OPEN ACCESS

The 3rd World Sustainability Forum
1-30 November 2013

http://www.sciforum.net/conference/wsf3

Article, Review, Communication (Type of Paper)

The future of biofuels for a sustainable mobility

Massimo Raboni[1,*], Vincenzo Torretta[1] and Giordano Urbini[1]

[1] University of Insubria, Department of Biotechnologies and Life Sciences, Via H.J. Dunant 3, Varese, I-21100, Italy

E-Mails: vincenzo.torretta@uninsubria.it (V.T); giordano.urbini@uninsubria.it (G.U.)

* Author to whom correspondence should be addressed; E-mail: massimo.raboni@uninsubria.it; Tel.: +39-0332-218787; Fax: +39-0332-218779

Received: 16 September 2013 / Accepted: 07 November 2013 / Published: 07 November 2013

Abstract: Biofuels production is strongly supported all over the world as a renewable energy source for reducing the dependence with respect to the unstable market of oil import. Bioethanol, the main biofuel produced in the world, is widely used for mobility in Brazil, and also in USA, but with little differences with respect to its sustainability. In Brazil it is produced from a by-product of the sugarcane industry; while, in USA it is manufactured from food crops. Biogas and biodiesel productions are growing fast but lesser than that of bioethanol. The European Union is looking at this issue with great interest and, in 2011, it adopted an extensive strategy to reduce carbon dioxide emissions related to transport by 60% within 2050. In order to achieve this result, a transformation of the current European transport system will be necessary. The ambitious goal will imply complex measures including the fossil fuels limitation in favor of renewable fuels. This program opens several possibilities concerning the development of biofuels (i.e. biogas, bioethanol and biodiesel) and their related technologies, which are still on trial (mainly regarding the bioethanol production) as well as object of economic and social sustainability analysis. The paper deals with the use of biofuels for transport in the European framework, showing that its sustainability could raise relevant negative social effects mainly due to the use of land for energy crops (e.g. change of food price and world food shortage).

Keywords: biofuel, European policies, sustainable mobility.

---

1. Introduction: The world policy toward biofuels

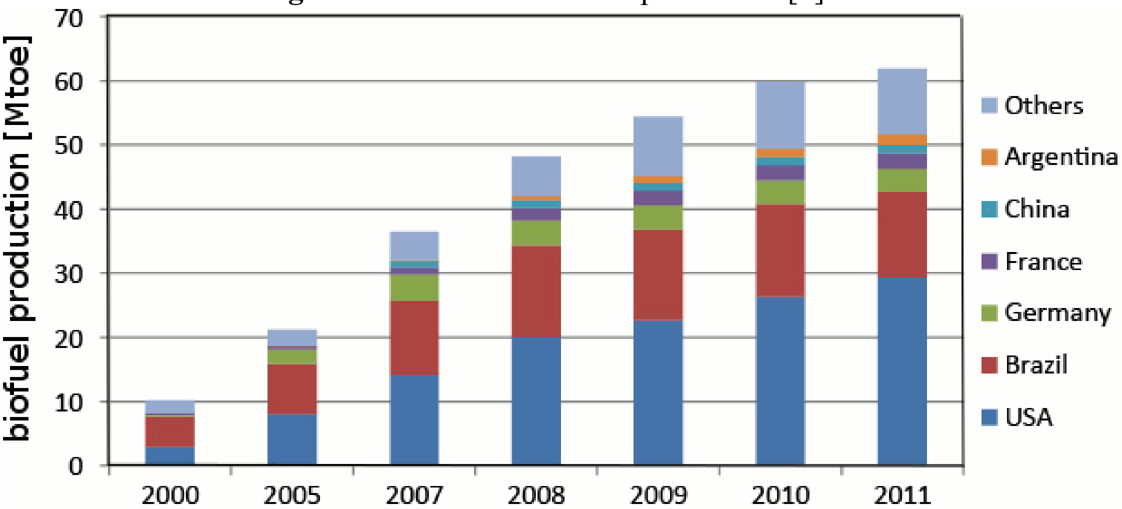
In general the term "biofuels" includes at least the following products derived from biomasses or sub-derived products: biogas, biodiesel, bioethanol, bio-methanol, bio-ethers (Bio-DME – DiMethylEhter; bio-ETBE – EthylTerButylEther; bio-MTBE - MethylTerButylEther), synthetic biofuels, bio-hydrogen and vegetable oils. Considering the level of production, the market interests are fundamentally focused on the first three ones.

Biofuels as renewable energy sources have several advantages:

- Significant benefits in reducing carbon dioxide (CO_2), micro- and macro-pollutants emissions [1,2];
- Biofuels can help countries to increase their energy security creating a more stable energy market;
- Interesting opportunities in developing a new economy associated with energy crop cultivation, industrial biofuels production and final use.

For these reasons many countries promoted programmes in favour of biofuels. The consequence has been a rapid biofuel production growth in the last 10 years (Figure 1).

Figure 1. Worldwide biofuel production [3].

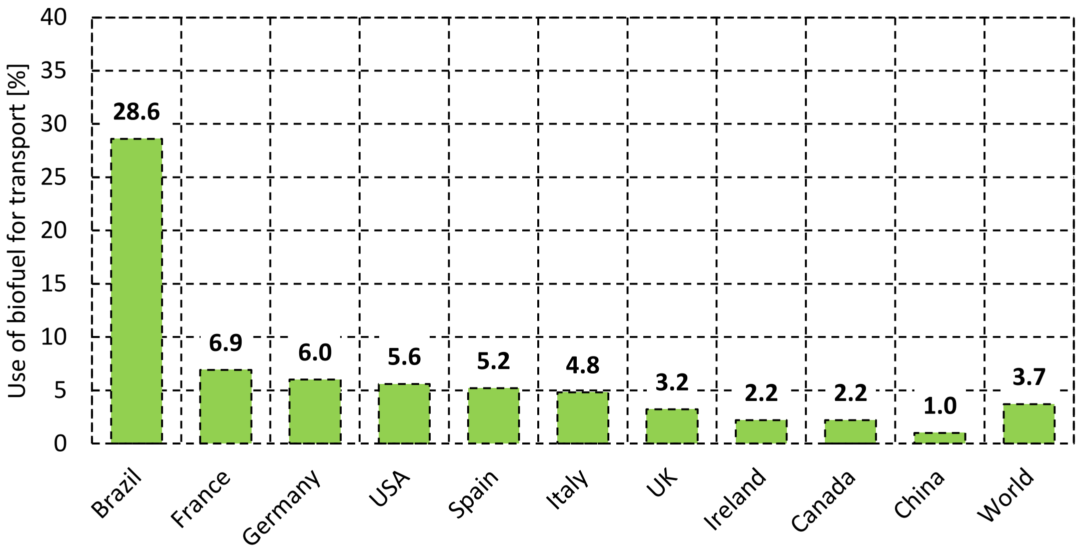


In the last few years the growth rate has been declining due to the global economic crisis which has appreciably reduced the energy demand. On this trend, also social sustainability reasons have assumed an important influence: they are related to the land use exploitation for energy crops instead of foodstuff production, with the unattractive perspective of reducing the food availability in the face of the continuous growing global demand.

The transport sector is the main biofuels consumer. In 2011, biofuels represented 3.7% of the total fuel used in road transport [3] as shown in Figure 2. This amount of biofuel is produced by an area close to $1.8 \bullet 10^3$ km², which is around 1.5% of whole cultivated land on earth.

Figure 2 gives particular evidence to Brazil, which stands out for its effective policy towards renewable energies. Since the early '70, Brazil has started a vast program for the ethanol production from sugarcane, primarily for motor vehicles. Today the ethanol and gasoline consumption are the same, and all the fuelling stations are equipped with alcohol pumps able to supply the so-called "flex" engines (engines fuelled with either gasoline, ethanol or mixtures of them) cars. In Brazil, the energy policy has also aimed at the biodiesel. Actually is under development a specific "Biodiesel program" based on vegetable oils derived from palm and castor seeds, *Jathropha curcas* as well as on the waste frying oil recovery which are widespread used especially in the regions of the North-East of the Country [4].

Figure 2. Percentage use of biofuel for transport [1].



Despite the data shown in Figure 2, since 2000 the European Union (EU) is making a great effort to promote the biofuels, issuing several programmatic actions, such as:

- The "Green Paper" [5], which introduced the target of replacing 20% of energy derived from fossil fuels with renewable energies by 2020;
- The Directive 2003/30/CE [6], which indicated the targets for biofuels use: 2% within 2005 and 5.75% within 2010;
- The package of proposals founding the common European energy policy, approved in 2007, which expected that by 2020 the biofuels will replace at least 10% of fossil fuels [7];
- The Directive 2009/28/CE [8] regarding the promotion of energy from renewable sources, which defines mandatory targets for the Member States in order to make more efficient the growth of the sector. The Directive aims at achieving 20% of renewable energy consumption in the whole European Union by 2020. Concerning the transport sector, the share of renewable energy sources should be, at least, the 10%.
- The "Transport 2050" plan [9], issued in 2011, aiming at creating an European common space able to improve the mobility of people and goods, as well as reducing 60% of CO_2 emissions in transport by 2050. In order to achieve this target, the plan foresees a deep transformation of the current European transportation system throughout a complex roadmap based on the followings main topics:
    - *urban transport*: halving the cars with traditional fuels (diesel and gasoline) in the cities by 2030 and excluding them by 2050;
    - *intercity travels*: the great part of passengers mid-range transport (over 300 km) will take place by railways by 2050. 30% and 50% of freight transport by road will switch to other modes of transport such as rail and inland waterways by 2030 and 2050, respectively;
    - *long range trips and intercontinental freight transport*: the use of low CO_2 emission fuels in aviation sector will reach 40% of the total fuel consumption within the 2050. By the same date, 40% of the maritime navigation CO_2 emission will be cut.

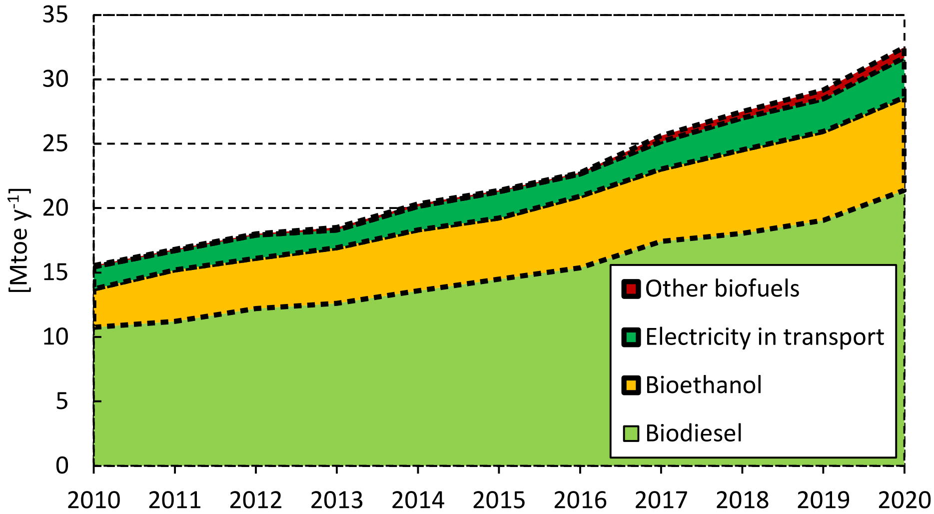
The EU strongly needs to reduce its oil dependence, which nowadays accounts more than $3 \cdot 10^5$ ktoe y^{-1} (kilotonne of oil per year). The attention is mainly addressed to the transport system, traditionally based on oil and responsible of more than 21% of overall greenhouse gases (GHGs) emissions, with an increasing trend higher than that of all the other economic sectors.

Actually, the attention is fundamentally focused on the biofuels which, as well-known, will grow to a minimum of 10% by 2020. Anyway, the EU estimated a real growth of 14%, which could lead to the substantial GHGs emissions reduction (101÷103 million t CO_2e y^{-1}).

The Directive on the biofuels [6] and on the promotion of electric energy produced from renewable sources [10] established different national targets in order to allow the EU to reach a share of renewable energy sources equal to 21% and 5.75% in produced energy and fuel for transport consumption, respectively. Both of the goals were not reached. Incidentally, the growth of renewable energy has settled to a value slightly lower than 12% [11].

By the examination of the Member States plans, in this decade the EU works out to double the production of renewable energies dedicated to transport, in order to achieve the target of 10% (Figure 3).

Figure 3. Development of renewable energies in transport, as foreseen by EU.



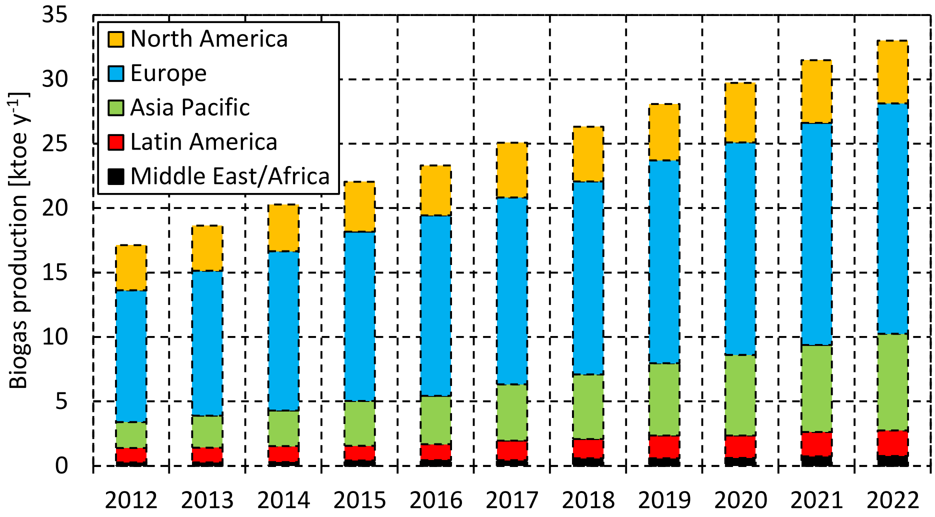
Biodiesel is the main biofuel source, followed by bioethanol, while other biofuels (e.g. bio-hydrogen) have and will have an almost null contribution.

To reach the 2020 targets both in terms of cost-effectiveness and environmental sustainability, the EU must invest in the field of advanced technologies related to renewable energies.

2. Biogas and biomethane production and their use in transport

The biogas production comes mainly from the Municipal Solid Waste (MSW) landfills, the sewage sludge anaerobic digestion, the MSW Organic Fraction (MSWOF) and the agro-zootechnical waste biogasification plants [12-15]. Figure 4 shows 2012 world biogas production and its trend till 2022.

Figure 4. Biogas production at 2012 and trend to 2022 in different area of the world.



Europe is the major producing continent (about 9 ktoe y^{-1}): 45% is supplied by Germany. United Kingdom (1.724 ktoe y^{-1}) is the second producer, followed by France (0.526 ktoe y^{-1}) and Italy (0.443 ktoe y^{-1}). Nevertheless, the biomethane contribution to European bio-fuels market is limited to 0.3%. These data include only the amount of biogas energetically exploited and exclude the flared biogas. Unlike Germany, in Italy, France and even more in UK, the biogas production is strongly bound to old landfills. Germany proves to be the only Country that has promoted, in the recent years, a confident and effective policy for the promotion of this renewable energy throughout the construction of numerous biogasification plants based on organic matrixes (including energetic crops). In Italy the number of the biogasification plants has shown a constant increase (318 units in 2011, 31 of them specific for agro-industrial waste, almost totally located in Northern Italy). It should be noted that this kind of biogas production in the EU amounts to just over 50% of the total, while in Italy it is still limited to 17.9% (2009 data).

In the EU the energetic conversion of biogas is almost entirely addressed to electricity production (about 26,000 GWh produced in 2010), while the use in vehicles is still very limited. In fact, only in few cases the produced biogas is converted in pure methane (bio-methane with a CH_4 content higher than 95%) and used as biofuel. The greatest use as bio-methane for transport is a concern of Central and Northern European countries (Switzerland and Sweden, in particular). In Sweden, all new biodigester fed by organic matrixes are equipped with systems able to upgrade the biogas into bio-methane in order to be injected in the natural gas network or used in vehicles. In this Country 4,000 light-duty vehicles as well as several fleets of vehicles for public transport fed by bio-methane or natural gas are currently circulating. In many Swedish cities the use of methane for transport is favored by different forms of incentives (e.g. free parking, detaxation of bio-methane purchase, toll exemption, dedicated lanes for bio-methane taxies, financial support for the purchase of bio-methane fed vehicles) which created an excellent level of acceptance for such a biofuel [15].

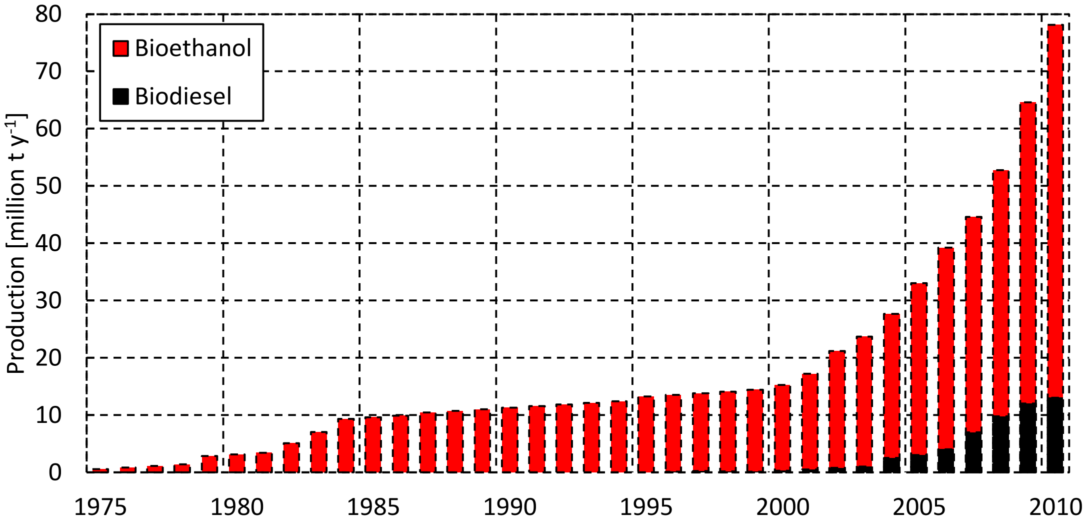
In the EU such kind of solutions are still rather isolated; even in Italy, the majority of the biogas is converted into electricity in cogeneration plants, by virtue of relevant incentives allowed by the Italian Financial Act 2008, known as “Green certificates” [16].

According to EU plans, the biogas production target at 2020 will raise to 15 ktoe y^{-1}, with a corresponding electricity production of 56,400 GWh y^{-1}.

3. Liquid biofuels (biodiesel and bioethanol)

Due to the marginal role of biomethane, it is possible to assert that world biofuels market is currently dominated by biodiesel and, above all, bioethanol. Figure 5 shows that biodiesel and bioethanol overall estimated production is about 80 million t y^{-1} and its growth is notable.

Figure 5. Biodiesel and bioethanol world production trend [17].



The world bioethanol production (about 65 million t y^{-1} in 2010) is mainly concentrated in North and South America: Brazil and USA hold about 90% of the overall production, while the European share is around 4÷5%.

In 2010, the world biodiesel production was estimated in approximately 15 million t y^{-1}: 60% is held by the EU, which has always played a dominant role in this specific field. The USA follows with a share of 17.7%, while the remaining quote is distributed in several emerging countries (Brazil and Argentina, particularly).

The reasons why Europe has favored, in the past, the biodiesel production are both historical and economic. The most used fuel in the EU is diesel. Moreover, EU is also a net importer of mineral diesel and a gasoline exporter. Therefore the priority for the EU policy was the search for a valid substitute to mineral diesel. From the economic point of view, the European bioethanol production relies on uncompetitive or unsuitable crops respect to the Brazilian one, based on the sugarcane which has an energetic productivity from four to seven times higher than wheat, maize and sugar beet. Moreover, bioethanol Brazilian production has great advantages in terms of sustainability because it is based mainly on molasses, by-products of sugarcane industry.

Bioethanol offers a great support to the Brazilian program for energetic sustainability, together with hydro-electricity. The Brazilian industries involved in bioethanol production and use account a thirty-year experience and have accompanied the fast growth of this country. It is necessary to consider that a Federal Decree imposes to sell gasoline only if mixed with 25% of bioethanol (E25). The growing success of “flex” vehicles (8,200,000 in 2009) allowed bioethanol consumption to overtake, in 2008, gasoline consumption, while only in 2006 the market share was 18%.

About biodiesel, in 2009 the European production was estimated in 9,406 million t y^{-1}, as reported in Table 1.

Table 1. Biodiesel and bioethanol European production in 2012 (million t y^{-1}) [18].

Country	Biodiesel	Bioethanol
Germany	2,539	600
France	1,959	1,000
Spain	859	349
Italy	737	57
Others	2,952	933
Total	9,046	2,939

The major biodiesel-producing countries are Germany (28.1%), France (21.7%) and Spain (9.5%).

The bioethanol production in the European Union is estimated in about 3 million t y^{-1} [18], with a remarkable contribution from France (34.0%), Germany (20.4%) and Spain (11.9%). The quote of imported bioethanol is less than 1 million t y^{-1}.

In 2009, the EU biofuels consumption reached 12.1 million toe y^{-1}, including the modest contribution offered by biogas and straight vegetable oils (1.2% of biofuels overall consumption). This value represents 4% of the total energy consumption in the EU. Therefore, the 5.75% target for the 2010, defined by the Directive 2003/30/CE [6], still remains far to be achieved.

Both biodiesel and bioethanol produced in the EU are almost completely used in blends with oil-derived fuels (gasoline and diesel); their development perspectives are sensitively bound with the increase of mixing quotes allowed in the different Member States. In Germany the overall incorporation rate (biodiesel and bioethanol) is 6.25% since 2009. In Italy was 3% (2009), still far from the 2010 target (5.75%). Both France and Spain are doing a lot better than Italy: 7% in 2010.

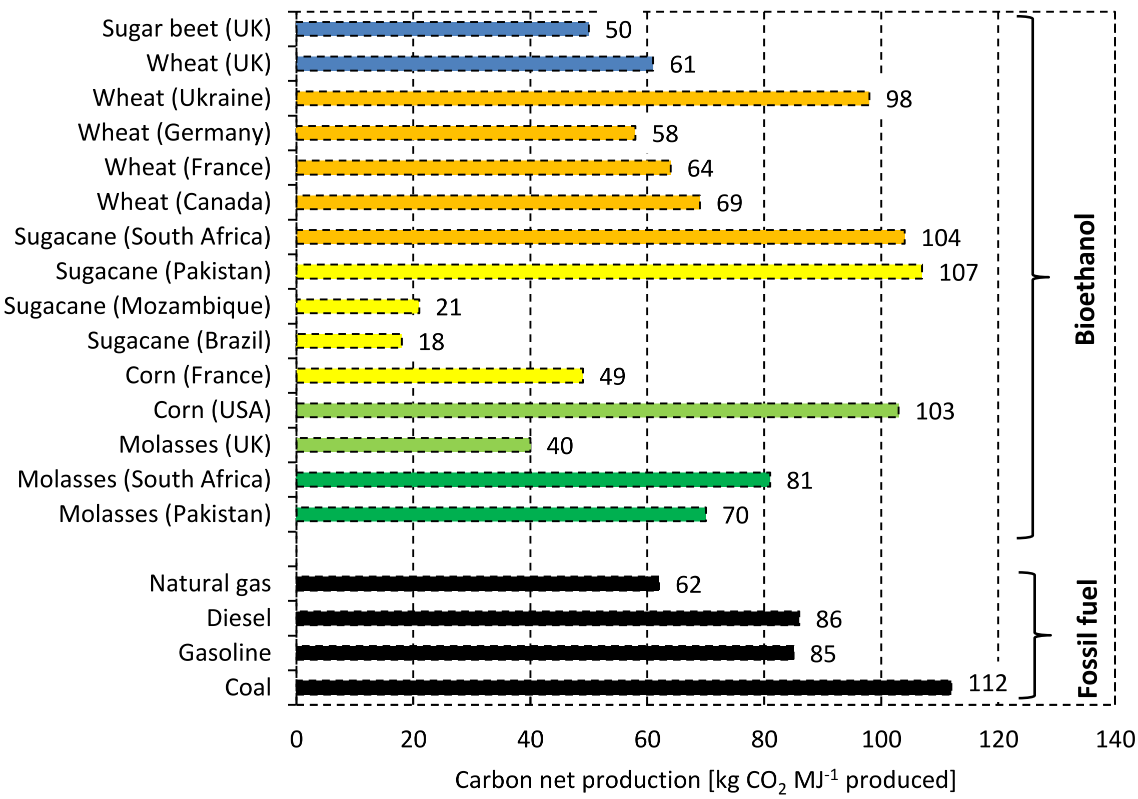
The European Commission, looking at 2020 target, believes that the real target for biofuels growth should be placed around 14%. It means that the biofuels production should increase, in 2020, from the current 12.5 million t y^{-1} up to 43.1 million t y^{-1} (27 million t y^{-1} composed of biodiesel).

In any case, this growth should be achieved respecting the principle of sustainability. The focal point now regards the social sustainability of biofuels production, which is strictly bound to the competition on the use of vegetable oils and cereals for energy or, alternatively, food production. Such competition could have relevant consequences both on the cultivable areas exploitation and the food price. The EU, very sensitive to these issues, acknowledges of having no enough arable areas for 2020 biofuel production goal. Among the possible scenarios considered by the EU [19], the most realistic one in terms of sustainability considers the importation of 50% of the whole needs. The remaining part will be produced in the EU on the 7.6% of the arable areas. It should be noted that internal production will include also bioethanol derived by “Second Generation Processes” involving lignocellulosic matrixes (7.5 million t y^{-1}). Pilot plants implementing such technologies are already working with a mixture of MSWOF and organic waste from orange industry (Valencia, Spain), straw (Salamanca, Spain), straw and reed ditch (Alessandria, Italy). Even in the USA there are currently about ten running or under construction plants operating on various agricultural, forestry and municipal solid waste. Several other experiments are reported in Japan, Canada and other countries.

4. Biofuels environmental sustainability

The biofuel environmental sustainability can be examined considering several aspects. One of the most significant is the net carbon emission, assessed by the means of the Life Cycle Analysis (LCA) technique. Biofuels aim to be carbon neutral, that is to say the carbon released during the fuel use (e.g. combustion in power transport or electricity generation) is absorbed and balanced by the new plants growth. Carbon neutral fuels lead to no increase of atmospheric CO_2 levels, reducing the human contributions to global warming. Actually, every biofuel has a net carbon emission considering the contribution of both the production (e.g. feedstock production; process technology) and the combustion processes. Figure 6 shows the so-called biofuels *carbon intensity* (expressed as kg CO_2 emitted MJ^{-1} produced) resulting from different feedstock and technology, compared with fossil fuels [20,21].

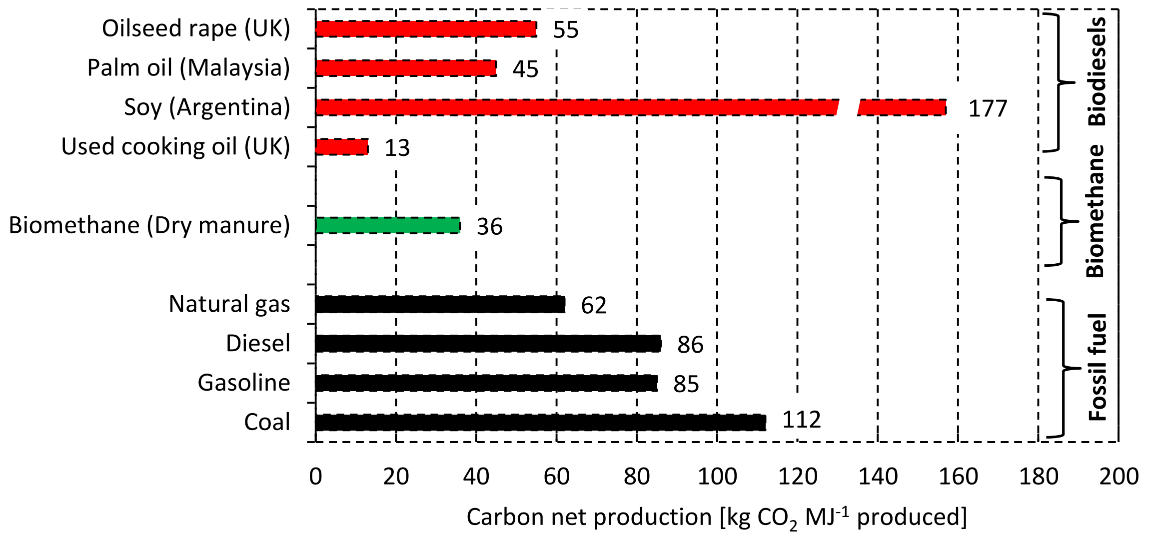
Figure 6. Net carbon emissions for bioethanol resulting from different feedstock and technology, compared with fossil fuels [20,21].



Brazilian and Mozambican sugarcane proves to be the most attractive source for the bioethanol production. On the contrary, it can be noticed that many others productions (e.g. USA corn; South Africa and Pakistan sugarcane; Ukraine wheat) do not allow substantial advantages respect to gasoline derived from mineral oil.

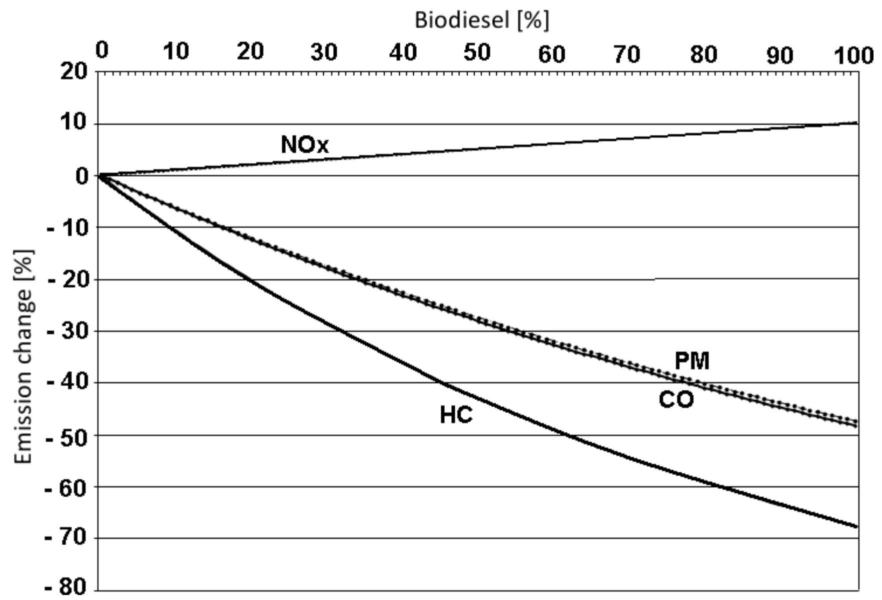
Figure 7 shows similar results relative to different biodiesel and biomethane productions [20,21]. Of particular interest is the biodiesel from used vegetable oils, as well as the biomethane from manure anaerobic digestion. Contrariwise, the biodiesel from soy reveals a carbon emission greater than all fossil fuels.

Figure 7. Net carbon emissions for biomethane and biodiesels resulting from different feedstock, compared with fossil fuels [20,21].



Another aspect of particular interest is represented by the pollutants emissions derived from combustion in motor vehicles. With regard to biodiesel, the emissions are proved to be lower than for mineral diesel [22]. These findings are shown in Figure 8, which shows the truck fleets emissions trend in relation to rising biodiesel-diesel blends [23].

Figure 8. Macro-pollutants average emissions changes from the exhaust pipe of trucks fueled by rising rates of biodiesel [23].



The graph clearly highlights the followings:

- The complex of macro-pollutants emissions is reduced progressively moving from mineral diesel toward blends with biodiesel, up to pure biodiesel (B100). The PM-CO and hydrocarbons (HC) reductions reach average values of about 50% and 70%, respectively;
- A slight NOx increase occurs, up to values of about 10% for B100.

No substantial variations have been highlighted in relation to the engine age or type.

The PM, HC and CO reduction is certainly correlated to the better combustion of the methyl-ester compared to traditional diesel due to both the presence of oxygen in the molecule and the high Cetane Number (CN). The NOx increase (5-20% depending on the authors) does not find a univocal justification by scientists: someone tends to correlate the phenomena with (i) the oxygen presence in the molecule and (ii) the combustion conditions (e.g.: pressure, temperature, low injection delay). Other hypotheses are the greater viscosity of biodiesel respect to mineral diesel and, in general, its specific composition.

In terms of macro-pollutants emission, biodiesel benefits the SOx reduction due to the almost absence of sulfur, while more or less significant concentrations of this compound characterize the mineral diesel. An USEPA study concerning a total of 11 organic compounds (e.g. Acetaldehyde, Acrolein, Benzene, 1,3-Butadiene, Ethylbenzene, Formaldehyde, n-Hexane, Naphthalene, Styrene, Toluene, Xylene) confirms that pure biodiesel reduces macro-pollutants emission of about 16% [23].

For what concerns bioethanol and gasoline, most of the experiments were carried out with ethanol/gasoline mixtures and the results are often contradictory. However, the most significant data show a NOx, CO and HC reduction increasing the ethanol quota. In an experience in which 85% bioethanol (E85) was compared with pure gasoline, the emissions reduction amounted to 6%, 27% and 49% for NOx, CO and HC, respectively [24].

An advantage stated for the bioethanol is that the unburned emissions contribute significantly less to the formation of ozone, compared to organic compounds present in the exhausted emissions of the gasoline. In addition, the very low, if not zero, sulfur content of bioethanol approximates to zero the sulfur dioxide (SO_2) emissions and improves the efficiency of catalytic emission control [21]. However, while some of the most toxic pollutants (e.g. benzene, 1,3-butadiene, toluene, xylene) decrease using bioethanol, others (e.g. formaldehyde, acetaldehyde, peroxyacetyl nitrate) increase. Just for this aspect there is a strong need for a deep human health and risk exposure assessment [21,22].

5. Biofuels energy sustainability

Biofuels production from raw materials requires energy for farming, transport and conversion processes. The biofuel energy balance is determined by the ratio between the energy amount released when fuel is burned into an engine and the energy amount spent in the production cycle (produced:consumed energy ratio). Such balance varies greatly by the used feedstock.

Biodiesel made from rapeseed and soybeans oils has a positive energy balance (2.1-2.55 produced:consumed energy ratio) [21,25] respect to gasoline and diesel made from petroleum (0.805 and 0.843, respectively) [26].

Table 2 shows the energy balance of bioethanol resulting from different feedstock [27]. An excellent balance belongs to the Brazilian production from sugarcane. This value is significantly higher than that of any other production.

Table 2. Bioethanol energy balance resulting from different feedstock [27].

Feedstock	Energy generation/Energy consumption
Wheat	1.2
Corn	1.2-1.8
Sugar beet	1.9
Sugarcane (Brazil)	8.3

Finally, the biogas energy balance results in the range 2.5-4.0 for the anaerobic treatment of manure, while it is less beneficial in the treatment of standalone or organic-matrixes mixed MSWOF (0.4-0.5) [28,29].

6. Conclusions

In the future the biofuel production and use in transport will be much diversified in the different regions of the world. Countries which made important progress in the field of bioethanol (e.g. Brazil) have relevant margins for further growth because they have vast uncultivated areas and enjoy favourable climatic conditions for energy crops. Similar developments could affect other regions, including parts of Eastern Asia as well as Central and Southern Africa. On the contrary, Europe does not enjoy the same favorable conditions. Nevertheless, the EU demonstrated a high sensibility to environment and health protection issuing the “Transport 2050“ plan. It aims at very ambitious targets in terms of sustainable mobility, to be achieved by the year 2050, with a mid-term at 2030. Consequently, the biofuels (biodiesel, bioethanol and its derivatives, in particular) will cover a significant role in the energetic policy. Biomethane role will continue to be very marginal, except in few local realities.

The biodiesel and the bioethanol estimated growth should face, anyway, two fundamental issues:

- the EU limited attitude to produce bioethanol;
- The environmental and, moreover, social sustainability due to the land use, part of that potentially subtracted to food production.

In order to overtake these obstacles it will be necessary to import relevant amount of bioethanol and vegetable oils suitable for biodiesel production. In addition, the EU plans to produce bioethanol from lignocellulosic residues. Some experimental initiatives are currently running. Only the results of these experiences will confirm the effectiveness and the economic convenience of such processes.

In order to achieve the biofuels growth targets, it is expected that a concrete political support will be necessary, through the adoption of incentives such as tax exemption, increase of blending quote with fossil fuels, benefits for production and purchase of dedicated/hybrid vehicles, facilitation in road circulation and parking. Therefore, in the next future biofuels could play a significant role in transport and could effectively contribute, together with electric vehicles already growing in medium-big cities, to achieve the EU “Transport 2050” plan targets, looking forward to the promising developments of hydrogen cars.

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Torretta, V.; Rada, E.C.; Panaitescu, V.N.; Apostol, T. Some consideration on particulate generated by traffic. *UPB Sci. Bull. Series D*, **2012**, 74(4), 241-248.
2. Ionescu, G.; Apostol, T.; Rada, E.C.; Ragazzi, M.; Torretta, V. Critical analysis of strategies for PM reduction in urban areas, *UPB Sci. Bull. Series D*, **2013**, 75(2), 175-186.
3. ENERDATA. Sluggish growth of World energy demand in 2011. **2012**.
4. Torres, E.A.; Cerqueira, G.S.; Ferrer, T.M., Quintella, C.M.; Raboni, M.; Torretta, V.; Urbini, G. Recovery of different waste vegetable oils for biodiesel production: A pilot experience in Bahia State, Brazil. *Waste Management* **2013**, 33(12), 2670-2674. DOI:10.1016/j.wasman.2013.07.030.
5. European Commission. A European strategy for sustainable, competitive and secure energy. Green paper of the European Commission. Brussels, Belgium, **2000**.
6. European Parliament. Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. Brussels, Belgium, **2003**.
7. European Commission. An energy policy for Europe. Brussels, Belgium, **2007**.
8. European Parliament. Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Brussels, Belgium, **2009**.
9. European Commission. White Paper 2011 - Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system. Brussels, Belgium, **2011**.
10. European Parliament. Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market. Brussels, Belgium, **2001**.
11. European Commission. Recent Progress In Developing Renewable Energy Sources And Technical Evaluation Of The Use Of Biofuels And Other Renewable Fuels In Transport In Accordance With Article 3 Of Directive 2001/77/EC And Article 4(2) Of Directive 2003/30/EC. Commission Staff Working Document, Brussels, Belgium, **2011**.
12. Jonsson, O.; Person, M.. Biogas as transportation fuel. *Proc. of Fachtagung Regenerative Kraftstoffe*, 13-14 November **2003**, Stuttgard, Germany. 37-43.
13. Rada, E.C.; Ragazzi, M.; Torretta, V. Laboratory-scale anaerobic sequencing batch reactor for treatment of stillage from fruit distillation. *Water Science & Technology*, **2013**, 67(5), 1068-1074.
14. Callegari, A.; Torretta, V.; Capodaglio, A.G. Preliminary trial application of biological desulfonation in anaerobic digestors from pig farms. *Environmental Engineering and Management Journal*, **2013**, 12(4), 815-819.
15. Martinez, S.; Torretta, V.; Minguela, J.; Siñeriz, F.; Raboni, M.; Copelli, S.; Rada, E.C.; Ragazzi, M. Treatment of slaughterhouse wastewaters using anaerobic filters, *Environmental Technology*. (in press). doi: 10.1080/09593330.2013.827729.
16. GSE. Green Certificates (GCs). Available online at: http://www.gse.it/en/qualificationandcertificates/GreenCertificates/Pages/default.aspx Last access: 12th October 2013.

17. Morosini, C.; Stella, S.; Urbini, G. Biofuels for the sustainable mobility: current and future role in Italy and in the EU. Proc. of the 9th Int. Symposium of Sanitary and Environmental Engineering SIDISA, 26-29 June **2012**, Milan, Italy.
18. EUROBSERV'ER. Biofuels barometer, *Le Journal des ènergies renouvelables* **2013**, 216, 48-63.
19. Commission of the European Communities. Biofuels progress report - Report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union. Brussels, Belgium, **2007**.
20. UK Department for Transport. *Renewable Transport Fuels Obligation (RTFO) guidance*; UK Government, London, 2013. Available online at: https://www.gov.uk/government/publications/rtfo-guidance. Last access: 1st November 2013.
21. UK Department for Transport. *Carbon and Sustainability - Reporting Within the Renewable Transport Fuel Obligation - Requirements and Guidance*; UK Government, 2008.
22. G. Urbini, S Stella. Development perspectives for biodiesel: new EU strategies, technological trends, environmental effects (in Italian). *Ingegneria Ambientale*, **2007**, 10/11.
23. US EPA. *A Comprehensive analysis of Biodiesel impacts on exhaust emissions. Report EPA420-P-02-001*. 2002.
24. Avella F. *Bioethanol as fuel for transport – Behaviour in engines and influence on pollutant emissions* (in Italian). Technical report 200904183. Combustibles Experimental Station. Milan, Italy, 2009.
25. Pradhan, A.; Shrestha, S.D.; Van Gerpen, J.; Duffield, J. The energy balance of soybean oil biodiesel production: a review of past studies. *Trans. of the ASABE*, **2008**, 51(1), 185-194.
26. Shapouri, H.; Duffield, J.A.; Wang, M. *The Energy Balance of Corn Ethanol: an update*. Report 813. US Dept. of Agriculture, USA, 2002.
27. Andrade Torres, E.; Quintella, C.M. *Bioalcohol for sustainable development: the Brazilian experience*. Proc. of the Int. Conf. on cooperation with developing countries: Proper solutions for environment, Energy and sustainable development. Varese, Italy, October 2007.
28. Urbini G.; Torretta V. *Anaerobic digestion and biogas recovery from MSWOF and other organic matrixes (in Italian)*. PRIN-2006 final report, November 2008.
29. Urbini G.; Torretta V. Anaerobic digestion: state-of-the-art of Italian and European plants (in Italian), *Rifiuti Solidi*, 2008, 6, 393-399.