The Creation of Greenhouse Gas Benefits Via Biobased Fuel and Chemical Production Within the Country of Guyana

Final Report

Michael A. Fatigati, Neco Sumait, and Mark Carver

Arkenol Holdings, Inc.
27401 Los Altos, Suite 400
Mission Viejo, CA 92691

(714) 582-7417 ph
(714) 588-3972 fax

March 1998

Prepared for

The U.S. Department of Energy
Chicago Operations Office

Under Award No. DE-FG02-97EE35031.A000

We have no objection from a patent
standpoint to the publication or
dissemination of this material.
MPD
Office of Intellectual
Property Counsel
DOE Field Office, Chicago
8/5/99
Date

This report was prepared as an account of work sponsored by the United States Government. Neither the United States Government nor the United States Department of Energy, nor any of their employees, nor any of their awardees, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed or represents that its use would not infringe privately-owned rights.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Table of Contents

	<i>page</i>
I. Introduction	1
II. Project Description	2
III. Arkenol / USIJI Common Objectives	3
IV. Scope of Work - Findings	4
A. Feedstock Assessment	4
B. Product Market	8
C. Site Selection	12
D. Technical and Economic Analysis	14
E. Participants	16
F. Greenhouse Gas Reduction Calculations	17
G. Preliminary Prospectus	18
V. Next Steps	19
VI. Conclusions	20

Attachments

1. Arkenol Proposal to the U.S. DOE's Solicitation No. DE-PS02-97EE35024
2. Feedstock Supply Letters of Interest & Support
3. Ethanol Marketing Letters of Interest & Support
4. Guyana Biorefinery Economic Model
5. OXY-Fuel News article on the U.S. DOE GHG study
6. Project Fact Sheet
7. Project Life Cycle

I. Introduction

This document constitutes the final report in compliance with requirements under the U.S. DOE grant number DE-FG02-97EE35031.A000 which was awarded to Arkenol Holdings, Inc. ("Arkenol") in response to its proposal to the U.S. DOE's *"Solicitation for Federal Assistance Application (SFAA) No. DE-PS02-97EE35024 - For Proposals To Support The Development And Implementation Of International Projects That Reduce, Avoid, Or Sequester Greenhouse Gas Emissions for Submission Under The U.S. Initiative On Joint Implementation (USJI) Program"*. (See Attachment 1.)

As stated in the proposal and subsequent documents submitted to the U.S. DOE, the goals of this investigation are to gather pertinent information and develop the necessary in-country relationships which will ultimately lead to the construction and operation of a biorefinery that will produce clean-burning, alcohol-based transportation fuel from residual agricultural and forestry materials. Arkenol has a patented process for the conversion of cellulosic materials into chemicals and fuels. The combined production and product use activities as a result of this project development are estimated to create a significant net reduction in greenhouse gas emissions within Guyana and the surrounding region and to serve as a demonstration for similar installations worldwide.

SCOPE OF WORK

The scope of work performed under the auspices of this grant included:

- ❖ an investigation of the amount, cost, and availability of appropriate biomass feedstocks;
- ❖ a determination of the viability of marketing and utilizing alcohol based transportation fuels in the Guyanese fuel mix;
- ❖ an analysis of appropriate sites for a biorefinery;
- ❖ a determination of the optimum size and preliminary technical and economic parameters of a production facility;
- ❖ the identification of strategic in-country joint venture partners and government sponsors;
- ❖ the quantification of expected in-country greenhouse gas emission reductions;
- ❖ the preparation of a preliminary prospectus for solicitation of investors and financial institutions for the construction and operations of a biorefinery in Guyana; and,
- ❖ providing additional, pertinent information to the USJI towards getting the Guyana Biorefinery Project certified.

The critical core of information for this report was obtained during a February 16-21, 1998 visit to Guyana. The balance of the information was developed in-house by Arkenol financial and engineering staff, from dialogue with Guyana nationals and in-country expatriates, and from a review of pertinent literature. The remainder of this report documents the findings realized by this *Scope of Work* and present an overview of the next steps that Arkenol intends to take toward reaching the ultimate goal: the construction and operation of a biorefinery. Finally, this report assumes that the reader is familiar with the information contained in Arkenol's proposal, referenced above and presented as *Attachment 1*.

II. Project Description

The national concerns on the current drain on Guyana's economy created by importation of petroleum, Guyana's desire to reap the benefits from its agricultural and forest resources without destroying them, and Guyana's commitment to global climate stabilization, create opportunities for collaboration between entities in Guyana and California-based, Arkenol, Inc. Arkenol's work begins advancement of the partnership to create significant greenhouse gas benefits through Joint Implementation.

The goal of this investigation is to complete feasibility studies necessary to advance the development of a biorefinery in the agricultural regions of Guyana located along its coastal strip which will reduce and sequester greenhouse gases through the production of cleaner burning fuels or chemicals from renewable materials. Completion of these pre-development activities has provided more specific information for use in calculating the baseline and greenhouse gas emissions reduced or sequestered by the biorefinery to supplement information submitted in Arkenol's proposal to USIJI on June 30, 1997. As stated above, the results of this study will be used to seek project financing for the detailed development and construction of the Guyana biorefinery project.

The proposed biorefinery will utilize Arkenol, Inc.'s patented technology for the conversion of cellulose into fuels or chemicals. Arkenol's technology for the production of ethanol, consists of four main steps:

1. Acid Hydrolysis
2. Acid- Sugar Separation
3. Fermentation
4. Distillation

In the Arkenol process, feedstock of roughly ¾ inch size and 10% moisture content is mixed with sulfuric acid and the slurry is fed into hydrolysis units producing a sugar/acid solution. The acid is removed from the sugar by ion separation and is reconcentrated for reuse in the hydrolysis units.

The neutralized sugar stream is fed to batch fermentation vessels with staggered operation to provide a continuous flow to the ethanol distillation process. Yeast is added to the sugar mixture with proper amounts of nutrients and the temperature is controlled for the fermentation period. In the fermentation process, sugars are converted into ethanol and carbon dioxide.

The carbon dioxide may be recovered, compressed, liquefied and sold as a commercial product. the ethanol is recovered from the unreacted sugar, cellulose and yeast by distillation producing a 95% purity stream. The ethanol is further provided to 100% using a molecular sieve to remove the residual water, immediately followed by a denaturing step with unleaded gasoline. Approximately five gallons of unleaded gasoline are mixed with 95 gallons of ethanol to denature the ethanol.

Arkenol's process operates on a minimum effluent basis through recycle of acid and water. In addition, all process streams are converted into salable by-products. A small amount of surplus yeast is removed from the process and disposed of as a feed additive. The biomass residue from the hydrolysis process is primarily lignin which is separated, dried, and used as solid fuel for the biorefinery boiler or sold off-site. Lignin can also be used a soil amendment or sold for other industrial uses. Gypsum is

produced as a by-product from the neutralization of the sugar mixture following the acid-sugar separation process to remove any remaining acid prior to fermentation of the sugar. The U.S. Patent and Trademark Office has allowed Arkenol's patent application on its core technology with others pending on other sugar conversion processes.

The construction and operation of the biorefinery will create the GHG emission changes. Biofuels, produced from waste biomass materials such as wood, rice straw and rice hulls reduce or eliminate CO₂ emissions by working with the Earth's carbon cycle. As they grow, plants absorb atmospheric CO₂ through photosynthesis. Much or all of the CO₂ released when biomass is converted to biofuels and burned in automobiles is recaptured when new biomass is grown to produce more biofuels. In contrast, consumption of fossil fuels causes release of carbon that has been locked away by nature for over 100 million years without providing a rapid mechanism to reabsorb it.

III. Arkenol / USIJI Common Objectives

It was felt when Arkenol responded to the U.S. DOE's solicitation that the business goals of Arkenol converged with many of the objectives of the USIJI for creating opportunities for expanded business. Arkenol's investigation into the potential of a biorefinery project in Guyana have strengthened that understanding. Among the common objectives are:

1. The opportunities for Arkenol's technology are worldwide and its implementation is an excellent way to increase the geographic and sectoral diversity of USIJI projects. The built-in flexibilities in the Arkenol process related to feedstock (wide range of cellulose base feedstock can be used), products (over 150 different chemicals can be produced from the sugars derived from the cellulose), and siting (urban or rural setting) create sustainable development and global climate change stabilization which can be replicated in many parts of the world.
2. Arkenol's technology presents an opportunity to promote technology cooperation to create sustainable development in developing countries and countries in transition. In this case, the Arkenol technology creates efficient uses of Guyana's agricultural and forests resources which are currently used inefficiently due to lack of technology and investments.
3. Guyana's national commitments to stabilization of GHG and economic development are advanced by the proposed biorefinery project. Guyana's government, through the Office of its Ambassador to the U.S., has communicated its interests on pursuing the opportunities for a biorefinery in Guyana. The opportunities for the Arkenol technology are worldwide, with a potential worldwide market of over \$500 billion a year. The products are competitively priced to allow penetration of existing markets and attract financial investments.
4. The reductions in greenhouse gas emissions from the production and use of biofuels are well documented. The successful implementation of the project will provide for real-life experience in utilizing methods to measure, track and verify emissions reductions costs and benefits.
5. The Arkenol technology is an innovative way to create GHG benefits. Arkenol hopes to attract participation by other private entities through projects that offer tremendous market opportunity,

attractive returns on investment, and environmentally responsible products, creating worldwide opportunities to reduce or sequester greenhouse gas emissions.

6. As stated earlier, discussions with Guyana representatives have been very favorable such that host country acceptance of the proposed USIJI project is expected.

IV. Scope of Work - Findings

The following presents the findings of the investigation to date and will serve as the basis for subsequent project development activities.

A. FEEDSTOCK ASSESSMENT

Guyana has three large scale industries which produce feedstocks that provide opportunity for GHG mitigation using Arkenol technology. These are the forestry, rice and sugar industries. Additionally, there is a large amount of underutilized land that could be planted with dedicated crops. As will be shown in Section II.D. *Technical and Economic Analysis* below, the patented biorefinery would utilize approximately 500 dry tons of biomass feedstock on a daily basis. The conclusion of the site visit and subsequent correspondence is that there is sufficient availability of rice straw, rice hulls, and waste wood to support this requirement.

To assess feedstock availability, it is important to understand a little about the geography of Guyana. The three regions in Guyana are the coastal plain, which is mostly below sea level and is protected by a system of sea walls and canals, the intermediate savanna, and, the inland forest. This understanding is critical to an assessment of available feedstocks.

The coastal plain is where the majority of the people live and where all the agricultural activity takes place. Here, sugar cane and rice are the primary crops and occupy the majority of the cultivated landscape. There are small plots for vegetables and citrus, all for domestic consumption. The coastal plain makes up about one-seventh of Guyana's total land area. The savanna is mostly scrub bush, has not been developed to any extent, and makes up about double the land area of the coastal plain. The vast majority of the country is heavily forested with a variety of hardwood species, although some of the forest has been cleared to make way for heavy mining activities in the south, near the border with Venezuela.

WASTE WOOD

Large tracts of land have been leased out to foreign logging companies. Arkenol interviewed senior management at two representative companies on its site visit, both of them are Malaysian owned. They are Demerara Timbers Ltd. and Barama Company Ltd. Both companies have a disposal problem with the sawdust from their mills. They also have a significant amount of "end cuts" and bark available. Current disposal practices are to leave it in place to rot, or to burn it

Barama currently produces 240,000 m³ of logs. In their logging activities they experience about a 4% wastage, which calculates to about 11,000 tons per year of waste wood feedstock available. Additionally, at their plywood/sawmill, they realize wood waste of around 100-120,000 m³ per year,

although some is used in boilers to generate steam. Demerara has a larger logging concession and a commensurately larger sawmill operation. They indicate, at one of their sawmills, that they have approximately 200 tons per day of sawmill waste, most of which could be made available to Arkenol. Both companies indicate that the material would be free for the hauling and verbally agreed that they would be willing to enter into long term contracts for the material. Transportation to the site is expected to average no more than \$5 per ton. Some material will come via truck and other material via barge as the sawmills are located near the rivers and have loadout facilities. Both companies also indicate that while the market is down due to the financial problems in South East Asia, their main market, that they expect to be in an expansion mode within two years.

For its economic projections, Arkenol is assuming that 10% of its feedstock needs, or 36 tons per day, and 45% of its boiler fuel, or 135 tons per day, will be supplied by wood at a cost of \$5 per ton, which represents the cost of transportation. (See Attachment 2.)

RICE STRAW & HULLS

Country wide, Guyana produces about 500,000 tons of rice and is looking to expand their planted acreage. According to figures obtained from a visit with Charles Kennard, CEO of the Guyana Rice Development Board, for every ton of rice, one can expect .7 tons of straw and .2 tons of rice hulls. Therefore, the current availability of feedstock would calculate to be 350,000 tons of rice straw and 100,000 tons of rice hulls.

Rice Straw - Due to weather patterns, rice growers plant and harvest two crops per year from which approximately two tons per acre per harvest are realized in rice yield. If the biorefinery were to use only rice straw as its feedstock (a requirement of 120,000 tons per year), it would utilize the production from about 43,000 acres. This acreage means that sufficient rice straw must be available within an economic transportation distance from the project site. Based on prior work elsewhere, Arkenol considers this to be a maximum of a fifteen mile radius, a very easy prospect given the layout and size of the rice growing areas in Guyana. (Note that the project will utilize only 60% of its feedstock as rice straw, therefore only about 25,000 acres will be necessary to supply the biorefinery.) Current practice is to burn the rice straw in the fields as a convenient disposal measure. However, given sufficient economic incentive, the rice farmer would rather harvest the straw.

The harvesting of rice in Guyana is a very mechanized process. Current mechanical harvesting practices would have to be modified only slightly to obtain the rice straw. Straw is not because there is no market. Mr. Kennard relates that there are two tiers of rice farmers. The majority of farmers are small land owners whose plots average 25 acres or less. There are also a few large farms of over, sometimes well over, 1,000 acres. The average profit for a rice farmer is a meager \$200 per acre per year. The small farmer would therefore be very eager to realize any additional income.

Mr. Kennard was reluctant to state a specific number for the cost of straw but gave an "outside" cost of \$30 per ton for harvesting, baling, and transportation. Arkenol has detailed knowledge of such costs in the U.S., Thailand, and Brazil and believes that, given Guyanese labor rates and

profit margins, that this number is quite high. When final negotiations with the farmers are completed, it is expected that the price will be more in the \$10-\$15 range. Mr. Kennard promised that the Guyana Rice Board would undertake a near-term study to determine what the actual cost of harvest and gathering would be. To that, it was agreed that a small profit would be added to ensure that the farmer would have long-term incentive to provide feedstock to the biorefinery. Also discussed was the development of an alternative mechanism that would have the farmer provide the straw for free or some *diminimus* amount but realize his profit as some percentage of sales, thereby incentivizing the farmer to continually deliver material to the biorefinery. Regardless, the Guyana Rice Board is eager to be of assistance and has agreed to assist the project in coming up with a program that will work within the agricultural costs and practices of Guyana. He sees no problem at all in obtaining the amount of straw needed as they are desperate for additional farm income and are under pressure to discontinue field burning practices. He also indicated that they expect to be expanding their planted lands by about 10% per year.

For its economic projections, Arkenol is assuming that 60% of its feedstock needs, or 216 tons per day will be supplied by rice straw at a cost of \$30 per ton. It is believed that this cost will be significantly reduced in actual practice.

Rice Hulls - Except for a small amount of acreage, the rice millers do not have any of their own fields. Therefore the rice millers do not own any straw. Farmers bring their harvested raw rice to any of several large and small mills within their region, depending on the price and service they can get from the rice miller. When the rice is milled, the hulls are cast aside as a waste product. In some mills, hulls are burned to produce a portion of their power and steam. However, most mills view the rice hulls as a problem waste, free for the taking. Sometimes it is simply burned in piles where it sits, in other places it is dumped into rivers and gullies.

Assuming access to material from 43,000 acres surrounding the biorefinery, there would theoretically be about 36,000 tons of rice hulls available. Since there is more than enough rice straw available and that the rice hulls are a disposal issue, we are assuming that those hulls that are not used for process energy in the mills would be available to us for free. If not, we would use the rice straw as a mechanism to keep the price of the hulls down. (Rice straw is a better feedstock as it contains less inerts than the rice hulls and therefore more convertible cellulose.)

For its economic projections, Arkenol is assuming that 30% of its feedstock needs, or 108 tons per day will be supplied by rice hulls at a cost of \$5 per ton, which represents the transportation cost only of getting the hulls to the biorefinery. (See Attachment 2.)

SUGAR CANE BAGASSE

With the large amount of sugar cane processed in Guyana, it was originally thought that the feedstock needs of the project could be entirely supplied with sugar cane bagasse and cane trash. However, discussions with representatives of the government owned sugar company, Guyana Sugar Company (or "GUYSUCO") and sugar mill plant managers indicates otherwise.

Due to the coastal plain being below sea level, the sugar lands have been broken up into relatively small plots surrounded by canals which provide irrigation and transportation routes to the sugar mills. This, along with the government's need to supply jobs, necessitates manual harvesting. Except in a few small areas, it is not practicable to implement more efficient mechanical harvesting techniques. Therefore, for the intermediate term future, it is not foreseen that any additions to sugar cane biomass will be made available through harvesting modernization programs as hoped.

Sugar cane bagasse is the leftover solids after the liquid sugars have been squeezed and cooked out of the cane. In all the sugar mills in Guyana, this bagasse is used to fuel the boilers that provide process steam and electricity. In other parts of the world there is usually excess bagasse available even after these needs are met. However GUYSUCO mills are very old and inefficient and there is little capital available to modernize the mills.

GUYSUCO is undertaking several feasibility studies for sugar mill expansion and diversification. If they do expand within the next 2-5 years as planned, they will do so with state-of-the-art milling equipment and high-efficiency boilers. This would have the effect of making excess bagasse. However, one of the diversification considerations is cogeneration which would utilize bagasse as boiler fuel. With these plans still up in the air and current operation's practice providing little, if any, excess bagasse, the project will not be depending on bagasse for any of its feedstock needs.

However, the situation could change within the 2-4 years that it will take to finalize development of the biorefinery. Fortunately, the site chosen for the biorefinery is also within reasonable transportation distance of several large sugar mills. Therefore if it does become available, the biorefinery would be well sited to utilize sugar cane bagasse as an alternative feedstock. Expectations would be that it would cost in the range of \$10 per ton.

DEDICATED CROPS

While not a focus of this study nor an assumed feedstock for this particular biorefinery, it is worth noting that there is a significant biomass feedstock opportunity in the implementation of plantations that would grow high-yielding biomass crops dedicated to supplying additional biorefineries. Guyana is essentially a tropical country and practically anything grows there. Many tropical grasses that grow wild in Guyana, such as Antelope Grass and Elephant Grass, could be efficiently cultivated and provide significant biomass density per acre. Dedicated cane crops such as energy cane and sweet sorghum could also be cultivated. Fast growing trees such as *Acacia aulococarpa* and *Leucaena leucocephala* could also be grown and used as biorefinery and power generation feedstock.

A couple of years ago, Arkenol did a study for the development of an integrated plantation, biorefinery and power generation plant in the State of Hawaii. The conclusion of that study was that the planting and harvesting of approximately 16,000 acres could support the production of 15 million gallons of ethanol and 19 MW of power for export. Such a development is ideally suited for Guyana and would provide new industry and open up the development of the underutilized savanna, thereby protecting the rain forest. It would be a model of sustainable economic development and agricultural practice, having the added benefit of the greenhouse gas mitigation

that is the subject of the current biorefinery project. This prospect may be studied for the development of subsequent biorefinery operations within Guyana.

B. PRODUCT MARKET

Guyana is not a large market for the commodity chemicals that can be produced from Arkenol technology. Rather, the country's desirability for siting a biorefinery rests with its abundance of inexpensive renewable feedstock; educated but relatively low cost labor pool; and market relationships within the European Community, the CARICOM, and South America.

Assuming the use of rice straw and hulls as the primary feedstock, the biorefinery will produce:

- 11.5 million gallons per year of fuel grade ethanol;
- 14,000 tons per year of ZSM zeolites;
- 29,000 tons of lignin;
- 35,000 tons of CO₂; and,
- 15,000 tons of gypsum.

ETHANOL

Ethanol (C₅H₅OH), also referred to as ethyl alcohol, is produced from the fermentation of natural sugars. In the case of the project, it will be fermented from the C₅ and C₆, or hexose and pentose, sugars produce from the hemicellulose and cellulose contained in the chosen feedstocks.

Although it has been considered in the past, there is not a current market for fuel ethanol in Guyana. However, commensurate with the actual production of ethanol within Guyana, the government is eager to utilize it to the greatest extent economically and technically possible. As can be seen from the table below, Guyana has recently begun to import unleaded gasoline and is taking steps to remove lead from all gasoline used within the country.

(gallons)	<u>1994</u>	<u>1995</u>	<u>1996</u>
Leaded Gasoline	22,974,336	24,931,368	23,725,590
Unleaded Gasoline	n/a	n/a	2,090,802
Kerosene	9,421,104	10,508,820	9,998,604
Gasoi/Diesel	32,714,388	40,036,668	46,861,752
Fuel Oil (Bunker "C")	46,036,578	47,907,048	41,197,170
Aviation Gasoline	3,002,454	595,350	2,723,616

At a minimum, it is expected that ethanol can be blended into the leaded and unleaded gasoline volumes at a 15% blend without modification to existing engines. This would provide a local market for about 3.9 million gallons per year of ethanol. Also, there is opportunity to have all of

the country's private bus fleet (they are actually Toyota and Mazda mini-vans and number about 75-100 vehicles) converted to use E85 as new vehicles are purchased. Additionally, that portion of aviation gasoline that is used by combustion engines could be supplied by 95% ethanol/gasoline blends. Finally, there are several diesel/ethanol blend formulations being developed (Brazil, for example, is implementing a 15% ethanol blend with diesel fuel) that could add to the use of ethanol in the local market. This market would add upwards of 6 million gallons per year of in-country ethanol use.

For the project, and based on prior work done by Arkenol in Brazil, Arkenol is assuming that initially, all of the ethanol will be exported to the northern regions of Brazil by road and oceangoing barge. Brazil has the world's largest ethanol blending program in the world, with the majority of its cars utilizing a 22% ethanol blend and the balance utilizing a 95% ethanol blend. Most all the ethanol is produced in the central and southern regions of Brazil and it is quite expensive to transport to the north, losing many times its value by the time it arrives. (Brazil's national price for all fuel is independent of actual transportation cost.)

Once the biorefinery is in operation, it is expected that the Guyanese government will begin to require implementation of ethanol blended fuels. There is additional, similar market opportunity in the neighboring countries of Suriname and French Guiana. However, it is hoped that once the first plant demonstrates financial and technical viability, that there will be call for additional biorefineries in those countries as well.

For its economic projections, Arkenol is assuming a sale price of \$1.20 per gallon, which is below the current Brazilian price of approximately \$1.36 per gallon. Unleaded gasoline in Guyana currently sells for about \$1.30 at the pump, including taxes. Arkenol is currently in discussion with two trading groups who do business in Brazil for the marketing of ethanol from the biorefinery. Each has expressed interest in handling the product on the projects behalf. (See Attachment 3.)

ZSM ZEOLITES

Among all biomass feedstocks, rice straw and hulls are unique in that they contain high amounts of silica. When processed via Arkenol's technology, the silica ends up in the lignin cake. It can be either left in the lignin cake (which makes it less desirable as a boiler fuel) or separated from it to make a separate product which is what will be done for this particular project.

Commonly known as "precipitated silica", ZSM zeolites are specialty silica products that result from the treatment of silica gel with acid. Precipitated silicas are valued for their amorphous (irregular or non-crystalline) structure, their thixotropic (time-dependent viscosity) qualities and their insulation properties.

Precipitated silicas have various applications. Produced to many similar, but different, specifications, they are used in the tire and rubber industries as fillers, and in the manufacture of soaps, detergents, cleaners, paints, and fluid cracking catalyst. They are also used in the food industry as a flow control agent.

Precipitated silica, as a performance chemical, is described by any of several physical parameters. The most critical of these is "BET" - a measure of the surface area of a particle. Commercial grade precipitated silicas range in BET from 10 to over 200 with this higher surface area providing a higher value for the rubber market.

Traditional methods of producing precipitated silicas do not readily produce higher BET surface areas. Arkenol's R&D efforts have resulted in BET value's of greater than 200, indicating that the plant will be able to produce the highest value product.

Commercial grade precipitated silica is generally produced through an energy intensive procedure using high-cost feedstock. The Arkenol process is expected to be a more economical alternative to the traditional process, making it possible to competitively sell into international markets. Because of the relatively large size that tire and rubber producers represent in terms of total market available for precipitated silicas, those users will be the primary target market for the commodity grade, ZSM zeolites produced at the biorefinery.

There is not a local market for ZSM zeolites. However, the international market is about 650,000 tons annually and is forecast to grow at 2-3% per annum. Current prices range from 40¢ /lb. to \$1.50 /lb., depending on quality and use. For its economic projections, Arkenol is assuming a very low sale price of \$500 per ton (25¢ /lb., although it expects to get a much higher price once the biorefinery is in operation. Arkenol is currently in preliminary negotiations with two international trading companies to handle this product. It is expected that the product will be marketed in the more industrialized regions of South America. Negotiations are expected to be finalized before construction financing is closed.

LIGNIN

Lignin is the plastic-like component of plant matter that makes up the cell walls of biomass materials. When dried, the lignin cake produced by the plant will contain a high heating value that can be used as a fuel replacement in biomass or coal-fired power generating plants. Alternatively, lignin may be sold to the landscaping and farming industries as a soil amendment. With the consistency and appearance of moist, black top soil, lignin serves as a vehicle to return nutrients, taken up by the rice straw, back to the soil. Using standard manure spreaders in the field, lignin can displace fertilizers. For use in plant nurseries or landscaping services, lignin also offers a nutrient rich mix in which to propagate plants. For this project, the lignin will be used for 40% of the in-plant boiler fuel requirement for the generation of process steam and electricity.

In contrast to other biomass to energy concepts, this process creates both a fuel for vehicular use and fixed (power generation) installations. Lignin has a fuel value comparable to many grades of coal, but both the lignin and ethanol from biomass when burned add no fossil CO₂ to the atmosphere. The net CO₂ generated will not exceed the amount withdrawn from the atmosphere by the original crop.

CO₂

When sugar is fermented into alcohol, one-half of the sugar converts into the gas, carbon dioxide. The resultant CO₂ is capable of being compressed and liquefied into a food-grade product or used for fire control, production of dry ice, and/or enhanced oil recovery. There is not much CO₂ produced in Guyana but it is a desirable product for which a local market will develop. The primary market will be for soda bottling operations and for dry ice for the fish and vegetable markets. For its economic projections, Arkenol is using the current average price of \$50 per ton. However, as the dry ice market develops, this average will rise as the price of dry ice generally exceeds \$80 per ton.

GYP SUM

Gypsum (CaSO₄2H₂O) has a composition of 79% calcium sulfate and 21% water, and is used as a commercial and generic term for all calcium sulfate materials. Gypsum is produced by the biorefinery through the treatment of the sulfuric acid waste (approximately 2% of the acid used in the hydrolysis process is not recoverable) with calcium hydroxide. This process neutralizes the acid, and produces marketable gypsum. Production is expected to exceed 15,000 tons (dry basis) per year.

Gypsum is used in the agricultural industry as a soil amendment. Agricultural gypsum which is a powdered form of calcium sulfate dehydrate, prevents polymer formation in clay and adobe soils, and thus prevents adobe formation in tillable soil after a rain. It is applied at the rate of one-fourth to one-half ton per acre. Calcium sulfate dehydrate is also the main ingredient of "Gypsum Wallboard" or "drywall", a familiar construction material.

The gypsum produced by the facility will be sold to local farmers as a soil conditioner for clay-rich soils characteristic of the region. As with the other byproducts of the process, the total Biorefinery's production of gypsum will represent a very small percentage of its potential market. For its economic projections, Arkenol is assuming a sale price of \$7 per bone dry ton.

OTHER PRODUCT OPPORTUNITIES

In addition to fuel-grade alcohol, there is an opportunity to produce other organic acids like food-grade citric acid. Depending on market conditions yet to be determined, the project may reduce the amount of sugars being fermented into ethanol and redirect them to the fermentation of citric acid. Citric acid sells into a smaller market than does ethanol and market considerations are more strategic. The world price of citric acid is at about 65¢ per pound at the low end. Via the Arkenol process, it can be produced for sale at less than 50¢ per pound. The production of citric acid is not accounted for in Arkenol's economic projections; however if the market can be developed, sale of citric acid from the biorefinery would greatly enhance the economics of the project.

While not a current focus of this project, there is an opportunity for a desirable add-on industry. Arkenol is working with a company in Indonesia who has developed a process for making lightweight construction materials out of ash and gypsum. Of particular use is ash from the

D. TECHNICAL AND ECONOMIC ANALYSIS

A comprehensive economic model has been developed which utilizes all the pertinent inputs to calculate project yield in terms of cash flow and return on investment. Included in this model is a presentation of development, capital, and operating costs along with cash flow data on a twenty year basis. At the core of the economic model is a very sophisticated mass and energy balance which generates the data necessary for engineering purposes as well as economic ones. This model is presented as *Attachment 4*. For purposes of intellectual property protection, only the mass and energy balance portion of the model is omitted.

The primary determinate to the technical feasibility of an Arkenol project is the type and quality of the feedstock available. The types of feedstocks being considered for the project will pose no unusual technical problems in the conversion process. While actual feedstock testing was not part of the Scope of Work, enough is known about the feedstocks to perform a preliminary engineering design using similar data from other project design work. (A simple process flow diagram of the project is presented on the following page.)

In its pilot plant in Orange, California, Arkenol has tested rice straw, rice hulls, sugar cane bagasse, and various types of wood. From these tests, detailed knowledge of how specific feedstocks will behave has been gained. The information from these test runs form the basis of the conversion yields that drive the heat and material balance upon which the economic model depends. The primary information sought here is the amount of cellulose, hemicellulose, lignin, and ash that is found in each of the feedstocks and what the specific kinetics are to break down the chemical bond between them prior to conversion into sugars. Prior to detailed engineering, extensive feedstock test runs on actual feedstock obtained from Guyana will be completed. This will provide not only data for the biorefinery's mass and energy balance, but it will provide yield data that will form the basis of the process guarantees that will be required by the financial community.

The table below presents the breakdown of the feedstock constituents. The glucans and the xylans are the resultant fermentable sugars which will be use to make ethanol and CO₂. The silica is the basis of the ZSM zeolites, and the remaining lignin becomes boiler fuel.

Feedstock	% of Total	Glucans	Xylans	Silica	Lignin
Rice Straw	60%	55.00%	12.50%	10.00%	22.50%
Rice Hulls	30%	49.00%	9.00%	20.00%	22.00%
Wood	10%	63.15%	14.35%	0.00%	22.50%
Weighted Avg.	100%	54.01%	11.64%	12.00%	22.45%

Economy of scale is an important parameter in the production of ethanol. As the focus of the project is the mitigation of GHG's, it would be desirable to construct a facility as large as possible for the feedstock available. However, capital costs and product market issues are a limiting factor. Using the computerized economic model, several economic sensitivities were run to determine the range of plant size. Primary determinants were capital cost, reasonable availability of feedstock,

Material	LBS/HR	101	102	103	104	105	106	107	108	109	110	111	112	113
		To Grinder	To Dec/Hyd	70% acid	Water	Fd 1st Filtr	Washwater	Filtrate	Cake	93% Acid	70% Acid	Fd 2nd Filtr	Lignin	Washwater
Ethanol					7	7	10	17						
Carbon Dioxide														
Glucose						9002		8822	180			7348	147	
Xylose					174	2975	254	3164	65			459	12	14
Glucans	16204	16204				8102		41	8062			1612	1604	
Xylans	3491	3491				873		4	868			521	518	
Lignin	2400	2400				2400		12	2388			2388	2376	
Silica	3600	3600				3600		18	3582			3582	3564	
Inerts	300	300	101		57	527	83	3	607		64	671	718	
Inorganics	870	870				870		4	866			866	861	
Sulfuric Acid			24619			24619		24126	492	1171	15715	17378	348	
Calcium Hydroxide														
Calcium Sulfate														
Nutrients/Yeast														
Water	3135	3127	10450	16663	29088	24273	36251	17109	88	6671	23104	10149	2006	
Total	30000	29992	35170	16901	82063	24620	72462	34219	1259	22450	57927	20297	30208	

THIS DRAWING IS A "TRADE SECRET" OF THE CALIFORNIA GOVERNMENT. IT IS NOT TO BE REPRODUCED, COPIED, SUPPLEMENTED OR REPLACED FOR ANY PURPOSE. IF THIS DRAWING IS USED FOR ANY PURPOSE, THE USER AGREES TO HOLD ARKENOL, INC. HARMLESS FROM ANY AND ALL CLAIMS, DAMAGES, LOSSES AND EXPENSES, INCLUDING ATTORNEY'S FEES, THAT MAY BE ASSERTED AGAINST ARKENOL, INC. BY ANY THIRD PARTY. THIS DRAWING IS THE EXCLUSIVE PROPERTY OF ARKENOL, INC. AND IT IS NOT TO BE REPRODUCED, COPIED, SUPPLEMENTED OR REPLACED FOR ANY PURPOSE. IF THIS DRAWING IS USED FOR ANY PURPOSE, THE USER AGREES TO HOLD ARKENOL, INC. HARMLESS FROM ANY AND ALL CLAIMS, DAMAGES, LOSSES AND EXPENSES, INCLUDING ATTORNEY'S FEES, THAT MAY BE ASSERTED AGAINST ARKENOL, INC. BY ANY THIRD PARTY.

113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
2nd Filtrate	Fd ISEP	EL. water	Dil Acid	FromAcCon	Sugar Soln	Lime Add	Ferment Fd	Yeast/Nutri	ToCentrifuge	CarbDioxide	Distill Fd	Dehyd Fd	Ethanol	
6	6	23	24		46		46			9452		9263	9217	9217
	7199	16021		320		15701	15565			8845				
55	502	3766	614	88		4292	4255					1197		
	8									1221				
	3													
	12			1										
	18													
50	4		200	10	165	190				380		389		
	4													
	17031	41157	4	40338	40334	823								
							471							
53	33019	69139	181697	134626	17121	116210		615	1673					
							115358	3373	123930			114547	424	46
26	57906	130106	182539	175383	57620	137262	471	135224	107676	136656	8845	125396	9641	9263

IT" AS DEFINED IN SECTION
INMENT CODE, AS AMENDED,
ROM TIMR TO TIME. AS A
DCORDED ALL CONFIDENTIAL
PPLICABLE LAW. IT IS THE
OL, INC. ITS ACCEPTANCE
IT SHALL BE TREATED AS A
T AND IS TO BE RETURNED
COMMUNICATED, DISCLOSED,
AUTHORIZED IN WRITING BY

REV.	DESCRIPTION	DATE	BY	ENG
				Ramesh Shah
				DRAWN BY
				Jeff Horowitz
				CHK BY
				APP BY
				DATE
				2/15/98

ARKENOL INC.

GUYANA BIOREFINERY PROJECT

SIZE	PROJ NO	DWG NO	REV
B			
SCALE	NA	SHEET	1 OF 1

product pricing, and investor return. From this analysis it was determined that an 11.5 mgpy ethanol biorefinery at a total all-in cost of \$76 million, provides a return on investment that will be attractive to the investment community (15 year, pretax IRR of 27%).

Process conversion rates and other engineering data used in the model conform to similar project models which have undergone extensive third-party engineering review. Cost data for primary inputs (feedstock, reagents, labor, etc.) have been verified by literature review or direct contact with suppliers. Capital costs are factored estimates from a similar project which Arkenol is developing and for which it has generated detailed engineering data and vendor quotes (Sacramento Ethanol Project, which is a 13.3 mgpy biorefinery that will use rice straw as its only feedstock). Product prices are conservative estimates gained from interviewing current suppliers and from literature review. Financing structures were set to reflect expected project finance equity/debt ratios and current rates for lending.

E. PARTICIPANTS

At present Arkenol is undertaking the initial development of the project on its own. However, it will be seeking additional equity investment partners for the project. (See Section IV. *Next Steps*, below.) The engineering firm for the project is currently Bateman Engineers & Constructors, located in Denver, Colorado. Bateman brings extensive experience with the Arkenol technology and stands ready to provide process guarantees to the project's investors and lenders. Due to other investment considerations, they may be a subcontractor to another construction firm who has expressed interest in project investment and construction responsibility.

The supply of feedstock will come from several sources as indicated above. The wood waste will come from the nearby operations of Demerara Timber. The rice hulls will come from the rice mills in the surrounding region and be coordinated under contract through the Guyana Rice Millers Association. The rice straw will come from local farmers. As the project will have to work with several farmers to obtain the amount of feedstock necessary, the Guyana Rice Development Board will assist the project in developing appropriate contractual and market arrangements.

AIAT Anstalt is a marketer of ethanol on a worldwide basis with its major market supplier being Brazil. They have indicated a desire to market the ethanol for export and will help set up a marketing program within Guyana if needed. GCP Limited is a Guyanese chemical company that has expressed interest in handling the supply of the projects reagents and will also handle in-country sales of CO₂ and gypsum.

While not formalized, the Government of Guyana, in the person of Leroy Cort from the Office of the President, has indicated that this type of project is highly desired by the country and that every effort will be made to assist in its development. (Please note that one of Mr. Cort's primary responsibilities is to be the watchdog, on the President's behalf, on corruption within the government. The country is highly sensitive to this issue as they are seeking to foster increased foreign investment.)

Arkenol is being assisted with the project in-country by the staff of GO-Invest, the government agency set up to work with foreign companies who wish to set up operations in Guyana, and Douglas Allan and Derek Drakes of the International Business Corporation (IBC). IBC is currently consulting on with Hydro Quebec on a hydropower project in Guyana and are well versed in project development. Mr. Allan has also been a consultant to the Inter-American Development Bank and the United Nations Development Program in Guyana and was the chief technical advisor for the country's Economic Recovery Programme.

F. GREENHOUSE GAS REDUCTION CALCULATIONS

The proposed project, as stated in the referenced proposal, will have two primary environmental benefits, the displacement of fossil fuel by a renewable fuel, and a decrease in open field burning.

TRANSPORTATION FUEL COMBUSTION

The first environmental benefit is the use of the primary product from the biorefinery, fuel-grade ethanol, as a clean-burning component of the transportation fuel mix. This benefit is derived from renewable ethanol's displacement of nonrenewable, petroleum derived gasoline. Therefore, the simple calculation to quantify the benefit is the subtraction of the GHG emissions due to the combustion of ethanol from the GHG emissions due to the combustion of gasoline.

The first step in this calculation is, then, obtaining an equivalency between the amount of GHG emissions and ethanol emissions on the same basis. A model developed by the U.S. DOE in collaboration with five national laboratories to compared GHG emissions for gasoline and ethanol in light duty vehicles. (The values for GHG emissions for each of these materials is taken from a 1997 U.S. DOE study titled, *Scenarios of U.S. Carbon Reductions*. See Attachment 5.) Total GHG emissions for gasoline including vehicle operations, fuel production and distribution, and vehicle manufacture was given as 11,832 grams CO₂ equivalent per gallon gasoline. The production and use of ethanol using cellulosic feedstocks results in the total GHG emissions of 58 grams CO₂ per gallon.

Using these factors, the proposed biorefinery, which will produce approximately 12 million gallons per year of ethanol, will annually sequester GHG in the amount of 1.4×10^9 kg CO₂ equivalent or 141,288 metric tons. $[12,000,000 \times (11,832 - 58)]$

Alternatively, a more conservative calculation of the reduction in GHG due to the use of ethanol as a fuel extender can be obtained. Using the ratio of the heating value of ethanol and gasoline it is possible to determine and compare both on an equivalency basis. Then, using the GHG emissions in grams per gallon for both ethanol (58 grams/gallon) and gasoline (11,832 grams/gallon), determine the differential in tons produced.

$$12 \times 10^6 \text{ gallons} \times (84,460 \text{ HHV ethanol} \div 124,800 \text{ HHV gasoline}) = 8,121,153 \text{ gallon gasoline equivalent}$$

Therefore, the net GHG reduction benefit derived from displacing gasoline with ethanol is the difference between GHG from gasoline and GHG from ethanol.

$$\begin{array}{rcl} \text{GHG from gasoline use} & - & \text{GHG from ethanol use} = \text{Total GHG reduced} \\ (8.121 \times 10^6 \times 11,832 \text{ grams/gallon}) & - & (12 \times 10^6 \times 58 \text{ grams/gallon}) = 95.4 \times 10^9 \text{ grams or } 95,392 \text{ metric tons} \end{array}$$

These two calculation pathways provide a range of GHG reductions from 95,392 MT to 141,288 MT. Note that these calculations assume that ethanol/gasoline blends are utilized in conventional combustion engines optimized for accepted gasoline formulations. If the ethanol or ethanol/gasoline blends were to be combusted in engines optimized for ethanol, then the net emission reductions would increase. The cost to realize this reduction over 20 years of the project's life would be about \$32 per ton of GHG. (\$60,000,000 capital cost $\div$ 95,000 MT $\div$ 20 years)

For its economic projections, Arkenol is assuming that the CO₂ credits can be sold for \$1.50 per ton. The economic model assumes the more conservative, 95,000 MT figure.

OPEN FIELD BURNING

The second environmental benefit is the reduction of particulate matter emissions which is the result of removing biomass material from the practice of open field burning. In the case of the project, this will be the removal of upwards of 25,000 acres of rice straw from the open field burning cycle. However, since the growing and disposal of rice in this fashion is part of nature's "closed loop". This modification to current practice will have no net effect on the reduction of carbon emissions but will reduce other GHG's such as VOC, NO_x and CO. For example, in a similar project that Arkenol is developing near Sacramento, California, calculations for the avoidance of open field burning show that 250,000 acres of rice straw results in annual net emissions reductions of 50 tons of NO_x, 31 tons of PM10, 23 tons of VOC, and 893 tons of CO.

G. PRELIMINARY PROSPECTUS

Arkenol has prepared a brief descriptive document presenting the investment opportunity represented by the Guyana Biorefinery opportunity. It includes similar information to that presented in the grant proposal and this final report with the addition of investment yield and partnership offering data. As this is a vehicle which Arkenol will utilize to solicit investors, it is inherently a confidential document and is not included with this report which is assumed to be a public document.

This preliminary prospectus, along with the project economic model and the Project Fact Sheet (*Attachments 4 and 6*, respectively) and a targeted cover letter, will be used to attract and gauge the interest of prospective investors. As the project develops and more extensive data is generated, this information will be inserted into two comprehensive offering memorandums, one each for debt and equity providers.

V. Next Steps

Each project development, while having its own unique characteristics, follows a general pattern of development. (See *Attachment 7, Project Life Cycle*.) With the completion of this first site visit and the submission of this report, the project is essentially in the middle of its feasibility period. As has been hopefully communicated, the project is not only quite feasible, it can also be offered as an attractive investment opportunity, especially to entities who want "green" projects in their portfolio. The next steps in the project development cycle include the:

- ❖ completion of a proposal to the USIJI to obtain project certification;
- ❖ solicitation of investors and financial institution support; and, the
- ❖ continuation of the relationship building effort with Guyanese governmental and private parties necessary to the project's development.

USIJI PROPOSAL SUBMISSION

This investigation has supplied the country information needed to complete Arkenol's proposal to the USIJI for the Guyana Biorefinery Project. There are, however, a couple of items still to be addressed. These include the sources of funding in addition to Arkenol, proof of host country acceptance, and a monitoring/external verification plan for emissions reductions. The requirements of monitoring/verification plan is currently being investigated and is expected to be outlined in sufficient detail within the next two months. Leroy Cort, from the Office of the President of Guyana, is researching, on Arkenol's behalf, which agency within the Guyanese government will act as the "host" agency and will assist us in preparing the required documents. He reports that discussions within the government are very positive in regard to the project and he does not expect that this will difficult to obtain; it will just take time to work through an admittedly inefficient bureaucracy.

FINANCIAL SOLICITATIONS

With the completion of this report and the preliminary prospectus, Arkenol will be approaching its network of investors to generate additional financial support for the equity requirements of the project. Potential equity partners include two separate oil companies who have expressed interest in obtaining CO₂ offset credits, two EPC (engineering, procurement, and construction) contractors who are looking to expand their activities within South America, and a Japanese trading firm with whom Arkenol is contemplating another project in Brazil.

At the appropriate time, contacts will be made with the multinational funding agencies such as the World Bank, the Inter-American Development Bank, Ex-Im Bank and other similar agencies in addition to the commercial banks and insurance companies with whom Arkenol normally works for provision of the debt portion of project funding.

CONTINUED PROJECT DEVELOPMENT

Initial written and phone communications and the first site visit introduced Arkenol to many people within Guyana who will be instrumental in bringing the project into successful operation. Many of these people have introduced the project to others within the government and private sector. Arkenol will continue to develop these relationships to further the understanding needed by the Guyanese and Arkenol towards the finalization of pertinent project parameters. With the assistance of the government agency staff and IBC, this effort will initially focus on the feedstock costing issues and the development of in-country markets for the fuel-grade ethanol. Once full development funding is secured, more intensive development activities will ensue. *Attachment 7, Project Life Cycle*, sets forth the general time line for these activities.

VI. Conclusion

This project, when fully implemented, will serve as a viable model for the mitigation of green house gases through sustainable agricultural development. As it will be utilizing feedstocks found in many parts of the developing and developed world, it can truly be easily duplicated. Such projects will have the dual benefit of utilizing waste agricultural residues, thereby fostering rural economic development, and it will also provide needed quantities of clean-burning, renewable fuel that will provide the world with an energy security that it will need as finite petroleum resource decrease and/or become more expensive. For Guyana, the biorefinery will produce several non-greenhouse gas benefits as follows:

- New Jobs: At peak construction, the project will employ over 150 employees. Approximately 40 permanent employees will be required for plant operations with another 200 indirect jobs related to the operations of the facility.
- Local purchases of supplies and services during construction and operation.
- Enhancement of agricultural sectors by creating new uses for their waste residues.
- Create new export market for citric acid or other chemicals.
- Demonstrate U.S. resolve to aid developing nations with GHG control without limiting their economic growth.
- Provide Guyana with a means to industrialization through a technology which can be duplicated in many parts of the country utilizing locally available feedstock.
- Commercial demonstration of an innovative technology to reduce greenhouse gas emissions, applicable on a worldwide basis.
- Production of cleaner burning fuels to displace petroleum imports and environmental consequences thereof.
- Advancement of Guyana's forest management goals
- Preservation of natural resources through a process designed for nearly zero discharge conditions.

Arkenol thanks the U.S. DOE for its assistance in the development of this very important project.

Notes

WORK PLAN

1. Scientific and Technical Quality of the Project

a. Project Summary

Guyana has abundant natural resources. It has a significant fraction of the South American rainforest. Yet its per capita gross national product of \$290 in 1991 is the lowest in the western hemisphere¹. Imports of petroleum is a major drain on its economy.

The President of Guyana has invited Arkenol to investigate the technical feasibility of using its technology to produce transportation fuels at home while protecting Guyana's rainforests from depletion. Through this proposal and continued collaboration with Guyana's public and private sectors, Arkenol will evaluate the development opportunities for its technology in Guyana to provide solutions to Guyana's challenges to create economic development and reduce petroleum imports while preserving its abundant natural resources.

The proposed project consists of the completion of feasibility and pre-development activities to advance the construction of a biorefinery in the agricultural regions of Guyana which will utilize Arkenol's proprietary technology to convert lignocellulosic feedstock from sugar milling operations, rice hulling and lumber mills to produce ethanol for displacement of imported gasoline. In addition, the production of other chemicals such as citric acid for export to the United States and other countries will be evaluated. The ultimate goal of this study is to develop information required for submission of the project under the USJI program. Additional information obtained will be used to supplement information in Arkenol's proposal to the USJI submitted on June 30, 1997. The information from this study will also be used to develop preliminary engineering and economic parameters for the biorefinery in order to obtain financing for its detailed development and construction to create the GHG benefits.

The proposed biorefinery will reduce Greenhouse Gas (GHG) emissions from the following existing sources:

1. Transportation emissions from the use of imported gasoline and diesel
2. Burning of sugar cane bagasse and timber waste

New greenhouse gas sinks will be established through:

1. Carbon sequestration in renewable fuels produced from existing crops
2. Carbon sequestration in new purpose grown native grasses or other crops

The proposed project will allow Guyana to reap the benefits of its forest without destroying them. It will also enhance the continued viability of Guyana's important agricultural sectors: rice and sugar. By creating new uses for these industries' waste residues, Guyana's farmers can become important catalysts in spurring a new industry for Guyana while contributing to Guyana's goals and commitments under the Framework Convention on Climate Change.

¹The World Bank, "Guyana Public Sector Review", 1993.

The major objectives of the proposal are to:

- Develop additional information required for submittal under the USII program
- Quantify amount and location of potential feedstocks
- Quantify GHG benefits from the proposed Biorefinery project
- Determine the optimum size, major products, and preliminary technical and economic parameters of the commercial plant
- Identify key NGOs to implement the biorefinery project
- Produce a report which can be used to obtain detailed development and construction financing

The proposed feedstocks include sugar cane bagasse, rice straw and wood waste from timber harvesting. Guyana's sugar production of about 250,000 tonnes per year results in approximately 700,000 tonnes of bagasse from the sugar cane crushing operations which can be used as feedstock for the biorefinery. Similarly, about 100,000 tonnes of rice straw are potentially available based on a 250,000 tonnes per year production rate. Waste materials from timber harvesting can also be used in the Arkenol process. An estimate of available wood waste, based on recent exports, is approximately 1,000,000 tonnes per year. In addition, purpose grown crops can be evaluated for feasibility.

While the optimum size of the biorefinery must be further evaluated as part of the feasibility studies, our preliminary evaluation proposes converting 150,000 tonnes/year of mixed feedstock to produce 12,000,000 gallons of ethanol. The study will also evaluate the production of high value co-products such as citric acid to enhance the overall project revenues.

By-products produced by the biorefinery include gypsum and lignin. Gypsum can be used for road base and dike construction. Lignin may be used as boiler fuel or as a soil amendment.

Completion of this study will advance an innovative approach to reducing greenhouse gas emissions through the conversion of locally available forest and agricultural waste materials into transportation fuels and other chemicals in a biorefinery while providing a number of other significant benefits, including:

- New uses for agricultural and forest waste materials;
- Technology cooperation and sustainable development with a developing country;
- Improvement of economy which reduces economic pressures for rainforest logging;
- Production of cleaner-burning transportation fuel to displace imported petroleum;
- Creation of a biobased chemical industry for export improving balance of trade;
- Economic development from creation of jobs and significant private investments;
- Preservation of natural resources through a process designed for near zero discharge; and
- Improvements in air quality from avoidance of open burning of waste materials.

b. Project Description

The national concerns on the current drain on Guyana's economy created by importation of petroleum, Guyana's desire to reap the benefits from its agricultural and forest resources without destroying them, and Guyana's commitment to global climate stabilization, create opportunities for collaboration between entities in Guyana and California-based, Arkenol, Inc. This proposal begins the advancement of the partnership to create significant greenhouse gas benefits through Joint Implementation.

The goal of this proposal is to complete feasibility studies necessary to advance the development of a biorefinery in the agricultural regions of Guyana located along its coastal strip which will reduce and sequester greenhouse gases through the production of cleaner burning fuels or chemicals from renewable materials. Completion of these pre-development activities will provide more specific information for use in calculating the baseline and greenhouse gas emissions reduced or sequestered by the biorefinery to supplement information submitted in Arkenol's proposal to USIJI on June 30, 1997. In addition, the results of this study will be used to seek project financing for the detailed development and construction of the biorefinery project.

The biorefinery will utilize Arkenol, Inc.'s patented technology for the conversion of cellulose into fuels or chemicals. Arkenol's technology for the production of ethanol, consists of four main steps:

1. Acid Hydrolysis
2. Acid- Sugar Separation
3. Fermentation
4. Distillation

In the Arkenol process, feedstock of roughly ¾ inch size and 10% moisture content is mixed with sulfuric acid and the slurry is fed into hydrolysis units producing a sugar/acid solution. The acid is removed from the sugar by ion separation and is reconcentrated for reuse in the hydrolysis units.

The neutralized sugar stream is fed to batch fermentation vessels with staggered operation to provide a continuous flow to the ethanol distillation process. Yeast is added to the sugar mixture with proper amounts of nutrients and the temperature is controlled for the fermentation period. In the fermentation process, sugars are converted into ethanol and carbon dioxide.

The carbon dioxide may be recovered, compressed, liquefied and sold as a commercial product. the ethanol is recovered from the unreacted sugar, cellulose and yeast by distillation producing a 95% purity stream. The ethanol is further provided to 100% using a molecular sieve to remove the residual water, immediately followed by a denaturing step with unleaded gasoline. Approximately five gallons of unleaded gasoline are mixed with 95 gallons of ethanol to denature the ethanol.

Arkenol's process operates on a minimum effluent basis through recycle of acid and water. In addition, all process streams are converted into salable by-products. A small amount of surplus yeast is removed from the process and disposed of as a feed additive. The biomass residue from the hydrolysis process is primarily lignin which is separated, dried, and used as solid fuel for the biorefinery boiler or sold off-site. Lignin can also be used a soil amendment or sold for other industrial uses. Gypsum is produced as a by-product from the neutralization of the sugar mixture following the acid-sugar separation process to remove any remaining acid prior to fermentation of the sugar.

The U.S. Patent and Trademark Office has allowed Arkenol's patent application on its core technology with others pending on other sugar conversion processes.

Production and use of biobased fuels and chemicals provide GHG benefits.

The construction and operation of the biorefinery will create the GHG emission changes. Biofuels, produced from biomass energy crops such as trees, grasses, forestry and agricultural wastes and a significant portion of municipal solid wastes reduce or eliminate CO₂ emissions by working with the Earth's carbon cycle. As they grow, plants absorb atmospheric CO₂ through photosynthesis. Much or all of the CO₂ released when biomass is converted to biofuels and burned in automobiles is recaptured when new biomass is grown to produce more biofuels. In contrast, consumption of fossil fuels causes release of carbon that has been locked away by nature for over 100 million years without providing a rapid mechanism to reabsorb it.

This study is the first measure which must be taken to deliver the GHG benefits.

In this study, Arkenol staff will:

- Evaluate feedstock supply, including;
 - A survey of the geographic distribution and supply of potential feedstocks
 - Evaluation of the current collection and disposal systems for the potential feedstocks
 - Recommend testing procedures for representative samples of a variety of feedstock to validate preliminary process parameters for the commercial plant
- Identify baseline greenhouse gas emissions from;
 - Existing disposal methods (burning, etc.) for agricultural residues
 - Use of diesel and gasoline
- Determine preliminary size and products produced by the biorefinery given geographic dispersion and amount of feedstocks
 - Prepare preliminary engineering parameters for full scale plant
 - Develop preliminary financial pro-formas for full scale plant
- Quantify baseline greenhouse gas emissions reductions created by the biorefinery through products produced and diversion of agricultural residues from burning or landfilling; and
- Review existing transportation sector and infrastructure to determine number and location of fleets, volumes of gasoline and diesel usage, typical vehicle profile, and refueling infrastructure.

The work will be conducted by Arkenol staff in conjunction with various agencies and other parties in Guyana. The principal investigator is Mr. Michael Fatigati, Arkenol, Inc.'s Program Manager for the development of the Guyana project. A brief summary of Mr. Fatigati's experience is provided in Appendix B along with other Arkenol staff who will assist in the investigations. A letter of commitment from Mr. Fatigati is also enclosed. Arkenol's investigations will include coordination with key business contacts in the U.S. and Guyana, including:

1. Dr. Odeen Ishmael, Ambassador, Washington, D.C.
2. Mr. Navin Chandrapal, Adviser on Science, Technology and the Environment, Office of the President

3. Mr. Michael Chan, Minister of Trade, Industry and Tourism
4. Mr. Yeso Persaud, Private Sector Commission
5. Mr. Maniram Prashad, Guyana Manufacturers Association

To control costs, much of the work will be conducted through telephone contacts, Internet and review of existing literature. However, the work will include visit(s) to Guyana to evaluate potential sites and conduct meetings with potential feedstock suppliers, product buyers, investors, vendors, and appropriate governmental agencies. Testing of feedstock samples will be conducted at a later date at Arkenol's pilot facility in the City of Orange. A description of the facilities is included below.

This proposal is relevant to the solicitation objectives.

1. The opportunities for Arkenol's technology are worldwide and its implementation is an excellent way to increase the geographic and sectoral diversity of USJI projects. The built-in flexibilities in the Arkenol process related to feedstock (wide range of cellulose base feedstock can be used), products (over 150 different chemicals can be produced from the sugars derived from the cellulose), and siting (urban or rural setting) create sustainable development and global climate change stabilization which can be replicated in many parts of the world.
2. Arkenol's technology presents an opportunity to promote technology cooperation to create sustainable development in developing countries and countries in transition. In this case, the Arkenol technology creates efficient uses of Guyana's agricultural and forests resources which are currently used inefficiently due to lack of technology and investments.
3. Guyana's national commitments to stabilization of GHG and economic development are advanced by the proposed biorefinery project. Guyana's government, through the Office of its Ambassador to the U.S., has communicated its interests on pursuing the opportunities for a biorefinery in Guyana. The opportunities for the Arkenol technology are worldwide, with a potential worldwide market of over \$500 billion a year. The products are competitively priced to allow penetration of existing markets and attract financial investments.
4. The reductions in greenhouse gas emissions from the production and use of biofuels are well documented. More project-specific information and methods to measure, track and verify emissions reductions costs and benefits will be reviewed in this study.
5. The Arkenol technology is an innovative way to create GHG benefits. Arkenol hopes to attract participation by other private entities through projects that offer tremendous market opportunity, attractive returns on investment, and environmentally responsible products, creating worldwide opportunities to reduce or sequester greenhouse gas emissions.
6. As stated earlier, discussions with Guyana representatives have been very favorable such that host country acceptance of the proposed USJI project is expected.

The proposal support the development and implementation of an international project for submission to the USJI. The project is consistent with the criteria for USJI projects as follows:

1. The construction and operation of the biorefinery project will create the GHG benefits. Specific measures to achieve this goal are listed below. This proposal focuses on item d below.

- a. Review of national policy to encourage the use of alternative transportation fuels derived from renewable materials
 - b. Public/private sector collaboration to collect and provide cellulosic waste streams;
 - c. Public/private sector collaboration to utilize biobased products; and,
 - d. Preliminary development efforts to finance, build and operate the facility.
2. Arkenol's preliminary discussions with representatives of Guyana's government, through their Ambassador to the U.S., indicate a significant level of interest on Arkenol's technology and the benefits it can bring to Guyana such that host country acceptance of the project for JI is expected.
3. The GHG benefits of biofuels are well documented by the Department of Energy and others. However, more specific information on the GHG benefits of the biorefinery project in Guyana will be developed as part of this proposal.
4. More specific plans for the tracking and monitoring of the greenhouse gas emissions reduced or sequestered by the Biorefinery project will be developed later. However, ethanol market share changes can provide an indicator of use, from which GHG benefits can be estimated.
5. External verification of the GHG benefits can be made by the appropriate governmental bodies in Guyana and U.S. or by an approved independent consultant.
6. The biorefinery also produces non-greenhouse gas benefits as follows:
 - a. New Jobs: At peak construction, the project will employ over 150 employees. Approximately 40 permanent employees will be required for plant operations with another 200 indirect jobs related to the operations of the facility.
 - b. Local purchases of supplies and services during construction and operation.
 - c. Enhancement of agricultural sectors by creating new uses for their waste residues.
 - d. Create new export market for citric acid or other chemicals.
 - e. Demonstrate U.S. resolve to aid developing nations with GHG control without limiting their economic growth.
 - f. Provide Guyana with a means to industrialization through a technology which can be duplicated in many parts of the country utilizing locally available feedstock.
 - g. Commercial demonstration of an innovative technology to reduce greenhouse gas emissions, applicable on a worldwide basis.
 - h. Production of cleaner burning fuels to displace petroleum imports and environmental consequences thereof.
 - i. Advancement of Guyana's forest management goals
 - j. Preservation of natural resources through a process designed for nearly zero discharge conditions.

7. The Biorefinery project will provide the GHG benefits over the life of the project which is estimated to be 50 years, a typical life cycle for state-of-the-art chemical plants. The GHG benefits will be lost or revised if the project fails to operate. Arkenol has and will continue to take steps necessary to insure that the GHG benefits are preserved. These steps, include:

Technology

The technology has been demonstrated at the pilot scale and its viability confirmed by reputable experts in the industry. Reviewers include; among others, Booz, Allen & Hamilton, A.D. Little, R.W. Beck, Bateman Engineers, Raphael Katzen & Associates, Babcock & Wilcox, Zurn NEPCO, and Albright & Wilson. Process guarantees are available through the collaboration of deep-pocket engineering and construction contractors.

Construction

As part of the financing for the construction of the facility, process guarantees and efficacy insurance will be available from qualified engineering firms and equipment manufacturers. This will insure project debt and equity investors that the process yields projected in the financial pro-formas are realized to allow payment of debt and return on investment.

Arkenol is committed to the successful implementation of its technology on a worldwide basis. To date, Arkenol has invested over \$16 million dollars to bring its technology to commercial readiness. Insuring that the proposed project is developed in accordance with good engineering, financing and marketing practices will allow for the implementation of Arkenol's business plan objectives and compliance with its mission to become the leader in the production and sale of biobased fuels and chemicals.

Markets

Ethanol is a proven alternative transportation fuel. National policies which encourage its use will assist in the initial market implementation and assure availability of long term markets.

The worldwide citric acid market is growing at a rate of 5-6% annually and the competitive production costs of producing it from inexpensive feedstock will allow for wider market penetration.

Feedstock

The Arkenol process is flexible in the feedstock which it can use. Furthermore, a variety of feedstock can be mixed or used interchangeably should seasonality in availability of the feedstock exist.

8. As appropriate, the Project proponents will provide periodic reports on development status and GHG benefits.

Status of Project Development/Financing Efforts

A proposal for the development of a biorefinery in Guyana was submitted to USIJI on June 30, 1997. Arkenol's relationships with Guyana representatives are recent, but the interest on both sides are strong such that an aggressive development schedule is being pursued. Arkenol representatives plan to travel to Guyana in October. In the meantime, discussions are on-going. As reflected in the project development schedule in Appendix A, Arkenol projects a 4 month schedule to complete the feasibility analysis. The next step is a 6 month schedule for detailed development, after which, and upon financing, a two year construction schedule will commence.

Arkenol has begun to identify potential sources of private and public funding sources for the project. More detailed discussions with interested parties must await the results of the work proposed herein. Arkenol has not applied to any other funding agencies for the work submitted under this proposal.

DOE support for funding is essential to deliver the greenhouse gas benefits described above. Arkenol is a small privately held business who has to date used private funds to prove its acid hydrolysis process. As such, Arkenol must focus its limited financial resources on the first full commercialization of its technology, currently a 12 million rice straw to ethanol plant in California, to begin the business plan objective of penetrating the markets of interest by producing products for sale. Although Arkenol staff can raise the project financing for strong project opportunities, the resources required to fully exploit the potential commercial application of the technology worldwide, is beyond Arkenol's current financial means. Therefore, Arkenol must look to other funding sources for initial development activities to create viable projects for third party financing.

The proposed efforts are consistent with Guyana's goals of economic development and national policies related to environmental protection and sustainable development.

The agricultural sector is the single most important sector in the economy of Guyana and is the main source of employment. Sugar and rice are the most important crops cultivated in terms of area, value of production and contribution to export earnings. Production of both crops declined dramatically during the 1980s due to poor economic policies. Finding new uses for agricultural residues will contribute significantly to the continued viability of the agricultural sector. Production of purpose grown crops for use in the biorefinery will expand the agricultural sector.

In addition, Guyana has about 14 million hectares of forest covering some three fourths of the nation's total area. Conversion of forest residues (from logging and fire protection) into valuable fuels and chemicals through Arkenol's technology is consistent with Guyana's government's desire to reap revenues from its forests without destroying them. In late 1995, President Jagan invited the World Resources Institute (WRI) to help him identify options for reforming forest policy in Guyana. One of the recommendations of WRI, to allow Guyana to realize the potential of its forests, is to build sustainable communities, especially around non-timber values. In the short-term, WRI suggests that a Community Forest Conservation and Development program should be initiated to provide basic technical assistance to communities interested in developing forest-based enterprises, such as the extraction and processing of non-timber forest products, fauna management, and green forestry.² This proposal is consistent with WRI's recommendations.

Guyana is already committed internationally to strong policies on forest management, global climate change, and respect for the rights of the Amerindians, and fair employment. Among other agreements, Guyana has signed and ratified the following accords:

- ☒ Rio Declaration which acknowledges the importance of integrating environmental conservation and sustainable economic development, of eradicating poverty to make development sustainable, of taking inclusive participatory approaches to conservation, and of honoring the rights of indigenous peoples in their communities vis-à-vis environmental management and development; and

²Sizer, Nigel, World Resources Institute, "Profit Without Plunder: Reaping Revenue From Guyana's Tropical Forest Without Destroying Them", September, 1996.

- ☒ Framework Convention on Climate Change which includes Joint Implementation to stabilize greenhouse gases.

c. Project Evaluation Plan

A feasibility study begins the implementation of projects by identifying the opportunities which must be developed as well as the hurdles which must be resolved to deliver the benefits of a project. Through the assistance of the Department of Energy on this proposal, the indigenous resources of Guyana can be transformed into significant opportunities of economic development and greenhouse gas emissions reductions and carbon sequestration to create sustainable development which can be easily replicated worldwide.

This study will culminate in a report which will be presented to public and private sector investors to obtain financing for the development and construction of the biorefinery. The successful completion of the tasks included in this proposal will provide preliminary technical and economic parameters for the full scale facility on which future financing will be based upon. Successful completion of project financing will allow for the ultimate measure of success, the construction and operation of the biorefinery.

Arkenol is embarking on this study based on preliminary knowledge of the Guyana's concerns, available resources and market opportunities. It is expected that the activities will lead to a viable project and that this study will be successful in:

- Identifying an economically viable project which results in GHG benefits;
- Creating a working document to encourage collaboration between U.S. and Guyana entities;
- Promoting the promulgation of appropriate national policies to encourage development of the biorefinery; and
- Providing the information which can be used as a basis for investments in the biorefinery project.

The Principal Investigator and other investigators for this study have extensive experience in the development of multifaceted projects. This, coupled with the investigators' intrinsic knowledge of the Arkenol technology assure that the scope of the feasibility study is defined to result in the needed information to go forward.

The major milestones and performance schedule for the project is included in Appendix A. Reports will be provided to U.S. DOE Chicago Operations as follows:

Status Reports - Within 2 months of upon award and start of work (November, 1997)
Final Report - Within 90 days of completion (April, 1997)

2. Applicant's Qualifications

Arkenol, the creator and owner of the proposed technology employs a team of professionals with many years of R&D and project development expertise. The current team has expertise in executive management, basic and applied research and development; chemical, electrical, mechanical, process and power engineering; project management; marketing; accounting and finance. The company is organized in a matrix structure which utilizes each team member's talent to complete the corporation's

priorities as established by executive management. Summary qualifications for investigators are included in Appendix B.

Feedstock validation testing is not included in this study. However, a testing plan will be developed based on the findings of the feedstock availability under this proposal. The feedstock testing will be conducted at Arkenol's pilot plant. The Arkenol pilot facility, having a nominal 1 ton/day biomass capacity, has been developed to test and evaluate commercially available equipment for use in a large-scale facility. As such, the facility was not engineered with continuous operations in mind and operates primarily in batch mode. The facility is, however, instrumented with standardized pressure, temperature and flow monitoring devices with a LAN-based data acquisition system providing real-time capability. The following is a list of major equipment found at the pilot facility:

- Jaygo Industries - Primary Decrystallizer/hydrolizer
- Myers Industries - Secondary Decrystallizer/hydrolizer
- Pfaudler - Vacuum reflux reactor vessel
- Moyno Pump - high viscosity hydrolyzate pump
- Eimco Filter - plate and frame lignin filtration
- IWT - Chromatographic separation unit
- Sanborn Technologies - Centrifuge
- Buffalo Technologies - Sulfuric acid Reconcentrator
- Parker Boiler - Steam Boiler (natural gas fired)
- Various - Liquid/Liquid Heat Exchanger
- Various - Fermenters

Prior to each hydrolysis campaign, each major unit operation must undergo repair and rehabilitation to insure proper functioning during the production of hydrolyzate from the cellulosic materials selected for processing.

3. Personnel Qualifications

Since its formation in 1992, Arkenol has met its goal to commercialize its technology. Arkenol's key accomplishments obtained through the cooperation and participation of all of its staff are listed below.

- Re-engineered and patented technology, bringing it to commercial readiness;
- Developed a comprehensive market analysis with the assistance of Booz-Allen & Hamilton;
- Established numerous strategic relationships with equipment vendors, engineering and construction firms, chemical and fuel marketing firms, lenders, and political entities, including; National Renewable Energy Laboratory, State of Pennsylvania, Department Of Energy, Azucarera Usina Santa Adelaide (Brazil), and Pure Energy Corporation;
- Successfully acquired federal, state and local permits for a 12 million gallon/yr ethanol plant
- Undertaken preliminary project development activities on projects domestically and internationally

Guyana - Feasibility Study Schedule and Budget

Milestones:	Oct-97	Nov-97	Dec-97	Jan-98	Rate	DOE Share Personnel Hours	DOE Share Personnel Cost	Arkenol Share Personnel Hours	Arkenol Share Personnel Cost	DOE Share Travel	Total Direct
FEEDSTOCK EVALUATION					90	80	\$7,200	80	\$7,200	\$5,025	\$19,425
Specification Development											
Audit by Type, Quant, Costs											
Longterm Availability											
Collection Methods and Costs											
ENGINEERING					85	40	\$3,400	40	\$3,400		\$6,800
Preliminary Engineering Parameters											
PRELIMINARY FINANCIALS					95			25	\$2,375		\$2,375
Pro-forma Development											
SITING/ENVIRONMENTAL					85	75	\$6,375	58	\$4,930	\$5,000	\$16,305
Selection of Alternative sites											
Environmental - GHG Benefits											
Socioeconomic impact											
PROJECT MANAGEMENT					100			40	\$4,000		\$4,000
REPORT DEVELOPMENT					100			40	\$4,000		\$4,000
						195	\$16,975	283	\$25,905	\$10,025	\$52,905

Fringe Benefits included in Hourly Rate
 Arkenol will pay for indirect costs (computer/library, etc.)

Arkenol Share
 DOE Share
 Total Budget
\$25,905
\$27,000
\$52,905

Notes

02/24/98 14:55 FAX 592 2 5555 BARAMA LOONG 401

BARAMA COMPANY LTD

FAX TRANSMISSION

To: Mark Carver
Arkenol, Inc.

From: S.K. Loong

Date: Feb. 24, 1998.

Barama Co. harvests logs from her own forest concession in the North-West District to feed the plywood factory and sawmill located at Land of Canaan, near Georgetown, Guyana.

The current level of log production is approximately 240,000 m3 per year. Since logs are debarked at the "logpond" in the forest, there is approximately 4% of waste in the form of bark together with off cuts left in the forest.

At the plywood mill/sawmill wood waste of around 100-120,000m3 per year is available for disposal, some of which is being fed to the industrial boiler to generate steam for heating/drying at the mill.

It is possible the waste volume would increase in 1-2 years' time when we expand our operation.

Any business arrangement beneficial to both parties is, of course, welcome and in particular on matter relating to waste disposal and creating a better environment for the country.

Best regards.

S.K. Loong
Executive Director
Corporate Services.

**GUYANA SUGAR
CORPORATION LIMITED**

22, Church Street, Georgetown, Guyana.
Telephone:

Fax: 592-2-57274

facsimile
TRANSMITTAL

TO: Arkenol, Inc.
Attn: Mr. Mark Carver

FAX #: 714 588 3972

FROM: B. Forse - Technical Director

DATE: March 2, 1998

PAGES: TWO (2) including cover sheet.

SUBJECT: RE: VISIT TO GUYSU

Thank you for your fax dated 24/2/98. I am pleased you were able to see our operations first hand at two of our plants Blairmont and Albion.

I found our discussions most interesting particularly in regard to Arkenol's Concentrated Acid Hydrolysis process. Although our industry at this point in time does not produce sufficient quantities of bagasse for this process, GuySuCo has plans to both increase production and more importantly upgrade our factories to become more thermally efficient. As indicated in our discussions attitudes are changing towards excess bagasse from being a disposal problem to being a source of additional revenue.

As the strategy for the industry develops, GuySuCo would like to explore value added options such as Arkenol's technology and in this regard will maintain interest in this direction whilst all opportunities are explored.

Regards

B. Forse - Technical Director

DEMERARA TIMBERS LIMITED

P.O. BOX 10265

1, WATER STREET & BATTERY ROAD
KINGSTON, GEORGETOWN, GUYANA
SOUTH AMERICA

TEL NO. 592-2-53835, 53277, 53706

FAX NO. 592-2-67486, 71663

FAX TRANSMISSION

TO : Arkenol, Inc.

DATE : March 05th, 1998

FOR : Mr Mark Carver

REF : DT 049/98

FROM : Robert O. Perry
(Sales Manager)

TOTAL : 1 Page

We do appreciate the interest you showed in our Company during your recent visit to Guyana.

We are very much interested in your project since our company have waste wood available for this project. We would be eager to discuss an arrangement between ourselves at any time appropriate to you.

We look forward to hearing from you.

Regards

R.O. Perry
(Sales Manager).

ADDRESS: 17 Cowan Street
Kingston
Georgetown
Guyana

TELEPHONE: 53619/53839

FAX: 572-2-56486

February 25, 1998

Mr. Mark Carver
Vice President, Business Development
ARKENOL
Mission Viejo
California
USA

Fax No. 714-580-6935

Dear Sir,

Thanks for your Fax of February 23, 1998.

It was indeed a pleasure meeting with you and discussing the utilisation of rice straws and hulls in feed stock. We support your initiative and look forward to the project becoming a reality in the near future.

The present annual production level in the various regions are as follows:

Region	Paddy Production (tonnes)	Rice Straws (tonnes)	Rice Hulls (tonnes)
2	104,347	78,000	20,000
3	73,476	55,000	14,700
4/5	259,893	194,000	51,000
6	130,463	97,000	26,000

Note: Ratio - Padi to Straw - 0.75
Padi to Hulls - 20%

Padi Production in Regions 4/5 and 6 is expected to increase annually by some 10%.

Cost of bailing, gather and transportation approximately US\$30. per tonne.

If I can be of further help, please let me know.

../2

With best regards.

Yours sincerely

GUYANA RICE DEVELOPMENT BOARD

A handwritten signature in cursive script, appearing to read 'Charles P. Kennard', is written over the typed name.

Charles P. Kennard, CCH
CHIEF EXECUTIVE/CHAIRMAN

CPK:gh

ADDRESS

117 Cowan Street
Kingston
Georgetown
Guyana

TELEPHONE: 53619/53839

FAX: 572-2-56486

February 26, 1998

Mr. Mark Carver
Vice President, Business Development
ARKENOL
Mission Viejo
California
USA

Fax No. 714-580-6935

Dear Sir,

With reference to your Fax of February 25, 1998, please be advised as follows:

- (i) Acreage cultivated in the Blairmont cum annexis (Region 5) is approximately 50,000 acres.
- (ii) The mills located in the area are as follows:

Name of Owner	Milling Capacity (tons of padi per hr.)
1. Mahaicony Rice Limited	10
2. Angad Rupee	10
3. MARDS Rice Milling Complex	20
4. Kayman Sankar Investment	15
5. Johanna Investment co.	12
6. Caribbean Rice Industry	5
7. Kissoon Dyal	5
8. Fairfield Investment	3
Total	80

If I can be of further help, please let me know.

With best regards.

Yours sincerely,

GUYANA RICE DEVELOPMENT BOARD

Charles P. Kennard, CCH

CHIEF EXECUTIVE/CHAIRMAN

Notes

AIAT

john mahler

telefax nº : 33 1 30533743
telephone : 33 1 30533101

TELECOPIER COVER FORM

DATE : 04.03.1998 Nº PAGES : 1
TO : ARKENOL, INC. FAX Nº : 1 714 5883972
MISSION VIEJO
ATT. : MR. MARK CARVER
REF. : GUYANA

Dear Mark,

Following your faxes and our telephon conversations these last days we confirm our interest in purchasing all the quantities you would have available for export from Gayana. We see 2 markets where we have good distribution nets:

- A) North of Brazil where we have imported in the last years 200-300.000 MT per year fuel ethanol;
- B) Europe where it exists already a fuel alcohol market but we would rather reprocess it and sell it as high grade refined product.

Regarding price it should vary between US\$ 1.20-1.40/ WG depending of the market conditions in Brazil, USA, Russia and Japan which are the main actors in the international ethanol trade.

We would appreciate to know as soon as possible the foreseen quantities that you will have available for export as well as the localization of the plant in order to study the logistic.

We wish you success in your project and look forward to co-operate with you.

Sincerely yours

John Mahler

Notes _____

Key Assumptions To Financial Projections

Model Base Case

	Then-Yr \$	
Total Project Cost (\$000)	\$76,177	
Turnkey EPC Contract (\$000)		
EPC Contract w/Process Risk Factor	45,815	
EPC Contingency	2,141	
Power Gen Capital (\$/kWh)	\$500 4,327	
Efficacy Insurance	1,500	
	\$53,782	
Development Costs (\$000)		
Developer's Contingency	3,000	
Development Costs	1,595	
Management During Construction	1,352	
Site Land Purchase	100	
	\$6,047	
Working Capital/Spares (\$000)		
Tools & Equipment	750	
Spare Parts	250	
Feedstocks & Chemicals (30/10 days)	300	
Start-up O&M Costs	1,310	
Working Capital	1,200	
Maintenance Reserve	1,000	
Debt Service Reserve (pct of cap)	5.45% 4,154	
	\$8,964	
Financing Costs & IDC (\$000)		
Placement/Advisory/Underwriting Fee	2.50% 1,412	
Construction/Term Debt Commitment Fee	Incl	
Lender's Direct Costs	1,500	
Interest During Construction	9.00% 4,471	
	\$7,383	
<hr/>		
Equity Capitalization (\$000)	\$22,853	30%
Vendor Debt Financing (\$000)	\$0	0%
Long Term Debt Financing (\$000)	\$53,324	70%
<hr/>		
Rate & Term	9.00%	10
Average Coverage & Annual Payment	1.73	\$8,309
Initial Debt Service Reserve	50%	\$4,154

Denatured Gallons Produced			
Annual Output (gallons)			11,567,028
Operating Costs (\$/gal EtOH)	1998	1999	2000
Labor, Benefits & Taxes	0.010	0.011	0.011
Reagents	0.281	0.291	0.334
Utilities	0.083	0.086	0.026
Operating Costs	0.189	0.196	0.203
Subtotal	0.563	0.584	0.574
Feedstocks	0.211	0.218	0.226
Total Operating Costs	0.774	0.802	0.799
Production Costs net of Product Sales (\$/gal)			
	0.774	0.802	0.799
ZSM Zeolite	(0.616)	(0.629)	(0.641)
Carbon Dioxide	(0.152)	(0.157)	(0.163)
Gypsum	(0.009)	(0.009)	(0.010)
Total Ethanol Production Costs	(0.003)	0.006	(0.014)

Tax Assumptions					Insurance Deductable LOC (\$000) 6,000
Property Tax Rate				0.00%	
Equity Detail	Cash	Grant	Other	Total	Share
Arkenol	0	0	0	0	0.00%
Investor / Partner	22,853	0	0	22,853	100.00%

Project Returns	End of Year:			
	5	10	15	20
Cash-on-Cash IRR	-0.71%	15.09%	18.61%	19.70%
Pre-Tax IRR	6.24%	21.32%	26.89%	27.93%

20-Year Partnership NPV Pre-Tax Cash (Yr 0 \$000)	Discount Rate			
	9.00%	10.00%	13.00%	16.00%
	61,034	53,546	35,995	23,728

Income Statement: OK Balance Sheet: OK

Full Year Production		Quantity		Base Year: 1998							
	Day	Month	Year	Pro-Forma Price		Esc.					
Product Sales											
Denatured Ethanol (gallo	35,052	963,919	11,567,028	\$1.20	per gal	2.0%					
200 Proof Ethanol (gallons)			11,016,217								
ZSM Zeolite (tons)	43	1,188	14,256	\$500.00	per ton	2.0%					
Gypsum (wet tons)	77	2,106	25,273	40%	Moisture						
Gypsum (bone-dry ton eq)			15,164	\$7.00	per b-d ton	3.5%	Btu / lb	@ Moist.	Total		
Lignin (wet tons)	176	4,853	58,238	50%	Moisture		5,500	40%	533,851	mmBtu	
Carbon Dioxide (tons)	106	2,926	35,107	\$50.00	per ton	3.5%					
Carbon Offset Credits (tons)			95,000	\$1.50	per ton						
Feedstocks											
Rice Straw (dry tons)	216	5,940	71,280	\$30.00	per dry ton	3.5%	Makeup	Glucans	Xylans	Silica	
Wood (dry tons)	36	990	11,880	\$10.00	per dry ton	3.5%	60%	55.00%	12.50%	10.00%	
Rice Hulls (dry tons)	108	2,970	35,640	\$5.00	per dry ton	3.5%	30%	49.00%	9.00%	20.00%	
Weighted Average	360	9,900	118,800	\$20.50	per dry ton	3.5%	100%	54.01%	11.64%	12.00%	
Boiler Fuel (dry tons)	135	3,712	44,542	\$10.00	per dry ton	3.5%	10,000 Btu/lb				
Purchased Utilities											
Water (kgals)	886	24,373	292,475	\$0.86	per kgal	3.5%	24.00	gal/gal EtOH = 615 gpm			800 gal/ton CO2
Sewer (kgals)	6	165	1,983	\$2.00	per kgal	3.5%	0.18	gals/gal EtOH			
CO2 Misc Costs				\$20.00	per ton	3.5%					
Reagents											
Denaturing Agent (kgals)	1.67	46	551	\$0.70	per gallon	3.5%					
Yeast (dry tons)	1.54	42	509	\$0.00	per dry pound	3.5%					
Sulfuric Acid (tons)	40	1,100	12,914	\$0.045	per pound	3.5%					
Calcium Hydroxide (tons)	20	500	5,650	\$0.025	per pound	3.5%					
Nutrients (dry tons)	1.40	39	464	\$0.20	per dry pound	3.5%					
Misc. Chemicals (boiler chemicals, etc. cost)				\$0.01	per gal EtOH	3.5%					
ZSM Zeolite Processing				\$20.00	per ton	3.5%	Type	Life (yrs)			Heat Rate 13,500
Resins (cubic feet)	n/a	n/a	1,254	\$200.00	per cu. ft.	3.5%	Anion	5			Efficiency 85.00%
Self-Generated Utilities											Heat Content 1,100
Electricity (mWh)	133	3,655	43,864	kWh/ton Feed		153	Percent of Full Capacity Load Rating: 80.00%				Fuel (mmBtu) 1,424,692
Steam (klbs)	1,949	53,610	643,315	kWh/ton CO2		549	Percent of Full Capacity Diversity: 80.00%				
				kWh/ton ZSM		449	Plant Required Capacity (kW): 8,654				
Other Miscellaneous Assumptions/Inputs							First Year of Operations:			2001	
Consumer Price Index (CPI)	3.50%		Annual Insurance (\$000)		400		Annual Production Days			330	
Interest Income Rate	5.00%		Employee Average Salary (\$/hr)		\$1.95		Monthly Production Days (ave			27.5	
Annual Repairs and Maint.	2.00%		Employee Utilization (Count/mmngal)		3.03		Book Depreciation Life (years)			20	
Ethanol Sales Commission	Sched										

Heat Rate	13,500
Efficiency	85.00%
Heat Content	1,100
Fuel (mmBtu)	1,424,692

Operating Income		Model Base Case														S:\BUSDEV\PROJECTS\IGUYANA\DOE1\IGUY0226.XLS									
	Base	1 2001	2 2002	3 2003	4 2004	5 2005	6 2006	7 2007	8 2008	9 2009	10 2010	11 2011	12 2012	13 2013	14 2014	15 2015	16 2016	17 2017	18 2018	19 2019	20 2020	20 Year Totals			
Revenues (\$000)																									
Ethanol Sales	0	11,784	15,025	15,325	15,632	15,944	16,263	16,588	16,920	17,259	17,604	17,956	18,315	18,681	19,055	19,436	19,825	20,221	20,626	21,038	21,459	354,955			
ZSM Zeolite Sales	0	6,051	7,716	7,870	8,027	8,188	8,352	8,519	8,689	8,863	9,040	9,221	9,405	9,593	9,785	9,981	10,181	10,384	10,592	10,804	11,020	182,280			
Other Commodities	0	1,651	2,136	2,211	2,288	2,368	2,451	2,537	2,626	2,718	2,813	2,911	3,013	3,119	3,228	3,341	3,458	3,579	3,704	3,834	3,968	57,593			
Carbon Offset		114	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	2,822			
Total Revenues	0	19,601	25,019	25,548	26,090	26,643	27,208	27,787	28,377	28,982	29,599	30,230	30,876	31,536	32,210	32,900	33,605	34,327	35,064	35,818	36,589	598,009			
Expenses (\$000)																									
Feedstocks	0	2,555	3,306	3,422	3,541	3,665	3,793	3,926	4,064	4,206	4,353	4,505	4,663	4,826	4,995	5,170	5,351	5,538	5,732	5,933	6,141	89,687			
Utilities	0	227	293	303	314	325	336	348	360	373	386	400	414	428	443	459	475	491	508	526	545	7,954			
Reagents	0	2,984	3,860	3,995	4,135	4,280	4,430	4,585	4,745	4,911	5,083	5,261	5,445	5,636	5,833	6,037	6,248	6,467	6,693	6,928	7,170	104,727			
Labor	0	132	136	141	146	151	156	162	168	173	179	186	192	199	206	213	221	228	236	245	253	3,723			
Operating Costs	0	2,426	2,511	2,598	2,689	2,784	2,881	2,982	3,086	3,194	3,306	3,422	3,541	3,665	3,794	3,926	4,064	4,206	4,353	4,506	4,663	68,597			
Royalties	3.00%	0	588	751	766	783	799	816	834	851	869	888	907	926	946	966	987	1,008	1,030	1,052	1,075	1,098	17,940		
Total Expenses	0	8,911	10,857	11,226	11,609	12,004	12,413	12,836	13,274	13,727	14,196	14,680	15,182	15,701	16,237	16,792	17,367	17,961	18,576	19,212	19,869	292,629			
Operating Income (\$000)		(69,823)	10,690	14,162	14,322	14,481	14,639	14,795	15,103	15,254	15,403	15,550	15,694	15,835	15,973	16,108	16,239	16,366	16,488	16,606	16,719	305,380			
Net Cost of Proof EIOH		11.57		0.02	0.03	0.04	0.06	0.07	0.08	0.11	0.13	0.14	0.16	0.18	0.20	0.21	0.24	0.26	0.28	0.30	0.33				
Cash on Cash IRR			n/a	n/a	-23.3%	-9.4%	-0.7%	5.0%	8.9%	11.6%	13.6%	15.1%	16.2%	17.0%	17.7%	18.2%	18.6%	18.9%	19.2%	19.4%	19.6%	19.7%			
Payback (years)		5.10	1.00	1.00	1.00	1.00	1.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
Interest Income		258	258	258	258	258	258	258	258	258	258	258	50	50	50	50	50	50	50	50	50	3,285			
Interest Expense		(4,799)	(4,483)	(4,139)	(3,764)	(3,355)	(2,909)	(2,423)	(1,893)	(1,315)	(686)	(0)	0	0	0	0	0	0	0	0	0	(29,765)			
Book Depreciatio	(0.289)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(3,341)	(66,811)			
Amortization		(291)	(291)	(291)	(291)	(291)	(291)	(291)	(291)	(291)	(291)	(291)	0	0	0	0	0	0	0	0	0	(2,912)			
Pre-Tax Income		2,517	6,305	6,809	7,344	7,910	8,513	9,154	9,836	10,565	11,343	12,467	12,404	12,545	12,683	12,817	12,948	13,075	13,198	13,316	13,429	209,177			
Operating Cash Flow (\$000)		10,690	14,162	14,322	14,481	14,639	14,795	14,950	15,103	15,254	15,403	15,550	15,694	15,835	15,973	16,108	16,239	16,366	16,488	16,606	16,719	305,380			
EtoH Capital Contributions	(69,823)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(69,823)			
Interest Payments	0	(4,799)	(4,483)	(4,139)	(3,764)	(3,355)	(2,909)	(2,423)	(1,893)	(1,315)	(686)	(0)	0	0	0	0	0	0	0	0	0	(29,765)			
Principal Payments	53,324	(3,510)	(3,826)	(4,170)	(4,545)	(4,954)	(5,400)	(5,886)	(6,416)	(6,993)	(7,623)	(0)	0	0	0	0	0	0	0	0	0	0			
Interest Income	0	258	258	258	258	258	258	258	258	258	258	258	50	50	50	50	50	50	50	50	50	3,285			
Debt Service Reserve	(4,154)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(4,154)			
Debt Service Reserve Cred	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Chg in Maintenance Reser	(1,000)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1,000)			
Change in Working Capital	(1,200)	(42)	(43)	(45)	(47)	(48)	(50)	(52)	(53)	(55)	(57)	(59)	(61)	(63)	(66)	(68)	(70)	(73)	(75)	(78)	(81)	(2,388)			
Pre-Tax Cash Flows	(22,853)	2,596	6,068	6,226	6,383	6,540	6,694	6,847	6,999	7,148	7,295	19,903	15,683	15,822	15,958	16,090	16,218	16,343	16,463	16,578	16,689	205,689			
Pre-Tax Rolling IRR		n/a	-42.5%	-17.0%	-2.5%	6.2%	11.9%	15.6%	18.2%	20.0%	21.3%	23.7%	24.9%	25.8%	26.4%	26.9%	27.2%	27.5%	27.7%	27.8%	27.9%				
Payback (years)		4.24	1.00	1.00	1.00	1.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				

Balance Sheet, Debt, & Working Capital																S:\BUSDEV\PROJECTS\GUYANA\DOE\1GUY0226.XLS						
	Year	Base	1 2001	2 2002	3 2003	4 2004	5 2005	6 2006	7 2007	8 2008	9 2009	10 2010	11 2011	12 2012	13 2013	14 2014	15 2015	16 2016	17 2017	18 2018	19 2019	20 2020
Assets																						
Plant		66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811	66,811
Accumulated Depreciation		0	(3,341)	(6,681)	(10,022)	(13,362)	(16,703)	(20,043)	(23,384)	(26,724)	(30,065)	(33,405)	(36,746)	(40,086)	(43,427)	(46,768)	(50,108)	(53,449)	(56,789)	(60,130)	(63,470)	(66,811)
Net Plant		66,811	63,470	60,130	56,789	53,449	50,108	46,768	43,427	40,086	36,746	33,405	30,065	26,724	23,384	20,043	16,703	13,362	10,022	6,681	3,341	0
Net Working Capital		1,200	1,242	1,285	1,330	1,377	1,425	1,475	1,527	1,580	1,635	1,693	1,752	1,813	1,877	1,942	2,010	2,081	2,154	2,229	2,307	2,388
Land		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Major Maintenance Reserv		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Debt Service Reserve		4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	0	0	0	0	0	0	0	0	0	0
Total Assets		73,265	69,967	66,670	63,374	60,080	56,788	53,497	50,208	46,921	43,636	40,353	32,917	29,638	26,361	23,086	19,813	16,543	13,275	10,010	6,748	3,488
Liabilities																						
Long Term Debt		53,324	49,814	45,988	41,818	37,273	32,319	26,919	21,032	14,616	7,623	0	0	0	0	0	0	0	0	0	0	0
Construction Debt		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Financing Costs		(2,912)	(2,621)	(2,329)	(2,038)	(1,747)	(1,456)	(1,165)	(874)	(582)	(291)	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities		50,412	47,193	43,659	39,780	35,526	30,863	25,754	20,159	14,034	7,332	0	0	0	0	0	0	0	0	0	0	0
Equity																						
EtOH Contributed Capital		22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853	22,853
Retained Earnings		0	(80)	157	741	1,701	3,072	4,890	7,196	10,034	13,451	17,499	10,064	6,784	3,507	233	(3,040)	(6,310)	(9,578)	(12,843)	(16,106)	(19,365)
Total Equity		22,853	22,773	23,011	23,594	24,554	25,925	27,743	30,049	32,887	36,304	40,353	32,917	29,638	26,361	23,086	19,813	16,543	13,275	10,010	6,748	3,488
Total Liabilities & Equity		73,265	69,967	66,670	63,374	60,080	56,788	53,497	50,208	46,921	43,636	40,353	32,917	29,638	26,361	23,086	19,813	16,543	13,275	10,010	6,748	3,488
Term Loan (\$000)																						
Interest Payment	9.00%	0	4,799	4,483	4,139	3,764	3,355	2,909	2,423	1,893	1,315	686	0	0	0	0	0	0	0	0	0	0
Principal Payment		0	3,510	3,826	4,170	4,545	4,954	5,400	5,886	6,416	6,993	7,623	0	0	0	0	0	0	0	0	0	0
Annual Loan Pay	8,309	0	8,309	8,309	8,309	8,309	8,309	8,309	8,309	8,309	8,309	8,309	0	0	0	0	0	0	0	0	0	0
Ending Balance		53,324	49,814	45,988	41,818	37,273	32,319	26,919	21,032	14,616	7,623	0	0	0	0	0	0	0	0	0	0	0
Debt Coverage	Average	1.73	1.29	1.70	1.72	1.74	1.76	1.78	1.80	1.82	1.84	1.85	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Debt Reserve (\$000)																						
Additions	50%	4,154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Withdrawals			0	0	0	0	0	0	0	0	0	0	(4,154)	0	0	0	0	0	0	0	0	0
Ending Balance (\$000)		4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	0	0	0	0	0	0	0	0	0	0
Interest on Balan	5.00%		208	208	208	208	208	208	208	208	208	208	208	0	0	0	0	0	0	0	0	0
Operating Capital																						
Additions			42	43	45	47	48	50	52	53	55	57	59	61	63	66	68	70	73	75	78	81
Reserve Returned to Owner			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ending Balance (\$000)		\$1,200	1,242	1,285	1,330	1,377	1,425	1,475	1,527	1,580	1,635	1,693	1,752	1,813	1,877	1,942	2,010	2,081	2,154	2,229	2,307	2,388
Major Maintenance Reserve																						
Additions			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reserve Returned to Owner			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ending Balance (\$000)		\$1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Interest on Balan	5.00%		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

[illegible]

		1	2	3	4	5	6	7	8	9	10
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Operating Percentage:		80%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Ethanol											
Denatured EtOH Price (\$/gal)	\$1.20	1.27	1.30	1.32	1.35	1.38	1.41	1.43	1.46	1.49	1.52
Proof EtOH Production (kgal)	11,016	8,813	11,016	11,016	11,016	11,016	11,016	11,016	11,016	11,016	11,016
Total EtOH Production (kgal)	11,567	9,254	11,567	11,567	11,567	11,567	11,567	11,567	11,567	11,567	11,567
Revenue (\$000)		11,784	15,025	15,325	15,632	15,944	16,263	16,588	16,920	17,259	17,604
ZSM Zeolite											
Sales Price (\$/ton)	\$500	531	541	552	563	574	586	598	609	622	634
ZSM Zeolite Produced (tons)	14,256	11,405	14,256	14,256	14,256	14,256	14,256	14,256	14,256	14,256	14,256
Revenue (\$000)		6,051	7,716	7,870	8,027	8,188	8,352	8,519	8,689	8,863	9,040
Gypsum											
Sales Price (\$/ton)	\$7.00	7.76	8.03	8.31	8.60	8.91	9.22	9.54	9.87	10.22	10.58
Gypsum Produced (tons)	15,164	12,131	15,164	15,164	15,164	15,164	15,164	15,164	15,164	15,164	15,164
Revenue (\$000)		94	122	126	130	135	140	145	150	155	160
Carbon Dioxide											
Sales Price (\$/ton)	\$50.00	55.44	57.38	59.38	61.46	63.61	65.84	68.14	70.53	73.00	75.55
CO ₂ Production (tons)	35,107	28,086	35,107	35,107	35,107	35,107	35,107	35,107	35,107	35,107	35,107
Revenue (\$000)		1,557	2,014	2,085	2,158	2,233	2,311	2,392	2,476	2,563	2,652
Total Byproduct Sales (\$000)		1,651	2,136	2,211	2,288	2,368	2,451	2,537	2,626	2,718	2,813

Product Sales

4 March 1998 10:03 am

	11	12	13	14	15	16	17	18	19	20
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Operating Percentage:	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Ethanol										
Denatured EtOH Price (\$/gal)	\$1.20	1.55	1.58	1.62	1.65	1.68	1.71	1.75	1.78	1.86
Proof EtOH Production (kgal)	11,016	11,016	11,016	11,016	11,016	11,016	11,016	11,016	11,016	11,016
Total EtOH Production (kgal)	11,567	11,567	11,567	11,567	11,567	11,567	11,567	11,567	11,567	11,567
Revenue (\$000)	17,956	18,315	18,681	19,055	19,436	19,825	20,221	20,626	21,038	21,459
ZSM Zeolite										
Sales Price (\$/ton)	\$500	647	660	673	686	700	714	728	743	773
ZSM Zeolite Produced (tons)	14,256	14,256	14,256	14,256	14,256	14,256	14,256	14,256	14,256	14,256
Revenue (\$000)	9,221	9,405	9,593	9,785	9,981	10,181	10,384	10,592	10,804	11,020
Gypsum										
Sales Price (\$/ton)	\$7.00	10.95	11.33	11.73	12.14	12.56	13.00	13.46	13.93	14.92
Gypsum Produced (tons)	15,164	15,164	15,164	15,164	15,164	15,164	15,164	15,164	15,164	15,164
Revenue (\$000)	166	172	178	184	190	197	204	211	219	226
Carbon Dioxide										
Sales Price (\$/ton)	\$50.00	78.20	80.93	83.77	86.70	89.73	92.87	96.13	99.49	106.58
CO ₂ Production (tons)	35,107	35,107	35,107	35,107	35,107	35,107	35,107	35,107	35,107	35,107
Revenue (\$000)	2,745	2,841	2,941	3,044	3,150	3,261	3,375	3,493	3,615	3,742
Total Byproduct Sales (\$000)	2,911	3,013	3,119	3,228	3,341	3,458	3,579	3,704	3,834	3,968

Feedstocks & Utilities

4 March 1998 10:03 am

	Year	1 2001	2 2002	3 2003	4 2004	5 2005	6 2006	7 2007	8 2008	9 2009	10 2010
Feedstocks											
Rice Straw (\$/ton)	\$30.00	33.26	34.43	35.63	36.88	38.17	39.50	40.89	42.32	43.80	45.33
Wood (\$/ton)	\$10.00	11.09	11.48	11.88	12.29	12.72	13.17	13.63	14.11	14.60	15.11
Rice Hulls (\$/ton)	\$5.00	5.54	5.74	5.94	6.15	6.36	6.58	6.81	7.05	7.30	7.56
Rice Straw (dry tons)	71,280	57,024	71,280	71,280	71,280	71,280	71,280	71,280	71,280	71,280	71,280
Wood (dry tons)	56,422	45,138	56,422	56,422	56,422	56,422	56,422	56,422	56,422	56,422	56,422
Rice Hulls (dry tons)	35,640	28,512	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640
Subtotal Rice Straw (\$000)		2,555	3,306	3,422	3,541	3,665	3,793	3,926	4,064	4,206	4,353
<i>Per Gallon Produced (\$)</i>		<i>\$0.276</i>	<i>\$0.286</i>	<i>\$0.296</i>	<i>\$0.306</i>	<i>\$0.317</i>	<i>\$0.328</i>	<i>\$0.339</i>	<i>\$0.351</i>	<i>\$0.364</i>	<i>\$0.376</i>
Water											
Commodity Price (\$/kgal)	\$0.86	0.95	0.99	1.02	1.06	1.09	1.13	1.17	1.21	1.26	1.30
Annual Usage (kgal)	292,475	233,980	292,475	292,475	292,475	292,475	292,475	292,475	292,475	292,475	292,475
Total Cost of Water (\$000)		223	289	299	309	320	331	343	355	367	380
Sewer											
Disposal Cost (\$/ton)	\$2.00	2.22	2.30	2.38	2.46	2.54	2.63	2.73	2.82	2.92	3.02
Waste Water (kgal)	1,983	1,586	1,983	1,983	1,983	1,983	1,983	1,983	1,983	1,983	1,983
Total Cost of Sewer (\$000)		4	5	5	5	5	5	5	6	6	6
Total Utilities (\$000)		227	293	303	314	325	336	348	360	373	386
<i>Per Gallon Produced (\$)</i>		<i>\$0.024</i>	<i>\$0.025</i>	<i>\$0.026</i>	<i>\$0.027</i>	<i>\$0.028</i>	<i>\$0.029</i>	<i>\$0.030</i>	<i>\$0.031</i>	<i>\$0.032</i>	<i>\$0.033</i>

Feedstocks & Utilities

4 March 1998 10:03 am

	Year	11 2011	12 2012	13 2013	14 2014	15 2015	16 2016	17 2017	18 2018	19 2019	20 2020
Feedstocks											
Rice Straw (\$/ton)	\$30.00	46.92	48.56	50.26	52.02	53.84	55.72	57.68	59.69	61.78	63.95
Wood (\$/ton)	\$10.00	15.64	16.19	16.75	17.34	17.95	18.57	19.23	19.90	20.59	21.32
Rice Hulls (\$/ton)	\$5.00	7.82	8.09	8.38	8.67	8.97	9.29	9.61	9.95	10.30	10.66
Rice Straw (dry tons)	71,280	71,280	71,280	71,280	71,280	71,280	71,280	71,280	71,280	71,280	71,280
Wood (dry tons)	56,422	56,422	56,422	56,422	56,422	56,422	56,422	56,422	56,422	56,422	56,422
Rice Hulls (dry tons)	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640
Subtotal Rice Straw (\$000)		4,505	4,663	4,826	4,995	5,170	5,351	5,538	5,732	5,933	6,141
<i>Per Gallon Produced (\$)</i>		<i>\$0.390</i>	<i>\$0.403</i>	<i>\$0.417</i>	<i>\$0.432</i>	<i>\$0.447</i>	<i>\$0.463</i>	<i>\$0.479</i>	<i>\$0.496</i>	<i>\$0.513</i>	<i>\$0.531</i>
Water											
Commodity Price (\$/kgal)	\$0.86	1.35	1.39	1.44	1.49	1.54	1.60	1.65	1.71	1.77	1.83
Annual Usage (kgal)	292,475	292,475	292,475	292,475	292,475	292,475	292,475	292,475	292,475	292,475	292,475
Total Cost of Water (\$000)		393	407	421	436	451	467	484	500	518	536
Sewer											
Disposal Cost (\$/ton)	\$2.00	3.13	3.24	3.35	3.47	3.59	3.71	3.85	3.98	4.12	4.26
Waste Water (kgal)	1,983	1,983	1,983	1,983	1,983	1,983	1,983	1,983	1,983	1,983	1,983
Total Cost of Sewer (\$000)		6	6	7	7	7	7	8	8	8	8
Total Utilities (\$000)		400	414	428	443	459	475	491	508	526	545
<i>Per Gallon Produced (\$)</i>		<i>\$0.035</i>	<i>\$0.036</i>	<i>\$0.037</i>	<i>\$0.038</i>	<i>\$0.040</i>	<i>\$0.041</i>	<i>\$0.042</i>	<i>\$0.044</i>	<i>\$0.045</i>	<i>\$0.047</i>

	Year	1 2001	2 2002	3 2003	4 2004	5 2005	6 2006	7 2007	8 2008	9 2009	10 2010
Denaturing Agent											
Commodity Price (\$/gal)	\$0.700	\$0.776	\$0.803	\$0.831	\$0.860	\$0.891	\$0.922	\$0.954	\$0.987	\$1.022	\$1.058
Denaturing Agent Used (kgal)		441	551	551	551	551	551	551	551	551	551
Subtotal Denaturing Agent (\$000)		342	442	458	474	491	508	525	544	563	583
Yeast											
Yeast Cost (\$/lb)	\$0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Usage (tons)	509	408	509	509	509	509	509	509	509	509	509
Subtotal Yeasts (\$000)		0	0	0	0	0	0	0	0	0	0
Nutrients											
Nutrients Cost (\$/lb)	\$0.200	\$0.222	\$0.230	\$0.238	\$0.246	\$0.254	\$0.263	\$0.273	\$0.282	\$0.292	\$0.302
Usage (tons)	464	371	464	464	464	464	464	464	464	464	464
Subtotal Nutrients (\$000)		164	213	220	228	236	244	253	262	271	280
Sulfuric Acid - (93% concentration)											
Acid Cost (\$/lb)	\$0.045	\$0.050	\$0.052	\$0.053	\$0.055	\$0.057	\$0.059	\$0.061	\$0.063	\$0.066	\$0.068
Usage (tons)	12,914	10,331	12,914	12,914	12,914	12,914	12,914	12,914	12,914	12,914	12,914
Subtotal Sulfuric Acid (\$000)		1,031	1,334	1,380	1,429	1,479	1,530	1,584	1,639	1,697	1,756
Calcium Oxide (97% concentration)											
Commodity Cost (\$/lb)	\$0.025	\$0.028	\$0.029	\$0.030	\$0.031	\$0.032	\$0.033	\$0.034	\$0.035	\$0.036	\$0.038
CaO Used (tons)	5,650	4,520	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650
Subtotal Calcium Hydroxide (\$000)		251	324	336	347	359	372	385	398	412	427
Resin Replacement											
Commodity Cost (\$/cu.ft.)	\$200	\$222	\$230	\$238	\$246	\$254	\$263	\$273	\$282	\$292	\$302
Commodity Used (cu. ft.)	1,254	1,003	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254
Subtotal Resins (\$000)		222	288	298	308	319	330	342	354	366	379
Other Chemical Costs											
ZSM Zeolite Misc. Chem	\$20	253	327	339	350	363	375	389	402	416	431
CO2 Misc. Costs	\$20	623	806	834	863	893	925	957	990	1,025	1,061
A/H Miscellaneous Chemicals	\$0.01	98	126	131	135	140	145	150	155	161	166
Total Reagents (\$000)		2,984	3,860	3,995	4,135	4,280	4,430	4,585	4,745	4,911	5,083
Per Gallon Produced (\$)		\$0.322	\$0.334	\$0.345	\$0.357	\$0.370	\$0.383	\$0.396	\$0.410	\$0.425	\$0.439

	Year	11 2011	12 2012	13 2013	14 2014	15 2015	16 2016	17 2017	18 2018	19 2019	20 2020
Denaturing Agent											
Commodity Price (\$/gal)	\$0.700	\$1.095	\$1.133	\$1.173	\$1.214	\$1.256	\$1.300	\$1.346	\$1.393	\$1.442	\$1.492
Denaturing Agent Used (kgal)		551	551	551	551	551	551	551	551	551	551
Subtotal Denaturing Agent (\$000)		603	624	646	669	692	716	741	767	794	822
Yeast											
Yeast Cost (\$/lb)	\$0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Usage (tons)	509	509	509	509	509	509	509	509	509	509	509
Subtotal Yeasts (\$000)		0	0	0	0	0	0	0	0	0	0
Nutrients											
Nutrients Cost (\$/lb)	\$0.200	\$0.313	\$0.324	\$0.335	\$0.347	\$0.359	\$0.371	\$0.385	\$0.398	\$0.412	\$0.426
Usage (tons)	464	464	464	464	464	464	464	464	464	464	464
Subtotal Nutrients (\$000)		290	300	311	322	333	344	357	369	382	395
Sulfuric Acid - (93% concentration)											
Acid Cost (\$/lb)	\$0.045	\$0.070	\$0.073	\$0.075	\$0.078	\$0.081	\$0.084	\$0.087	\$0.090	\$0.093	\$0.096
Usage (tons)	12,914	12,914	12,914	12,914	12,914	12,914	12,914	12,914	12,914	12,914	12,914
Subtotal Sulfuric Acid (\$000)		1,818	1,881	1,947	2,015	2,086	2,159	2,234	2,313	2,394	2,477
Calcium Oxide (97% concentration)											
Commodity Cost (\$/lb)	\$0.025	\$0.039	\$0.040	\$0.042	\$0.043	\$0.045	\$0.046	\$0.048	\$0.050	\$0.051	\$0.053
CaO Used (tons)	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650	5,650
Subtotal Calcium Hydroxide (\$000)		442	457	473	490	507	525	543	562	582	602
Resin Replacement											
Commodity Cost (\$/cu.ft.)	\$200	\$313	\$324	\$335	\$347	\$359	\$371	\$385	\$398	\$412	\$426
Commodity Used (cu. ft.)	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254
Subtotal Resins (\$000)		392	406	420	435	450	466	482	499	516	534
Other Chemical Costs											
ZSM Zeolite Misc. Chem	\$20	446	462	478	494	512	530	548	567	587	608
CO2 Misc. Costs	\$20	1,098	1,137	1,176	1,218	1,260	1,304	1,350	1,397	1,446	1,497
A/H Miscellaneous Chemicals	\$0.01	172	178	185	191	198	205	212	219	227	235
Total Reagents (\$000)		5,261	5,445	5,636	5,833	6,037	6,248	6,467	6,693	6,928	7,170
Per Gallon Produced (\$)		\$0.455	\$0.471	\$0.487	\$0.504	\$0.522	\$0.540	\$0.559	\$0.579	\$0.599	\$0.620

	Head Count	\$/hr	Annual Salaries	8.0% Bonus	Total Salaries	10.0% Overtime
Plant Manager	1	0.00	12,414	993	13,407	0
Secretary*	1	0.00	4,138	331	4,469	414
Purchasing/Acc't	1	0.00	8,690	695	9,385	0
Senior Lab Technician	1	0.00	2,648	212	2,860	0
Electrical & Maint*	2	0.00	3,724	298	8,044	745
Shift Supervisor*	4	0.00	3,559	285	15,375	1,424
Lab Technician	1	0.00	2,334	187	2,521	0
Operations Technicians*	2	0.00	1,903	152	4,110	381
Operations Apprentices*	17	0.00	1,490	119	27,356	2,533
Accountant	1	0.00	8,690	695	9,385	0
DCS Operator/Other*	4	0.00	1,903	152	8,221	761
	35	0.00			105,134	6,257
*Indicates 10% Overtime In Salary				Benefits	0.07	7,359
				Taxes	0	0
				Total O&M Labor		112,493

	1 2001	2 2002	3 2003	4 2004	5 2005	6 2006	7 2007	8 2008	9 2009	10 2010
Plant Manager	15	15	16	16	17	18	18	19	20	20
Secretary*	5	5	5	5	6	6	6	6	7	7
Purchasing/Acc't	10	11	11	12	12	12	13	13	14	14
Senior Lab Technician	3	3	3	4	4	4	4	4	4	4
Electrical & Maint*	9	9	10	10	10	11	11	11	12	12
Shift Supervisor*	17	18	18	19	20	20	21	22	22	23
Lab Technician	3	3	3	3	3	3	3	4	4	4
Operations Technicians*	5	5	5	5	5	5	6	6	6	6
Operations Apprentices*	30	31	32	34	35	36	37	39	40	41
Accountant	10	11	11	12	12	12	13	13	14	14
DCS Operator/Other*	9	9	10	10	10	11	11	12	12	12
Subtotal O&M Labor	117	121	125	129	134	138	143	148	153	159
Benefits	8	8	9	9	9	10	10	10	11	11
Overtime	7	7	7	8	8	8	9	9	9	9
Taxes	0	0	0	0	0	0	0	0	0	0
Total O&M Labor (\$000)	132	136	141	146	151	156	162	168	173	179
<i>Per Gallon Produced (\$)</i>	<i>\$0.014</i>	<i>\$0.012</i>	<i>\$0.012</i>	<i>\$0.013</i>	<i>\$0.013</i>	<i>\$0.014</i>	<i>\$0.014</i>	<i>\$0.014</i>	<i>\$0.015</i>	<i>\$0.016</i>

Year	11 2011	12 2012	13 2013	14 2014	15 2015	16 2016	17 2017	18 2018	19 2019	20 2020
Plant Manager	21	22	22	23	24	25	26	27	28	29
Secretary*	7	7	7	8	8	8	9	9	9	10
Purchasing/Acc't	15	15	16	16	17	17	18	19	19	20
Senior Lab Technician	4	5	5	5	5	5	5	6	6	6
Electrical & Maint*	13	13	13	14	14	15	15	16	17	17
Shift Supervisor*	24	25	26	27	28	29	30	31	32	33
Lab Technician	4	4	4	4	5	5	5	5	5	5
Operations Technicians*	6	7	7	7	7	8	8	8	8	9
Operations Apprentices*	43	44	46	47	49	51	53	54	56	58
Accountant	15	15	16	16	17	17	18	19	19	20
DCS Operator/Other*	13	13	14	14	15	15	16	16	17	18
Subtotal O&M Labor	164	170	176	182	189	195	202	209	217	224
Benefits	12	12	12	13	13	14	14	15	15	16
Overtime	10	10	10	11	11	12	12	12	13	13
Taxes	0	0	0	0	0	0	0	0	0	0
Total O&M Labor (\$000)	186	192	199	206	213	221	228	236	245	253
<i>Per Gallon Produced (\$)</i>	<i>\$0.016</i>	<i>\$0.017</i>	<i>\$0.017</i>	<i>\$0.018</i>	<i>\$0.018</i>	<i>\$0.019</i>	<i>\$0.020</i>	<i>\$0.020</i>	<i>\$0.021</i>	<i>\$0.022</i>

Operating Costs

4 March 1998 10:03 am

		1	2	3	4	5	6	7	8	9	10
	Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Operating Costs (\$000)											
Management Cost (Travel, Acctg, etc.)	\$450	499	516	534	553	573	593	613	635	657	680
Consulting Costs (R&D, etc.)	\$50	55	57	59	61	64	66	68	71	73	76
O & M Fee	\$500	554	574	594	615	636	658	681	705	730	756
Miscellaneous Expenses	\$250	277	287	297	307	318	329	341	353	365	378
Insurance	\$400	443	459	475	492	509	527	545	564	584	604
Property Taxes	0	0	0	0	0	0	0	0	0	0	0
Repairs & Maintenance	2.00% 26,891	596	617	639	661	684	708	733	759	785	813
Total Operating Costs		2,426	2,511	2,598	2,689	2,784	2,881	2,982	3,086	3,194	3,306
<i>Per Gallon Produced (\$)</i>		<i>\$0.262</i>	<i>\$0.217</i>	<i>\$0.225</i>	<i>\$0.233</i>	<i>\$0.241</i>	<i>\$0.249</i>	<i>\$0.258</i>	<i>\$0.267</i>	<i>\$0.276</i>	<i>\$0.286</i>

Operating Costs

		4 March 1998 10:03 am									
		11	12	13	14	15	16	17	18	19	20
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Operating Costs (\$000)											
Management Cost (Travel, Acctg, etc.)	\$450	704	728	754	780	808	836	865	895	927	959
Consulting Costs (R&D, etc.)	\$50	78	81	84	87	90	93	96	99	103	107
O & M Fee	\$500	782	809	838	867	897	929	961	995	1,030	1,066
Miscellaneous Expenses	\$250	391	405	419	433	449	464	481	497	515	533
Insurance	\$400	626	647	670	694	718	743	769	796	824	853
Property Taxes	0	0	0	0	0	0	0	0	0	0	0
Repairs & Maintenance	2.00% 26,891	841	871	901	933	965	999	1,034	1,070	1,108	1,146
Total Operating Costs		3,422	3,541	3,665	3,794	3,926	4,064	4,206	4,353	4,506	4,663
<i>Per Gallon Produced (\$)</i>		<i>\$0.296</i>	<i>\$0.306</i>	<i>\$0.317</i>	<i>\$0.328</i>	<i>\$0.339</i>	<i>\$0.351</i>	<i>\$0.364</i>	<i>\$0.376</i>	<i>\$0.390</i>	<i>\$0.403</i>

Notes

ETHANOL-FROM-BIOMASS COULD HELP MEET GREENHOUSE REDUCTIONS

A recently released study by the Department of Energy (DOE) concludes reductions in greenhouse gas (ghg) emissions can be reached without increasing U.S. energy costs. Part of the solution could include the use of ethanol and other alternatives to fossil fuel. However, it is biomass-based ethanol, rather than the current corn-derived product, that will assist in the reductions of ghg, said DOE.

"Renewable energy technologies will likely play a crucial role in limiting carbon emissions over the long term," said the DOE study titled, Scenarios of U.S. Carbon Reductions. "Low carbon energy supply options are needed to fuel domestic and international economic development without stimulating further global warming."

The study looks at the technological advances in the four major sectors of the economy, buildings, industry, transportation and electric utilities. For the transportation sector, the study analyzes the impacts of end-use energy efficiency.

"Among the alternative fuels under consideration, biomass fuels derived from wood appear to have the greatest potential to reduce greenhouse gas emissions," noted the study. "Whereas ethanol derived from corn may actually produce higher levels of CO₂ equivalent emissions than conventional gasoline (depending on the fuel source used to power the distillation plant and other factors), ethanol derived from cellulosic sources, can reduce carbon emissions by about 90% for both light-duty and heavy-duty vehicles (see chart)."

**Greenhouse Gas Emissions Factors
for Transportation Fuels**

Fuel	grams/Btu	Btu/gallon	grams/gallon
Conventional Gasoline			
Summer	0.10554	114,500	12,084
Winter	0.10304	112,700	11,613
Average	0.10421	113,537	11,832
Diesel	0.09617	128,700	12,377
Ethanol from Corn	0.13390	76,100	10,190
Ethanol from Biomass	0.00076	76,100	58

Source: U.S. DOE (1997)

"The study is a good first step and correctly mentioned biofuels and bioenergy as significant contributors in reducing greenhouse gas emissions," said Bill Holmberg, president of Sustainable New Wealth Industries. "It did not, however, highlight the true potential of biofuels, which could account for 10% of the transportation fuels market by 2010."

The study did address ethanol growth. "The market for cellulosic ethanol in 2010 will be largely be as a blending component for gasoline," concludes the study.

"Demand curve estimates for ethanol blending with gasoline for the year 2010 show the value to refiners of being able to produce gasoline refined to be blended with alcohol downstream." Demand for ethanol is affected by the RFG market, notes DOE, but not necessarily in the positive. Most RFG demand to date has been met by MTBE blends.

Ethanol demand is also extremely price sensitive. Demand would be about 2 billion gal/year at an ethanol price of just over \$1/gal, but would rise to 5 billion gallons at 80c/gal, and reach 9 billion at 65c/gal, DOE predicts. From this point, increases in demand associated with further price decreases drop off sharply as the limits of economical blending are reached.

The scenarios in the report were based on current projections that carbon emissions reductions of 390 million metric tons (MMT) would be required to reduce U.S. emissions in 2010 to 1990 levels. Using these projections, the study combines a national technology program with a domestic system of carbon trading to achieve the reductions, according to the DOE.

"What is basically shown [in the DOE study] is that there is a way to substitute technology for energy consumption and therefore possible to reduce carbon dioxide emissions at much lower costs," said Dan Lashof of the Natural Resources Defense Council. - *By Katrin Olson*

[illegible]

Project Fact Sheet

PROJECT NAME:	Guyana Biorefinery Project
FUNDING REQUEST:	Approximately \$76,000,000 in debt and equity needed to complete the construction of the project. About 30%, \$22,800,000, is being sought as equity capital and the balance as long term debt.
PROJECT DESCRIPTION:	The construction and operation of a biorefinery in the Blairemont region adjacent to the Berbice River in the country of Guyana. The biorefinery will utilize waste wood, rice straw and hulls to produce approximately 11.5 million gallons per year of fuel grade ethanol, 14,000 tons of ZSM zeolites, 29,000 tons of lignin which will be used as boiler fuel, 35,000 tons of food grade CO ₂ , and 15,000 tons of gypsum. The ethanol will be sold in-country and also exported to nearby countries, mainly the northern region of Brazil. The zeolites will be sold into the South American market. Lignin will be used as a boiler fuel for plant operations.
PROJECT PARTICIPANTS:	Arkenol will be the primary developer. Additional parties with interest in participating at various project levels include an internationally recognized engineering firm, an international marketer of ethanol, and the local rice industry.
PROJECT ECONOMICS:	Preliminary pro forma analysis indicates a pretax, 20 year IRR of 29%.
PERTINENT ISSUES:	The biorefinery will utilize Arkenol's patented improvements to the concentrated acid hydrolysis process. Arkenol can obtain appropriate process guarantees from its engineering and construction vendors, as well as efficacy insurance from Lloyd's of London.
PROJECT BENEFITS:	The project will be a commercial demonstration of an innovative technology to reduce greenhouse gas emissions and enhance sustainable rural economic development which can be applicable worldwide. It will generate approximately 95,000 MT of CO ₂ offsets which can be sold to investors. The project will also decrease the amount of particulate in the air by reducing the amount of open field burn acreage. It will assist the Guyanese in getting the lead out of their gasoline and lessening their dependence on imported oil, a serious drain on their economy.
PROJECT STATUS:	3/98 - A site has been selected, pertinent in-country relationships have been developed, preliminary engineering and economic feasibility issues have been determined, and a pro forma has been created.
NEXT STEPS:	The securing of funds necessary to complete project feasibility and development activities which include optimization of pro forma inputs, conceptual and detailed engineering, finalizing EPC contract and scope of work, finalizing feedstock supply and product sale agreements, developing the necessary financing structure and identifying pertinent financial sources, and developing a detailed project business plan.

Notes

ARKENOL, Inc.

PROJECT LIFE CYCLE: DEFINITIONS

An Arkenol biorefinery project is typically implemented in five phases which are defined as follows:

[illegible]

1. **PRE-DEVELOPMENT** - The identification of the opportunity; performing the initial ground work; and screening the investment against financial return criteria. The milestones which indicate the end of this phase, are:
 - preliminary pro-forma created,
 - letters of intent for feedstock and product offtake obtained,
 - site leased or optioned,
 - preliminary cost estimates and terms for EPC contract are prepared, and
 - written summary of the project drafted.
2. **DEVELOPMENT PHASE I** - Working out the details of the project and making the final determination of the project's economic viability. The milestones which indicate the end of this phase, are:
 - all pro-forma inputs validated,
 - term sheets/contracts signed for feedstock and product offtake obtained,
 - EPC contract scope of work, schedule and cost estimates completed,
 - permitting is in process with requirements and timetable known,
 - feedstocks tested,
 - minimum design criteria engineering report completed,
 - potential financing structure evaluated and sources identified, and
 - project business plan is prepared.
3. **DEVELOPMENT PHASE II** - The securing of contractual commitments of all the parties to construct and operate the project. The milestones which indicate the end of this phase, are:
 - final cost estimates complete,
 - EPC contracts with performance warranties, feedstock, product and operations contracts in place,
 - financing commitments (construction loan and equity investment) funded, and
 - permits issued.
4. **CONSTRUCTION AND STARTUP** - The construction and performance testing of the facility. The milestones which indicate the end of this phase, are:
 - construction complete,
 - performance testing completed with problems resolved.