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BIO-ENERGY FROM SUGARCANE:
POTENTIALS, IMPACTS AND STRATEGIES FOR INTERNATIONAL COOPERATION

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ABSTRACT

As the world's most economically significant bio-energy crop, the sugarcane plant is appropriately viewed as a global resource for sustainable development and climate protection. The two most commercially significant bio-energy co-products in the near-term are ethanol and co-generated electricity. The cane-based ethanol potential is shown to be roughly equal to the estimated potential fuel blending market in the year 2020. With biomass gasification, the cane cogeneration potential by 2020 is nearly two orders of magnitude higher than current levels. The potential for carbon reductions is significant. Because sugarcane is based predominantly in the developing world, it also offers special opportunities for sustainable development in rural areas. The technologies to achieve the potential are well-developed and widely available, but face barriers due to trade distortions, lack of investment capital, and a lack of institutional support. A significant amount of international cooperation is therefore needed in order to achieve sugarcane's tremendous potential as a bio-energy resource.

1 THE CANE RESOURCE BASE

The sugarcane plant is one of the world's most cost-effective and diversified renewable resources, offering many alternatives for production of food, feed, fibre, and energy. Owing to climatic factors, sugarcane is found predominantly in the developing world and as such represents a valuable tool in the simultaneous search for sustainable energy sources and new development alternatives. Co-generated electricity and ethanol are the most important cane co-products in commercial terms. As sugar companies look to diversify into bio-energy, new markets can emerge through international cooperation in modernising the cane resource base.

Due to the fact that sustained growth is limited to tropical and sub-tropical regions, the cane resource base is overwhelmingly concentrated in the developing world. As shown in Figure 1, India and Brazil together today account for half of global production. However, there are over 130 countries that produce sugarcane, making it a potentially more evenly distributed energy resource than fossil fuels in many respects.

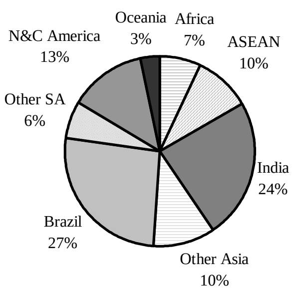

Figure 1: Shares of cane production in 2000. *Source:* [3]

Even without expanded irrigation, there exist significant opportunities for expanding cane yields in many parts of the world, using new varieties, pest management, and other options. Assuming annual improvements varying between 0.5% and 1.5% depending on the region, a 25% increase in cane yield is achieved by 2020, as given in Table 1.

Table 1: Cane Yields (tc/ha). *Source, 2000:* [3]

Region	***2000***	***2020***
Africa	63	84
ASEAN Countries	61	82
India	71	87
Other Asia	58	71
Brazil	68	83
Other South America	71	87
North and Central America	59	80
Oceania	81	95
WORLD	*66*	*82*

Table 2: Cane Production (Million tc). *Source, 2000:* [3]

Region	***2000***	***2020***
Africa	86	173
ASEAN Countries	125	227
India	299	384

Other Asia	132	178
Brazil	328	442
Other South America	81	133
North and Central America	165	246
Oceania	42	54
WORLD	*1259*	*1836*

In some parts of the world, there are also good opportunities for expanding the land devoted to sugarcane, assuming that concerted bio-energy strategies and the need for GHG reductions will help to open up new market opportunities. Expansion of up to 2% annually is feasible in underdeveloped and/or less densely populated areas, particularly in southern Africa. Expansion of 1% to 1.5% is feasible in parts of South America and Asia. Other regions are likely to be constrained by land pressures (India), limited markets (Australia), or limited opportunities for expansion (North America, including Central America and Caribbean). For these regions, small growth rates (0.25% to 0.5%) were assumed. These expansions in combination with the improvements in yield would increase world production by 46% by 2020 (see Table 2).

2 ETHANOL SCENARIOS

Using these regional projections for the cane resource base, some scenarios can be designed to show the bio-energy potential, focusing on ethanol and cogeneration. It is assumed that the feedstock for ethanol production will be either molasses or cane juice. Yields were assumed to reach the levels given in Table 3 by 2020. It is possible that higher yields can be achieved, but higher levels might be less appropriate to use for a regional average.

Table 3: Assumed ethanol yields in 2020 (litres/tc)

		Molasses		
Location	Juice	A	B	C
Brazil	93	27	15	10
Rest-of-World	87	26	14	9

A number of scenarios can be developed by assuming different combinations of production options. In the case of maximum ethanol production (from cane juice), it is assumed that the distillery will operate using other feedstocks 80% of the time in the off-season. Four scenarios along with the reference scenario were defined:

[1] Ref: 90% from C-molasses; 10% from B-molasses; except Brazil which continues its production trend.
[2] E1: 50% from C-molasses; 30% from B-molasses; 10% each from C-molasses and juice.
[3] E2: equal proportion from all feedstocks
[4] E3: 50% from juice; 10% from A-molasses; 20% each from B- and C-molasses.
[5] E4: 80% from juice; 20% from C-molasses

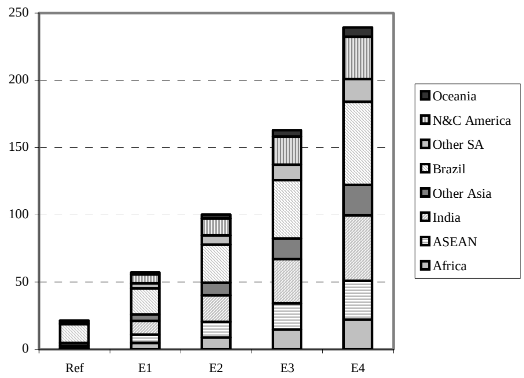

Figure 2: Ethanol production in 2020 under different scenarios (Billion litres).

The results indicate the potential for a ten-fold increase in cane-based ethanol production, under fairly modest assumptions about improvements in yields. The results also suggest the potential for a geographical redistribution in the production of ethanol (see Table 4). Regions where very little cane ethanol is currently produced could see substantial gains in market share. India, ASEAN, and Africa could potentially gain major increases in market share. India's market share would roughly double, to 20%. Brazil, which currently produces about two-thirds of the cane-based ethanol (i.e. excluding grain and other sources), would drop to 26%.

Table 4: Projected market shares of cane ethanol in 2020

Region/ Scenario:	*Ref*	*E4*
Africa	1%	9%
ASEAN Countries	2%	12%
India	10%	20%
Other Asia	10%	9%
Brazil	65%	26%
Other South America	4%	7%
North and Central America	8%	13%
Oceania	1%	3%

The current ethanol market is one in which Brazil exerts extreme market power, as the world's only major swing producer between sugar and ethanol. The expansion of the ethanol market could help to create many medium-size players and make the industry more competitive in the long-term. The geographical diversification will contribute to a transition towards ethanol as a global bio-energy resource rather than a regional one.

The scenarios considered here do not address the impacts on the sugar market itself. Indeed, some of the scenarios, particularly E3 and E4, may appear to be physically impossible, since the cane-based sugar supply would all but disappear in such scenarios. However, the scenarios are not intended to portray the market developments themselves, but rather to represent the range of options available. Furthermore, by 2020 there will certainly be major changes in the sugar market that impact the sources and origins for the relevant products, especially after expected agricultural reforms are introduced and subsidies removed. At the same time, although not analysed here, other crops such as sweet sorghum are expanding and will offer new feedstocks, so that the overall sugar supply will not necessarily be as linked to cane as it has been in the past.

3 CO-GENERATION SCENARIOS

The cogenerations systems installed at most factories today provide only a small surplus after accounting for the factory needs. A Condensing Extraction Steam Turbine (CEST) would provide a ten-fold increase, assuming adoption of steam conservation measures so as to optimise overall efficiency. Gasification with a Biomass Integrated Gasifier/Combined Cycle (BIG-CC) system could increase surplus electricity by sixty-five fold under year-round operation.

The cogeneration scenarios were built up based on the systems and operating assumptions given in Table 5. Year-round operation would require another source of biomass in addition to bagasse, presumably cane trash, which is abundantly available where cane can be harvested green. The bulkiness of handling cane trash has tended to be an obstacle, but new techniques and machines have addressed some of the problems.

Table 5: Unit surplus electricity levels at the factory

System	***Operation***	***kWh/tc***
Reference	Harvest-only	10
CEST	Harvest-only	120
CEST	Year-round	210
Gasification	Harvest-only	390
Gasification	Year-round	650

The cogeneration scenarios were defined as follows:

[1] Ref: existing development continues, with CEST systems installed and operated during harvest-season only in a very limited number of countries.
[2] C1: Half of all factories have CEST systems by 2020, with 20% of these operating year-round.
[3] C2: All factories have CEST systems installed by 2020, with 80% of these operating year-round.
[4] C3: Half of all factories have CEST, the other half BIG-CC, with 20% of each operating year-round.
[5] C4: All factories have gasification, 80% operating year-round.

The results of the scenario calculations are given in Figure 2. The reference scenario results in just 35 TWh annually while the gasification scenario (C4) would result in 1100 TWh. Of course these results are only representative of the potential. Even if development goes well with gasification and costs come down, there will still be many cases where it is either not cost-effective or is too risky. Yet even the all-CEST scenario would achieve 353 TWh per year. CEST systems are mature and will generally be economic wherever institutional conditions have levelled the playing field for small power producers to sell to the grid, and where financing is available at reasonable interest rates.

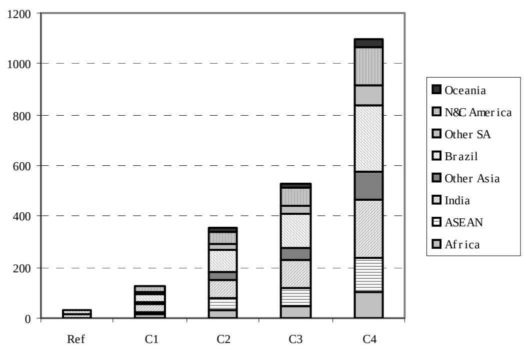

Figure 3: Co-generated electricity production in 2020 under different scenarios (TWh).

4 FUEL SUBSTITUTION

Fuel ethanol can be blended with gasoline at levels varying from 10% to 25% with little or no effect on fuel economy and with relatively minor adjustments, if any (depending on the share) to the engine. It can also be blended with diesel in shares from 3% to 5% although some experience suggests that higher percentages can be used. Table 6 gives current and projected gasoline and diesel consumption and Table 7 provides a comparison of the projected gasoline and diesel markets with the E4 scenario defined above. A conservative assumption is a worldwide blend of 10% for gasoline and 3% for diesel.

Table 6: Gasoline & diesel consumption (billion litres)
Sources: [6] – 1998 data; [2] – 2020 forecast

	Gasoline		***Diesel***	
Region	***1998***	***2020***	***1998***	***2020***
Africa	30	65	34	65
ASEAN	30	63	60	111
India	8	22	43	100
Other Asia	186	397	253	469
Brazil	24	50	34	61
Other SA	30	56	34	56
N&C America	561	778	242	293
Oceania	22	32	16	21
Europe (incl. Russia)	242	366	333	439
WORLD	*1132*	*1829*	*1050*	*1614*

Table 7: Comparison of 2020 blending scenario with cane ethanol scenario E4 supply (billion litres)

Region	*10% gas-oline + 3% diesel*	*Ethanol (E4 scenario)*	*Balance*
Africa	9	22	13
ASEAN	10	29	19
India	6	49	43
Other Asia	56	23	-33
Brazil	7	62	55
Other SA	8	17	9
N&C America	88	31	-57
Oceania	4	7	3
Europe (incl. Russia)	52		-52
WORLD	*239*	*239*	*1*

The comparisons are interesting in several respects. First, the total potential for cane ethanol is roughly equal to the projected blending demand. Second, the disparity between current centres of demand and supply suggests a need for addressing the transportation difficulties associated with ethanol, if it is to become an international product. Third and finally, the export/import implications offer a strategy for north-south cooperation in ethanol, providing Africa and other regions with new export options while achieving environmental goals. Given that the energy balance of cane ethanol is several times better than that of grain ethanol and other sources, the environmental costs of transport are easily outweighed by the much higher renewable energy content. There are major political barriers in the form of protectionism, but as more prominence is given to global free trade, these issues will have to be addressed long before 2020.

5 ELECTRICITY SUBSTITUTION

Surplus electricity from cogeneration plants at sugar factories is already increasing at a fast pace in a number of countries, such as Mauritius, Reunion, India, and Brazil. The plants compare favourably from an environmental perspective since they will in many developing countries offset marginal sources from gas, diesel, or oil. Where cane cogen is developed on a large scale, it will also be able to offset new or existing coal plants. At the same time, continuous supply makes it more reliable than the intermittent renewables, and can be a strategic investment where there is an over-reliance on hydropower. Furthermore, the existence of industrial infrastructure and know-how at the factories makes the integration and commissioning of the cogen plants straightforward from an operational perspective.

Table 8: Electricity consumption and cane cogen (TWh)
Sources: [6] – 1998 data; [2] – 2020 forecast

	Electricity Consumption		*Cane Cogen (as share of 2020 consumption)*	
Region	***1998***	***2020***	***CEST (C2)***	***BIG-CC (C4)***
Africa	390	849	4%	12%
ASEAN	344	718	6%	19%
India	496	1127	7%	20%
Other Asia	3474	10162	0%	1%
Brazil	361	786	11%	34%
Other SA	291	704	4%	11%
N&C America	4670	7377	1%	2%
Oceania	238	337	3%	10%
TOTAL	*10264*	*22061*		

Table 8 shows that cane cogen potential represents a reasonable share of projected electricity consumption in 2020, and this is in spite of the fact that electricity consumption will more than double in most regions. Even in the CEST-only scenario (C2), cane cogen can contribute a smaller but still respectable percentage of electricity supply in a number of countries, particularly in Brazil, India, and other producers such as Thailand in the ASEAN group.

6 CARBON REDUCTIONS

Carbon reductions are estimated as the sum of the substitution by ethanol and the substitution with cane co-generated electricity. Ethanol substituted for gasoline saves approximately 2.2 kg Carbon per litre. For electricity, the savings will vary from zero (when substituted for nuclear or renewables) to 1.2 kg per kWh in the case of diesel substitution. Intermediate values include gas (400-600 grams/kWh) and coal (900 – 1000 grams per kWh). Assuming marginal sources (mainly gas and diesel), an estimate can be made for each region of the carbon reductions, which are added to the ethanol reductions in the combined scenario results in Figure 4.

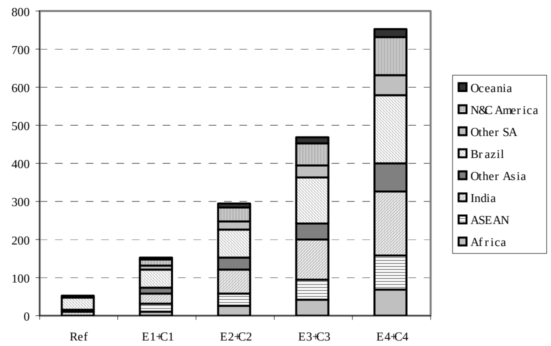

Figure 4: Carbon reductions in 2020 under different scenarios (Million tonnes C).

The total estimated potential reductions for 2020 range from 150 to 750 million tonnes Carbon. These totals are significant in comparison to the first commitment period Kyoto targets. For example, EU carbon emissions in the energy sector were 3150 million tonnes in 1990. The cane potential is equivalent to 5% and 25% of this total, which compares favourably with the EU Kyoto reduction commitment of 8%.

7 CONCLUSIONS

There exists significant potential for bio-energy from sugarcane, particularly for ethanol production and co-generated electricity. The ethanol potential ranges up to 10% of projected gasoline plus 3% of projected diesel consumption in 2020, suggesting significant opportunities for regional and global blending strategies. The cogen potential is equivalent to 10% to 20% or more of electricity consumption in India, Brazil, and several other major cane-producing areas. The carbon reduction potential amounts to 150 to 750 million tonnes.

In spite of this potential, cane is still largely seen as a source of sucrose. The transition to cane as a bio-energy resource requires much more international cooperation if it is to help in meeting GHG reduction targets while also defining new paths for sustainable development and returning the sugar industry to competitiveness. Because of its high efficiency and its concentration in the developing world, the cane resource should be viewed as a global resource for sustainable development and should command much greater focus and concerted policy action through north-south and south-south cooperation.

8 REFERENCES

[1] Cornland, D., Johnson,F. ,Yamba, F. et al *Sugarcane Resources for Sustainable Development: A Case Study in Luena, Zambia.* Stockholm Environment Institute, April 2001. ISBN: 9188714 713.
[2] DOE 2002, *International Energy Outlook 2002*, DOE/EIA-0484. U.S. Department of Energy.
[3] FAO 2002, Food and Agriculture Organisation ECO-CROP database (www.fao.org).
[4] F.O. Licht 2001, World Ethanol Report.
[5] Johnson, F.X., “Bioenergy from Sugarcane for Sustainable Development and Climate Mitigation: Options, Impacts, and Strategies for International Cooperation,” *European Bioenergy Conference*, Amsterdam, June 2002.
[6] UN2002 *Energy Statistics Yearbook* United Nations.