



Can the Fijian economy be saved by ethanol production?

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Fiji is totally dependent on imported fossil fuel for its transport sector and options for alternative motor fuels are limited. In the past, when petroleum prices soared, there were discussions at various levels about alternatives. These discussions might have been sporadic but the seriousness of the issue should not be understated. The economic viability of options such as the production of ethanol from sugar or other bio-fuels needs detailed economic analysis to give direction to future discussions. This article analyses the economics of ethanol production from sugar cane. The analysis is influenced by the experiences of countries such as Brazil, where ethanol is produced and used as a transport fuel on a commercial level. The foreign exchange savings potential of this fuel option is also explored briefly. The framework for economic analysis is based on the Dutch Sustainable Development Group's study of 2005.

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There is a risk that Fiji will become a lost state like Haiti in the next few years because of its unstable political situation and its weak economic performance. At the moment, Fiji is suffering economically because of the worldwide economic crisis, particularly because of its impact on the tourism industry. Because of these pressures, the government devalued the Fijian currency by 20 per cent in April 2009. Fiji has been generating a relatively large trade

deficit, which was equivalent to about 32 per cent of GDP in 2007. The trade deficit fell in 2008, but remained relatively high at about 30 per cent of GDP.

The sugar industry in Fiji is running into huge problems with reductions in the price paid for sugar imports by the European Union and foreign aid from the European Union for the sugar industry being frozen due to the interim government's abrogation of the constitution.¹ Despite numerous nega-



tive developments, however, sugar remains an important export crop for Fiji (sugar's share of total exports has varied between 15 and 20 per cent, but has been trending downwards). On the other hand, Fiji's main import is petroleum. Petroleum imports account for between 20 and 35 per cent of total imports, with an increasing tendency. What are the economic possibilities for Fiji to increase its exports through the production of ethanol from sugar cane and thereby reduce its imports of fossil fuels?

In the next section, we explain how ethanol from sugar cane can be used as a fuel alternative. In the third section, a cost-benefit analysis of the economic viability of ethanol production is reported. This analysis is based on a study by the Dutch Sustainable Development Group (DSD 2005), which was carried out for the Dutch government. Of course, this study is not directly applicable to Fiji, but it can be applied with some adjustments.

Advantages of ethanol production from sugar cane

In principle, ethanol is usable in all kinds of combustion engines. It is possible to use it as fuel in modern petrol and diesel cars and, with some restrictions, in older vehicles. Generally, all cars can run on a mixture of ethanol and mineral petrol with the ethanol share at about 10 per cent (known as E10). Most post 1999 model cars can run on an ethanol share between 0 and 100 per cent—so-called flexible-fuel vehicles. Pure ethanol fuel is called E100.

Typically, the energy output of 1 unit of ethanol E85 is lower than that of mineral petrol, implying 20–25 per cent higher consumption of ethanol E85. These physical characteristics have to be taken into account when comparing ethanol with mineral petrol. It is quite likely that different kinds

of ethanol mixtures will be offered in future. For example, in the United States, Australia and Thailand, E10 is in use, while in Brazil, E25 is used. In Sweden, buses use E100 and E5 is offered for cars in the European Union. It is, however, intended that by 2020, 20 per cent of all fuel consumed in the European Union will be ethanol (European Commission, COM [2008] 0019, C6-0046/2008, 2008/0016 [COD]). Similar trends can be observed in other countries, such as Brazil and Thailand. This is due to the fact that the ecological impact of ethanol is much better than that of mineral fuels.

The reduction in greenhouse gas (GHG) emissions as a result of using ethanol will depend on the production processes and the type of feedstock used to manufacture ethanol. The reduction of GHG emissions from the use of bio-fuels can be compared with that from the use of mineral fuel (Table 1). Assuming that ethanol production from sugar cane in Fiji would be similar to that in Brazil, the reduction in GHG emissions from substituting ethanol for mineral fuel would be 80–85 per cent.² That is, even if Fijian cars are able to use only E10, the reduction of GHG emissions from cars would fall by 8–8.5 per cent. Because the combustion of ethanol produces no other environmentally harmful substances, use of ethanol would also improve local pollution levels, which are currently quite serious in urban areas. If, however, the use of E85 were made possible, the higher fuel octane of ethanol would also make it possible to reduce the consumption of fuel per kilometre (US Department of Energy 2008).

As can be seen from Table 1, besides sugar cane, there exist a number of other possible types of feedstock for the production of ethanol, although none is as land efficient as sugar cane and sugar beet. It is possible to compare the litres of ethanol produced per hectare from various sources and their estimated costs (Table 2).



Table 1 Reduction in GHG emissions from substituting bio-fuels for mineral fuels (per cent)

Ethanol feedstock	Grain (EU, US)	Sugar beet (EU)	Sugar cane (Brazil)	Cellulosic feedstock (US)	Canola (EU)
Minimum reduction of GHG	-20	-35	-80	-60	-45
Maximum reduction of GHG	-43	-55	-85	-100	-60

Source: US Department of Energy, 2008. *Handbook for Handling, Storing, and Dispensing E85*, (DOE/GO-102008-2450), April 2008, US Department of Energy, Washington, DC.

Table 2 Ethanol production and costs from various feedstock

Feedstock	Ethanol/ha (litres)	Estimated costs per '000 litres (US\$)
Sugar beet	2,500–3,000	300–400
Sugar cane	3,500–5,000	160–400
Corn	2,500	250–420
Wheat	500–2,000	380–480
Potatoes	1,200–2,700	800–900
Sweet sorghum	3,000–5,000	200–300
Cassava	1,500–6,000	700
Synthetic	0	540

Source: Micro distillery, LAMNET project ICA4-CT-2001-10106 EU-project.

Table 3 Ethanol prices on the Chicago and Sao Paulo exchanges, 2006–09

Year	2009	2008	2008	2007	2007	2006	2006
Place	Chicago	Chicago	Sao Paulo	Chicago	Sao Paulo	Chicago	Sao Paulo
Average price per '000 litres (US\$)	399.63	621.67	501.27	561.32	405.33	648.86	466.944
Price (US\$/L)	0.40	0.62	0.50	0.56	0.41	0.65	0.47
Exchange rate (€/US\$) (1 January)	1.3	1.47	1.47	1.32	1.32	1.18	1.18
Price (€/L)	0.31	0.42	0.34	0.43	0.31	0.55	0.40

Sources: Weekly data are from Bundesverband der Deutschen Bioethanolwirtschaft (<http://www.bdbe.de/>).w

In Brazil, the ethanol output per hectare is higher than shown in Table 2 (6,800–8,000L/ha), which is due mostly to the farm structure: most sugarcane farms in Brazil are larger than 10,000ha. In Fiji, sugarcane farms are mostly very small (on average 5.5ha).³ Nevertheless, the productivity of the farms could be enhanced if the land laws were improved.⁴

Globally, the demand for ethanol is likely to increase. The DSD (2005) projects ethanol consumption to grow at a minimum of 2.3 per cent per annum. Consumption could thus increase from 30–40 billion litres in 2003 to about 120 billion litres per annum by 2020. An indication of the possibilities for ethanol use as a motor fuel can be observed



from Brazil, where production and use of ethanol as a car fuel dates back to 1975—a consequence of the oil crisis. *Gesellschaft fuer Technische Zusammenarbeit* (German Technical Cooperation) (GTZ 2006:20) noted with respect to Brazil

From 1980 to 2002, the price reduction obtained was to the order of 71%. As the efficiency and cost competitiveness of ethanol production evolved over time, this support was no longer needed and was not applied... Today [September 2005], alcohol is sold in gas stations at around 51% of [the] gasoline price. This economic competitiveness [has been] a reality for several years and will continue for years to come, especially with the current increase of the crude oil prices on the world market.

It could therefore be concluded that there exist a learning curve and economies of scale in the production of ethanol.

It should also be noted that ethanol production in Brazil has created an additional 60,000 jobs on small sugarcane farms, even though these farms produce only 17 per cent of Brazil's sugarcane output. Additionally, GTZ (2006) reported

Salaries and benefits for the employees...are 3.5 times more than the national minimum salary (now equivalent to US\$83.62 per month) in the crops—where the workers have a low level of skill and school education—and 5.3 times higher in the industrial businesses.

Additionally, GTZ (2005) noted that ethanol production in Brazil had directly created 700,000 jobs and indirectly created 3.5 million jobs from the production of 350 million additional tonnes of cane. Most of the jobs were created in rural areas and infrastructure was significantly improved. It can be concluded that the Brazilian gov-

ernment's promotion of the production of ethanol was a very good idea.

The main advantages of ethanol production appear to be: 1) reduction of the trade deficit; 2) reduction of GHG emissions; 3) increases in GDP and employment; and 4) improvements in energy security.

It was not possible to carry out input–output analysis of the production and use of ethanol in Fiji due to the lack of appropriate data, so we can refer only to the experiences of countries such as Brazil and China that produce ethanol from sugar cane. The qualitative results are, however, obvious. Less fossil fuel imports mean an improvement in the trade balance for Fiji and the use of ethanol means a reduction in GHG emissions. If it is proven that the production of ethanol can be profitable, a viable economy could be developed and sugarcane farming and on and off-farm employment would increase.

Cost–benefit analysis

It needs to be established which inputs (feedstock) and which technologies are appropriate for ethanol production in Fiji. This will provide the basis for measuring the cost and benefits of production. Ethanol is traded in Sao Paulo (Brazil) and Chicago (United States) (Table 3). Chicago prices, however, are not representative of world prices because they reflect the domestic situation, where the production of ethanol is subsidised and ethanol imports are taxed. We therefore take the prices in Sao Paulo to represent world market prices. Taking into account that international investors mostly have a short time horizon, we calculate the costs per annum, with the costs of the investment never being paid back. The break-even point is reached when the interest payments and the depreciation costs exceed the returns from the investment.



These calculations are based on information from the DSD (2005) report, together with informal information from managers and engineers from Gazprom and Sweftneft.⁵ We have taken into account all costs—divided into fixed costs, variable costs and costs of the feedstock (sugar cane). We compare the production costs under different scenarios regarding investment costs, interest rates, wages and sugarcane prices, with the world market price of ethanol at the exchange market in Sao Paulo. Transportation costs play no role in this analysis because the ethanol produced is not stored in Sao Paulo (including the Brazilian ethanol). All prices are measured in euros, because it is the most stable currency.⁶

Criteria for the calculation of benefits

Even if we assume that the price of ethanol will increase, the costs per litre of ethanol produced cannot not be higher than €0.34. There is, however, a strong correlation between mineral fuel prices and ethanol prices, since ethanol and petrol are substitutes to a significant degree, and mineral fuel prices are widely expected to increase.⁷ Additionally, the use of ethanol creates positive externalities, because of its GHG neutrality.

The GTZ (2006) calculated the estimated production costs, excluding investment costs, for the production of ethanol from different feedstock for China (Table 4). In one sense, these costs can be considered distorted, because no-one bears the investment costs.

Proposed technology

In principle, three technologies exist for the production of ethanol from sugar cane (Biofuels Russia [www.biofuels.ru]; Gazprom 2009; Sweftneft 2009)

1. bio-ethanol produced directly on a stand-alone basis
2. bio-ethanol produced instead of cane sugar but applying the same production process
3. bio-ethanol produced next to cane sugar.

Given the information from Gazprom and Sweftneft engineers, a plant to produce ethanol on a stand-alone basis would cost, at a minimum, €150–200 million; therefore, this technology can be excluded as an option in the first instance. The second technology seems adoptable at first, because it is possible to produce sugar and/or ethanol. For this option, however, the investment costs are also relatively high—ranging between €80 and €120 million for each unit.

Table 4 China: estimated production costs for ethanol from various feedstock

Feedstock	€/L ethanol
Corn	0.379990836
Manihot esculenta	0.244900539
Manihot esculenta	0.304150669
Sugar cane	0.288350634
Sorghum bicolor	0.2271255

Source: *Deutsche Gesellschaft für Technische Zusammenarbeit* [German Technical Cooperation] (GTZ), 2006. Liquid biofuels for transportation: Chinese potential and implications for sustainable agriculture and energy in the 21st century, Assessment study, February 2006, Beijing, *Deutsche Gesellschaft für Technische Zusammenarbeit*, Eschborn, Germany.



The most preferable technology for Fiji is the third model, because only a distillery has to be added to existing sugar mill facilities. One significant advantage with this is that ethanol can be produced throughout the year. In the harvest period, ethanol production can be based on the raw cane juice. Molasses can be used as the feedstock in the off season, requiring storage during the harvest season. The bagasse, leaves and all other remaining biomass (heads of the plants and so on) can be used to produce electricity and heat, and the unused electricity can be supplied to the main electricity network. Additional plant for this purpose would cost €10–15 million and would be capable of producing an average of 80,000 litres of ethanol a day.

One tonne of sugar cane produces 78 litres of ethanol and 1t of molasses produces 278L. Each day, therefore, either 1,025t of sugar cane or 288t of molasses would be required to produce a mill capacity of 80,000L of ethanol—meaning Fijian sugarcane farmers would have to produce 374,125t of sugar cane or 105,120t of molasses a year. Fiji presently produces about 10 times this volume. Under this technology option, ethanol production could be a diversification strategy for Fiji's sugar industry.

Details of production costs

The costs of ethanol production depend on many factors; here we provide details of the cost structure of the third option discussed above. Total production costs are the sum of: 1) interest payments on the investment costs of €10–15 million; 2) maintenance costs (2 per cent of the investment costs) of the plant; and 3) labour costs. These are the fixed costs. To these we add the variable costs of inputs (steam, heavy oil, electricity and process water) and the costs of the raw

materials (molasses, sugarcane B-syrup and cane sugar).

Adding up these costs and dividing by the quantity of ethanol produced gives the production cost per litre, not taking into account any taxes or transportation costs. Various scenarios were examined to estimate the possible range of these costs. Cost assumptions are made for 2008 and are shown in euros, except wages, which are shown in Fijian dollars. Although the prices for natural resources were very high in 2008, the same calculation could be done for other recent years, generally without changing the results. The costs are defined in the following way (Equation 1).

$$C(Q) = \underbrace{I(m+i) + wL}_{\text{fixed costs}} + \underbrace{(P_{\text{steam}} + P_{\text{electricity}} + P_{\text{water}} + P_{\text{oil}} + P_{\text{chemicals}})}_{\text{costs of materials}} Q + \underbrace{P_x Q}_{\text{costs of raw materials}} \quad (1)$$

In Equation 1, $C(Q)$ is the production cost of ethanol; Q is the quantity of ethanol in litres; I is the fixed investment cost; i is the interest rate; m is the maintenance rate; w is the daily wage rate; L is the quantity of labour (aggregate labour days); P_{steam} is the price of steam per litre of ethanol; $P_{\text{electricity}}$ is the price of electricity per litre of ethanol; P_{water} is the price of process water per litre of ethanol; P_{oil} is the price of heavy oil per litre of ethanol; $P_{\text{chemicals}}$ is the price of chemicals per litre of ethanol; P_x is the price of raw materials per litre of ethanol; and $x \in \{\text{molasses, B-syrup, cane sugar}\}$.

The range of assumptions covered by the scenarios makes clear that the production of ethanol from molasses and cane syrup is profitable under realistic conditions. The ethanol production cost is below the 2008 world price in Case 1 (the best case),



Table 5 Economic scenarios for the production of ethanol from sugar cane, cane syrup and molasses in Fiji (2008 costs)

	Case 1 (best case)	Case 2	Case 3	Case 4	Case 5	Case 6 (worst case)
Investment costs (€)	10m	10m	10m	15m	15m	15m
Interest rate (%)	5	5	15	5	15	15
Daily wage (F\$)	50	50	75	75	100	100
Steam (€/L)	0.07	0.07	0.07	0.07	0.07	0.07
Heavy oil (€/L)	0.02	0.02	0.02	0.02	0.02	0.02
Electricity (€/L)	0.02	0.02	0.02	0.02	0.02	0.02
Process water (€/L)	0.05	0.05	0.05	0.05	0.05	0.05
Molasses (€/t)	33.00	37.62	37.62	37.62	37.62	40.00
Sugarcane B-syrup (€/t)	42.00	47.16	47.16	47.16	47.16	52.00
Cane sugar (€/t)	290.00	324.40	324.40	324.40	324.40	350.00
Production ccost/L(€)						
From molasses	0.30	0.32	0.36	0.33	0.39	0.40
From sugarcane B-syrup	0.30	0.32	0.36	0.33	0.39	0.40
From cane sugar	0.67	0.73	0.76	0.74	0.80	0.84
2008 Sao Paulo ethanol price (€/L)	0.34	0.34	0.34	0.34	0.34	0.34

Source: Authors' calculations.

Case 2 and Case 4. For example, in Case 2, with the interest rate at 5 per cent, the daily wage rate at F\$50 and the investment cost at €15 million, the production cost per litre of ethanol would be €0.33 (the 2008 world price was €0.34). Note that the assumption of a 15 per cent interest rate is unrealistically high. We have not taken into account other positive effects of ethanol production with regard to the labour market, the trade balance and the environment.

Ethanol production from molasses and syrup would not be profitable in Cases 3, 5 and 6, which are based on a set of rather unrealistic assumptions, such as the wage rate of F\$100/day, €15 million for investment costs, a 15 per cent interest rate and €40/t for molasses. The production of ethanol from sugar cane (in lieu of sugar) is not profitable, however, in any of the scenarios,

as the opportunity cost of the use of sugar cane in this way is presently too high.

The profitable production strategy would therefore be to produce sugar and ethanol at the same time through investment in ancillary ethanol plants.

Conclusions

It has been shown that production of ethanol in Fiji from molasses or cane syrup is likely to be profitable if it is undertaken in conjunction with the production of sugar. Moreover, the analysis does not take into account the possible benefits of the externalities from domestic use of ethanol as a substitute for mineral fuels. A complete cost-benefit analysis would include these possible advantages of ethanol production and use.



The further advantages for Fiji include the use of ethanol in cars, which would reduce the trade deficit through substitution for petroleum imports. Assuming the use of E10, domestic use of ethanol could reduce annual imports of fuel by up to 10 per cent—or F\$122 million. Fiji could also export any excess ethanol, possibly increasing the value of exports significantly.⁸ In the long run, the use of bio-fuel as a substitute for mineral fuels could be increased to 100 per cent given that appropriate technologies will become readily available (for example, Egebäck 2004; Haupt, Nord, Egebäck and Ahlvik 2004). It also seems likely that the number of low-skilled jobs would increase—directly in the production process and indirectly in the transport industry.

The sugarcane industry should try to find a partner in industrialised countries to set up a Clean Development Mechanism (CDM) project. The CDM is one of four mechanisms established under the Kyoto Protocol, allowing firms from industrialised countries to invest in GHG-reducing projects in developing countries to comply with the (reduction of) emission rights in their home country (see the article by Kalara McGregor in the *Pacific Economic Bulletin* vol 24 1:161-173). Because the combustion of ethanol is much more environmentally friendly than the use of petrol, the main conditions for a CDM project should be easily fulfilled.

Notes

- ¹ The price paid by the European Union was reduced by 20 per cent in 2006 and 2007 and by 33 per cent in 2008. As compensation, the European Union offered a subsidy for Fijian sugarcane farmers of €135 million, payment of which at present has been blocked because of the coups of 2006 and 2009.
- ² Note that contrary to what has been happening in Brazil, in Fiji, it is not necessary to cut

down rainforests, as the sugarcane fields already exist. Only the ethanol production process is responsible for GHG emissions.

- ³ See Lal (2008) and Prasad (1998) for details of farm sizes and costs of sugarcane production in Fiji.
- ⁴ It is beyond the scope of this article to go into the details of the Fijian land laws and the conflicts associated with it; for details, see Prasad (1998); Lal and Reddy (2003); Lal, Lim-Applegate and Reddy (2001).
- ⁵ We contacted many firms, but information about investment costs is mostly confidential. Unnamed friends of P.J. Stauvermann from Gazprom and Sweftneft confirmed the calculations of DSD. They do not wish to be cited for confidentiality reasons.
- ⁶ On request, the corresponding author, Peter J. Stauvermann, will send an Excel file in which the prices can be changed to examine other scenarios (stauvermann_p@usp.ac.fj and pstauvermann@t-online.de). Within a few months, the Excel file will also take into account all other costs and it will then take only minutes to calculate the production costs, given the user has the necessary data.
- ⁷ The degree of substitutability depends on the age of the car fleet.
- ⁸ The overall effect on the trade balance is difficult to calculate because it depends on the quantity of ethanol produced and the world price of ethanol and other fuels.

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