Chapter 2
Sugarcane Ethanol: Strategies to a Successful Program in Brazil

José Goldemberg

Abstract Presently, ethanol from sugarcane replaces approximately 50% of the gasoline that would be used in Brazil if such an option did not exist. In some aspects, ethanol may represent a better fuel than gasoline and to a great extent a renewable fuel contributing little to greenhouse gas emissions in contrast with fossil-derived fuels. Production of ethanol increase from 0.6 billion liters in 1975/1976 to 27.6 billion liter in 2009/2010. Although production costs in 1975/1976 were three times higher than gasoline prices in the international market, such costs declined dramatically thanks to technological advances and economics of scale becoming full competitive (without subsidies) with gasoline after 2004. This was achieved through appropriate policies of the Brazilian government. These policies and the rationale for them as a strategy to reduce oil imports are discussed here with the possibilities of replication in other countries.

1 Introduction

Sugarcane has been cultivated in Brazil since the sixteenth century and more recently the country became the largest producers of sugar accounting for approximately 25% of the world's production. The production of ethanol has been small but starting in 1931 the Government decided that all the gasoline used in the country (mostly imported) should contain 5% of ethanol from sugarcane. This was done to benefit sugar producing units when faced by declining prices of sugar in the international market which notoriously fluctuate over the years (Fig. 1).

Around 1970 the sugar industry in Brazil was stagnated, processing only 70–80 million tonnes of sugarcane per year mainly due to Government policies of guaranteed prices to producers: when the international price of sugar was low the

J. Goldemberg (✉)
University of São Paulo, Institute of Eletrotechnics and Energy, São Paulo, Brazil
e-mail: goldemb@iee.usp.br

J.W. Lee (ed.), *Advanced Biofuels and Bioproducts*, DOI 10.1007/978-1-4614-3348-4_2,

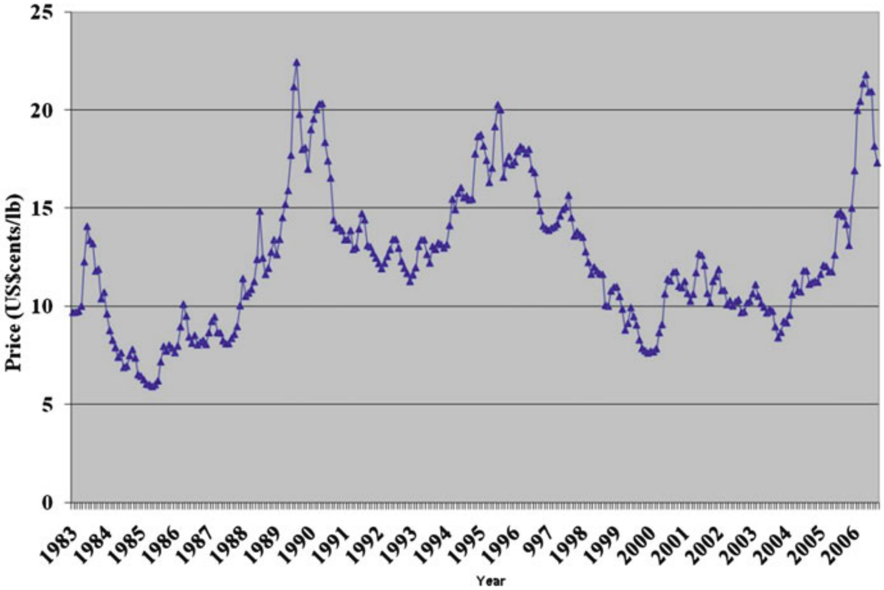

Fig. 1 World refined sugar price—1983/2007

government purchased the sugar at prices that satisfied the producers. Competition and modernization were thus discouraged; each producer had a quota and therefore few concerns about losing money. Sugar producers did not plan in the long run and usually produced strictly what they considered attractive in a given year. Since the price of sugar in the international markets varies significantly over time, as seen in Fig. 1, such lack of planning frequently left them out of the market when prices suffered strong fluctuations [1].

The solution proposed at that time by Ministry of Industry and Commerce [2] was to expand production regardless of the prices of sugar and use the excess production (when prices were low) to produce ethanol which was more expensive to produce than gasoline. One of the drivers for that was the need to eliminate lead components from gasoline (lead tetraethyl) which was imported saving thus foreign currency. Such ideas did not prosper until the oil crisis of 1973: the cost of oil went suddenly from US$ 2.90 per barrel to US$ 11.65 per barrel. The import bill with oil (80% of which was imported) skyrocketed from 600 million dollars in 1973 to 2.5 billion in 1974, approximately 32% of all Brazilian imports and 50% of all the hard currency that the country received from exports.

2 The Expansion of Ethanol Production

Under these conditions the Government decided to accelerate ethanol production thorough decree 76,593 of November 14, 1975 which is really the *birth certificate* of the Brazilian “Alcohol Program.” The idea was to reduce gasoline consumption

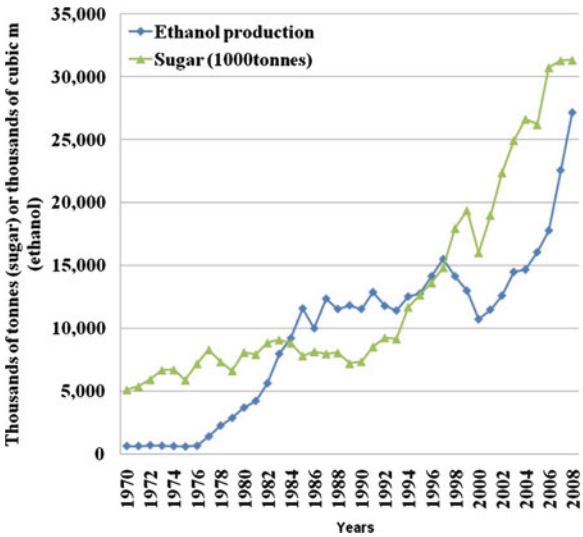

Fig. 2 Ethanol and sugar production—Brazil 1970–2008

and therefore decrease oil imports. Production goals were set at three billion liters of ethanol in 1980 and 10.7 billion liters in 1985.

This decree determined that very generous financing terms were to be offered to entrepreneurs through Government banks[1] and that the price of ethanol should be on a parity with sugar 35% higher than the price of 1 kg of sugar.[2]

The decree made the production of ethanol and the production of sugar equally attractive to the entrepreneurs. This opened the way for the increase in the production of ethanol which happened indeed as seen in Fig. 2.

Production increased from 600 million liters/year in 1975/1976 to 3.4 billion liters per year in 1979/1980. This corresponded to 14% of the gasoline used in 1979.

3 The Expansion of Ethanol Consumption

In principle, therefore the problem of increasing ethanol production was solved. The remaining problem was to make sure that the ethanol produced was consumed.

The Government solved the problem using two instruments [1]:

- Adopting mandates for mixing ethanol to gasoline. Up to 1979, the mixture of ethanol in the gasoline increased gradually to approximately 10% which required small changes in the existing motors. In 1981, ethanol consumption reached 2.5 billion liters.

[1] The interest to be paid on these loans was lower than the rate of inflation which resulted in a negative real interest rate.

[2] Theoretically one can produce 0.684 L of ethanol with 1 kg of sugar which is fairly close to the value established by the decree 76,593.

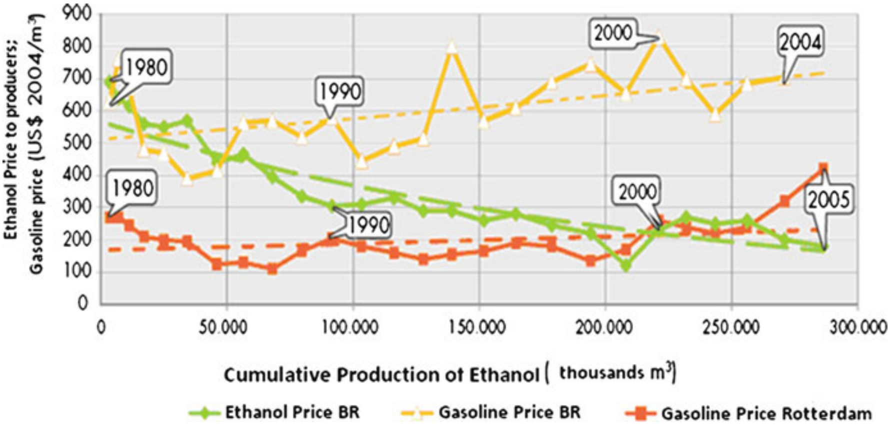

Fig. 3 Learning curve for ethanol production from sugarcane in Brazil. *Source*: Refs. [8, 9]

- Setting the price of ethanol paid to producers at 59% of the selling price of gasoline (which was more than twice the cost of imported gasoline). The high price of gasoline has been used for a long time by the Government as a method of collecting resources to subsidize diesel oil. Parts of such resources were then used to subsidize ethanol.

Subsidies of approximately one billion dollars per year on the average over the 30 years were needed to sustain the program. These subsidies were removed gradually and in 2004 the price paid to ethanol producers was similar to the cost of gasoline in the international market as seen in Fig. 3.

4 Technologies for Ethanol Use

Decree 76,593 and its consequences were adopted purely for economic reasons. Only in 1978 it become evident through work of university groups [2] that ethanol for sugarcane was very close of being a renewable energy source (except for the minor ingredients of pesticides, fertilizers, and some diesel oil needed for its production). All the energy for the process of crushing the sugarcane, fermenting and distillation originated in the bagasse of the sugarcane. The ratio of the energy contained in a 1 L of ethanol to the energy of fossil origin used in the process was approximately 4.53 to 1 when the first evaluation was carried out [3]. Today, evaluations are showing that the rate is even better (8 to 1) due to the significant agricultural and industrial efficiency improvements [4, 5]. Impressive productivity gains of 3% per year over 30 years have been achieved. As an example, Fig. 4 gives the growth of sugarcane agriculture productivity in different regions of Brazil, from 1977 to 2009, indicating an increase of 51% in the period.

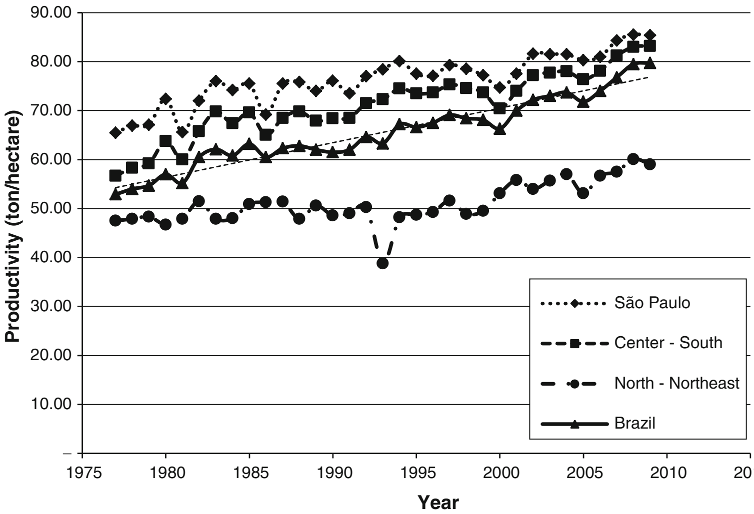

Fig. 4 Evolution of the sugarcane productivity in Brazil. *Source*: Ref. [10]

The second oil shock in 1979 led the Government to the drastic move to introduce cars with motors designed to operate exclusively with hydrated ethanol in order to increase ethanol consumption [2].

A few years earlier President Ernesto Geisel had visited the Air Force Technological Center in São José dos Campos, São Paulo, and was very impressed by the work being done there by engineers, led by Urbano Ernesto Stumpf, on ethanol-fueled cars using hydrated ethanol (95.5% pure ethanol and 4.5% water). Important changes in the engine were needed to use that fuel, which required a compression ratio of 12:1, compared to 8:1 for regular gasoline. The higher compression ratio meant higher efficiency, which partly compensated for ethanol's lower energy content. Combining all these factors, 199 L of pure (anhydrous) ethanol replace one barrel of gasoline (159 L). This change to engines meant a drastic change in auto manufacture, but under Government pressure, local carmakers adapted and nationalistic elements in the Government saw ethanol as an instrument of national independence. In addition to that Brazilian auto manufacturers could no longer export their cars since hydrated ethanol was not available in other countries. It was also a problem to drive Brazilian cars in neighboring countries (and even some states in Brazil) that did not have service stations selling hydrated ethanol. Despite that the production of these cars began in earnest at the end of the decade; between 1979 and 1985, they accounted for 85% of all new car sales [2]. Over this same period, the percentage of ethanol in gasoline reached approximately 20% [1].

Two fleets of automobiles were circulating in the country: some running on gasoline, using a blend of up to 20% anhydrous ethanol and 80% gasoline, and others running on hydrated ethanol. In 1985, the scenario changed dramatically, as petroleum prices fell and sugar prices recovered on the international market. Subsidies were reduced and ethanol production could not keep up with demand. The production of ethanol leveled off but the total amount being used remained more or less constant because the blend was increased to 25% and more cars were using the blend. Thus, by 1990 a serious supply crises occurred and due to a shortage of the appropriate fuel. The government tried to mitigate the shortage importing ethanol and methanol. Methanol was blended with gasoline and ethanol yielding another fuel that could be used in gasoline cars, freeing more ethanol for the neat ethanol powered ones. But, the shortage crisis lasting 1 year scared consumers and the sales of neat ethanol cars dropped rapidly: by the year 2000, it was lower than 1% of total new cars sold.

Then, after 2003, ethanol consumption rose again, as flexible-fuel engines were introduced in the cars produced in Brazil. These cars are built to use pure ethanol with a high compression ratio (approximately 12:1) but can run with any proportion of ethanol and gasoline, from zero to 100%, as they have sensors that can detect the proportion and adjust the ignition electronically. Flex-fuel cars were an immediate hit; today, they represent more than 95% of all new cars sold because they allow drivers to choose the cheapest blend on any given day. Approximately 50% of the gasoline that would otherwise be used in Brazil today was replaced by ethanol. The production of pure ethanol driven cars is being discontinued because of the success with the flexible-fuel engines.

In the 30 years since 1976 ethanol substituted 1.51 billion barrels of gasoline which correspond to savings of US$ 75 billion (in dollars of 2006) taking into account the amount of gasoline saved each year at the world market price [6].

5 Expansion of the Ethanol Program to Other Countries

To emulate the successful Ethanol Program of Brazil, which is clearly an instrument to reduce CO_2 emissions from gasoline, a number of countries have adopted ethanol mandates to introduce ethanol in their automotive fleets. As a consequence, it is necessary to subsidize producers at a rate of approximately 11 billion dollars per year mainly in the United States where ethanol is produced from corn.

Table 1 shows the existing mandates in a number of countries and projections of the amount of ethanol that will be needed by 2020/2022.

Present gasoline consumption in these countries is 943.2 billion liters, 82% of present gasoline consumption.

The potential demand for 2020/2022 on the basis of existing mandates [7] is 178.7 billion liters.

Clearly, an enormous effort will have to be made to meet the projected demand for 2020 in the basis of either first- or second-generation technologies.

Table 1 Present production and potential demand for ethanol

Country/region	Present gasoline consumption[a] 2007 (billion liters per year)	Present ethanol production[b] 2008 (billion liters per year)	Potential demand resulting from present mandates up to 2020/2022 per year
US	530	34	136
European Union	148	2.3	8.51
China	54	1.9	5.4
Japan	60	0.1	1.8
Canada	39	0.9	1.95
United Kingdom	26	0.03	1.3
Australia	20	0.075	2.0
Brazil	25.2	27	19.6
South Africa	11.3	0.12	0.9
India	13.6	0.3	0.68
Thailand	7.2	0.3	0.7
Argentina	5.0	0.2	0.25
The Philippines	5.1	0.08	0.26
Total	943.2	67.3	178.7

[a]*Source*: From [11]
[b]*Source*: From [7]

6 Summary

A discussion is made of the policies adopted by the Brazilian government in the mid 1970s of last century to increase the production of ethanol from sugarcane. The success of such policies can be assessed by the enormous increase in production (from 0.6 billion liter in 1975/1978 to 27.6 billion in 2009/2010) as well as the sharp decline in production costs which turned this renewable fuel competitive with gasoline.

References

1. Goldemberg J (2009) The Brazilian experience with biofuels. Daedalus 4(4, Fall):91–107
2. Silva O, Frischetti D (2008) Etanol: a revolução verde e amarela. Bizz Comunicação e Produções. 1 ed - São Paulo, Brasil. ISBN 978-85-61163-01-3
3. Silva JG, Serra GE, Moreira JR, Gonçalves JC, Goldemberg J, Goldemberg J (1978) Energy balance for ethyl alcohol production from crops. Science 201:903–906
4. Macedo IC, Leal MRLV, Da Silva JEAR (2004) Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil. Secretariat of the Environment of the State of São Paulo, Brazil, p 32
5. Pacca S, Moreira JR (2009) Historical carbon budget of the Brazilian ethanol program. Energy Policy 37 (2009) 4863–4873
6. BNDES and CGEE (2008) Sugarcane-based bioethanol: energy for sustainable. 1 ed - Rio de Janeiro, Brasil: BNDES, p 304. ISBN: 978-85-87545-27-5

7. REN21 (2009) Renewables Global Status Report: 2009 Update (Paris: REN21 Secretariat)
8. Goldemberg J, Coelho ST, Lucon O, Nastari PM (2004) Ethanol learning curve: the Brazilian experience. Biomass Bioenergy 26:301–304
9. Goldemberg J (2007) Ethanol for a sustainable energy future. Science 315:808–810
10. IBGE (Brazilian Institute of Geography and Statistics) (2010) Pesquisa Agrícola Municipal (Agriculture Municipal Research 2010) Compiled by Center of Sugarcane Technology (CTC). Availableat:http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?z=t&o=11&i=P&c=99. Accessed 24 June 2010
11. OECD/IEA (2010) IEA Statistics Oil Information, Paris. ISBN 978-92-64-08422-3

Springer

http://www.springer.com/978-1-4614-3347-7

Advanced Biofuels and Bioproducts
Lee, J.W. (Ed.)
2013, XIII, 1122 p. In 2 volumes, not available separately., Hardcover
ISBN: 978-1-4614-3347-7