A Comparison Between Ethanol and Biodiesel Production: The Brazilian and European Experiences

Pery Francisco Assis Shikida, Adele Finco, Bárbara Françoise Cardoso, Valdir Antonio Galante, Daliane Rahmeier, Deborah Bentivoglio and Michele Rasetti

Abstract Industrialized countries' dependence on fossil fuels has been distressing for a long time for countries that do not have self-sufficiency, whether for environmental, economic, geopolitical, or other reasons. In this context, it is understood that the burning of fossil fuels contributes to greenhouse gas emissions (GHG) increasing the risk of intensifying climatic disturbances that can deteriorate the processes of production, consumption, and welfare in the world. Therefore, the development of alternative energy sources can provide solutions for the gaps, since reducing exposure to the vulnerability of supply and price volatility, environmental issues, and even the development of new investment opportunities in these countries. This is due to the possibility of developing innovations in the production and processing industry, which would contribute to the economic activity. Thus, increasing the use of bioenergy is one of the existing ways to reconcile the need to

P. F. A. Shikida (✉) · B. F. Cardoso · V. A. Galante · D. Rahmeier
Universidade Estadual do Oeste do Paraná, Toledo, Brazil
e-mail: peryshikida@hotmail.com

B. F. Cardoso
e-mail: barbarafcardoso@gmail.com

V. A. Galante
e-mail: vgalante@hotmail.com

D. Rahmeier
e-mail: daliane.rahmeier@gmail.com

A. Finco · D. Bentivoglio · M. Rasetti
Università Politecnica delle Marche, Ancona, Italy
e-mail: a.finco@univpm.it

D. Bentivoglio
e-mail: d.bentivoglio@univpm.it

M. Rasetti
e-mail: m.rasetti@univpm.it

A. Domingos Padula et al. (eds.), *Liquid Biofuels: Emergence, Development and Prospects*, Lecture Notes in Energy 27, DOI: 10.1007/978-1-4471-6482-1_2,

expand the supply of energy with the slowdown in global warming, i.e., the most important and disseminated use would be the biomass power generated by the consumption of biofuels, once it reduces GGE emissions.

1 Introduction

Global ethanol and biodiesel production are projected to expand at a slower pace than in the past. Ethanol markets are dominated by the USA, Brazil, and, to a smaller extent, the European Union. Biodiesel markets will likely remain dominated by the European Union and followed by the USA, Argentina, and Brazil.

The world biofuels production reached almost 124 billion liters in 2011; 80 % of that global production of liquid biofuels consists of ethanol and 20 % consists of biodiesel. The European Union produced in 2011 about 9.5 million metric tons of biodiesel, but in 2011, the production decreased about 10 % compared to 2010. However, the share of biodiesel is rapidly increasing due to emergence of new producing countries in Southeast Asia. The USA and Brazil are the largest ethanol producers, with 54 and 34 % of global ethanol output in 2009, respectively; while the European Union accounts for 57 % of global biodiesel production.

Brazil is the world's second biggest producer of fuel ethanol (about 23 billion liters in 2011) and the world's biggest exporter of fuel ethanol. The production started in the early 1970s by a program which led to the development caused by local automobile companies with flex-fuel engine technology. Presently, around half of all Brazilian cars use these hybrid engines, which can run with any mixture of pure ethanol and gasohol (around 80 % gasoline and 20 % ethanol). In 2010, cars used nearly equal volumes of gasoline and ethanol.

The chapter aims at revisiting the recent developments in biofuels markets and their economic and environmental impacts. The analysis compares the performance of ethanol versus biodiesel produced in Brazil and Europe, respectively.

This chapter is organized as it follows: Sects. 2 and 3 discuss the scenario of Brazilian ethanol and European biodiesel in terms of policies, production, supply, and demand. Section 4 examines the environmental impacts of both biofuels. Finally, we draw key conclusion.

2 Brazilian Ethanol Policies, Production, Supply, and Demand

2.1 Ethanol Policy Scenario

With the growing concern around climate and environment, the viable alternatives to replace fossil fuels with biofuels provided Brazil the possibility of an array of interests among the agents involved in the ethanol production chain. This arrangement allowed the creation of the National Alcohol Program (PROALCOOL) in

1975, in which the main objective was to leverage the Brazilian ethanol production through incentives and subsidies. It is pointed out that, even after the discontinuation of the Program in the early 1990s, it has continued acting in institutional arrangements formed with its creation allowing expansion of ethanol production (Shikida and Perosa 2012).

The Brazilian government started subsidizing ethanol production with the beginning of PROALCOOL, and even at the end of this program, the subsidies are indirectly maintained by the Federal Law 8723/1993, which enforce the 20–25 % proportion of ethanol in gasoline. However, there are no subsides of gasoline in the strict sense. There are cross-subsidies between petroleum derivatives such as variation in the tax burden of the ethanol and control of prices of petroleum products (because this prices affect transportation) due to anti-inflationary policy. Indirectly, the variation in the percentage of ethanol in gasoline can also encourage or discourage the gasoline consumption. The international sugar and oil prices also affect ethanol consumption. According to the Sugarcane Industry Union (UNICA) (2011: 11), 'gasoline pricing remains artificial, with cross-subsidies between petroleum derivatives. In addition to causing problems to the industrial sector, this also distorts the market where hydrous ethanol competes directly with gasoline.'

In the last decade, the alcohol sector began a new phase of expansion with the permission of the European Union to import Brazilian sugar. However, the increase in exportation of sugar caused an increase in ethanol's price and a decrease in its consumption, since both use the same raw material. Another fact is the appearance of flex-fuel cars in Brazil, which allows the use of any combination of ethanol and gasoline on the same engine.

In recent years, the decrease in sugar prices in the international market has reduced the stimulus for expansion of this sector. The price control policy adopted by the Brazilian government, which is stimulated by the lobbying of the alcohol sector, has raised the interference in the ethanol market. In addition to offering low interest loans to sugarcane production, the percentage of ethanol in the gasoline was increased and it promoted greater tax relief in the sector.

2.2 Ethanol Production, Supply, and Demand

Brazil stands as the second largest producer of ethanol obtained from sugarcane in the international market, having similar energy potential and much lower cost vis-a-vis ethanol from corn of countries such as the USA, and regions such as the European Union (EU), from beet and starch. Table 1 presents the global ethanol production between 2007 and 2012.

In Table 1, it is observed that the USA, Brazil, and Europe account for over 90 % of global ethanol production. The first two countries had similar production scale at the beginning of the period mentioned, occurring an expressive shift in favor of the USA during the period. In turn, EU has doubled its production without, however, reducing the difference to the first two significantly.

Table 1 Worldwide ethanol production: 2007–2012 (billions of gallons[a])

Worldwide ethanol production	2007	2008	2009	2010	2011	2012
USA	6.49	9.23	10.94	13.00	13.90	13.30
Brazil	5.02	6.47	6.58	6.92	5.57	5.58
Europe	0.57	0.73	1.04	1.21	1.17	1.18
China	0.49	0.50	0.54	0.54	0.55	0.56
Canada	0.21	0.24	0.29	0.36	0.46	0.45
Asia (except China)	0.13	0.16	0.53	0.24	0.33	0.40
Other countries	0.15	0.21	0.39	0.74	0.37	0.33

Source USDE (2013)

[a]1 gallon (EUA) is equal to 3.785 l

Brazil is pointed out as a tropical country with continental dimensions, in which the supply of biomass has great potential for use in power generation by Castro and Dantas (2008). In 2007, biomass was the second source of energy used in Brazil, with 31.1 % of the energy matrix, preceded by oil and its derivatives. Considering the national supply, biomass, along with other sources of internal origin, accounted for 3.7 % of the offer, according to the National Energy Balance (NEB) (ANEEL 2008).

According to Tolmasquim (2012), a great part of the Brazilian territory is within the most thriving region of the planet for the production of biomass, not only due to the high degree of sunlight on its territory, but also for its environmental conditions. In bioenergy, sugarcane stands out owing to technological advances, both in the agricultural and industrial phases, making ethanol and bioelectricity competitive products internally and externally.

The technological advance was not only due to the energy offer. The flex-fuel vehicle, whose engines work on any proportion of ethanol or gasoline, has already been consolidated in the market. Such was the acceptance of the Brazilian consumer that only 9 months after its release in 2003, the fleet of flex-fuel vehicles accounted for 57 % of the national fleet of light vehicles, i.e., about 18 million units (UNICA 2013b).

According to the Center for Sugarcane Technology (CTC) (2005), the biomass of sugarcane may become more important in energetic, economic, and environmental terms, with the increasing search for improvements in the production systems of the sugarcane industry.

According to Dias et al. (2009), this highlight is due to the relevance of ethanol production, its by-products, bagasse (cogeneration of electricity), and straw, as well as most of the biomass residues obtained in the agricultural and industrial activities, which become raw material capable of producing energy.

Among the sources of biomass for electricity generation in the country, sugarcane is an alternative with great potential through the use of bagasse and straw. The participation of the cane is not only important for the diversification of the electric matrix, but also because the harvest coincides with the dry season in the Southeast and Midwest regions, where the greatest capacity of hydropower in Brazil is concentrated (ANEEL 2008).

Table 2 presents the main secondary sources, being expressively featured the electricity, produced mainly from hydropower and biomass, which have the sustainable characteristics due to the low GHG generation.

Table 2 Secondary sources of biomass in Brazil in 2011 (production and total consumption)

Type of energy (10^3 eot[a])		Production	Total consumption
		177.919	185.370
Electricity	(GW/h)	531.758	480.120
Total ethyl-ethanol	(10^3 m^3)	22.916	21.729
Hydrated ethanol	(10^3 m^3)	13.866	13.103
Anhydrous ethanol	(10^3 m^3)	9.050	8.626
Charcoal	(10^3 t)	7.933	7.725
Biodiesel	(10^3 m^3)	2.673	2.547
Tar	(10^3 t)	289	289

Source MME (2012)
[a]Equivalent oil ton

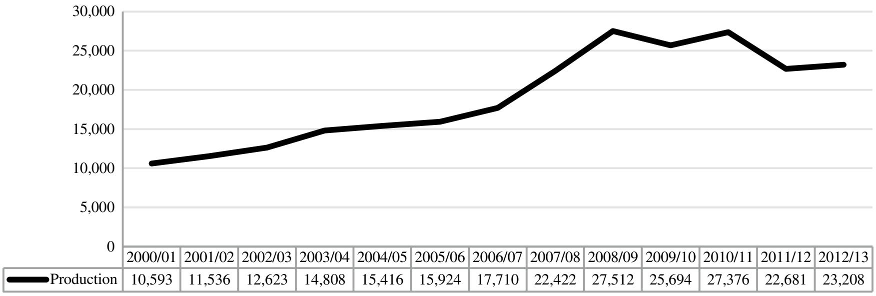


Fig. 1 Trend dynamics of ethanol production in Brazil: 2000–2012 (million m^3). *Source* Adapted of UNICA (2013b)

2.2.1 The Sugarcane Biomass

Both in Brazil and in the international market, biomass has been considered one of the main alternatives for diversification of energy sources and reduction of the use of fossil fuels (ANEEL 2008).

According to UNICA (2013a), there are 64.7 millions of hectares fit to sugarcane plantation, i.e., 7.5 % of Brazilian cultivable area. However, sugarcane plantation occupied only 1 % of cultivable area in 2012. The sugarcane productivity in 2011/2012 harvest was 58.25 ton/ha for an area of 9.6 millions of hectares. The sugarcane production for milling was of 559.2 millions of tons, of which 297 millions of tons of sugarcane were earmarked for the production of ethanol and the rest were earmarked for the production of sugar. It was produced a total of 22.7 millions of m^3 of ethanol (8.6 million m^3 of anhydrous ethanol and 14.1 million m^3 of hydrated ethanol), i.e., about 6.8 m^3/ha (UNICA 2013b) (Fig. 1).

In Brazil, there are 327 mills and distilleries allowed to operate for sugar and ethanol production, in which average capacity is about 810 m^3/day. These mills are distributed in most Brazilian states, but their concentration is in Middle-South region. The total quantity of workers in these mills and distilleries was 160,984 in 2011 (Portal da Cana 2013; RAIS 2012). According to Shikida (2013), '1 ton of sugarcane produces, simultaneously, 120–135 kg of sugar and 20–23 l of ethanol, or if only produce ethanol, the amount is 80–86 l of ethanol' (oral information).

Fig. 2 Areas suitable for the cultivation of sugarcane in Brazil. *Source* EMBRAPA (2009)

The Brazilian areas suitable for the cultivation of sugarcane are concentrated in the Central-South region of Brazil (Fig. 2).

The sugarcane production is not adequate to the biome of the Brazilian Amazon or Pantanal, not only because they are protected areas by environmental legislation, but also because they do not have edaphoclimatic conditions for sugarcane cultivation. It is noted that most of the sugarcane units, i.e., mills and distilleries are located in the Central-South and the northeastern coast of the country.

Veiga Filho (2008:3) reinforces this statement saying:

> Rodrigues, [coordinator of the Agribusiness Center of Getulio Vargas Foundation] and Marcos Jank, [former] president of UNICA [Sugarcane Industry Union], say that 75 % of the sugar cane expansion occurs in pasture areas, which disallows another aspect of the offensive mounted against Brazilian ethanol. They say that the cane does not represent a real threat to the environmentally critical areas, such as the Amazon.

Chagas (2012) points out that in Brazil, ethanol is used in three sectors of the economy: transport, the chemical industry, and beverage manufacturing. Regardless of its allocation, Brazilian ethanol is more competitive than that produced in other countries due to the large scale, which provides low production cost and low GHG emission, among other factors.

Table 3 depicts the volume of primary sources of biomass used in Brazil in 2011, highlighting the by-products of cane, which represent for more than 78 % of the primary sources.

In Brazil, there is no importation and exportation of sugarcane by-products. These by-products are consumed in the same mills and distilleries which they are produced because their transportation is infeasible. The transport of sugarcane also is infeasible for distance about 50–80 km from the mills (Rangel et al. 2008).

Table 3 Sugarcane biomass used in Brazil in 2011 (production and total consumption)

		Production		Total consumption	
Cane bagasse	(10^3 t)	146.943	47.43 %	146.943	47.43 %
Sugarcane juice	(10^3 t)	143.310	46.26 %	143.310	46.26 %
Molasses	(10^3 t)	19.557	6.31 %	19.557	6.31 %
Total	(10^3 t)	309.810	100.00 %	309.810	100.00 %

Source MME (2012)

Table 4 Cost of sugarcane production and processing in 2011/2012 harvest, per region

		Traditional	Expansion	Northeast
Suppliers cost[a]	(US$/ton)	43.99	34.73	44.10
Mill agricultural cost[b]	(US$/ton)	41.07	37.48	38.24
Cost of industrial processing of sugarcane	(US$/ton)	60.66	58.14	55.81
Cost of producing anhydrous ethanol	(US$/$m^3$)	737.72	724.33	713.73
Cost of hydrated ethanol	(US$/$m^3$)	695.87	685.83	664.03

Source Adapted from Xavier and Rosa (2012)
[a]It refers to the cost of sugarcane when the mill buys it from suppliers
[b]It refers to the cost of sugarcane when the mill supplies the sugarcane itself
Note The original data were transformed from R$ to US$ through average exchange rate from July 2011 to June 2012 (harvest 2011/2012): (R$/US$) 1.792

2.3 Production Costs

Brazil capitalizes more on the production of ethanol in relation to other countries, mainly due to the advancement in the technology of production and the scale that enables cost reduction in the production process. Veiga Filho (2008) showed in his study that in the pump, the cost of Brazilian ethanol was $ 0.20 per liter, while in the USA, it was $ 0.40 per liter.

The Continuing Education Program in Economics and Business Management (PECEGE) (2012)—and Xavier and Rosa (2012) calculated the cost of production of sugarcane, sugar, and ethanol for the 2011/2012 harvest, separating these costs by region: 'Traditional,' 'Expansion,' and 'Northeast' region. 'Traditional' is the region where the production of sugarcane is traditional in Brazil such as states São Paulo, Paraná and Rio de Janeiro. 'Expansion' region are the states where the production of sugarcane is in expansion (agricultural frontier) such as Goiás, Minas Gerais, Mato Grosso do Sul and west of São Paulo. The 'Northeast' region is composed by states of Northeast Brazilian region such as Alagoas, Paraíba and Pernambuco.

These three regions, aggregated, accounted for 96.59 and 94.87 % of the Brazilian sugarcane and ethanol, respectively, in the 2011/2012 harvest. Table 4 presents a summary of the costs of production of sugarcane and its processing in the 2011/2012 harvest.

The suppliers cost of sugarcane and the mill agricultural cost were lower in the 'Expansion' region, while the cost of industrial processing and anhydrous and

Table 5 Industrial processing cost of sugarcane in 2011/2012 harvest (US$/ton)

	Traditional	Expansion	Northeast
Raw material	*40.66*	*37.33*	*38.78*
Sugarcane (%)	37	25	39
Machinery and Implements (%)	26	35	15
Workforce (%)	7	9	19
Inputs (%)	8	11	14
Leasing (%)	10	7	2
Others (%)	12	13	11
Industrial	*15.08*	*14.83*	*14.00*
Workforce (%)	19	19	19
Inputs (%)	11	10	16
Maintenance (%)	22	25	22
Administration (%)	3	2	2
Depreciation (%)	16	15	14
Cost of capital (%)	29	29	27
Administration	*4.91*	*5.95*	*3.06*
Workforce (%)	32	37	58
Inputs and services (%)	38	36	33
Working capital (%)	30	27	9
Total	*60.66*	*58.14*	*55.81*

Source Adapted from Xavier and Rosa (2012)
Note The original data were transformed from R$ to US$ through average exchange rate from July 2011 to June 2012 (harvest 2011/2012): (R$/US$) 1.792

hydrated ethanol production were lower in the 'Northeast' region. Most of this difference is due to the implantation of new cropping and technological techniques. This observation features the difference between the production modes in each region.

In a better explanation of these models, an analysis of the costs entailing the industrial processing in manufacturing ethanol is of utmost importance. This cost can be divided into the raw material cost, manufacturing cost, and administrative cost which, in turn, can be subdivided. Table 5 shows the summary of these costs for each of the regions and their subdivisions.

The cost of the raw material seems to be more expensive in the 'Traditional' region due to the varieties of sugarcane produced. The varieties with higher content of Total Recoverable Sugar (TRS) are more expensive than other types, so the cost of sugarcane accounted for 37 % of the cost of the raw material. Moreover, the major research centers of the country related to sugarcane are located in this region, which enables testing of the most productive varieties. In the 'Expansion' region, the most representative cost is of machinery and equipment, since it uses a more intensive technological process.

The 'Expansion' region has advantages in relation to the 'Traditional' region concerning costs due to some characteristic features, such as better quality of raw material, consolidation of technological advantages of newer mills and increased production of bioelectricity. On the other hand, it has disadvantages regarding prices of ethanol (PECEGE 2012).

As for the production model, we can infer that the 'Traditional' and 'Expansion' regions production and processing of sugarcane are intensive in capital, since the cost participation on agricultural machinery and implements is greater than the share of the cost with workforce. The opposite is observed in the 'Northeast' region, and we may infer that the production model in this region is intensive in workforce.

In the manufacturing cost, the share of capital cost seems more representative than the others, followed by maintenance cost. This situation is consistent with an industry that has a complex industrial plant that requires ongoing maintenance. In the administrative cost, workforce is the most expensive especially in the 'Northeast' region. Furthermore, the working capital is the less expensive in this region.

PECEGE (2012: 57) highlights that the differences in costs between regions reflect 'the challenges of market development and infrastructure for transportation of the production in sugarcane production borders.'

2.4 Costs on Transport and Logistics

The logistics of Brazilian ethanol is poor. Most of the distribution for the domestic market is carried out by road transportation, which is not in good condition in some main key perimeters. For the overseas market, ethanol uses road transport associated to the duct mode, which connects the mills to the harbors. Although they are more efficient than road transport for long distances, the rail and waterways are still little used for both the domestic market and to the external market (Milanez et al. 2010).

'The costs of cutting, loading, and transporting account for 30 % of the total cost of production of sugarcane, and only the transport costs are equivalent to 12 % of that total' (EMBRAPA 2013:1). The average cost of road freight for ethanol in Brazil was R$ 0.1557/m^3/km in 2010, ranging between R$ 0.0568/m^3/km and R$ 0.9588/m^3/Km (SIFRECA 2011). Therefore, efficient logistic system would result in lower production costs, providing Brazil more competitiveness both in the domestic as in the international market.

Milanez et al. (2010) argue that the logistics of the Brazilian ethanol prevents the supply in some states, especially in northern Brazil due to the lack of efficient infrastructure. Furthermore, most of the infrastructure associated with the transport of ethanol is in the Central-South region of the country, mainly in São Paulo.

Figure 3 shows the main transport corridors of sugar and ethanol in Brazil. It can be observed that the concentration of the infrastructure is in the state of São Paulo and adjacent areas, while the surrounding areas (including those not shown in the figure) have lower modal infrastructure, imposing additional difficulty in the product process of distribution.

The insufficient offer of more efficient transportation modes lead to road transport, in which ethanol is transported in fuel tank trucks similar to the way gasoline and diesel are transported. Other modes also lack expansion and modernization,

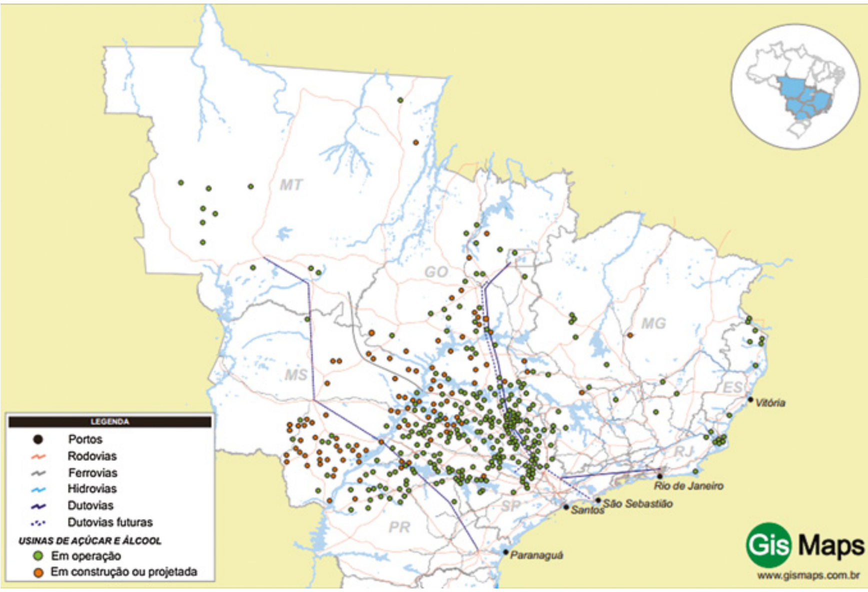


Fig. 3 Transport corridors of sugarcane and ethanol: Central-South regions. *Source* ESALQ-LOG (2013)

such as the rail systems, which are not usually used due to 'the lack of tank wagons, the locomotive enhanced traction capacity, and the low capacity of the railways because of poor maintenance […]' among other factors (Milanez et al. 2010:69). Moreover, according to the authors, the waterway mode is also not viable to transport this fuel since they are mostly in the Amazon Basin, which has no interconnection link to the Central-South modes.

Ducts are not feasible to transport ethanol, mainly due to the high investment and low availability of infrastructure, but this reality might be changed with the completion of ducts that will connect the Midwest region to Santos-SP and Paranaguá-PR harbors, crossing some of the largest consumer centers in Brazil, where they can interact with other modes, allowing the distribution to other regions (Milanez et al. 2010).

2.4.1 Market Prices of Ethanol

Domestic price of Brazilian ethanol is regulated by the government since the creation of PROALCOOL. For this reason, domestic price is stable along the time (Fig. 4).

In Brazil, the prices of ethanol show relative stability despite the instability of prices in petroleum international market. This fact is due to economic policy in Brazil, especially the price policy, that is regulated by the government.

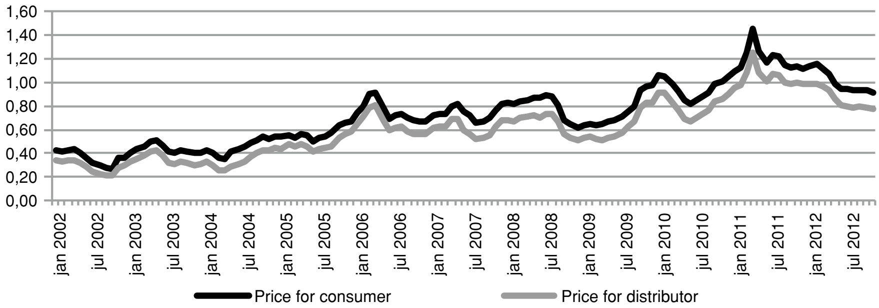


Fig. 4 Trend of ethanol price in Brazil: consumer prices and distributor in US$/liter (Jan 2002 to Nov 2012). *Source* ANP (2012). *Note* The original data were transformed from R$ to US$ through monthly exchange rate

3 European Biodiesel Policies, Production, Supply, and Demand

3.1 EU Biofuel Policy Scenario

In the European context, two political decisions have had a fundamental role in the biofuels expansion: the Directive 2003/30/EC and Directive 2009/28/EC (RED). The objectives of RED policy in 2009 included the following: increasing farm income, improving environmental quality, and increasing national energy security.

A large variety of biofuel support policies are in place in EU member states, ranging from command and control instruments such as standards and shares, economic and fiscal measures, such as tax exemptions, to information diffusion. This implies that market demand is created by policies, as the production costs of biofuels lie above those of fossil fuels. This can be done through basically two instruments: subsidization or prescription of a mandatory production. Under the first scheme, biofuels are subsidized in order to reduce the price level to that of fossil fuels (or below). The second approach consists of prescribing a specific quantity of biofuels to be supplied by fuel suppliers on an obligatory basis (blending or use target mandates).[1]

The first option is implemented by the following: (a) tax reduction scheme, which has proven successful although it has caused important revenue losses for the government and (b) support to the cultivation of agricultural feedstock

[1] The list below gives the main tools which are/have been used to promote biofuels in the EU: Proposal directive European Communication COM (2012) 595 final: *ILUC proposal;* European Communication COM (2010) 160/01; COM (2010) 160/02: *sustainability criteria;* European Decision 2010/335: *Guidelines for the Calculation of Land Carbon Stocks;* Renewable Energy Directive (RES-D) Directive 2009/28/EC: *RED;* Directive 2009/30/EC: *Fuel Quality Directive* (*FQD*); EU Climate and Energy Package 17th December 2008; Directive Biofuels Directive 2003/30/EC: *Biofuels Directive;* Directive 2003/17/EC: *Fuel Quality Directive;* Directive 98/70/EC: *Fuel Quality Directive;* Directive 2003/96/EC: *Energy Taxation;* Common Agricultural Policy (CAP).

production by the Common Agricultural Policy (CAP). Unfortunately, in 2011, both of measure *budgetary support* were deleted. The second option (use target mandates) provides that fuel suppliers are obliged to achieve a certain biofuel share in their total sales. Currently, the latter measure is working.

The European Union climate and energy package from 2008 nullifies or updates much of the previous legislation. Its implementation will have a profound impact on how biofuels are used and the level of market penetration achieved in the future. The package aimed achieving the 20–20–20's objectives: 20 % reduction in emissions, 20 % renewable energies, and 20 % improvement in energy efficiency by 2020.

Within the package, the *Renewables Directive* (RED) has arguably the highest significance with regard to biofuels. The *Directive* deals with biofuels in several ways, of which the most noteworthy is the mandatory target which states that 10 % of final energy consumption in transport should be met by renewable energy by 2020. Another important aspect of the *Directive* is the mandatory sustainability criteria to which all biofuels are subject. This aspect, in particular, has received high publicity, and its detailing in the *Directive* has left serious questions open regarding indirect land-use change and potential clashes with trading laws (Amezaga et al. 2010; European Federation for Transport and Environment 2009).

Regarding the sustainability criteria, the RED ensures that the production of raw materials for biofuels does not lead to losses of high carbon stock land such as wetland, forested areas, and peatland; and high land biodiversity such as primary forest and other protected areas including grassland. EU production shall, in addition, comply with certain agricultural and environmental requirements. In particular, biofuels are required to ensure a saving of greenhouse gas emission of at least 35 % when compared to the replaced fossil fuel. This minimum saving would be increased by 50 % in 2017 and by 60 % in 2018 for new installations. The emissions shall be calculated over the entire life cycle of the biofuels and include, if any, carbon losses from conversion of land for biofuel crop production.

Currently, similar sustainability requirements were set in the Fuel Quality Directive 2009/30/EC on the specification of petrol, diesel, and gas oil, which provided also a 6 % reduction in greenhouse gas (GHG) emissions from road transportation fuels by the blending with biofuels.

Only sustainable biofuels, domestically produced or imported, will be eligible to be counted against the target and for any other public support.

In June 2010, the European Commission announced a set of guidelines explaining how the Renewable Energy Directive Verification, on compliance with the sustainability criteria for biofuels and bioliquids, should be implemented (COM (2010)160/01; COM (2010) 160/02; and Decision 2010/335).

In addition, the European Commission was asked to come forward with proposals by the end of 2010 to limit indirect land-use change. The RED criteria, in fact, exclude some important GHG emissions such as the indirect effects, for example, on land use. For this reason, on October 17, 2012, the Commission published a proposal of directive issued as COM (2012) 595 aiming at limiting global land conversion for biofuel production (include indirect land-use change, ILUC) and to raise the climate benefits of biofuels used in the EU.

The proposal (named ILUC proposal) should amend both the Renewable Energy Directive (2009/28/EC) and the Fuel Quality Directive (98/70/EC). With these new measures, the Commission would limit the use of food-based biofuels and include ILUC[2] emissions when assessing the greenhouse gas effect of biofuels. The use of first generation of biofuels to meet the 10 % renewable energy target of the Renewable Energy Directive will be limited to 5 %. The intention of the proposal is to introduce three ILUC emission factors (for cereals 12 g CO_2 eq/MJ, sugars 13 g, and oil crops 55 g). The high ILUC factor especially for oil crops could disqualify most biodiesel made from rapeseed, soybeans, as well as palm oil (first-generation biofuels).

The sustainability criteria proposed by the EU, which aim to combat the environmental problem, have been subject to widespread criticism and extensive discussion. Social criteria and indirect land-use change are hot topics, both of which are not dealt with in the *Directive* and face similar difficulties (Amezaga et al. 2010). Both are recognized struggles but how to quantify their effects and incorporate them into policy remains a serious issue. For this reason, the proposal ILUC, nowadays, is largely called into question by European stakeholders.

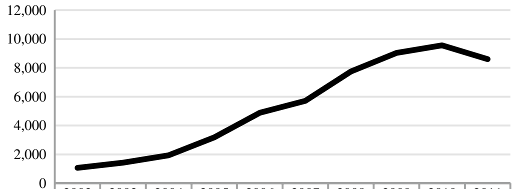
3.2 Biodiesel Production, Consumption, and Trade

In Europe, most of the biofuel used in transportation is essentially sourced from biodiesel, which accounts for 78.2 % of the total energy content (10.9 million tons in 2011), as opposed to 21 % for bioethanol (2.9 million tons in 2011) (EurObserv'ER 2012).

Compared to USA and Brazil, and also to the European biodiesel sector, the EU fuel alcohol sector is rather small. Nowadays, the monthly production in USA is higher than the EU production per year. In 2008, a record in terms of imports in EU was registered. Total imports of bioethanol (fuel and non-fuel) are estimated to have reached 1.9 billion liters (increasing by 400 million compared to 2007), most of which (between 1.4 and 1.5 billion liters) came from Brazil (ePURE) (Shikida 2002; Ferreira Filho and Horridge 2009).

The EU is the world major player in biodiesel production with a share of 57 % of total world production in 2009. In the same year, biodiesel represented about 73 % of total biofuels produced in Europe (Biofuels-platform 2012).The European

[2] Indirect land-use change (ILUC) can occur when land currently cropped for non-energy production is diverted for biofuel feedstock cultivation. The diverted crops must then be compensated for by converting other natural land, usually native systems (Ravindranath et al. 2009). Direct land-use change (dLUC) occurs when additional cropland is made available through the conversion of native ecosystems such as peatlands, forests, and grasslands, as well as by returning fallow or abandoned croplands into production. Particularly, when virgin land, such as rainforest or peatland, is converted to agricultural land, the initial induced carbon losses can only be compensated after many decades of biofuels production (Ravindranath et al. 2009).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Production	1,065	1,434	1,933	3,184	4,890	5,713	7,755	9,046	9,570	8,607

Fig. 5 Biodiesel production in EU27 from 2002 to 2011 (1,000 tons). *Source* EBB (2013)

biodiesel industry consolidates its position at an international level despite a lower increase in its growth rate of production in 2010 when compared to previous years. For example, with a 9.5 million tons of biodiesel produced in 2010, EU biodiesel production registered an increase of 5.5 % on the basis of the previous year. However, that stands below the increase in production of 17 % registered in 2009 and in the previous years (35 % in 2008). In 2011, the production decreased by 10 % when compared to 2010 (Fig. 5).

Currently, the production capacity of European biodiesel has reached approximately 22 million tons. The number of existing biodiesel facilities in July 2011 was 254 with a slight increase compared to 2009 due to the start of a few new production units (EBB 2011). This strong industrial basis is the result of considerable investments in biodiesel production planned before 2007. These investments are in reliance to the ambitious objectives for biofuels consumption given by EU authorities (EBB 2010). In 2011, Germany and France remained by far the leading biodiesel producing nations, while Spain confirmed its position of the third European biodiesel producer, ahead of Italy.

Within the EU, the first four largest biodiesel-producing member states that account for two-thirds of total production are Germany (33 % of total European production), followed by France (18 %), Spain (7 %), and Italy (5.6 %) (EBB 2013). Table 6 shows the biodiesel production and consumption of the countries of EU.

According to the European Biodiesel Board, in the first two-quarters of 2011, for the first time, the entire European production slightly decreased. Increased imports from third countries such as Argentina, Indonesia, and North America are mostly likely to have contributed to lessen European domestic production.

According to the EurObserv'ER (2012), biofuels consumption in transport continued to increase in the UE at a slower pace though. It should stabilize at around 13.9 Mtoe in 2011 compared to 13.6 Mtoe of consumption in 2010. Thus, growth was only 2.7 % between 2010 and 2011, down from 13.9 % between 2009 and 2010, 24.6 % between 2008 and 2009, and 41.7 % between 2007 and 2008.

The biofuel market is very geographically concentrated, with a limited number of member states (Germany, France, Spain, Italy, UK, and Poland) representing over 78 % of EU-27 consumption.

The EU is the world's largest biodiesel producer, consumer, and importer. The shift from tax incentives to mandates across Europe has been one of the key reasons for the growing amount of biodiesel imports. This shift can be attributed to a previous loss in fuel tax revenues for member states, causing a reduction of tax exemptions and compensation via mandates. Without tax exemptions, biodiesel was not price competitive against fossil diesel, even though the price of fossil

Table 6 EU biodiesel production and consumption in 2011

	Production (K tonnes)		Consumption (Mtoe)
Germany	4,968	Germany	2,190
Spain	4,391	France	2,299
The Netherlands	2,517	Spain	1,718
France	2,456	Italy	1,263
Italy	2,310	Poland	755
Poland	884	UK	499
Greece	812	Sweden	307
Belgium	770	Austria	449
Others	4,430	Others	2,681
Total	23,538	Total	11,409

Source Biofuels Barometer (2013) and EBB (2013)

Table 7 EU biodiesel imports in 2008–2010 (Ktonnes)

	2008	2009	2010
USA	1993	510	172
Argentina	102	1144	1179
Canada	2	188	90
Indonesia	200	212	496
Malaysia	50	166	78
India	11	33	37
Singapore	0.3	27	12
Norway	2	3	6
Others	17	14	27
Total	2377.3	2297	2097

Source ECOFYS (2011) and European Commission SEC 130 (2011)

diesel increased. Under a mandate, fuel suppliers tend to opt for blending low-cost biofuels causing the increase of biodiesel imports (Ecofys 2011).

Imported biofuels in the EU come from a range of countries, with considerable changes in the list of countries from which the EU imported biofuels year by year, thus reflecting the impact that EU tariff preferences can have on such imports. This is demonstrated in Table 7 that depicts changes in EU biodiesel imports from 2008 to 2010 (European Commission, SEC 130 2011).

Looking at the trade volumes, in 2010, Argentina and Indonesia were the main exporters. The imports from USA and Canada reduced considerably regarding the previous years due to the application of the EU anti-dumping and countervailing duties for biodiesel.

3.2.1 Biodiesel Feedstocks

In EU-27, the biomass consumption accounts approximately for 95.7 Mtoe, of which only a small part is used for biofuels, the rest for heat (40 Mtoe) and for electricity (48 Mtoe). If the renewable targets of the EU are to be met, an additional 120 Mtoe

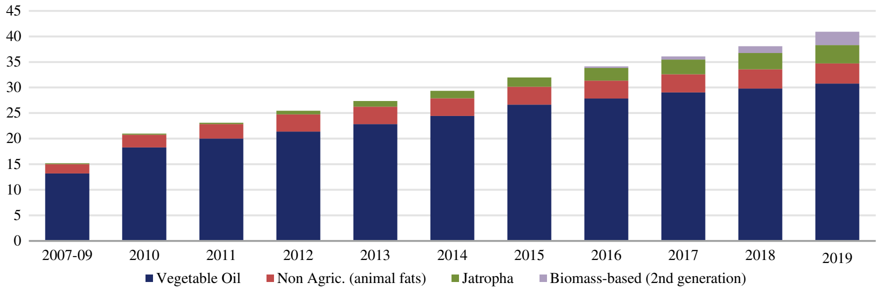


Fig. 6 Evolution of biodiesel production by feedstock (billion liters). *Source* OECD-FAO (2010)

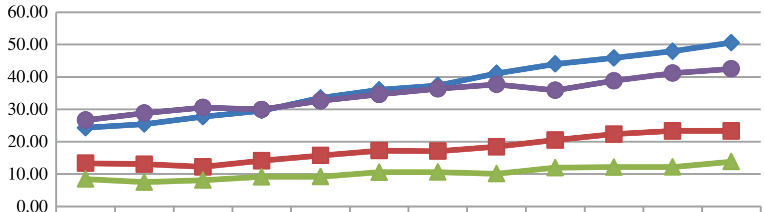
of biomass needs to be produced by 2020, which would have to be obtained mainly from additional forest resources, but also new sources such as aquatic biomass, and eventually imports that will have to meet sustainability criteria.

In the European Union, the utilized agricultural area (UAA) is 178.44 million of hectares (Mha) which represents 41 % of the whole EU27 territorial area, while arable land represents almost one-quarter of European territory (24 %). In Europe, it is estimated that approximately 2.5 Mha of agricultural land is dedicated to bioenergy crops for liquid biofuels (Aebiom 2012), which represents about 1.4 % of the utilized agriculture area (UAA). 'The European Commission (2011) calculated that 17.5 million ha of land would be required to reach the 10 % biofuels target, which would amount to about 10 % of the total utilized agricultural area (UAA) in EU27' (Panoutsou et al. 2011: 3).

For this reason, the biodiesel companies of different member states have invested in third countries and in particular in Africa, to produce vegetable oil from Jatropha. But in order to be sustainable, the use of biomass for fuel and energy purposes must not jeopardize European and third countries' ability to secure its people's food supply, nor should it prevent achieving environmental priorities such as protecting forests, preventing soil degradation and keeping a good ecological status of waters.

The European agricultural land for biodiesel is used to produce oilseed crops (rapeseed, sunflowers, soybean) which are the major feedstock used to produce biodiesel (Fig. 6). Increased demand for oils from biodiesel producers has become over the past few years one of the driving forces of the global vegetable oil market. Any changes in biofuel policies in the European Union and in the USA as well as any advances being made on the next generations of biofuels is bound to alter the demand of vegetable oils for non-food purposes. Furthermore, in the coming years, national biofuel policies may also increasingly affect international trade in vegetable oils used as biodiesel feedstock as well as trade in biodiesel itself (OECD-FAO 2012).

At global level, rapeseed oil, sunflower oil, soybean oil, and palm oil are the most produced vegetable oils. According to USDA data (Fig. 7), the global production of palm oil accounted for 39 % of all vegetable oils in 2011, followed by soybean oil (33 %), rapeseed oil (18 %), and sunflower oil (11 %). Figure 7 shows that



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Palm oil	24.30	25.44	27.71	29.59	33.53	35.98	37.35	41.08	43.99	45.86	47.93	50.57
Rapeseed oil	13.33	13.06	12.21	14.14	15.72	17.24	17.08	18.44	20.51	22.32	23.32	23.33
Sunflowers oil	8.46	7.48	8.12	9.13	9.19	10.57	10.60	10.11	11.97	12.13	12.16	13.81
Soybean oil	26.68	28.85	30.57	29.97	32.60	34.60	36.32	37.69	35.87	38.83	41.17	42.49

Fig. 7 Vegetable oil world production in million tons (2000–2011). *Source* USDA (2011)

the production of palm oil from 2000 to 2011 had a constant positive trend with an increase of 108 %. Remarkable results, in the same period, are also observed for rapeseed oil with an increase of 75 %, followed by sunflower (63 %) and soybean (59 %).

Although rapeseed oil and soybean oil are projected to remain the main feedstock, the use of palm oil is expected to more than double over the coming decade, with around 9 % of global palm oil production absorbed by the biofuel industry in 2021.

EU-27 and China are the world's largest importers of vegetable oils, followed by India which shows an increase of 55 % respect to 2007. Despite Malaysia and Egypt being the countries with the highest increase of imports (81 and 73 %, respectively), their import levels are still low (USDA 2011). Indonesia, Malaysia, and Argentina have dominated the export market since 2007, even with Argentina's decrease (−17 %) with respect to the previous years. Russia and Ucrania are the countries with the highest increase of exports (263 and 100 %, respectively), but their contribution to the export market remains marginal (USDA 2011).

Demand from the biodiesel industry is set to grow less than in the previous decade when biofuel demand accelerated as policies were put in place. The use of vegetable oil for biodiesel is still expected to expand to 30 Mt, which corresponds to a 76 %increase over the 2009–2011 and raises the share of vegetable oil consumption used for world biodiesel production from 12 % in 2009–2011 to 16 % in 2021 (Fig. 8) (OECD-FAO 2012).

In the developed world, biodiesel demand should account for 73 % of total consumption growth. Biodiesel demand growth should continue to be lead by the European Union, where biofuel producers are expected to absorb 51 % of domestic vegetable oil up from 40 % in 2009–2011. Starting from a relatively small base, demand from the biodiesel industry is expected to almost double in the developing world, with growth in absolute terms not far behind the one projected in developed countries. Growth is expected in the traditional producers, Indonesia, Malaysia, and Argentina, but also in other parts of Asia (Thailand, India) and South America (Brazil, Colombia). Argentina further expands its export-oriented biodiesel industry, which, by 2021, could absorb 31 % of domestic vegetable oil output (OECD-FAO 2012).

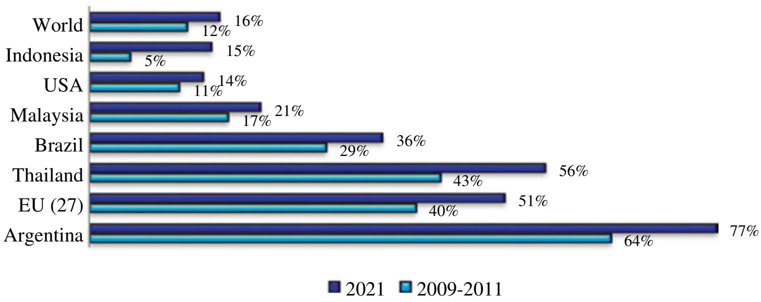


Fig. 8 Share of vegetable oil consumption used for biodiesel production (%). *Source* OECD-FAO (2012)

3.3 Biodiesel Production Cost

The cost of producing biodiesel depends on a number of factors, including the feedstock used in the process (i.e., the production cost of biomass), the capital and operating costs of the production plant, the current value and sale of by-products, and the yield and quality of the fuel and by-products. Table 8 provides total and unit production costs of a representative European biodiesel plant (Italy) using rapeseed oil as feedstock (2010), which is a good example that includes the average characteristics of Italian plants, on the base of the information collected through firm survey (Finco 2012). The plan has capacity for 150,000 tons and produces 150,000 tons of biodiesel.

Table 8 shows that the major economic factor to consider for input costs of biodiesel production is the feedstock, which is about 80 % of the total production cost. This means that the market trend commodities prices highly influence the result of the biodiesel industry. In particular, feedstock costs can vary significantly from region to region due to their availability and market fluctuations, which can also make biodiesel production costs vary over time. Vegetable oils prices have changed significantly in the last 5 years. The prices have been rather stable until end of 2006, while from 2007 to 2008, they are more than doubled, declining again in 2009 reaching the 2006 level. In the second semester of 2010, the price registered another increase followed by a slight fall in 2012 (OECD-FAO 2012).

Table 9 shows the net margin of our representative plant. Nowadays, our plant perceives a negative economic result because revenues do not cover production costs. This result is mainly driven by the biodiesel price that is fixed by the refineries and it is not connected with the production costs.

There are two components that influence the value of biodiesel: the diesel price on Platts and a premium price. The premium is determined by the refinery industry, and it depends on the vegetable oils price and the contractual power of the biodiesel plant. Technically, the premium price should correspond to the difference between the production costs and the diesel price on Platts, which biodiesel producers widely call the 'business margin.'

Table 8 Total production cost of biodiesel (2010)

Cost Item	USD $	%
Annual rate of depreciation	2,064,459.53	1.19
Management and maintenance plant cost	15,941,280.00	9.19
Biomass cost (rapeseed oil)	137,493,540.00	79.28
Other costs	1,992,660.00	1.15
Processing cost	12,952,290.00	7.47
Transportation costs	2,988,990.00	1.72
Total production cost	173,433,219.53	100.00
Production cost per ton (USD/ton)	1,155.74	

Source Finco and Padella (2012)

Table 9 Net margin of biodiesel plant

Biodiesel sales	(ton)	150,000
Biodiesel price	(USD/ton)	964
Glycerin sales	(ton)	15,000
Glycerin price	(USD/ton)	103
Net margin	(USD)	−21,669,249
Net margin per ton	(USD/ton)	−144

Source Finco and Padella (2012)

However, according to the data from biodiesel plants, the premium price perceived corresponds to approximately 65 % of the 'business margin.' Moreover, this percentage depends on the policies adopted by the Governments, such as tax excise reductions or subsidies.

It is important to underline that biodiesel plants use a blend of vegetable oils and, consequently, the price can probably be lower than the rapeseed oil price that was used in the Table 9. Taking this into account, the results present an accurate representation of the Italian biodiesel industry.

However, the increased price of vegetables oil, the economic crisis, and policy changes at European level had negative impact on biodiesel production. For example, in Italy, the reduced tax exemption in 2009 and the subsequent abolition has diminished the profitability of the biodiesel plant realizing losses.

4 Biofuels Sustainability of Ethanol and Biodiesel

The concept of sustainability is derived from 'sustainable development,' which has been defined in the Brundtland report as 'development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs' (WCED 1987: 45). The concept of sustainable development has traditionally focused on three pillars (i.e., social, environmental, and economic), and in recent years, it has evolved including other components such as policies and institutions (Diaz-Chavez, 2011).

The EU, since first announcing its intention to set a mandatory biofuels target, has maintained that any production or use of biofuels must be sustainable (European Federation for Transport and Environment 2009). The Renewables Directive (2009/28/EC) aims to ensure this ambition is met through the use of mandatory sustainability criteria. The criteria set out three main requirements which biofuels must meet in order to be counted toward the target or to be eligible to receive tax rebates or subsidies:

- The greenhouse gas emission savings from the use of biofuels and bioliquids must be at least 35 % (rising to 50 % in 2017) compared to fossil fuels;
- The feedstock of biofuel is not to be derived from land with high biodiversity value such as high biodiversity grassland; and
- The feedstock of the biofuel is not to be derived from land with a high carbon stock. These criteria apply to biofuels and bioliquids and for both imported and domestically produced feedstock.

A significant part of biofuels debate since 2009 focused on indirect land-use change and its exclusion from the EU sustainability criteria. ILUC is not accounted in the Renewables Directive, and therefore, the emissions resulting from ILUC are not included in the greenhouse gas life cycle analysis calculations (Amezaga et al. 2010).

For biofuels, the length and complexity of the supply chains make the sustainability issue very challenging. Biofuels' pathways include several successive segments over the fuels life cycle (e.g., feedstock production, conversion of the feedstock to biofuels, wholesale trade, retail, and use in engines) and multiple actors (e.g., feedstock suppliers, biofuels producers, biofuels consumers, and public authorities).

In order to be sustainable, biofuels should be carbon neutral, especially considering the necessity of fossil fuel substitution and global warming mitigation. Also, biofuels should contribute to the economic development and equity. Moreover, they should not affect the quality, quantity, and use of natural resources as water and soil, should not affect biodiversity, and should not have undesirable social consequences (Lora et al. 2011).

Several authors have recently raised concerns about the environmental costs benefits and social implications of biofuels production such as underlying uncertainties over the life cycle emissions of greenhouse gas emissions (GHG), possible deforestation for feedstock production, degradation of soil and air quality, increased water consumption, possible loss of biodiversity, possible competition with food production, and other potential social imbalances (Ajanovic 2011; Gnansounou 2011; Finco et al. 2012; Padella et al. 2012).

Land-use change is considered one of the most important environmental impacts to address, mainly because of its impacts on GHG and wider ecosystems. Recently, many studies are working on land use, direct and indirect (LUC, ILUC). For example, the research studies of Brazil show that the amount of new land required for sugarcane production would be relatively small (Arima et al. 2011; Macedo et al. 2012). In the same way, the LUC module based on a transition matrix developed by Ferreira Filho and Horridge (2011) and calibrated with data from the Brazilian Agricultural Censuses of 1995 and 2006 shows how land use changed across different uses (crops, pastures, forestry, and natural forests) along those years. The results obtained by general equilibrium models approach show that the ILUC effects of ethanol expansion are of the order of 0.14 ha of new land coming from previously unused land for each new hectare of sugarcane. This value is higher than the values found in Brazilian literature (Ferreira Filho and Horridge 2009, 2011).

Careful assessment of these impacts has given rise to criticisms from economists, ecologists, NGOs, and international organizations, who call for additional analysis of biofuels' effects. Furthermore, the European Union and several countries have adopted certification schemes to biofuels to respond to these growing concerns and to address the sustainability issues derived from the expanding production of biofuels.

Current and future biofuels production could have important environmental and ecological impacts. One of the major reasons for producing biofuels is to reduce greenhouse gas emissions and to mitigate the effects of global warming produced by fossil fuels. However, some unintended impacts of biofuel production are land, air, water, and biodiversity.

4.1 Environmental Impacts of Biofuels: The GHG Emissions Saving

One of the aims for the utilization of biofuels is the climate change mitigation through the reduction of GHG emissions in the transport sector. Measuring the consequences of biofuels requires consideration of their full life cycle, from biomass production and its use of various inputs to the conversion of feedstocks into liquid fuels and the subsequent use of the biofuels in combustion engines (Rasetti et al. 2012).

The potential mitigation varies across types of feedstock, feedstock production process/technology (e.g., usage of nitrogen fertilizer), and fossil fuel consumption in both production of feedstocks and its conversion to biofuels.

Several standard life cycle analyses (LCA) of biofuels in the literature have reported a wide variation on the reduction of GHG emissions; this is mainly due to differences on underlying assumptions on system boundaries, by-product allocation, and energy sources used in the production of agricultural inputs and feedstock conversion to biofuels. Most studies (Sims et al. 2010; Rutz and Janssen 2007) indicate that biofuels show some emission reductions when compared to their fossil fuel counterparts, especially when the emissions from the director indirect land-use changes (LUC/ILUC) due to biofuels feedstock production are excluded.

4.1.1 Brazilian Ethanol GHG Emissions

Oil products account for approximately 95 % of the energy used for transportation in the world in their various modes. The technological standards for the use of this energy source, which has been strongly disseminated in the world, developed over more than a century.

However, several liabilities accompany its hegemonic use, since the reduction of available stocks of this essential non-renewable resource (petroleum), pollution, and GHG emissions (Seabra 2008: 83).

Therefore, the continuation of fossil fuel energy resources use provides strategic and environmental drawbacks, seeing that the use of non-renewable sources is revealed as a way of releasing elements captured in a remote past, which expose the modern lifestyle to a not properly dimensioned future risk.

On the other hand, the production and the consumption of biofuel obtained from agricultural biomass (renewable resources) entails a GHG balance (CO_2 eq.) close to neutrality. Thus, unlike fossil fuels, the biomass has sustainable features, since human systems capitalize on energy use with little interference in the GHG balance (ANEEL 2008; Macedo et al. 2008; Garcia 2011).

According to Table 10, the sugarcane has the best energy efficiency (9.3) among the different sources of biomass available in Brazil and it has the highest reduction percentage of GHG emissions (89 %). These indicators are much higher than those obtained by corn (US option) or beet (an option used in Europe).

When the Life Cycle Assessment (LCA) of some biofuels was performed, ethanol was highlighted due to the high percentage of GHG reduction, as depicted in Fig. 9.

Even though the options of energy production are within the renewable status, they are not free of interfering negatively on the environment. One of the most important liabilities is the interference in the soil and the formation of monocultures over large areas. However, these problems can be mitigated by techniques and processes that increase biomass productivity per area. An example of this is that Brazil produces 6,800 l of ethanol per hectare of sugarcane, while the USA produces 3,100 l/ha of maize (ANEEL 2008).

In Brazil, several crops have the potential to produce bioenergy, among them soy, sugarcane, castor bean, and palm oil. The cultivation of sugarcane has been highlighted in the production of ethanol. With a focus on increasing productivity, the mills have opted for mechanical harvesting, including suitability for the current legislation which restricts fires of sugarcane straw for the crop.

Another element of this sustainable supply chain is the use of bagasse to produce electricity through thermal power plants (ANEEL 2008).

The techniques and processes evolution and R&D also contribute to the increased efficiency in the various stages of the production process, such as harvesting sugarcane in Brazil, which is abandoning the straw burning for the harvest and better studies about the emission levels in the various stages of production and processing of this biomass (Table 11).

4.1.2 European Biodiesel GHG Emissions

A recent empirical analysis has demonstrated that, for example, the use of rapeseed biodiesel represents a saving of approximately 56 % of emissions when compared to conventional diesel, measured in CO_2 equivalents (Rasetti et al. 2012). According to Timilsina and Shrestha (2010), biodiesel from palm oil is generally considered to

Table 10 Energy efficiency and avoided GHG emissions by the use of ethanol

Raw material	Energy efficiency (Mj/MJ)[a]	GHG emissions saving (%)
Sugarcane ethanol	9.3	89 (61–91)
Cellulose residues (cane)	8.3–8.4	66–73
Manioc	1.6–1.7	63
Beet	1.2–1.8	35–56
Wheat	0.97–1.11	19–47
Corn	0.6–2.0	30–38

Source Garcia (2011:32)

[a]Relation between renewable energy produced and the non-renewable energy necessary to produce biofuel

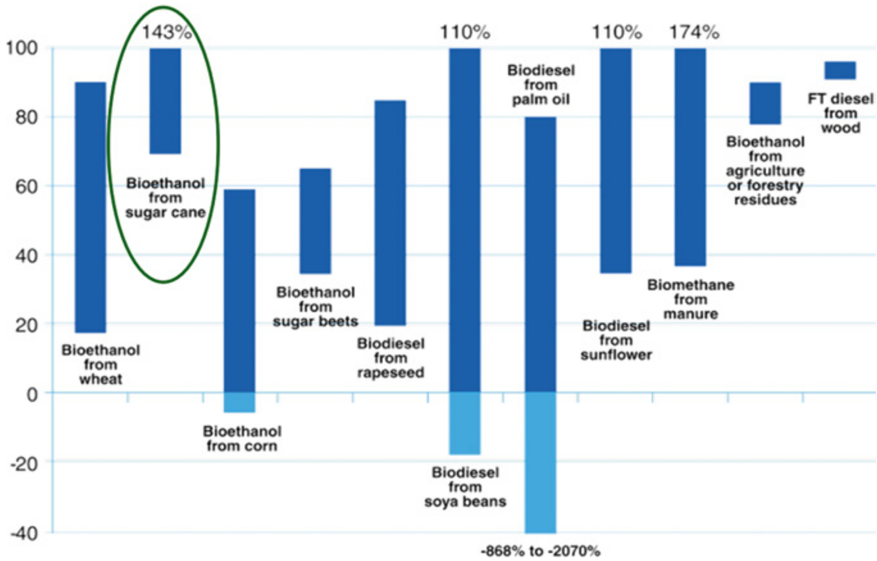


Fig. 9 Reduction of GHG emissions of biofuel. *Source* Souza (2009:16)

yield the most substantial GHG savings, typically in the range of 50–80 %. Biodiesel both derived from sunflower and from soybean delivers significant GHG savings: Emission savings from biodiesel based on sunflower appear to converge around 60–80 %, while those from soybean biodiesel tend to be around 50–70 %.

However, recent studies have shown that the production of biofuels can lead to a net rise in CO_2 emissions if dLUC and in particular ILUC effects are taken into account (see Table 12); this is the reason why the EU in the COM 595 wanted to limit the contribution that conventional biofuels make toward attainment of the targets in the RED.

Furthermore, starting with commodity cultivation up to its final use, it must be verified that the greenhouse gas reduction accompanying the use of biofuel is currently at least 35 % and from 2017 at least 50 % compared to fossil fuel.

Table 11 Environmental indicators of sugarcane ethanol versus cereals and beet ethanol

Source	Sugarcane	Corn	Wheat	Beet
Country	Brazil	USA	EU	EU
Energy balance (unit of renewable energy per unit of fossil fuel input)	9.3	1.4	2.0	2.0
Productivity (liters/hectare)	7,000	3,800	2,500	5,500
GHG reduction (%) (from USA and EU legislations)	61–91	0–38	16–69	52

Source adapted of UNICA (2011)

Table 12 Improvement in GHG emissions of biodiesel versus diesel (%) and energy efficiency

Biodiesel	Criteria			
	GHGs saving (%)	Land-use change (direct) (%)	Land-use change (indirect) (%)	Energy efficiency (MJ/MJ)
Rapeseed oil	40	−8.0	−45	2.5
Sunflower oil	55	7.0	−30	2.4
Soybean oil	42	−6.0	−43	2.3
Palm oil	60	−132.0	26	9.1

Source Finco et al. 2012

EU Commission instructed various scientific institutes in order to verify the connection between what land extents would have to be additionally cultivated and what quantity of greenhouse gases would be emitted from these areas if the EU target value of 10 % of renewable energies in the transport sector was achieved.

A cause–effect relationship could not be verified. The reason for this is very complex connections to the international agricultural markets and the low amount of commodities for biofuel production. This is why the EU Commission had initially suggested having this 'ILUC phenomenon' further investigated by scientists.

Table 12 shows the average GHGs emission savings (in %) in the production of biodiesel from different feedstocks (rapeseed, sunflower, palm, and soybean) compared to those related to the diesel life cycle in three different scenarios: the first without land-use changes and the second and the third including direct and indirect land-use changes, respectively. Negative values indicate increase in emissions.

It also provides the ratio between the energy generated during the use of biodiesel in road transport and the energy used during production, processing, and transportation of the biodiesel (energy efficiency).

These data derive from an exploratory meta-analysis of 32 scientific and technical reports emerging from international research (Bentivoglio et al. 2012).

Looking at the data in the Table 12, it results that, in the scenario without land-use change, all the biofuels considered provide GHG emission savings. In the second scenario, the most remarkable result is the huge loss in emission savings bound to the production of biodiesel from palm oil due to the substitution of peatlands in Malaysia. Regarding the energy efficiency, biodiesel from palm oil recorded the best performance (9.1).

5 Conclusions

The sustainability of biofuels derived from agricultural biomass is widely debated nowadays. On the one hand, the production of biofuels ensures energy security for the historically non-oil producing countries; on the other hand, it turns on the food versus fuel debate and the land-use change issue, generally responsible for a net loss in GHG emissions savings related to biofuels production and consumption. However, these issues need to be addressed keeping in mind different variables: the geographical area of production of energy biomass, the type of biofuel (ethanol or biodiesel) produced, and the feedstock used (corn, sugarcane, beet, vegetable oils).

This work compares different aspects related to the production of ethanol from sugarcane in Brazil (first generation) with those bound to the production of European biodiesel and of rapeseed oil that it is a principal European feedstock.

The goal was to highlight the differences between Brazil and European Union in the biofuel production and the reasons why Brazil has a competitive advantage in the ethanol production and the European Union has a competitive advantage in the biodiesel production.

The comparison between the two biofuels summarizes the results derived from the extensive scientific literature, taking into account production and energy efficiency, but also economic and environmental sustainability.

The sugarcane ethanol energy balance is 9.3, much higher if compared to 1.4 for ethanol from corn in the USA and to 2.5 for rapeseed biodiesel in EU. The ethanol productivity is approximately 7,000 l/ha, whereas biodiesel from rapeseed yield (the most frequently used biomass in the EU) is about 1,320 l of biodiesel per hectare. At the same time, ethanol production costs from sugarcane are much lower than those required to produce biodiesel from rapeseed oil. According to international literature, the costs derived from empirical analysis are about 0.56–0.58 $/l for the Brazilian sugarcane ethanol (Xavier and Rosa 2012) versus 1.00 $/l for the European rapeseed biodiesel (Finco and Padella 2012).

Concerning environmental sustainability, the performances in terms of GHG emissions saving, too, are in favor of sugarcane ethanol. However, in this case, the production of biodiesel, and in particular from palm oil and soybean, does not seem to deviate very much from those values. The fundamental question is that palm oil is not indigenous production and EU imports it from Asia. In addition, if it include direct and indirect land-use changes in the average GHGs emission savings (%) from different feedstocks (rapeseed, sunflower, palm and soybean), it is possible to identify GHG emissions increase especially in palm oil production. In the opposite case, the sunflower which is widely produced in southern Europe (Italy, Spain) shows the best performance with regard to environmental LUC and ILUC.

It should be noted that the assessment of the effects of land-use change on the direct and indirect are very controversial and the international literature presents many methodological approaches that are not always comparable.

Regarding the Brazilian scenario, there are many studies on land use, direct and indirect (LUC, ILUC). For example, the research studies of Brazil show that the amount of new land required for sugarcane production would be relatively small (Arima et al. 2011; Macedo et al. 2012). In the same way, the LUC module based on a transition matrix developed by Ferreira Filho and Horridge (2011) and calibrated with data from the Brazilian Agricultural Censuses of 1995 and 2006 shows how land use changed across different uses (crops, pastures, forestry, and natural forests) between those years. The results obtained by general equilibrium models approach show that the ILUC effects of ethanol expansion are of the order of 0.14 ha of new land coming from previously unused land for each new hectare of sugarcane. This value is higher than values found in the Brazilian literature (Ferreira Filho and Horridge 2011).

In this context, the contribution of government policies (Brazil and EU) is essential in order to guide the biofuel sector toward a sustainable development. A first step in this direction was the introduction of certification schemes and criteria, accepted worldwide as well as the attempt to avoid direct and indirect land-use changes, preventing the exploitation of sensitive areas to the detriment of biodiversity and carbon stocks reduction. However, according to Amezaga et al. (2010), the sustainability criteria proposed by the EU, which aim to combat the environmental problem, have been subject to widespread criticism and extensive discussion. Problems have been voiced not only about the measures that are in place, but also about significant factors which are not dealt with in the *Directive*.

Nevertheless, it should be noted that the market-oriented policies implemented by governments should be consistent and continuous in time so as to avoid market distortions and even more failures in the sector as is being done in the European context after the abolition of the instrument of tax exemption and the imposition of product requirements is not always appropriate.

Despite the competitive advantage, in terms of economic and environmental sustainability, taken by sugarcane ethanol compared to other biofuels as enlightened by the previous considerations, we believe in the importance of defending even a small European biodiesel production to sustain energy security, considered by all the BRIC countries the main engine of economic development.

References

European Biomass Association (AEBIOM) (2012) European bioenergy outlook 2012. Statistical report 2012, Brussels, Nov

Ajanovic A (2011) Biofuels versus food production: does biofuels production increase food prices? Energy 36:2070–2076

Amezaga JM, Boyes SL, Harrison JA (2010) Biofuels policy in the European Union. Paper presented at the 7th international biofuels conference, New Delhi, 1–12 Feb 2010. http://research.ncl.ac.uk/reimpact/Related%20Documents/Reports/Biofuels%20Policy%20in%20the%20European%20Union.pdf. Accessed 13 Feb 2013

Agência Nacional de Energia Elétrica (ANEEL) (2008) Atlas de energia elétrica do Brasil, 3rd edn. http://www.aneel.gov.br/visualizar_texto.cfm?idtxt=1689. Accessed 16 Feb 2013

Agência Nacional do Petróleo (ANP) (2012) Sistema de levantamento de preços. http://www.anp.gov.br/preco/. Accessed 12 Dec 2012

Arima EY, Richards P, Walker R, Caldas MM (2011) Statistical confirmation of indirect land use change in the Brazilian Amazon. Environ Res Lett 6:024010

Bentivoglio D, Finco A, Nijkamp P (2012) Multicriteria analysis for biofuels policy decision making in agriculture. In: Finco A (ed) Biofuels economics and policy: agricultural and environmental sustainability. Franco Angeli, Milan, pp 138–153
Biofuels-Platform (2012) Biodiesel production. http://www.biofuels-platform.ch/. Accessed 14 Dec 2012
Biofuels Barometer (2013) http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro216_en.pdf. Accessed 21 Sept 2013
Castro NJ, Dantas GA (2008) Bioenergia no Brasil e na Europa: uma análise comparativa. UFRJ, Rio de Janeiro. http://www.nuca.ie.ufrj.br/gesel/artigos/0810XX_CastroDantas_BioenergiaBrasilEuropa.pdf. Accessed 13 Feb 2013
Chagas ALQ (2012) Economia de baixo carbono: avaliação de impactos de restrições e perspectivas tecnológicas. Relatório estudos setoriais: biocombustíveis. Núcleo de Estudos de Economias de Baixo Carbono. USP, Ribeirão Preto
Centro de Tecnologia Canavieira (CTC) (2005) Alternativas a partir da Cana de Açúcar. Paper presented at the Alternativas energéticas a partir da cana de açúcar. CTC, Aug 2005. http://www.ctcanavieira.com.br. Accessed 06 Feb 2013
Dias MOS, Ensinas AV, Nebra SA, Filho RM, Rosell CEV, Maciel MRW (2009) Production of bioethanol and other bio-based materials from sugarcane bagasse: integration to conventional bioethanol production process. Chem Eng Res Des 87:1206–1216. http://www.academia.edu/626811/Production_of_bioethanol_and_other_bio-based_materials_from_sugarcane_bagasse_Integration_to_conventional_bioethanol_production_process. Accessed 10 Feb 2013
Diaz-Chavez RA (2011) Assessing biofuels: aiming for sustainable development or complying with the market? Energy Policy 39:5763–5769
European Biodiesel Board (EBB) (2010) 2009–2010: EU biodiesel industry restrained growth in challenging times. http://www.ebb-eu.org/stats.php. Accessed 14 Dec 2012
European Biodiesel Board (EBB) (2011) 2010–2011: EU biodiesel industry production forecasts show first decrease in 2011 since data is gathered. http://www.ebb-eu.org/stats.php. Accessed 14 Dec 2012
European Biodiesel Board (EBB) (2013) Production by country. http://www.ebb-eu.org/stats.php. Accessed 14 Feb 2013
Ecofys (2011) International biodiesel markets. Developments in production and trade. UFOP, Berlin
Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) (2009) Zoneamento agroecológico da cana-de-açúcar. Embrapa Solos, Rio de Janeiro (55). http://www.cnps.embrapa.br/zoneamento_cana_de_acucar/ZonCana.pdf. Accessed 03 Jul 2013
Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) (2013) Logística e transporte. http://www.agencia.cnptia.embrapa.br/gestor/cana-de-acucar/arvore/CONTAG01_133_22122006154842.html. Accessed 10 Feb 2013
ESALQ-LOG Grupo de Pesquisa e Extensão em Logística Agroindustrial (2013) Corredores de transporte de açúcar e álcool: região centro-sul. http://log.esalq.usp.br/home/pt/mapas.php#mapid008. Accessed 10 Feb 2013
EurObserv'ER (2012) L'observatoire des energies renouvelables. http://www.eurobserv-er.org/default.asp. Accessed 12 Nov 2012
European Commission (2011) 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. SEC (2011)130
European Federation for Transport and Environment (2009) Biofuels in Europe: an analysis of the new EU targets an sustainability requirements with recommendations for future policy. European Federation for Transport and Environment (T&E), Brussels, Belgium
Ferreira Filho JBS, Horridge M (2011) Ethanol expansion and the indirect land use change in Brazil. Paper presented at the 14th annual conference on global economic analysis, Venice, June 2011, p 20

Ferreira Filho JBS, Horridge MJ (2009) The world increase in ethanol demand and poverty in Brazil. Paper presented at the 12th annual conference on global trade analysis, Santiago, June 2011, p 27

Finco A (ed) (2012) Biofuels economics and policy: agricultural and environmental sustainability. Franco Angeli, Milan

Finco A, Bentivoglio D, Nijkamp P (2012) Integrated evaluation of biofuel production options in agriculture: an exploration of sustainable policy scenarios. Int J Foresight Innovation Policy 8(2/3):173–188

Finco A, Padella M (2012) Biodiesel sector in Italy. In: Finco A (ed) Biofuels economics and policy: agricultural and environmental sustainability. Franco Angeli, Milan, pp 85–91

Garcia JCC (2011) Emissão de gases de efeito estufa na obtenção do etanol de cana-de-açúcar: uma avaliação considerando diferentes cenários tecnológicos em Minas Gerais. Thesis, Federal University of Minas Gerais

Gnansounou E (2011) Assessing the sustainability of biofuels: a logic-based model. Energy 36:2089–2096

Lora EES, Palacio JCE, Rocha MH, Renó MLG, Venturini OJ, Del Olmo OA (2011) Issues to consider, existing tools and constraints in biofuels sustainability assessments. Energy 36:2097–2110

Macedo IC, Seabra JEA, Silva JEAR (2008) Greenhouse gases emissions in the production and use of ethanol from sugarcane in Brazil: the 2005/2006 averages and a prediction for 2020. Biomass Bioenergy 32:582–595

Macedo MN, Fries RS, Morton DC, Stickler CM, Galford GL, Shimabukuro YE (2012) Decoupling of deforestation and soy production in the southern Amazon during the late 2000s. PNAS 109(4):1341–1346

Milanez AY, Nyko D, Garcia JLF, Xavier CEO (2010) Logística para o etanol: situação atual e desafios futuros. In: Sucroenergético. BNDES Setorial 31, p 49–98

MME Ministério de Minas e Energia (2012) Balanço energético nacional 2012: ano base 2011. http://www.mme.gov.br/mme/galerias/arquivos/publicacoes/BEN/2_-_BEN_-_Ano_Base/1_-_BEN_Portugues_-_Inglxs_-_Completo.pdf. Accessed 20 Jan 2013

OECD, FAO (2010) Agricultural outlook 2010–2019. http://stats.oecd.org/Index.aspx?QueryId=23336. Accessed 15 Jan 2013

OECD, FAO (2012) Agricultural Outlook 2012–2021. http://stats.oecd.org/Index.aspx?DataSetCode=HIGH_AGLINK_2012. Accessed 15 Jan 2013

Padella M, Finco A, Tyner WE (2012) Impact of biofuels policies in the EU. Econ Energy Environ Policy (EEEP) 1(3):87–103

Panoutsou C, Elbersen B, Böttcher H (2013) Energy crops in the European context. Biomass Futures. http://www.biomassfutures.eu/public_docs/final_deliverables/WP8/D8.4%20Energy%20crops%20in%20the%20European%20context%20(contribution%20to%20FNR%20workshop).pdf. Accessed 23 Jul 2013

PECEGE Programa de Educação Continuada em Economia e Gestão de Empresas (2012) Custos de produção de cana-de-açúcar, açúcar e etanol no Brasil: acompanhamento da safra 2011/2012—Centro-Sul. Universidade de São Paulo, Piracicaba

Portal da cana (2013) Lista completa das usinas de etanol autorizadas pela ANP a operar. http://www.novacana.com/n/industria/usinas/lista-completa-usinas-etanol-autorizadas-anp-operar-170113/. Accessed 04 Jul 2013

RAIS Relação Anual de Informações Sociais (2012) Vínculos. http://bi.mte.gov.br/bgcaged/caged_rais_vinculo_id/caged_rais_vinculo_basico_tab.php. Accessed 01 Sept 2012

Rangel JJA, Cunha AP, Pacheco AP, Morgado IF, Montané FAT (2008) Simulação computacional para análise do frete no transporte de cana-de-açúcar: um estudo de caso no estado do Rio de Janeiro. Sistemas Gestão 3(3):250–261

Rasetti M, Bentivoglio D, Finco A (2012) Rapeseed biodiesel environmental impacts using life cycle assessment (LCA) methodology. In: Finco A (ed) Biofuels economics and policy: agricultural and environmental sustainability. Franco Angeli, Milan, pp 155–168

Ravindranath NH, Manuvie R, Fargione J, Canadell JG, Berndes G, Woods J, Watson H, Sathaye J (2009) Greenhouse gas implications of land use and land conversion to biofuel crops. In: Howarth RW, Bringezu S (eds) Biofuels: environmental consequences and interactions with changing land use. Island, New York, pp 111–125
Rutz D, Janssen R (2007) Biofuel technology handbook. WIP Renewable Energies, München
Seabra JEA (2008) Avaliação técnico-econômica de opções para o aproveitamento integral da biomassa de cana no Brasil. Thesis, Universidade Estadual de Campinas
Shikida PFA (2013) Evolution and challenges of the ethanol in Brazil. Seminar for professors, PhD students undergraduate and graduate students. In: Università Politecnica delle Marche (UNIVPM), Facoltà di Economia; Ancona
Shikida PFA (2002) The economics of ethanol production in Brazil: a path dependance approach. In: Moraes MAFD, Shikida PFA (Orgs). Agroindústria canavieira no Brasil: evolução, desenvolvimento e desafios, ch 10. Atlas, São Paulo, p 214–240
Shikida PFA, Perosa BB (2012) Álcool combustível no Brasil e path dependence. Revista de Economia e Sociologia Rural 50:243–262
Sistema de Informações de Frete (SIFRECA) (2011) Anuário 2010. http://log.esalq.usp.br/home/pt/livros.php. Accessed 10 Feb 2013
Sims REH, Mabee W, Saddler JN, Taylor M (2010) An overview of second generation biofuel technologies. Bioresour Technol 101:1570–1580
Souza ELL (2009) Etanol e bioeletricidade: a cana-de-açúcar no futuro da matriz energética. http://www.agencia.cnptia.embrapa.br/Repositorio/cana3_000g7qv8w9w02wx5ok0wtedt3lg1kjxs.pdf. Accessed 20 Jan 2013
Timilsina GR, Shrestha A (2010) How much hope should we have for biofuels? Energy, pp 1–15
Tolmasquim MT (2012) Perspectivas e planejamento do setor energético no Brasil. Estudos Avançados [online] 26(74):247–260. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40142012000100017&lng=en&nrm=iso. Accessed 03 Feb 2013
UNICA Brazilian Sugarcane Industry Association (2011) Ethanol and bioelectricity: sugarcane in the future of the energy matrix [coordination and supervision Eduardo L. Leão de Sousa e Isaias de Carvalho Macedo]. Unica, São Paulo
UNICA Brazilian Sugarcane Industry Association (2013a) Timeline. http://www.unica.com.br/linhadotempo/index.html. Accessed 04 Jul 2013
UNICA Brazilian Sugarcane Industry Association (2013b) Production. http://www.unicadata.com.br/historico-de-producao-e-moagem.php?idMn=32&tipoHistorico=4&acao=visualizar&idTabela=1325&safra=2011%2F2012&estado=RS%2CSC%2CPR%2CSP%2CRJ%2CMG%2CES%2CMS%2CMT%2CGO%2CDF%2CBA%2CSE%2CAL%2CPE%2CPB%2CRN%2CCE%2CPI%2CMA%2CTO%2CPA%2CAP%2CRO%2CAM%2CAC%2CRR. Accessed 10 Feb 2013
USDA United States Department of Agriculture (2011) EU-27 Annual Biofuels Report, July. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-27_6-22-2011.pdf. Accessed 14 Apr 2013
USDE United States Department of Energy (2013) Alternative fuels data center. http://www.afdc.energy.gov/data/tab/fuels-infrastructure/data_set/10331. Accessed 25 Apr 2013
Veiga Filho L (2008) Energia sustentável dinamiza a economia. Valor Econômico. http://infoener.iee.usp.br/infoener/hemeroteca/imagens/114791.htm. Accessed 10 Feb 2013
WCED World Commission on Environment and Development (1987) Our common future. Oxford University Press, Oxford
Xavier C, Rosa J (2012) Custos de produção de cana-de-açúcar, açúcar e etanol no Brasil: safra 2011/2012. http://www.agricultura.gov.br/arq_editor/file/camaras_setoriais/Acucar_e_alcool/21RO/App_ESALQ_A%C3%A7%C3%BAcar.pdf. Accessed 10 Feb 2013

Springer

http://www.springer.com/978-1-4471-6481-4

Liquid Biofuels: Emergence, Development and Prospects

Edwards, S. - Domingos Padula, A.; Silveira dos Santos, M.; Benedetti Santos, O.I.; Borenstein, D. (Eds.)

2014, XII, 272 p. 72 illus., 23 illus. in color., Hardcover
ISBN: 978-1-4471-6481-4