HIGH EFFICIENCY ELECTRICITY PRODUCTION IN THE SUGAR INDUSTRY OF THE FUTURE: THE PACIFIC INTERNATIONAL CENTER FOR HIGH TECHNOLOGY RESEARCH PROJECT (>6 MW_e)

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INTRODUCTION

The Pacific International Center for High Technology Research (PICHTR) is presently starting up a 100 tpd bagasse Renugas® gasifier which was developed under license from the Institute of Gas Technology (IGT).

For thousands of years, mankind has used biomass for energy, burning it first in campfires. In more modern times, combustion boiler systems were developed such as those fueled by coal. Through inefficient, these systems answered an increasing need for energy brought on by the industrial revolution. Yesterday's systems are being replaced with more efficient methods of energy conversion and extraction. Recognizing the untapped potential for biomass power to provide clean and efficient energy, the U.S. Department of Energy established the National Biomass Power Program in 1991. The State of Hawaii Department of Business, Economic Development & Tourism is collaborating in this national program to complement the development of its own sustainable resource program. As a key player in this program, PICHTR will design, construct, and operate a biomass gasification facility that will be the centerpiece of the nation's biomass gasification technology.

Current Power Generation by the Sugar Industry in Hawaii

Worldwide, the sugarcane industry has the potential to be a major generator of electric power for the electricity grid through the use of the by-product of sugarcane processing called bagasse as a fuel source. Initially, bagasse was used as a fuel solely for the evaporation of water in order to concentrate the sugar, since animal or hydropower was originally used to crush the cane. In time, the benefits of using steam power for in-plant power needs resulted in increased use of these by-products in energy production. The history of the industry in Hawaii was that although[1] some export of electricity to communities took place in the industry prior to 1970, the really major growth in generating capacity took place in the 1970s as the sugar industry consolidated its low pressure boilers into higher pressure units to produce more electricity. The passage of the 1978 Federal Public Utilities Regulatory Policies Act (PURPA) further stimulated the use of bagasse to the point where, in 1991, the industry burning bagasse in conjunction with fossil fuels supplied about 5.5% of the grid electricity. The generation in that year[2] was 495 TWh, down from a high of 681 TWh in 1988. Further, Biomass energy in Hawaii was provided in the form of energy recovered from the H-power plant in Honolulu, an ultra-modern Waste-to-Energy plant recovering steam and electricity from municipal waste generated on Oahu.

Global Sugarcane Power Potentials

The sugar industry worldwide offers the potential to produce about 500 TWh of electricity for export if significant energy-efficient gains could be made internally to the process of sugar production and advanced power generation technology was to be adopted along with increased residue collection from sugarcane growing[3]. To reach this output would require a power generation rate of 450–600 kWh/tc where tc is a tonne of cane processed. Table 1 shows the world cane production statistics from two viewpoints, the geographic area, and the development status. It can be seen that the majority of the sugarcane production is in developing countries.

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1 C.M. Kinoshita. *Cogeneration in the Hawaiian Sugar Industry,* Bioresource Technology. 35(3). pp 231–237. 1991

2 DBEDT. *The State of Hawaii Data Book 1992.* A Statistical Abstract. Table 476, 477

3 R.H. Williams, and E.D. Larson. Advanced Gasification based Biomass Power Generation in Eds. T.B. Johansson, H. Kelly, A.K.N. Reddy, and R.H. Williams. Renewable Energy: Sources for Fuels and Electricity. Chapter 17, pp 729–785, Island Press: Washington, D.C. 1993

The current average rate of power generation from sugarcane in most developing countries is much less than 500 kWh/ton cane processed (tc)—typically less than 10 kWh/tc. Average values range from 15 to 25 kWh/tc in plants that do not require any fossil fuel input. This is barely sufficient to meet the internal needs of these sugarmills. Traditionally, the industry need has been for only sufficient electric power to meet the in-plant or factory demand, with the steam exhaust in balance with the thermal energy requirements. Essentially, the boilers are operated as a bagasse disposal unit since there is a need to maintain an equilibrium between bagasse production and utilization.

Additionally, the sugarcane industry does not normally operate on a year round basis—the cane harvesting and processing season in Hawaii can be quite long at 200 days, but in many places the season is less than 150 days. It is only when there is an incentive to sell power to the grid that the sugar industry can undertake the necessary investments in higher pressure steam boilers and turbogenerators along with energy efficiency improvements. In the Hawaiian industry (footnote 1) low pressure boilers were systematically replaced by higher pressure boiler systems of larger capacity in the period 1960 through 1980, with the average steam pressure and temperature increasing from 1.3 MPa and 210°C to 4.4 MPa and 380°C. Meanwhile, the net steam consumption in the mills decreased significantly from 600 kg/tc to about 300–400 kg/tc; resulting in a power output of about 60 kWh/tc on average, with the best mills reaching over 100 kWh/tc. The thermal efficiency to generate electricity is approximately 15%–20% in such combined heat and power arrangements. Increasing the power to heat ratio will require advanced technologies—such as the use of integrated gasification combined cycles (IGCC). The estimated steam that would be available from an IGCC is only 275 kg/tc and necessitate severe energy efficiency improvements in the sugar production process but would increase the electricity output in the sugarcane season to about 600 kWh/tc. For this to be produced on a year round basis would require additional fuels such as the tops and leaves from the sugarcane harvest (called *Barbojo* in Spanish-speaking countries) other Biomass fuels including wood and wastes or additional fossil fuel input.

PICHTR's development of the Renugas® gasifier is targeted towards this global market, as well as the needs of Hawaii. Recent studies of the profitability of using sugarcane and energy cane crops to increase the power output to the grid have shown that increasing both the power output and the power to heat ratio of the Pioneer Mill on the island of Maui will lead to a rate of return of 30% under a set of selling price assumptions that include sale of electricity at 5 c/kWh. A typical steam plant under the same conditions would not be profitable[4]. The typical performance and economic improvement according to NREL is given in Table 2.

The PICHTR Gasifier

The U.S. Department of Energy (DOE) and the State of Hawaii joined with PICHTR in this cost-shared cooperative project, with the objective of scaling up the process development unit (PDU) of IGT Renugas® pressurized air/oxygen gasifier to a 45–90 ton/day engineering development unit (EDU) operating at 1–2 MPa using bagasse and wood as feed. Other participants in the project are IGT, the Hawaii Natural Energy Institute (HNEI), the Hawaii Commercial and Sugar Company (HC&S), and the Ralph M. Parsons Company, the architectural and engineering firm for the project. The site is the HC&S sugar mill at Paia, Maui, Hawaii. The National Renewable Energy Laboratory is providing project oversight in addition to systems analysis.

The scaleup will be completed in several stages, as shown in Figure 1.

The first phase, which is now being commissioned, consists of the design, construction, and preliminary operation of the gasifier to generate hot, unprocessed gas. The gasifier is designed to operate with either air or oxygen at pressures up to 2.2 MPa, at typical operating temperature of 850°–900°C. In Phase 1, the gasifier will be operated for about four months at a feed rate of 45 ton/day at a maximum pressure of 1 MPa. Following the end of Phase 1 in late 1995, a hot-gas cleanup unit will be added and operated for a planned period of about 500 hours to generate design data and experience with third generation ceramic candle filters. In late 1997, a gas turbine will be added to the system to generate 3 to 5MW of electricity. In this phase, the gasifier feed rate will be 90 ton/day, and the system will operate at pressures up to 2.2 MPa. In a projected but not yet funded Phase 3, the system will be operated in an oxygen-blown mode to produce a clean syngas for methanol synthesis in addition to producing electricity. Discussions are underway with interested commercial partners which could focus on a 1-2 MW power producing system.

A key element of the development in Hawaii will be to prove the suitability of ceramic barrier filters in gas turbine applications. PICHTR is working with Westinghouse, IGT, Gilbert Commonwealth, and the National Renewable Energy Laboratory to demonstrate this technology and have just completed short duration testing of a hot gas cleanup train on the Renugas® pressurized air-blown fluidized bed gasifier at IGT in Chicago. The tests in Chicago demonstrated that ceramic barrier filtration technology is effective in this application; however, the first generation ceramic filters used will not have a sufficiently long service life at the severity projected in this application. More advanced and more stable filters are now available for the following on testing at the BGF.

The project in Hawaii will establish the operational experience and broad data base needed to demonstrate full scale viability of the technology.

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4 PICHTR Sustainable Biomass Energy Program, NREL LOI—Maui Project. Draft Report dated May 1995

Table 1. Sugarcane Production Statistics

WORLD CANE PRODUCTION
Source FAO—Agristat database 1990
Data in 1,000 tonnes (kt)

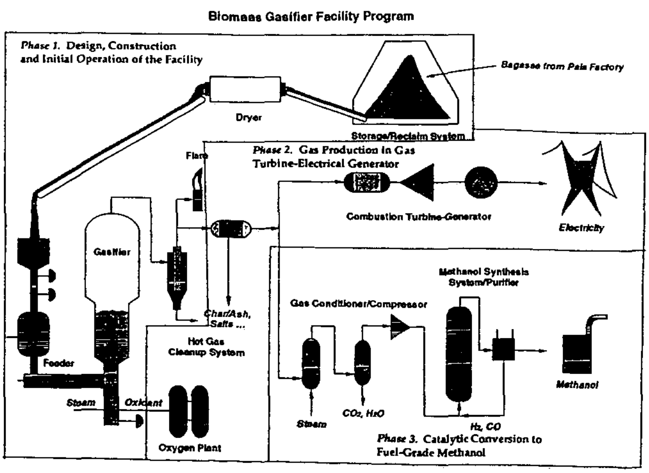
BY DEVELOPMENT CLASS			GEOGRAPHICAL DISTRIBUTION		
World	1,035,096				
Developed	72,193				
North America		24,575	N&C America	173,278	
Europe		256	USA		24,576
Oceana		26,226	South America	332,016	
Other		21,135	Africa	72,982	
Developing	962,903		Asia	426,006	
Africa		38,839	Europe	256	
Latin America		480,718	Oceana	30,559	
Near East		17,316			
Far East		421,698			
Other		433			
Least Developed		25,021			

Table 2. Comparison of Present Day Steam Generation With IGCC[5]

COST FACTORS (¢/kWh)	STEAM GENERATION	IGCC
Operations and Maintenance	0.5	0.5
Fuel Only Cost	3.6	1.6
Capital Recovery	4.2	3.0–3.5
Cost of Electricity	8.3	5.1–5.6

Notes to Table 2. Assuming a marginal cost of fuel of \$2/million Btu (or approxmately \$40/tonne of dry Biomass), a load factor of 85% (base loaded), and a return on capital invested of 8%/year, it is possible to see the effect of the new technology. Both plants are approximately 50 MW_e capacity. The efficiency of the steam plant is about 20%, while the IGCC is estimated to have an efficiency of 45%. The capital cost of the steam plant is \$1.8/W, while that of the IGCC is expected to be in the range of \$1.3 to \$1.5/W.

Fig. 1



[5] Table generated from systems studies by Kevin Craig and R.P. Overend, NREL