The ethanol program in Brazil

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Received 2 August 2006
Accepted for publication 13 November 2006
Published 24 November 2006
Online at stacks.iop.org/ERL/1/014008

Abstract
The number of automobiles in the world has been growing fast and today requires one quarter of the global petroleum consumption. This problem requires adequate solutions, one of which Brazil has achieved with the Sugarcane Ethanol Program. This paper presents the history of this program, from its launch in the 1970s to the today’s condition of full competitiveness in a free market. It also shows how it can be replicated to other countries, in order to replace 10 per cent of the world’s gasoline consumption.

Keywords: renewable energy, sugarcane ethanol, Brazil

1. The impact of transport
One of the most striking characteristics of the 20th century was the emergence of the automobile for personal transportation. There are today in the world 700 million of these vehicles in circulation, the great majority of them with Otto cycle engines running on gasoline. Automobiles are today an integral part of our way of living. They shaped the whole transportation system of mankind and represent a very significant fraction of the GDP of many countries. As developing countries grow and develop, the number of automobiles in the world will grow. The number of such vehicles per capita is approaching 1 in industrialized countries but is much smaller in today’s developing countries and thus likely to grow significantly. In China there are only 20 automobiles per 1000 people compared to 700 per 1000 people in the United States.

The gasoline necessary to feed these automobiles is roughly 20 million barrels of oil equivalent per day, one quarter of the world petroleum consumption from which it is produced and, unfortunately, petroleum is found in relatively few regions of the world. Exports and imports of this commodity are a most important item in international trade and many countries are critically dependent on petroleum imports. This is the case for the United States, as well as many developing countries. Figure 1 indicates the major fluxes of petroleum around the world.

2. The Brazilian program
Brazil was in that category in the 1970s and was for that reason critically affected by the oil crisis of 1973. At that time, the cost of oil imports in hard currency represented approximately a full half of all exports (roughly US$ 4 billion at historical value, equivalent to US$ 12 billion in 2005). The increase of petroleum prices therefore exerted considerable strain on the Brazilian economy at that time.

To face that situation the Brazilian Government embarked on two programs:

(1) a significant effort of prospecting for petroleum mainly under the deep waters of the continental shelf which has successfully taken the country to self-sufficiency after 30 years;

(2) an ambitious program of producing large quantities of ethanol from sugarcane (PROALCOHOL) as a substitute for gasoline.

Conditions in Brazil are very favourable for the production of ethanol. Sugarcane has been an important crop since the 18th century and Brazil was the world’s third largest sugar producer (five million tones of raw sugar equivalent) in 1975. During the 1970s oil crisis, sugar was experiencing a long period of low prices in the international market, so the decision to divert some of the sugarcane to ethanol production was very reasonable, considering also that the technology needed has been available for decades.

The PROALCOHOL was launched by the Government in two variants:

(i) compulsorily using 10% anhydrous ethanol as an additive to gasoline not requiring changes in the motors;

(ii) voluntarily using 100% hydrated ethanol (95% ethanol + 5% water) in modified Otto cycle motors.
Multinational automobile industries based in Brazil have introduced all the necessary engine and vehicle modifications for ethanol use. Gasohol vehicles running with up to 10% ethanol (in volume basis) require almost no changes, but more modifications are required for a larger share of ethanol in the fuel blend. In Brazil, with minor adaptations developed by the car manufacturers, all gasoline vehicles run with blends ranging between 20% and 26% of ethanol. After 20 years, these manufacturers have developed a flexible fuel technology, commercially available and predominant in car sales today at no additional cost.

A remarkable characteristic of the program is that all the automobile manufacturers agreed to produce automobiles with converted motors. Essential for that was the availability of an infrastructure for ethanol pumps in most of the service stations around the country. At that time, gas stations were offering different pumps with ‘regular’ and ‘super’ gasoline (with higher octane and lead additives). Tanks and pumps for ‘super’ gasoline were easily replaced by ones for pure ethanol.

Ethanol production costs were close to US$ 100 a barrel in the initial stages of the Alcohol Program in 1980. Until 1985, as production increased, prices paid to producers reflected average costs of production (Goldemberg et al 2003). During this initial phase, prices fell slowly, reflecting only the gains in agro-industrial yield and economies of scale captured by producers, and these gains were transferred to consumers through a pricing regulation scheme.

In the past, the Brazilian Government subsidized this programme through a variety of mechanisms, particularly ‘soft’ loans to the sugarcane growers, which built ethanol distilleries, and incentives to encourage people to purchase pure ethanol driven cars. Estimates of the total amount
of investment in the agricultural and industrial sectors for automotive ethanol fuel between 1975 and 1989 reach a total of US$ 4.92 billion (2001 US$). Oil imports avoided meant savings amounting to US$ 52.1 billion (January 2003 US$) from 1975 to 2002.

More recently, economies of scale and competition led to a reduction in production costs (figure 2). They were due mainly to a significant increase in agricultural yield, which is a function of soil quality, weather conditions and agricultural practices, and is also strongly influenced by agricultural management. Productivity gains and cost reductions were also achieved as a result of the introduction of operation research techniques in agricultural management and the use of satellite images for species identification in cultivated areas. Similar decision-making tools have been applied in relation to harvesting, planting and application rates for herbicides and fertilizers.

Also, this cost reduction was highly influenced by the use of sugarcane bagasse (a by-product of sugarcane crushing) for energy production, avoiding the use of any fossil fuel in the industrial project. That is why the energy balance for sugarcane ethanol is the best in the world for biofuels with commercially available technologies: up to 10 output units for each input unit (figure 3).

The evolution of the programme can be gauged in figure 4. Note that the 2001 drop was due to the low international prices of sugar and of gasoline. Prior to the flexible fuel vehicles there was little incentive for owners of ethanol-dedicated cars, so sales dropped and consumption was reduced. With rising oil prices and the flexibility provided by the FFVs the ethanol...
was again considered a good option. This situation is more permanent now, with the present end-use technology and climate change related policies at all levels.

A comparison of ethanol costs with gasoline in the international market is shown in figure 5, a remarkable example of the ‘learning curve’ effect for a renewable energy such as ethanol. The figure considers tax-free prices (international gasoline market and ethanol price paid to producers), but with embedded subsidies for ethanol, until the 1990s. Subsidies paid by society were progressively phased out and the net returns were significantly positive.

3. Replication of the program

The experience with ethanol in Brazil could be replicated in other developing countries, because many of these countries already have sugarcane plantations and could gradually start to produce alcohol fuel both for domestic supply and, later on, for export (despite the existing barriers in industrialized countries against the import of biofuels produced in developing nations). Table 1 lists the main producers of sugarcane in the world, showing that this is a concrete possibility.

There is enough area available for an ambitious introduction of 10% of ethanol in the world’s gasoline. There would be a need for nearly 30 million hectares of land, which is only 3% of the total area of harvested crops in the world (1042 million hectares in 2001).

If ethanol from sugarcane were to replace 10% of the gasoline consumed in the world (34.75 million TJ in 2000, according to the IEA (2003)), carbon emissions would be reduced by 66 million tonnes (Ceq) per year. This is equivalent to approximately 1% of the world’s emissions, or one fifth of the Kyoto Protocol target (IPCC 2001). For that, another 30 million hectares of land are needed, corresponding to 50% more than the existing area. There is enough potential area in the world, as shown by the databases from the UN Food and Agriculture Organization (FAO 2005).

Environmental aspects must be taken into account, but the production of biofuels (especially sugarcane ethanol) is a win-win perspective for both developing and developed countries.

Table 1. World sugarcane producers.

| Sugarcane          | Production (million ton) | Area (thousand ha) |
|--------------------|--------------------------|--------------------|
| Brazil             | 416.26                   | 5634.55            |
| India              | 236.18                   | 4000.00            |
| China              | 90.98                    | 1392.10            |
| Thailand           | 64.97                    | 1121.41            |
| Pakistan           | 53.42                    | 1047.50            |
| Mexico             | 45.13                    | 639.06             |
| Colombia           | 40.02                    | 431.74             |
| Australia          | 36.99                    | 448.00             |
| Philippines        | 32.50                    | 395.00             |
| United States of America* | 26.32                  | 379.68             |
| Indonesia          | 25.60                    | 360.00             |
| Cuba               | 24.00                    | 700.00             |
| Argentina          | 19.30                    | 350.00             |
| South Africa       | 19.09                    | 321.57             |
| Guatemala          | 18.00                    | 186.34             |
| World              | 1328                     | 20452              |

* Source: FAOSTAT (2005). According to another source, the sugarcane harvested area (in thousands of hectares, year 2004) was 385 in the whole United States, of these 170 in Florida, 9 in Hawaii, 188 in Louisiana and 18 in Texas (USDA 2005).

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