Chapter 15
The Future of Biofuel in Brazil

Modern production of ethanol for biofuel use started in Brazil, whose industry grew significantly until the 2010–2011 harvest season. Between 1998–1999 and 2010–2011, Brazilian sugarcane production grew from 315 to 620 million t, and ethanol production increased from 13.8 to 27.4 billion L.

However, after this period of rapid growth, there was a reduction in the production of both sugarcane (observed production of sugarcane was 559 million t) and ethanol (production was reduced to 22.7 billion L in the 2011–2012 harvest season). Several factors may explain this reversal: increased costs of production (through higher wages and land prices), the global financial crisis, lack of credit, climate and weather changes, indebtedness of productive units (and, consequently, the postponement of investment for renovation of sugarcane plantations), and loss of competitiveness of hydrous ethanol compared to gasoline.

Moreover, since 2008, there has been a drastic reduction in new investments for ethanol expansion in Brazil[1] contrary to the previous expectations of growth.

Key questions moving forward are how will the production of sugarcane ethanol in Brazil grows and at what pace, and what are the forces affecting the evolution of the biofuel industry in the country? Did the changes in the economic environment resulting from the 2008 global economic crisis, and more recently the economic difficulties faced by European countries, reduce concerns about climate change and thus the desire to further integrate biofuels? To what extent is society really concerned about greenhouse gas (GHG) emission reduction?

In order to fully examine these issues, it is important to consider the political and economic environments, both in Brazil as well as internationally.

As we have seen earlier, sugarcane is grown on a small amount of Brazil's farmland, occupying only 9.5 million ha of a total of 340 million ha of arable land. Of

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[1] As is presented later in this chapter, investments of around US$ 13.5 billion were carried out to optimize the production and marketing of existing ethanol companies, having been made for the renewal of plantations, infrastructure, industry (including cogeneration of electricity) and logistics.

M. Azanha Ferraz Dias de Moraes, D. Zilberman, *Production of Ethanol from Sugarcane in Brazil,* Natural Resource Management and Policy 43, DOI 10.1007/978-3-319-03140-8_15,

that amount, 4.6 million is used to grow sugarcane to be processed into ethanol, and that represents 0.5 % of Brazilian territory (850 million ha). The group of restrictions regarding the environment, economy, society, climate risks, and soil conditions, set by Agro-ecological Sugarcane Guidelines for Sugarcane (ZAE Cana), guides the expansion of Sugarcane in 7.5 % of Brazilian lands (64.7 million ha). According to ZAE, 92.5 % of the national territory is not suitable for sugarcane plantation. There is a potential to introduce up to 60 million ha of land for biofuel production without requiring any deforestation (Somerville et al. 2010).

Furthermore, productivity of sugarcane can be enhanced (De Souza et al. 2008; Zhang et al. 2006), and there are proposals to use bagasse as a feedstock for second-generation biofuels (Khanna and Zilberman 2012). With all of this potential, biofuel in Brazil can replace 25 % or more of the global gasoline supply (Zilberman 2013). The key question is to what extent this potential of biofuel will actually be met. Obviously, the answer lies in both economics as well as political considerations.

Despite the fact that many countries have goals of adding biofuels to fossil fuels in the coming years (as shown in Chap. 13), the frequent discussions about the benefits of the different types of biofuels, as well as the imposition of increasingly stringent rules regarding its production (resulting in increased costs), indicate that the large-scale adoption of biofuels should happen at a slower pace than originally anticipated.

When produced sustainably, biofuels can provide environmental benefits, create jobs, promote development, and increase energy security. But it is important to recognize that not all biofuels have the same benefits (IPCC 2011; Marelli et al. 2011; Johnson and Rosillo-Calle 2010). According to Nogueira et al. (2013), although ethanol always has the molecular form C_2H_5OH, its production from sugarcane in Brazil, corn in United States, and wheat and sugar beet in Europe are completely different. Results presented by Marelli et al. (2011) estimated that for eight feedstocks (4 for ethanol and 4 for biodiesel), the indirect land use change (ILUC)-generated GHG emissions from ethanol crops generally have lower ILUC impacts than oilseed/biodiesel crops. Emissions from ethanol feedstocks range from about 4 to 20 gCO_2/MJ, while ranging from about 36 to 60 gCO_2/MJ for biodiesel feedstocks. The authors point out that these JRC results are in line with the emissions calculated by the International Food Policy Institute (IFPRI) Report (Laborde 2011).

However, biofuels often tend to be grouped as a whole, and are thought of as having the same properties or impacts without considering that there are several sources of agricultural raw materials and production processes, each differing in terms of energy efficiency, competition for agricultural land use, water use, and level of GHG emissions reduction.[2]

[2] As is discussed later in this chapter, the "Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources," of October 2012, does not consider the differences in GHG emissions reductions of the alternative biofuels.

According to Gali (2011), serious concerns about large-scale ethanol production have been raised in terms of its effects on loss of biodiversity as well as competition for land between food and ethanol production. The author seeks to clarify these divergent views and conflicts concerning Brazilian ethanol. It is important that the life cycle of the product as well as the specifics of different alternatives both be considered in order to clarify the real benefits and impacts in each case.

The economic, social, and environmental benefits of replacing fossil fuels with ethanol from sugarcane produced in Brazil are widely discussed in the literature (Satolo and Bacchi 2013; Nassar and Moreira 2013; Moraes et al. 2011; Assato and Moraes 2011; IPCC 2011; EPA 2010; Neves and Castro 2013). Additionally, the American Environmental Authorities classified Brazilian sugarcane ethanol as an advanced biofuel (EPA 2010), as previously mentioned in Chap. 13.

Several authors (Adami et al. 2012; CGEE 2012; Goldemberg 2008; Goldemberg et al. 2008; Nassar and Moreira 2013; Neves et al. 2011) have presented evidence that the food versus fuel debate in Brazil is not an issue, given the large availability of raw materials and agricultural land in the country (as will be discussed later in this chapter).

The expansion of biofuel production in Brazil is regulated by several standards (as discussed in Chap. 14). These include the Agro-ecological Zoning standard, which considers maps of soil, climate and rainfall, topography, environmental regulation, and desire to respect areas that should be preserved. It also aims to reduce competition in areas dedicated to food production (MAPA 2009).

Despite the vast literature elucidating the social and environmental benefits of the production and use of Brazilian sugarcane ethanol, its recent expansion is lower than expected, and not consistent with the benefits mentioned. A key question then is, what is preventing such an expansion when it seems to be beneficial for both Brazil and the global population?

In addition to changes in the global economy, there will likely be negative impacts on the biofuel market that arise from new technologies enabling cheaper fuels to be obtained, such as shale gas through fracking. It is important that environmental externalities be considered in order to avoid cheaper, but less environmentally friendly fuels.

As discussed in Chap. 14, the current gasoline pricing policy has discouraged long-term investment in the expansion of ethanol production and in the infrastructure for its distribution and transport because the profitability of ethanol is unpredictable, and because there is a lack of transparency and no clearly defined rules for all of the players operating in this market. The pricing policy of Petrobrás aims to reduce gasoline price oscillations in the domestic market that are caused by international prices variations. Given current Brazilian macroeconomic conditions, including rising inflation, it is not expected that the federal government (via Petrobrás) will increase gasoline prices for consumers in the short term. This pricing policy reduces the consumption of hydrous ethanol[3] and consequently the expansion of ethanol production.

[3] The Brazilian consumer is very sensitive to the price differences between gasoline and hydrous ethanol, and usually chooses the cheapest fuel.

Several authors have shown that this policy is likely unsustainable for the Petrobrás: fixed gasoline prices at the refinery level induce losses for the company (importing gasoline at higher importation prices than sold in the domestic market). This policy makes hydrous ethanol less competitive than gasoline in the domestic market, so consumers choose gasoline instead of hydrous ethanol, thus increasing demand for gasoline and increasing the need to import.

The pricing policy applied by Petrobrás is bringing serious damage to company (Romero 2013; Ming 2013; Pires 2013; Zylbersztajn and Pires 2013; Safatale 2013). Among the main causes of cash flow problems for Petrobrás is the misalignment of consumer prices in relation to prices in the international market (Ming 2012). As the company cannot process the entire volume of fuel (within Brazil) needed to meet domestic demand, Petrobrás is forced to sell in the domestic market at prices lower than what it pays to external suppliers. This policy affects the investment capacity of the company. Furthermore, Pires (2013) emphasizes that it is inexplicable how gasoline and diesel have been exempted from payment delegated by the *Contribução para Intervenção Domínio Econômico* (CIDE, Contribution for Intervention in the Economic Domain). According to the author, the government has failed to collect R$22 billion from gasoline since 2008. This exemption has caused a loss of competitiveness in the fuel sector and a reduction of Petrobrás' investment in the sector, not to mention the portion of the CIDE that would be divided among municipalities.

Although unsustainable, there are no expectations, at least in the short run, of increases in gasoline prices in Brazil. This scenario reinforces the need to reduce costs and increase production efficiency of ethanol so that it may compete with gasoline prices charged in the country. In the next sections, we discuss these issues more comprehensively.

Can Brazil Expand Ethanol Production in a Sustainable Way?

The possibility of expanding the demand and exports of sugarcane-derived products, including ethanol, highlighted the importance of having its production occur in a planned and well thought-out manner in order to preserve natural resources.

As shown in Chap. 13, Brazil has one of the most complex, rigorous, and advanced environmental legislations in the world. The Agro-ecological Sugarcane Zoning Guidelines for Sugarcane (Decree no. 6,969, issued in September 2009)[4] was an initiative to induce the expansion of sugarcane production in areas that are agronomical as well as climatically and environmentally suitable, created a national map of the areas considered appropriate for the expansion of sugarcane cultivation. This pioneer initiative was essential in guaranteeing the sustainable growth of sugarcane production.

[4] Available at: http://www.cnps.embrapa.br/zoneamento_cana_de_acucar/ZonCana.pdf.

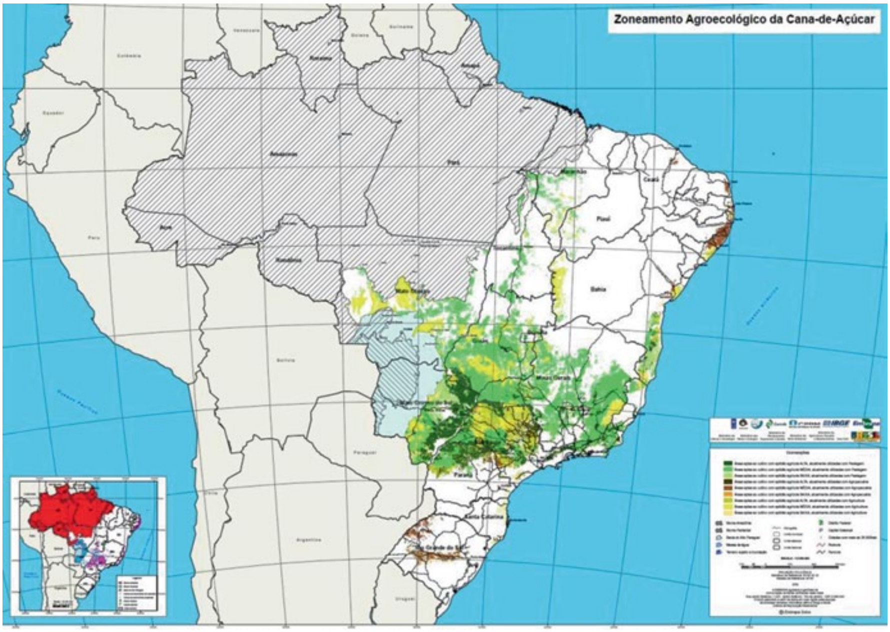

Fig. 15.1 Agro-ecological Sugarcane Zoning

In general, the criteria and guidelines adopted represent a strict control over the expansion of sugarcane cultivation in the country. The rules established by the Agro-ecological Zoning include: (1) No sugarcane expansion or new ethanol production facilities in sensitive ecosystems like the Amazon, the Pantanal wetlands, and the Upper Paraguay river basin. (2) No clearance of native plants to expand sugarcane cultivation anywhere in the country (this order protects the native Cerrado). (3) Identification of suitable areas where sugarcane can be produced should be prioritized. These areas include land with proper conditions for the use of mechanical harvesting, cattle breeding areas that are underused or degraded (more than 34 million ha), as well as regions with a lower need for water usage in production.

Looking at the map given in Fig. 15.1, it is clear that the industry has reached its limitations in the São Paulo state area and that its expansion should occur in states such as Minas Gerais, Goias, and Mato Grosso do Sul e Mato Grosso, as is already being seen.

Thus it is important to emphasize that the expansion can occur without deforesting preserved areas across the country. However, many of the areas where biofuel can be grown are areas that are not being cultivated with sugarcane today or are degraded pasture areas that require significant investments.

Besides agricultural and industrial investments themselves, there is also demand for investments in infrastructure (building pipelines and other infrastructure to move biofuel to the coasts or target areas), qualification and training of workers, etc.

Investments

In terms of expansion of biofuel capacity in Brazil, immense investments in infrastructure will need to be made by both the public and the private sectors. The public sector needs to develop the infrastructure to provide the training and knowledge in introducing biofuel in areas that have not been under production before, and develop financial mechanisms to start a new industry. The public sector may also need to develop a system of property rights that can provide access to investors to develop feedstocks as well as refining capacity. These investors may be from Brazil or other countries. When it comes to investment of biofuel by both the public and the private sector, key questions are how does public sector investment in biofuel stand up to other investments considered by the government, and how does it fit the macroeconomic environment? A key element for assessing the return on this investment is its profitability, which depends on future demand for biofuel. The various policies that affect the future of biofuel reflect a political economic perspective, which will be provided later in the chapter.

With respect to private investments made in recent years, it has been observed that, although they were reduced drastically in new production units (which occurred significantly between 2006 and 2010), the investments made in recent years occurred in agricultural areas, the industry itself, and in the logistics of production. According to Farina (2013), the negative economic conditions the industry faced in the past several years resulted in major structural changes of the sugarcane industry, with redirection of investments (previously designated to the construction of new plants) to production optimization, seeking efficiencies and productivity gains.

Farina (2013) presented data on investments in logistical and technological gains, including tillage practices, achieved over the last years. She suggests that even considering the closure of nearly 40 industrial units in the last five seasons, the balance of production is still very positive. More than 100 plants were opened in the last decade, creating a jump in production capacity by more than 120 million t during this period.

Farina (2013) pointed out the major targets of these investments: those involved with the consolidation of the sector, the entry of large groups, and new international agents including trading and oil companies (also discussed in Chap. 13). It is estimated that during this process, about one-third of the assets changed hands, resulting in increased economies of scale in the industry. She pointed out that during the 2005–2006 harvest season, the top five groups were completely held by national capital, while in the 2010–2011 season, each of the top five groups consisted of some proportion of international capital.

Another area of increased investment was in logistics, including construction of railways and port terminals for sugar exports. According to Farina (2013), investment in this area exceeded US$ 1.5 billion, which should reduce logistics (transportation) costs for export of sugar by 15% in 2015. As for logistics in the exportation of ethanol, the estimated investments (US$ 3.5 billion until 2017) in ethanol pipelines being constructed by the consortium Logum[5] should decrease the logistical costs by 30 % when operational.

The author also cites private investments in production optimization. In sugarcane fields, harvesting mechanization occurred between 2006 and 2012 and reached 4 million ha under an investment of US$ 4.5 billion. Only in 2012 did the investment amount reach US$ 4 billion in renovation of the sugarcane plantations in the Center-South region. Furthermore, Farina (2013) also pointed out investments in research for the genetic improvement of sugarcane and second-generation ethanol, which will improve productivity. She cited estimates from the Sugarcane Technology Center (CTC) indicating that the current production of 7,100 L/ha can more than triple by 2025.

According to the Banco Nacional de Desenvolvimento Econômico e Social (BNDES) Sectorial Report in June 2013, the BNDES' disbursements to the sugar-ethanol industry segment fell for the second year in a row in 2012. However, to accelerate technological development in the industry, the BNDES began to prioritize innovation projects, especially after its successful experience with the Innovation Support Plan for the Sugar-Ethanol and Sugar-Chemical Sectors (PAISS).

Thus, although no investments have been made in new greenfield plants in Brazil during the recent period, there have been a large amount of investments aimed at increasing agricultural and industrial productivity, which expanded sugarcane, sugar, and ethanol production in existing units and in new plants already created up through 2011.

What Are the Factors Hindering (or Slowing) Sugarcane Ethanol Expansion?

Food versus Fuel and ILUC are the two most relevant indirect effects associated with the biofuels debate. The food versus fuel debate, as discussed previously in Chap. 14, represents a global concern that has been widely addressed in the media regarding the production of biofuel using agricultural feedstocks (especially maize, sugarcane, and cereals). It has been accused of displacing land that could be used to produce food, causing food prices to increase and threatening food security in certain regions. However, in Brazil there is enough available land for the production of food and biomass for biofuels (CGEE 2012; Goldemberg 2008; Goldemberg et al. 2008; Nassar and Moreira 2013; Neves et al. 2011). For example, agricultural expansion has been taking place in degraded pasture areas because the productivity

[5] Logum Logistics is an association of six Brazilian companies: Petrobrás, Raizen, Uniduto, Camargo Correa, Odebrecht and Copersucar. It is responsible for the construction and operation of the logistics system for ethanol based in pipelines, waterways, ports, and terminals. The integrated system is responsible for loading and unloading, handling and storage, and operation of terminals and inland waterways.

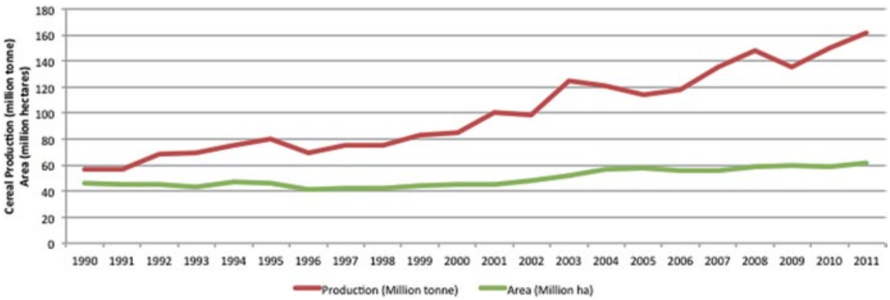

Fig. 15.2 Evolution of cereal production and area. (Source: Elaborated from Instituto Brasileiro de Geografia e Estatística (IBGE) data (several years). Note: Cereals include cotton, peanuts, rice, oats, rye, barley, beans, sunflower, castor, corn, soybean, sorghum, wheat, and triticale)

of livestock production has increased significantly, from 0.92 heads/ha in 2000 to 1.15 heads/ha in 2010 (IBGE 2012; Fiesp 2012; Nassar and Moreira 2013).

According to Rosillo-Calle (2012), biofuel production and food security needs to be complementary. It is important to assess food security impacts from biofuel production, and it is equally important to assess the benefits that these alternative fuels generate if they meet their most important objective, which is the reduction of GHG emissions. Under appropriate conditions, biofuels can even be an important factor for improving the food security in some African countries (Lynd and Woods 2011).

Much of the evidence indicates that the expansion of sugarcane ethanol in Brazil has not undermined food production. The same evidence also shows that concerns regarding a direct causal relationship between ethanol expansion and native land conversion are not supported in reality. This evidence is based on the following facts: (1) Brazilian agriculture is facing a process of intensification and efficiency gains with increasing yields in crops and livestock. (2) There is still a lot of space for intensification of cattle production in Brazil. (3) Brazil has developed a double-cropping system that allows the production of soybean and corn on the same land in the same year. (4) The expansion of sugarcane for ethanol, although very strong, has not undermined the expansion of other annual and perennial crops. Therefore, rather than a food versus fuel scenario, the reality in Brazil shows a food and fuel situation. The cultivation of oilseeds in rotation with sugarcane is also generating food and fuel in the same systems (Flight Path to Aviation Biofuels in Brazil: Action Plan 2013 and Nassar and Moreira 2013).

Figure 15.2 presents the evolution of crop production in Brazil. Trends of increased production as well as a reduction in the production area can be observed, indicating an increase in productivity. Thus, it is evident that the increased production of sugarcane in Brazil has not reduced the production of cereals.

Similar situations can be observed for cattle production and pasture areas, as is shown in Figs. 15.3 and 15.4.

In regards to ILUC, there are many scientific articles and great controversy on the ILUC effects of biofuels. Thus far there is no widely accepted methodology and an insufficient amount of data to calculate ILUC in a robust way.

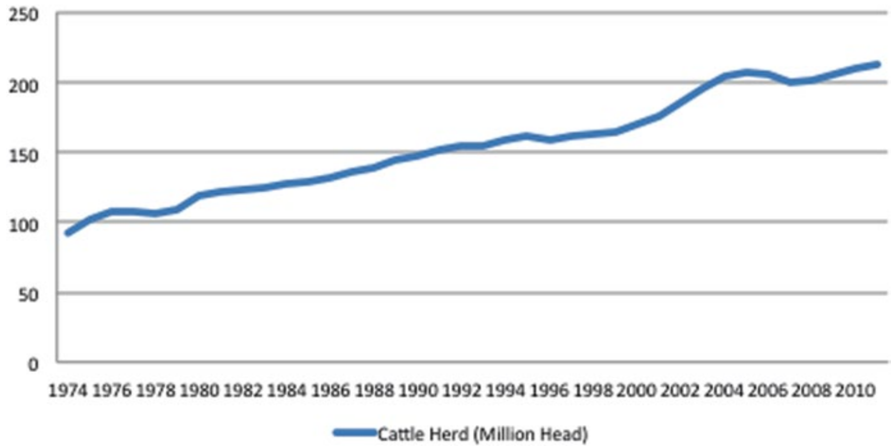

Fig. 15.3 Evolution of cattle herds (million heads). (Source: Elaborated from IBGE data (several years))

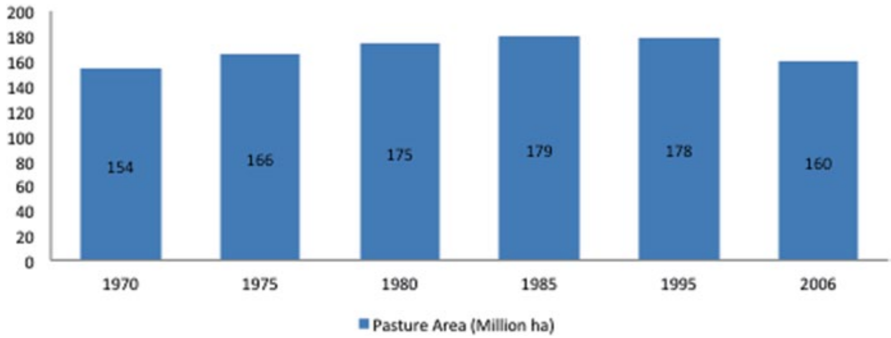

Fig. 15.4 Pasture area (million ha). (Source: Elaborated from IBGE data (several years))

As covered in Chap. 14, there are regulations in place related to indirect land use change emissions of biofuels in both Europe and the U.S. (only the U.S. has defined a methodology to measure ILUC while the Renewable Energy Directive (RED) states that all relevant indirect effects must be considered). However, the concepts and methodologies used to measure ILUC are still being discussed.

In April 2009, the California Air Resources Board (CARB) approved the specific rules and carbon intensity reference values for the California Low-Carbon Fuel Standard (LCFS), which includes ILUC considerations. For some biofuels, CARB identified land use changes as a significant source of additional GHG emissions. Sugarcane ethanol from Brazil was considered an advanced biofuel due to its verifiable 90 % GHG emission reduction.

In February 2010, the US Environmental Protection Agency (EPA) issued its final Renewable Fuel Standard (RFS2) regulation for 2010 and beyond. It incorporated direct and significant indirect emissions, including ILUC. EPA's analysis accepted both ethanol and biobutanol produced from corn starch as renewable fuels. Ethanol produced from sugarcane was classified as an advanced fuel. Diesels produced from algae oils, biodiesel from soy oil, and diesel from waste oils, fats, and greases fell in the "biomass-based diesel" category. Cellulosic ethanol and cellulosic diesel met the "cellulosic biofuel" standard. Thus, exports of sugarcane ethanol to the US market are feasible (as is already happening today) given that it meets the sustainability requirements established.

In contrast, the European market seems to be closed to biofuels each day. In October 2012, the European Commission decided to include amendments to the Directive 98/70/EC and to the Directive 2009/28/EC,[6] claiming two main concerns: (1) environmental, notably the ILUC effect, and (2) social, which is the impact of biofuel production on the production of food.

Unlike the U.S. (which incorporated the ILUC effect for the different biofuels to evaluate GHG emissions), the EU, understanding that scientific studies addressing this issue are not yet sufficiently clear to be included in legislation,[7] decided to limit the proportion of first-generation biofuels made from agricultural raw materials (including ethanol from sugarcane) to 5 % of the fuel supply. All support for first-generation ethanol ends in 2020. Incentives for the growth of advanced biofuels on nonarable land are expected to cause its further expansion into the market. The remaining growth in the biofuels market is expected to come from advanced biofuels grown on nonarable land, for which incentives are also increased.

This way, in the case of the EU, first-generation fuels will only be able to make up half of the existing blend mandate, which calls for the incorporation of 10 % biofuel in liquid fuels. However, this 5 % share includes both biofuels that meet the minimum level of emission reduction (which is 35 %)[8] and ethanol from sugarcane, which has reductions over 75 %. It seems that the logic of this legislation is more technological (i.e., prevent the use of agricultural raw materials for biofuel) than effectively linked to GHG emissions reductions.

Therefore, any biofuel produced from food crops, such as cereals and other starch rich crops, sugars, and oil crops is considered a conventional biofuel and its participation in the EU 2020 renewable energy target in transportation is limited to 5 %. The intention of the EU authorities is to stimulate the growth of biofuels whose production does not require agricultural land but rather uses land that is not suitable

[6] These amendments are under scrutiny by the European Parliament and the Council (until September 2013).

[7] The ILUC factor will not be counted in the calculation of emissions, but should be informed, for signaling to the market.

[8] RED dictates minimum CO_2 savings of 35 % GHG savings from biofuels compared to petrol and diesel in order to qualify for the 10 % target and receive state subsidies.

for producing food. These fuels are named “low-ILUC advanced biofuels” (Nassar and Moreira 2013).

Implementing this measure risks the end of the European market for ethanol, since the 5 % will likely be filled with biodiesel (approximately 80 % of the biofuel market in Europe). This should be interesting for the distributors of biofuels, given that the EU has a deficit of diesel. According to Thomsen (2013),[9] EU’s dependence on foreign oil is great. In 2010, approximately 83 % of oil used in the EU was imported, and this proportion is likely to increase since domestic production is declining faster than consumption (Thomsen 2013).

Sugarcane ethanol producers’ ambition to include it in the EU is greatly reduced if the restricting amendments are approved. Besides the complaints from Brazil (Kutas 2013), there are representatives of European ethanol producers who look for and determine the impacts of these amendments (Vierhout 2013). Thus, instability and changes in rules and policies for biofuel is a factor that explains not only the reduction of investments in Brazil, but also in European countries themselves.

Long-term investment certainty and policy stability are key for the growth of biofuels and the attraction of long-term investments. According to Vierhot (2013), EU decision makers are undermining their credibility due to the changes in biofuel protocol they are implementing “halfway through the game”, so to speak.

Institutional instability (both national and international) also impacts long term investments in new “greenfield” units in the country, as it is unclear how many new plants will be needed given the changes in rules and the potential demand.

According to Pedro Parente, president of Bunge company in Brazil, investments to increase the processing capacity of sugarcane in Brazil are still “on hold” until the Brazilian government sets a clear policy on fuel pricing and electricity in the country. In August 2011, Bunge announced investments of US$ 2.5 billion to increase the cane crushing capacity from the current 21–30 million t. The expansion project announced by the company predicted that the production of ethanol and sugar would increase 50 % and the energy cogeneration from bagasse six-fold. However, Parente said the investment announced in 2011 could only be achieved if the company is able to calculate the rate of return, which depends both on the price of ethanol and electricity. Without a forecast of the price formation of these two products, there is no way to project the return and the project continues to remain on hold. (Valor Econômico, Junho 2013).

This way, to plan for the future, a clear and stable regulatory framework, including a well-developed system of property rights, is essential in order to attract the necessary long term investments.

[9] Brita Thomsen, member of the European Parliament.

Segment	Amount (US$ billion)	% of Total
Exploration & Production (E & P)	147,5	62%
Supply	64,8	27%
Gas & Power (G & E)	9,9	4%
International	5,1	2%
PBio Petrobras Biofuels	2,9	1%
BR Petrobras Biofuels Distributor	3,2	1%
ETM	2,3	1%
Other Areas[1,2]	1	0,4%
Total	237,7	100%

Fig. 15.5 Business Plan and Management 2013–2017 (US$ billion). (Source: Petróleo Brasileiro S.A.—Petrobrás Companhia Aberta. FATO RELEVANTE. Plano de Negócios e Gestão 2013–2017)

The Role of Petrobrás

To analyze the future of the biofuel industry in Brazil, it is interesting to look at its political and economic reality. At the time of Proalcool, ethanol was viewed as an alternative fuel to solve the foreign exchange problems and soften the cost of importing gasoline, and was not considered to be as much of an export good.

However, since the discovery of the pre-salt oil reserves, Brazil realized its potential to become a big player in the international oil business, and decided to make a US$ 250 billion investment in pre-salt oil rather than make a similar investment in biofuel production that would produce as many gasoline-equivalent liters of ethanol annually.

Though representatives of Petrobrás (Rossetto 2013) claim interest in the area of biofuels, when analyzing the investments Petrobrás has made towards biofuel, it can be seen that they are marginal (about 1 % of total investment). The biofuel investments are distributed between projects for biodiesel and ethanol (Fig. 15.5).

The Chicken and Egg Problem of the Future of Biofuel Supply in Brazil

Thus far, biofuel has been adopted on a large scale in Brazil, a somewhat smaller scale in the U.S. and a much smaller scale over the rest of the world. Both Brazil and the U.S. have one thing in common: they can grow biofuel due to large amounts of arable land. For them, as we have seen before, biofuel can address exchange rate challenges and support the local agricultural sector, reduce vulnerability to oil supply crises because of political or economic reasons, and combat concerns about climate change. Even in the U.S., the adoption of biofuel in 2013 has been constrained by the blend wall, namely the government has set a limit on the upper bound on the amount of ethanol that can be mixed safely with gasoline in automobiles. Raising the blend wall has faced objections because of added risk to existing vehicles (Plummer 2013). Even if the blend wall in the U.S. is increased to 15 % or 20 %, the amount of ethanol that can be added is significant, yet still limited.

There are debates about the future investment in ethanol in the long run, and whether or not the United States should use two fuels (hydrous and anhydrous) or if they should only use anhydrous ethanol and mix it with pure gasoline. Brazilian experience indicates that the best way to use biofuels is in a mixture with gasoline. Having two types of ethanol, completely different infrastructures, different pumps in gas stations, different pricing polices, and so on will lead to significant transaction and regulatory costs (Moraes 2011). In addition, ethanol has some disadvantageous properties compared to butanol and other fuels, and is viewed by some authors as a transitional fuel. Its main advantage, however, is that it is currently cheaper to produce under existing infrastructure (Fountain 2012).

Because of fuel security concerns, several countries need to reduce dependence on Middle Eastern oil. Countries are also concerned about climate change, which has already led some of them (as mentioned in Chap. 13) to adopt blended mandates, and may lead more countries, like Japan, with limited capacity for production of biofuel to consider introducing biofuel mandates that will create demand for ethanol. However the introduction of such policies is unlikely if supplies of ethanol or other biofuels are not assured.

Two factors prevent countries from relying on biofuel exports from Brazil as part of climate change and energy strategy. First, Brazil was challenged in meeting its own ethanol needs towards the end of the first decade of the new millennium (around 2010). Sugarcane yields were declining in parts of Brazil for several reasons in this period, as mentioned in Chap. 14. Since 2007, it has been importing ethanol for domestic consumption and has reduced the anhydrous ethanol requirement for gasoline during certain periods (according the limits of the legislation). A related problem is lack of assurance about obtaining access to ethanol by international buyers. Thus, without an assured source of ethanol, many countries, especially those without much capacity to produce biofuel themselves, will not engage in legislation to mandate ethanol. This lack of sufficient capacity to export ethanol by Brazil combined with the uncertainty about the prospects of second-generation biofuels reduce the creation of demand for ethanol by countries that may be potential buyers of this biofuel.

Of course, this lack of immediate demand for biofuels may prevent Brazil from further developing its ethanol industry, introducing a chicken and egg problem that may slow the evolution of biofuel in Brazil. One hypothetical way to break this logjam is through long-term commitments to expand biofuel production in Brazil and to secure supplies for foreign buyers even in periods of shortages by using private long-term contracts. The government, through incentives and collaboration with actors in the private sector, may strive to establish long-term markets for Brazilian ethanol. These kinds of efforts require financial resources that may be lacking, but may also encounter deeper obstacles related to the political economy of biofuel, which will be discussed below.

The Political Economy of Biofuel in Brazil

Economists have realized that the principles of self-interest rational choices and collaboration and exchange between agents that explain market outcomes are useful for analysis of political outcomes, leading to the emergence of the literature on political economics. One strand of the literature emphasizes choices by regulators and bureaucrats (Romer and Rosenthal 1979), while another strand of literature originated from the Downs (1957) model of the median voter, which analyzes outcomes under various voting schemes and governance structures. An early model of regulatory behavior is the capture model (Posner 1974), which claims that regulatory agents may be dominated by and serve the interest of the regulated industry. The regulated may influence regulators by information and economic power (Levine and Forrence 1990). Grossman and Helpman (2001) and Rausser et al. (2012) overview frameworks that accommodate the multiple players in political systems. Following Becker (1985), they argue that politicians and regulators aim to get reelected and gain personally from their position, and thus introduce policies that garner support—both electoral and financial—from interest groups. These choices are constrained by economic, institutional, and cultural constraints.

We will provide the perspective of select interest groups that are relevant to biofuel and energy policies and the government, and use both parties to interpret existing policies and hypothesize about future biofuel directions in different countries.

Low- and middle- income consumers are interested in low fuel prices, i.e., continuous social welfare support that suggests setting limits on fuel prices. It also suggests need for government income to finance income transfer. Thus, consumers will support biofuel as long as it reduces fuel prices and does not deplete government budgets.

According to Dunning (1981), a country is more likely to internalize the ownership of unique resources and is more open to foreign investment when it complements domestic resources. This nationalistic attitude may explain the establishment of strong oil companies and restrictions on foreigner land ownership in countries like Brazil, Mexico, and other developing countries. Additionally, while it is clear that the government and military are aware of natural resources, the extent to which regular citizens are aware of them is unclear (Stapp et al. 1969). But ownership of natural resources can be raised in elections to be a topic of national pride that may gain popular support.

Environmental groups are also an important part of the biofuel debate. In Brazil, the two major concerns are climate change and deforestation. Different environmental groups have varying agendas: some are suspicious of any expansion of land use because they believe that expansion of biofuel, even away from the Amazon, may have secondary effects leading to deforestation, while others, who are mostly concerned about climate change, may view biofuel as an effective mechanism of abatement and reduction of GHG emissions. On the other hand, individuals concerned about deforestation and expansion of farmland may worry that any expansion of farmland, even far from the Amazon, may lead to further deforestation for biofuel purposes. There are articles (Havlik et al. 2011; Lima et al. 2011) that suggest that biofuel may be associated with deforestation, however, as exposed in the previous sections, there are several studies and conversations held with Brazilian environmental groups suggesting that Brazil has large reserves of land and that the expansion of sugarcane biofuel will not have a significant impact on deforestation. However, there is much greater concern about biodiesel from soybeans.

Sugarcane and ethanol producers are interested in high prices for sugar and ethanol. They are also interested in low prices of inputs, including credit, and thus are interested in government credit support programs as well as other support policies. At the same time, they are interested in minimal environmental regulation loads. Farmers may also support government policies that promote investment in research to increase productivity and infrastructure projects that reduce operation costs, for example, building ethanol pipelines, improved roads, and water projects. Obviously farmers are not a homogenous lot; they are heterogeneous in terms of location, crops, and size, and farmers of different categories may have different preferences. The changes of ownership in the biofuel sector and the expansion of production to other regions may change the power distribution within agriculture and its political influence (Lehtonen 2011). If the expansion of biofuel takes place in other regions outside of São Paulo, it is not clear to what extent the existing São Paulo sugarcane producers will support it politically.

Brazil has a presidential system, and in a system of this type, executive branch considerations have more significant weight than in a parliamentary system (Linz 1990). In the case of Brazil, the current president is an expert in issues of energy, which is one area in which she has direct influence (Moreira 2010). Generally, the executive branch is concerned with several aggregate measures of performance (balance of trade, economic growth, climate change, budget deficit, and inflation) that apply to the economy as a whole as well as the needs and desires of interest groups. Thus, in case of Brazil, the government aims to develop policies that will keep the price of fuel as low as possible (to avoid increases in inflation), and at the same time uses fuel as a source of income through taxation (ability to implement an income tax is limited). As a result, the Brazilian government established a fuel tax and set an upper bound on gasoline price at the refinery level. At the time of the Proalcool creation, as previously analyzed, Brazil was mostly an importer of oil, and a major incentive to introduce ethanol was for the purpose of improving balance of trade. The government may subsidize biofuel to some extent because its production makes Brazil look better from a climate change perspective. However, this subsidization is limited by the government's budget deficit. In certain periods the taxation of ethanol may be lower than gasoline, but this is not the case today, as analyzed in Chap. 13. Finally, the government is interested in pursuing projects that institute power and capacity, which may lead to support for activities like big investment in oil, which carries other advantages as well (balance of trade, employment, growth, political power, etc.) (Sachs 2007). The government may also be interested in further developing biofuel, but may be hampered by budgetary constraints and will be dependent, to a large extent, on the private sector to do the job.

The energy sector in Brazil, like other developing countries, is dominated by a national oil company, Petrobrás, which is partially owned by the state. Petrobrás optimizes its activities subject to the constraints imposed by regulation and interests of the state (Mueller and Pereira 2002; Pires and Silveira 2013). The company is run as an oil company, and its management is much more familiar with oil than it is with biofuel, and they are personally interested in developing oil production rather than biofuel. Furthermore, Petrobrás receives first priority in developing oil reserves in Brazil, and while it needs to pay the government a significant royalty, it retains all of the rents gained from the oil. It needs to cover the costs of exploration, which can be very substantial, but once the reserve is discovered, the marginal gain is significant and will go directly to the company.

In the case of biofuel, about 25 % of the raw material is produced by sugarcane producers, and the rest produced and processed by mills. Thus, these enterprises will capture much of the rent, which may make ethanol less appealing to Petrobrás. However, Petrobrás' main obligation is to meet Brazil's need for fuel. Since Petrobrás emphasizes development of gasoline and other oil-based products as their main avenue to the international market, and views ethanol mostly as a fuel to replace fossil fuels in the domestic market, it may not be very supportive of development of biofuel for export by other companies, domestic or international.

Capture theory can provide one lens to look at the relationship between Petrobrás and ANP,[10] the regulatory agency of fuels in Brazil. However, the agency power is limited and oil and energy policies are affected by the larger political system (Mueller and Pereira 2002; Fishman 2010).

Who will be interested in developing biofuel for both the domestic market as well as for export? As we argued earlier, Brazil has up to 60 million ha of land that can be developed for biofuel, and only a small fraction of this land needs to be used to augment domestic consumption, thus much of this development will aim to target the export market. As mentioned earlier, Petrobrás has a strong preference for the development of oil, and moreover it made a R$ 250 billion investment in pre-salt oil (Busquet 2010) and faces large constraints.

This opens the door for another set of players that have the capacity and knowledge to develop biofuel and market it. Natural candidates are oil companies in the U.S. or European countries with limited domestic reserves; companies include BP, Chevron, Shell, and Total. Their home countries are running out of oil and have few reserves, and may have a difficult time competing for access to reserves in developing countries with strong national oil companies. Furthermore, the continuous large-scale pursuit of the development of oil reserves implies that many players in

[10] Agência Nacional do Petróleo, Gás Natural e Biocombustíveis.

the market do not see climate change as a main constraint on the profitability of oil over the next 40–50 years. Perhaps the European companies have stronger belief that climate change will be an important issue in terms of oil prices, and having an alternative that is environmentally sound will be a good diversification strategy in case climate change considerations limit profitability of oil.

However, the investment by international companies in the development of biofuel in Brazil may be constrained by several factors. First, Brazilian ethanol obtains a premium in the international market if it is perceived to be environmentally superior to fossil fuel. Concerns about deforestation or any other side effect of ethanol may reduce its appeal to international investors. Since many of the concerns about the environmental side effects of ethanol may be small because of the vast amount of nonforest land that can be developed, the international companies and their Brazilian allies face the challenge of convincing the world that this is the case.

The second, and perhaps more significant constraint, is the limitation on ownership of land by international companies in Brazil. Ideally, companies will be able to buy land cheaply, develop it for biofuel production, and gain from the appreciation in the value of the land. But meetings to work with local partners and developing a constraint on the ability to sign long term contracts may constrain the capacity of international companies to invest in Brazil.

The third factor is a resource availability constraint in the areas where biofuel can be developed. The frontier areas of Brazil lack the manpower needed for massive development efforts. Large-scale development of new biofuel infrastructure will require significant effort in identifying and relocating talent to these areas, and while oil companies have strength working in remote areas, they are not as strong in developing farming capacity in new regions. They may need to establish alliances with biofuel companies, both domestic and international, in order to engage in large scale development efforts. Moreover, some of the activities that are required for development are public goods, like roads and pipelines, and companies would not be willing to invest in these activities alone. They will need the help of government or develop consortiums, which again takes time and requires institutional innovation.

Finally, most oil companies do not have the accounting procedures that project the value of investment in biofuel appropriately. When oil companies invest in developing oil fields, they know that if successful, the reserves are easily translatable to monetary terms. But what is the value of developing biofuel production potential, especially when a company does not own the land and much of the production is done by contract farmers? The share of rent and revenue for biofuel may be smaller than with oil, as it has to be shared with the farmers. The randomness of yield and prices also increases uncertainty, another disadvantage compared to oil. At the same time, these rents may last indefinitely because, unlike oil reserves, we are speaking about a renewable resource. Furthermore, refining and production technology is continuously improving over time, and improvements in this technology will increase profitability per unit of capacity. Once companies develop procedures that capture the profitability of biofuel, it is more likely that they will invest in it.

Likely Scenarios

Given our analysis, we foresee several different scenarios about the future of biofuel in Brazil. The lack of obvious demand for biofuel beyond Brazilian domestic demand and some demand in the U.S. combined with political economic factors that deter major investment in expansion of biofuel in Brazil will most likely lead to moderate expansion of the biofuel sector. Much of this expansion will take place through improvements in the performance of existing facilities, but some will take place by expanding the land area utilized by the industry, especially in inland regions.

However, there may be some situations where the growth of biofuel may occur much faster. For example, an entrepreneur or a company may be able to obtain an agreement with a country that introduces a mandate guaranteeing a certain level of purchasing of biofuel. In this case, the entrepreneur may invest in infrastructure that will provide the amount required by the purchasing country, thus solving the chicken and egg problem mentioned previously. Once such an agreement is established, it may lead to a precedent for other agreements that will accelerate the growth of the biofuel industry. As mentioned before, the property rights scheme must be very well defined.

Another scenario that will accelerate the development of biofuel in Brazil is growing evidence and concern about climate change, which will lead to more effective action, for example a carbon tax or a binding tradable permit system. Such systems will make biofuel more attractive and petroleum less attractive. If the likelihood and negative effect of climate change becomes more apparent, it may be that companies like Petrobrás will reduce their commitment to new fossil fuel production and expand their interest in biofuel.

The future of biofuel also depends on productivity. Increased yield of feedstocks, better varieties, and improved cultural practices make biofuel more competitive, lead to enhanced supply, and may induce countries that do not use it to give it a second look. Furthermore, improvements in refining technologies, especially for cellulosic ethanol, may make it profitable to produce biofuel from bagasse and sugarcane leaves, which would be another source of expansion of biofuel yield and profitability. Problems, both in terms of production as well as the food vs. fuel tradeoff, which may hamper profitability of corn ethanol, may also lead to expansion of sugarcane ethanol. Additionally, biofuel may face a dimmer future if, for example, electric cars are introduced intensively because of improvements in battery capacity or through more efficient hybrid technology.

Thus far we have spoken about ethanol, but biofuel may include a wide variety of products, and over time as biofuel science continues to advance, sugarcane may become the primary feedstock not only for producing ethanol but other fuels as well, including biodiesel. As a result, we expect that the development of biofuel in Brazil may be associated with the development of research capacity and, more importantly, with the development of a refining industry that produces different kinds of biofuel both for domestic consumption and export.