*.
[51] World Energy Council, *op.cit*.
[52] Bailey, *op.cit.*

When assessing biofuels GHG emissions, it is necessary to take into account the whole chain of transformation which can lead to emissions, from production to combustion. This analysis estimates that for corn ethanol the emissions reductions range between 10-15% compared to gasoline while for the Brazilian sugarcane ethanol they are higher 70-120%, also taking into account secondary products. In the case of biodiesel produced from oil-seed the reductions are between 30-60% in contrast to fossil diesel. These estimations do not take into consideration the indirect emissions resulted from land conversion.[53]

Through governmental programs at global level, biofuels production has been on the rise. We can observe this in Figure 1, where biofuels production has grown over 5 times, reaching over 60.000 thousand toe in the course of a decade.

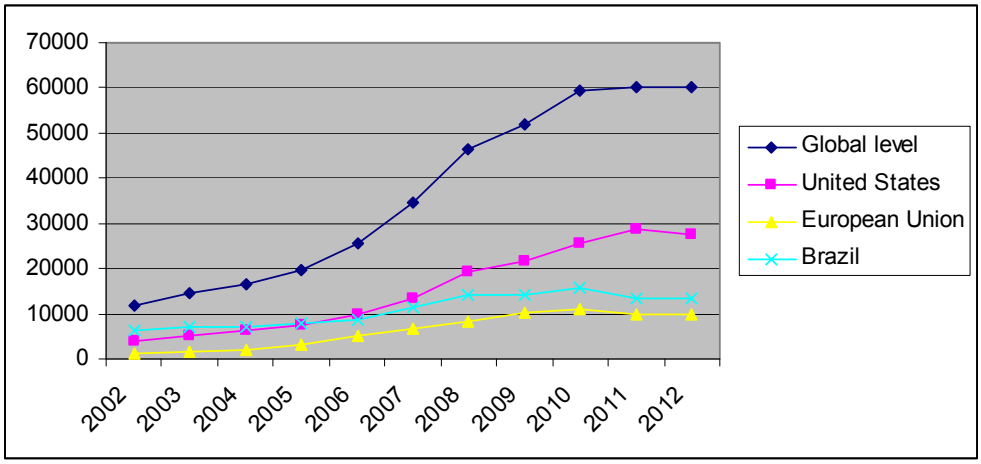

Figure 1: Biofuels production 2002-2012, thousand toe. Source: BP, 2013 after F.O. Lichts, US Energy Information Administration

Although production has risen at global level, there are only three major players in this field. The United States is the leading biofuel producer with over 27.000 thousand toe, this representing about 45% of the global production. Brazil, a traditional producer due to its sugarcane crops comes

[53] International Energy Agency, *CO_2 Emissions from Fuel Combustion Highlights*, 2013, [http://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustionHighlights2013.pdf], 20.10.2014.

in second with about half of the US production, and the European Union in third with close to 10.000 thousand toe. At European level France and Germany dominate the production reaching in 2012 a volume of 4714 thousand toe. These three actors have an 84.33% share in the global production.[54] If we analyze the production from the perspective of developed versus developing economies (OECD/non OECD countries), we can observe that biofuels production tends to be localized in the area of developed economies, 63.86%, which are inclined to find alternatives to oil consumption in their transportation sector.

This aspect can also be highlighted by analyzing the evolution of the share of biofuels in transport fuels in the last decade in representative countries (Figure 2). During this interval at OECD level biofuels reached close to 6%.

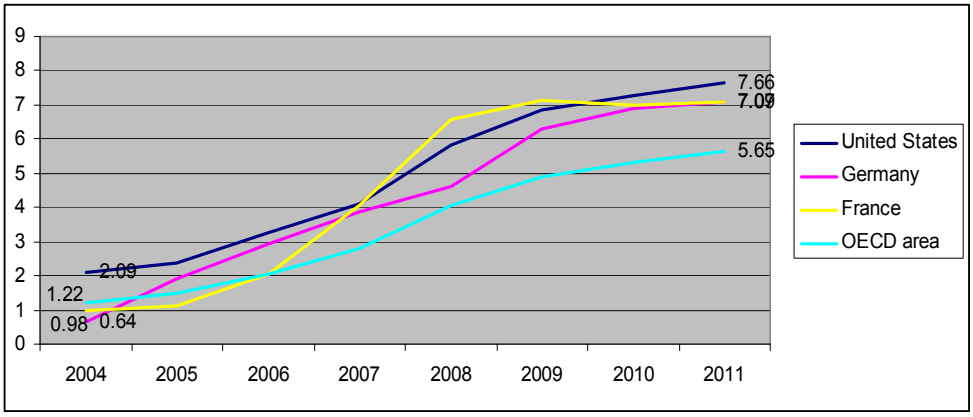

Figure 2: Percentage evolution of biogasoline and biodiesel in transport fuels, selected countries. Source: IEA, 2013 after Annual Oil Statistics.

However, despite the growing trend of biofuels use in the transportation sector, the overall impact of biofuels in thie area is quite limited, as we can observe it in Figure 3, biofuels represent about 2% of the fuel use in transportation. Oil dominancy in this field can not challenged currently by any of the existing alternatives despite current trends.

[54] British Petroleum, *BP Statistical Review of World Energy June 2013*, 2013, [http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf], 20.10.2014.

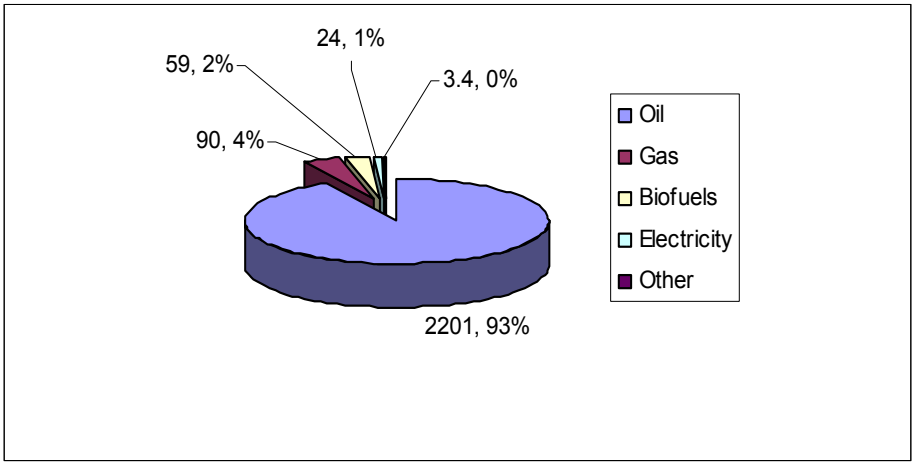

Figure 3: Energy demand by fuel in transport, 2011, mtoe. Source: IEA, 2012.

If we analyze the legal instruments used to promote biofuel use we can find in the United States the Renewable Fuel Standard (RFS) released in 2005, which stated the biofuel quantity (ethanol mainly) that must be found in refineries sales. According to the standard, its objective is to substitute oil use and reduce GHG emissions.[55]

However, similar to the Brazilian policy from the seventies, we can also identify in this case the need to find an alternative market for the American corn. In 2004 due to rich harvests, corn prices felled and reduced farmer revenues.[56] Through the standard farmers can sell their harvests for energy purposes with a market at hand. If refineries can not meet the expected level of biofuels, they must acquire credits for quantities already sold on the market. The existence of the blending wall for engines does not allow for the number of credits to follow demand and thus the price of credits evolved from cents to dollars. Besides the provisions for first generation biofuel use, the RFS also mentioned requirements for cellulose ethanol but production did not proved to be viable and the levels were lowered and in the end dropped, however penalties were paid by the refineries.[57]

[55] Loris, *op.cit.*
[56] Bailey, *op.cit.*
[57] Loris, *op.cit.*

In the European Union, through directive 2009/28/CE it is stipulated that each member state must meet until 2020, a minimum of 10% renewable sources in the final energy consumption from the transportation sector. Environmental considerations are taken into account for the deployment of biofuels. The directive mentions that the biofuels involved must meet a target of at least 35% GHG reductions, target that will evolve to 50% and 60% in the future. The crops used for the biofuels production process must not originate from lands with high carbon stocks. Lands rich in biodiversity must not be used for biofuels crops. Biofuels produced from wastes, residues, non-alimentary cellulosic material and lingo-cellulosic present a premium. Regarding the information of the public, member states must inform the consumers of the fuel composition only when the volumes of biofuels mixed are higher than 10%.[58] From 2012, the European Commission has limited the share of biofuels originating from food crops to 5%.[59] Similar to the US policy, the European biofuel policy aims at offering public goods such as energetic security, GHG emissions reductions and rural development.[60]

In the case of the EU there is also the agricultural character of new member states which is taken into account in order to redirect revenues towards them. Both in the EU and the US it is intended to raise farmers revenues and reduce the need direct agricultural payments.[61]

Biofuels production growth will also imply a growing demand for agricultural land which will increase prices. Thus higher rents will reduce farmer profits. This competition for land can have adverse consequences upon biodiversity such as the case of Germany where in the period 2003-2009, 55.000 hectares of grassland were converted to maize.[62] Intensive

[58] European Parliament and Council, *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*, 2009, [http://www.energy-community.org/pls/portal/docs/360177.pdf], 15.10.2014.

[59] European Commission, *Proposal for a directive of the European Parliament and of the Council amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources.* European Commission, Brussels, 23. 2012, *apud* Charles, *op.cit*.

[60] European Commission (2009), *DIRECTIVE 2009/28/EC on the promotion of the use of energy from renewable sources (Renewable Energy Directive, April 23). apud* Charles, *op.cit*.

[61] Bailey, *op.cit*.

[62] Charles, *op.cit*.

agricultural practices are also encouraged for energy crops which can affect the environment.[63]

Analyzing biofuels from the perspective of international trade, we can observe that by harvesting energy crops and producing biofuels, new actors can be attracted in the fuel market, thus diversifying the number of suppliers. Countries like Brazil, China, Argentina and Thailand have an important potential in producing biofuels at industrial scale and exporting them to consumer areas.[64] Although opening export possibilities for developing countries, biofuels production can also be associated with growing poverty and food insecurity in poor countries.[65] In these countries, food and cereals have an important share in the household expenses in contrast with developed ones.

Productions costs represent one of the main barriers that limit the deployment of biofuels.[66] For the moment, they are not competitive with fossil fuels thus requiring governmental support. Without government intervention it is highly probable that the biofuel industry would not develop. For example in 2010, estimated production costs for petrol and diesel in Europe were 0.42 euro/liter respectively 0.45 while in the case of biofuels they were estimated at 0.58 for ethanol and 0.84 for biodiesel.

Taking into account their energetic balance the spread between fossils and biofuels is about 0.48 euro/liter.[67] One exception is Brazil, where ethanol can be competitive with fossil fuels without direct subsides. However the high sugar price on the international market, can affect its competitiveness. In this country ethanol is founded in gasoline in shares ranging from 20% to 25%. In 2011, 95% of new cars sold were flexible-fuel vehicles in which ethanol can be blended from 20%-100% allowing the consumer to choose the cheapest available option.[68] However Brazil is a

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[63] World Energy Council, *op.cit.*

[64] International Energy Agency, *Sustainable Production of SecondGeneration Biofuels. Potential and perspectives in major economies and developing countries*, OECD/IEA, Paris, 2010 [http://www.iea.org/publications/freepublications/publication/second_generation_biofuels.pdf], 20.10.2014

[65] Bailey, *op.cit*.

[66] International Energy Agency, *CO_2 Emissions from Fuel Combustion Highlights*, 2013, [http://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustionHighlights2013.pdf], 20.10.2014.

[67] Rauch, *op.cit*.

[68] International Energy Agency, *op.cit*.

special case, it has an important experience in this area being a traditional sugarcane producer for hundred of years. Its climate and tropical conditions offers a unique opportunity for producing cheap biofuels. These conditions can be hardly replicated in any other part of the world. Due to experience gains, Brazil succeeded in raising ethanol productivity from 4.6 liters/hectare in the seventies when it begun production to 7.6 currently.[69] For these reasons biofuels contribute significantly to the Brazilian transport energy mix, while in other parts in spite of governmental efforts biofuel their impact on the market is limited. For example in 2008, in Brazil 21% of the road fuel demand was met by biofuels whereas in USA and the EU it was 4%, respectively 3%.[70] In order for biofuels to become a viable alternative to oil, significant progresses are to be made in the area of indirect greenhouse gases emissions and production costs.

4. Conclusions

Currently our world energetic mix, in the field of transports is dominated by oil, with over 90% of the fuel supply. The main problem of supplying our transportation system is not represented by availability of the resource but by its geographic concentration of the great majority of resources. Over 70% of the global oil reserves are distributed in OPEC countries[71], aspect that raises problems regarding the energetic security of importing countries with high levels of oil demand and also price volatility. Looking back in the seventies regarding the distribution of oil consumption across sectors we can observe that oil tends to be a specialized resource in the transportation field. For example from 1973 to 2011 the sector share of oil consumption in industry has decreased from 19.90% to 8.90%, while in transportation has risen from 45.40% to 62.30%.[72] If we analyze the evolution of oil consumption in developed countries in the last two decades, we can observe in Figure 4, that starting with the middle of the last decade, oil consumption has decreased while in the same period the use of

[69] World Energy Council, *op.cit*.
[70] International Energy Agency, *Technology Roadmap Biofuels for Transport*, 2011, [http://www.iea.org/publications/freepublications/publication/biofuels_roadmap.pdf], 10 October 2014.
[71] British Petroleum, *op.cit*.
[72] International Energy Agency, *World Energy Outlook*, 2012, [http://www.iea.org/publications/freepublications/publication/WEO2012_free.pdf], 10 October 2014.

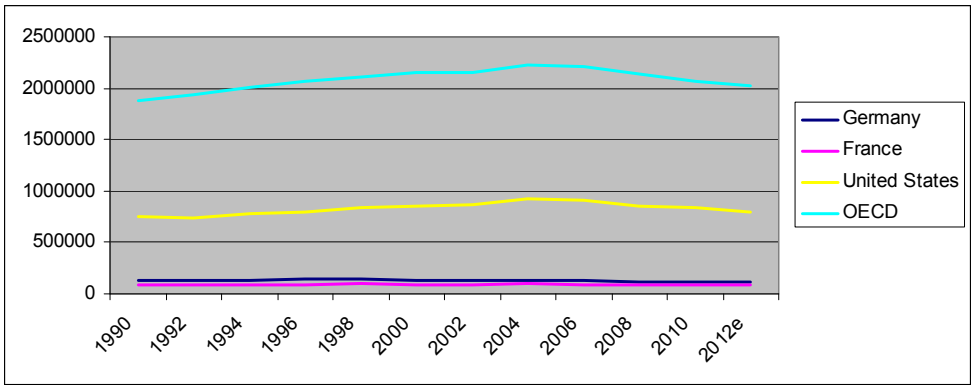

Figure 4: Oil gross consumption 1990-2012e, thousand metric tones.
Data for 2012 are estimated. Source: IEA, 2013.

biofuels in transportation has known an ascending trend. Thus in developed economies with energetic consumption in the transportation field, such as the US or Germany, oil is being replaced with biofuels through the use of governmental programs and measures such as blending mandates. Taking account also that over 80% of the global biofuel output in produced by three actors, from which one, Brazil is a traditional sugarcane producer with unique conditions that facilitate the use of biofuels, we can say biofuels represent a policy option for developed countries in search of an alternative to oil. However, in spite of the trends observed from 2004 onwards, at global level the impact of biofuels is quite limited. The main argument in favor of using biofuels, is the possibility of assuring ones country energetic security through the use of renewable resources, namely energetic crops, that can be locally harvested or imported from countries with an important agricultural output. Also states saw in biofuels, a possible market for farmers in order to diversify their revenues and stabilize the agricultural commodities prices, while in same time reducing the direct payments through agricultural programs. Greenhouse gases reductions from the transportation sector represented another reason in favor of using energy crops instead of oil. Therefore, biofuels use was sustained by governments for a variety of reasons. If we observe the history of biofuels use in automotive fuel industry back at the beginning of the 19th century we can see that their access was denied by

their lack of competitiveness in relation with fossil fuels. Also practical reasons such as the existence of fuel distribution networks played an important role in the emergence of oil use. Differences regarding competitiveness between the two types of fuels are present, due to higher productions costs which are passed to the consumers. The biofuel industry would not exist in the absence of governmental support. Biofuels substitute oil, through the use of oil and blending mandates because they need specially designed engines found in flexible-fuel vehicles which are not common on the market. Their energetic content is lower in relation their fossil counterparts, and also the engine performance that they supply is modified. One of their main attributes is the fact that they can supply vehicles through the modification of the current fuel supply distribution network, without the need of building a new one as in the case of electrical vehicles plug-ins. Taking into account their present limited share in the transportation energy mix, it is clear that for biofuels to achieve a significant role there will be the need of considerably growing the output of energy crops which will affect the food market due to the substitution of energy with food, and also the environment due to the need of agricultural land. Even if the second generation of biofuels becomes commercially available in the future there will still be a competition for the agricultural production factors such as labor and land which will affect the food market and prices. Energetic crops can represent an option for agricultural regions and developing countries but they can also affect poor countries where cereals have an important share in the household's expenses. Regarding their sustainability, indirect emissions must be also taken into account for a balanced overview of the biofuels efficiency in reducing GHG emissions. For these reasons, we conclude that biofuel do not represent for now an alternative to oil, but an effort of developed countries to diversify their transportation energetic mix. Biofuels use presents a number of drawbacks that can have potentially greater impacts once production is to be raised in significant shares to affect the transportation mix. Oil has emerged for practical and also economic reason in the transportation area, it does not have only a high energetic content but it also flexible to use, to supply and can be shipped over sea. If an alternative to oil is to be found it will also have to present a degree of practicability in use and supply. In this area electricity can be identified as the main

challenger. It can be produced far away from the point of supply and it has a reduced impact upon the environment especially if the resource used is not of fossil origin. Also it contributes to the energetic security of a country as it can be locally produced or traded. It does not require the extensive use of land, nor does it affect any other market such as the food market. Even more it links the transportation sector to the power sector which can have beneficial aspects due to the fact that it will reduce the importance of oil that becomes substitutable to electricity which can be obtained from varied number of resources and technologies. Similar to current status of biofuels, there will be the need for a significant technological leap as current electrical vehicles need improvements in the areas of engine performance, batteries costs and driving range. Also their current deployment is quite limited, in 2011 only 40.000 units were globally sold.[73] However for these arguments only we believe that they are a far adequate alternative to oil than biofuels. These considerations are also valid for hydrogen cells, a technology that also can help diversify the energy transportation mix. In conclusion, biofuels represent an alternative fuel to oil that raises issues regarding deployment, competitiveness and even sustainability while electricity can represent an alternative technology to the combustion engine with far better advantages.

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