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NEW PROSPECTS FOR COGENERATION IN THE CANE SUGAR INDUSTRY*

by

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Using advanced cogeneration technologies fired with cane residues, the cane-sugar industry could produce about as much electricity as is now provided by oil or about 1/5 of the total electricity generated by utilities in cane-producing developing countries (Table 1).

Such a major role for cane-sugar producers in power generation is feasible despite the fact that at present all the bagasse, the fibrous residue of cane milling, is typically burned as fuel in small steam-turbine cogeneration systems to meet the modest steam, mechanical power, and electricity demands of sugar factories. A typical factory today might produce some 30-40 kWh of mechanical work and electricity per tonne of cane crushed. The present balance between supply and onsite demand reflects traditional sugar-factory designs intended to insure that the factory is energy self-sufficient and that bagasse "waste" is fully disposed of. If more energy-efficient power generating equipment were used, considerable amounts of power could be produced for export to the utility grid. Even more power could be produced if steam-conserving process technologies now widely used in the oil-dependent beet-sugar industry (e.g. condensate juice heaters and falling film evaporators) were adapted to cane-sugar factories [1]. Moreover, if the recovery and storage of barbojo, the tops and leaves of the cane plant that are customarily burned off the cane just before harvest, prove to be commercially successful, its use as fuel would lead to additional electric power production during the months of the year when cane is not milled [2].

Larger, more energy-efficient steam-turbine cogeneration systems have been installed in a few sugar factories. In Hawaii, some systems produce about 50 kWh/tc more than is needed onsite for export to the electric utility grid [3]. An even more efficient steam-turbine system is being considered for installation in one large sugar factory in Jamaica [4]. The proposed unit would produce about 75 kWh/tc of exportable electricity. Plans for the Jamaica plant include the use of barbojo to permit the plant to produce power during the off-season. This would boost total exportable electricity to about 180 kWh/tc. In a "steam-conserving" factory a steam-turbine plant of the type proposed for Jamaica would be able to export 110-210 kWh/tc depending on the amount of barbojo used in the off-season. Investments in steam-conserving retrofits would be quickly paid back from the revenues resulting from the extra electricity sales to the utility [1].

Advanced gas turbines offer the advantages of higher thermodynamic efficiency and lower unit capital costs compared to the more familiar steam-turbine technologies [1].[1] Moreover, in contrast to the situation for steam-turbines, scale economies are weak for gas turbines, so that the economics of power generation are typically favorable at scales of just a few megawatts.

To date gas turbines have required high quality oil or natural gas for fuel. However, operation of gas turbines on gas derived from coal has been successfully demonstrated in California [6], and lower-cost, more energy-efficient aircraft-derivative gas turbines fired with gasified coal are now being developed in the US [7], where a 5 MW pilot plant and a 50 MW commercial demonstration plant are being planned for start-up in the early 1990s. The

[1] Recently there have been major improvements in the performance of gas turbines, stimulated largely by the surge in gas-turbine sales for cogeneration applications in the US. The cogeneration market began growing rapidly after passage of the 1978 Public Utility Regulatory Policies Act (PURPA), which facilitates the sale of excess electricity from cogenerators to electric utilities. Many of the improvements being made in stationary gas turbines have resulted from advances in jet engine technology, which were stimulated by the market pressures of high fuel costs for commercial airlines and more than $400 million of annual expenditures by the US government on R&D for jet engines for military aircraft over the last decade [5].

technology for firing gas turbines with coal gas would be largely transferable to firing with gasified bagasse or other biomass. In fact, operating gas turbines on biomass fuels should be easier because there are no significant amounts of troublesome sulfur emissions to contend with. One major US manufacturer has already begun development of gas-turbine systems fired with gasified biomass.

An investment in a gasifier/gas-turbine system would be financially attractive, typically generating a higher internal rate of return than an investment in a steam-turbine system [1]. Moreover, because of its greater efficiency, the gasifier/gas-turbine system could produce more power. For a steam-conserving sugar factory the amount of excess electricity available for export would be some 240 to 430 kWh/tc, depending on the amount of barbojo utilized--roughly double that for a steam turbine (Figure 1). At a sale price of 6 cents per kWh, up to $25 of revenue would be generated per tonne of cane; sugar revenue would be comparable for a sugar price of $0.25 per kg ($0.11/lb, about twice the 1986 world price).[2]

The economics of bagasse gasifier/gas-turbine cogeneration should also be attractive for many utilities. The busbar costs for power generation with a 52 MW biomass-gasifier/gas-turbine power system, calculated for an illustrative case in Jamaica, are shown in Figure 2 for five levels of fuel processing (none, drying, baling and drying, briquetting, and pelletizing), with and without barbojo recovery, in relation to the busbar cost for a central-station

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2 Gas-turbine systems could also be installed at ethanol-from-sugar-cane distilleries. As in-house steam and electricity demands per tonne of cane would be comparable at modern distilleries to those at steam-conserving sugar factories [8], such distilleries could also produce up to some 430 kWh/tc of exportable electricity. The producer price of alcohol would have to be $0.35 per liter (75% higher than in Brazil today) for alcohol revenues to equal those from electricity in this case, assuming 70 liters of alcohol per tonne of cane.

coal plant. The calculations are presented for these different cases because it is unknown what level of fuel processing will be needed for gasification and because the success of barbojo recovery has not yet been proven. In all cases except those where no barbojo is recovered and extensive fuel processing is required, cane power would be cheaper than power from what has previously been identified as one of the least-cost generating options for Jamaica, a 61 MW steam-electric plant fired with imported coal [9].[3] If stack-gas scrubbers were required on the coal plant to reduce sulfur oxide emissions (as they are in the US), cane power would probably be cheaper in all cases.[4]

Some engineering development work and a pilot demonstration remain to be carried out to bring biomass-gasifier/gas-turbine cogeneration systems to commercial readiness. How rapidly this technology is commercialized in the cane-sugar industry will probably depend more on how quickly institutional thinking patterns change than on technological constraints. The introduction of gas turbines would be facilitated by a willingness of the sugar industry to view itself as a producer of two primary products, sugar and electricity, as well as by the willingness of electric utilities to consider gas turbines burning cane residues as a candidate least-cost power-generating option.

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[3] The power cost shown for the case of no barbojo recovery could be reduced by using an alternative fuel in the off-season. One possibility would be to burn distillate oil. Another would be to use another biomass feedstock (e.g. wood grown on plantations). Or a lower capacity cogeneration facility could be installed and some bagasse could be processed and stored for use in the off-season.

[4] The unit capital cost ($ per kW) for a new 200 MW coal steam-electric plant with scrubbers in the US [10] would be about 40% higher than that estimated in [9] for a 61 MW plant (Figure 2). At a size of 61 MW the cost would be higher still because of the sharp scale economies of steam-turbine power generation.

Table 1. Electricity potential from sugarcane based on the 1985 production of cane, (A),[a] and actual total electric utility generation in 1982, (B),[b] in developing countries (10^9 kWh).

		A	B		A	B	A	B
ASIA							85	599
	India	30.2	129.5	Iran	0.86	17.5		
	China	18.3	327.7	Vietnam	0.78	1.69		
	Thailand	10.3	16.2	Burma	0.43	1.52		
	Indonesia	7.3	11.9	Bangladesh	0.40	2.98		
	Philippines	7.1	17.4	Malaysia	0.30	11.1		
	Pakistan	6.1	14.9	Nepal	0.12	0.284		
	Taiwan	3.0	45.0	Sri Lanka	0.073	2.07		
CENTRAL AMERICA							63	100
	Cuba	33.9	10.8	Jamaica	0.90	1.30		
	Mexico	15.0	73.2	Panama	0.69	2.71		
	Dominican Rep.	4.0	2.38	Belize	0.47	0.065		
	Guatemala	2.2	1.42	Barbados	0.43	0.339		
	El Salvador	1.2	1.45	Trinidad & Tob.	0.34	2.30		
	Nicaragua	1.1	0.945	Haiti	0.22	0.352		
	Honduras	1.0	1.04	St.Chris.-Nevis	0.12	na		
	Costa Rica	0.99	2.42					
SOUTH AMERICA							56	257
	Brazil	36.3[c]	143.6	Guyana	1.1	0.255		
	Colombia	5.9	21.3	Bolivia	0.75	1.40		
	Argentina	5.2	36.2	Paraguay	0.34	0.569		
	Peru	3.1	7.25	Uruguay	0.22	3.47		
	Venezuela	2.0	39.0	Suriname	0.043	0.175		
	Ecuador	1.3	3.09					
AFRICA							30	167
	South Africa	10.9	109.0	Mozambique	0.26	3.25		
	Egypt	3.5	17.2	Somalia	0.23	0.075		
	Mauritius	2.9	0.320	Nigeria	0.22	7.45		
	Zimbabwe	2.0	4.16	Angola	0.22	1.46		
	Sudan	1.9	0.910	Uganda	0.15	0.569		
	Swaziland	1.7	0.075	Congo	0.11	0.195		
	Kenya	1.6	1.73	Mali	0.090	0.080		
	Ethiopia	0.82	0.618	Gabon	0.052	0.530		
	Malawi	0.66	0.410	Burkina Faso	0.043	0.123		
	Zambia	0.61	10.3	Chad	0.034	0.065		
	Ivory Coast	0.54	1.94	Guinea	0.021	0.143		
	Tanzania	0.45	0.720	Sierra Leone	0.021	0.136		
	Madagascar	0.43	0.342	Benin	0.021	0.016		
	Cameroon	0.30	2.15	Liberia	0.013	0.389		
	Zaire	0.28	1.48	Rwanda	0.009	0.066		
	Senegal	0.28	0.631					
OCEANIA							2	1
	Fiji	1.6	0.241	Papua N. Guinea	0.13	0.44		
ALL SUGAR-PRODUCING DEVELOPING COUNTRIES							236	1,124

[a]For the 1985 levels of sugar production [11], assuming 100 kg of sugar is produced, on average, from each tonne of cane. For cogeneration based on the General Electric LM-5000 steam-injected gas turbine. (See Figure 1).

[b]From [12], except Taiwan, Iran, South Africa, Cuba, Trinidad & Tobago, and Venezuela, which are from [13].

[c]Based on cane used for sugar production only, which accounted for about 40% of all cane harvested in 1985 [14]. Including the cane used for ethanol production (see footnote 2), the total electricity potential from cane in Brazil is about 94 TWh.

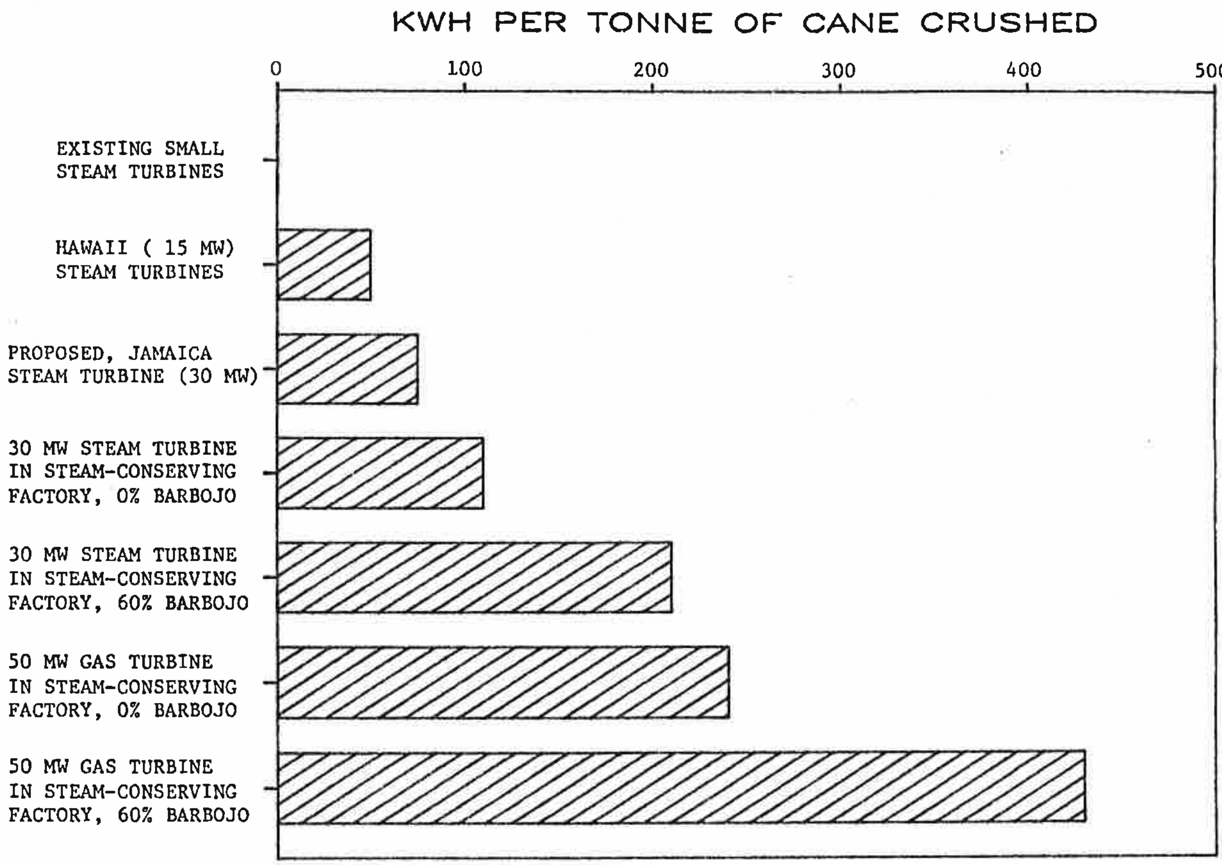

Figure 1. Potential generation of exportable electricity from sugar factories with alternative cogeneration technologies [1].

The 30 MW steam turbine is a condensing unit with a single controlled extraction, as proposed for a sugar factory in Jamaica [4]. The gas turbine is a General Electric LM-5000 gas turbine modified for steam injection and coupled to a Lurgi dry-ash gasifier. Retrofits to convert an existing sugar factory into a "steam-conserving" factory include the use of condensate juice heaters and falling film evaporators. The two levels of barbojo recovery indicated are for 0% and 60% of the estimated total recoverable barbojo.

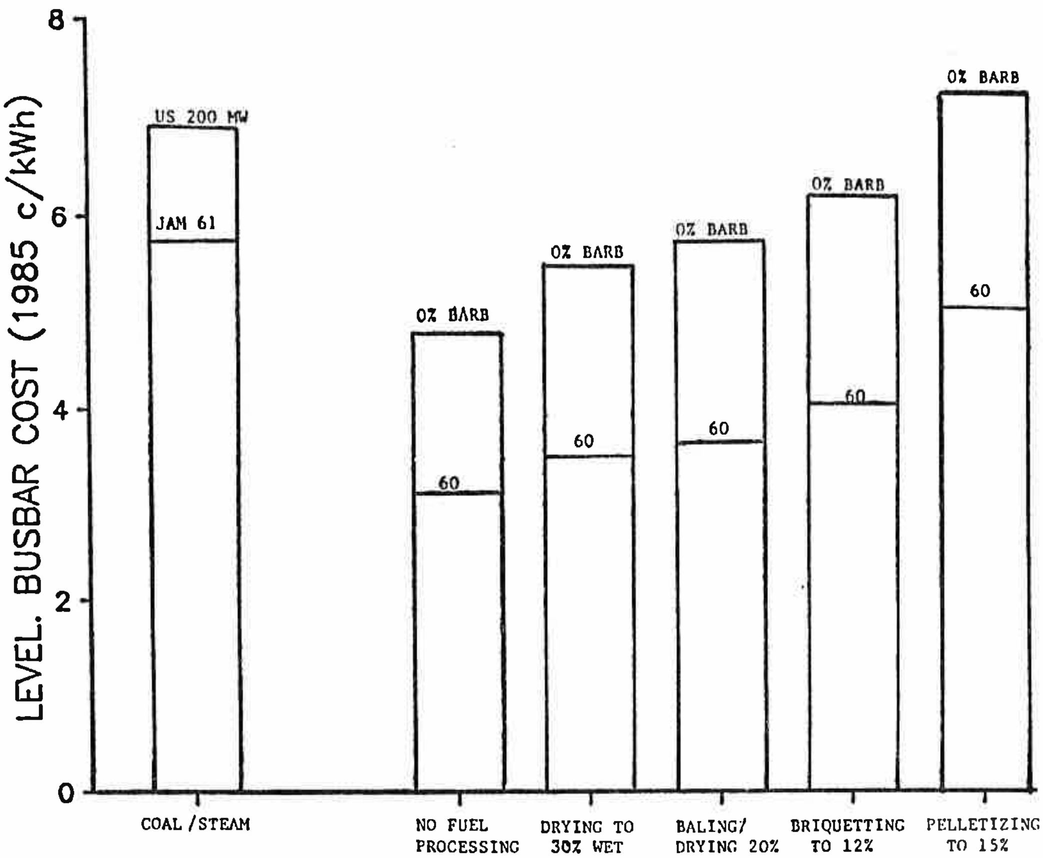

Figure 2. Estimated levelized busbar costs for generating electricity in new powerplants (for a 12% real discount rate and a 30 year plant life) [1].

The bar labeled COAL/STEAM is for central-station, coal-fired, steam-electric plants. The lower cost shown is for a 61 MW plant plus coal-handling infrastructure located in Jamaica, for which the total installed capital cost is estimated to be about $1300 per kW [9]. The plant is assumed to operate with an annual average capacity factor of 66%, and the cost of coal imported into Jamaica is assumed to be $2.10 per GJ. The upper cost shown is for a 200 MW plant with flue gas desulfurization, located in the Midwestern United States, for which the installed cost is about $1800/kW [10]. The plant is assumed to operate with an annual average capacity factor of 66%, and the cost of coal is assumed to be $1.60 per GJ, appropriate for the US Midwest.

The bars at the right are for a 52 MW steam-injected gas turbine (based on the General Electric LM-5000) operating on gasified biomass produced in a Lurgi dry-ash gasifier. The installed capital cost for the system (including the gasifier) plus steam-conservation retrofits to the sugar factory is estimated to be $1060 per kW [1]. If no processing is required, the bagasse is "free," but barbojo would cost about $1.00 per GJ for harvesting, drying, and storing. The following total fuel costs (in $/GJ) are estimates with additional fuel treatment:

	Bagasse	Barbojo
Drying to 30% moisture:	0.60	1.00
Baling and drying to 20% moisture	0.80	1.00
Briquetting (12% moisture)	1.15	1.35
Pelletizing (15% moisture)	2.00	2.20

The annual average capacity factors for the gasifier/gas turbine would be 40% with no barbojo recovery and 72% with the 60% recovery.

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