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ENERGY COSTS OF SUGAR PRODUCTION IN THE PHILIPPINE CONTEXT

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The total energy use to produce and mill one t of cane was estimated at 61.68 L diesel oil energy (2.38 GJ/TC). The share of cane production was 11.26 LDOE/TC (0.43 GJ/TC) which is about 18.25% of the total energy use while cane milling used about 50.42 LDOE/TC (1.95 GJ/TC) or about 81.74% of the total energy use. But cane milling sources 87.0% of its energy bill from bagasse and only 5.9% from bunker oil. Re-estimating the fossil fuel energy (FFE) costs of cane milling shows that it only uses 2.97 LDOE/TC or 23% of the total FFE use. Thus, the FFE/kg raw sugar is only 0.15 LDOE (0.00569 GJ/kg) and not 0.65 LDOE/kg raw sugar (0.025 GJ/kg). Chemical fertilizer utilized the largest amount of FFE at about 60% (31.5 GJ/ha) in plant cane and 64.7% (21.8 GJ/ha) in the ratoon crop. N consumed the largest amount of energy. Of the national average FFE equivalent for NPK fertilizer at 9.10 GJ/ha (238 LDOE/TC), 92.2% (8.39 GJ/ha was N. This is because N fertilizer was applied the most at 106.14 kg/ha, with P only 31.45 kg/ha and K only 42.46 kg/ha. Furthermore, N consumed the largest FFE during manufacture. Luzon farmers were applying more N fertilizer than Visayas and Mindanao farmers. Thus, their FFE equivalent for fertilizer was highest. The FFE equivalent for fertilizer through the years doubled from 9.28 GJ/ha (0.158 GJ/TC) in 1983-84 to 20.5 GJ/ha (0.315 GJ/TC) in 2000-2001. Correlation analysis showed that tonnage (TC/ha) was highly correlated with energy use (r=0.90) and with the FFE equivalent of N fertilizer (r=0.996). Since N consumed the largest quantity of FFE, its reduction would have the greatest impact on the fuel economy of cane production. To reduce FFE-based fertilizer use in cane production, sugarcane trash farming is suggested. To reduce costs, the use of renewable biomass fuel as 'green power' alternative for cane milling is forwarded.

Keywords biomass fuel, costs of production, fertilizer use, fossil fuel energy use, fuel economy, green power, N fertilizer, NPK, sugarcane, trash farming

INTRODUCTION

While sugarcane, a high-yielding, perennial C4 crop species, remains to be the cheapest source of caloric energy food, it also requires huge amounts of energy to grow in the farm (Mendoza et al 2003) and process the cane in the mill (Corpuz & Aguilar 1992). This is because, unlike many other tropical upland crops grown in the Philippines, sugarcane production and cane stalk processing in the mill are machine-dependent (Figure 1).

Also, high-energy costs of sugarcane farms derive from production inputs like chemical fertilizers that historically have been consuming tremendous amounts of energy in their manufacture (Soriano 1982, Pimentel et al 1983, Mudahar & Hignett 1985). Necessarily therefore, increasing productivity particularly for sugarcane is directly proportional to the increase of fossil fuel oil energy use under conventional sugarcane growing and cane processing in the mill (Bony 1993).

Examining the yield equation to find out what production factor or operation involved and at what stage of production should be altered or improved is necessary to increase yield or achieve higher efficiency in production. Conceptually, the yield equation can be described as:

$$Y = \{(G * E) * M\}$$

where

Y = Yield
G = Genotype (variety)
E = Environment (climate, soil factor)
M = Management (inputs supplied, cultural practices, ie, land preparation, planting, cultivation and weeding, fertilizer application practices, irrigation, harvesting/milling practices).

The parentheses around G * E indicate that both are influenced by management. E can be optimized by optimizing tillage, timing of planting/harvesting etc. G can be exploited fully by planting location-adapted cultivars and programming varietal traits in relation to their maturity/milling schedules (ie, early, medium, late milling schedules). It is M where farmers can come up with desirable results. Sugarcane production is basically management of photosynthesis and inputs (form, timing, proportion) and all other cultural management practices (planting, cultivation, weeding, harvesting, ratooning) can be altered, improved or regulated. It is a management decision to change or adopt new practices or systems. Thus, it is M which can decisively influence Y.

Computed separately, the energy value for sugarcane milling (Corpus & Aguilar 1992), and the energy value for growing and harvesting sugarcane in the farm (Mendoza 2000), have already been known. However, no attempt in the past had been made to combine the two aspects of sugarcane production in one equation to arrive at a complete picture. The present study is an attempt to quantify the total energy required in sugar production.

METHODOLOGY

In quantifying the energy use involved in the various operations at farm-level cane production, the primary field survey data obtained by Mendoza & Samson (2000) and Samson (2003) were used. Mendoza & Samson's 2000 data were gathered in Batangas Province, while Samson's 2003 data were obtained in Negros Occidental Province. Though conducted in two different places, the same input data for the various field operations (Figure 1) were gathered.

In both study sites, two crop types were involved: plant cane and ratoon crop. The associated operations for each crop type were delineated as follows:

Plant Crop:

1) Land preparation - plowing, harrowing, furrowing
2) Planting - cane paint preparation, hauling, distribution, planting
3) Cultivation - ridge busting, off-barring, hilling-up
4) Amount of fertilizer applied (source of NPK for each)
5) Harvesting and hauling of canes

Ratoon Crop:

Since a ratoon crop starts with what is left in the field after the harvest of a plant cane crop, naturally, only the data in numbers 3, 4 and 5 were obtained.

Appropriate energy values for the various field operations and inputs (fertilizer, NPK) were obtained from Pimentel (1980), Soriano (1982), Pimentel et al (1983), and Panesar & Fluck (1993).

For the energy use in cane processing in the mill, the published data of Corpuz & Aguilar (1992) were adopted. The data had been obtained from 33 mills out of the 38 operating sugarcane mills, the source of energy delineated into bagasse, supplementary fuel (fuel oil, wood, others) and electricity (grid, diesel).

To reconcile the data obtained in the farm with that in the mill, energy use figures were all converted into energy use/t cane or energy use per kg-sugar as appropriate.

RESULTS & DISCUSSIONS

Total Energy Use

The total energy use in sugar production (cane production up to cane milling, Figure 1) was estimated at 61.68 liter-diesel oil energy/t cane (LDOE/TC) or about 2.38 GJ/TC (Table 1). The share of cane production up to harvesting and hauling canes to the mill is about 11.26 LDOE/TC (0.43 GJ/TC), which is about 18.25% of the total energy use. Cane milling accounted for about 50.42 LDOE/TC (1.95 GJ/TC) or about 81.74% of the total energy use. This translates to an energy use of about 0.65 LDOE/kg sugar (0.025 GJ/kg sugar).

It appeared that cane milling was very energy-intensive as it used 4.5 times more energy than cane growing in the farm. Corpuz & Aguilar (1992) in their study showed an itemized source of energy for the 50.42 LDOE/TC, ie, 87% of that energy was coming from bagasse, 2.9% from wood, 4.2% from electricity and 5.9% from bunker oil. Using 5.9% coefficient representing fossil fuel energy use in cane milling, the total fossil fuel energy use for sugar production was re-estimated at 14.23 LDOE/TC (0.54 GJ/TC). Cane milling used only 2.97 LDOE/TC (0.11GJ/TC). This fossil fuel energy use was only 29% of the total energy use (Table 2). Cane production in the farm was 3.8 times more FFE-intensive (0.43 GJ/TC) than cane milling. Thus, the FFE use is only .00569 GJ/kg raw sugar and not 0.025 GJ/kg.

Energy Use in Cane Production

The energy consumed in sugarcane production in the two study sites is shown in Table 3. The total energy use for the plant cane was 51.2 LDOE/kg while it was 33.4 LDOE/ha in the ratoon cane. There was 38% reduction in energy use in the ratoon compared to that in the plant cane crop.

On a/t cane basis, the energy use was 0.512 GJ/TC (13.4 LDOE/TC) in plant cane and 0.36 GJ/TC (9.43 LDOE/TC) in ratoon crop. The reduction in energy use was only 30%. This was due to the higher tonnage yield in plant cane. The average energy use was 40.67 GJ/ha (1064.98 LDOE/ha) or 0.43 GJ/TC (11.26 LDOE).

The proportions of energy use by operation and inputs were also estimated (Table 3). By operation, it was the fertilizer that utilized the highest energy in plant cane at 31.5 GJ/ha (60%) and about 21.8 GJ/ha (64.7%) in the ratoon. The next highest energy-using operation was harvesting/hauling, at 23.26% (11.5 GJ/ha) in plant cane and 31.12% (10.5 GJ/ha) in the ratoon crop. Thus, two operations (fertilizer and hauling) consumed 83.26% of the total energy use in the plant cane and 95.82% in the ratoon crop.

Table 1. **Fossil fuel oil energy use in sugar production (cane production + cane processing)**

Stage	GJ/TC	LDOE/TC	%
Cane production [1]	0.43	11.26	791
Cane milling [2]	0.11	2.97	29
Total	0.54	14.23	100

[1] Data based on Table 3

[2] Data based on Corpuz & Aguilar (1992)

Total energy use per tonne cane = 50.42 LDOE but 5.9% is bunker oil, 87% bagasse, 2.9% wood, electricity + others = 4.2%

*GJ/TC = LDOE/TC * GJ L^{-1} -oil; 1 L-oil = 0.0386 GJ*

Fossil Fuel Oil Energy

Use/ kg-sugar

= GJ/TC ÷ kg – sugar/TC

= 0.54 ÷ 94.877 kg sugar/TC

= 0.00569 GJ/ kg sugar

Since fertilizer application was the most energy-intensive requiring operation in cane production, it became important to find out which of the three sources of macronutrients was most FFE-intensive.

In literature (Soriano 1982, Bony 1993),

Table 2. **Energy use in sugar production (cane production + cane milling)**

Stage	GJ/TC	LDOE/TC	%
Cane Production [1]	0.43	11.26	18.25
Cane Milling [2]	1.95	50.42	81.74
Total	2.38	61.68	100

[1] Data was based on 2 case studies (Table 3).

[2] Data based on Corpuz & Aguilar (1992).

GJTC-1 = LDOE/TC * GJ L-1-oil, GJ/TC = Giga Joule per tonne cane

1 L-oil = 0.086 GJ,LDOE/TC = L Diesel Oil Equivalent per tonne cane

Energy use/ kg sugar
= GJ/TC ÷ kg – Sugar/TC
= 2.38 GJ/TC ÷ 94.877 kg-sugar/TC
= 0.0251 GJ/ kg – sugar (raw)
= LDOE/TC ÷ kg-sugar/TC
= 61.68 ÷ 94.877
= 0.65 LDOE/ kg – sugar (raw)

the energy consumed/kg NPK were as follows:

N = 0.07 GJ/kg
P = 0.012 GJ/kg
K = 0.0079 GJ/kg

As it appeared, it was N that consumed the largest amount of energy by nutrient. From Covar (1988), the NPK application rates in Luzon, the Visayas and Mindanao and for the Philippines are shown in Table 4. The national average energy equivalent for NPK fertilizer was estimated at 9.10 GJ/ha (238 LDOE/ha), for N fertilizer at 92.2% (8.39 GJ/ha). This was because, nutrient wise, it was N fertilizer that was applied the largest at 106.14 kg/ha, compared to only 31.45 kg/ha for P and 42.46 kg/ha for K. As cited earlier, N consumed the largest amount of energy during manufacture at 6.58 times more than P and 10 times more than K.

The same trend in the estimated FFE value of fertilizer was observed in 1996 (Table 5). N fertilizer accounted for 93%, P for 4% and K for 3% of the 17.74 GJ/ha FFE equivalents.

By region, it was Luzon where N had the largest share at 97.8% (9.7 GJ/ha) of the 9.92 GJ/ha energy equivalent for fertilizer.

Table 3. **Fossil fuel energy consumed based on various operations in sugarcane production (2 sites) (Samson 2000)**

Operation/Crop Type	**Energy use in Batangas**		**Energy use in Negros Occidental**		**Average energy use**	
	(GJ)	**%**	**(GJ)**	**%**	**(GJ)**	**%**
A. Plant Crop						
1. Land Preparation	4.9	8.06	4.9	11.75	4.9	9.90
2. Planting	0.96	1.57	2.3	5.51	1.6	7.08
3. Cultivation	1.7	2.79	1.7	4.07	1.7	3.43
4. Fertilizer	41.7	68.63	21.3	51.08	31.5	60.00
5. Harvesting/hauling	11.5	18.96	11.5	27.58	11.5	23.2
TOTAL ENERGY GJ)	60.76	100	41.7		51.2	100.00
LDOE/ha	591.06		1091.9		1340.8	
TOTAL YIELD (tonne/ha)	120		80		100	
ENERGY USE (GJ tonne^{-1})	0.36		0.52		0.43	
B. Ratoon Crop						
1. Cultivation	1.72	4.56	0.57	2.00	1.1	3.28
2. Fertilizer	23.9	63.39	19.8	66.00	21.8	64.70
3. Harvesting/Hauling	11.4	30.23	9.6	32.00	10.5	31.12
TOTAL ENERGY (GJ)	437.7	100.0	30	100.00	33.4	100.00
LDOE/ha	987.3		785.7		870.2	
TOTAL YIELD (tonne/ha)	120		65		92.5	
ENERGY USE (GJ tonne^{-1})	0.31		0.46		0.36	
Average (A + B)						
Total GJ/ha	45.49		36.85		40.67	
LDOE/ha	1191.34		938.88		1064.98	
Energy as per tonne	0.38		0.49		0.43	
LDOE/TC	9.95		12.83		11.26	

L-diesel oil equivalent (LDOE); 1 L-oil = 0.0386 GJ

LDOE/ha = GJ/ha ÷ GJ L^{-1} - oil; L-diesel oil equivalent per ha

LDOE/TC = GJ/TC ÷ GJ L^{-1}-oil; L-diesel oil equivalent per tonne cane

GJ/TC = GJ/ha ÷ TC/ha; Gega Joule per Tonne Cane

LDOE/TC = LDOE/ha ÷ TC/ha; L-diesel oil equivalent per tonne cane

Table 4. **Energy equivalent (GJ/ha) of NPK fertilizer applied in Luzon, Visayas and Mindanao, and average for the Philippines***

Nutrient	**Luzon**			**Visayas and Mindanao**			**Average**		
	kg/ha	**GJ/ha**	**%**	**kg/ha**	**GJ/ha**	**%**	**kg/ha**	**GJ/ha**	**%**
N	116.05	9.70	97.8	102.65	8.11	90.1	106.14	8.39	92.2
P	9.88	0.12	1.2	41.89	0.50	5.5	31.45	0.38	4.2
K	13.14	0.10	1.0	48.90	0.40	4.4	42.46	0.33	3.6
Total		9.92	100.0		9.01	100.0		9.10	100.00

** Data summarized from Covar (1989), average from 6 cropping years; 1982-83 to 1997-88.*

** GJ values for NPK adopted from Soriano (1982)*

N = 0.079 GJ/ kg; P = 0.012 GJ/ kg; K = 0.0079 GJ/ kg

On one hand, sugarcane farmers in Luzon were applying more N (116.05 kg/ha) than P (9.88 kg/ha) and K (13.14 kg/ha). On the other hand, the Visayas and Mindanao sugarcane farmers applied more P (41.89 kg/ha) and K (48.9 kg/ha) than Luzon farmers. This explains why the percentage energy equivalent for N was only 90.1% (8.11 GJ/ha) in the Visayas and Mindanao.

A special audit of FFE use was done for Negros Occidental since more than half of Philippine sugar is produced in that province. The audit results for the energy equivalent of fertilizer are shown in Table 6. The total energy equivalent of fertilizer for plant cane was 21.2 GJ/ha or about 0.265 GJ/TC (6.86 LDOE/TC) and 19.8 GJ/TC or about 0.304 GJ/TC (7.88 LDOE/TC) for the ratoon crop. Of the 21.2 GJ/ha total energy use in plant cane, 84.2% (17.9 GJ/ha) was N. It was higher in the ratoon crop at 90.4% because the sugarcane farmers were applying only N and K (Samson 2003).

Based on the available data for fertilizer application, an energy audit for the energy equivalent of fertilizer application was done for the following crop years: 1983-84, 1987-88, 1995-96, and 2000-2001. The results of the energy audit are shown in Table 7. The nitrogen fertilizer had consistently accounted for the highest energy use, ie, 92.88% for crop year 1983-84, 93.09% for 1987-88, 93.0% for 1995-96, and 87.3% for 2000-2001. This merely suggests that farmers recognize and put more priority in buying and applying N fertilizer among the 3 major elements (NPK) applied in sugarcane production both in the ratoon and plant cane crops.

What was evidently shown also in the audit was the increasing energy use (GJ) through the years (Table 8). In 1983-84, the energy equivalent of fertilizer was 9.28 GJ/ha or 0.158 GJ/TC, 10.41 GJ/ha (0.179 GJ/TC) in 1987-88, 17.74 GJ/ha (0.34 GJ/TC) in 1995-96 and 20.5 GJ/ha (0.315 GJ/TC) in 2000-2001. While there was a slight increase for P and K application, the increase was largest in N. The yearly increases for the energy equivalent of N were as follows:

1983-86 = 0.66 GJ/ha (7.65%)
1988-97 = 6.81 GJ/ha (70.3%)
1996-00 = 1.4 GJ/ha (8.85%)

There was a very noticeable increase to 70.3% in 1988-97 from 7.65% in 1983-86 for N fertilizer. This could be due to the relatively high price of sugar in those years, which encouraged the sugarcane farmers to apply more N fertilizer hoping to increase yield. A correlation analysis was done for tonnage yield (TC/ha), total energy use (GJ/TC), and energy value for N fertilizer (GJ/ha N). On the average, the tonnage yield was highly

Table 5. **Energy equivalent (GJ/ha) of NPK fertilizer applied in 1996.**

Nutrient *	**Kg/ha**	**GJ/ha**	**%**
N	208.8	16.50	93.0
P	55.3	0.66	4.0
K	74.0	0.58	3.0
Total		17.74	

** Estimated from the survey data of 340 kg/ ha fertilizer applied in 1996, ratio of NPK were derived from Covar (1989) fertilizer NPK application rates.*

GJ values for NPK were adopted from Soriano (1982) correlated with the energy value of the NPK fertilizer applied (r = 0.90). This was also true for N fertilizer (r = 0.996). While the tonnage yield increased as N fertilizer increased, the increase due to N fertilizer was small especially for years 1987-88 to year 1995-96. The increase of the FFE equivalent for N fertilizer was 70.3% (6.8 GJ/ha) but the increase in yield was only 3.53 TC/ha (6.08%). It is correct to state that many factors influence yield as pointed out earlier, but these data indicate that sugarcane farmers must evaluate their fertilizer application practices.

Table 6. Fossil fuel energy equivalent (GJ/ha, GJ/TC) of NPK fertilizer in plant and ratoon cane in Negros Occidental. Philippines.

	Kg/ha	**GJ/ha**	**%**
Plant Cane			
N	225	17.9	84.2
P	120	1.4	6.8
K	240	1.9	9.0
Total (GJ/ha)		21.2	
Per tonne		0.265	
LDOE/TC		6.86	
Ratoon Cane			
N	225	17.9	90.4
P	-		
K	240	1.9	9.6
Total (GJ/ha)		19.8	
Per tonne (GJ/TC)		0.304	
LDOE/TC		7.88	

Tonnage Yield; Plant Cane = 80 TC/ha; Ratoon = 65 TC/ha

LDOE/TC = L-diesel oil equivalent per tonne cane

1 L-oil = 0.0386 GJ

GJ/ha = Giga Joule per ha

N fertilizer accounted for at least 90% of energy consumed in cane production. By sugar produced, it is also N fertilizer that can be singularly identified as the most energy-consuming input. Of the total energy equivalent of about 0.54 GJ/TC (production + milling, Table 2), the share of N fertilizer was 0.275 GJ/TC, or about 50.9% of the total energy use.

GENERAL DISCUSSION & IMPLICATIONS

Since N fertilizer consumed the largest quantity of fossil fuel energy (FFE), reduction of its use would have the greatest overall impact on the energy economy of sugarcane production. Reducing the fertilizer use in cane production can be achieved (Mendoza et al 2003). In fuel energy use for operations, trash farming is lower by 48% than conventional cane farming (Table 4). This was mainly due to lower N fertilizer input and the impact of higher yield. Fertilizer reduction was estimated at 99 kg N/ha to 110 kg N/ha. The total FFE equivalent of the fertilizer in the ratoon crop is thereby reduced to 9.1 GJ/ha (Mendoza et al 2003).

Furthermore, trash farming conserves a considerable amount of N in the soil (approximately 30-35 kg N/ha). Trash farming also helps conserve organic matter during the decomposition process and it encourages N fixation in sugarcane litter. Hill & Patriquin (1990) described a highly active system, involving a microaerophilic N2-fixing *Azosprillium brasilense* and adematiaceous fungus *Helicomyces roseus*. In Brazilian cane varieties, high yields without N fertilizer are associated with greater biological N2-fixation and include *Acetobacter diazotrophicus* (Boddey 1995).

In Brazil, gains in soil nitrogen equivalent to 54 kg N/ha/yr over 9 years were reported for unburned cane (Boddey et al 1995). Burned cane lost soil N at an average of 44 kg N/ha/yr. N fixation levels of 50-200 kg N/ha occurred in trash-farmed sugarcane fields, with the higher range associated with higher trash levels. A mean value of 125 kg N/ha was estimated where trash farming was established as a practice (Patriquin 1992). In Brazil, where trash farming was frequently practiced, only 60 kg N/ha on average is applied to the crop, while 150-300 kg N/ha are used in most cane-producing countries such as Cuba, Peru, India and the United States (Boddey 1995). Of 135 field experiments in Brazil, only 19% of plant crop trials showed significant responses to fertilizer (Azeredo et al 1986). The N response of the ratoon crop was rarely more than half the amount that the crop accumulates, possibly because the sugarcane cultivars in Brazil were bred under low N conditions. Boddey (1995) found that breeding low N-requiring plants generated major energy savings in terms of N use for the Brazilian biofuel industry.

But the impact of trash farming in reducing FFE goes beyond the reduction in the energy-intensive manufacture of chemical fertilizers, particularly N. The energy-consuming operations like crop establishment and tillage are also reduced.

Table 7. **Fossil Fuel Energy Usage through the NPK fertilizer in cane production for years 1983 to 2001**

Year	**TC/ha**	**Energy Use**			
		GJ/ha	**(GJTC^{-1})**	**LDOE/ha**	**LDOE/TC**
1983-84	58.66	9.28	0.158	240.41	4.09
1987-88	57.98	10.41	0.179	269.69	4.64
1995-96	61.51	17.74	0.304	459.58	7.88
2000-01	65.0	20.5	0.315	531.08	8.16

LDOE/ha = GJ/ha ÷ GJ L^{-1}-oil; L-diesel oil equivalent per ha

LDOE/TC = GJ/TC ÷ GJ L^{-1}-oil; L-diesel oil equivalent per tonne cane

1 L-oil = 0.0386 GJ

GJ/TC = GJ/ha ÷ TC/ha; Giga Joule per Tonne Cane

LDOE/TC = LDOE/ha ÷ TC/ha; L-diesel oil equivalent per tonne cane

The energy equivalent of NPK fertilizer use in cane production was summarized rom Table 6.

Along with the use of cane varieties good for ratooning, trash farming could extend the ratoon cycles of 4 years or more. This has been achieved already in Australia and Brazil (Boddey et al 1995) and it can also be done in the Philippines.

Furthermore, under trash farming, trash-mulched inter-rows need no cultivation. According to a trash farming scheme (Mendoza 1979, Mendoza 1985), the ratio of non-trash and trash mulched rows is 50:50. This represents a 50% reduction in inter-row cultivation.

Some of the P and K can also be lost through burning (Cook 1994). In trash farming systems, P uptake appears more efficient as the mulch protects the soil from desiccation and permits root proliferation in the soil surface where P levels are high. Mulching permits a greater recycling of P from residues than burning. Ball-Coelno et al (1993) suggest that lower P fertilizer rates could be used to maintain productivity on sites where burning is practiced.

Upon decomposition, sugarcane trash (as organic matter) is transformed into a stable product called humus. Conserved as mulch, sugarcane trash decomposes into humus, improving soil tilth and decreasing the tillage required. Hodge (1998) points to the importance of organic matter for long-term sustainability of crop production.

At the mill level, it is also feasible to reduce if not entirely eliminate the use of non-renewable fossil fuel energy. About 5.9% of the total energy use equivalent to 365,000 barrels of imported bunker oil (Mendoza et al 2003) is still used in the mill. The use of imported bunker oil can be eliminated as Thailand and Molawi have already done (Corpuz & Aguilar 1992). This could be achieved with renewable biomass fuel as 'green power' alternative for sugarcane milling (Mendoza et al 2003).

Alternative biomass materials are as follows:

1) baled sugarcane trash
2) high-yielding perennial grass, ie, Napier (*Pennisetum purpureum*)
3) fast-growing tree species.

To displace all the bunker oil currently imported for sugar processing, it would require only 246,000 t (at 26% moisture) of cane trash. This volume represents 50% of the 496,000 t of recoverable trash (low estimate) that could be harvested following the final ratoon crop in a three year cane planting- harvesting cycle. A cane trash price of US$ 33/t (1$=50P) would provide sufficient incentive for farmers to develop this opportunity and provide an alternative to boiler fuel at the cost of oil at US$ 20 barrel. Several baling and storage systems are available that are suitable for retrieving materials from both large and small farms.

The production of fast-growing grasses such as Napier grass, and fast growing trees such as Leucaena and Eucalyptus, were the other renewable biomass options that could be added if trash near the mill is inadequate. The cost of producing Napier grass was projected to be 7% higher than the cost of cane trash harvesting, mainly due to land lease for the crop. A purchase price equal to that of sugarcane trash (US$ 33/t) would likely encourage farmers to plant the crop.

Table 8. **Energy equivalent (GJ/ha) of NPK fertilizer use in selected crop years.**

Year/Nutrient	Amount Applied (kg/ha)	Energy value (GJ/ha)	%	GJ/TC
1983-84				
N	109.2	8.62	92.88	0.147
P	30.8	0.37	3.98	0.006
K	40.9	0.29	3.12	0.005
Total Energy Value		9.28	100	0.158
1987-88				
N	122.70	9.69	93.09	0.167
P	32.70	0.38	3.65	0.006
K	43.40	0.34	3.26	0.006
1995-96				
N	208.8	16.50	93.00	0.260
P	55.3	0.66	4.00	0.010
K	74	0.58	3.00	0.009
Total Energy Value		0.288		
Energy (GJ) Per Tonne				
2000-2001				
N	225	17.9	87.30	0.275
P	60	0.7	3.40	0.010
K	240	1.9	9.30	0.029
Total Energy		20.5	100	0.315

The main concern with fast growing trees is the long period farmers would have to wait prior to receiving an economic return. In the case of firewood crops such as Leucaena, they can be harvested every 2 to 3 years, and command a high retail price of approximately $51.20/t. To provide biofuel to mills at a cost-equivalent to oil of $20 US per barrel, wood could be bulk-purchased at $40/t. The major concern with promoting wood biofuel use is the further contribution to deforestation problems in the Philippines. Sugar refineries have been cited as a major source of deforestation in the past.

Overall, the economic, environmental and social implications of utilizing cane trash in the final ratoon crop year as a substitute for bunker oil appears promising. It represents an opportunity for advocating bioenergy use within the sugarcane industry. Positive socio-economic impacts include the provision of rural employment and the minimization of oil imports. It can also develop the expertise necessary to create a renewable and reliable 'green power' supply for year-round power generation. Thus, investment in the research and development of these technologies is essential to create an effective biomass utilization system for the future.

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Table 9. Comparative fossil/fuel energy use in conventional and trash-farmed sugarcane

	Conventional **GJ/ha**	**%**	**Trash Farm** **GJ/ha**	**%**
Plant Crop				
Land preparation	4.9	11.7	4.9	14
Planting	2.3	5.5	1.6	4
Interrow cultivation	1.7	4.0	1.7	5
Fertilizer	21.3	51.0	17.7	50
Harvesting/hauling	11.5	27.5	9.7	27
Total	41.7	100	35.6	100
Energy per tonne (GJ/TC)	0.52		0.42	
Base yield (TC/ha)	80		84	
Ratoon Crop				
Interrow cultivation	0.57	2.0	0.9	5
Fertilizer	19.8	66.0	9.1	48
Harvesting and hauling	9.6	32.0	9.0	47
Total	30.0	100	19.0	100
Energy per tonne (GJ/TC)	0.46		0.24	
Base field (TC/ha)	65		78	

% Radiation of energy use per tonne cane = 1-0.24/ 0.46 x 100 = 48 %

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