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SUSTAINABLE BIOMASS ENERGY PROGRAM

HAMAKUA PROJECT

"Sustainable Biomass Products Development And Evaluation"

FINAL DRAFT REPORT

Prepared by
The Pacific International Center For High Technology Research
Honolulu, Hawaii
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This report was prepared by The Pacific International Center For High Technology Research for the United States Department of Energy (USDOE) with funding from the USDOE; the Electric Power Research Institute (EPRI); the Governor's Agriculture Coordinating Commitee (GACC), State of Hawaii, the Office of State Planning (OSP), State of Hawaii; and the Department of Business, Economic Development and Tourism (DBEDT), State of Hawaii.

DISCLAIMER

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EXECUTIVE SUMMARY

The PICHTR Sustainable Biomass Energy Program was developed to evaluate the potential to cultivate crops for energy production as an alternative use of lands made available by the closing of large sugar plantations. In particular, the closing of the Hamakua Sugar Company on the island of Hawaii brought a great deal of attention to the future of agriculture in this region and in the state. Many options were proposed. Several promising alternatives had been proposed for cane lands. These included dedicated feedstock supply systems (DFSS) for electrical energy production, cultivation of sugarcane to produce ethanol and related by-products, and the production of feed and crops to support animal agriculture.

Implementation of some of the options might require preservation of large tracts of land and maintenance of the sugar mills and sugar infrastructure. An analysis of the technical, financial, and other issues necessary to reach conclusions regarding the optimal use of these lands was required.

At the request of the Office of State Planning and Senator Akaka's office, the Pacific International Center for High Technology Research (PICHTR) established and coordinated a working group composed of state, county, federal, and private sector representatives to identify sustainable energy options for the use of idle sugar lands on the island of Hawaii. The program is based on inputs from the State of Hawaii's Department of Agriculture (DOA), Department of Business, Economic Development and Tourism (DBEDT), Department Office of State Planning, and the Department of Land and Natural Resources (DLNR); the University of Hawaii's College of Tropical Agriculture and Human Resources (CTAHR), and Hawaii Natural Energy Institute (HNEI); the Hawaiian Sugar Planters' Association (HSPA); the Pacific International Center for High Technology Research (PICHTR); the county of Hawaii; and other private sector companies, individuals, experts, and researchers, with recommendations from the National Renewable Energy Laboratory (NREL), U.S. Department of Energy (USDOE), and U.S. Department of Agriculture (USDA).

The Sustainable Biomass Energy Program's Hamakua Project was established to complete a comprehensive evaluation of the most viable alternatives and assess the options to grow crops as a source of raw materials for the production of transportation fuel and/or electricity on the island of Hawaii.

The motivation for evaluating biomass to energy conversion embraced the considerations that Hawaii's energy security would be improved by diversifying the fuels used for transportation and reducing dependency on imported fossil fuels. Local production of transportation fuels and feedstocks could also improve Hawaii's economic security and provide jobs for Hawaii's people. The use of waste products as feedstocks could divert wastes from landfills and/or reduce the pollution potential of those wastes and maintain scarce and valuable land resources for agriculture, housing, and business.

This report reviews issues and provides a detailed perspective on biomass energy production in Hawaii. Key topics to be reviewed in this report are:

- Selection of biomass material - comparing feedstocks;
- Evaluation of process technologies - processing into usable forms;
- Identification and evaluation of possible conversion options.
- Consideration of environmental and community related concerns.
- Evaluation of financial performance of conversion options.
- Identification of potential markets for products produced.

The central question this study addresses is:

Can energy be produced from biomass competitively in Hawaii, and can we develop the markets necessary for the products produced?

An extensive list of crops and other sources of biomass was reviewed to identify the most promising candidates. Starting with a list of twenty crops and sources of biomass in Hawaii, a short list of feedstocks was developed. Ethanol and electricity production options were evaluated independently. The most promising crops were sugarcane, leucaena, eucalyptus, napier grass, and sweet sorghum. Waste paper and green waste were also identified as potentially promising feedstocks for energy production.

ETHANOL

Emerging technologies allow for the production of ethanol from agricultural by-products such as corn stover, bagasse, yard and wood waste, etc. This is very significant: for example, where one acre of sugarcane produces about ten tons of edible sugar and a half ton of molasses, it also produces an additional twenty to twenty-five tons of materials in the form of leaves and stalks, that can be processed to ethanol. On the basis of available data, it was concluded that sweet sorghum, sugarcane and green wastes were the biomass sources with the greatest potential to provide fermentable sugars for ethanol production or as sustainable sources of biomass for electricity. It is also possible to produce ethanol from energy grasses or tree crops.

A collaborative effort with the Energy Division of the Department of Business Economic Development and Tourism was established to evaluate the performance of technical options for producing ethanol from biomass. A combination of direct inquiry and literature review was used to compare and contrast the capital and operating costs of a variety of technologies with traditional fermentation. Due to the proprietary nature of many of the approaches evaluated, in many cases it was necessary to rely on estimates made by owners of the technologies. In most cases, these individuals were the developers of the technologies and the owners of the patent rights, and therefore, may have been somewhat biased in their claims.

Seven different systems were felt to be representative of the range of technologies but should not be construed to be specifically representative of any one company or developer.

1) Simultaneous saccharification and fermentation;
2) Concentrated acid hydrolysis, neutralization and fermentation;
3) Ammonia disruption, hydrolysis and fermentation;
4) Steam disruption, hydrolysis and fermentation;
5) Acid disruption and transgenic microorganism fermentation;
6) Concentrated acid hydrolysis, acid recycle and fermentation; and
7) Acidified acetone extraction, hydrolysis and fermentation.

Estimated capital costs for plants producing 25 million gallons of ethanol per year ranged from 30 to 130 million dollars. At this scale, ethanol production costs ranged from less than $0.50 per gallon to almost $3.00 per gallon, depending on the technology and cost assumed for the feedstock.

ETHANOL FEEDSTOCK AND PRODUCTION COSTS

BIOMASS MATERIAL	$/gallon for feedstock cost alone (high end of range)	$/gallon for feedstock cost alone (low end of range)	$/gallon processing cost (high end of range)	$/gallon processin g cost (low end of range)	total (high end of range)	total (low end of range)
Sugarcane	$0.83	$0.61	$1.14	$0.52	$1.97	$1.12
Leucaena	$2.06	$1.80	$1.14	$0.52	$2.42	$2.15
Eucalyptus	$1.78	$0.75	$1.14	$0.52	$2.92	$1.26
Napier grass	$1.26	$0.78	$1.14	$0.52	$2.40	$1.30
Sweet sorghum	$0.72	$0.51	$1.14	$0.52	$1.86	$1.03
Newspaper	$0.14	$0.05	$1.14	$0.52	$1.28	$0.56
Municipal Solid Waste	$0.42	$0.00	$1.14	$0.52	$1.56	$0.52
Molasses	$0.50	$0.50	$1.14	$0.52	$1.64	$1.01
Bagasse	$0.84	$0.44	$1.14	$0.52	$1.98	$0.96
Unburned sugarcane	$0.98	$0.52	$1.14	$0.52	$2.12	$1.04
Assuming 25 million gallon-per-year ethanol production facility						

Since the level of uncertainty associated with the analyses may be greater than the apparent differences between the technologies, it is not clear from this analysis what process is the "best." All technologies evaluated displayed innovations which, if combined in one integrated system, might out-perform any one individual approach. A detailed analysis of each step indicated that additional technical innovations were possible. In spite of the previously-described uncertainties, and variations in levels of optimism, the analyses resulted in similar cost projections. This similarity lends a degree of confidence that, as the technologies mature, ethanol production costs in Hawaii will fall within this range.

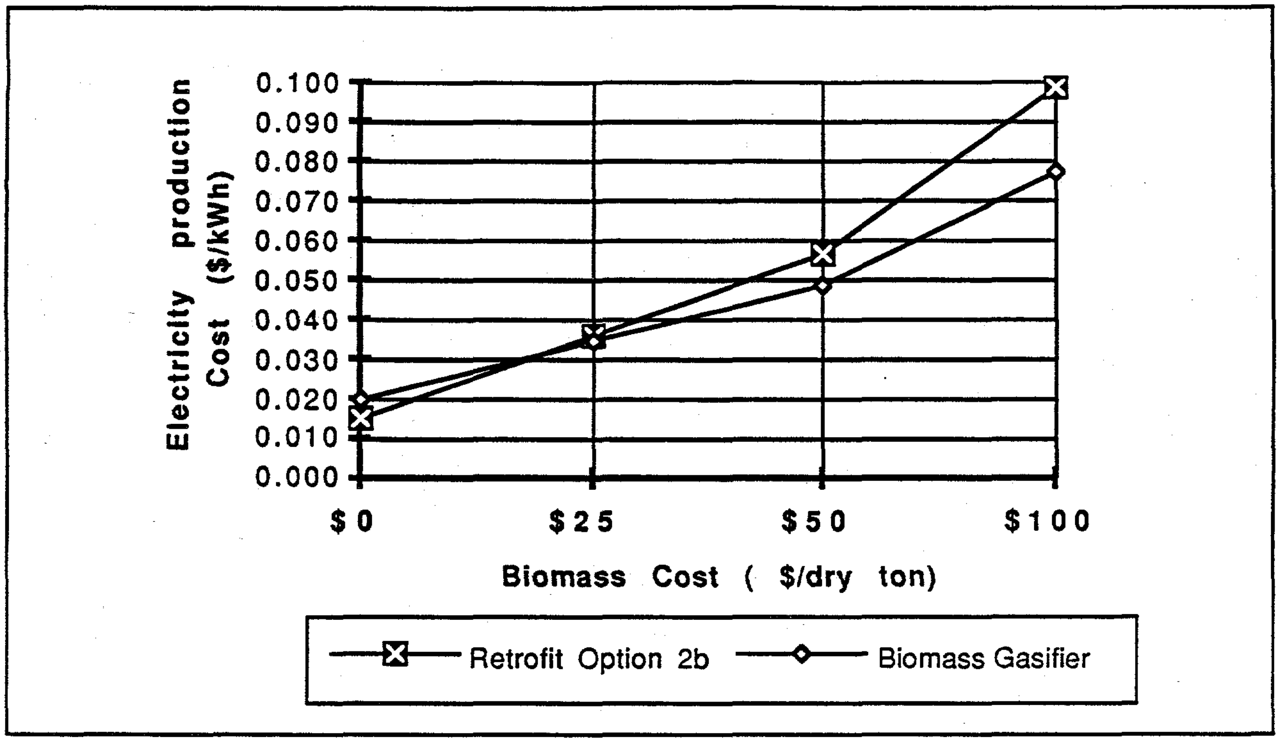
Simultaneous saccharification and fermentation technology was among the more promising approaches evaluated. Based on the extensive information available, the costs developed for this technology were used for a more detailed analysis of the potential to direct the sugar crop to ethanol production. This was contrasted with the performance of the sugar industry and combinations of producing sugar and ethanol. As a stand alone business, production of ethanol from the sugar crop is marginal. Processing the sugarcane to produce sugar from the juice and ethanol from the bagasse appears to be the most promising option at this time. However, tax benefits are required to produce ethanol from cultivated crops at a price that is competitive with gasoline in Hawaii. If paper and green waste are used as part of the feedstock the economic performance is substantially improved. If $1.03 in federal and state tax benefits per gallon of ethanol use can be applied, the opportunity is more promising.

ELECTRICITY

The evaluation of using biomass for electricity production focused on the potential of utilizing some or all of the power generating equipment at the sugar mills in the process. These evaluations showed that the existing facilities did not have the efficiency to produce power at a competitive price. It was concluded that the Hamakua Sugar Company system was unsuitable for retrofit. The results of this preliminary analysis suggested that, from a technical standpoint and in its present condition, the Hilo Coast Processing Company facility had the potential to operate as-built as a dedicated power station that can produce approximately 13 to 19 MW of exportable electrical power at moderate efficiency burning either biomass, No. 6 fuel oil, or coal.

Two options were proposed for the HCPC facility: 1) continue operation with no modifications other than those required by the bagasse handling system to accommodate different biomass fuels; exportable power is 18 MW; and 2) increase net capacity to 32 MW with the addition of a new low-pressure turbine-generator and condenser. In addition to the two retrofit options, an option to implement a biomass gasifier was also reviewed. The gasifier option would increase net capacity to approximately 26 MW. Upgrading the boilers and generator was contrasted with the addition of newly developed gasification technology to produce methane gas for generator fuel. A sensitivity analysis of biomass cost to cost of electricity showed that as the price of biomass increased, the addition of the gasifier technology could have a positive impact on lowering the production cost of electricity.

SENSITIVITY OF ELECTRICITY PRODUCTION COST TO BIOMASS COST



COMPARISONS

The economic performance of using biomass for ethanol production was contrasted with use of the material to produce electricity. After consideration of the economy of scale, income from operations per acre was the only common basis of comparison that could be used. Producing combinations of sugar and electricity offers some promise. If existing tax benefits are considered, producing a combination of sugar and ethanol also appears to present an opportunity. The cost of biomass is the single most important factor influencing the cost of production. If biomass can be supplied at a lower cost, the options for competitive production of ethanol and electricity are increased as the price declines. The table below provides a synopsis of the various scenarios for using prepared sugarcane supplied at the current cost of $31.00 per wet ton to produce sugar, ethanol, and electricity.

PROCESS ECONOMIC SUMMARY
(VALUES PER HARVESTED ACRE PREPARED CANE)

Scenario	Products Using Prepared Cane	Sales Value	Production Costs/Acre	Profit per acre	Tax Benefits Concessions	Profit After Tax
1	Prep. Cane to Sugar & Molasses & Energy	$4,904	($4,706)	$197	$0	$197
2	Juice to Ethanol Bagasse to Ethanol SSF	$3,647	($7,161)	($3,513)	$347	($3,167)
3	Juice to Sugar & Molasses Bagasse to Ethanol	$6,411	($6,288)	$123	$167	$291
4	Juice to Ethanol-Bagasse to Electricity	$2,141	($5,553)	($3,413)	$179	($3,223)
5	Juice to Sugar & Molasses Bagasse to Electricity	$4,990	($5,522)	($532)	$123	($409)
6	Power Plant Retrofit	$5,756	($5,400)	$355	$352	$708
7	Addition of Gassifier	$6,187	($6093)	$94	$481	$575

There are specific opportunities to develop biomass to energy businesses in Hawaii. These will be dependent on location, feedstock, technology, and product forms. Conclusions emerging from this evaluation are as follows:

a) In order to be economically competitive for energy production in Hawaii, biomass must be delivered at less than $50 per dry ton.
b) On a stand alone basis, cultivation of crops as dedicated feedstocks for energy production in Hawaii is marginal at this time.
c) Initially, subsidies will be needed to establish infrastructure and sustain the energy industry.
d) Multiple output products are essential to the economic viability of any dedicated process.
e) The use of dedicated feedstocks holds promise when integrated with appropriate waste streams.
f) Further development of ethanol technology should be directed to constructing engineering development units for one or more technologies appropriate for promising feedstocks.
g) The Hamakua Sugar facilities are not practical as a biomass energy system, however, many of the components have potential to be used in new systems.
h) The Hilo Coast Processing Company should be considered for upgrading to augment the power supply on the island of Hawaii.
i) Coupling ethanol and electric production by using advancing technologies such as saccharification of lignocellulosic material for ethanol and biomass gasification for electricity looks promising; however, this will require further evaluation and demonstration.

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ACOS	Acid-Catalyzed Organosolv Saccharification
ATC	Authority To Construct
BGF	Biomass Gasifier Facility
Btu	British thermal unit
CAP	Consolidated Application Process
CCA	Central Coordinating Agency
CTAHR	College of Tropical Agriculture and Human Resources (University of Hawaii)
DBEDT	Department of Business, Economic Development and Tourism (State of Hawaii)
DFSS	Dedicated Feedstock Supply System
DLNR	Department of Land and Natural Resources (State of Hawaii)
DOA	Department Of Agriculture (State of Hawaii)
DOT	Department Of Transportation (State of Hawaii)
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ETBE	Ethyl Tertiary Butyl Ether
GIS	Geographic Information System
GACC	Governor's Agriculture Coordinating Committee (State of Hawaii)
HCPC	Hilo Coast Processing Company
HSPA	Hawaiian Sugar Planters' Association
HECO	Hawaiian Electric Company
HELCO	Hawaii Electric Light Company
HITAHR	Hawaii Institute of Tropical Agriculture and Human Resources (University of Hawaii)
HNEI	Hawaii Natural Energy Institute (University of Hawaii)
HSC	Hamakua Sugar Company

HSPA	Hawaiian Sugar Planters' Association
LOI	Letter of Interest
MBI	Michigan Biotechnology Institute
MECO	Maui Electric Company
MSW	Municipal Solid Wastes
NPS	National Park Service
NREL	National Renewable Energy Laboratory
OEQC	Office of Environmental Quality Control (State of Hawaii)
OSP	Office of State Planning (State of Hawaii)
PICHTR	Pacific International Center for High Technology Research
SSF	Simultaneous Saccarification and Fermentation
TVA	Tennessee Valley Authority
UH	University of Hawaii
USDA	United States Department of Agriculture
USDOE	United States Department of Energy
USFWS	United States Fish and Wildlife Service
VLC	Very Low Color

I. INTRODUCTION, BACKGROUND AND APPROACH

The closing of the Hamakua Sugar Company on the island of Hawaii has brought a great deal of attention to the future of agriculture in this region and in the state. State, county, and federal agencies, as well as a variety of task forces and working groups, have been assembled to propose solutions. Many options have been proposed. Each level of input provides a unique and important perspective on this complex problem. Some of the alternatives are site sensitive and at present lack analysis of the technical, financial, and other issues necessary to reach conclusions regarding the optimal sustainable use of the lands that may be available. In order to assess the problems and issues, a comprehensive evaluation effort was undertaken to identify the most viable alternatives.

A. BACKGROUND

1. Agriculture

The cultivation of sugarcane and the plantation life style has been a long standing agricultural tradition along the Hilo/Hamakua Coast of the island of Hawaii and in the entire state of Hawaii. This one hundred and fifty year history has also been an economic mainstay in many of Hawaii's rural communities. Families in these regions have been employed by the sugar industry for several generations. The traditional agriculture industry in Hawaii is in crisis.

Historically, agriculture has been the primary industry and still represents approximately 10% of the economic base on the island of Hawaii. However, the traditional role of the large plantations as an economic base on the island of Hawaii is diminishing. This situation places considerable pressure on the economy, the future of agriculture, the generation of electricity, and the traditional lifestyle of many rural areas. This economic decline is reaching a crisis situation in many of these communities.

2. Energy

The state is dependent on imported petroleum to meet more than 90% of its energy needs.[1] This condition results in an outflow of capital at a time when energy development opportunities may provide a means of rebuilding Hawaii's rural economy and expanding jobs in the agriculture sector.

There are significant energy issues which are directly tied to the closing of sugar mills on the island. In 1992, electricity generation on the island of Hawaii was comprised of the following: oil, 78.6%; biomass, 18.3%; wind, 1.7%; hydroelectric, 1.2%; and coal, less than 0.1%.[2] All electricity produced from biomass was generated from burning bagasse at the sugar mills. Unfortunately, due to the continuing decline of the sugar industry, the amount of excess electricity produced from sugar plantations on the island of Hawaii has decreased from a high of 40 MW in 1988 to the current 28 MW.[3]

3. Current Situation in Hamakua and the Island of Hawaii

Much of the land previously cultivated for sugarcane is either no longer in use or will be taken out of cultivation soon. There are presently three operating sugar companies employing approximately 1350 people on the island of Hawaii.[4] Hamakua Sugar Company is, under a bankruptcy court order, harvesting its final crop. Seven hundred and fifty people will be unemployed by the end of 1994. Mauna Kea Agribusiness Company (Hilo Coast Processing Company) is scheduled to close sugar operations by the end of 1994 resulting in further layoffs. Approximately 1,100 direct jobs are at immediate risk along the Hamakua Coast. Ka'u Agribusiness Sugar Division is committed to sugar operations only through 1994. Approximately 250 people are employed at this location. Elsewhere in the state, Oahu Sugar Company, which employs 355 people, has announced the closure of sugar operations by June 1995. Waialua Sugar Company directly employs about 450 workers and is likely to go a similar route soon.[5] Many of these difficulties are due to the inevitable forces of low sugar prices and intense international competition.

The scheduled closing of the sugar plantations on the island of Hawaii has brought this situation to focus in the state of Hawaii. One promising alternative for utilizing the land being taken out of sugar production is Dedicated Feedstock Supply System (DFSS) for the production of electrical energy and transportation fuels. If the growing of energy crops were shown to be economically viable, it is possible that more than 40,000 acres on the Big Island could be available to cultivate biomass for energy. Development of these options may require preservation of large tracts of land, maintenance of the sugar mills and sugar industry infrastructure, detailed economic evaluations of promising technologies, and long-term cooperation of various groups. The successful development of a biomass energy program would allow the state of Hawaii to reduce its dependence on imported petroleum, thereby, increasing its energy security. A primary goal of this work was to complete a comprehensive evaluation of the most viable alternatives for biomass energy production before opportunities for contributing to a promising sustainable energy and agricultural future are lost. Sustainable, in this regard, includes economic, environmental, and social sustainability. Biomass-based energy businesses may offer the potential to reduce the dependence on fuel imports and establish new agriculture enterprises.

4. Previous and Related Work

The efforts of this program build upon work previously completed in studies sponsored by the State of Hawaii's Department of Business, Economic Development and Tourism (DBEDT)[6] and the US Department of Energy (USDOE). Figure I-1 below provides a representation of the flow of information into the present study and between related work, including follow-on programs which will carry potential opportunities identified in this study on to the next phase of development. The primary studies that contributed to this work are described below:

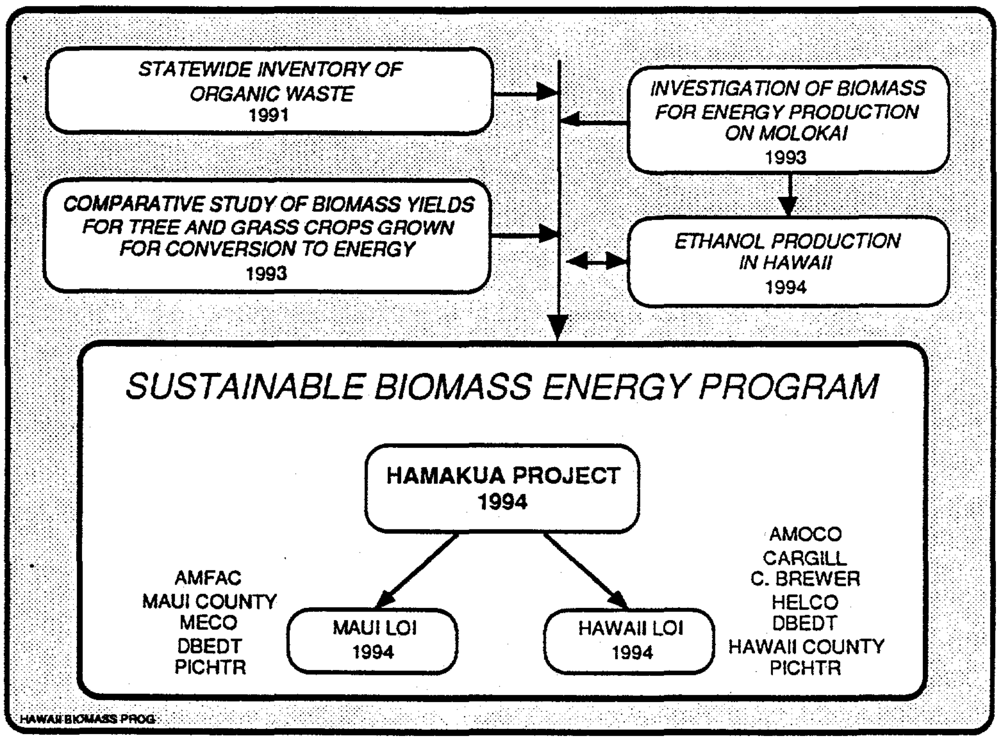
A *Statewide Inventory of Organic Waste* was completed in 1991 by UNISYN Corporation under a contract with DBEDT.[7] The draft report provided a comprehensive survey of the composition and locations of organic wastes produced in Hawaii. This information provided a basis for further evaluation of the potential to use organic waste materials to produce ethanol and electricity in the Hamakua Project.

An *Investigation of Biomass for Energy Production on Molokai* was completed by the Hawaii Natural Energy Institute (HNEI) in 1993[8] with input from the Hawaiian Sugar Planters' Association (HSPA) and the Hawaiian Electric Company (HECO). This study provided a substantial amount of information on the performance of crop alternatives for biomass production for the Hamakua Project.

A *Comparative Study of Biomass Yields for Tree and Grass Crops Grown for Conversion to Energy* was completed by HSPA in 1993 under a contract with DBEDT. Results of this study were used to develop the data base on crop alternatives for the Hamakua Project.[9]

A report on *Ethanol Production in Hawaii - Feedstocks, Processes, and Current Economic Feasibility of Fuel-grade Ethanol Production in Hawaii* was completed in 1994 under a contract with DBEDT with funding from the USDOE. This report provided a preliminary review of the potential of crops that could be grown in Hawaii to provide sources of feedstock for ethanol production.[10] This report also provided a comparative review of technologies for the conversion of lignocellulosic biomass to ethanol. The *Ethanol Production in Hawaii* report was developed in parallel with the Hamakua Project report. Through a collaborative effort with DBEDT, a common data base was developed to support both activities, and the Hamakua Project report duplicates some material presented previously in the DBEDT ethanol report.

FIGURE I-1
HAWAII BIOMASS PROGRAMS



The *Maui LOI* and *Hawaii LOI* Projects and Proposals are currently ongoing studies which will be completed after the Hamakua Project. While the Hamakua Project was in progress, the National Renewable Energy Laboratory solicited Letters of Interest (LOIs) for Economic Development Through Biomass Systems Integration. The LOIs were to evaluate the potential for cost-shared field demonstrations or pre-commercial developments of integrated systems in anticipation of future joint ventures to commercialize these systems.

In July, 1993, with the cooperation of the Sustainable Biomass to Energy Program Team, PICHTR submitted two proposals to perform research under the Economic Development Through Biomass Systems Integration Project. The proposals were accepted by NREL and PICHTR was awarded two contracts, commonly referred to as "the Maui LOI" and "the Hawaii LOI."

The Maui LOI, to be conducted jointly with AMFAC, Maui Electric, DBEDT and Maui County, concentrates on conversion of biomass to electricity at AMFAC's Pioneer Mill Site. The Hawaii LOI, to be conducted jointly with AMOCO, Cargill, C. Brewer, Hawaii Electric Light Company, DBEDT and Hawaii County, concentrates on evaluating the potential to convert biomass to ethanol at C. Brewer's Ka'u Mill site on the island of Hawaii.

B. THE HAMAKUA PROJECT

Responding to concerns about the decline of the sugar industry, potential shortages of electrical energy, and dependence on imported petroleum, in December of 1992 Senator Akaka's Office and the Office of State Planning requested the Pacific International Center for High Technology Research (PICHTR) to establish the Hamakua Project.

The intent of the project was to refine the list of options and conduct preliminary economic evaluations of the most promising opportunities to convert biomass to energy. To accomplish this, the Hamakua Project, together with related projects comprising PICHTR's Sustainable Biomass Energy Program, have been successfully integrated into the National Biofuels Program. This allows Hawaii to leverage a development pathway which could lead to the successful commercialization of a sustainable biomass energy industry for the state.

As project manager, PICHTR's responsibility was to coordinate all activities relating to the development of sustainable biomass to energy options, establish and maintain communication with all interested parties, and make available the information gathered by the various projects to potential commercial developers.

C. OBJECTIVES AND APPROACH

The primary objectives of the Hamakua Project were to define options for crops and land uses which could possibly be made available for the production of energy and complementary higher value co-products and determine if viable business opportunities could be developed along the Hamakua/Hilo Coast. This would be accomplished by analyzing the technical and financial performance of promising options to convert crops and available organic materials into fuel, electricity, or energy related products.

The associated objectives included:

- Definition of possible economically viable and sustainable biomass energy options for sugarcane lands which may become available due to the closing of sugar companies on the island of Hawaii and the state of Hawaii in general.
- Coordination of the activities of various groups relating to the development of potential biomass energy options for the state of Hawaii.
- Determination of the potential of the defined options to provide the basis for realistic business opportunities.

This report attempts to answer the following questions:

1) Which sources of biomass would be best suited to the production requirements of this region?
2) Is there sufficient land available to develop a dedicated feedstock supply system in the region?
3) What technologies would be best suited for the specific conditions of this region?
4) Is there a sustainable biomass to energy option for the Hilo/Hamakua Coast? Are there options for biomass to energy elsewhere in the region?

1. Tasks Defined

In order to answer the questions posed above, tasks were defined as follows:

- **Task 1** - Program Coordination and Development: Establish communication with all parties interested in the development of a sustainable biomass energy program for the state of Hawaii. Present results to government, community, and business leaders for review and participation in formulating policy necessary for development;
- **Task 2** - Crop Assessment: Identify a short list of crops and agricultural practices that may be appropriate under the physical and economic conditions that exist in the region;
- **Task 3** - Land Capability: Identify land areas that are most suitable for production of potential biomass crops;
- **Task 4** - Identification of Facilities: Evaluate the suitability of the facilities which may be available for the purposes of demonstrating and ultimately developing the appropriate technologies;

- **Task 5** - Identify Applicable Biomass to Energy Technologies: Establish communication with interested private sector entities that are leaders in the biomass energy industry;

- **Task 6** - Electricity Options: Evaluate current biomass-fueled electricity production facilities in the region; evaluate options for continued or expanded production of electricity from these facilities;

- **Task 7** - Ethanol Options: Evaluate promising technology options for the conversion of biomass to ethanol;

- **Task 8** - Environmental and Community Concerns: Consolidate information on permit requirements; discuss environmental and community related issues such as environmental concerns, biodiversity, aesthetic value, and social acceptability as they relate to sustainable biomass energy industries;

- **Task 9** - Economic Analysis: Conduct detailed analyses of the financial performance of various options which may have application on the island of Hawaii and in the state in general;

- **Task 10** - Market Development: Outline potential markets options; identify primary products, co-products, and potential higher value products which may result from conversion of biomass;

- **Task 11** - Requirements for Sustainability: Examine the environmental and social impacts of the proposed options to ensure that they are in the widest sense sustainable in the area;

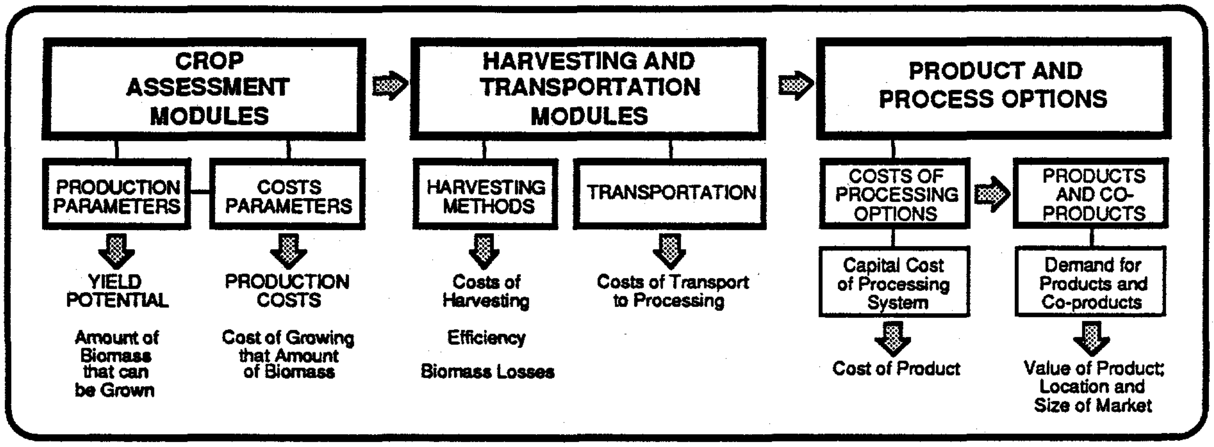
- **Task 12** - Identification of Potential Barriers: Identify potential barriers to development; and

- Conclusions and Recommendations: Summarize conclusions and make recommendations for implementation.

2. Modular Approach

The approach taken in the project involved separating the various processes into modules and then evaluating the technical and economic performance of the various options at each stage of the process. Spreadsheets showing the relationships of sources of biomass to their potential to produce ethanol and electrical energy were developed. A modular approach was used to allow several aspects of an integrated biomass energy process to be interchangeable. This modular approach partitioned the integrated process into major categories as illustrated in Figure I-2.

FIGURE I-2
BIOMASS TO ENERGY ASSESSMENT PROCESS



3. Sources of Data

Project management relied on experts and previously completed work whenever possible. Members of both the technical team and the advisory group provided valuable assistance throughout the project by attending meetings, reviewing data, offering guidance in their respective areas of expertise, and providing information and pertinent reports where required. Fortunately, substantial amounts of information were available from the technical literature and field experiences embodied in the technical team.

D. PROJECT TEAM

The Hamakua Project was initiated by the concern over the announced closing of Hamakua Sugar Company. This project created interest at the federal, state, county, and private sector levels.

1. Participants

This project provided a focus for a diverse of group which was interested in the potential of using sustainable sources of biomass for the production of electricity and/or transportation fuel. This interest resulted in both technical and economic support and active participation by many of the interested parties.

a) Advisory Group and Technical Team

PICHTR assembled technical and advisory teams representing the technical skills, political perspective, and business interests that were considered essential to develop the project. federal, state, county, and private sector representatives were assembled into an advisory group and a technical team. Both groups met periodically throughout the study period. The advisory group addressed issues relating to policy and overall direction of the program while the technical team was responsible for the work effort. It was the objective of both groups to reach a consensus regarding the information presented in this report. Members of the advisory group and the technical team are listed in Tables I-1 and I-2 respectively.

TABLE I-1
HAMAKUA PROJECT ADVISORY GROUP

GROUP MEMBER	ORGANIZATION
Gary Doi	Governor's Agriculture Coordinating Committee
Rick Egged	State of Hawaii DBEDT
H. M. Hubbard	Pacific International Center For High Technology Research
Maurice Kaya	State of Hawaii DBEDT - Energy Division
Yukio Kitagawa	State of Hawaii Board of Agriculture
Michael Kitamura	Senator Daniel Akaka's Office
Ralph Overend	National Renewable Energy Laboratory - Biofuels Program
Victor Phillips	HITAHR, CTAHR, University of Hawaii
Diane Quitiquit	County of Hawaii
Bob Shleser	Pacific International Center For High Technology Research
Patrick Takahashi	Hawaii Natural Energy Institute, University of Hawaii
Dennis Teranishi	State of Hawaii Office of State Planning
Andrew Trenka	Pacific International Center For High Technology Research

TABLE I-2
HAMAKUA PROJECT TECHNICAL TEAM

TEAM MEMBER	ORGANIZATION
David Harada	BHP Petroleum
Celia Hildebrand	State of Hawaii DBEDT - Business Development & Marketing
Alan Kennett	C. Brewer and Company/Olokele Sugar Company
Charly Kinoshita	Hawaii Natural Energy Institute, University of Hawaii
Warren Lee	Hawaii Electric Light Company
Tung Liang	Department of Engineering, University of Hawaii
Lynn Maunakea	State of Hawaii DBEDT - Business Services Division
Jim McElvaney	McElvaney and Associates
Bob Osgood	Hawaiian Sugar Planters' Association
Art Seki	Hawaiian Electric Company
Bob Shleser	Pacific International Center For High Technology Research
John Sprague	Pacific International Center For High Technology Research
George St. John	AMFAC/JMB Agricultural Operations
Maria Tome	State of Hawaii DBEDT - Energy Division
Andrew Trenka	Pacific International Center For High Technology Research
Robert Tsuyemura	State of Hawaii Department of Agriculture
Larry Zestar	Chevron, USA

b. Federal Participation

NREL - The National Renewable Energy Laboratory (NREL) has had a long term involvement in the development of technology for producing energy from biomass. Work conducted in the laboratory of Dr. Charles Wyman has been exceptionally useful in developing a format for the technical evaluations. Dr. Ralph Overend of Dr. Wyman's program has been particularly helpful in providing technical information and referrals to other individuals and laboratories for technical assistance.

TVA - The Biomass R&D Program of the Tennessee Valley Authority (TVA), coordinated by Wayne Barrier, provided the services of Millicent Bulls as a consultant to the project. Her work contributed to the development of an economic model which served as the basis for financial analyses.[11]

c. State Participation

DBEDT - The Energy Division of the Department of Business, Economic Development & Tourism (DBEDT) became a very active participant. DBEDT has had a long standing interest in the potential of alternative fuels as a partial substitute for the petroleum that Hawaii imports to meet about 90% of its energy needs. In particular, the opportunity to substitute ethanol produced from locally grown sources of biomass was a key area of concern. During 1993, DBEDT sponsored an analysis of the opportunities to produce ethanol from biomass.[12] The results of that study provided a foundation for aspects of this work. In addition, DBEDT provided the services of Maria Tome, Energy Division engineer, to serve as co-manager of the project; and assist in data acquisition assistance.

GACC - The Governor's Agriculture Coordinating Committee (GACC) is charged with the responsibility of maintaining an overview of agriculture in Hawaii. The decline of the sugar industry has been an area of primary concern. For these reasons, GACC has been an active participant in the PICHTR program. Jo-Anna Nakata served as an active member of the project and GACC provided $30,000 in financial support to the project.

HNEI - The Hawaii Natural Energy Institute (HNEI) of the University of Hawaii has had extensive involvement in evaluating the potential of using crops for energy production. Dr. Charly Kinoshita made substantial contributions to the program and has continually reviewed and evaluated technical data developed.

CTAHR - Dr. Victor Phillips and staff of the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii provided background on tree crops and land use options.

d. Private Sector Participation

AMFAC/JMB HAWAII, INC. - George St. John, Vice President of Plant Operations and Planning for AMFAC/JMB, contributed numerous hours assisting in evaluating potential options associated with using the sugar crop for ethanol and electricity production.

AMOCO CORPORATION - Joe Masin, Project Engineer with the Alternative Feedstock Development Department of Amoco, provided assistance with cost estimates and development of the economic evaluation procedures. He reviewed process flow diagrams and designs of facilities for processing biomass to ethanol. His assistance was fundamental in refining the capital and operating cost evaluations in Chapter IV, Sections IV D, and IV G.

C. BREWER & COMPANY, LTD. - Alan Kennett, Former Director of Sugar Technology and Engineering for C. Brewer, contributed substantially to providing an understanding of the operating considerations and costs associated with the production and processing of sugarcane in Hawaii.

CARGILL - Cargill brought an agriculture perspective to the analyses. Loren Luppes and Tom Geiger of Cargill's Ethanol Division were most helpful in providing technical information on manufacturing ethanol from sugars.

EPRI - The Electric Power Research Institute (EPRI) expressed interest in the possibility that Hawaii might serve as a location for a 3,000 to 5,000 acre biomass to energy demonstration site. Jane Turnbull, Project Manager for the EPRI Biomass Program, assembled a technical team to visit Hawaii during May, 1993. The group consisted of Jane Turnbull, Jack Ranney with Oak Ridge National Laboratory, Pam Sydelko with Argonne National Laboratory, and Dave Schlagel with the University of California Agricultural Research Station. These individuals are members of the National Biofuels Roundtable, an organization whose focus is on developing principles for producing biomass energy in the United States.[13] The group was able to visit several facilities on various islands and meet with a variety of interested parties. During a very short stay, they were able to acquire an overview of the biomass and energy related programs under way in Hawaii and the support for such programs. Interactions during the visit provided a perspective for the evaluations presented in this report. As a result of their interest, EPRI provided financial support to the program.

HSPA - The Hawaii Sugar Planters' Association (HSPA) was exceptionally helpful in providing production data on sugarcane and other potential energy crops. Dr. Robert Osgood and Mr. Lee Jakeway contributed substantial time and information to clarify issues on crops and energy.

2. Subcontractors

A series of subcontracts were awarded in order to address the various tasks associated with this report.

The Hawaiian Sugar Planters' Association (HSPA) was awarded a subcontract to provide a detailed summary of all costs associated with the planting, production, maintenance, harvesting, and transporting of sugarcane and alternative biomass crops which appear to have potential for energy conversion in Hawaii. The HSPA was also asked to provide yield data on all potential energy crops based on previous studies conducted in Hawaii. This information was used to develop much of the discussion in Chapter IV., Section A.–Crop Assessment.

The Hawaii Natural Energy Institute (HNEI), through the University of Hawaii, was awarded a subcontract to provide data, relevant reports, and analysis regarding biomass to energy crops. HNEI was also responsible for review of data, calculations, and projections developed by the Hamakua Project pertaining to this report. Maps and information, used as the basis for the discussion on land capability were also provided by HNEI.

The Tennessee Valley Authority (TVA) was contracted to evaluate the design and assist in determining the economic performance of alternative technologies for the production of ethanol from biomass. They assisted in the creation of process flow diagrams, and financial projections on capital and operating costs for the various technologies under review. Assistance from TVA enabled the Sustainable Biomass Energy Team to further refine the economic analysis models.

Bechtel Corporation was awarded a subcontract to complete an analysis of the technical and economic performance of approaches to convert cultivated biomass into electrical energy. This analysis provided the fundamental basis of the cost evaluations in the section on electricity options.

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1 Department of Business, Economic Development & Tourism. 1991. *Hawaii Integrated Energy Policy.*

2 Department of Business, Economic Development & Tourism. 1991. *Hawaii Integrated Energy Policy.*

3 Lee, Warren. President, Hawaii Electric Light Company, Presentation to Federal Panel. January 1993.

4 Hawaiian Sugar Planters' Association. Personal communication. 1994.

5 *Honolulu Advertiser.* March 4,1994.

6 It should be noted that since the DBEDT report was developed in parallel with this study that a common data base was established for both activities. In some instances material presented in the DBEDT report is duplicated in the present study.

7 UNISYN Bioconversion Technology. 1991. *An Inventory of and Potential Uses for Organic Waste in Hawaii.* Draft report to the Department of Business and Economic Development, State of Hawaii, June 1991.

8 Hawaii Natural Energy Institute. 1993. *Investigation of Biomass for Energy Production on Molokai.* September 1993.

9 Department of Business, Economic Development & Tourism. 1993. *Comparative Study of Biomass Yields for Tree and Grass Crops Grown for Conversion to Energy.* November 1993.

10 Department of Business, Economic Development & Tourism. 1994. *Ethanol Production in Hawaii.* Draft report. April 1994.

11 Bulls, Millicent. 1993. Consultation to PICHTR on Biomass Process Costs and Performance. Tennessee Valley Authority. November 1993.

12 Department of Business, Economic Development & Tourism. 1994. *Ethanol Production in Hawaii.* Draft report. April 1994.

13 Electric Power Research Institute. 1992. "EPRI and the National Audubon Society Establish the National Biofuels Roundtable." Announcement. December 1992.

II. CROP AND BIOMASS ASSESSMENT [TASK 2]

Economic and environmental conditions in Hawaii differ from most locations on the U.S. mainland. A year-round growing season, high levels of solar insolation, and a knowledgeable agriculture community offer a unique opportunity to grow biomass with potential for energy production. However, costs of fuel, fertilizer, energy, and labor are greater than in most other locations in the United States. Therefore, the first challenge was to determine what can be grown, or what may be available, that can produce the greatest amount of biomass, appropriate for conversion to fuel or other forms of energy, at the least cost. If the cost of biomass is too high, no technology can establish an industry! Identification and evaluation of biomass feedstocks' availability, suitability, and costs were the objectives of this part of the project.

Crop yield is very location specific since environmental conditions such as sunlight, water, and soil must be consistent with the needs of the crop. Economic factors including production, harvesting, and transportation costs were evaluated. Contiguous land areas of sufficient size within a reasonable distance from the processing plant had to be available. Processing technologies appropriate to converting the biomass to desired intermediates and product forms had to be available. All these factors must be considered in selecting the crop with the most potential for conversion to energy. The potential of any feedstock to be used for energy production depends on:

- The energy content or composition of the crop;
- Yield of biomass per harvest;
- Time required to produce a harvestable crop;
- Delivered cost of the biomass to the plant;
- Cost of processing the biomass material to the desired product forms; and
- Efficiency of the conversion technology on the particular feedstock.

The selection of crops or alternative sources of biomass to be evaluated was based on the following criteria:

- Production or availability has been demonstrated in Hawaii;
- Production requirements and yields are well known;
- Energy or lignocellulose content (cellulose, hemicellulose & lignin content) is consistent with objectives; and
- Yields and production costs are consistent with objectives.

A. CROP YIELD AND COMPOSITION

In order to evaluate the potential of feedstocks for production of electrical energy or liquid fuel, data on the energy content and content of sugars and sugar containing compounds that can be processed was obtained from technical publications and direct discussions with researchers who had unpublished information on the composition of promising feedstocks. The promising crops and materials and their corresponding content of cellulose, hemicellulose, and lignin (dry weight basis) are shown in Table II-1.

TABLE II-1
COMPOSITION OF POTENTIAL CROPS AND WASTE MATERIALS
(% DRY WEIGHT)

Biomass Source	Sugars	Cellulose	Hemicellulose	Lignin	Other
Bagasse[1, 2]	3	38	27	20	12
Eucalyptus grandis[3, 4]	--	38	13	37	12
Eucalyptus saligna[5]	--	45	12	25	18
Leucaena leucocephala[6]	--	43	14	25	18
Molasses[7]	61	--	--	--	39
Napier grass[8]	--	32	20	9	39
Sweet sorghum[9]	34	36	16	10	3
Sugarcane hybrids[10]	28	37	14	15	6
Sugarcane (whole plant)[11]	33	25	17	12	13
Sugarcane leaves[12]	--	36	21	16	27
Sugarcane ("prepared" cane)[13]	43	22	15	11	9
Municipal Solid Waste[14]	--	33	9	17	41
Newspaper	--	62	16	21	1

As can be seen in Table II-1, some non-crop materials also show promise. Municipal solid waste (MSW) and newspaper are exceptional sources of cellulose and hemicellulose and will be discussed later in this chapter.

B. SUGARCANE AS A SOURCE OF BIOMASS

At one time, there were almost 200,000 acres of sugarcane cultivated in Hawaii.[15] Considering the historic significance and extensive local experience and success with growing this crop, it was not surprising that the question of continuing to cultivate sugarcane to produce ethanol and electricity at Hamakua and other locations would be of significant interest.

1. Definitions

The following definitions are taken from the *HSPA Sugarcane Factory Analytical Control Methods Manual,* a standard in the Hawaiian Sugar Industry:[16]

Field Cane– Crop material as harvested, including field trash.

Prepared Cane– Harvested material after preparation for extraction, including field trash not removed in the cleaner and adhering water.

Net Cane– The clean cane stalks, from which sugar can be recovered, from the stool to the growing point (the region at the distal end of the stalk where new leaves and new internodes are being formed by cell division).

96DA Sugar– The raw unrefined sugar resulting from the milling process.

2. Potential Biomass Yield From Sugarcane

Sugarcane is considered to be among the highest yielding crops. However, the modern hybrids of sugarcane in commercial production are selected for high sugar content at some detriment to the potential for maximum biomass production. Sugarcane grown exclusively for dry matter production for biomass would require the use of higher fiber varieties and changes in the cropping cycle and harvesting methods. HSPA estimates that yield of dry biomass from Hawaii's sugarcane crop could be increased by 30 to 40 percent with such changes resulting in recovered biomass yields on the order of 20 to 22 dry matter tons per harvested acre per year. This could result in approximately 160 wet weight tons of biomass per harvested acre.[17]

In 1991, the average net cane yield per acre was reported to be 86.4 tons per harvested acre (wet weight basis). The average prepared cane yield for the Hawaii's sugar industry was 1.2 times this amount per acre or approximately 104 tons of prepared cane per harvested acre. Field cane reported in industry figures averaged about 124 tons per acre which usually represents burned, standing cane (a significant amount of soil and rocks may be included in this figure).

Hawaiian cane production is considered to be among the highest in the world.[18] Data for the years 1981 through 1992 is presented in Table II-2 and Figure II-1. For the purposes of this study, the biomass production from sugarcane was estimated from unpublished sugar industry statistics. Biomass production for the sugar industry for these years averaged approximately 14 dry matter tons per acre per year.[19]

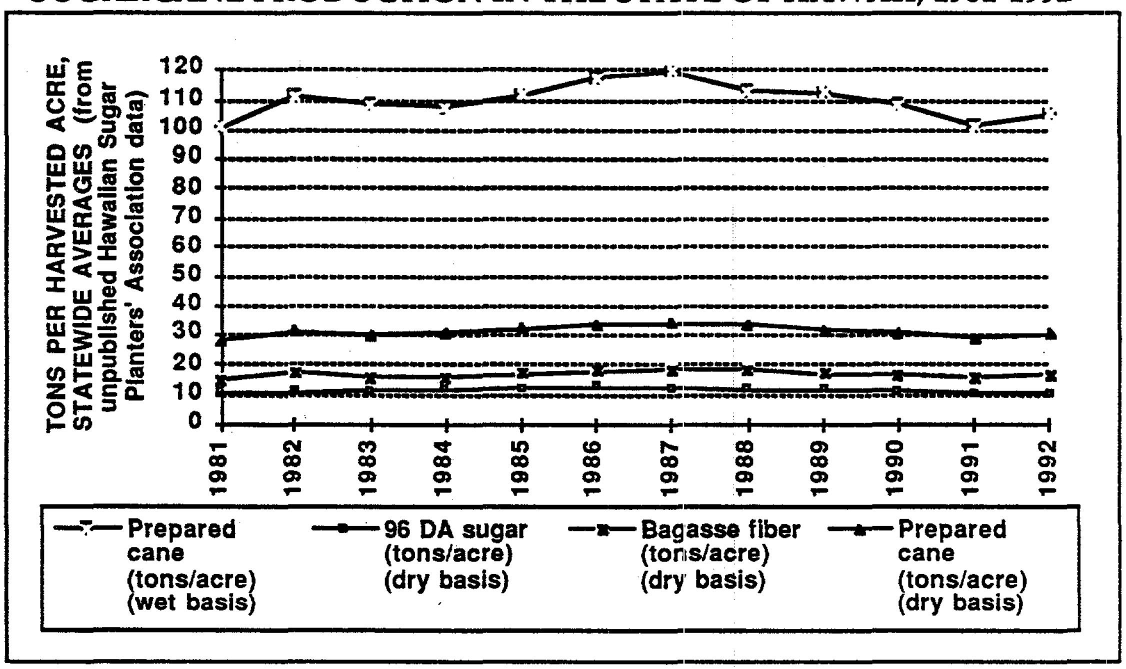
TABLE II-2
HAWAII SUGAR INDUSTRY STATISTICS*

YR	Acres in crop	acres harves-ted	Crop time	96 DA sugar produced (total)	Prep'd cane, wet	96 DA sugar	Fiber produced	Molasses solids	Dry matter pro-duced **	Dry matter pro-duced	Est. un-burned cane dry matter
			yr	tons	t/a/hrv	t/a/hrv	t/a/hrv	t/a/hrv	t/a/hrv	t/a/yr	t/a/yr
81	216,100	97,570	2.2	1,047,520	101	10.7	14.9	2.7	28.3	12.8	16
82	204,749	89,260	2.3	982,910	111	11.0	17.4	2.8	31.2	13.6	18
83	194,258	92,820	2.1	1,044,190	108	11.2	15.6	2.8	29.7	14.2	18
84	188,396	89,540	2.1	1,061,814	108	11.9	15.8	3.0	30.6	14.6	19
85	187,858	83,029	2.3	1,012,249	112	12.2	17.0	2.8	32.0	14.1	18
86	184,181	83,584	2.2	1,042,452	117	12.5	17.8	3.0	33.3	15.1	19
87	180,966	79,497	2.3	979,209	120	12.3	18.4	3.0	33.7	14.8	19
88	177,693	78,862	2.3	928,195	113	11.8	18.6	2.9	33.3	14.8	19
89	170,813	74,660	2.3	871,614	112	11.7	17.2	2.7	31.5	13.8	18
90	162,000	71,999	2.3	819,632	108	11.4	16.5	2.6	30.5	13.6	18
91	155,600	69,439	2.2	724,100	102	10.4	15.9	2.5	28.8	12.9	17
92	–	61,734	2.2	652,304	105	10.6	16.8	2.7	30.1	13.5	18
HIGH	–	97,570	2.3	1,061,814	120	12.5	18.6	3.0	33.7	15.1	19
LOW	–	61,734	2.1	652,304	101	10.4	14.9	2.5	28.3	12.8	16
AVG.	–	–	2.2	–	110	11.5	16.8	2.8	31.1	14.0	18

* From production statistics of Hawaii's Sugar Industry as reported to the USDA and DOA, and unpublished HSPA data

** Total dry matter is the sum of sugar, fiber, and molasses soluble solids produced.

FIGURE II-1
SUGARCANE PRODUCTION IN THE STATE OF HAWAII, 1981-1992



Sugarcane yield trials are continuously installed and harvested by the HSPA. A summary of these data is out of the scope of this report; however, a small sampling of some recent trials reported in the *HSPA Variety Report Series* shows the type of data available and the procedure for calculating biomass from the data gathered. The best estimate of actual commercial yields for sugarcane in Hawaii come from the sugar factory records. Biomass produced is estimated by summing the production of 96DA sugar (although, to be more accurate, 96DA sugar should be reduced by 5% to reflect true commercial sugar production), fiber, and the dry solids in molasses.

Sample Variety Test - Variety H73-6110 planted on Maui and harvested at 23.6 months yielded 132.5 tons of net cane per harvested acre (fresh weight basis). The fiber as a percent of cane (fresh weight basis) was 13.1% and the yield of refractometer solids as a percent of cane (fresh weight basis) was 20.6%. Adding the fiber percent and the refractometer solids percent provides a good estimate of percent dry weight. In the Maui case, the dry matter is estimated to be 33.6% (taken from the fiber and refractometer solids); therefore, the potential yield of dry matter produced in this test was (132.5*0.336 = 44.5 tons per harvested acre). Since the crop was grown for 23.6 months, the dry matter produced per month was 1.89 tons per acre per month. Annualized, the yield of dry matter is, therefore, 22.7 tons per acre per year. Commercial yield, using the 25% discount is estimated to be 17.4 dry matter tons per acre per year. The conversion from gross acres to net acres is performed as part of the model for the variety test yield calculations.

Another example from Ka'u shows Variety H82-1600 planted at Ka'u Sugar Company and harvested at 28 months, yielded 138 tons of net cane per harvested acre (fresh weight basis). The fiber was 11.8% and the refractometer solids were 17.5 percent of the cane fresh weight. Therefore, dry matter was estimated to be 29.3%. The cane yield multiplied by the estimated dry weight percent gives a dry matter yield of 40.4 tons per harvested acre. The dry matter produced is therefore, 1.44 tons per acre per month. Annualized, the yield is 17.3 dry matter tons per acre per year. Variety tests are burned before harvest; therefore, yields of whole cane are higher than reported in the variety tests. However, not all the additional biomass can be recovered in a real commercial harvesting operation. Commercial yield of dry matter at this location is estimated to be 13 tons per acre per year after applying the 25% discount.

3. Sugarcane Components and Products

Stalks. "Prepared cane" is primarily the stalk of the sugarcane plant, with some leaves and some water remaining from the washing process. Sugar (sucrose), the primary commercial product of the sugar industry, is contained in the stalk. The sugarcane stalks are processed to sugar, bagasse, and molasses. Most of the raw sugar is sent to California to be refined; most of the bagasse is burned in boilers to produce process steam and electricity; and most of the molasses is shipped to California and sold as cattle feed.[20]

Leafy trash. Prior to harvesting the sugarcane, the fields are usually burned (weather and other conditions permitting) to reduce the harvesting, transporting, and processing costs associated with hauling in excess material (primarily leafy trash). Most reported amounts of "field cane" and "prepared cane" do not include the total amount of biomass that was available before the fields were burned.

4. Yield Potential from Unburned Fields

The Hawaii sugar industry burns its fields, whenever possible, prior to harvesting so field cane would not include the potential amount of biomass that would be there if sugarcane was left unburned. Studies have been performed by HSPA on the effects to a sugar factory should sugarcane be harvested unburned. Sloane and Rhodes, in 1972, reported that harvesting and hauling requirements would go up significantly coupled with a reduction in factory processing rates and sugar quality.[21] An internal sugar industry study performed in 1983 showed that ceasing burning of sugarcane fields would be economically distressing to the sugar industry despite increased revenue from power sales.

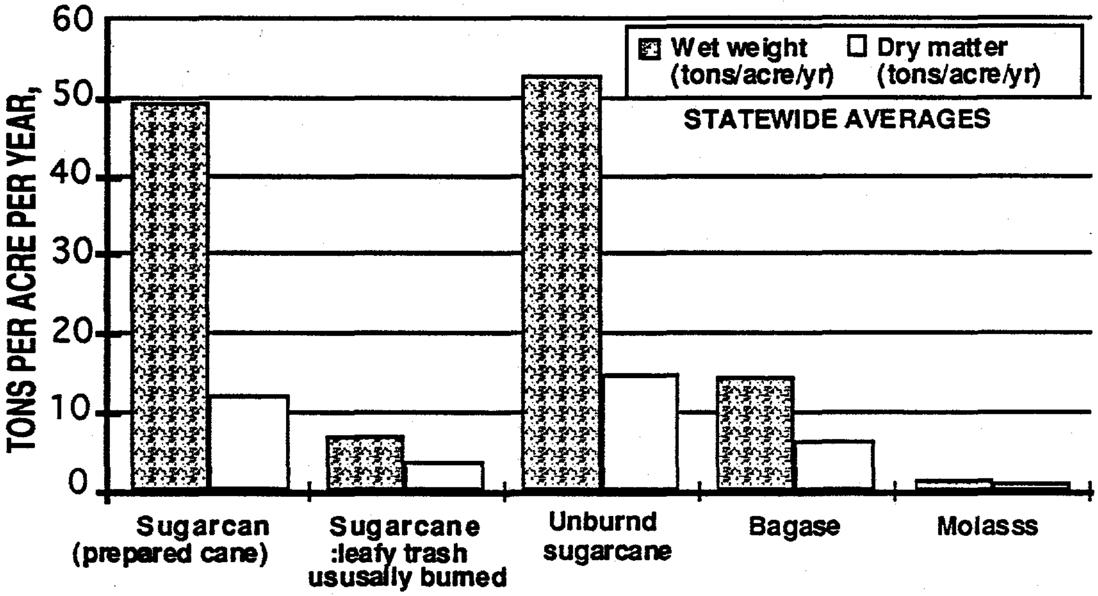
A study of the composition of unburned cane performed by Kinoshita in 1988 showed that the amount of bagasse would increase 54% over burned cane. Twenty-one plots of unburned cane, on eleven plantations, were hand-cut prior to field burning to determine total biomass available in unburned cane. Figure II-2 shows reported and projected yields for burned and unburned sugarcane.

Using the Hawaii sugar industry average net cane yield of 86.4 tons per harvested acre, and assuming that net cane is presently 30% dry matter (=25.9 dry matter tons), the amount of dry matter that can be commercially produced per acre is projected to be about 39 tons per harvested acre.

Santo reported, in 1991, that the amount of additional dry matter expected from agricultural residue left behind after hand harvesting in unburned conditions would be about 12 metric tons per hectare for one year cane (5.4 tons per acre-year). When added to the dry matter production from two year net cane, this would yield approximately 36 tons dry matter per harvested acre.

Assuming the potential biomass dry matter yield is about 35 tons per harvested acre for a two-year sugarcane crop, the potential increase in biomass in unburned sugarcane fields would be about 35% [(35-26)/26*100)]. This is equivalent to 17.3 tons per acre-year for commercial sugarcane. The actual amount of dry matter recovery will more than likely be less because of fiber losses experienced during harvesting, transporting, and pre-processing as discussed earlier. Figure II-2 shows reported and projected yields for burned and unburned sugarcane.

FIGURE II-2
SUGARCANE COMPONENT YIELDS



5. Yield Potential from Irrigated Versus Unirrigated Fields

The distinction must also be made between irrigated and unirrigated plantations because operations are quite different for the two. Unirrigated, rain-fed plantations do not require irrigation from an established source of water which, for irrigated plantations, represents an additional cost. Sugar yields are normally lower on a per acre-month basis for unirrigated plantations. Historically, in Hawaii, unirrigated plantations have usually shown higher overall operating costs compared to irrigated plantations. This is attributed, in part, to the lower sugar yields and higher productions costs of mechanized field equipment which in most cases has to be track-type-tractors due to the steep terrain and wet field conditions associated with unirrigated plantations (the fields are generally wetter in unirrigated conditions due to the heavy rains in these areas). However, if the Hawaii sugar industry did not provide its own power to pump its irrigated water and/or it had to pay "market" rates for irrigation water, the situation would be reversed.

6. Cost of Sugarcane Production

Cost data was obtained for two commercial sugarcane grower/processors located on the island of Hawaii. Production cost data for 1991 was used as this represented the most up-to-date costs for normal operations in this region.[22] The two plantations analyzed were unirrigated plantations and were very similar in terms of sugar production although operations were quite different because of terrain and weather conditions which are known to have significant affects on the cost of operations. The combined costs for the two plantations studied should represent mid-range costs for an unirrigated plantation on the island of Hawaii under conditions such as those experienced in 1991. It should be noted that, as illustrated in Figure II-1, statewide reported sugarcane and sugar yields in 1991 were lower than the "average" for the 1981-1992 period. This was true for the island of Hawaii as well (e.g. in 1985, a more "average" year, the Hawaii island plantations harvested 28,673 acres and produced 319,441 tons of sugar, or an average of 11.1 tons per acre. In 1991, the Hawaii island plantations harvested 18,134 acres and produced 181,825 tons of sugar, or an average of 10.0 tons per acre.) Since costs for a given acre are generally the same regardless of yields, years of relatively low yields show a correspondingly higher cost per ton.

It should also be noted that these costs are not representative of other sugar plantations operating in Hawaii. The range of production costs varies considerably from one plantation to the next, especially between irrigated and unirrigated plantations. The average cost to produce a ton of sugar in 1991 for the Hawaii sugar industry was reported to be $417 dollars per ton of 96DA sugar which includes by-product credits for molasses and power revenue. The average production cost per ton of sugar for all plantations operating on the Big Island in 1991 was $455 per ton of sugar.[23] This reflects the higher costs usually associated with operating irrigated plantations as discussed earlier.

A summary of the production cost information adjusted to reflect the cost of prepared cane is given in Table II-3 for the 1991 production year. Cultivation, harvesting, transporting, and preparation costs with appropriately applied general and administrative costs are itemized for labor, materials, equipment service charges, and other costs. Costs not pertaining to producing sugarcane for strictly biomass (such as ripener application costs which maximizes sucrose production and sugar/molasses marketing expenses) were not included. Production costs and credits were excluded for the boiling house and power generation, respectively, since it was not assumed that the infrastructure from an existing sugar factory would be available. If power must be purchased from the utility to run operations, costs would, in all probability, be higher than those presented here. This would be especially true at locations where irrigation water must be pumped.

The accounting system utilized by the two sugar companies studied, provides cost data which includes costs for other operations such as the cultivation of macadamia nuts. This made it difficult to delineate actual labor, materials, and other charges as they applied to these two specific sugarcane operations.

The values given for each column listed in Table II-3 reflect our best ability to extract these numbers for sugar operations alone. However, the values given for the column listing net operating expense represents actual costs due to sugarcane operations. This data was then utilized to make cost comparisons.

TABLE II-3
PRODUCTION DATA FOR TWO HAWAII PLANTATIONS

	Labor (5)	Materials	Equipment / Service Charges (6)	Other Direct Costs (7)	Total Indirect Costs (8)	TOTAL NET OPERATING EXPENSES (9)
CULTIVATION:						
Land Preparation	87,348	75	307,943	14,753	40,488	450,607
Planting	219,328	1,493	725,145	4,281	51,660	1,001,907
Ratoon Preparation	63,200	190	207,746	13,618	33,552	318,306
Ratoon Replanting	424,673	7,010	1,413,173	11,942	12,600	1,869,398
Weed Control	652,419	1,482,833	340,210	95,263	102,372	2,673,097
Fertilization (1)	106,556	3,709,869	232,238	315,651	51,011	4,415,325
Agriculture Overhead	847,056	87,923	91,745	233,116	125,632	1,385,472
HARVEST/TRANSPORT:						
Mechanical Harvesting	909,291	1,165	2,595,358	93	353,416	3,859,323
Trucking	1,373,070	4,692	3,682,805	10,574	190,462	5,261,603
General	550,072	22,106	129,216	4,911	40,454	746,759
OTHER FIELD:						
Road Maintenance	1,270	56,968	1,036,023	-2,048	221,811	1,314,024
CANE PREPARATION:						
General (2)	220,783	15,781	227,978	8,849	93,283	566,674
Millyard	201,302	76,427	381,481	3,933	59,739	722,882
Cleaning Plant	282,374	394,597	331,285	11,154	160,630	1,180,040
Other Factory	143,157	310,008	153,203	30,432	68,574	705,374
APPLIED G&A	2,510,021	115,117	-1,081,702	6,447,522	1,990,574	9,981,532
TOTAL COSTS (4)	8,591,920	6,286,254	10,773,847	7,204,044	3,596,258	36,452,323

Table II-3 notes:

(1) Ripener application cost excluded @ $40 dollars per harvested acre

(2) Expenses prorated for cane preparation only, includes 15% of crushing plant expenses (fire room and boiling house/laboratory expenses excluded)

(3) Expenses prorated according to combined field and factory cane preparation cost only

(4) Total excludes sugar and molasses marketing expense

(5) All costs in columns include expenses from other operations such as macadamia nut, etc.

(6) Includes equipment R&M costs including repair labor, fuel and lubrication, equipment rental, and service credits from other operations

(7) Outside services, employee benefits, corporate service charge and other costs

(8) Taxes, insurance, depreciation and amortization, and other equipment/land rental costs

(9) Represents the true operating cost due to sugarcane operations

The basis for comparison used by the Hawaiian sugar industry is dollars per ton of sugar. Production figures for sugar and types of cane were taken from the HSPA Summary of Factory Results (an internal report distributed within the sugar industry) for 1991. The results shown in Table II-3 indicate that, for the two plantations considered, the cost of producing sugar exceeds $360 dollars per ton. From production data provided for net cane and prepared cane, costs are about $37 dollars per ton of net cane and $31 dollars per ton of prepared cane. This results in a production cost per ton of dry biomass for sugarcane of $115 dollars for delivered prepared cane. Once again, these costs are not considered to be representative of the Hawaii sugar industry costs on the whole.

Production costs per harvested acre and per acre-year are also presented so that comparisons can be made with other published data. Information published by HNEI in the report "Investigation of Biomass for Energy Production on Molokai" indicated that total delivered cost for sugarcane for an irrigated plantation was $1,367/acre-year.[24] By comparison, the cost presented in Table II-3 is $1,381/acre-year which includes processing costs for prepared cane. Sugarcane production cost figures published by the USDA Economic Research Service for operating year 1991 showed that, for Hawaii, average growing cost per net ton of sugarcane was about 35 dollars excluding cane transportation and processing to prepared cane costs. Using the USDA figures for transportation costs of $2.86 per ton and processing costs determined from Table II-3 of $3.18 per ton, the adjusted USDA production costs would be over $40 per ton net cane which compares to $37 per ton net cane in Table II-3. From these comparisons, it is possible that the cost of production figures presented in Table II-3 might actually be a low estimate of what the projected production costs would be for a sugarcane biomass to energy operation on the island of Hawaii, especially when considering the rugged terrain of the Hamakua Coast.

Costs will be affected significantly by the amount of dry matter produced per acre which has not been the emphasis of the sugarcane breeding program in Hawaii to date. With more emphasis on fiber production, for example, the total dry matter production for sugarcane could be increased. This approach, often referred to as the "energy cane" concept, implies harvesting the total amount of biomass produced by the sugar crop including tops and leaves which are currently burned before harvest.

7. Sugarcane Hybrids ("Energy Cane")

One possible approach in the development of sugarcane as a feedstock for energy and fuels, is the development and improvement of varieties of sugarcane optimized for the production of all components of the biomass – including sucrose, cellulose, hemicellulose, and lignin – rather than optimized for the production of sucrose alone. Several varieties of sugarcane, including varieties for energy production, have been grown and evaluated in Hawaii.[25]

C. ALTERNATIVE CROPS

The Hawaii sugar industry has been in existence for over 150 years and has detailed cost information for growing and processing sugarcane. The Hawaiian Sugar Planters' Association (HSPA) had previously developed information on alternative crops and was asked to develop a report to identify production costs and yields for the various biomass crops under consideration. Their report provided the foundation of the material found in this section.

A short list of crops and agricultural practices that may be appropriate under the physical and economic conditions that exist in the Hamakua/Hilo region are identified in Table II-4.

1. Eucalyptus and Leucaena

Eucalyptus and leucaena are tree crops that show potential for biomass production in Hawaii. Production has been demonstrated at several locations in Hawaii.[26] A range of experimental and projected commercial yields for eucalyptus and leucaena are shown in Figure II-3 below.

The State of Hawaii Department of Business, Economic Development and Tourism has sponsored several tree biomass tests.[27,28] Two categories of tree yield tests were conducted in five locations. During small plot, closely-spaced species trials, yields of dry biomass were determined for the Kilohana and Mountain View sites on the Big Island. These trials were part of the HSPA Biomass to Energy Project. The highest yielding trees were *Eucalyptus grandis, Eucalyptus urophylla*, and *Acacia mearnsii*. Averaged over two sites, yields for these species were: *E. grandis* : 15.9 dry matter tons per acre per year; *E. urophylla* : 18.6 dry matter tons per acre per year; and *A. mearnsii:* 17.1 dry matter tons per acre per year. Using the 25% discount, commercial production of trees (averaged) on a gross acre basis is estimated to be about 13 dry matter tons per acre per year. Converted to a net acre basis, the commercial yield is expected to be approximately 11 dry matter tons per acre per year. Yields for the individual tree species are given in Table II-4.

Large plot demonstration trials were also conducted as a part of the HSPA Biomass to Energy Project. The yield of dry biomass from the highest yielding trees harvested from large replicated plots at five sites was approximately 9 dry matter tons per acre per year for *E. grandis* at the Mountain View site, approximately 14 dry matter tons per acre per year for *E. urophylla* at the Honokaa site, approximately 11 dry matter tons per acre per year for *Leucaena leucocephala* at the Puunene site, approximately 9.5 dry matter tons per acre per year for *L. leucocephala* at the Hoolehua site, and approximately 8 dry matter tons per acre per year for *L. leucocephala* at the Kilohana site. Yields for the best performing trees averaged over the five sites was about 10 dry matter tons per acre per year. Commercial yield on a gross area basis was estimated to be about 8 dry matter tons per acre per year. On a net area basis, the commercial yields are expected to be about 6.5 dry matter tons per acre per year. Yields for individual species are given in Table II-4.

One of the best attributes of tree crops for biomass production is their adaptability to upland rain-fed sites not well suited for other crops. Biomass stored in trees is directly usable after felling and chipping, since it has a higher dry matter content. Grass crops require natural drying or dewatering in a mill to produce a suitable boiler feed stock at about 50% moisture. The yield potential for trees in rain-fed sites can be substantially improved by first selecting elite trees in existing plots and cloning them by either conventional procedures or by micropropagation. These selected trees along with germplasm from other sources could be the basis for a breeding program with the aim of producing more productive trees. The development of higher yielding trees will substantially reduce the cost per ton of tree biomass. Based on work in Brazil, the HSPA is confident that a considerably greater yield from trees can be obtained by simply selecting elite types and planting vegetatively propagated cuttings in commercial fields. In the future, production from 12 to 14 tons of dry matter per acre may be achievable commercially.[29]

The costs of production for eucalyptus were primarily developed at BioEnergy Development Corporation, a subsidiary of C. Brewer Company, in Hilo, Hawaii. This information was extracted and formed the basis of a spreadsheet model for eucalyptus production costs for the island of Hawaii. The costs were modified by the HSPA to include additional costs of production such as land costs, other field costs (i.e. road maintenance, etc.), general and administration costs, and research costs. Costs are summarized in Table II-4 below.

2. Napier Grass *(Banagrass)*

One of the "energy grasses" which has been demonstrated and studied in Hawaii is napier grass (banagrass, also commonly discussed as a potential energy crop, is a variety of napier grass). A range of experimental and projected commercial yields for napier grass is shown in Figure II-3 below.

The yield potential of napier grass (banagrass) was studied in two types of experiments: an environment by yield study including two ratoon crops; and a longer term four year yield trial at a single location on Molokai. The environment by yield study for napier grass was conducted by HNEI. This study evaluated the yield potential of napier grass in five locations. The average yield of biomass in the combined plant and ratoon crops was 31.8 dry matter tons per acre per year, demonstrating the high yield potential of this crop. Yield in the ratoon crop, primarily summer-grown, was 3 times the yield in the plant crop, primarily a winter-grown crop. Yield in the ratoon crop was double that of sugarcane grown in the same experiments. After applying the 25% discount, commercial yield on a gross acreage basis was estimated to be approximately 24 dry matter tons per acre per year. Conversion to a net acre basis results in an estimated yield of approximately 20 dry matter tons per acre per year (see Table II-4).

TABLE II-4
EXPERIMENTAL BIOMASS YIELDS AND CALCULATIONS OF EXPECTED COMMERCIAL YIELDS (1)

BIOMASS CROP	Experi-mental Yields	Estimated Commercial Yields	Estimated Commercial Yields	Harvest Cycle	Estimated Commercial Yields
	dry tons/gross acre/yr	dry tons /gross acre/yr (2)	dry tons/net acre/yr (3)	years	dry tons gross yield/ harvest
Sweet Sorghum (6 cult.; avg. 2 crops)	23.2	17.4	14.8	0.38	6.67
Sweet Sorghum (MN 1500; 2 crops)	32.7	24.5	20.8	0.38	9.41
Sorghum-Sudan grass	17.6	13.2	11.2	0.33	4.30
Corn (Avg. 2 crops)	20.0	15.0	12.8	0.25	3.82
Alfalfa (Avg. of 2 Experiments; 22 harvests)	11.8	8.9	7.5	0.08	0.73
Napier grass (Avg. 2 crops; 5 locations)	31.8	23.9	20.3	0.55	13.07
Napier grass (Avg. 7 crops; 1 location)	19.6	14.7	12.5	0.67	9.91
Eucalyptus grandis (close spacing trial)	15.9	11.9	10.1	2.00	23.85
Eucalyptus urophylla (close spacing trial)	18.6	14.0	11.9	2.00	27.90
Acacia mearnsii (close spacing trial)	17.1	12.8	10.9	2.00	25.65
Eucalyptus grandis (large plots - Mt. View)	9.1	6.8	5.8	5.00	34.13
Eucalyptus urophylla (large plots - Honokaa)	14.2	10.7	9.1	5.00	53.25
Leucaena leucocephala (large plots - Maui)	11.0	8.3	7.0	5.00	41.25
Leucaena leucocephala (large plots - Molokai)	9.6	7.2	6.1	5.00	36.00
Eucalyptus urophylla (large plots - Kauai	7.8	5.9	5.0	5.00	29.25
Sugarcane Maui (from HSPA Variety Tests) (4)	22.2	16.7	16.7	1.95	32.39
Sugarcane Ka'u (from HSPA Variety Tests) (4)	16.7	12.5	12.5	2.33	29.17
Sugarcane (5 locations; 2 harvests)	19.5	14.6	14.6		
Commercial Sugarcane (recovered biomass) (5)					
Commercial Sugarcane (recovered biomass)1991			14.1		
Commercial Sugarcane (recovered biomass)1990			14.2		
Commercial Sugarcane (recovered biomass)1989			14.7		
Commercial Sugarcane (recovered biomass)1988			15.2		
Commercial Sugarcane (recovered biomass)1987			15.7		

Notes:

(1) Information taken from HSPA experiments (1982-1993).

(2) Experimental Yields Discount (%) 25%

(3) Gross to Net Acreage Conversion (%) 15%

(4) Based on HSPA net acre (Sq. Ft.) 37,026

(5) Includes sugar, fiber, soluble molasses solids. Yields based on crop age rather than crop rotation time. Commercial Sugarcane Data obtained from HSPA reports and unpublished HSPA reports.

The long-term napier grass study on Molokai was supported with funding from DBEDT. In this study, napier grass vs. banagrass was grown on Molokai for 4.3 years and harvested 7 times without replanting. The average yield obtained over this period was 19.6 dry matter tons per acre per year. The expected commercial yield on a gross acreage basis was estimated to be approximately 15 dry matter tons per acre per year. Conversion to a net acre basis results in an estimated commercial yield of 12.5 dry matter tons per acre per year (see Table II-4).

The primary constraints to biomass production with banagrass is the propensity to flower, thus limiting winter growth potential. Breeding and selection on non-flowering or reduced flowering types would be a primary research goal. Another research project which could result in increased winter yields would involve the treatment of napier grass with the growth regulator gibberellic acid. Gibberellin has been successfully applied to sugarcane for increasing winter growth and ethephon is presently used commercially to inhibit sugarcane flowering. Both gibberellin and ethephon have considerable potential to increase the biomass production of grass crops in the winter.

The HSPA and the HNEI have estimated the cost of production to be lower than for sugarcane owing to its ability to produce a large number of high yielding ratoon crops and its greater yield potential as a result of greater partitioning of its biomass to fiber which is more efficiently recovered than the soluble carbohydrates produced by sugarcane. The cost of production of napier grass vs. banagrass for an irrigated site on Molokai was estimated in a collaborative project including HSPA, HNEI, and Hawaiian Electric Company (HECO) personnel. These costs, modified to reflect different assumptions, are summarized in Table II-5.

3. Sweet Sorghum and Sweet Sorghum-Sudan Grass Hybrid

Sweet sorghum is currently grown in small quantities in Hawaii. Although not studied as extensively recently as some other potential energy crops (e.g. napier grass, eucalyptus, and leucaena), it has demonstrated good yields in Hawaii and elsewhere, its sucrose content makes it attractive from an ethanol production standpoint, and its protein content could provide an animal feed by-product of some value. A range of experimental and projected commercial yields for sweet sorghum is shown in Figure II-3.

In 1982, preliminary biomass trials were cooperatively established by the USDA and the HSPA at the HSPA Kunia substation, a leeward, high sunlight location with deep soil and adequate irrigation. Kunia is considered a prime agricultural location. In these trials, six cultivars of sweet sorghum produced an average summer-grown yield of 14.1 tons per acre dry matter in 144 days (See Table II-4). A ratoon crop of these cultivars produced only 3.9 tons per acre when grown during the winter (only 28% of the summer yield).[30] The extreme yield difference for the summer and winter-grown crops of sweet sorghum is an important consideration for biomass production in Hawaii. The combined winter and summer yield of the sweet sorghum produced in 283 days was about 18 tons of dry matter per acre. On an annualized basis, the yield is estimated to be approximately 23 tons per acre per year. One cultivar of sweet sorghum, MN1500, yielded over 40 percent more than the average of the other six cultivars studied. Since these yields are from small, hand harvested plots, they were discounted by 25% to estimate commercial yield of mechanically harvested biomass and further discounted by 15% to account for the difference between gross and net acreage.

Forage Project. In 1984, the HSPA was supported with funding from the GACC to conduct several large scale forage yield trials with corn and sorghum-sudan grass hybrids. The work was conducted in the Ewa region of Oahu in shallow soil. The site was considered marginal for commercial sugarcane production. Like the earlier sweet sorghum trials, HSPA grew both a summer plant crop and a winter ratoon crop of sorghum-sudan grass hybrid. The summer yield was 4.3 dry matter tons per acre and the winter crop yield was 2.6 dry matter tons per acre (only 60% of the summer yield). The total time of growing the sorghum-sudan grass crops was only 144 days. This results in an annualized yield of 17.6 dry matter tons per acre per year. If this is discounted by 25%, the expected commercial yield for this location would be 13.2 dry matter tons per acre per year (Table II-4).

4. Corn

Corn experiments at the same location yielded 12.9 tons per acre in 185 days not including a winter cycle. The annualized yield including a winter cycle at 50% of the summer yield would be 20 dry matter tons per acre per year. Discounting this by 25% would yield a commercial estimate of 15 dry matter tons per acre per year. Discounting these yields further to account for differences in gross versus net acres would result in estimates of commercial production for sorghum-sudan grass and corn to be 11.2 and 12.8 tons per acre per year respectively (see Table II-4).

5. Alfalfa

Alfalfa yield potential was studied over a three year period, from 1985 to 1987, by the HSPA. The data is included in this report for comparison with more traditional biomass crops. Alfalfa yield was also substantially affected by the season in which the harvest took place. Yield was reduced by 50% during the winter months compared to peak summer yields. The most productive variety, FLa 77, averaged over two experiments, where harvests were made monthly for two years, yielded about 12 tons dry matter per acre per year. Applying the 25% discount to these yields results in an expected commercial yield on a gross acre basis for alfalfa of about 9 tons dry matter per acre per year. Further discounting for gross to net acreage yields an expected commercial production of 7.5 dry matter tons per acre per year (see Table II-4).

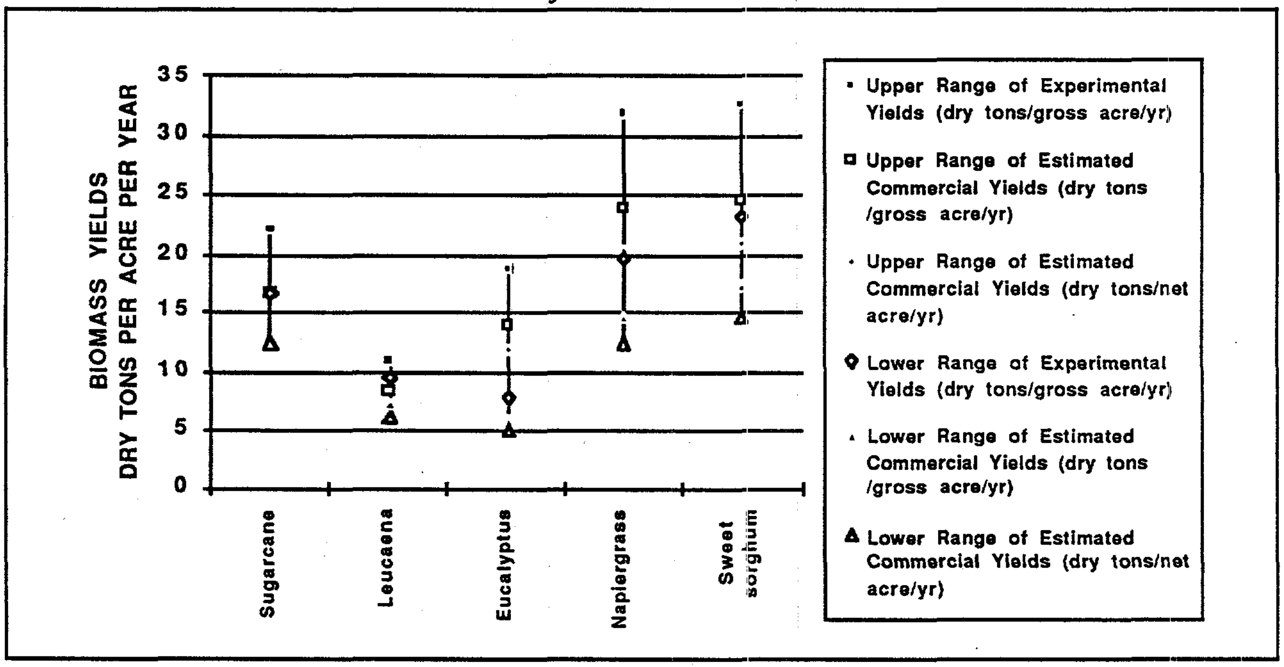
Experiments on alternative crops were usually installed on prime agricultural land and the yield data was obtained from hand harvested experimental plots. As a result, higher yields than could be expected from commercial operations are obtained. To adjust, HSPA initially discounts the yields obtained in experimental plots by 25% to account for selection of prime sites for experimental plots, losses in mechanical harvesting, and other production losses. An additional discount of 15%

is made to account for gross versus net acres under production, where gross area is occupied by in-field roads, irrigation equipment, etc. (see notes, Table II-4 above).

Yield data is presented for a wide variety of crops grown under widely varying conditions in Table II-4. After discounting for the above mentioned losses, to reflect expected commercial production, crop yields are annualized and presented on both experimental and an adjusted basis. The crops with the highest yield potential were the grasses including sugarcane, sweet sorghum, and napier grass. For comparison, biomass yields for the commercial sugarcane crops harvested between 1986 and 1991 are included. Yield data has been presented on a dry weight basis in short tons (2,000 lbs.) per acre, unless otherwise stated.

<u>A word of caution regarding comparisons of crop yields.</u> The choice of biomass crop, crop yields, and delivered costs is highly site-specific. For example, some crops do better in sunnier, warmer locations while others flourish in cooler, wetter conditions. Although grasses generally achieve higher dry matter yields per acre per year than do trees, in specific locations (the eucalyptus plantings in Hamakua, for example) the trees out-performed the grasses. This illustrates the importance of using these estimates as a general guide from a statewide perspective rather than as an absolute relationship for all sites.

FIGURE II-3
EXPERIMENTAL AND PROJECTED YIELDS FOR BIOMASS CROPS



6. Production Costs

Estimated cost projections for selected potential alternative energy crops are shown in Table II-5. The crops included are napier grass (banagrass), haole koa (*Leucaena leucocephala* - K636), and *Eucalyptus*. Costs of production are estimated for both irrigated and rain-fed sites. For the purposes of these analyses, the land costs were kept constant at $100 dollars per acre per year. This represents the cost of renting the land. General and administration was set at 10% of overall operating costs. It should be noted that labor costs and harvesting practices differ from conventional sugarcane operations for these alternative energy crops which is reflected by the lower projected delivered costs per dry ton of biomass. The cost of water, set at $0.10 per 1000 gallons, represents a considerable hurdle for production of biomass in areas requiring irrigation. This water cost can partially be offset by higher yield potentials for irrigated lands, however. Water costs vary substantially by site and may be charged at a low internal rate for companies who have developed their own water supply and delivery system or at a very high rate for new operations required to purchase water or install new irrigation systems. Actual water costs for specific sites must be determined.

TABLE II-5
ESTIMATED COSTS OF BIOMASS FEEDSTOCK AT THE CONVERSION PLANT (1)

COST CENTER	Sugar-cane	Napier grass	Leu-caena	Sugar-cane	Napier grass	Eucalyp-tus	Eucalyp-tus (2)
($/acre)	Irrigated	Irrigated	Irrigated	Rainfed	Rainfed	Rainfed	Rainfed
Land Holding	100	100	100	100	100	100	100
Soil Preparation	53	27	5	53	27	49	42
Planting/Ratooning (Includes Nursery)	135	67	16	135	67	16	22
Weed Control	92	46	64	92	46	41	33
Irrigation	260	371	328	0	0	0	0
Fertilizer	115	148	40	115	148	40	54
Other Field	179	89	89	179	89	30	30
Harvesting	123	115	238	123	115	251	209
Hauling	155	180	36	155	180	48	40
G&A (Field) (3)	121	114	92	95	77	58	53
Total Delivered Costs ($/acre)	1,333	1,257	1,008	1,047	849	633	583
Total Delivered Costs ($/Dry Ton)	**83**	**70**	**101**	**75**	**57**	**74**	**69**
Assumptions:							
G&A (Field)	10%	10%	10%	10%	10%	10%	10%
Harvests Per Planted Crop	1	7	4	1	7	1	1
Harvests Per Year	0.5	1.5	0.2	0.5	1.5	0.2	0.17
Average Crop Cycle (Mo.)	24	8	60	24	8	60	72
Dry Matter (tons/acre/yr)	16	18	10	14	15	8.5	8.5
Irrigation Costs ($ / 1000 gal)	0.1	0.1	0.1		0	0	0
Irrigation Reqmt (gal/acre/day)	6,000	6,000	5,000		0	0	0

Notes:
(1) Modified From Hubbard And Kinoshita (1993) Investigation of Biomass for Energy Production on Molokai
(2) Modified from BioEnergy Development Corporation's work on Eucalyptus
(3) G&A estimated at 10% of total cost

D. WASTES AS A SOURCE OF BIOMASS

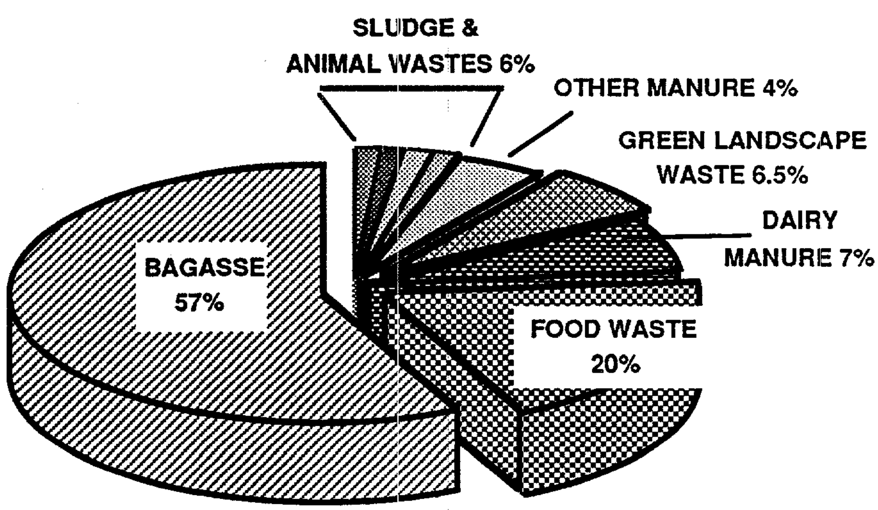
Organic wastes and municipal solid wastes (MSW) also represent targets of opportunity. Agricultural wastes, green wastes from landscaping and households, and materials directed to landfills contain significant amounts of cellulose, hemicellulose, and lignin. Diversion of these materials from landfills to energy production could make raw material available at a reasonable cost (in some instances subsidized by tipping fees), and contribute to reductions in the waste disposal problem.

In a sense, wastes such as paper and MSW will be available as long as there is a population and for this reason should be considered as sustainable as – and may be even more dependable a supply source than – cultivated biomass. These sources can also be considered as renewable since they are originally derived from crops and trees.

1. Organic Material

As described earlier, an inventory of organic material produced in the state of Hawaii was carried out in 1991. This survey provided an overview of material in the state and identified the amounts available by county and region. A summary of the inventory results is presented in Figure II-4 below.

FIGURE II-4
PRIMARY CATEGORIES OF ORGANIC MATERIAL IN HAWAII



2. Municipal Solid Waste and Organic Waste

a. Composition

The composition of MSW varies substantially depending on location. In Hawaii, MSW contains almost 32% green material from yards, hotels, golf courses, parks, and construction sites. Paper and food wastes also contain significant amounts of lignocellulosic material. A detailed analysis of wastes deposited in the Kauai County landfill in 1990 was used as the basis for projections (see Figure II-5). The detailed evaluation showed that almost 64% of the material disposed (wood, yard, green waste, food waste, and paper) had the potential to be used for ethanol or to produce electricity.

b. Quantity

As shown in Table II-6, significant amounts of lignocellulose-containing materials are produced statewide.

FIGURE II-5
MSW COMPOSITION

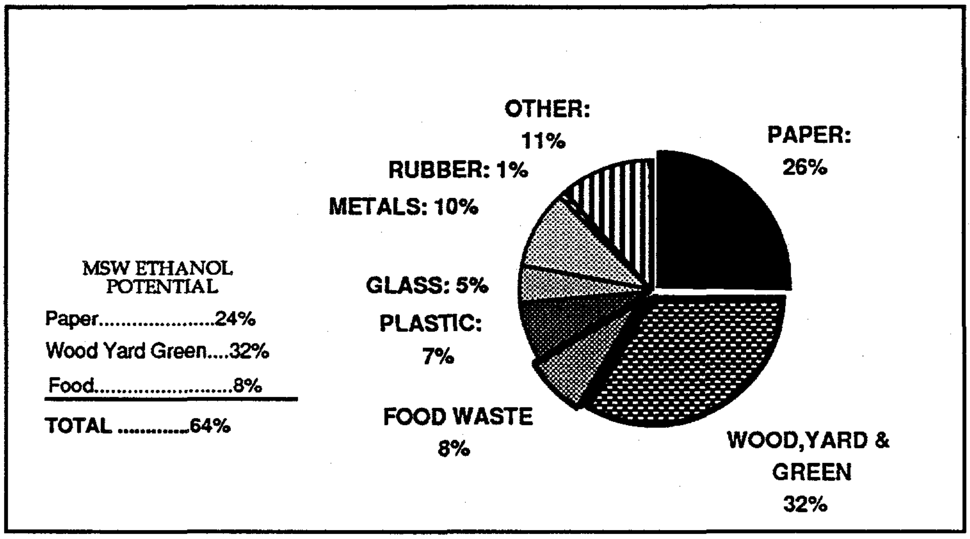


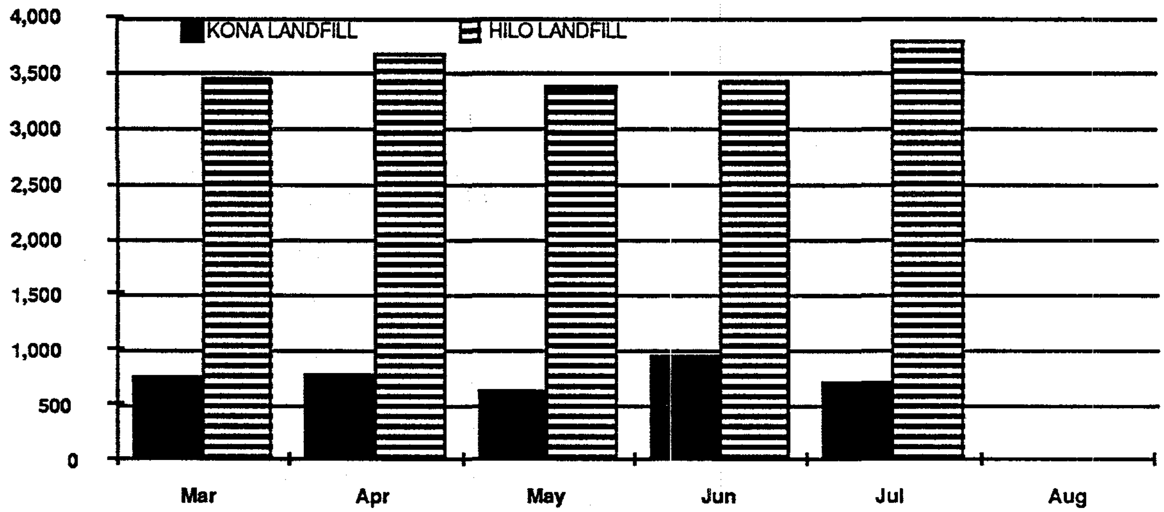
TABLE II-6
QUANTITIES OF MUNICIPAL SOLID WASTE AVAILABLE IN HAWAII

ISLAND Population 1991	OAHU 836,231	MAUI 100,504	HAWAII 120,317	KAUAI 51,177
PAPER (tons per year)				
Old corrugated cardboard	71,200	26,500	15,200	7,800
Old newspaper	65,500	9,500	5,500	2,800
High-grade paper	26,500	23,500		700
Mixed paper	120,400	10,400	19,500	3,000
TOTAL PAPER	283,600	69,900	40,200	14,300
Other organics	244,300	58,100	36,100	14,000
Green waste	200,600	53,800	13,900	15,800
TOTAL OTHER	444,900	111,900	50,000	29,800
MSW with ethanol potential	708,500	181,800	90,200	44,100
Other solid waste				
Glass	61,800	12,300	7,000	3,600
Aluminum	15,900	2,500	1,400	800
Tin		5,000		1,400
Metals (ferrous/non ferrous)	153,900	11,200	13,900	3,300
Mixed plastics	74,000	13,600	11,100	5,500
Batteries	12,000			
Tires	6,000	1,300		400
Construction demolition	93,200			
Others	335,900	45,300	15,500	21,200
TOTAL MSW (tons per year)	1,481,200	273,000	139,100	80,300

3. Municipal Solid Waste - (Hawaii County Case Study)

As part of evaluating the opportunities in the Hamakua area we have evaluated the MSW resource. A detailed evaluation showed that almost 64% of the material disposed (wood, yard, green waste, food waste, and paper) had the potential to be used for energy production, as shown in Figure II-5. In the Hilo/Hamakua region alone, almost 136,000 tons of wastes per year are potentially available.[31] Much of this material is not disposed of in the landfill. Data on the Hawaii County landfills was provided by Hawaii County (See Figure II-6).

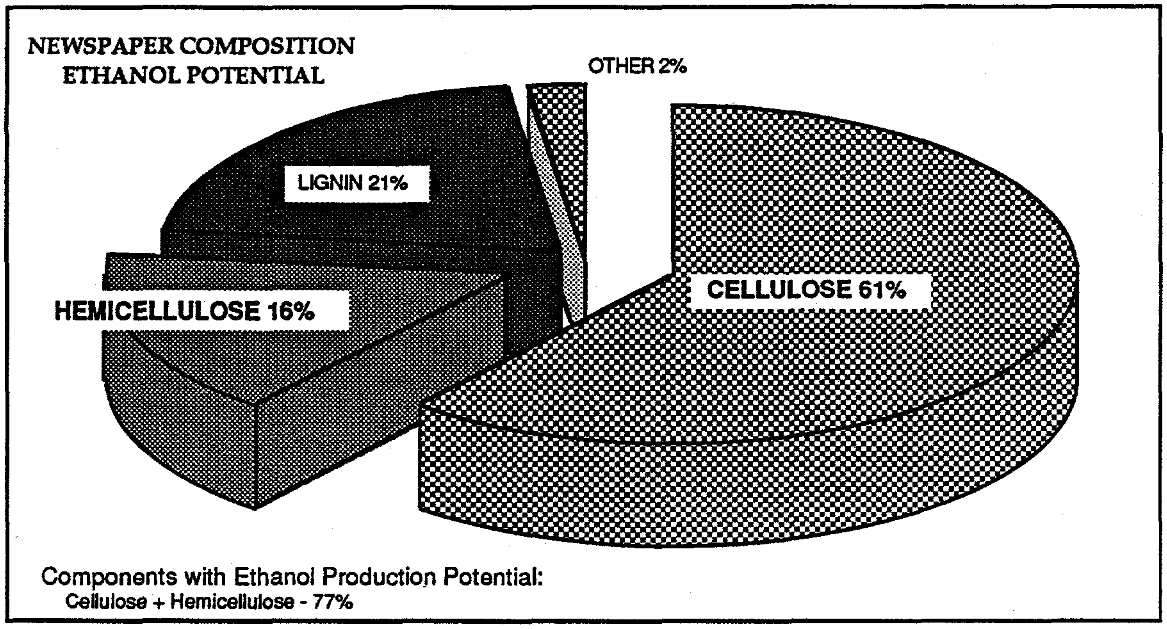
FIGURE II-6
REFUSE HAULED ON THE ISLAND OF HAWAII (TONS PER MONTH)



4. Newspaper and Mixed Waste Paper

An independent study of magazine mail and newspaper volume in Hawaii estimated that we produce almost 2 pounds per capita of paper products per day. Much of this material does not presently enter the disposal system, but is potentially available. Almost 77% of the material in paper products is made up of sugars that can be converted to ethanol (see Figure II-7). The opportunity to use newspaper as a source of material for ethanol production should also be given a great deal of attention.

FIGURE II-7



At present, much of the newspaper collected in Hawaii is sold to Asian markets for about $8.00 per ton (FOB Hawaii).

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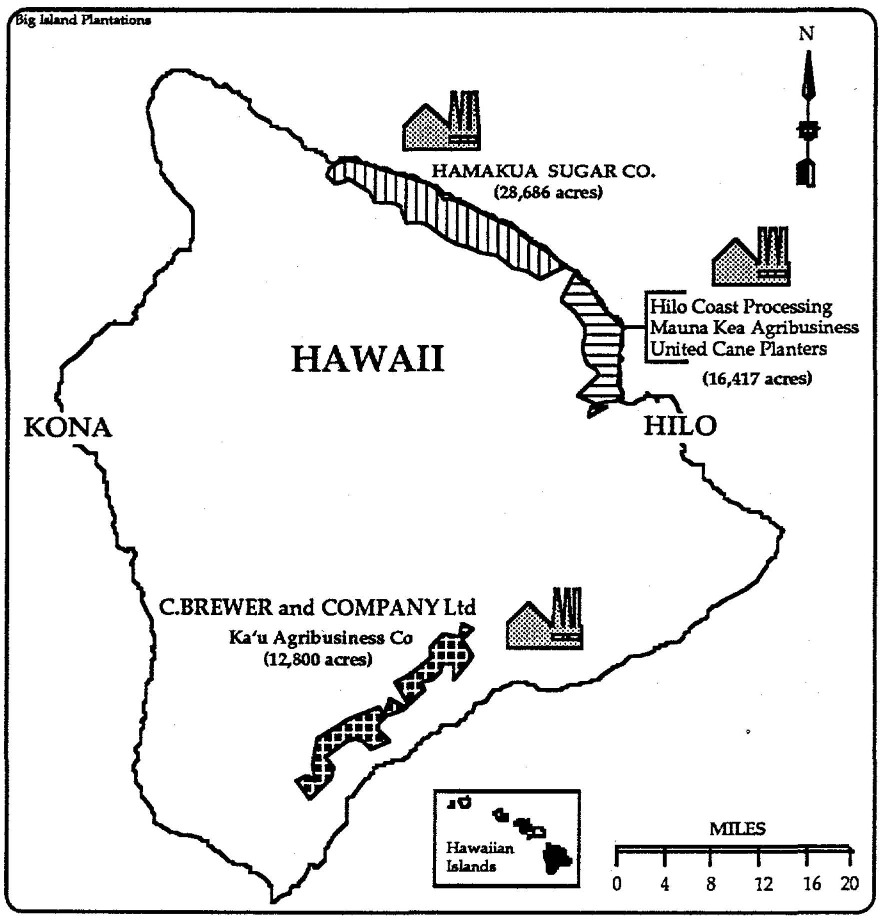
III. LAND AND FACILITIES [TASKS 3 AND 4]

A. LAND CAPABILITIES

The Hamakua/Hilo Coast region is located on the island of Hawaii. Both sugar operations, Hamakua Sugar Company and Hilo Coast Processing Company, in this region are expected to discontinue production soon. The remaining sugar operation on the island of Hawaii, Ka'u Sugar Company, is also discontinuing sugar operations. The possibility to convert up to 60,000 acres of potentially available lands to the production of dedicated feedstocks for conversion to ethanol and/or electricity exists (See Figure III-1). These lands include the areas of the Big Island that are most suitable for the production of biomass crops.

FIGURE III-1
SUGAR PLANTATIONS ON THE ISLAND OF HAWAII



The island of Hawaii is the largest island and youngest in the state of Hawaii, covering approximately 4,035 square miles or 63 per cent of the total land area in the state.[1] The most outstanding climatic features are remarkable differences in rainfall over short distances, mild temperatures, persistent northeasterly trade winds and distinct climatic regimes in localities sheltered from the prevailing wind. The topography contributes to a diversity of micro-climates.

Lands on the island of Hawaii were assessed by Geographic Information Systems developed by the Hawaii Natural Energy Institute of the University of Hawaii. Lands were classified broadly by zoning, usage, ownership, elevation, soil type, temperature, rainfall, insolation, and slope. Various parameters conducive to biomass production and potential availability of lands were then overlaid to provide an approximation of the amount of land suitable for biomass to energy production on the island of Hawaii.

1. Zoning

Over 95 per cent of the lands on the island of Hawaii are zoned either conservation (50%) or agriculture (46%) (see Figure III-2). There are approximately 1,225,000 acres of agricultural zoned lands on the island of Hawaii.[2]

2. Usage

Current agricultural usages include commercial sugarcane, papaya, banana, coffee, and macadamia nut production; cattle grazing; and small areas of diversified agriculture production (see Figure III-3).

3. Ownership

Lands which are zoned agriculture on the island of Hawaii are owned by several different entities. These include, but are not limited to: the State of Hawaii, the Hawaiian Homes Commission, Bishop Estate, Hamakua Sugar Company, C. Brewer and Company, Samuel M. Dale Estate, and Richard Smart (see Figure III- 4).

4. Elevation

The elevations are the highest in the state. They range from sea level along the coast to nearly 14,000 feet on Mauna Loa and Mauna Kea (see Figure III-5). Elevations ranging from 2,000 to 4,000 feet in the region between Laupahoehoe and Waipio Valley have been designated as "prime" forest lands by the State of Hawaii Department of Land and Natural Resources. These elevations are suitable for the production of Short Rotation Intensive Crop (trees) production. Lands below this elevation are currently under sugarcane production and could be utilized for the production of grass varieties.

5. Soil Type

The island of Hawaii has a variety of soils due to the variations in climate, vegetation, geologic history, relief, and drainage. The soil types most conducive to biomass production are found in the Andisol order (formerly Inceptisol order) (see Figure III-6).

The sugarcane lands of Hamakua consist of moderately fine textured soils (silty clay loams) that developed in geologically recent volcanic ash. The majority of these soils belong to the Hydrud and Great Group of the Andisol order (formerly Hydrandepts in the Inceptisol order) in the U.S. Soil Taxonomy System. Hydrudands are high in organic matter concentration, very porous, and continuously wet, but well-drained. The average topsoil (0 to 8 inch soil depth) organic carbon concentrations (5 to 6%), in Hamakua Coast Hydrudands presently under sugarcane production, compare favorably with the average organic carbon concentration (2%) of other agricultural soils in the humid tropics. However, the effective cation exchange capacity (sum of exchangeable cations) of Hamakua soils is generally low.

Major soil fertility concerns with the sugarcane lands of Hamakua are phosphorus (P) fixation (retention of fertilizer P in forms unavailable to plants), soil acidity, and potassium (K) and nitrogen (N) leaching. The extraordinarily high phosphorus-fixing capacity of Hamakua soils has been associated with the presence of high concentrations of allophane and hydrous oxides of iron (Fe) and aluminum (Al). For most crops, this requires the application of high rates of phosphorus fertilizer to obtain acceptable yields. Because of leaching, split applications of N and K are recommended during the growing season. Near complete depletion of exchangeable K from Hamakua soils can occur if it is not reapplied periodically. Periodic applications of liming materials also are needed to maintain a pH of approximately 6.0.[3]

6. Temperature

The mean annual temperature of the island of Hawaii varies between 72° and 75°F. along the coastal region and decreases by approximately 3°F. for each 1,000 feet of elevation. The daily range between high and low temperatures is 10° to 20°F (see Figure III-7). August and September are the warmest months; December, January, and February are the coolest. The seasonal range in temperature is only 4° to 8°F. Although the tropical temperatures of the Hawaiian Islands do not vary as dramatically as temperatures on the mainland, they do vary enough to reflect significant differences in seasonal growth rates for crops under consideration. This factor must be taken into consideration when projecting biomass yields.

7. Rainfall

Rainfall on the island of Hawaii ranges from 8 inches to over 300 inches per year.[4] The principal cause of this extreme variability is the rain that forms within the moist trade wind air as it ascends and traverses the mountains. Generally speaking, the dry arid regions show more of a seasonal variation than the wetter regions which derive their rainfall from winter storms as well as year-round trade wind showers (see Figure III-8).

8. Insolation

The solar insolation levels on the Big Island range from 300 to over 570 langleys and are therefore among the highest recorded in the United States (see Figure III-9). This contributes significantly to the yield potentials of biomass crops in this region.

9. Potentially Available Land

The predominant land use in the Hilo/Hamakua area is forest reserve and unused open space. The County of Hawaii's Land Use Inventory identifies over 400,000 acres as "Unused Open Space". Agricultural uses in the area occupy over 250,000 acres with the majority dedicated to ranching. Sugar operations currently account for approximately 45,000 acres of the lands zoned agriculture. As recently as 1990, approximately 51,000 acres were dedicated to sugarcane production along the Hilo/Hamakua Coast (34,000 acres at Hamakua Sugar Company and 17,000 acres at Mauna Kea Agribusiness & United Cane Planters' Cooperative) (see Figure III-1).

Table III-1 shows the potential yield of biomass on a dry tons per year basis that could be produced if lands at the sites identified in the table were committed to dedicated biomass production.

TABLE III-1
ESTIMATED BIOMASS YIELD FROM POTENTIALLY AVAILABLE LANDS ON THE ISLAND OF HAWAII[5]

LOCATION:	Type of Biomass Considered	Total Acres Considered	Commercial Yields (dry tons/net acre/yr)	Potential Biomass Production (dry tons/year)
Paaukau	Trees	11,400	8.3	94,620
Pepeekeo	Trees	19,100	8.3	158,530
Pahala	Trees	2,200	8.3	18,260
Ka'u Agribusiness	Grasses	18,200	14.6	265,720
Mauna Kea Agribusiness	Grasses	14,700	14.6	214,620
Hamakua Sugar Company	Grasses	27,800	14.6	405,880
TOTALS		**93,400**		**1,157,630**

Notes: * Commercial yields were estimated by averaging the tree and grass crop yields respectively.

Although sugar production at Hamakua has historically represented some of the most productive yields in the state, some of the potentially available lands have slope, temperature, and rainfall characteristics that may not be supportive of short rotation biomass crops. These marginal lands should be considered for longer rotation crops such as tree species that may not require high energy inputs to be sustainable. This would be a less destructive use of these lands.

FIGURE III-2
ZONING

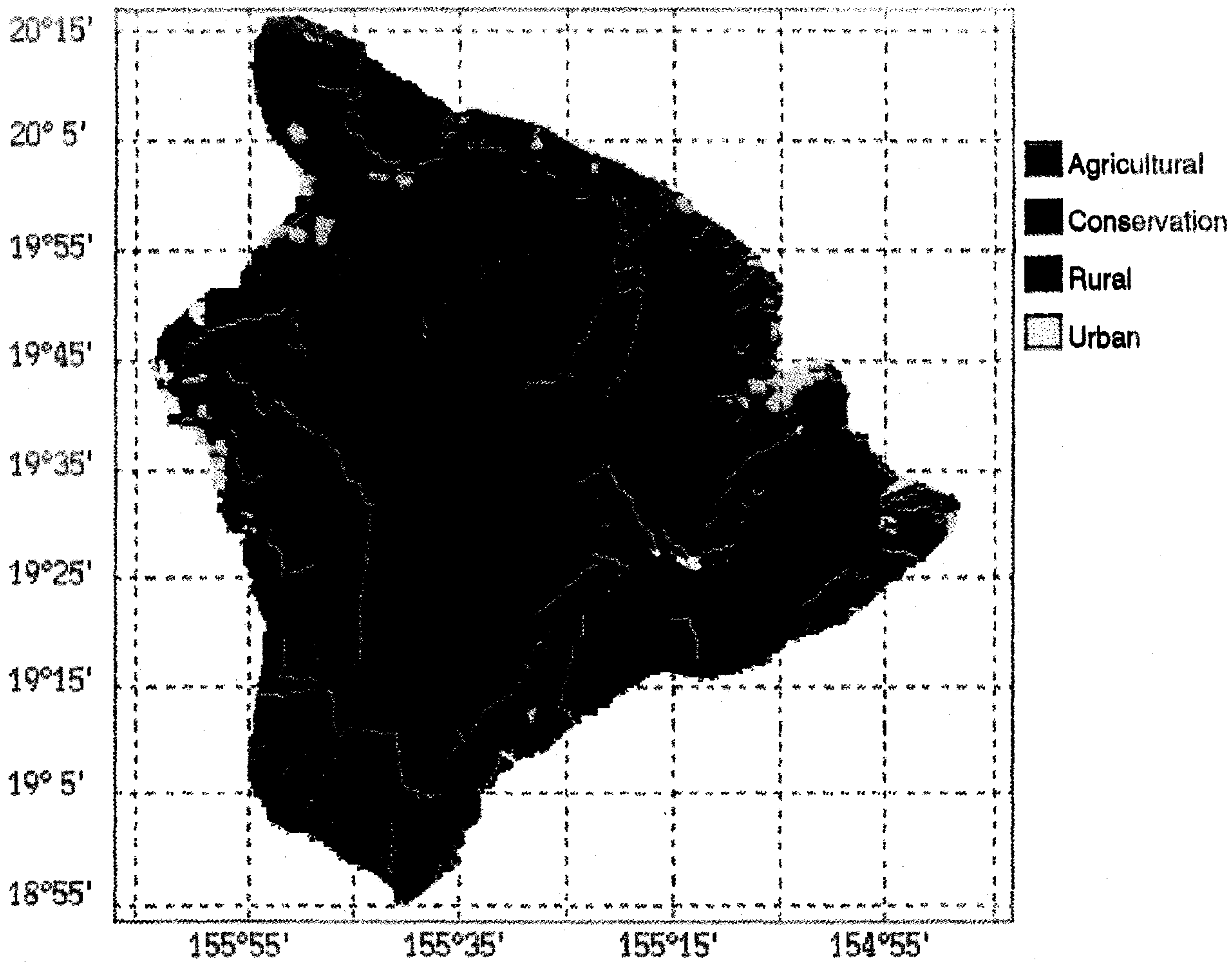


FIGURE III-3
USAGE

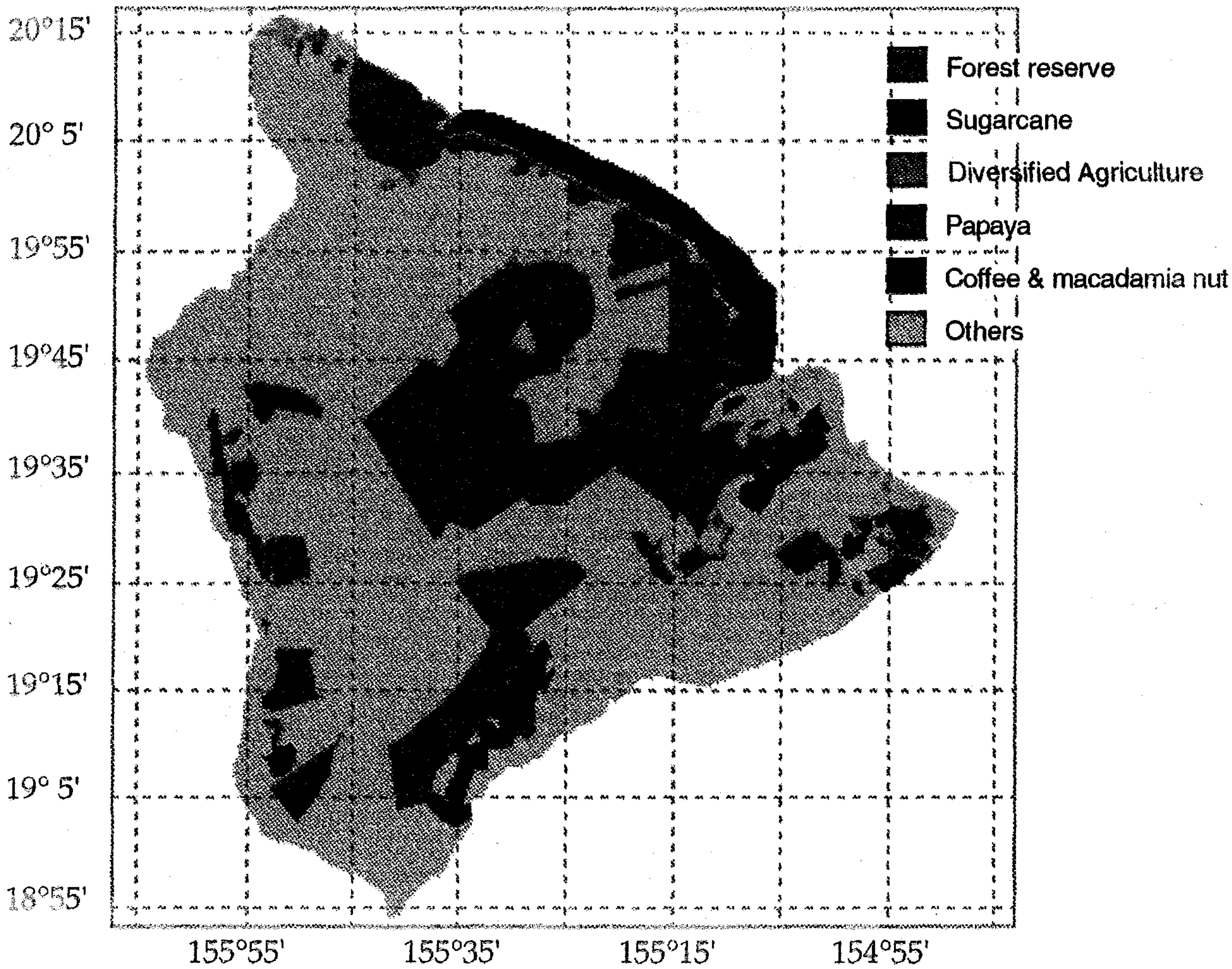


FIGURE III-4
OWNERSHIP

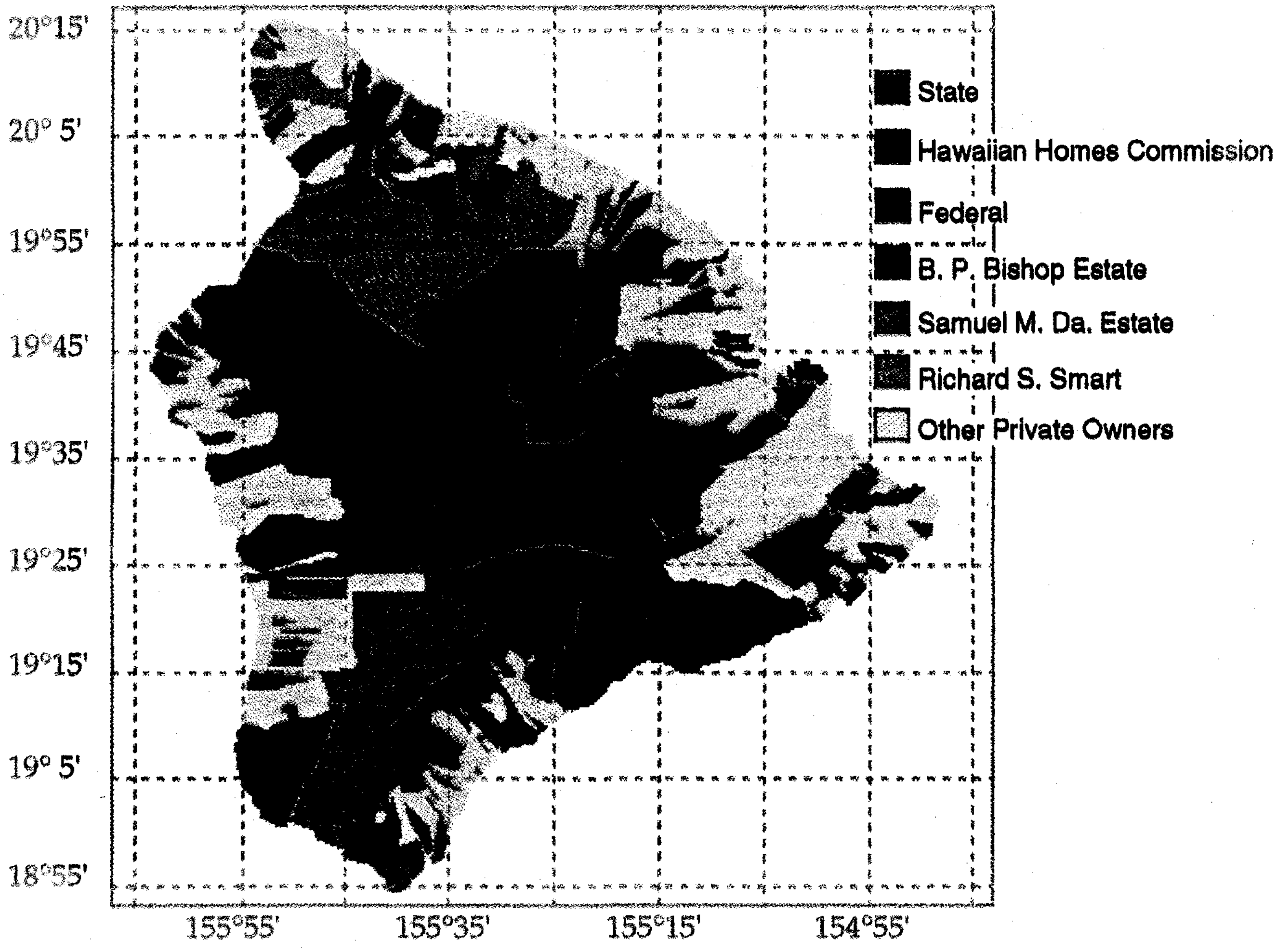


FIGURE III-5
ELEVATION

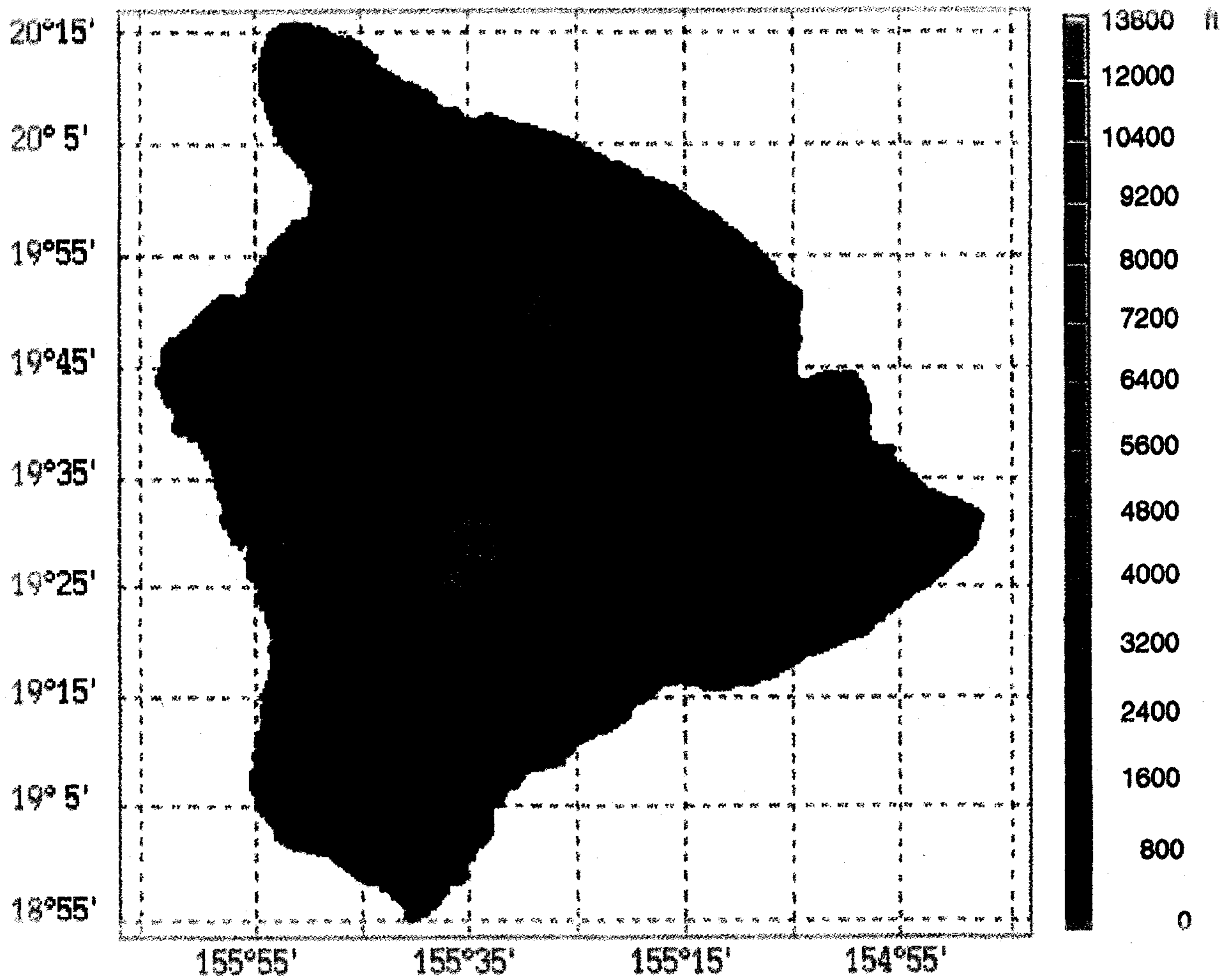


FIGURE III-6
SOIL

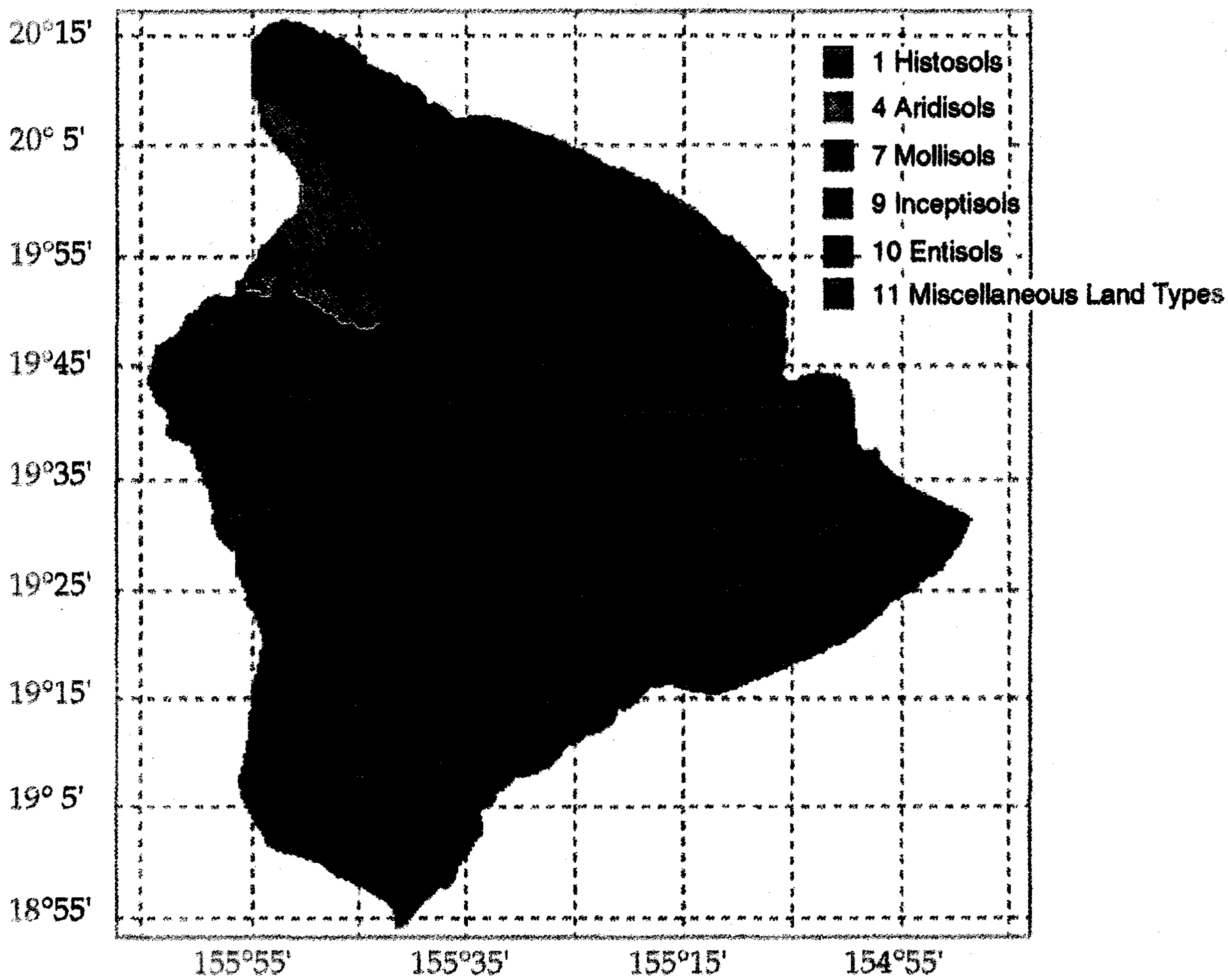


FIGURE III-7
TEMPERATURE

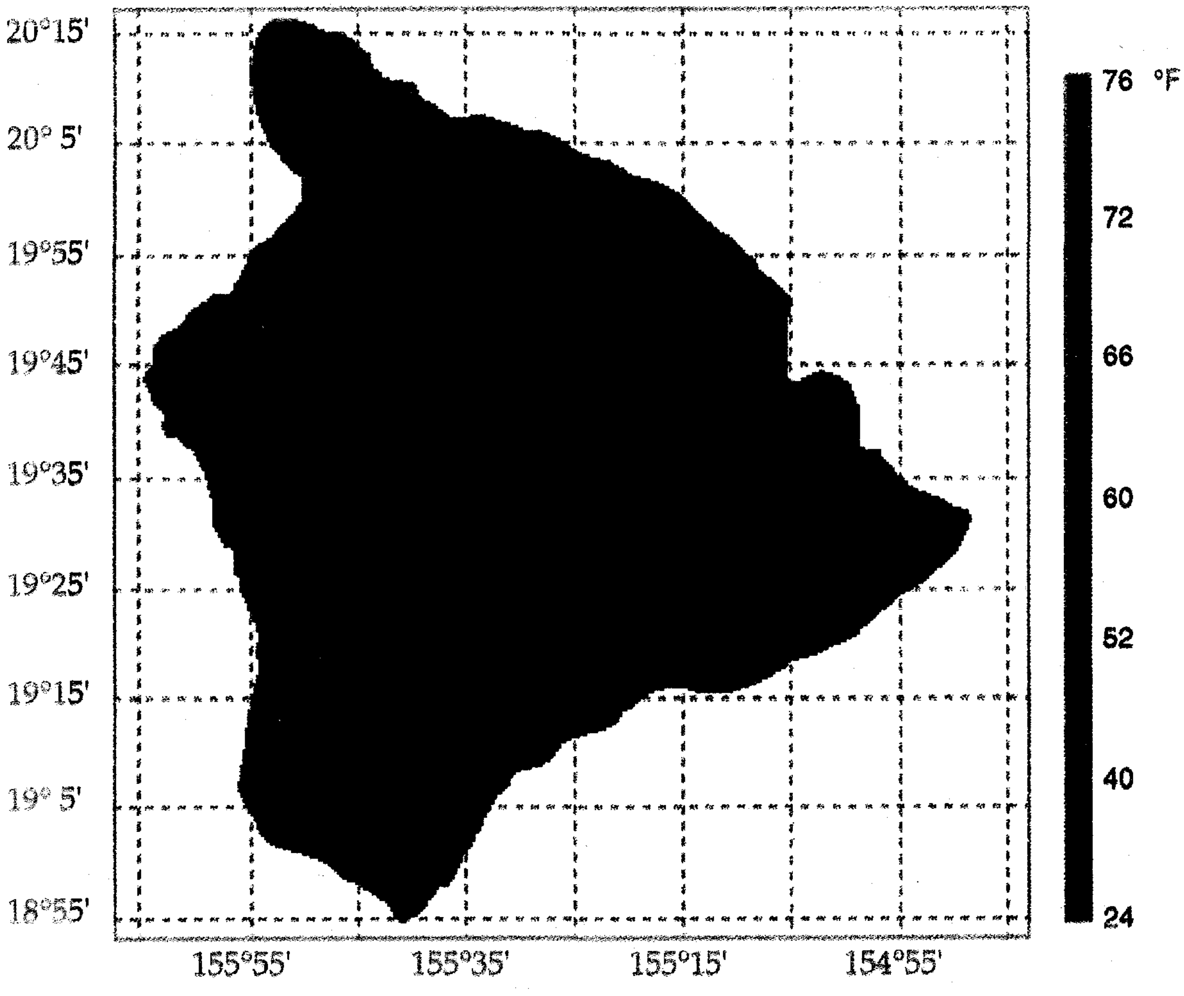


FIGURE III-8
RAINFALL

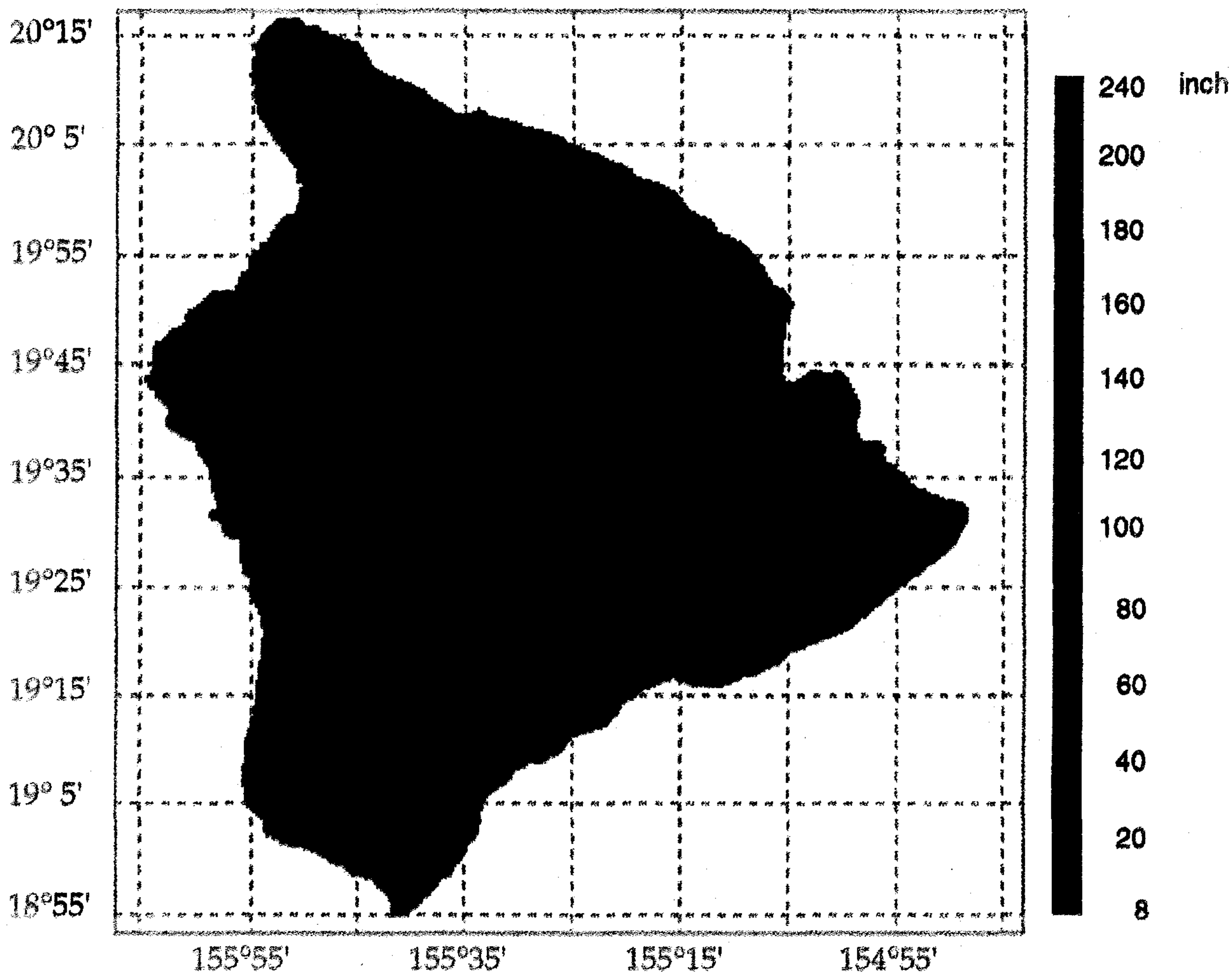
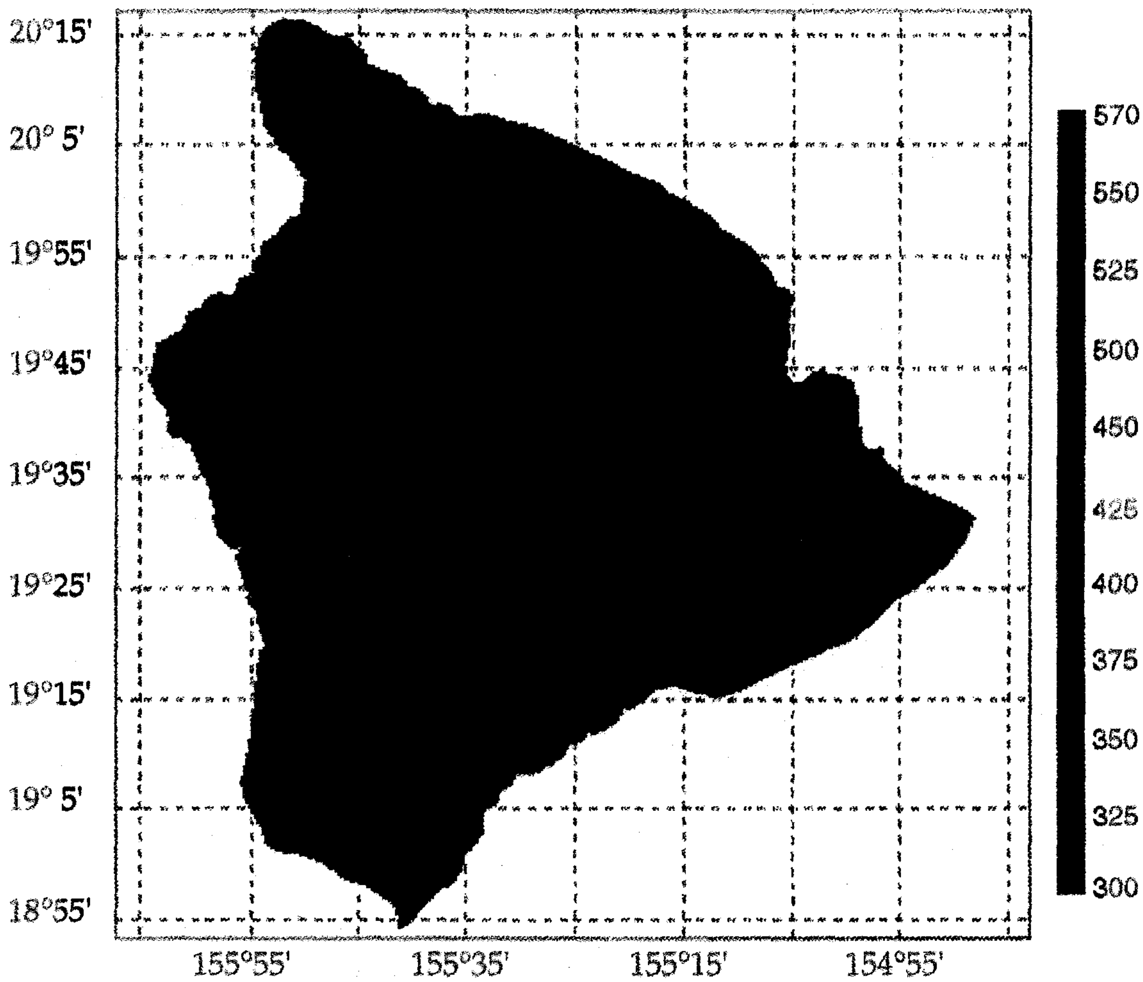


FIGURE III-9
INSOLATION



B. FACILITIES IN THE HAMAKUA/HILO COAST REGION

Suitable facilities which may have application for the purposes of demonstrating and ultimately developing the appropriate technologies are discussed.

1. Hamakua Sugar Company

The Hamakua Sugar Company mill at Haina follows the general operations of the sugar industry in Hawaii. A general overview of this process and specific equipment involved at Hamakua Sugar Company follows.

a. Cane Handling Process

All cane is trucked to the factory and weighed on a 50-ton Howe platform scale with Fairbanks Morse strain gauge type readout. Trucks equipped with cargo nets are unloaded by hoists, using the side dump method which delivers the cane to the cane cleaner/feeder tables, either directly or by means of a mobile stacker which handles cane from a ground storage unloading area.

b. Milling Equipment

The field cane is first processed in a wet cleaning plant which removes dirt, trash, rocks, and other foreign material prior to milling. A system incorporated in early 1979 and modified in 1992 allows the recovery of all washed trash, which is then simultaneously processed with the cane.

c. Extraction Plant

The extraction plant is preceded by a motor driver leveler and a Hamakua designed and built 2,500 hp shredder installed in 1985. The cane then passes under an Eriez belt type tramp iron magnet located above a 300 feet per minute belt conveyor. The extraction plant was erected and commissioned in 1976. It consists of four Walkers 84" x 42" mills, each equipped with a heavy-duty continuous two-roll pressure feeder. Each mill is driven by a 700 hp Terry steam turbine reducer and a Welsh gear reducer connected to Walkers spur gearing which is equipped with anti-friction bearings.

d. Steam Plant

One Foster Wheeler steam generator commissioned in 1978 and capable of 288,000 lbs. of steam per hour at 800°F and 610 p.s.i.g. when fired with bagasse at 50% moisture. The boiler is equipped with a stationary water-cooled pinhole grate; one 1,776 hp Combustion Engineering, two-drum type VU-50X water tube boiler, 610 lbs. working pressure, 750°F total temperature, and 17,780 sq. ft. heating surface with dumping grate on line. For air pollution control, the boiler is equipped with two UOP Air Correction division Type 6P high-efficiency multiclone mechanical collectors in series.

e. Electric Plant

One 6,000 kW, 13.8 kv back pressure turbo generator, inlet pressure 600 psig, exhaust 235 psig. The exhaust is used for all other prime movers, including a 1,500 kW G.E. turbine and a 7.5 MW condensing turbo-generator which was commissioned in early 1981. An 800 kW hydro generator is used to generate power on the off season as well as during the grinding season. A 4 MW generator moved from the Ookala Factory to Haina and commissioned in early 1987 uses steam at 450 psig from the Combustion Engineering boiler.

f. Bagasse Drying and Densifying Plant

System commissioned in 1980 employing boiler stack gases to dry all bagasse from approximately 50% to 35% moisture. The densification plant has been removed as there is insufficient surplus bagasse to warrant densification.

g. Clarification

The clarification section consists of two juice heaters in parallel on primary heating, 2,422 and 2,486 sq. ft. respectively, followed by two heaters of 2,875 sq. ft. each in parallel on secondary heating with vapor from the pre-evaporator, and one Graver clarifier 30' diameter by 17'8" high.

h. Evaporation

First effects are two pre-evaporators in series 26,000 and 24,000 sq. ft.. These are followed by three sets of triple effects. The first set of triples has units of the following h.s.: 17,317, 10,000, and 7,000 sq. ft. each. The second set of triples has units of the following h.s.: 8,000, 7,000, and 7,000 sq. ft. each. The third set of triples has units of 6,500 sq. ft. each. Vapor from the preevaporator serves all the pans and secondary juice heater, and first vapor from the two triples serves the primary heater.

i. Pan Storage Tanks

For syrup, tank storage of 8,756 cu. ft.; for A molasses, 2,800 cu. ft.; and for B molasses, 1,700 cu. ft..

j. Vacuum Pans

For raw VLC (very low color) sugar, one 18-1/2" diameter calandria pan of 2,000 cu. ft. capacity and 4,215 sq. ft. h.s.; one 2,000 cu. ft. pan with 4,200 sq. ft. h.s. calandria pan of 1,600 cu. ft. capacity and 2,396 sq. ft. h.s.. For B sugar, one Hamill 10'/11'6" diameter calandria pan of 900 cu. ft. capacity with 1,200 sq. ft. h.s. and one 16'10" diameter calandria pan of 2,000 cu. ft. capacity and 3,000 sq. ft. h.s.. For low grade sugar, one H.I.W. 12' diameter calandria of 1,100 cu. ft. capacity with 1,755 sq. ft. h.s. and one 17'6" diameter calandria of 2,000 cu. ft. capacity with 4,035 sq. ft. h.s..

k. Evaporators and All Pans

Individual vacuum pumps (Nash Hytor) and individual stainless steel condensers, 12,000 gpm of water at 115 F° is recirculated and cooled to 90 F°.

l. B Crystallizers

Four Honolulu Iron Works-type cyrstallizers of 900 cu. ft.; two installed in 1948, converted to B massecuite in 1988.

m. Crystallizers

Five Honolulu Iron Works-type cyrstallizers of 900 cu. ft., two installed in 1948, three in 1970. Individual drive on the last three. Two Ducasse/Unice continuous crystallizers of 900 cu. ft. each.

n. Centrifugals

For raw sugar, six 48 x 36 automatic Western States centrifuges. For B station, two BMA k1100 (1988) and one CC-4 (1969) Western States continuous centrifugals. For low grade, one 34" x 34" Western States (1985) and BMA k1100 (1988) continuous centrifuges.

o. Sugar Storage

The sugar is elevated from the centrifugals into two steel bulk sugar bins, one of 350 tons and the other of 400 tons. The bins are located adjacent to the milling building.

p. Molasses Storage

The final molasses is pumped through a cooler, temperature reduced to 105 F° and into a 500-ton molasses storage tank which was installed at the factory in 1959. All molasses is hauled by tank truck to the 10,000-ton receiving and storage tanks at the port of Kawaihae.

q. Waste Water Treatment

Cane wash water and boiler ash water are treated prior to being discharged from the factory. The waters pass through a screening conveyor with 1/4" diameter holes, then through a grit separator before being distributed to two 60' diameter Dorr-Oliver clarifiers. Underflow from the clarifiers is dewatered by two 10' diameter x 20' long Dorr-Oliver vacuum filters. The mud is then removed by truck to land disposal.

2. Hilo Coast Processing Company

The sugar mill at Hilo Coast Processing Company follows the general process flow of the Hawaii sugar industry and will be further detailed in the efforts of the NREL LOI Hawaii Project.

3. Ka'u Agribusiness

The sugar mill at Ka'u follows the general process flow of the Hawaii sugar industry and will be further detailed in the efforts of the NREL LOI Hawaii Project.

1 State of Hawaii, Department of Business, Economic Development & Tourism, *DATA BOOK 1992.*

2 HNEI, Personal communication.

3 Bruce W. Mathews, Agronomy and Soils, College of Agriculture, University of Hawaii at Hilo. Paper presented at the Symposium on Alternative Crops to Sugar for Hilo/Hamakua Land. November 20, 1993.

4 Atlas of Hawaii 1992 Second Edition University of Hawaii Press pp 62-63 extrapolation

5 Adapted from the Renewable Energy Resource Assessment Project of the Hawaii Energy Strategy, 1994, *Phase I Report - Biomass Resources*, by the College of Tropical Agriculture and Human Resources, University of Hawaii, for R. Lyneete & Associates, Inc.

IV. ETHANOL OPTIONS [TASKS 5 AND 7]

A. ETHANOL FOR HAWAII?

This section of the report is devoted to evaluating the potential to produce ethanol from the sources of biomass described previously. There are several reasons for interest and support for the production of ethanol in Hawaii. These include:

- The potential to establish a local industry to substitute for some portion of the approximately 50 million barrels of petroleum that we currently import each year to meet our energy needs.
- Use of ethanol in a 10% blend with gasoline is being done nation-wide (in forty-four other states), and all auto makers approve the use of properly blended ethanol fuels in their vehicles.
- Cultivation of crops for ethanol might provide a basis for establishing alternative uses for agriculture lands that are coming out of production and may generate new sources of employment in the agriculture sector.
- Use of municipal solid waste to produce ethanol could reduce the flow of material to the landfill and provide a low cost source of feedstock.
- Ethanol production from local feedstocks may offer an opportunity to develop new businesses and provide some economic diversification in rural areas.

The possibility of producing ethanol in Hawaii has been of interest for decades. Numerous studies have been completed and several attempts at commercial production have been made with less than positive results. Advances in technology in recent years provided the basis for a re-evaluation of the potential to produce ethanol from biomass in Hawaii. Technical progress has been accompanied by economic improvement. Much progress has been made by government, universities, and the private sector in advancing the technology for hydrolyzing biomass to sugars fermentable to ethanol. Experts in the field have stated that, "over the past ten years, efficiencies have improved and costs have decreased to the point that an ethanol plant built today may cost as little as a third as much (in constant dollars) as a comparably sized ethanol plant built ten or fifteen years ago."[1] Significant progress has been made in the areas of feedstock preparation, hydrolysis, fermentation of the sugars, and distillation.

The costs of ethanol production are highly sensitive to the cost of the feedstock delivered to the processing site and the volume and composition of the material. The success of any plan to grow crops for ethanol production will be dependent on the selection of appropriate crops, production methods, and locations. A system established around the lowest cost starting material and fully integrated to "squeeze out" the greatest economic outputs by utilizing all of the by-products in the system, will present the best opportunity for economic success.

B. "LIGNOCELLULOSIC BIOMASS" AND SYSTEM ECONOMICS

Historically, production of ethanol was limited to using sources of sugar that were available in soluble forms, such as sugar (sucrose), molasses from sugarcane, or fructose from the corn plant. Since these soluble sugars are edible[2], their relative value tends to be higher than for the rest of the plant (leaves, stalks, etc.) which is inedible and usually has a much lower value. In many cases, the inedible portions of the plants are considered to be waste materials. New technologies have developed that make it possible to produce ethanol from the other plant components or "lignocellulosic biomass." Lignocellulosic biomass is made up of the leafy or woody part of plants: corn stover, bagasse, yard and wood waste, paper pulp, etc.

Biomass is principally composed of the compounds **cellulose, hemicellulose, and lignin. Cellulose,** a primary component of most plant cell walls, is made up of long chains of the **6-carbon sugar, glucose,** arranged in bundles. Cellulose is a primary component of paper. In the plant cell wall, the cellulose molecules are interlinked by another molecule, **hemicellulose.** The **hemicellulose** is primarily composed of the **5-carbon sugar, xylose.** Another molecule, called **lignin,** is also present in significant amounts and gives the plant its structural strength. Improvements in technology have recently provided a variety of methods of extracting and dissolving the cellulose and hemicellulose to produce the component sugars in a form that can be converted to ethanol. Appropriate pre-treatment can free the cellulose and hemicellulose from the plant material. Further treatment using chemicals, enzymes or microorganisms can be used to liberate simple sugars from the cellulose and hemicellulose making them available to microorganisms for fermentation to ethanol.[3,4,5,6,7,8,9,10,11,12,13] A recent technology brief published by NREL stated: "Many of the recent advances in biomass fuel technology relate to the breakdown of lignocellulosic material so it can be fermented to ethanol. Conversion of lignocellulosic material could substantially reduce ethanol costs and enormously expand available feedstocks. In addition to specially grown grasses and trees, other potential feedstocks include agricultural and forestry residues, along with paper and other municipal solid waste."[14]

The nature of the feedstock puts certain constraints on the technology required for the manufacture of ethanol. For example, molasses or sugar solutions can be fermented directly by yeast, using traditional and well-established technology. However, lignocellulosic feedstocks such as wood or bagasse must be hydrolyzed into component molecules and sugars before fermentation by one or more specifically selected microorganisms. Though currently requiring increased capital investment, technologies for conversion of lignocellulosic materials are near-term and have the potential for dramatic improvements of ethanol yields.

If the cost of a feedstock is sufficiently low, more expensive conversion technology may be justified.

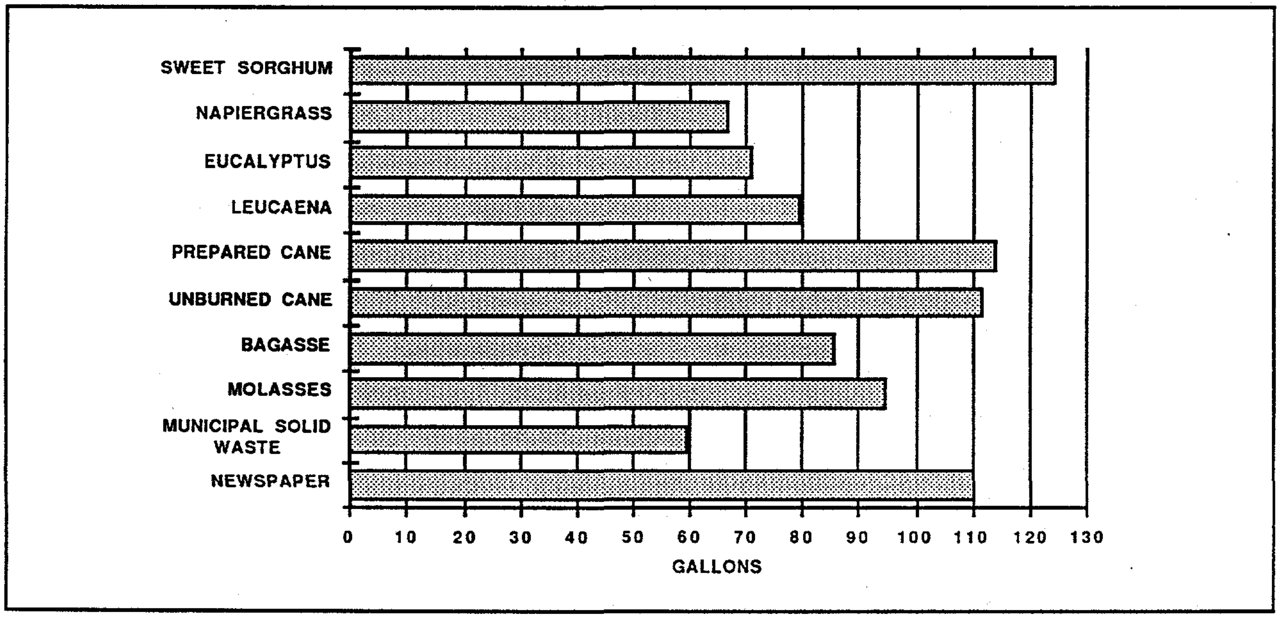
C. POTENTIAL GALLONS OF ETHANOL PER TON OF BIOMASS

On the basis of composition of each type of biomass, it is possible to estimate the ethanol potential per ton for the materials identified above. Figure IV-1 provides a comparison of the potential ethanol yields, based on fermentable sugars and assumed conversion efficiencies presented in Table IV-1.

TABLE IV-1
CONVERSION EFFICIENCIES ASSUMED FOR SUCROSE, CELLULOSE, AND HEMICELLULOSE TO ETHANOL

CONVERSION EFFICIENCIES ASSUMED	LOW END OF RANGE	HIGH END OF RANGE	USED IN CALCULATIONS
Sucrose to glucose & fructose	99%	100%	99.5%
Cellulose to glucose	95%	100%	97.5%
Hemicellulose to xylose	50%	90%	70.0%
Glucose to ethanol	95%	100%	97.5%
Fructose to ethanol	95%	100%	97.5%
Xylose to ethanol	40%	90%	65.0%
Sucrose to ethanol	94%	100%	97.0%
Cellulose to ethanol	90%	100%	95.1%
Hemicellulose to ethanol	20%	81%	50.5%

FIGURE IV-1
POTENTIAL GALLONS OF ETHANOL PER DRY TON BIOMASS

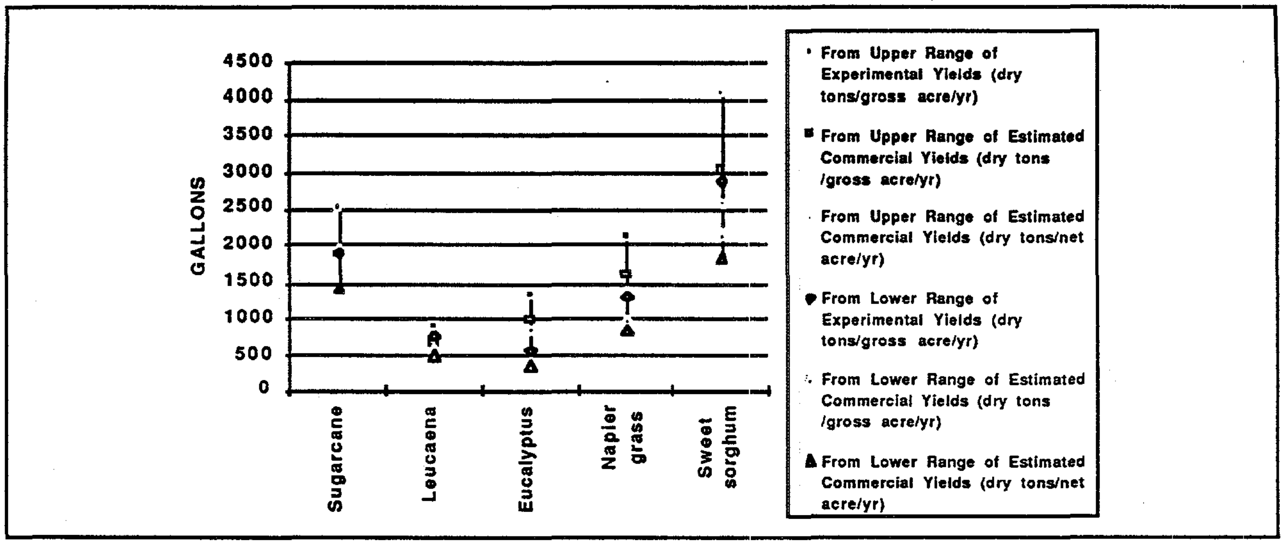


D. POTENTIAL GALLONS OF ETHANOL PER ACRE

1. Potential Yields of Ethanol from Agricultural Crops

Crop productivities, results from experimental plantings, and projected commercial yields for several crops were discussed in Chapter 2. Figure IV-2 presents the resultant ethanol potential from various crops on an annualized basis, using biomass yield reported in Chapter 2.

FIGURE IV-2
POTENTIAL GALLONS OF ETHANOL PER ACRE, PER YEAR



2. Potential Yields of Ethanol from Sugarcane Components

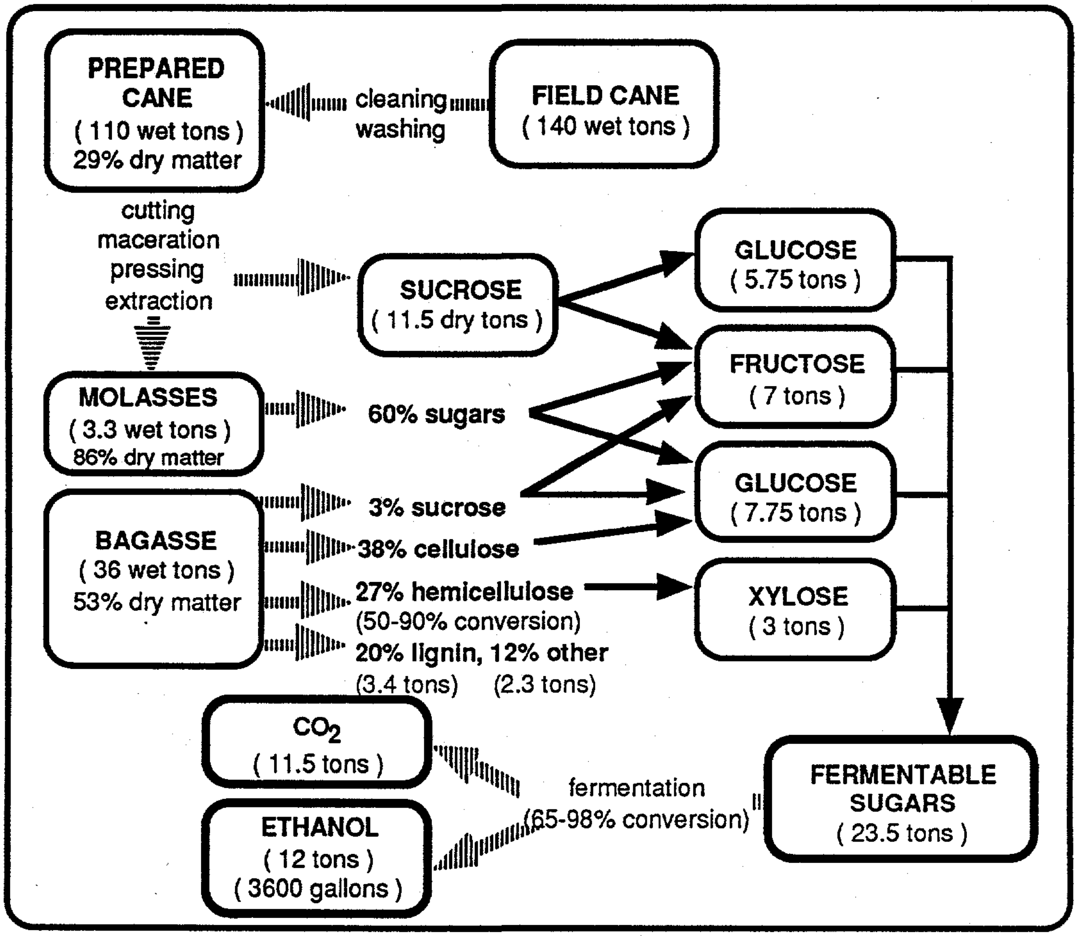
Sugarcane has been grown in Hawaii for over 150 years; as such, yields and costs of commercial production are well known within the industry. However, the question of "ethanol from sugarcane" requires consideration of a number of variables, each of which has its own associated costs and side-effects. The relative costs and returns of any of these scenarios are site and technology specific. Possible approaches are shown in Table IV-2.

TABLE IV-2
POSSIBLE APPROACHES TO ETHANOL FROM SUGARCANE

HARVESTING	PRODUCTS	ETHANOL FROM
Burned fields	Sugar, bagasse, and molasses	No ethanol produced
Burned fields	Sugar, bagasse, and ethanol	Molasses
Burned fields	Sugar and ethanol	Bagasse and molasses
Burned fields	Ethanol	Sugar, bagasse and molasses
Unburned fields	Sugar, bagasse, molasses, and unburned leafy trash (leafy trash used for electricity generation)	No ethanol produced
Unburned fields	Sugar, bagasse, molasses, and ethanol	Unburned leafy trash
Unburned fields	Sugar, bagasse, and ethanol	Molasses and unburned leafy trash
Unburned fields	Sugar and ethanol	Bagasse, molasses and unburned leafy trash
Unburned fields	Ethanol	Sugar, bagasse, molasses and unburned leafy trash

Potential ethanol from the conversion of one harvested acre of sugarcane ("prepared cane") is shown in Figure IV-3. The quantities shown are per harvested acre and have not been adjusted on an annualized basis. Potential additional biomass from unburned cane (see discussion on burned vs. unburned sugarcane in Chapter 2) is not shown.

FIGURE IV-3
PREPARED CANE TO ETHANOL DIAGRAM



E. FEEDSTOCK COST PER GALLON OF ETHANOL

1. Agricultural Crops

Table IV-3 shows biomass costs per ethanol gallon based on information presented in Chapter 2 and conversion efficiencies presented earlier.

TABLE IV-3
CULTIVATED FEEDSTOCKS:
ESTIMATED COST PER DRY TON AND PER ETHANOL GALLON

CROP	Estimated cost per ton ($/ton dry matter)	Estimated feedstock cost ($/gallon ethanol)
Sugarcane (irrigated)	$83	$0.73
Napier grass (irrigated)	$70	$1.04
Leucaena (irrigated)	$101	$1.26
Sugarcane (rainfed)	$75	$0.65
Eucalyptus (rainfed)	$74	$1.11
Napier grass (rainfed)	$57	$0.72

3. Sugarcane Components

For the purposes of this section, the costs of the various sugarcane-derived materials were considered separately, as described below:

a. Bagasse

The cost per ton of bagasse was based on the cost that would be incurred in replacing the bagasse with #2 diesel, #6 fuel oil, or coal for electricity production (the low end of the range is for coal at $60 per ton; the high end of the range is for #2 diesel at $32.00 per barrel).

b Molasses

Molasses cost per ton was based on the 1991 average return to growers of $40.00 per wet ton.[15] If the molasses was to be shipped to another location, rather than used at the point of production, the assumption of $40.00 per ton, which does not include consideration of transport costs, would be low.

c. Prepared cane

The cost per ton of "prepared cane" was based on Osgood and Dudley (1993) estimated sugarcane costs per acre, thus are consistent with napier grass, leucaena, and eucalyptus estimated costs obtained from the same source[16]. In subsequent calculations (such as those used to generate Figure IV-4), an average of 50% irrigated and 50% unirrigated acreage was assumed.

d. Sugarcane trash

"Sugarcane trash" refers to unburned leaves and trash not counted in prepared cane. These costs were based on an estimate of an increase of 50% in harvesting costs and an increase of 40% in hauling costs per acre,[17] using estimates of cost centers from Osgood and Dudley (1993). There is some concern that harvesting without burning may lower recoverable sucrose yields by some percentage. The cost of reduction in recoverable sucrose yield has not been taken into account in the comparison below.

e. Unburned sugarcane

The cost per ton of "unburned sugarcane" is the sum of the costs of "prepared cane" and the "unburned leaves," determined on a per-acre basis then reduced back to a per-ton basis to maintain the relative proportions of the various parts of the plant.

2. Municipal Solid Waste, Organic Waste and Newspaper

As discussed in Chapter 2, significant quantities of MSW and organic wastes are available in the study region. Although some waste-to-ethanol studies have included tipping fees (i.e., a fee is collected from the person(s) disposing of the organic waste at the collection site) in their cost analyses, such tipping fees may reduce the amount of material coming to the facility if there are cheaper (or free) alternatives such as public landfills, composting or disposing of the waste by illegal dumping. Therefore, although the potential may exist to collect fees for taking these waste materials, such fees were not assumed in this analysis. Almost 5 million gallons of ethanol per year, or about 13% of the gasoline consumption of the island of Hawaii, could (theoretically) be produced from these materials.

3. Summary of Feedstock Costs

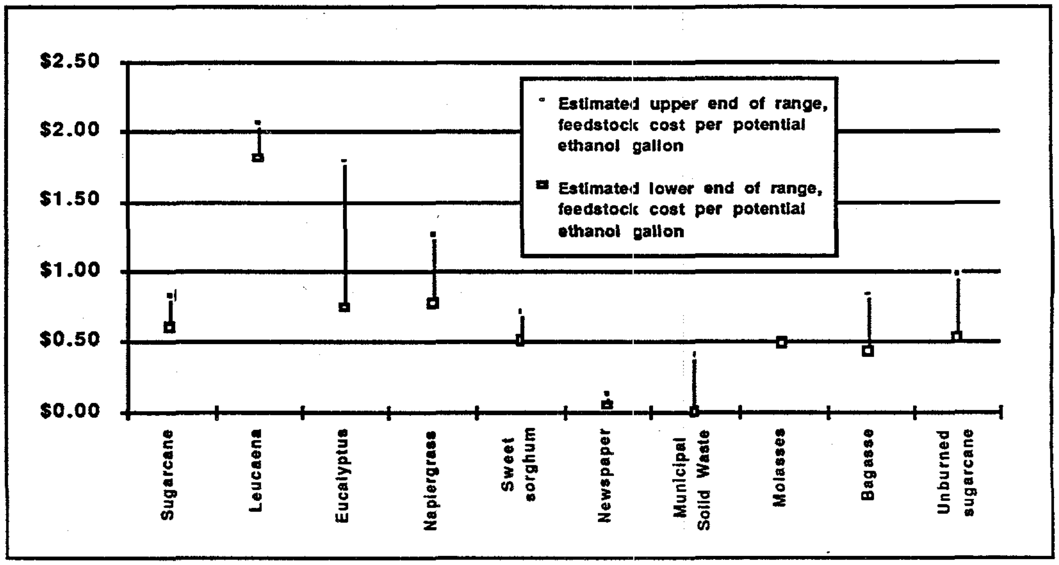
Estimated feedstock costs per ton and on a per-gallon-ethanol basis are shown in Table IV-4 and in Figure IV-4. The ranges shown are intended to indicate a range of costs which may be expected due to variations in yields between locations (assuming costs per acre to be relatively constant). Sweet sorghum costs were assumed to be similar, on an annual acre basis, to irrigated sugarcane.

TABLE IV-4
RANGE OF ESTIMATED BIOMASS COSTS PER POTENTIAL ETHANOL GALLON

BIOMASS	Estimated upper end of range, feedstock cost per dry ton	Estimated lower end of range, feedstock cost per dry ton	Estimated upper end of range, feedstock cost per potential ethanol gallon	Estimated lower end of range, feedstock cost per potential ethanol gallon
Sugarcane	$95.20	$69.18	$0.83	$0.61
Leucaena	$165.25	$144.00	$2.06	$1.80
Eucalyptus	$126.60	$53.19	$1.78	$0.75
Napier grass	$84.76	$52.19	$1.26	$0.78
Sweet sorghum	$90.07	$64.09	$0.72	$0.51
Newspaper	$15.00	$5.00	$0.14	$0.05
Municip Solid Waste	$25.00	$0.00	$0.42	$0.00
Molasses	$47.20	$47.20	$0.50	$0.50
Bagasse	$72.23	$38.05	$0.84	$0.44
Unburned sugarcane	$110.29	$58.66	$0.98	$0.52

On the basis of the assumptions and information presented thus far, sugarcane varieties, sweet sorghum, MSW and paper wastes appear to have the most immediate potential to serve as sources of biomass for ethanol production.

FIGURE IV-4
ESTIMATED BIOMASS COST PER POTENTIAL ETHANOL GALLON



F. LAND REQUIREMENTS

A critical consideration in a state the size of Hawaii is the number of acres in production required to meet the needs of a specific size processing plant or the needs of an identified market. Production on each island, to meet the local demand and eliminate the cost of shipping, may present the best opportunity. Extensive discussions with developers of technology suggest that a plant producing 25 million gallons of ethanol per year might provide the optimal economy of scale for commercial production. This size plant corresponds to the acreages shown in Table IV-5 below.

TABLE IV-5
ACREAGE REQUIRED TO PRODUCE BIOMASS FOR A 25 MILLION GALLON PER YEAR ETHANOL PRODUCTION FACILITY

BIOMASS MATERIAL	TONS BIOMASS required (dry, per year) for 25 million gallon-per-year facility	ACRES REQUIRED for biomass for 25 million gallon-per-year facility
Sugarcane ("prepared cane")	218,933	15,270
Sugarcane - whole plant (no open field burning)	238,655	12,709
Sugarcane varieties (Puerto Rico & Hawaii)	219,768	7,578
Napier Grass	372,670	17,257
Sweet Sorghum	200,290	8,231
Eucalyptus	327,054	31,547
Leucaena	312,397	33,956
Newspaper.	226,260	--
Municipal Solid Waste	417,282	--

G. STEPS IN THE ETHANOL PRODUCTION PROCESS

Production of ethanol from biomass involves a series of steps that liberate constituent sugars making them available for fermentation to ethanol. The technologies described in this section share the capability of liberating the cellulose and hemicellulose from the plant material and producing the component sugars for fermentation to ethanol. Figure IV-5 shows the various steps in a lignocellulosic biomass-to-ethanol conversion process. The starting material, "organic biomass," is in the top row on the left. This material is processed by treatments such as "crushing" and "grinding," with the resulting product being "prepared biomass."

Next, the prepared biomass, shown in the second row, is subjected to a hydrolysis process, with the resultant products being cellulose, hemicellulose, and lignin. Cellulose and hemicellulose are shown in the third and fourth row, with their semi-hydrolyzed counterparts, hexosans and pentosans, and so forth. Intermediate products and process by-products (such as lignin, stillage, carbon dioxide, methane, algae, pharmaceuticals, feed ingredients, etc.) will be discussed in the section of this report which deals with markets and by-products.

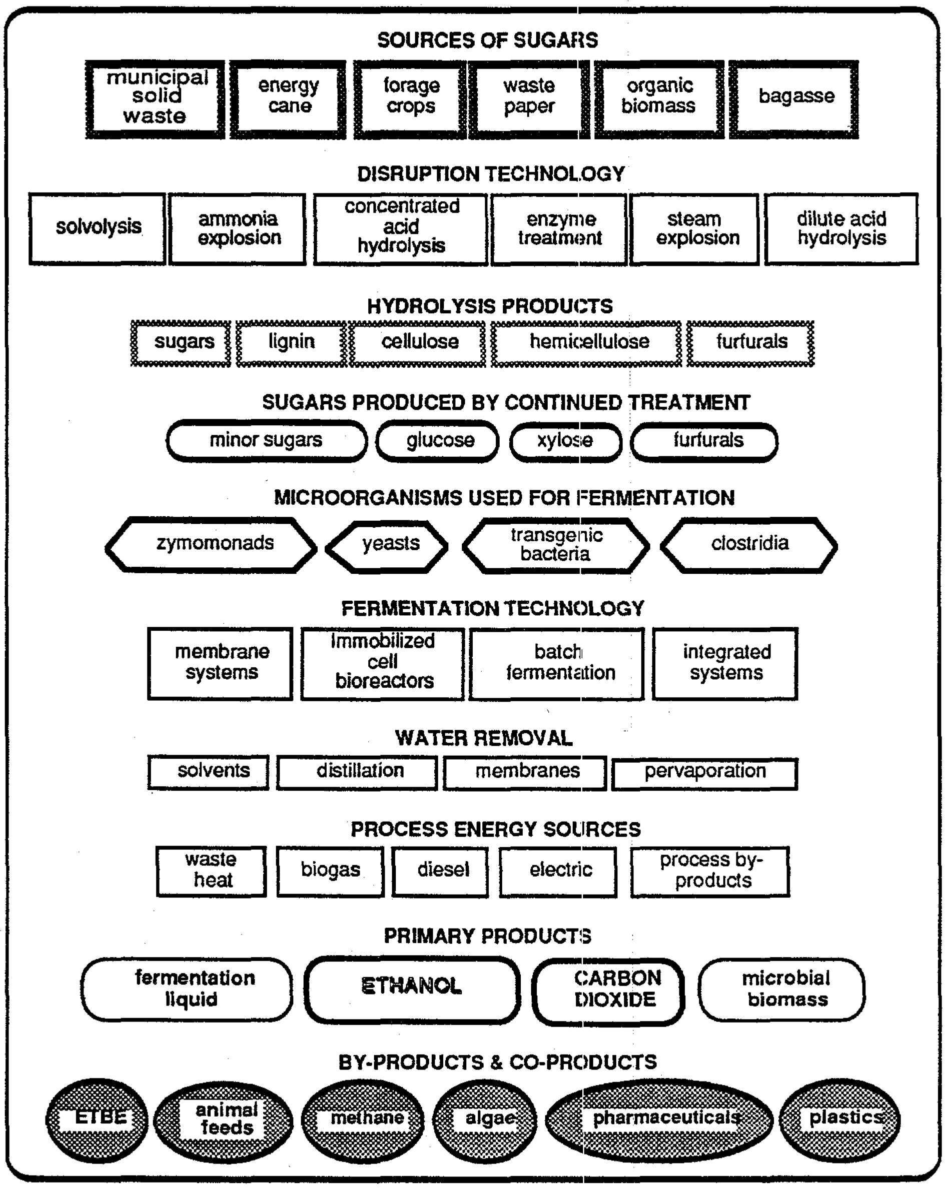
FIGURE IV-5
BIOMASS CONVERSION PRODUCTS

MATERIAL	TREATMENT	PRODUCTS	VALUE/USE
ORGANIC BIOMASS →	Crushing Grinding →	Prepared Biomass	Raw Feedstock for Processing
Prepared Biomass →	Hydrolysis →	Cellulose Lignin Hemicellulose	6 carbon sugars fuel/chemicals 5 carbon sugars
Cellulose Hexosans →	Continued Hydrolysis →	Glucose	6 Carbon Sugars for Fermentation
Hemicellulose Pentosans →	Continued Hydrolysis →	Xylose Pentose Sugars	5 Carbon Sugars for Fermentation
Glucose →	Yeast or Bacterial Fermentation →	Stillage ETHANOL CO_2	Feed Ingredients Fuel Feedstock
Xylose Pentose Sugars →	Bacterial Fermentation →	Stillage ETHANOL CO_2	Feed Ingredients Fuel Feedstock
CO_2 →	Bioconversion →	METHANE ALGAE	ENERGY Pharmaceuticals Commodities
ETHANOL →	Chemical Conversion →	ETBE	OCTANE ENHANCER
ALGAE →	Processing Extraction →	Pharmaceuticals ß CAROTENE Feed Ingredients	MEDICINE ANIMAL FEEDS

H. OPTIONS AT EACH STEP IN THE ETHANOL PRODUCTION PROCESS

There are many options available at each of the steps shown in Figure IV-5. Several government laboratories, academic institutions and private sector companies have devised various techniques to accomplish each of the steps required to process the biomass to ethanol. In many instances, organizations select a particular combination of steps and consider the sequence to be "their" system. The options at each step of the biomass-to-ethanol processes are illustrated in Figure IV-6. "Systems" described in the following section deal with various combinations of these options. The material presented largely duplicates information contained in the DBEDT Report, *Ethanol Production in Hawaii*. For more detailed information on the following section, the reader is encouraged to review the detailed appendices in the *Ethanol Production in Hawaii* report.

FIGURE IV-6
ETHANOL PRODUCTION TECHNOLOGY OPTIONS



I. APPROACH TO EVALUATION OF SYSTEMS

Caution is recommended in interpreting the information in this section. Because only limited information was provided by the developers of technologies, the evaluations are only approximations of the costs and yields from processes that appear to be ready for commercial scale development. The evaluations are only as good as the process information available. In no case was there sufficient information to conduct a rigorous comparison of the technologies. Material presented in this section indicates that a variety of approaches have potential to produce ethanol from biomass in Hawaii, although an assessment of the time frames to commercialization was beyond the scope of this report.

The first step in system and technology comparisons was the development of a questionnaire. This questionnaire was forwarded to a comprehensive list of experts and technology owners. Quantitative, factual information was requested for each step of each of the systems. The success of this approach was limited for four primary reasons:

- The slow response to questions from technology developers;
- A reluctance to provide details that are considered proprietary;
- The processes are at different stages of development, making extrapolations to commercial scale inconsistent across all processes; and
- Different information sources and assumptions are used by the developers, providing no common base for comparison.

Questionnaire responses were not sufficient enough on any key points to enable detailed comparative analysis of the process or even to compare the approaches to each step outlined in Figure IV-6. In the process of trying to obtain the specific details of each system it became clear that many of the technologies had not yet been demonstrated on a commercial scale and that much of the design information provided previously was based on laboratory or limited pilot data.

The limited success with the first questionnaire led to the development of a second survey requesting non-proprietary numbers. The results provided additional information; however, there was still insufficient information on key points to complete the detailed comparison. In order to make comparisons, it was necessary to make extrapolations to fill in missing pieces.

Due to the nature of this study, it was necessary to rely on claims made by those most familiar with the various technologies. In most cases, these individuals were the developers of the technologies and the owners of the patent rights, and therefore may have been somewhat biased in their claims; it should be expected that some individuals may have been more conservative in their projections, and others may have been more optimistic.

J. ASSUMPTIONS USED IN EVALUATIONS

Dr. Hans Grethlein, at the Michigan Biotechnology Institute (MBI), has developed an approach using data from the more complete systems to fill in missing parts from less complete technologies. This method was of great help in these evaluations, and in some cases this information was used directly.[18, 19] Grethlein compared performance of systems producing 25 million gallons per year using corn stover as the source of biomass substrate.

A similar approach was used in this study. Information provided by the questionnaire respondents was for plants of many different sizes and capacities. Scaling factors of 0.7 and 0.9 were used for the plant and personnel, respectively. For the purposes of the comparison, prepared cane was identified as the baseline feedstock. Other assumptions common to the evaluations are shown in Table IV-6.

TABLE IV-6
EVALUATION ASSUMPTIONS

Power Law Scaling Factor	0.7		Process cost only (biomass ($0)	0
Contingency	10%		Biomass Cost 1	$50
Start-up factor	5%		Biomass cost 2	$108
Working Capital	7.50%		Denaturant cost, $/gal	$0.87
Operating Days per Year	330		Denaturant Use	5%
Personnel Scaling Factor	0.9		Fringe Benefits	25%
Property Tax & Insurance	1.50%		Capital Charge, %/yr.	0

K. REVIEW OF ETHANOL TECHNOLOGIES[20]

The material below is presented primarily as a comparative review of technology. Although most of the technologies described below are associated with a specific company, additional information from the technical literature and projections on capital and operating costs in Hawaii were used to complete the comparative evaluations. Because much of the information provided was incomplete, the extrapolations below cannot be used to reach final conclusions regarding economic performance of a specific technology in Hawaii. The results should not be considered representative of the current status of this technology.

NOTE: **The information below is for comparative purposes only, and may not represent the actual performance of any specific proprietary technology in Hawaii.**

1. Simultaneous Saccharification and Fermentation

This technology is largely associated with the research and development program of the National Renewable Energy Laboratory (NREL) in Golden, Colorado. This institution has had a long history of involvement in developing technology for producing ethanol from lignocellulosic biomass. In a succession of development steps, they have settled on the process of Simultaneous Saccharification and

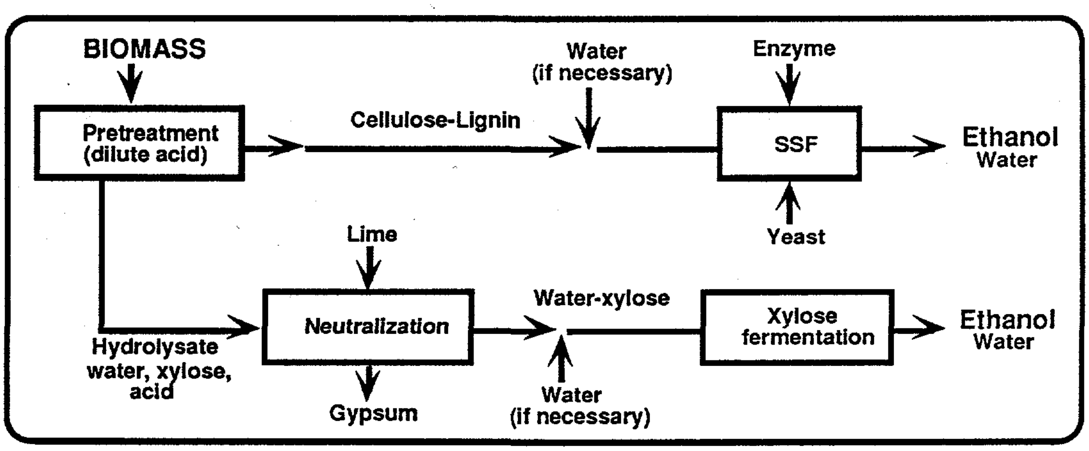
Fermentation (SSF).[21, 22, 23] A 1988 paper by Wright, Wyman, and Grohman[24] provides a useful overview. Quoting selectively from this publication:

> "...All enzymatic processes consist of four major steps that may be combined in a variety of ways — pre treatment, enzyme production, hydrolysis and fermentation. · The key to increasing the digestibility of lignocellulose lies in increasing the cellulose surface area that is accessible to enzymes · by carrying out a pre hydrolysis (dilute 1.1% sulfuric acid at 160°C for 10 minutes) the hemicellulose fraction is removed (93% of the xylan is hydrolyzed resulting in fully digestible cellulose pulp) enlarging pore size and thus opening the structure to attack by enzymes · the degree of digestibility is almost directly proportional to the fraction of xylan removed. Cellulose is then broken down by enzymes. In the SSF process enzymes that break down cellulose are produced separately by the fungus *T. reesei.* Yeast and the enzymes are added to the remaining material where the enzymes digest the cellulose to produce glucose. Glucose is then fermented by yeast or other microorganisms to produce ethanol."

Essential elements of the SSF approach are presented in Figure IV-7. As presented, this is not a complete system; however, it describes an approach to pre-treating and processing biomass that distinguishes this process from the others evaluated. The unique aspect of the NREL approach is that the microorganisms and the enzymes are present in the same system. By converting the sugars to ethanol as they are formed, the inhibitory effect of sugar build-up on enzyme performance is reduced. Wright et al comment (28):

> "...simultaneous saccharification and fermentation systems offer large advantages over separate saccharification and fermentation systems for the production of ethanol from lignocellulosic materials because of their great reduction of the cellulase enzyme complex."

FIGURE IV-7
SIMULTANEOUS SACCHARIFICATION AND FERMENTATION



A very important issue is identified by the statement:

> "The performance of SSF appears to be limited by the performance (combined temperature and ethanol tolerance) of the yeast rather than by the performance of the enzyme."

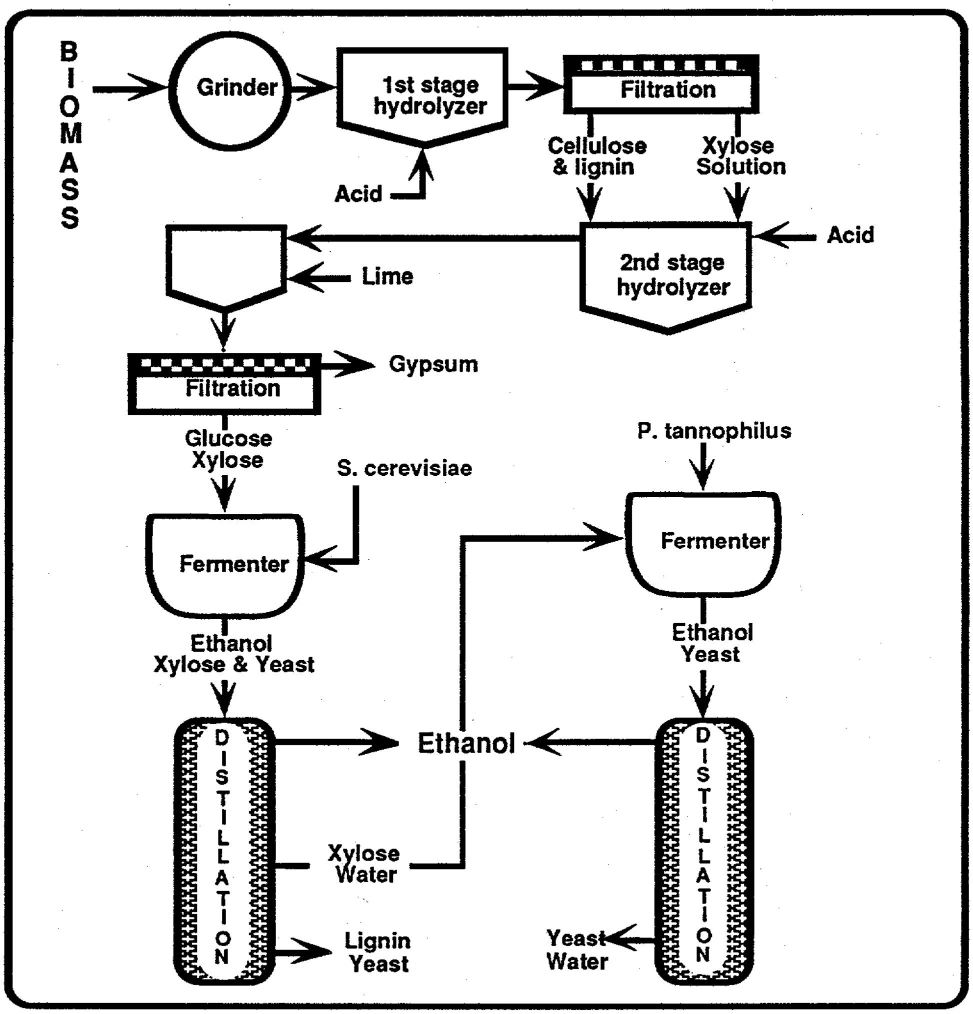
A solution to this problem will be discussed under the section "Technology for Hawaii."

Information provided and available was for a facility producing about 58 million gallons per year, as shown in the Appendix. Cost savings may be possible on the basis of scale and financing mechanisms. Scaling factors for facilities and personnel were used to generate the performance estimates for systems producing 5 and 25 million gallons per year; results are presented in Tables IV-7 and IV-8.

2. Concentrated Acid Hydrolysis, Neutralization, and Fermentation

The Tennessee Valley Authority (TVA) began developing technology for conversion of cellulosic feedstock to fuel ethanol in the 1950s. TVA focused on developing dilute and concentrated acid hydrolysis technologies.[25] Much of the work at TVA focused on processing biomass feedstocks and effluent to multiple products. The TVA programs have developed and evaluated many of the technical options for converting cellulose bound in biomass to sugars, bioconversion of those sugars to ethanol and other chemicals, and waste utilization for conversion of co-products from waste effluent.[26, 27, 28, 29] Although the work at TVA has progressed to include approaches for acid recovery, (discussed later in this section) the use of a base to neutralize acid is presented here to provide a contrast with other technologies. A simplified summary of the process follows:

FIGURE IV-8
CONCENTRATED ACID HYDROLYSIS, NEUTRALIZATION, AND FERMENTATION



The biomass is collected, dried, and milled to pass through a 4 mesh screen. Next, the material is transferred to a first stage hydrolyser or large vat. Sulfuric acid (7.65% by weight) is added to the vat which is heated to 100°C for 2 hours. About 75% of the hemicellulose is hydrolyzed to xylose. The remaining solids (lignin and cellulose) are removed in a screw press and transferred to a separate vessel where additional acid and much of the acidified xylose are added back to increase the sugar concentration. The temperature is again raised which results in the hydrolysis of the remaining cellulose to glucose.

The result is a mixture of 5 carbon (pentose) and 6 carbon (hexose) sugars in acid solution. Lime is added to neutralize the acid, producing gypsum, which is removed in a rotary filter. The remaining solution stream contains both glucose (11.6%) and xylose (9.0%) The fermentation is also conducted in steps. First, glucose is fermented to ethanol by the yeast *Sacromyces cerevisiae*. The mixture is then distilled to remove the ethanol leaving the unconverted xylose behind.

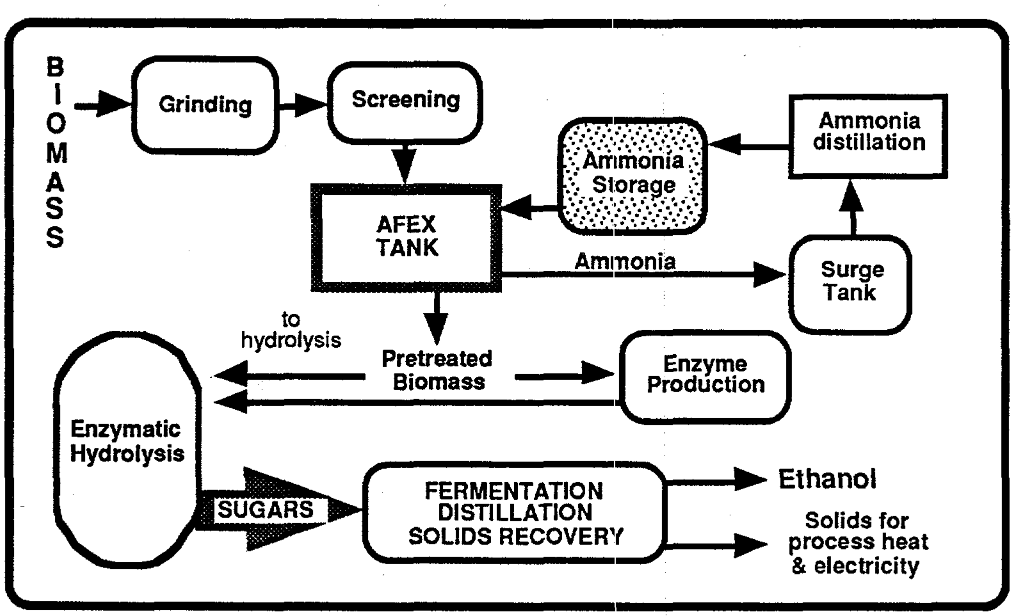
A second yeast *Pachysolen tannophilus* which ferments xylose to ethanol is added to the remaining solution. Ethanol produced from xylose is then distilled. Lignin and cellular material remaining is dried and burned in a boiler to provide process energy or produce electricity. The process is shown in Figure IV-8.

Grethlein et al. made a number of assumptions in their theoretical cost evaluation of the TVA process.[30] Further assumptions have been made in this study regarding financing, start up time, and working capital. Estimated costs for plants producing 5 and 25 million gallons per year using the acid hydrolysis and fermentation process are presented in Tables IV-7 and IV-8.

3. Ammonia Disruption, Hydrolysis, and Fermentation

The development of this technology and its application in converting lignocellulosic material to animal feed was described in the technical literature in the late 1980s. Ammonia is used to pre-treat the lignocellulosic biomass.[31, 32, 33] The biomass is ground and milled into small particles. Ammonia is then infused at high pressures for about 30 minutes at temperatures ranging from 25-90°C (Figure IV-9).

FIGURE IV-9
AMMONIA DISRUPTION, HYDROLYSIS AND FERMENTATION



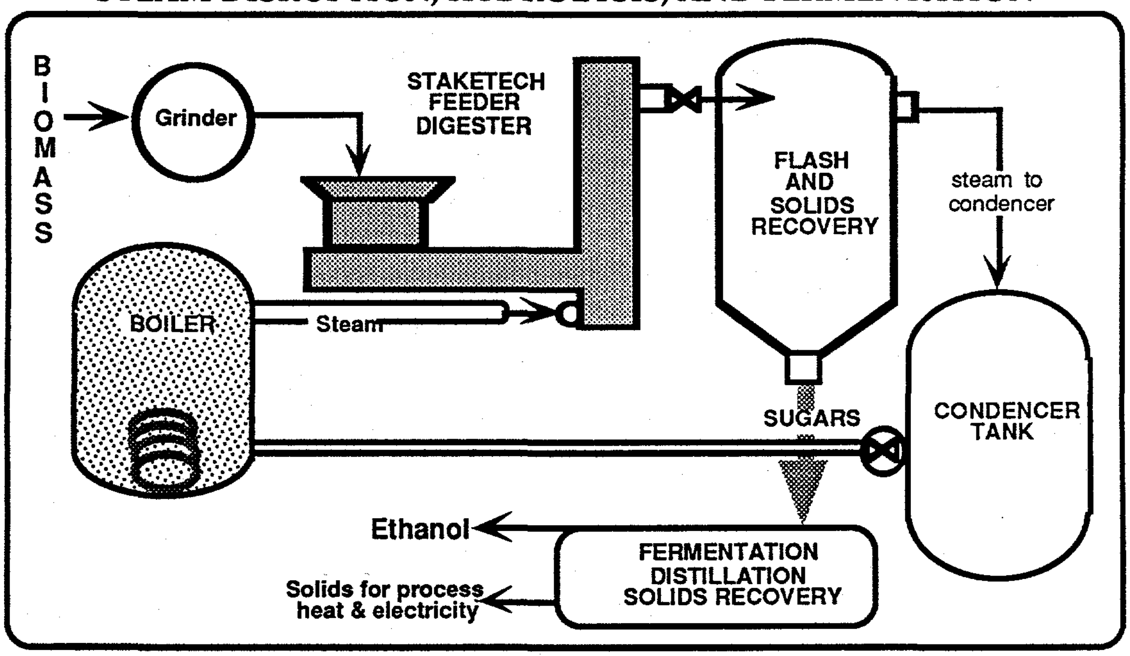
In this process, ammonia infused at elevated pressure and temperature swells and de-crystallizes the cellulose/hemicellulose complex so the biomass is very accessible to the enzyme cellulase. When the pressure is released the ammonia virtually explodes or gasifies. It is then recaptured in a surge tank and recycled. Hydrolysis of cellulose and hemicellulose to sugars is accomplished by adding enzymes that are produced separately on site to the ammonia treated biomass. This process does not degrade protein which can be recovered as an animal feed ingredient. Fermentation is accomplished sequentially as with the concentrated acid hydrolysis process above.

Information provided by Grethlein,[34] technical publications,[35, 36] and local cost estimates were used to complete the economic projections in Tables IV-7 and IV-8.

4. Steam Disruption, Hydrolysis, and Fermentation

Stake Technology Limited, of Norval, Ontario, Canada has been one of the pioneering firms involved with processing of lignocellulosic biomass. The company initially was involved with preparing cattle feed from wood chips using steam to disrupt the crystalline cellulose structure in a fashion similar to ammonia explosion. The Stake Tech people have been involved in sustaining an interest in ethanol in Hawaii for decades and have provided a great deal of information.[37, 38] Figure IV-10 below summarizes the key elements of the process.

FIGURE IV-10
STEAM DISRUPTION, HYDROLYSIS, AND FERMENTATION



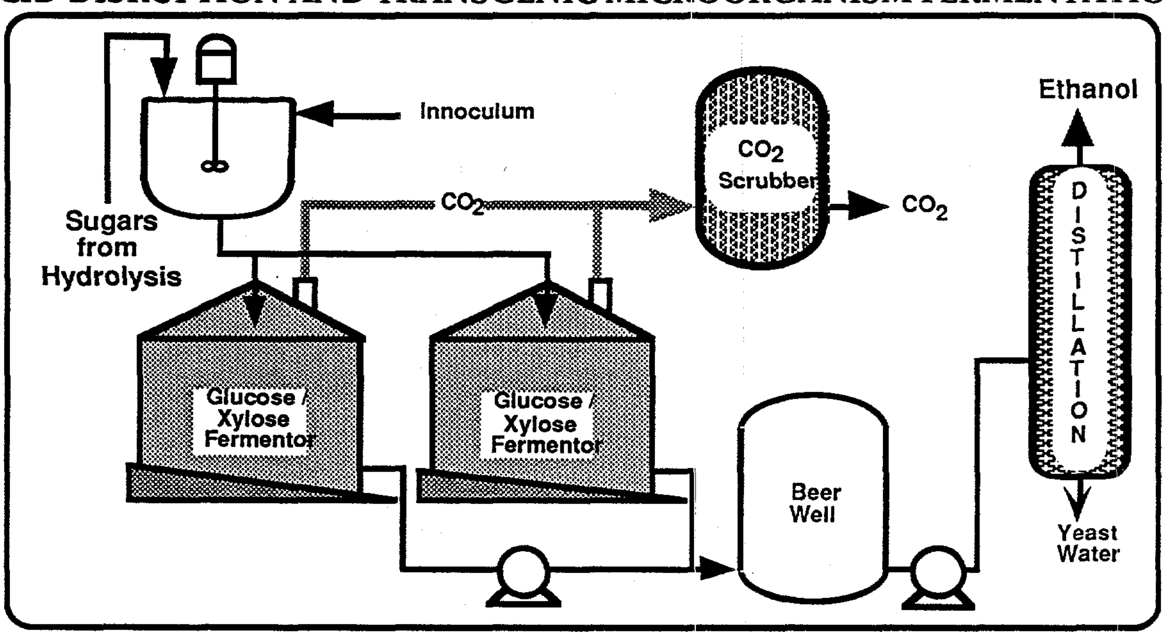
In the steam explosion process, biomass is chopped to an appropriate size and fed into a high pressure reaction cylinder. The solids are moved continuously through the steam reactor tube with an auger and pushed through an orifice where the material literally explodes into a flash tank, where the exploded biomass and steam are recovered. When the pressure is released it causes the deacetylation and auto hydrolysis of the hemicellulose to xylose. The lignin is also melted in this treatment and the remaining biomass becomes a viscous slurry of cellulose and polysaccharides that are available for enzyme digestion to component sugars (primarily glucose).

When the biomass exits the recovery tank it can be fermented and distilled to produce ethanol. It should be noted that volatile organics such as furfural, an inhibitor of microbial fermentation, are also formed. In order to compare the performance of this approach, information provided by Stake Tech was combined with estimates of the costs elements not described by the company and estimates of costs in Hawaii. The projections for a steam disruption, hydrolysis, and fermentation plant producing 5 and 25 million gallons of ethanol per year are presented in Tables IV-7 and IV-8.

5. Acid Disruption and Transgenic Microorganism Fermentation

BioEnergy International, L.C., is a subsidiary of Quadrex Corporation, a publicly held company. They have the exclusive worldwide license for a constructed set of genes that when inserted into a microorganism has the ability to ferment both pentose (5-carbon) sugars and hexose (6-carbon sugars).[39, 40, 41, 42, 43]. This genetic construct, developed by Dr. Lonnie Ingram and co-workers at the University of Florida, was issued U. S. Patent No. 5,000,000 in 1991. This patent outlines the methodology for constructing a unique portable operon for ethanol production, which consists of alcohol dehydrogenase II, and pyruvate decarboxylase genes from *Zymomonas mobilis,* which is inserted into the genome of a host cell such as *E. coli, Erwinia* or *Klebsiella*.[44, 45] This system is designed to enhance ethanol production by diverting pyruvate to ethanol during growth under either aerobic or anaerobic conditions. This allows lactose, glucose, xylose, arabanose, galactose and mannose to be converted to ethanol without producing organic acids.

FIGURE IV-11
ACID DISRUPTION AND TRANSGENIC MICROORGANISM FERMENTATION



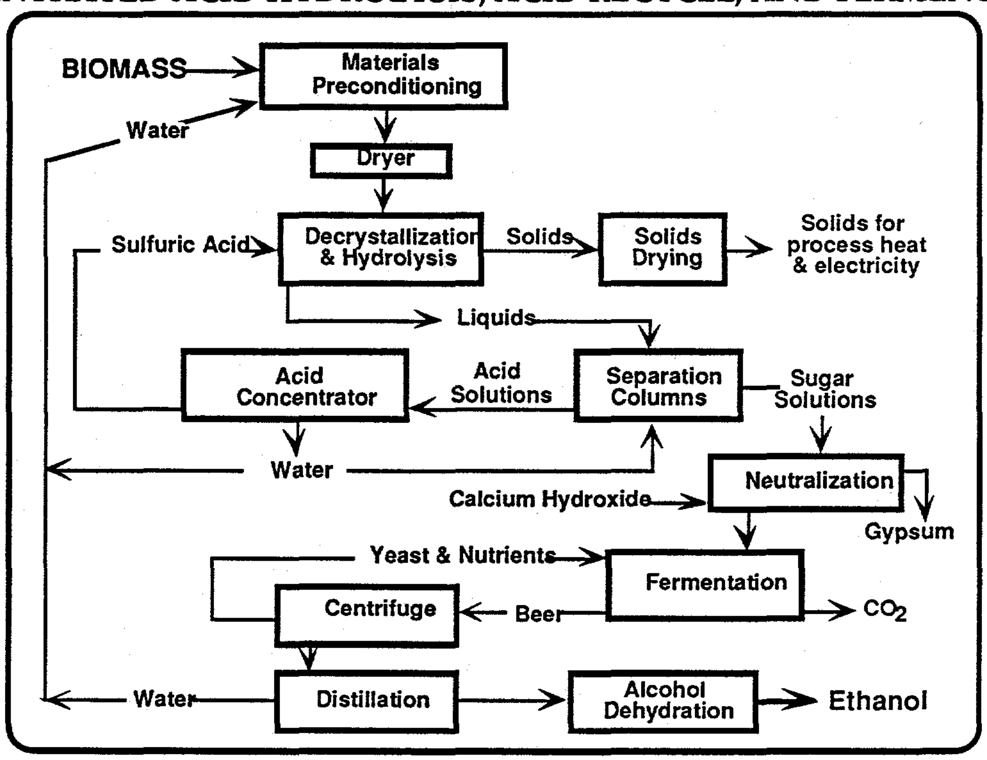
Bioenergy also has the exclusive worldwide rights to all improvements under an on-going research agreement. A simplified view of the downstream process is shown in Figure IV-11 (feed preparation and hydrolysis are not shown).

BioEnergy states that its "...new organisms offer, for the first time, the ability to economically ferment five-carbon sugars to ethanol as well as offering the opportunity to hydrolyze economically the cellulose with enzymes." Complete data on the BioEnergy system and associated costs were not available. Again, Grethlein's approach was used to project performance of a 5 and 25-million gallon per year ethanol plant in Hawaii, shown in Tables IV-7 and IV-8.

6. Concentrated Acid Hydrolysis, Acid Recycle, and Fermentation

Recognizing that the cost of acid, chemicals for neutralizing the acid, and gypsum disposal costs were constraints to using concentrated acid to hydrolyze lignocellulosic biomass, several laboratories have been investigating methods for separating and recovering acid from the hydrolysis mixture.[46, 47] This approach contrasts with those described previously in that it uses concentrated acid hydrolysis with almost 100% acid recycle. Some of the most notable work in developing this technology has been the work done at the Tennessee Valley Authority and the University of Southern Mississippi.[48, 49] Also active in this area is Arkenol Inc., a Nevada corporation, formed in 1992, to develop "thermal host" industrial applications and facilities for the co-generation electric power industry. Biomass-to-ethanol was selected as one of the complementary activities[50] for development.

FIGURE IV-12
CONCENTRATED ACID HYDROLYSIS, ACID RECYCLE, AND FERMENTATION



The process is made up of six basic unit operations: (1) feedstock preparation; (2) hydrolysis; (3) separation of the acid and sugars; (4) acid recovery and recycle; (5) fermentation of the sugars; and (6) distillation. A schematic of the concentrated acid hydrolysis, recycle, and fermentation process is provided in Figure IV-12.

Incoming biomass feedstocks are ground to reduce the particle size for introduction into the process equipment. The pre-treated material is then dried to a moisture content consistent with the acid concentration requirements for de-crystallization (separation of the cellulose and hemicellulose from the lignin), then de-crystallized and hydrolyzed (degrading the chemical bonds of the cellulose) to produce hexose and pentose sugars at the high concentrations necessary for fermentation. Insoluble materials, principally lignin, are separated from the hydrolysate, by filtering and pressing, and then further processed into fuel or other uses.[51, 52]

Commercially available resins are used to separate the acid from the sugar without diluting the sugar. The separated sulfuric acid is re-circulated and re-concentrated to the level required by the de-crystallization step. Any acid left in the sugar solution is neutralized with lime to make hydrated gypsum, $CaSO_4 \cdot 2H_20$, an insoluble precipitate that is separated from the sugar solution. In some cases this material can be sold as an agricultural soil conditioner.

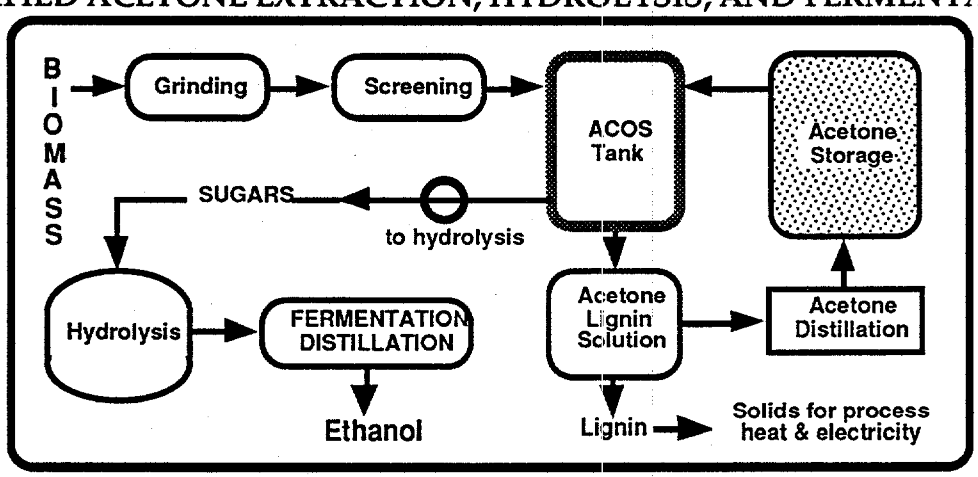
At this point, the process yields a stream of mixed sugars (both C-6 and C-5) for fermentation. The sugars are mixed with nutrients and inoculated with yeast that converts both C-6 and C-5 sugars to fermentation beer (an ethanol, yeast and water mixture) and carbon dioxide. Yeast is separated from the fermentation beer by a centrifuge and returned to the fermentation tanks for reuse. Ethanol is separated from the beer by conventional distillation technology and dehydrated to 200 proof with conventional molecular sieve technology.

Much of the basic process and financial information was provided by Arkenol[53] although, as in other analyses, Hawaii-specific information was included as well. Evaluations of the 5 and 25 million gallon per year production systems are presented in Tables IV-7 and IV-8.

7. Acidified Acetone Extraction, Hydrolysis and Fermentation

Dr. Laszlo Paszner has developed a unique approach to the pre-treatment and hydrolysis of biomass for ethanol production.[54, 55, 56, 57] The process, known as ACOS (Acid-Catalyzed Organosolv Saccharification), involves pre-treatment and grinding of biomass to make the material available for processing. The Organosolv process is shown in Figure IV-13.

FIGURE IV-13
ACIDIFIED ACETONE EXTRACTION, HYDROLYSIS, AND FERMENTATION



The lignin in the biomass is extracted by subjecting the material to acidified acetone at elevated temperature and pressure. Acetone is distilled from the lignin acetone mixture, leaving the lignin available for generation of electricity or process heat. The remaining residue consists of cellulose and hemicellulose that are now easily hydrolyzed to produce sugars for fermentation. The process has been designed to allow continuous extraction of the lignin, hydrolysis of the cellulosic material and fermentation of the sugars to ethanol[58 59]. Based on information provided by Paszner, and estimates for system capital and operating costs in Hawaii, projections for an ACOS type facility producing 5 and 25 million gallons of ethanol per year are shown in Tables IV-7 and IV-8.

8. Traditional Fermentation of Sugars to Ethanol

Fermentation of sugars to ethanol, using commercially-available fermentation technology, provides a fairly simple, straightforward means of producing ethanol with little technological risk. The system modeled assumes the molasses is clarified, then fermented via cascade fermentation with yeast recycle. The stillage is concentrated by multi-effect evaporation and a molecular sieve is used to dehydrate the ethanol.[60]

L. SUMMARY OF TECHNOLOGY COMPARISONS

1. Developmental Status of Technology Options

Although some of the steps in each process have been demonstrated at the pilot-scale or even commercial-scale level (e.g. grinding, screening, pre-hydrolysis, fermentation, distillation, etc.), the integrated systems described in subsections 1 through 7 of the previous section have not yet been demonstrated at a commercial scale. The newly developed steps in the technologies evaluated are generally at the early or late pilot scale stage of development.

The information below is for comparative purposes only, and may not represent the actual performance of any specific proprietary technology in Hawaii. As described earlier in this chapter, data from more complete systems was used to fill in missing parts from less completely described technologies. Due to uncertainties associated with pilot-scale results, and subsequent efforts to evaluate the technologies on a comparative basis, the extrapolations below should not be taken as final conclusions regarding performance of specific technologies in Hawaii.

2. Ethanol Production Costs and Sensitivity Analysis

As stated above, the purpose of these evaluations is to estimate the relative economic performance and appropriateness of the various technologies and to develop a rough estimate of the costs of production of ethanol from biomass sources in Hawaii. Tables IV-7 and IV-8 and Figure IV-14 provide summaries of the evaluation results and indicate the relative sensitivities of the processes to facility size and feedstock cost. Since the costs used in these comparisons are best estimates and may not be consistent for all technologies and processes, these estimates cannot be taken as an endorsement of one process over another. A more detailed site- and technology-specific analysis would be required for a detailed comparison of the processes.

TABLE IV-7
ETHANOL PLANT CAPITAL AND PROCESS COSTS
(BIOMASS COSTS NOT INCLUDED)

	PROCESS COST ONLY (biomass = $0 /ton)					
	25 MILLION GALLONS PER YEAR			5 MILLION GALLONS PER YEAR		
PROCESS	CAPITAL (million $)	$/gallon ethanol	Biomass tons/day	CAPITAL (million $)	$/gallon ethanol	Biomass tons/day
Simultaneous saccharification and fermentation	$81	$0.52	820	$26	$0.65	164
Concentrated acid hydrolysis, neutralization and fermentation	$99	$1.14	952	$32	$1.29	190
Ammonia disruption hydrolysis and fermentation	$124	$0.60	863	$40	$0.83	173
Steam disruption, hydrolysis and fermentation	$110	$0.52	814	$36	$1.78	163
Acid disruption and transgenic microorganism fermentation	$127	$0.64	838	$41	$0.83	168
Concentrated acid hydrolysis, acid recycle and fermentation	$72	$0.94	833	$23	$1.04	167
Acidified acetone extraction, hydrolysis and fermentation	$88	$0.73	779	$29	$0.87	156

TABLE IV-8
ETHANOL PLANT PERFORMANCE SUMMARY
(BIOMASS COST INCLUDED)61

	Biomass cost: $50 / ton (dry matter)		Biomass cost: $109/ ton (dry matter)	
PROCESS	Ethanol $/gallon, 25 million gallon-per-year plant	Ethanol $/gallon, 5 million gallon-per-year plant	Ethanol $/gallon, 25 million gallon-per-year plant	Ethanol $/gallon, 5 million gallon-per-year plant
Simultaneous saccharification and fermentation	$1.06	$1.19	$1.70	$1.83
Concentrated acid hydrolysis, neutralization and fermentation	$1.77	$1.92	$2.51	$2.66
Ammonia disruption hydrolysis and fermentation	$1.17	$1.35	$1.84	$2.02
Steam disruption, hydrolysis and fermentation	$1.06	$1.22	$1.69	$1.86
Acid disruption and transgenic microorganism fermentation	$1.20	$1.38	$1.85	$2.03
Concentrated acid hydrolysis, acid recycle and fermentation	$1.49	$1.59	$2.14	$2.24
Acidified acetone extraction, hydrolysis and fermentation	$1.24	$1.39	$1.85	$1.99

Table IV-8 above shows the cost projection when the delivered cost of biomass[62] is $50 and $108 per dry ton respectively.

FIGURE IV-14
ETHANOL PRODUCTION COST SUMMARY FOR 7 TECHNOLOGIES
(Feedstock Costs Ranging from $0 to $108 per Ton)

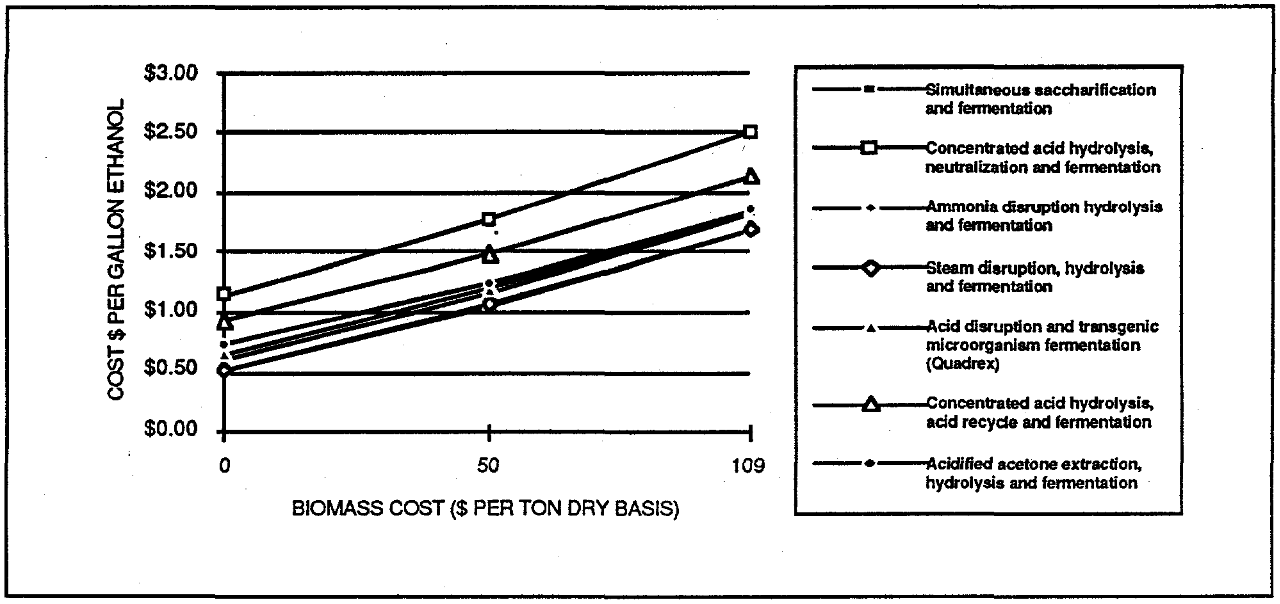


Figure IV-14 provides a graphic representation of the performance of the seven technologies in a 25 million-gallon-per-year plant, with biomass costs shown at $0, $50 and $109 per dry ton.

The analysis does indicate that there are a variety of technologies that may produce ethanol, depending on amounts paid for feedstock, at costs ranging from less than $1.00 to over $2.60 per gallon. This is represented graphically in Figure IV-14. These ethanol production cost estimates do not take into account any potential revenues from by-products. By-products and markets for those products are discussed later in this report.

NOTE: In constructing this chart it was necessary to rely on claims made by those most familiar with the various technologies. It should be expected that some individuals may have been more conservative in their projections, and others may have been more optimistic. Also, these analyses were not site-specific, and significant differences would be expected for different sites, feedstocks, financing costs, labor costs, and so forth. These costs should be viewed as first-cut estimates only.

M. CONCLUSIONS REGARDING ETHANOL OPTIONS

As described in the previous sections, there are several approaches to the production of ethanol from lignocellulosic biomass. However, since the level of uncertainty associated with the analyses may be greater than the apparent differences between the technologies, it is not clear from this analysis what process is the "best." In spite of the previously-described uncertainties, variations in levels of optimism, etc., the analyses resulted in similar cost projections. This similarity lends a degree of confidence that, as the technologies mature, ethanol production costs in Hawaii will fall within this range.

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1 Statement made by an engineer who has been building ethanol plants for over twenty years. He was referring to corn-based ethanol; however, many of the cost reductions and efficiency improvements would be valid for non-corn-based ethanol as well.

2 "Edible" as used here means for human consumption.

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60 Personal correspondence, Carroll R. Keim, April 1994.

61 In constructing these tables it was necessary to rely on claims made by those most familiar with the various technologies. It should be expected that some individuals may have been more conservative in their projections, and others may have been more optimistic. Also, these analyses were not site-specific, and significant differences would be expected for different sites, feedstocks, financing costs, labor costs, and so forth. These costs should be viewed as first-cut estimates only.

62 For the purposes of this evaluation, "prepared cane" provided the chemical composition assumed for "biomass."

V. ELECTRICITY OPTIONS [TASKS 5 AND 6]

At the onset of this program it was not clear if directing biomass to produce electricity, liquid fuels, or a combination of these options would provide the greatest benefits in energy recovery or economic performance. The sugar mills in the state of Hawaii are co-generation facilities which use bagasse biomass as boiler fuel to produce steam for factory operations and electricity for factory operations and sale into the existing grid. An evaluation of the status of facilities in the Hilo/Hamakua region was conducted to determine the feasibility of implementing possible biomass to electricity options. This analysis reviewed the electricity generating capacity of these facilities and defined potential options for stand alone electric generating facilities and/or increasing the efficiencies of these facilities.

The existing power generating facilities at Hilo Coast Processing Company (HCPC) and Hamakua Sugar Company (HSC) were reviewed in terms of process flow and operations, and power equipment and specifications for such equipment. An electric power generation and fuel inventories review was also conducted for both plants. From the information attained during these reviews, a preliminary thermoeconomic analysis for the existing facilities at both plants was conducted.

This analysis provided the basis for defining possible retrofitting options for the existing facilities at HSC and HCPC. The description and results of the analysis of possible retrofit options are presented in this chapter.

Information was then provided to the Bechtel Corporation on the most viable retrofit option and the defined biomass gasification option. A subcontract was awarded Bechtel to conduct an approximate cash flow analysis for these two possible stand alone electric options. The Bechtel report provided the foundation for determining capital costs and costs of operations for stand alone electric options.

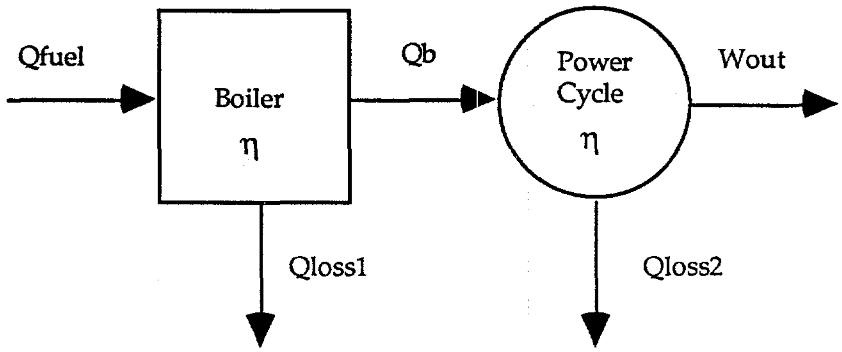
A preliminary financial analysis for the three electric options - existing conventional steam option, retrofit option, and biomass gasifier option - as they affected the sugar mill's overall total income from operations was then conducted. Complete costs of operations for HSC and HCPC were not available do to the existing shut down mode of these facilities. In order to conduct an income from operations comparative analysis, complete costs of operations were obtained from a sugar mill which desired to remain anonymous.

A. POWER CYCLE THERMOECONOMIC ANALYSIS

A rudimentary thermodynamic analysis was conducted to infer values of boiler, cycle, and equipment efficiencies from gross operating data. A simplified representation of the energy conversion process of a combustion power system is given in Figure V-1. The chemical energy of the fuel, Q_{fuel} = mass of fuel x HHV (higher heating value), is released by combustion in the boiler. A portion of this energy, Q_b, is transferred to the working fluid of the power cycle, in the present application, steam, while the balance, Q_{loss1}, is lost to the environment in the form of thermal and chemical energy of the discharged flue gases and solid residue (leaving losses), or by heat transfer to the surroundings (stray losses). Heat recovery techniques such as air preheat, bagasse drying, and the use of economizers reduce both leaving losses and the amount of fuel that must be burned to achieve a given value of Q_b. To characterize performance, a boiler efficiency, h_b, is defined as the fraction of fuel energy transferred to the power cycle working fluid.

FIGURE V-1
POWER CONVERSION PROCESS REPRESENTATION

$$\eta_b \equiv Q_b/Q_{fuel} . \tag{1}$$



The power cycle is a 2T heat engine that converts a portion of the energy input from the boiler to usable (exported) work, W_{out}. The difference between Q_b and W_{out}, Q_{loss2}, is rejected as waste heat to the environment. In conventional steam power systems, heat transfer in condensers accounts almost entirely for Q_{loss2}. In sugar factory cogeneration facilities, however, Q_{loss2} represents the sum of the steam energy that leaves the system by heat transfer to cooling water in the T-G condensers and during the sugar production process (i.e., as a result of the condensation of extracted process steam). Q_{loss2} must also account for the energy generated by mechanical drive units that is consumed in-house by plant equipment.

To assess the ability of the power cycle to produce exportable electrical energy, a cycle efficiency, η_c, is defined as the fraction of thermal energy input from the boiler that is converted to electricity that can be output to the utility grid:

$$\eta_c \equiv W_{out}/Q_b . \tag{2}$$

While, in the present analysis, it typically is assumed that W_{out} represents the energy or power measured at the T-G output terminals, in certain applications, it may be more useful to reduce this quantity by the amount of energy consumed by plant parasitics, such as fans and pumps, that are electrically-driven.

In addition to the parameters η_b and η_c , power system performance often is characterized by a heat rate, HR, that expresses the number of BTU's (British thermal units) that must be supplied, either from the fuel directly or as heat transfer from the boiler, to produce 1 kWh of electrical energy. Following the convention employed by Hubbard et al. (1993), a heat rate based on fuel energy content is defined:

$$HR \equiv Q_{fuel}/W_{out} = \text{fuel Btu content/kWh exported} = 3412/(\eta_b \times \eta_c)\ . \qquad (3)$$

From an operational standpoint, it also may be of interest to determine the quantity of fuel, ***M***, required to produce 1 kWh of exportable electricity:

$$\boldsymbol{M} \equiv \text{quantity of fuel/kWh exported} = HR/HHV\ . \qquad (4)$$

If, for example, the units of HHV are [Btu/lb biomass (dry)], then M yields the lbs biomass (dry) that must be burned in the boiler to produce 1 kWh of electricity.

Finally, to determine the fuel cost associated with the production of 1 kWh of exportable electrical energy, FC, multiply M by the unit cost (say, $/lb (dry) biomass or $/bbl oil) of fuel delivered, in combustible condition, to the boiler:

$$FC \equiv \$/kWh = UC \times M = (UC \times 3412)/(HHV \times \eta_b \times \eta_c)\ , \qquad (5)$$

where UC is the unit cost (delivered) of fuel in $/lb (dry) (for biomass) or $/bbl (for oil) and HHV must then be given as BTU/lb or BTU/bbl, respectively.

Heating values of boiler fuels of interest to the present investigation are available in the literature. The cost of fuel oil and coal delivered to the HSC and HCPC factories are documented in the HSPA database and studies have been undertaken to determine delivered costs of different varieties of prepared biomass fuel stocks. Examination of equations (3), (4), and (5) suggest, therefore, that a preliminary assessment of the viability of power generation options based at the HSC and HCPC factories may be completed if values of plant electrical output capacities and the parameters, η_b and η_c, can be estimated.

B. POWER GENERATION FROM BAGASSE ON THE ISLAND OF HAWAII

An evaluation of the existing steam power generation facilities at the Hamakua Sugar Company (HSC) and Hilo Coast Processing Company (HCPC) has been completed. A first-cut analysis was conducted to estimate power generation potential and conversion efficiencies of several alternatives for stand-alone operation, employing all or part of the installed equipment. Results are presented that can be applied to an economic assessment of these biomass electricity options.

1. Percentage of Big Island Electrical Production Represented by HSC and HCPC

The Hamakua Sugar Company (HSC) and Hilo Coast Processing Company (HCPC) cogeneration facilities located on the eastern coast of the island of Hawaii are scheduled to cease operation within the next two years. They make an important contribution to electricity production on the Big Island. Compounding the loss to the local economy, closure of these factories is expected to impact electric utility services in the near term by reducing the reserve margin of installed power generation capacity. At present, HSC is capable of producing up to about 20 MW using three steam turbine-generators and a 5.4 MW diesel generator. The single HCPC turbine-generator is rated at 23.8 MW. In 1993, the combined firm capacity commitment of these two factories to HELCO (Hawaii Electric Light Company), the local utility, was 26 MW (8 MW from HSC; 18 MW from HCPC), or approximately 12.6% of the total 205.6 MW installed on the island. This 26 MW represents more than 50% of the 1993 reserve margin of 50.6 MW. Moreover, HCPC and HSC have been major power exporters since 1974 and 1982, respectively. For example, in 1991 HCPC and HSC exported a total of 181 x 10^6 kWh to the utility grid, representing about 22% of the electrical energy distributed to the general public that year.

HCPC exported and sold 77.3% (110.13 x 10^6 kWh) and 79.2% (118.92 x 10^6 kWh) of the electricity generated in 1986 and 1991, respectively, to the local utility, Hilo Electric Light Company (HELCO). In 1986, HSC exported and sold approximately 65% of the electricity generated by its cogeneration system. The value for total power exported to the utility grid by HSC in 1991 (62.06 x 10^6 kWh) provided by HSPA, however, also includes a substantial portion generated by a 5.400 MW diesel generator placed on-line that year. It is difficult, therefore, to determine precisely what percentage of the electricity produced by the steam cogeneration system was sold to HELCO in 1991 (HSC diesel-generated electricity was 19.16 x 10^6 kWh in 1991; hence 70.8% of steam- and diesel-generated electricity was exported). In 1991, the combined electricity sold into the grid by HSC and HCPC was 180.98 x 10^6 kWh. This represented approximately 20% of the total Big Island net electrical generation for 1991.[3]

Although HELCO has taken steps to minimize the effects of the announced closures, benefits associated with maintaining partial or full operation of the HSC and HCPC power generation facilities recommend that a study be conducted to evaluate the possibility of converting these sugar factories to dedicated power stations. Since both facilities were designed to burn bagasse as a primary fuel, and in consideration of the traditional agricultural base of the community, biomass would be the energy resource of choice for these power stations.

2. HSC & HCPC Cogeneration Systems Overview

The cogeneration systems installed at the HSC and HCPC factories are described in a report by Kinoshita (1990). The primary source for recent (through 1991) operating data was the Hawaiian Sugar Planters' Association (HSPA). The present investigation assesses the stand-alone power generating potential of the HSC and HCPC factories. Several operating options are proposed that involve moderate investments in the form of new or upgraded equipment. This strategy of utilizing existing equipment (and, hence, minimizing capital expenditures) results in favorable energy costs and can be implemented almost immediately; it is believed to represent the most viable near-term alternative.

Table V-1 provides a summary of information on the power boilers and related equipment.

TABLE V-1
POWER EQUIPMENT AT HSC AND HCPC

	HSC	HCPC
Boiler Manufacturer	Foster-Wheeler, Comb. Eng.	Babcock & Wilcox
Boiler Capacity (1000 lb/hr)	290, 100	330
Steam Pressure (psig)	610, 610	1260
Steam Temperature (°F)	800, 800	825
Heat Recovery Devices	A, D	A, D, E
Boiler Efficiency (%)	68-70	68-70
Emissions Control Devices	D, M, S	D, M
T-G Capacity (MVA)	5.0, 7.5, 9.4	28.0
Extraction Pressures (psig)	15	160, 12

Notes: Boiler Efficiency is for bagasse (≤ 48% moisture before dryer).
Heat Recovery Devices: A: air preheater; D: bagasse dryer; E: economizer
Emissions Control Devices: D: bagasse dryer; M: multicyclone dust collector; S: wet scrubber

The two HSC boilers can be fired with bagasse or No. 6 fuel oil, while the single HCPC boiler also burns coal. Both facilities employ high-, intermediate-, and low-pressure headers to distribute steam between turbine-generator (T-G) modules, mechanical drive units, and the sugarcane processing factory. At HSC, three T-Gs rated at 5.0, 7.5, and 9.4 MVA (17.5 kW total rated capacity, based on a power factor of 0.8) generate approximately 14.4 MW of electrical power under typical processing operation. Mechanical drives produce a nominal power output of 7,100 hp (5.3 MW), which is consumed internally by sugar factory equipment and power plant parasitics (i.e., IDFs, cooling water pumps, etc.). Approximately 73% of the steam is extracted at 15 psig (0.205 MPa) for factory processing use.

The HCPC cogeneration system employs a single 28.0 MVA T-G that produces between 23 and 24 MW of electrical power. Mechanical drives provide about 4600 hp (3.4 MW) to operate plant equipment and 48% of the steam is extracted at 12 psig (0.184 MPa) for processing use. Unlike the HSC power loop, which essentially comprises a simple Rankine cycle, the HCPC system utilizes regeneration (i.e., feedwater heating) to improve thermal efficiency. Approximately 15% of the total steam flow is extracted from the intermediate-pressure header at 160 psig (1.2 MPa) and is diverted through a closed feedwater heater.

From an (exportable) electrical power generation perspective, the HSC cogeneration system is poorly configured. A large fraction of the steam energy is expended in the plant mechanical drive units or is lost in sugar processing operations. Moreover, the multiple T-G modules complicate operation and probably compromise thermal efficiency. In comparison, the HCPC facility has a higher ratio of generated electrical power to plant mechanical drive output (6.8:1 vs. 2.7:1 for HSC) and a smaller extracted process steam fraction (48% vs. 73%).

3. HSC and HCPC Electrical Power Generation Capabilities

Table V-2 presents data on total electrical energy generated and fuels burned by the HSC and HCPC steam cogeneration systems for 1986 (Kinoshita, 1990) and 1991 (unpublished HSPA data).

TABLE V-2
ELECTRICAL POWER GENERATION AND FUEL INVENTORIES FOR 1986 AND 1991

	HSC 1986	HSC 1991	HCPC 1986	HCPC 1991
Generated (10^6 kWh)	63.25	68.47	142.43	150.22
Boiler Bagasse (dry tons)	246,008	159,606	135,986	104,951
Boiler Fuel Oil Equivalent (bbl)	54,708	90,018	129,480	234,886
Bagasse Heat. Value (10^9 Btu)	4,035	2,650	2,230	1,744
Fuel Oil Heat. Value (10^9 Btu)	345	567	816	1,480
Total Heat. Value (10^9 Btu)	4,379	3,217	3,046	3,224

Notes: In 1991, HCPC burned 8,318 tons of coal @ 0.3 ton coal equivalent to 1 bbl No. 6 fuel oil.
HHV of bagasse ranges from 8,200 to 8,300 Btu/lb.
Both HSC and HCPC burn No. 6 fuel oil w/HHV of 6.3 x 10^6 Btu/bbl.

4. Hamakua Sugar Company Assessment

In its current condition, the HSC steam cogeneration system is poorly configured to supply exportable electric power to the utility grid. Although the combined rating of the three turbine-generators exceeds 17 MW, they apparently have been designed or modified to operate at flows and pressures defined by the steam requirements of the sugar processing plant. These flow rates and inlet and outlet pressures are summarized in Table V-3. As a consequence, integrating these three prime movers into a dedicated steam power cycle would require that a number of the units be operated significantly off-design, with a resulting degradation in performance and an increased possibility of damage. It should be noted that efficiencies of the turbine-generators (inferred from operating data) are rather low even when employed as-designed. Furthermore, since a large fraction of steam (73%) was intended to be extracted for sugar processing use, the existing system lacks adequate condensing capacity. The single surface condenser is capable of handling only about 80,000 lb/hr of the 390,000 lb/hr of steam that the boilers can produce.

TABLE V-3
HSC STEAM TURBINE-GENERATORS

Nameplate Rating (MVA)	Steam Flow Rate (lb/hr)	Inlet Pressure (psig)	Outlet Pressure (psig)	Inferred T-G Efficiency (%)
9.4	80,000	235	2" Hg abs.	70
7.5	250,000	610	235	60
5.0	85,000	480	15	59

The HSC facility utilizes two steam generators: a 290,000 lb/hr Foster-Wheeler unit and a 100,000 lb/hr Combustion Engineering boiler. Both can produce steam at 610 psig and 800°F and are fired with bagasse or No. 6 fuel oil. The Combustion Engineering boiler is the older of the two steam generators. It was decommissioned once and later brought back into service. Discussions with sugar industry personnel suggest that its condition is marginally poor. The Foster-Wheeler boiler was damaged by a major fuel fire in 1991 and its current condition is unknown. Industry personnel have mentioned that, after the fire, problems occurred with fluctuating drum water levels, boiler tube failures, and air leaks into the combustion chamber. Given the relatively low operating pressures of these steam generators (which limit the attainable cycle efficiency) and the high probability that major repairs will be required in the near future, the long-term potential for utilizing the Foster-Wheeler and Combustion Engineering units as part of a dedicated biomass combustion power system does not appear to be good.

A final factor that argues against retrofitting the HSC facility to operate as a dedicated biomass power station is the poor condition of the bagasse handling system. Ideally, this system would be retained in a retrofitted plant, although modifications might be required to accommodate different biomass feed stocks. Over the past few years, failures in the HSC bagasse handling system (usually related to conveyers and carriers) have resulted in significant downtime. It is believed that correcting the existing problems would require a substantial capital investment.

Based on the difficulty of integrating the existing turbine-generators into a dedicated power system, the lack of condensing capacity, and the marginal condition of the steam generators and bagasse handling system, it is recommended that retrofit options not be considered for the HSC facility. In the long-term, it probably would be more cost-effective to consider the alternative of installing a new biomass gasifier/combined-cycle plant at this location.

5. Baseline Plant Performance

The HSC cogeneration cycle has installed T-G capacity (nameplate) of 21.9 MVA (approx. 18 MW). The two 610 psig boilers can produce 390,000 lb/hr of superheated steam at 800°F. At 100% availability, the system can generate approximately 153 x 10^6 kWh per year.

Kinoshita (1990) recommends η_b = 0.68 (68%) as an average value for the two HSC boilers burning bagasse with a moisture content of 48.5% upstream of the bagasse dryer units. It is estimated that flue gas drying reduces the moisture fraction to about 45% at the furnace inlet. While discussions suggest that the existing boilers can be employed successfully to burn other biomass fuels such as banagrass, eucalyptus chips, or leucaena, it should be emphasized that modifications may be required to utilize the existing dryer units. This is an important consideration since studies indicate that h_b decreases by about 0.6 percentage points for each 1 percentage point increase in fuel moisture content. HSPA operating data, which provide values of Q_{fuel} and Q_b, confirm that h_b lies in the range of 68% to 70%.

HSPA data indicate that η_b increases to 80% when No. 6 fuel oil is substituted for bagasse. This value is comparable, albeit slightly low, to typical boiler performance in conventional fossil fuel power plants.

Power cycle efficiency was estimated using annual generated electricity given in Table V-2 (taken as equal to W_{out}) and calculated values of Q_b obtained by multiplying the heating values of all bagasse and fuel oil burned during the year by the appropriate boiler efficiency. It should be observed that η_c determined in this fashion reflects a weighted average of the HSC electrical generation system being run in both a sugar processing mode (full process steam extraction and mill equipment operation) and a much more efficient weekend, or full-condensing, mode (minimal process steam extraction and plant parasitics). The 1986 data yield $\eta_c = 7.2\%$; 1991 data correspond to $\eta_c = 10.1\%$.

Medium capacity conventional fossil fuel power stations typically operate with a steam cycle efficiency of between 30% and 40%. The very low value of η_c calculated above was confirmed by a more detailed cycle analysis and reflects the large fraction of the available energy carried away by the process steam as well as the substantial internal parasitics of the mill.

6. Hilo Coast Processing Company Assessment

In contrast to the HSC factory, the HCPC cogeneration facility appears to offer good potential to operate as a dedicated biomass power station. The major components of the fuel handling and steam power generation systems are fairly new and efficient and have been well-maintained; hence, they are in good operating condition. Moreover, the HCPC facility was designed originally to satisfy a primary function of exporting electric power.

During sugar processing, the turbine-generator produces about 24 MW, with 48% of the steam being extracted for factory use. Off-season, the facility is operated in a full-condensing (no extraction) mode to generate 21 MW of power, of which 18 MW is exported to the utility grid. In order not to exceed the rated capacities of the L.P. turbine stages and the condenser, steam production and flow rate through the H.P./I.P. turbine stages is reduced from about 325,000 lb/hr to 200,000 lb/hr. An analysis conducted utilizing data provided by plant personnel indicates that the system heat rate corresponding to full-condensing mode operation is reasonably good. It is proposed, therefore, that one viable option may be to use the plant without modification as a dedicated biomass power station. A second option would fully exploit the power production potential of the boiler and the H.P./I.P. turbine stages by installing a second L.P. turbine-generator and surface condenser to utilize the additional steam.

The single HCPC cogeneration cycle T-G has a nameplate capacity of 28.0 MVA (approx. 23 MW). The 1260 psig boiler can produce 330,000 lb/hr of superheated steam at 825°F. At 100% availability, the system can generate approximately 208 x 10^6 kWh per year.

Kinoshita (1990) recommends $\eta_b = 0.68$ (68%) when burning bagasse with a moisture content of 48.6% upstream of the bagasse dryer unit. HSPA operating data indicate that η_b lies in the range $68\% \leq \eta_b \leq 71\%$. It is emphasized, once again, that fuel moisture content will strongly impact this parameter. As in the case of the HSC boilers, the high-pressure HCPC boiler appears to be able to accommodate other biomass fuel stocks. When burning fossil fuels such as No. 6 fuel oil or coal, η_b increases to 85%.

Following the procedure described in the Power Cycle Thermoeconomic Analysis discussion, a weighted average of power cycle efficiency during sugar production and full-condensing mode operation of approximately 22% was calculated. This comparatively high η_c results from a number of factors, including relatively low fractions of extracted process steam and mill parasitics and also the use of regeneration to increase the average temperature at which energy is transferred in the boiler.

C. OPTIONS FOR FUTURE POWER GENERATION FROM BIOMASS IN THE REGION

An evaluation of the existing steam power generation facilities at the Hamakua Sugar Company (HSC) and Hilo Coast Processing Company (HCPC) has been completed. A first-cut analysis was conducted to estimate power generation potential and conversion efficiencies of several alternatives for stand-alone operation, employing all or part of the installed equipment.

This phase of the work focused on the evaluation of options for improving the capacity for electricity production in the Hilo/Hamakua region. The evaluations involved the following tasks :

1) Evaluate the option for a stand alone, co-fired, generating station based on biomass resources with backup capacity by a co-fired fossil fuel system to meet the electricity supply needs of HELCO in the next 5 to 10 years.

2) Determine the timing, type, size, and location(s) of biomass power plant(s) best suited to integrate into HELCO's resource needs for energy and capacity.

The analysis considers several options for producing exportable electrical power from biomass combustion, utilizing all or part of the equipment currently installed at the HSC and HCPC factories.

1. OPTIONS FOR ELECTRICITY PRODUCTION AT HAMAKUA

The three options for the Hamakua Sugar Company electricity production facility are:

a. HSC Option 1: Pseudo Processing Mode (Baseline)

To maximize capacity (MW) without modification of equipment, the cogeneration facility will be run in a "pseudo-processing" mode where the steam production in the boilers is essentially unchanged from the current operation. Process steam is extracted and condensed in the boiling house using water instead of cane juice as a coolant. Mechanical drives are run as necessary to ensure full steam flow rate through the T-Gs, and as required to power essential equipment such as IDFs, pumps, etc. This option clearly is not practical due to the large amount of wasted energy and is considered primarily to establish a baseline; however, such a pseudo-process may be required for brief periods of time when electrical output must be increased above the limits of operation for the full-condensing mode described below.

b. HSC Option 2: Full Condensing Mode (Minimal Modifications)

To maximize cycle efficiency utilizing the existing or slightly modified equipment, steam production in the boilers will be reduced to a value that results in no significant degradation of performance of any T-G stage or condenser, while, at the same time, bypassing the mechanical drives and steam extraction loop. All steam produced in the boiler will be condensed in the existing low pressure (about 1.5 psia) condensers. Since flow rates through the high-pressure turbine stages typically will be reduced significantly (by roughly the amount that currently is extracted), gross output power will fall. This full-condensing mode operation will have improved cycle efficiency at the cost of reduced capacity.

c. HSC Option 3: Utilize Existing Boilers; Upgrade Other Equipment

A preliminary assessment of the existing power equipment suggests that the most salvageable items are the boiler units (although the Combustion Engineering boiler at HSC is somewhat marginal). Since boilers typically represent the major capital cost item of a combustion power plant, it may be feasible to consider replacing the other power cycle equipment (i.e., T-Gs and condensers) with state-of-the-art units that will yield a significant increase in η_c. For this option, the maximum output capacity of a biomass power station utilizing the existing boilers is estimated.

d. Summary of HSC options

Table V-4 summarizes the results of the analysis of the three biomass electricity options for HSC.

TABLE V-4
ESTIMATED OPERATING PARAMETERS FOR BIOMASS OPTIONS FOR HSC

Option	Capacity (MW)	η_b (biomass/oil)	η_c	HR (biomass/oil)
1	14.4	0.70/0.80	0.11	44,300/38,800
2	7 - 9	0.70/0.80	0.24	20,300/17,800
3	30 - 40	0.70/0.80	0.30	16,200/14,200

Notes: Capacity is electrical power available for export after reduction by in-house parasitics.
η_b for biomass is for approx. 45% moisture at the furnace inlet w/heat recovery.
Units for Heat Rate, HR, are [Btu/kWh].

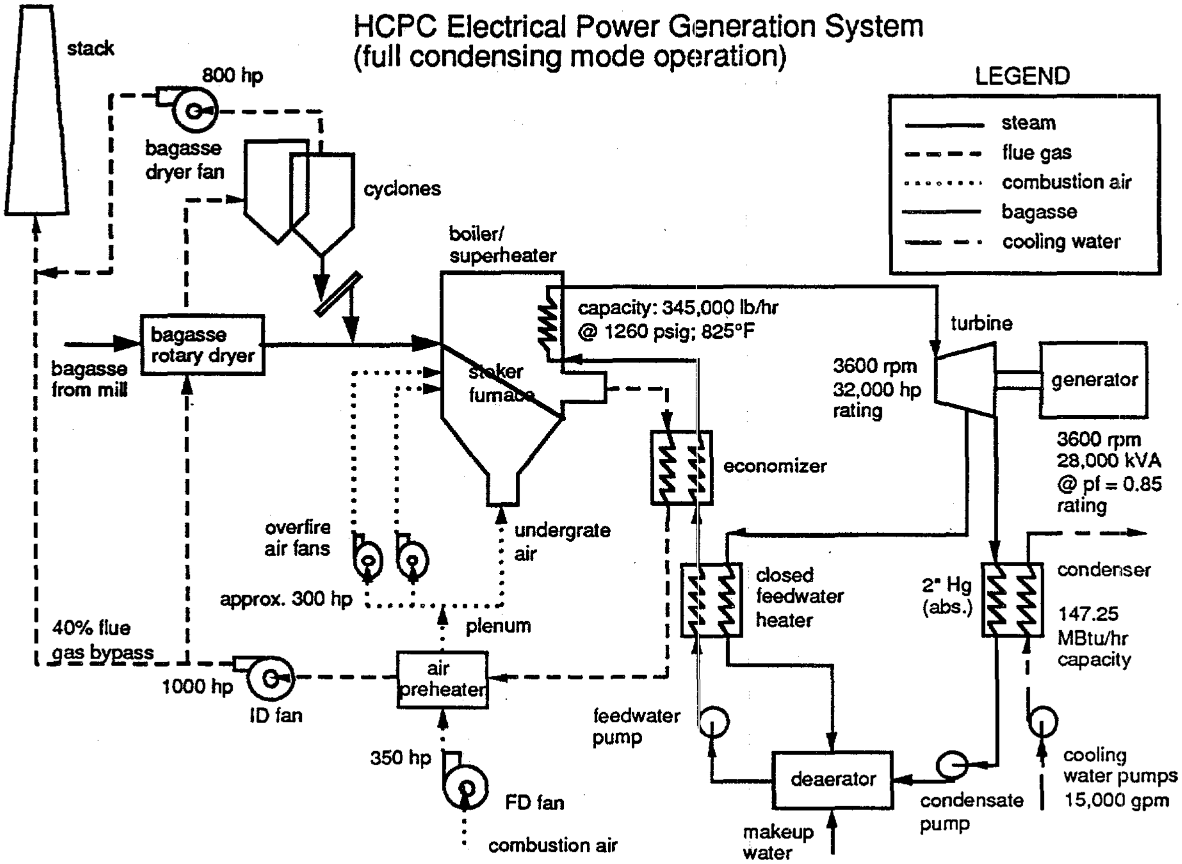
2. OPTIONS FOR ELECTRICITY PRODUCTION AT HILO COAST PROCESSING COMPANY

The two options for the Hilo Coast Processing Company electricity production facility are:

a. HCPC Option 1: Full Condensing Mode, No Modifications

A schematic diagram which identifies the major components of the HCPC biomass (bagasse) power cycle that are presently being utilized during full-condensing mode operation is presented in Figure V-2. Superheated steam is generated in a traveling-grate Babcock & Wilcox (BW) stoker furnace that can be fired with bagasse, coal, or No. 6 fuel oil. Boiler capacity is 345,000 lb/hr of steam (upgraded from an original value of 330,000 lb/hr) at 1260 psig and 825°F. Combustion air is supplied to the furnace by a 350 hp forced-draft (FD) fan and two overfire air fans having a combined motor rating of approximately 300 hp. Flue gases are exhausted using a 1000 hp induced-draft (ID) fan. Approximately 60% of these gases are diverted through a rotary drum bagasse dryer, designed originally for use with wood chips, and pass through a series of cyclones to remove entrained bagasse fines before being exhausted from a stack. A mechanically-driven 800 hp fan is employed to sustain the flow through this fuel drying system.

FIGURE V-2
HCPC FULL-CONDENSING MODE OPERATION SCHEMATIC



In addition to fuel drying, the HCPC plant pursues flue gas heat recovery through the use of an economizer and air preheater. Tests performed in the late 1980s indicate that the HCPC Babcock & Wilcox unit has a boiler efficiency, η_b, of between 68% and 71% when burning bagasse with a moisture content of about 48% upstream of the dryer. Biomass fuel moisture content strongly affects boiler efficiency: typically, efficiency decreases by approximately 0.6 percentage points for each 1 percentage point increase in fuel moisture. When burning conventional fossil fuels such as coal or oil, η_b increases to 85%.

The steam power cycle utilizes regeneration (i.e., closed feedwater heating) to improve thermodynamic performance. Superheated steam from the boiler expands through the high- and intermediate-pressure stages of a 16 stage, axial flow De Laval turbine before a portion (up to about 48,500 lb/hr) is extracted at about 160 psig to be condensed in the Yuba feedwater heater. The balance expands through the low-pressure turbine stages and is condensed in a titanium shell-and-tube De Laval surface condenser. The turbine is rated at 32,000 hp for 325,000 lb/hr of steam (1250 psig and 825°F at the inlet flange; 2" Hg absolute exit pressure) through the H.P. and I.P. sections and 155,000 lb/hr through the L.P. section. The turbine shaft is coupled to a 3600 rpm, TEFC, synchronous generator manufactured by Electric Machinery. This generator is rated at 28,000 kVA at a power factor of 0.85.

Thermal duty of the two pass surface condenser is 147.25 million Btu/hr, which corresponds to 155,000 lb/hr of steam at 950 Btu/lb. To satisfy this heat load, 14,750 gpm of 70°F cooling water must be provided. At HCPC, brackish cooling water is pumped from deep wells near the coastline and passes through the surface condenser once before being discharged. No cooling towers are employed to recycle this water. The salt and dissolved mineral content of the cooling water to date has posed only minor corrosion and fouling problems to the heat exchanger.

Power consumption by the fans and pumps comprises the primary parasitic losses in this system. Since the FD, ID, and overfire fans are damper controlled, their loads, totaling about 1.23 MW, do not scale with generator output.

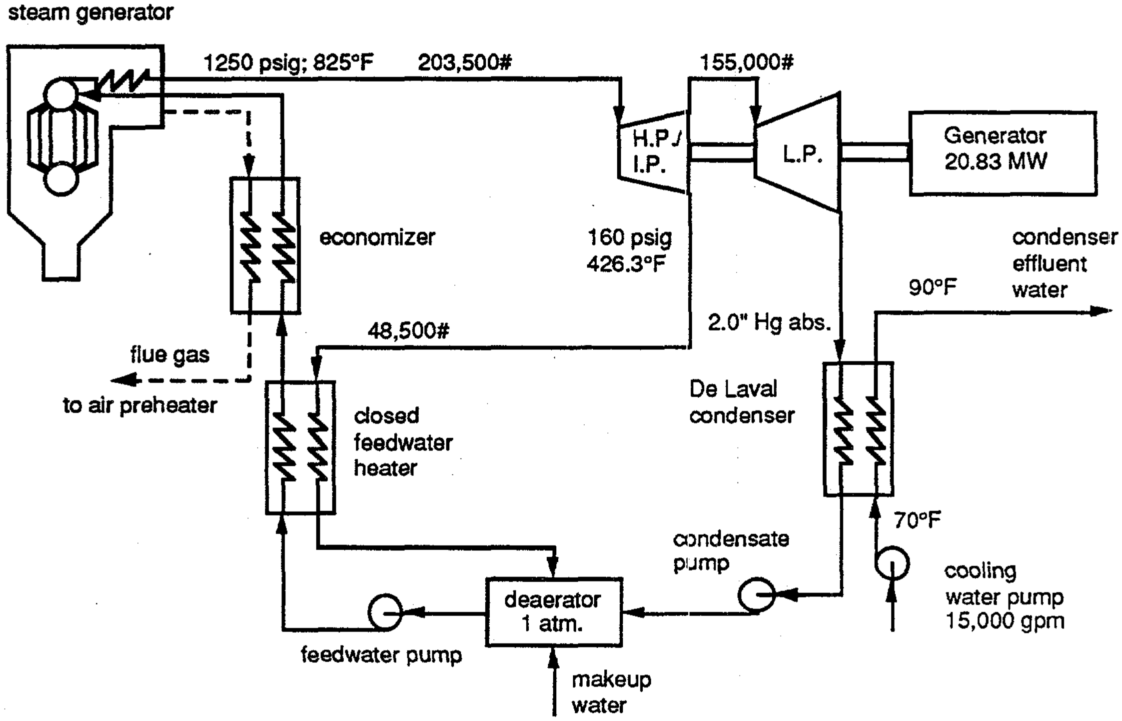
Table V-5 summarizes information on the major components of the HCPC steam power cycle that would be employed for dedicated electricity generation.

As a first option, it is proposed that the HCPC facility be operated without modification in full-condensing mode to produce approximately 20.83 MW of electrical power at the generator terminals. If biomass is burned as a fuel, total back-work, including the fuel dryer fans and biomass conveyers and carriers, is estimated to be 2.83 MW, resulting in 18.0 MW exportable power. Figure V-3 shows the steam power loop corresponding to this option. Here, power output is limited by the flow capacities of the turbine low pressure stages and the surface condenser.

TABLE V-5
POWER EQUIPMENT INFORMATION

Component	Description	Comments
Steam Generator	Babcock & Wilcox traveling-grate stoker furnace; 345,000 lb/hr steam at 1260 psig, 825°F; brought into service 1973	
Turbine	De Laval axial flow turbine; 16 stages; 3600 rpm; 1250 psig, 825°F rated conditions at inlet flange; 2" Hg rated exhaust pressure; 32,000 hp rated output; brought into service 1973	
Electric Generator	Electric Machinery TEFC synchronous generator; 3600 rpm; 28,000 kVA @ 0.85 p.f.; brought into service 1973	rewound 1985 new rotor 1990
Surface Condenser	De Laval shell and tube cylindrical surface condenser; DWB; two pass; shop tubed; 13,700 ft^2 cooling surface; 147.25 x 10^6 Btu/hr thermal duty; 14,750 gpm cooling water supplied by 15,000 gpm pumps; brought into service 1973	B-111 Al. Brass tubes upgraded to titanium
Fans	1000 hp electric ID fan; 350 hp electric FD fan; (2) electric overfire air fans (approx. 300 hp total); 800 hp mech. drive bagasse dryer fan	
Feedwater Heater	Yuba shell and tube; approx. 48,500 lb/hr steam at 160 psig; brought into service 1973	replaced 1985

FIGURE V-3
HCPC ELECTRIC POWER GENERATION OPTION NO. 1



A thermodynamic analysis based on HCPC operating data was conducted to estimate the efficiency of the proposed steam power cycle. This efficiency then was employed to calculate heat rates and other relevant parameters for both biomass and fossil fuel combustion scenarios. Results are summarized in Table V-6.

The principal advantages of this option is that it requires minimal or no additional capital investment and that reliable operation has been demonstrated. Moreover, substitution of candidate biomass fuels such as banagrass, eucalyptus chips, or leucaena for bagasse probably can be performed without extensive modification of the fuel handling system or furnace (caution must be exercised, however, if the fuel is known to produce large quantities of slag when burned). Although conversion of the HCPC facility to utilize 100% coal or oil may be advantageous from the perspective of reducing the fuel cost of the generated electrical power, additional pollution control devices, such as scrubbers, may need to be installed. The associated costs could offset any potential benefits. Furthermore, a fossil fuel combustion plant does not provide a means to sustain agriculture in the host community.

TABLE V-6
OPERATING PARAMETERS FOR HCPC OPTION NO. 1

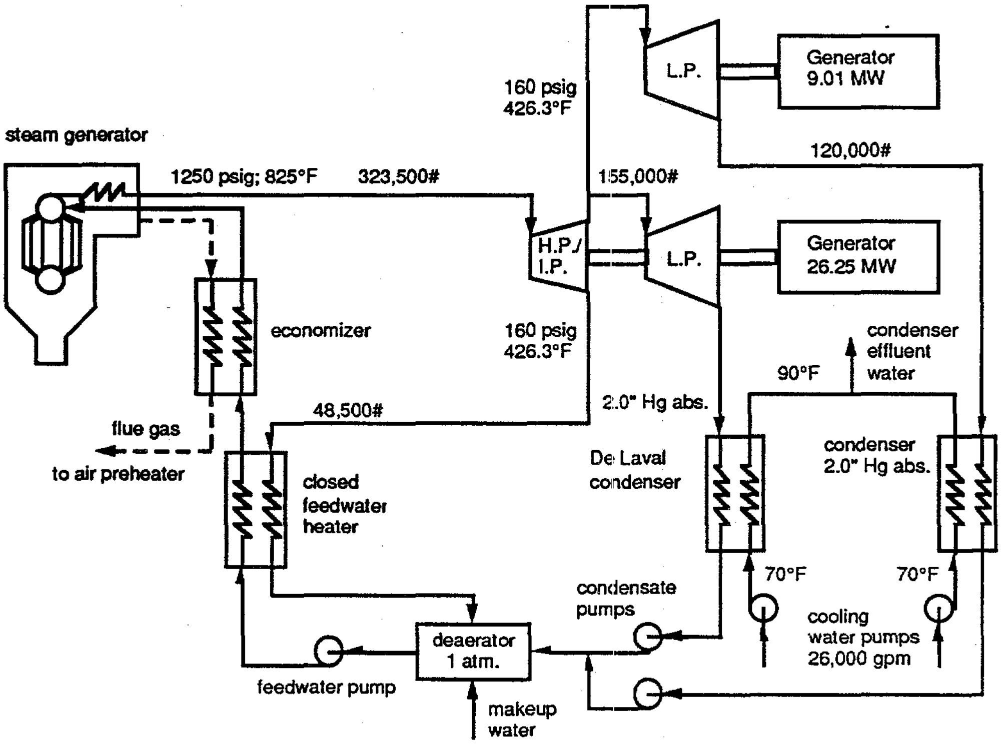
Parameter	Biomass Fuel	Coal or Fuel Oil
Steam generated [lb/hr]	203,500	203,500
Feedwater steam [lb/hr]	48,500	48,500
L.P. turbine steam [lb/hr]	155,000	155,000
Condenser duty [Btu/hr]	138.7×10^6	138.7×10^6
Gross power [MW]	20.83	20.83
Back-work [MW]	2.83	2.24
Back-work ratio [%]	13.6	10.8
Net power (exportable) [MW]	18.0	18.58
Steam cycle efficiency based on net power and heat transferred to steam in the boiler [%]	29.05	29.99
Boiler efficiency [%]	70	85
Heat rate [Btu/kWh exported]	16,789	13,385
Fuel required to produce 1 kWh exported	lb/kWh: bagasse: 2.023 banagrass: 2.125 Eucalyptus: 1.999 Leucaena: 2.023	No. 6 oil: 2.125×10^{-3} bbl/kWh Coal (@ 10,500 Btu/lb) : 6.374×10^{-4} [ton/kWh]
Annual kWh generated @ 100% availability (kWh)	157,680,000	162,760,800
Max. annual fuel requirement	157,680 to 167,535 dry tons	345,800 bbl oil 103,740 tons coal

2. HCPC Retrofit Options 2a and 2b: Additional Low Pressure Turbine

The option described in the preceding section fails to exploit fully the power generation potential of the boiler and H.P./I.P. turbine rows. Due to limitations imposed by the existing L.P. turbine stages and surface condenser, less than two-thirds of the steam that could be produced is generated. A second option is proposed that would maximize the capacity of the HCPC facility by adding an additional low-pressure turbine-generator and condenser. Bechtel was contracted to conduct a more detailed analysis of this alternative.

Figures VI-4. and VI-5 present two variations of this option that produce essentially the same exportable power. The difference lies in the division of steam between the two L.P. turbines. In option 2a (Figure V-4), 323,500 lb/hr of steam flows into the existing turbine and 155,000 lb/hr expands through its low pressure stages resulting in an estimated output of 26.25 MW at the generator terminals. Since this exceeds the 23.8 MW generator rating, modifications may be required. In option 2b (Figure V-5), the 23.8 MW generator is operated at its rated capacity by reducing the L.P. stage steam flow rate to 122,437 lb/hr and redirecting the difference to the new turbine. Although this alternative avoids the cost and system downtime of a generator upgrade, it requires a larger (new) turbine-generator and condenser than option 2a.

FIGURE V-4
HCPC ELECTRIC POWER GENERATION OPTION NO. 2A



Increasing steam generation from 203,500 lb/hr to 323,500 lb/hr results in exportable power increasing by 78% to about 32 MW. Although feedwater and condenser cooling water pumping losses increase, the back-work ratio will decrease due to the fact that the fixed fan power consumption becomes a smaller fraction of the generated power. Estimated cycle efficiencies and heat rates change negligibly. Operating parameters for this option are shown in Table V-7.

The principal benefit of this option is the substantial increase in power generation capability. Since thermodynamic performance remains essentially unchanged from option no. 1, no reduction in the fuel cost of electricity is anticipated to be available to offset the penalty associated with the required capital investments. Specifically, an additional low-pressure turbine generator and surface condenser, as well as cooling water and feedwater pumps and pipelines must be procured and installed. Modifications also may be required to upgrade the utility interface and system controls.

FIGURE V-5
HCPC ELECTRIC POWER GENERATION OPTION NO. 2B

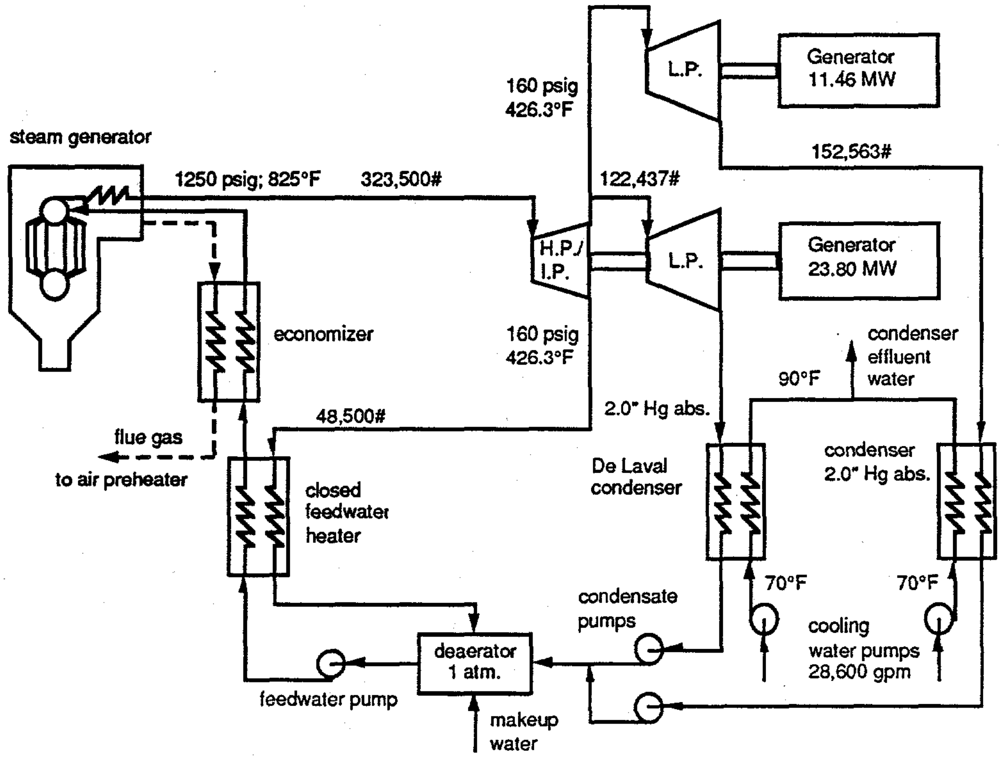


TABLE V-7
OPERATING PARAMETERS FOR HCPC OPTIONS NO. 2A AND 2B

Parameter	Biomass Fuel	Coal or Fuel Oil
Steam generated [lb/hr]	323,500	323,500
Feedwater steam [lb/hr]	48,500	48,500
Existing L.P. turb. steam [lb/hr]	155,000 (2a); 122,437 (2b)	155,000 (2a); 122,437 (2b)
New L.P. turb. steam [lb/hr]	120,000 (2a); 152,563 (2b)	120,000 (2a); 152,563 (2b)
Existing cond. duty [MBtu/hr]	138.7 (2a); 109.6 (2b)	138.7 (2a); 109.6 (2b)
New cond. duty [MBtu/hr]	107.4 (2a); 136.5 (2b)	107.4 (2a); 136.5 (2b)
Gross power [MW]	35.26	35.26
Back-work [MW]	3.52	2.92
Back-work ratio [%]	10.0	8.3
Net power (exportable) [MW]	31.74	32.34
Steam cycle efficiency based on net power and heat transferred to steam in the boiler [%]	29.3	29.9
Boiler efficiency [%]	70	85
Heat rate [Btu/kWh exported]	16,622	13,434
Fuel required to produce 1 kWh exported	lb/kWh: bagasse: 2.003 banagrass: 2.104 Eucalyptus: 1.979 Leucaena: 2.003	No. 6 oil: 2.132×10^{-3} [bbl/kWh] Coal @ 10,500 Btu/lb: 6.397×10^{-4} [ton/kWh]
Annual kWh generated @ 100% availability [kWh]	278,042,400	283,298,400
Max. annual fuel requirement	275,120 to 292,500 dry tons	603,990 bbl oil; 181,230 tons coal

Finally, it must be confirmed that the existing wells can supply the additional cooling water for the new condenser. Estimates of the costs of the turbine and condenser, based on recent vendor quotes for comparable items, are provided for reference in Table V-8. Total capital investment to upgrade net capacity from 18 MW to 32 MW is estimated to be approximately $18 million.

TABLE V-8
TURBINE-GENERATOR AND SURFACE CONDENSER DESCRIPTIONS

Quantity	Option 2a	Option 2b
Turbine inlet press. [psig]	160	160
Turbine inlet temp. [°F]	426.3	426.3
Turbine exit press. ["Hg]	2.0	2.0
Turbine steam flow [lb/hr]	120,000	152,600
Turbine isentropic eff. [%]	78.5% (min.)	78.5% (min.)
Turb./gen. speed [rpm]	3600	3600
Turbine rating [hp]	12,580 (min.)	16,000 (min.)
Generator rating [kVA]	10,600 @ 0.85 power factor	13,500 @ 0.85 power factor
Condenser duty [Btu/hr]	107.4×10^6	136.5×10^6
Condenser press. ["Hg]	2.0	2.0
Est. cond. h-t surf. area [ft^2]	10,000	12,700
Est. cool. water flow [gpm]	10,700	13,600
Condenser tube material	Titanium	Titanium
Estimated T-G cost (complete incl. oil skid, control panel, sealing system)	$3,600,000 (based on $400,000/MW)	$4,600,000 (based on $400,000/MW)
Estimated surface condenser cost	$500,000 (based on $50/$ft^2$)	$640,000 (based on $50/$ft^2$)

TABLE V-9
ESTIMATED OPERATING PARAMETERS FOR BIOMASS OPTIONS FOR HCPC

Option	Capacity (MW)	η_b (biomass/oil)	η_c	HR (biomass/oil)
1	23 - 24	0.70/0.85	0.22	22,200/18,300
2	13 - 19	0.70/0.85	0.31	15,700/12,900
2a, 2b	27 - 37	0.70/0.85	0.33	14,800/12,200

Notes: Capacity is electrical power available for export after reduction by in-house parasitics.
η_b for biomass is for approx. 45% moisture at the furnace inlet w/heat recovery.
Units for Heat Rate, HR, are [Btu/kWh].

Evaluation of the economic viability of Options 2a and 2b require an estimate of the capital cost of replacement power components. In the near term, depending on the availability and price of suitable (i.e., prepared and dried) biomass fuel stocks, it appears that full-condensing mode operation, Option 1, might provide adequate performance and capacity at a minimal level of investment.

Specifications, as defined by PICHTR, for retrofit option 2b were provided to the Bechtel Corporation for a cash flow analysis. This analysis provided the foundation for determining capital and operational costs for retrofit option 2b. These costs are presented in Tables V-10 through V-12.

TABLE V-10
CAPITAL AND OPERATING COSTS FOR RETROFIT OPTION 2B
(BIOMASS COSTS = $0 PER DRY TON)

Plant Feed Rate (dry tons/day)	709	Annualized Capacity Factor	85%	
Biomass Required (dry tons/yr)	220,000	Days of Operations Per Year	310	
Biomass Costs ($/dry ton)	0	Depreciation Period (years)	25	
Gross Power Output (MWe)	35.3	Gross Electricity (kWh/yr))	262,843,800	
Exportable Electricity (kWh/yr)	236,038,200	Net Power Output (MWe)	31.7	
CAPITAL COSTS	$	COST OF OPERATIONS	$/Yr	$/kWh
Fuel Handling & Processing				
Truck Unloader	250,000	VARIABLE COSTS		
Trucks	225,000			
Hoppers For Storage Silos	81,650	Subtotal Biomass	0	0.0000
Belt Conveyors	388,080			
Screen With Magnet	182,180	Plant Operations		
Cane Press	395,500	Direct Labor	978,000	0.0037
Shredder	200,000	Supplies	302,000	0.0011
Conveyor to Dryer	92,320	Maintenance and Repairs	270,000	0.0010
Dryer	978,820	Repair Reserves	100,000	0.0004
Conveyor to Hoppers	184,640	Miscellaneous	100,000	0.0004
Instrumentation & Controls	100,000	Subtotal Plant Operations	1,750,000	0.0067
Subtotal Fuel Handling Block	3,078,190			
		Utilities		
Power Block		Water	80,000	0.0003
Steam Turbine	4,187,000	Electricity	20,000	0.0001
Condenser/Cooling Tower	5,000,000	Subtotal Utilities	100,000	0.0004
Instrumentation & Controls	500,000			
Other Equipment & Materials	500,000	Other		
Subtotal Power Block	10,187,000	Waste Disposal	280,000	0.0011
		Subtotal Other	280,000	0.0011
Other				
Construction & Start-up	1,500,000	TOTAL VARIABLE COSTS	2,130,000	0.0081
Engineering	1,500,000			
Subtotal Other	3,000,000	FIXED COSTS		
		Management	360,000	0.0014
Contingency/Fee @ 15%	2,439,779	Lease Fees	0	0.0000
		Property Tax & Insurance	500,000	0.0019
TOTAL POWER PLANT COSTS	18,704,969	Depreciation	530,608	0.0020
		TOTAL FIXED COSTS	1,390,608	0.0071
		TOTAL COST OF OPERATIONS	3,520,608	0.0152

TABLE V-11
CAPITAL AND OPERATING COSTS FOR RETROFIT OPTION 2B
(BIOMASS COSTS = $50 PER DRY TON)

Plant Feed Rate (dry tons/day)	709	Annualized Capacity Factor	85%	
Biomass Required (dry tons/yr)	220,000	Days of Operations Per Year	310	
Biomass Costs ($/dry ton)	50	Depreciation Period (years)	25	
Gross Power Output (MWe)	35.3	Net Power Output (MWe)	31.7	
Gross Electricity (kWh/yr)	262,843,800	Exportable Electric (kWh/yr)	236,038,200	
CAPITAL COSTS	**$**	**COST OF OPERATIONS**	**$/Yr**	**$/kWh**
Fuel Handling & Processing		**VARIABLE COSTS**		
Truck Unloader	250,000	**Subtotal Biomass**	**10,999,991**	**0.0418**
Trucks	225,000			
Hoppers For Storage Silos	81,650	Plant Operations		
Belt Conveyors	388,080	Direct Labor	978,000	0.0037
Screen With Magnet	182,180	Supplies	302,000	0.0011
Cane Press	395,500	Maintenance and Repairs	270,000	0.0010
Shredder	200,000	Repair Reserves	100,000	0.0004
Conveyor to Dryer	92,320	Miscellaneous	100,000	0.0004
Dryer	978,820	**Subtotal Plant Operations**	**1,750,000**	**0.0067**
Conveyor to Hoppers	184,640			
Instrumentation & Controls	100,000	Utilities		
Subtotal Fuel Handling Block	**3,078,190**	Water	80,000	0.0003
		Electricity	20,000	0.0001
Power Block		**Subtotal Utilities**	**100,000**	**0.0004**
Steam Turbine	4,187,000			
Condenser/Cooling Tower	5,000,000	Other		
Instrumentation & Controls	500,000	Waste Disposal	280,000	0.0011
Other Equipment & Materials	500,000	**Subtotal Other**	**280,000**	**0.0011**
Subtotal Power Block	**10,187,000**			
		TOTAL VARIABLE COSTS	**13,129,991**	**0.0500**
Other				
Construction & Start-up	1,500,000	**FIXED COSTS**		
Engineering	1,500,000	Management	360,000	0.0014
Subtotal Other	**3,000,000**	Lease Fees	0	0.0000
		Property Tax & Insurance	500,000	0.0019
Contingency/Fee @ 15%	**2,439,779**	Depreciation	530,608	0.0020
		TOTAL FIXED COSTS	**1,390,608**	**0.0071**
TOTAL POWER PLANT COSTS	**18,704,969**			
		TOTAL COST OF OPERATIONS	**14,520,599**	**0.0571**

TABLE V-12
CAPITAL AND OPERATING COSTS FOR RETROFIT OPTION 2B
(BIOMASS COSTS = $106 PER DRY TON)

Plant Feed Rate (dry tons/day)	709	Annualized Capacity Factor	85%	
Biomass Required (dry tons/yr)	220,000	Days of Operations Per Year	310	
Biomass Costs ($/dry ton)	106	Depreciation Period (years)	25	
Gross Power Output (MWe)	35.3	Net Power Output (MWe)	31.7	
Gross Electricity (kWh/yr)	262,843,800	Exportable Electric(kWh/yr)	236,038,200	
CAPITAL COSTS	**$**	**COST OF OPERATIONS**	**$/Yr**	**$/kWh**
Fuel Handling & Processing		**VARIABLE COSTS**		
Truck Unloader	250,000	**Subtotal Biomass**	**23,319,982**	**0.0887**
Trucks	225,000			
Hoppers For Storage Silos	81,650	Plant Operations		
Belt Conveyors	388,080	Direct Labor	978,000	0.0037
Screen With Magnet	182,180	Supplies	302,000	0.0011
Cane Press	395,500	Maintenance and Repairs	270,000	0.0010
Shredder	200,000	Repair Reserves	100,000	0.0004
Conveyor to Dryer	92,320	Miscellaneous	100,000	0.0004
Dryer	978,820	**Subtotal Plant Operations**	**1,750,000**	**0.0067**
Conveyor to Hoppers	184,640			
Instrumentation & Controls	100,000	Utilities		
Subtotal Fuel Handling Block	**3,078,190**	Water	80,000	0.0003
		Electricity	20,000	0.0001
Power Block		**Subtotal Utilities**	**100,000**	**0.0004**
Steam Turbine	4,187,000			
Condenser/Cooling Tower	5,000,000	Other		
Instrumentation & Controls	500,000	Waste Disposal	280,000	0.0011
Other Equipment & Materials	500,000	**Subtotal Other**	**280,000**	**0.0011**
Subtotal Power Block	**10,187,000**			
		TOTAL VARIABLE COSTS	**25,449,982**	**0.0968**
Other				
Construction & Start-up	1,500,000	**FIXED COSTS**		
Engineering	1,500,000	Management	360,000	0.0014
Subtotal Other	**3,000,000**	Lease Fees	0	0.0000
		Property Tax & Insurance	500,000	0.0019
Contingency/Fee @ 15%	**2,439,779**	Depreciation	530,608	0.0020
		TOTAL FIXED COSTS	**1,390,608**	**0.0071**
TOTAL POWER PLANT COSTS	**18,704,969**			
		TOTAL COST OF OPERATIONS	**26,840,589**	**0.1040**

3. OPTIONS SUMMARY

The HSC and HCPC cogeneration facilities were evaluated to identify possible retrofit options to convert operations to dedicated electric power generation using biomass as the primary fuel. It was concluded that the HSC system is unsuitable for retrofit. It probably would be more practicable to salvage the HSC Foster Wheeler Boiler and procure new turbines and condensers. Two options were proposed for the HCPC facility: 1) continue operation with no modification other than those required by the bagasse handling system to accommodate different biomass fuels; exportable power is 18 MW; and 2) increase net capacity to 32 MW by the addition of a new low-pressure turbine-generator and condenser. The HCPC cogeneration facility has the potential to operate as-built as a dedicated power station that can produce approximately 13 to 19 MW of exportable electrical power at moderate efficiency burning either biomass, No. 6 fuel oil, or coal. The required capital investment for this upgrade is estimated to be approximately $18 million.

D. TECHNOLOGY FOR FUTURE CONSIDERATION: GASIFICATION

Excluding the cost of biomass, the cost of producing electricity in the retrofited HCPC plant is approximately 1.5 cents per kWh. The capital costs for implementing the biomass gasifier option is estimated at $52.8 million. Excluding the cost of biomass, this would result in a cost of about 2 cents per kWh. We estimate that the gasifier option would increase net capacity to approximatley 26 MW and would cost approximately $53 million.

NOTE: At a biomass cost of $0 per dry ton, the production costs of electricity for retrofit option 2b is approximately 1.5 cents per kWh while that of the gasifier option is approximately 2 cents per kWh. This apparent anomally can be explained by the higher capital costs attributed to the biomass gasifier. When the biomass cost is $0, the cost of electricity production is more greatly influenced by depreciation and direct labor, thus resulting in a higher production cost per kWh for the gasifier option than for the retrofit option.

Because of the high level of interest in evaluating the potential of continuing to use the sugar crop as a source of biomass, an evaluation of the two technologies was carried out using the cost of $106 per dry ton as the cost of biomass. As shown in Figures VI-6, when the biomass cost is $106 per dry ton (the current cost of prepared cane) the production costs of electricity for retrofit option 2 b is approximately 10 cents per kWh while that of the gasifier option is approximately 8 cents per kWh. At the current avoided rate of approximately 5 cents per kWh, prepared cane is not economically feasible as a source of biomass for producing electricity. However, there may be a variety of scenarios that involve production of multiple products and integration of waste resources that could present opportunities to produce electricity at near the avoided cost. These are presented in the economic summary (Section VII).

TABLE V-13
CAPITAL AND OPERATING COSTS FOR A BIOMASS GASIFIER
(BIOMASS COSTS = $0 PER DRY TON)

Plant Feed Rate (dry tons/day)	400	Annualized Capacity Factor	85%	
Biomass Required (dry tons/yr)	124,100	Days of Operations Per Year	310	
Biomass Costs ($/dry ton)	0	Depreciation Period (years)	25	
Gross Power Output (MWe)	29.0	Net Power Output (MWe)	26.2	
Gross Electricity (kWh/yr)	215,934,000	Exportable Electricity (kWh/yr)	195,085,200	
CAPITAL COSTS	$	COST OF OPERATIONS	$/Yr	$/kWh
Gasification Block		VARIABLE COSTS		
Site Improvements	1,851,120	Subtotal Biomass	0	0.0000
Electric Power/Area Lighting	992,400			
Truck Unloader/Trucks	1,225,000	Gasification		
Circular Storage Silo System	4,248,190	Direct Labor	1,000,000	0.0046
Screen With Magnet	121,450	Supplies	300,000	0.0014
Cane Press/Shredder	363,660	Maintenance and Repairs	270,000	0.0013
Dryer System	535,570	Repair Reserves	300,000	0.0014
Fuel Feed Hopper System	613,310	Miscellaneous	100,000	0.0005
Gasifiers	1,211,330	Subtotal Gasification	1,970,000	0.0091
N2 Instrumentation Purge	20,000			
Cyclone Separators	916,590	Utilities		
Ash Collection & Disposal	300,520	Water	80,000	0.0004
Tar Crackers	559,060	Electricity	20,000	0.0001
Hot Gas Filter	125,360	Subtotal Utilities	100,000	0.0005
Alkali Getter	123,550			
Spray Quench	10,000	Other		
Exhaust Stack	70,780	Waste Disposal	150,000	0.0007
Processing Piping	536,140	Subtotal Other	150,000	0.0007
Instrumentation & Controls	350,000			
Subtotal Gasification Block	14,174,030	TOTAL VARIABLE COSTS	2,220,000	0.0103
Power Block				
Gas & Steam Turbines	13,250,000	FIXED COSTS		
HRSG	2,000,000	Management	300,000	0.0014
Instrumentation & Controls	775,000	Lease Fees	0	0.0000
Other Equipment & Materials	4,000,000	Property Tax & Insurance	500,000	0.0023
Subtotal Power Block	20,025,000	Depreciation	1,367,961	0.0063
Other		TOTAL FIXED COSTS	2,167,961	0.0100
Construction & Start-up	6,195,000			
Engineering	5,522,000	TOTAL COST OF OPERATIONS	4,387,961	0.0203
Subtotal Other	11,717,000			
Contingency/Fee @ 15%	6,887,405			
TOTAL POWER PLANT COST	52,803,435			

TABLE V-14
CAPITAL AND OPERATING COSTS FOR A BIOMASS GASIFIER
(BIOMASS COSTS = $50 PER DRY TON)

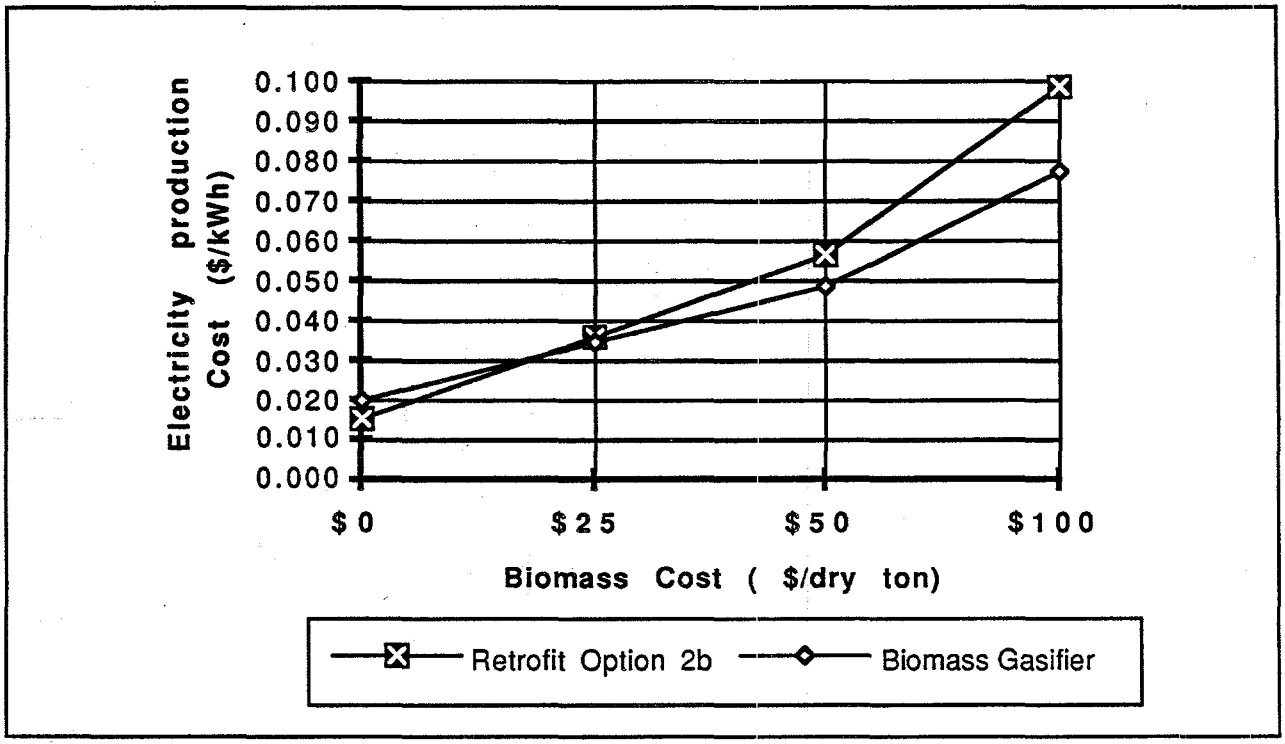
Plant Feed Rate (dry tons/day)	400	Annualized Capacity Factor	85%	
Biomass Required (dry tons/yr)	124,100	Days of Operations Per Year	310	
Biomass Costs ($/dry ton)	50	Depreciation Period (years)	25	
Gross Power Output (MWe)	29.0	Net Power Output (MWe)	26.2	
Gross Electricity (kWh/yr)	215,934,000	Exportable Electricity (kWh/yr)	195,085,200	
CAPITAL COSTS	**$**	**COST OF OPERATIONS**	**$/Yr**	**$/kWh**
Gasification Block		**VARIABLE COSTS**		
Site Improvements	1,851,120	**Subtotal Biomass**	**6,205,000**	**0.0287**
Electric Power/Area Lighting	992,400			
Truck Unloader/Trucks	1,225,000	Gasification		
Circular Storage Silo System	4,248,190	Direct Labor	1,000,000	0.0046
Screen With Magnet	121,450	Supplies	300,000	0.0014
Cane Press/Shredder	363,660	Maintenance and Repairs	270,000	0.0013
Dryer System	535,570	Repair Reserves	300,000	0.0014
Fuel Feed Hopper System	613,310	Miscellaneous	100,000	0.0005
Gasifiers	1,211,330	**Subtotal Gasification**	**1,970,000**	**0.0091**
N2 Instrumentation Purge	20,000			
Cyclone Separators	916,590	Utilities		
Ash Collection & Disposal	300,520	Water	80,000	0.0004
Tar Crackers	559,060	Electricity	20,000	0.0001
Hot Gas Filter	125,360	**Subtotal Utilities**	**100,000**	**0.0005**
Alkali Getter	123,550			
Spray Quench	10,000	Other		
Exhaust Stack	70,780	Waste Disposal	150,000	0.0007
Processing Piping	536,140	**Subtotal Other**	**150,000**	**0.0007**
Instrumentation & Controls	350,000			
Subtotal Gasification Block	**14,174,030**	**TOTAL VARIABLE COSTS**	**8,425,000**	**0.0390**
Power Block				
Gas & Steam Turbines	13,250,000	**FIXED COSTS**		
HRSG	2,000,000	Management	300,000	0.0014
Instrumentation & Controls	775,000	Lease Fees	0	0.0000
Other Equipment & Materials	4,000,000	Property Tax & Insurance	500,000	0.0023
Subtotal Power Block	**20,025,000**	Depreciation	1,367,961	0.0063
Other		**TOTAL FIXED COSTS**	**2,167,961**	**0.0100**
Construction & Start-up	6,195,000			
Engineering	5,522,000	**TOTAL COST OF OPERATIONS**	**10,592,961**	**0.0491**
Subtotal Other	**11,717,000**			
Contingency/Fee @ 15%	**6,887,405**			
TOTAL POWER PLANT COST	**52,803,435**			

TABLE V-15
CAPITAL AND OPERATING COSTS FOR A BIOMASS GASIFIER
(BIOMASS COSTS = $106 PER DRY TON)

Plant Feed Rate (dry tons/day)	400	Anualized Capacity Factor	85%	
Biomass Required (dry tons/yr)	124,100	Days of Operations Per Year	310	
Biomass Costs ($/dry ton)	106	Depreciation Period (years)	25	
Gross Power Output (MWe)	29.0	Net Power Output (MWe)	26.2	
Gross Electricity (kWh/yr)	215,934,000	Exportable Electricity (kWh/yr)	195,085,200	
CAPITAL COSTS	**$**	**COST OF OPERATIONS**	**$/Yr**	**$/kWh**
Gasification Block		**VARIABLE COSTS**		
Site Improvements	1,851,120	**Subtotal Biomass**	**13,154,600**	**0.0609**
Electric Power/Area Lighting	992,400			
Truck Unloader/Trucks	1,225,000	Gasification		
Circular Storage Silo System	4,248,190	Direct Labor	1,000,000	0.0046
Screen With Magnet	121,450	Supplies	300,000	0.0014
Cane Press/Shredder	363,660	Maintenance and Repairs	270,000	0.0013
Dryer System	535,570	Repair Reserves	300,000	0.0014
Fuel Feed Hopper System	613,310	Miscellaneous	100,000	0.0005
Gasifiers	1,211,330	**Subtotal Gasification**	**1,970,000**	**0.0091**
N2 Instrumentation Purge	20,000			
Cyclone Separators	916,590	Utilities		
Ash Collection & Disposal	300,520	Water	80,000	0.0004
Tar Crackers	559,060	Electricity	20,000	0.0001
Hot Gas Filter	125,360	**Subtotal Utilities**	**100,000**	**0.0005**
Alkali Getter	123,550			
Spray Quench	10,000	Other		
Exhaust Stack	70,780	Waste Disposal	150,000	0.0007
Processing Piping	536,140	**Subtotal Other**	**150,000**	**0.0007**
Instrumentation & Controls	350,000			
Subtotal Gasification Block	**14,174,030**	**TOTAL VARIABLE COSTS**	**15,374,600**	**0.0712**
Power Block				
Gas & Steam Turbines	13,250,000	**FIXED COSTS**		
HRSG	2,000,000	Management	300,000	0.0014
Instrumentation & Controls	775,000	Lease Fees	0	0.0000
Other Equipment & Materials	4,000,000	Property Tax & Insurance	500,000	0.0023
Subtotal Power Block	**20,025,000**	Depreciation	1,367,961	0.0063
Other		**TOTAL FIXED COSTS**	**2,167,961**	**0.0100**
Construction & Start-up	6,195,000			
Engineering	5,522,000	**TOTAL COST OF OPERATIONS**	**17,542,561**	**0.0812**
Subtotal Other	**11,717,000**			
Contingency/Fee @ 15%	**6,887,405**			
TOTAL POWER PLANT COST	**52,803,435**			

Figure V-6 provides a summary of the sensitivity to biomass cost of biomass combustion and biomass gasification systems.

FIGURE V-6
SENSITIVITY OF ELECTRICITY PRODUCTION COST TO BIOMASS COST



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VI. ECONOMIC ANALYSIS [TASK 9]

A. SUMMARY OF RESULTS AND BASIS FOR THE ECONOMIC PERFORMANCE EVALUATIONS

The analysis of crops with potential to be used for ethanol production indicated that the sugarcane crop and sweet sorghum offered the most potential to supply biomass for ethanol production in Hawaii. Newspaper and municipal solid waste were also identified as reliable low cost sources of biomass to produce electricity or as a feedstock for ethanol production. A detailed analysis showed that Hawaii produces sufficient lignocellulosic waste biomass to produce ethanol volumes equal to 10% of the gasoline consumed annually.[1]

Since the sugar crop was one of the most promising sources of biomass and information on the industry was abundant, this information was used to make projections on supply costs and potential for energy production. Although the analysis of ethanol production technology did not conclusively identify the best system, the Simultaneous Saccharification and Fermentation (SSF) approach showed sufficient promise to be used as the basic format for conducting sensitivity analyses. Prepared cane was selected as the crop component to be used on the cost comparisons. The specific assumptions for estimating ethanol and electricity production using prepared cane as the feedstock are outlined in Table VI-1.

B. TECHNOLOGY PERFORMANCE

For many years there has been a sustained interest in Hawaii in the comparison of the performance of using prepared cane for the production of sugar with using the same material to produce ethanol. Based on this information it is possible to evaluate a variety of scenarios for using prepared cane to produce various combinations of ethanol, sugar, and electricity.

Once all the costs of providing specific substrates were identified, it was possible to develop estimates of the cost of producing ethanol or any electricity based on selected technologies. As stated previously, there was insufficient information to make a definitive comparison of technologies for production of ethanol or electricity.

A format was developed to outline the economic performance of each of the technologies for ethanol production. As the basis for overall comparison, the simultaneous saccharification and fermentation (SSF) technology was selected as the base case.

TABLE VI-1
PARAMETERS FOR ETHANOL AND ELECTRICITY PRODUCTION

PARAMETER	PER HARV. ACRE	PARAMETER	PER HARV. ACRE
Crop Production time (years)	2.20	Fermentable Sugars Potential (tons/harv . acre)	25.48
Prepared Cane (wet tons/harv. acre)	109.82	Sugars-Annual Pot. (tons/acre/year)	11.58
Prep. Cane Cost/ton After Washing (wet)	$31.35	TONS SUGARS/DRY TON BIOMASS	0.80
Prep. Cane Dry Wgt (%)	29%	Ethanol tons /ton sugar (theoretical)	*0.50*
Prep. Cane-dry Weight (tons/harv. acre)	31.85	Ethanol (pounds/gal)	*6.58*
Cost/ton After Washing (dry weight)	$108.1	Ethanol Theo. Pot. (gal./harv. acre)	3,872
ALTERNATIVE COST 1 $0.00/DRY TON	$0.00	Sucrose to Ethanol- Conversion	92%
ALTERNATIVE COST 2 $25.00/DRY TON	$25.00	Released Sugars- Conversion efficiency	76%
ALTERNATIVE COST 3 $50.00/DRY TON	$50.00	Est. Ethanol Pot. (gal./harv acre)	2,943
Prepared Cane Yield (dry tons/harv. acre)	31.85	Est. Ethanol Pot. (gal./ton ferm sugars)	115.50
Sucrose (% dw in prepared cane)	43%	Ethanol Potential (gal./acre/year)	1,338
Sucrose (total dry tons/harv acre)	13.69	Ethanol Gal/wet ton processed	26.80
Sugar Current Sales Price ($ per ton)	$360.0	Ethanol Gal/dry ton processed	92.40
Sugar Production Cost ($ per ton)	$449.74	Ethanol Sales Price per gallon	$0.90
Bagasse Dry (tons /harv. acre)	18.15	Bagasse(lbs/ton wet weight)	2,000
Bagasse % Dry Weight	52%	Bagasse wet (BTU/Lb)	4,200
Bagasse Wet (tons / harv. acre)	35	Bagasse (BTU/ dry ton)	16,153,846
Bagasse Value ($/wet ton)	$16.00	Boiler Efficiency %	60%
Molasses from Prep. cane (tons/acre)	3.40	Bagasse Effective BTU/pound (wet)	2,520
Molasses value ($/ton)	$42.00	Lignin BTU/pound (dry)	12,700
Sugar Content of molasses	40%	Lignin BTU/ton (dry)	25,400,000
Sugar in molasses (tons/acre)	1.36	Steam (BTU/lb)	1,300
Sucrose produced (tons/harv . acre)	12.33	Steam (lbs/lb bagasse)850 psig 730°F	1.94
Cellulose (% dw in prepared cane)	22%	Oil (BTU/ No.6 barrel)	6,300,000
Hemicellulose (% dw in prepared cane)	15%	BTU/kWh	12,600
Lignin (% dw in prepared cane)	11%	HECO (BTU /kWh)	10,500
Cellulose (tons/harvested acre)	7.01	Bagasse pounds/kWh electricity	2.50
Hemicellulose (tons/harv. acre)	4.78	kWh / wet ton Bagasse	666.67
Lignin (tons/harvested acre)	3.50	Electricity Generation Cost /kWh	$0.02
Glucose (tons/harvested acre)	13.85	Bagasse used for factory %	50%
Fructose(tons/harvested acre)	6.85	Electricity Avoided Cost /kWh	$0.05
Xylose (tons/harvested acre)	4.78		

Table VI-2 shows the capital and operating costs of a SSF plant using prepared cane as the substrate to produce 25 million gallons of ethanol per year. The format summarizes the costs of building a plant capable of processing prepared cane to ethanol. (Note: since the same format was used to compare all technologies are elements not required for the SSF process are displayed as 0.000.) For the purpose of presenting the format used in the analysis, the value of the biomass is arbitrarily set at $50 per dry ton.

TABLE VI-2
25 MILLION GALLONS ETHANOL PER YEAR FROM PREPARED CANE

Plant feed rate (dry tons/day)	820	Biomass Source	Prepared cane
Million gallons /year production	25	Cost/dry ton	$50

AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
100	Biomass Preparation	3.609	Biomass	13,528	0.54
200	Pretreatment	11.461			
210	Recovery & Recycle	0.000	Denaturant	1,088	0.04
300	Hydrolysis	0.000	Acid	0	0.00
400	Fermentation (Unallocated)	0.000	Ammonia	0	0.00
410	Hexose Fermentation	11.239	Nutrients	0	0.00
420	Pentose Fermentation	3.134	Enzymes	0	0.00
500	Distillation & Dehydration	1.963	Yeast	0	0.00
600	By-Product Preparation	0.000	Other Chemicals	3,341	0.13
610	Stillage Evaporation	0.000	Total Raw Materials	17,957	0.72
700	Product Storage & Denature	1.583			
800	Utilities & General	0.000	Electricity/ Energy	-1,390	(0.06)
810	Boiler	10.009	Water	52	0.00
820	Non-Boiler Utilities	16.780	By-products	173	0.01
830	Environmental	2.074	Total Utilities	-1,166	(0.05)
840	Miscellaneous & Control	3.213			
900	Enzyme Production	1.361	Operators	1,520	0.06
			Laborers	1,000	0.04
1,000	Total Fixed Capital	66.426	Technicians	210	0.01
			Maintenance	800	0.03
1,010	Contingency	6.643	Fringe Benefits	882	0.04
1,020	Startup	3.321	TOTAL LABOR	4,412	0.18
1,030	Working Capital	4.982			
			VARIABLE COST TOTAL	34,732	1.39
	TOTAL CAPITAL	81.372	GEN. & ADMIN.	1,590	0.06
			Property Tax & Insur.	1,220	0.05
			TOTAL CASH	36,322	1.45
			ANNUAL CAPITAL COST	0	0.00
			Depreciation	2,441	0.10
			TOTAL PRODUCTION	36,322	1.06

The example presented does not include any financing costs in calculating the cost to produce a gallon of ethanol. The complete set of spreadsheets for all technologies is included in the Appendix.

1. Sensitivity Analysis

A sensitivity analysis was carried out to evaluate the impact of system size and biomass cost on the economic performance. The scaling factors used to evaluate the economic performance of systems sized for 5 and 25 million gallons per year are presented in Table VI-3.

TABLE VI-3
FACTORS USED IN THE SENSITIVITY ANALYSIS

Power Law Scaling Factor	0.7		Feedstock Cost, $/ dry Ton	0, 25, 50,109
Contingency	10 %		Denaturant Cost, $/gal	0.87
Start-up factor	5%		Denaturant Use	5%
Working Capital	7.50%		Fringe Benefits	25 %
Operating Days per Year	330		Capital Charge, %/yr.	0%
Personnel Scaling Factor	0.9			
Property Tax & Insurance	1.50%			

2. Biomass Cost

Varying the cost of prepared cane biomass at $0, $25, $50, and $109 per dry ton provided a way of looking at the impact of biomass cost on economic performance. An analysis of production costs in the sugar industry indicated that the cost of producing a ton of prepared cane was $31.04 per wet ton or $109 per dry ton. An analysis in which the biomass is valued at $0 per ton provides a means of looking at the process costs exclusive of the cost of biomass. These results are presented in Table VI-4 below.

TABLE VI-4
ECONOMIC PERFORMANCE OF SSF BASED ON BIOMASS COST

	5 MILLION GALLON PER YEAR SSF PLANT				25 MILLION GALLON PER YEAR SSF PLANT			
CAPITAL COST	$26,000,000				$81,000,000			
Biomass (tons /day)	164				820			
PREPARED CANE	BIOMASS COST($/dry ton)				BIOMASS COST($/dry ton)			
	$0	$25	$50	$109	$0	$25	$50	$109
Ethanol Cost($/gallon)	$0.65	$0.92	$1.19	$1.83	$0.52	$0.79	$1.06	$1.70

Assumes equity funding -no capital charges

Varying the cost of biomass from $25 to $109/dry ton showed a cost of production ranging from $0.92 to $1.83 per gallon for an ethanol plant producing 5 million gallons per year. In contrast, a plant producing 25 million gallons per year resulted in production costs ranging from $0.79 to $1.70 per gallon.

3. Production Scenarios

As previously discussed, both HSC and HCPC have generated electricity using the steam generated by burning bagasse. It was of great interest to contrast the economic performance of the sugar industry as now operated," business as usual", with the performance of a plant utilizing the harvested sugar crop to produce ethanol or various combinations of ethanol, electricity.

The section below provides a comparison of the financial performance per harvested acre of converting prepared cane to sugar, ethanol, and electricity with the performance of using prepared cane to produce electricity and sugar with three configurations: the existing electric generating facilities; a retrofit of the HCPC plant; and the addition of a biomass gasifier.

The following scenarios were evaluated using the costs developed for a plant producing 25 million gallons of ethanol annually using prepared cane valued at $109.00 per dry ton as the feedstock. In order to achieve a common basis of comparison we used net income from operations per harvested acre as the basis of comparison. The scenarios are as follows:

Ethanol Scenarios

a. Prepared cane to sugar - bagasse to electricity (business as usual).

b. Prepared cane juice to ethanol (by simple fermentation), and fiber to ethanol (using SSF) - lignin to electricity.

c. Sucrose to sugar and molasses - bagasse to ethanol (using SSF) - lignin to electricity.

d. Sucrose to ethanol (by simple fermentation) - bagasse to electricity (by conventional combustion).

Electricity Scenarios

e. Prepared cane to sugar - bagasse to electricity via conventional steam combustion (business as usual).

f. Prepared cane to sugar - bagasse to electricity via retrofit option 2b .

g. Prepared cane to sugar - bagasse to electricity using biomass gasifier.

a. Prepared cane to sugar, molasses, and energy (business as usual).

This represents the performance of the sugar industry as it is now practiced. Prepared cane supplied at a cost of $38.00 per wet ton (or $109.82 per dry ton[2])is the source of biomass. Prepared cane is produced by burning the sugar crop in the field, harvesting, and washing. The resulting product is prepared cane. The cane is then crushed and squeezed to produce juice containing sucrose that is in turn processed to sugar. The remaining fiber or bagasse is then burned as boiler fuel to produce steam and electricity. Steam energy is used as processed heat and electricity for the mill and plantation. Any remaining electricity is sold to the utility at the avoided rate of 5 cents per kW hour.[3] At current sugar prices, these assumptions result in a profit of about $197 per harvested acre. A synopsis is presented in Table VI-5 below.

b. Prepared cane to ethanol by simple fermentation and SSF; lignin to electricity .

In this case, the prepared cane is produced as in the sugar industry. A cost of $38.00 is applied to each ton of wet prepared cane biomass (or $109.82 per dry ton). The cane is then crushed and squeezed to produce juice containing sucrose. The sucrose is fermented to ethanol in a conventional fermenter. The remaining fiber or bagasse is then treated with enzymes in a SSF system to release the sugars bound in the cellulose and hemicellulose. The released sugars in the mixture is then fermented by microorganisms to produce ethanol. Lignin, originally present in the fiber, largely remains intact and is used as boiler fuel to make process heat and electricity. In this case, additional fuel is required to provide enough energy for the operation. This approach results in a before tax loss of about $3,500 per harvested acre. The results are summarized in Table VI-6.

c. Juice to sugar and molasses; bagasse to ethanol by SSF; lignin to electricity

Prepared cane is the raw material. The cane is crushed and squeezed to produce juice containing sucrose. The sucrose containing juice is processed to produce crystalline sugar (DA 96 sugar) and molasses. The remaining fiber (bagasse) is processed using the SSF technology to produce ethanol and lignin. The lignin is then used as a fuel to produce process heat and electricity. Once again, additional fuel is required to meet the energy needs of the process. This approach results in a profit of about $123 per acre. If existing tax benefits are applied the net income is a positive $291 per acre. The results are presented in Table VI-7.

TABLE VI-5

ESTIMATED INCOME FROM OPERATIONS PER HARVESTED ACRE Prepared Cane to Sugar & Molasses, Bagasse to Electricity (Business As Usual) Scenario 1 Total Cane Costs $ 38/wet ton				
	YIELD tons, kWh or gallons	**COST OF OPERATION** $ per ton of prepared cane	**VALUE OF PRODUCT** $ per ton, kWh or gallon	**NET VALUE** $ per harvested acre
REVENUES				
DA96 Sugar (tons/harvested acre)	12.16		$360.00	$4,377
Molasses (tons/harvested acre)	2.95		$40.00	$118
Ethanol-SF (gals/harvested acre)	0		$0.90	$0
Ethanol-SSF (gals/harvested acre)	0		$0.90	$0
Electricity sold (kWh/harvested acre)	8,181		$0.05	$409
TOTAL REVENUES				**$4,904**
COSTS				
Prepared Cane (wet tons)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion/Dewatering		$0.29		(36)
Waste Disposal		$0.01		(2)
Boiling House/Sugar Processing		$1.62		(199)
Ethanol Production (SSF)				0
Ethanol Production (SF)				0
Additional Fuel Costs				0
Electricity production		$2.69		(331)
Other Factory		$3.40		(418)
G&A		$5.80		(714)
TOTAL COSTS OF OPERATIONS		$38.25		**($4,706)**
TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				**$197**
	YIELD gallons or kWh		**VALUE** $ per gal or kWh	**NET VALUE** $ per harv. acre
CREDITS				
Federal Small Producer Credit	0		$0.10	$0
State Indigenous Fuels Prod Credit	0		$0.00	$0
Ethanol Tax Credits				$0
Dedicated Feedstock Electric Credit	0		$0.015	$0
Electricity Tax Credits				$0
TOTAL CREDITS				**$0**
TOTAL VALUE WITH CREDITS				**$197**

TABLE VI-6

ESTIMATED INCOME FROM OPERATIONS PER HARVESTED ACRE Scenario 2
Prepared Cane Juice to Ethanol by Simple Fermentation, Bagasse to Ethanol by SSF, Lignin to Electricity
Total Cane Costs $ 38/wet ton

	YIELD tons, kWh or gallons	**COST OF OPERATIONS** $ per ton of prepared cane	**VALUE OF PRODUCT** $ per ton, kWh or gallon	**NET VALUE** $ per harvested acre
REVENUES				
DA96 Sugar (tons/harvested acre)	0.00		$360.00	0
Molasses (tons/harvested acre)	2.95		$40.00	118
Ethanol-SF (gals/harvested acre)	1,793		$0.90	1,613
Ethanol-SSF (gals/harvested acre)	1,674		$0.90	1,507
Electricity (kWh/harvested acre)	8,181		$0.05	409
TOTAL REVENUES				**$3,647**
COSTS OF OPERATIONS				
Prepared Cane (wet tons/cost)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion/Dewatering		$0.29		(36)
Waste Disposal		$0.01		(2)
Boiling House/Sugar Processing		$1.62		(199)
Ethanol Production (SSF)		$7.79		(959)
Ethanol Production (SF)		$6.88		(847)
Additional Fuel Costs		$5.06		(622)
Electricity production		$2.90		(357)
Other Factory		$3.40		(418)
G&A		$5.80		(714)
TOTAL COSTS		$58.20		**($7,161)**
TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				**($3,513)**

	YIELD gallons or kWh		**VALUE** $ per gal or kWh	**NET VALUE** $ per harv. acre
CREDITS				
Federal Small Producer Credit	3,467		$0.10	$347
State Indigenous Fuels Production Credit	3,467		$0.00	$0
Ethanol Tax Credits				$347
Dedicated Feedstock Electric Credit	0		$0.015	$0
Electricity Tax Credits				$0
TOTAL CREDITS				**$347**
TOTAL VALUE WITH CREDITS				**($3,167)**

TABLE VI-7

ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE Scenario 3
Prepared Cane to Juice to Sugar & Molasses, Bagasse to Ethanol by SSF, Lignin to Electricity
Total Cane Costs $ 38/wet ton

	YIELD tons, kWh or gallons	COST OF OPERATIONS $ per ton of prepared cane	VALUE OF PRODUCT $ per ton, kWh or gallon	NET VALUE $ per harvested acre
REVENUES				
DA96 Sugar (tons/harvested acre)	12.16		$360.00	$4,377
Molasses (tons/harvested acre)	2.95		$40.00	$118
Ethanol-SF (gals/harvested acre)	0		$0.90	$0
Ethanol-SSF (gals/harvested acre)	1,674		$0.90	$1,507
Electricity (kWh/harvested acre)	8,181		$0.05	$409
TOTAL REVENUES				**$6,411**
COSTS OF OPERATIONS				
Prepared Cane (wet tons)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion/Dewatering		$0.29		(36)
Waste Disposal		$0.01		(2)
Boiling House/Sugar Processing		$1.62		(199)
Ethanol Production (SSF)		$7.79		(959)
Ethanol Production (SF)				0
Additional Fuel Costs		$5.06		(622)
Electricity production		$2.69		(331)
Other Factory		$3.40		(418)
G&A		$5.80		(714)
TOTAL COSTS		$51.10		**($6,288)**
TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				**$123**
	YIELD gallons or kWh		**VALUE** $ per gal or kWh	**NET VALUE** $ per harvested acre
CREDITS				
Federal Small Producer Credit	1,674		$0.10	$167
State Indigenous Fuels Production Credit	1,674		$0.00	$0
Ethanol Tax Credits				$167
Dedicated Feedstock Electric Credit	0		$0.015	$0
Electricity Tax Credits				$0
TOTAL CREDITS				**$167**
TOTAL VALUE WITH CREDITS				**$291**

Table VI-8

ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE Scenario 4
Prepared Cane Juice to Ethanol by Simple Fermentation, Bagasse to Electricity
Total Cane Costs $ 38/wet ton

	YIELD tons, kWh or gallons	COST OF OPERATIONS $ per ton of prepared cane	VALUE OF PRODUCT $ per ton, kWh or gallon	NET VALUE $ per harvested acre
REVENUES				
DA96 Sugar (tons/harvested acre)	0.00		$360.00	0
Molasses (tons/harvested acre)	2.95		$40.00	118
Ethanol-SF (gals/harvested acre)	1,793		$0.90	1,613
Ethanol-SSF (gals/harvested acre)	0		$0.90	0
Electricity (kWh/harvested acre)	8,181		$0.05	409
TOTAL REVENUES				**$2,141**
COSTS OF OPERATIONS				
Prepared Cane (wet tons/cost)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion/Dewatering		$0.29		(36)
Waste Disposal		$0.01		(2)
Boiling House/Sugar Processing		$1.62		(199)
Ethanol Production (SSF)				0
Ethanol Production (SF)		$6.88		(847)
Additional Fuel Costs				0
Electricity production		$2.69		(331)
Other Factory		$3.40		(418)
G&A		$5.80		(714)
TOTAL COSTS		$45.13		**($5,553)**
TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				**($3,413)**
	YIELD gallons or kWh		**VALUE** $ per gal or kWh	**NET VALUE** $ per harvested acre
CREDITS				
Federal Small Producer Credit	1,793		$0.10	$179
State Indigenous Fuels Production Credit	1,793		$0.00	$0
Ethanol Tax Credits				$179
Dedicated Feedstock Electric Credit	0		$0.015	$0
Electricity Tax Credits				$0
TOTAL CREDITS				**$179**
TOTAL VALUE WITH CREDITS				**($3,233)**

d. Sucrose to ethanol (by simple fermentation) and bagasse to electricity (by conventional combustion)

In contrast with the SSF process that requires the use of acid and enzymes to liberate the sugar molecules that are bound in the cellulose and hemicellulose, this approach uses simple fermentation to convert the sucrose expressed in the juice to ethanol. The physical plant for this system is simplified and less costly.

Prepared cane is the raw material. The cane is crushed and squeezed to produce juice containing sucrose. The sucrose containing juice is filtered and put into a simple fermentation device where yeast converts the sucrose and remaining soluble sugars to ethanol. The remaining fiber (bagasse) is then used as a fuel to produce process heat and electricity. Any remaining electricity in excess of the process requirements is sold to the utility at the avoided rate of 5 cents per kilowatt hour. Economic performance of this scenario is summarized in Table VI-8.

The amount of prepared cane biomass required to produce the required volumes of ethanol is substantially greater than in the SSF approach. In this instance, the capital and operating costs for the facility were reduced because using just the sugar juice to produce ethanol did not require the expense of the specialized equipment and operating costs of hydrolyzing the fibrous material to the component sugars and fermentation of the 5 carbon sugars. In spite of these advantages, this approach results in a net loss of more than $3,200 per acre

The possibility that there may be improvements in production technology that can have significant impact on the economic performance is most likely. Whether any combination of improvements can make this industry self-sustaining remains to be determined. This is the focus of programs now in progress at PICHTR, NREL, TVA, Oak Ridge National Laboratory and various university and government facilities.

4. Options for Producing Electricity From Biomass at the Sugar Mill.

The previous section reviewed the options for using the facilities at the sugar mill to produce ethanol and some energy with residual biomass or by-products . This section emphasizes the use of prepared cane biomass to produce electricity. The stand alone options for producing electricity using prepared cane as the source of biomass at the mill include :

e. ***Conventional steam boiler using bagasse derived from prepared cane as the fuel in the existing facilities.*** This is the same as *a.* above "business as usual".

f. ***Simple retrofit option - optimizing the conventional steam system with improvements using prepared cane as the fuel source .***

g. The biomass gasifier - optimizing the conventional steam system with improvements in the boiler and addition of a gasifier to process the bagasse to methane for the production of electricity.

The following evaluation provides a projection of economic performance of the three approaches with biomass supplied at different prices.

The assumptions presented below apply to the analyses:

ASSUMPTIONS:	
Tons Bagasse /Barrel Oil.......	1.00
BTU/Barrel Oil......................	6,200,000
OIL (cost/barrel)..................	$16.00
Value/million BTU..................	$5.16
Sugar Industry (BTU/kWh).....	10,250
Theoretical BTU/kWh............	3,414
Sugar Industry (BTU/kWh).....	10,250

As in the above scenarios, income from operations was chosen as a method of conducting a preliminary financial analysis on the effects various electrical options have on the economic performance of a sample sugar mill. Tables VI-9 through VI-11 show the total income from operations for a possible sugar mill with each of the three electric options. Prepared cane costs are assumed to be $38 per wet ton ($109 per dry ton).

e. Conventional steam boiler using bagasse derived from prepared cane as the fuel in the existing facilities.

Total income from operations for the business as usual option - sugarcane processed to sugar and molasses, and bagasse converted to electricity in a conventional steam combustion power facility - is estimated at a profit of $4,555 per harvested acre (Table VI -9). This scenario is based on a ten year average of data available and supporting assumptions and cannot be extrapolated to the entire industry.

f. Simple retrofit option - optimizing the conventional steam system with improvements using prepared cane as the fuel source.

The total income from operations for the business as usual option with inclusion of retrofit option 2b - sugarcane processed to sugar and molasses, and bagasse converted to electricity via the retrofit option 2b - described in Chapter VI is approximately $350.00 per harvested acre (Table VI-10). This indicates a slightly positive cash flow from operations and warrants a more in depth financial analysis to determine if this cash flow is enough to create a viable business opportunity.

g. The biomass gasifier - optimizing the conventional steam system with improvements in the boiler and addition of a gasifier to process the bagasse to methane.

Total income from operations for the business as usual option with inclusion of a biomass gasifier option - sugarcane processed to sugar and molasses and bagasse converted to electricity via a biomass gasifier option described - in the Chapter VI is approximately $94.00 per harvested acre. If tax credits are added the revenue per acre is $1,193.00 (Table VI-11).

TABLE VI-9
BUSINESS AS USUAL WITH CONVENTIONAL STEAM COMBUSTION OPTION

ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE
Sugar Company Harvesting With Open Field Burning (Scenario 1A)
Sugarcane Processed To Sugar and Molasses/Bagasse Burned for Electricity
(Business As Usual/Conventional Steam Combustion Option)

	YIELD KWh or tons per harv. acre	COST OF OPERATIONS $/ton Prep cane	VALUE OF PRODUCT $/ton or kWh	NET VALUE $/harv. acre
REVENUES				
96DA Sugar (tons per harvested acre)	12.16		$360.00	4,377
Molasses (tons per harvested acre)	2.95		$40.00	118
Electricity Sales (kWh's/harv. acre)	95,332		$0.05	4,767
Total Revenues				**$9,261**
COSTS OF OPERATIONS				
Prep Cane (wet tons)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion		$0.14		(17)
Dewatering		$0.15		(18)
Waste Disposal		$0.01		(2)
Boiling House/Processing		$1.62		(199)
Electricity Production		$2.69		(331)
Other Factory		$3.40		(418)
G&A Costs		$5.80		(714)
Total Costs		$38.25		**($4,706)**
TOTAL INCOME FROM OPERATIONS (per acre)				**$4,555**
	YIELD gallons or kWh		**VALUE** $ per gal or kWh	**NET VALUE** $ per harvested acre
CREDITS/EXEMPTIONS				
DFS Electric Credit	0		0.015	$0
Electricity Tax Credits				**$0**
TOTAL VALUE WITH CREDITS				**$4,555**

TABLE VI-10
BUSINESS AS USUAL WITH RETROFIT- OPTION 2B

ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE
Sugar Company Harvesting With Open Field Burning (Scenario 1B)
Sugarcane Processed To Sugar and Molasses/ Bagasse Burned for Electricity
(Business As Usual/Inclusion of Retrofit Option)

	YIELD KWh or tons	COST OF OPERATIONS $/ton Prep cane	VALUE OF PRODUCT $/ton or kWh	NET VALUE $/harv. acre
REVENUES				
96DA Sugar (tons per harv. acre)	12.16		$360.00	4,377
Molasses (tons per harvested acre)	2.95		$40.00	118
Electricity Sales (kWh's/harv. acre)	15,769		$0.05	788
Total Revenues				**$5,283**
COSTS OF OPERATIONS				
Prepared Cane (tons/harvested acre)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion		$0.14		(17)
Dewatering		$0.15		(18)
Waste Disposal		$0.01		(2)
Boiling House/Processing		$1.62		(199)
Electricity Production		$2.81		(345)
Other Factory		$3.40		(418)
G&A Costs		$5.80		(714)
Total Costs		$38.37		**($4,721)**
TOTAL INCOME FROM OPERATIONS (per acre)				**$561.92**
	YIELD gallons or kWh		**VALUE** $ per gal or kWh	**NET VALUE** $ per harvested acre
CREDITS/EXEMPTIONS				
DFS Electric Credit	0		0.015	$0
Electricity Tax Credits				**$0**
TOTAL VALUE WITH CREDITS				**$562**

TABLE VI -11
BUSINESS AS USUAL WITH BIOMASS GASIFIER

ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE
Sugar Company Harvesting With Open Field Burning (Senario 1C)
Sugarcane Processed To Sugar and Molasses/ Bagasse Burned for Electricity
(Business As Usual/Inclusion of Gasifier Option)

	YIELD KWh or tons	COST OF OPERATIONS $/ton Prep cane	VALUE OF PRODUCT $/ton or kWh	NET VALUE $/harv. acre
REVENUES				
96DA Sugar (tons per harv. acre)	12.16		$360.00	4,377
Molasses (tons per harvested acre)	2.95		$40.00	118
Electricity Sales (kWh's/harv.acre)	22,391		$0.05	1,120
Total Revenues				**$5,614**
COSTS OF OPERATIONS				
Prepared Cane (tons/harv. acre)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion		$0.14		(17)
Dewatering		$0.15		(18)
Drying		$0.20		(25)
Waste Disposal		$0.01		(2)
Boiling House/Processing		$1.62		(199)
Electricity Production		$2.90		(357)
Other Factory		$3.40		(418)
G&A Costs		$5.80		(714)
Total Costs		$38.67		**($4,757)**
TOTAL INCOME FROM OPERATIONS (per acre)				**$857**
	YIELD gallons or kWh		**VALUE** $ per gal or kWh	**NET VALUE** $ per harvested acre
CREDITS/EXEMPTIONS				
DFS Electric Credit	22,391		0.015	$336
Electricity Tax Credits				**$336**
TOTAL VALUE WITH CREDITS				**$1,193**

TABLE VI-12
PROCESS ECONOMIC SUMMARY
(VALUES PER HARVESTED ACRE PREPARED CANE)

Scenario	Products Using Prepared Cane	Sales Value	Production Costs/Acre	Profit per acre	Tax Benefits Concessions	Profit After Tax
1	Prep. Cane to Sugar & Molasses & Energy	$4,904	($4,706)	$197	$0	**$197**
2	Juice to Ethanol Simple Fer Bagasse to Ethanol SSF	$3,647	($7,161)	($3,513)	$347	**($3,167)**
3	Juice to Sugar & Molases SSF Bagasse to Ethanol	$6,411	($6,288)	$123	$167	**$291**
4	Juice to Ethanol- Bagasse to Electric	$2,141	($5,553)	($3,413)	$179	**($3,223)**
5	Prep. Cane to Sugar & Molasses Bagasse to Electric	$4,990	($5,522)	($532)	$123	**($409)**
6	Power Plant Retrofit	$5,756	($5,400)	$355	$352	**$708**
7	Addition of Gassifier	$6,187	($6093)	$94	$481	**$575**

Profitability is dependent on the location of the market. Serious consideration must be given to the costs of transporting ethanol produced on one island to meet the demands on another island. Factors such as back hauling to Oahu from the outer islands may present an opportunity to reduce these costs. All these factors must be considered in evaluating the business opportunity.

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[1]Ethanol Production in Hawaii 1994 Department of Business Econimic Develoment and Tourism

[2]HSPA subcontract Report to PICHTR

[3]Avoided cost established by the PUC

VII. REGULATIONS, PERMITS, AND BENEFITS [TASK - 8]

A. ENVIRONMENTAL AND COMMUNITY RELATED CONCERNS AND BENEFITS

Environmental, safety, and health issues have taken on increased significance as it is increasingly necessary to adequately address these issues in order to obtain permits and approvals for new facilities. Biomass energy projects are no exception to this rule. Failure to recognize the time and costs associated with the permitting process could cause significant impacts to the overall project schedule. The legal and political aspects of establishing a new endeavor can be as difficult and time consuming as the actual physical implementation of the activity. Information was collected and consolidated on permit requirements. Environmental and community issues such as biodiversity, aesthetic value, and social acceptability of the proposed options were outlined to ensure that a potential project is in the widest sense "sustainable" in the area.

This section of the report provides overviews of the federal, state, and county permitting processes along with a comprehensive list of potential permits. Predictions of which permits are "likely" to be required for an ethanol and/or electricity production facility are presented below. In addition, the major permits and approvals, preliminary schedules and cost estimates are provided. Recommendations are made relating to permits and approvals.

There are environmental and social costs associated with all industrial processes. Technically informed individuals understand that the environmental costs of using biomass as feedstocks for energy production are much less than those associated with fossil fuels. But it is naive to assume that these notions are generally accepted in the community at large.

1. Environmental Issues - Benefits Versus Costs

There are costs and benefits associated with any development. In designing a project, it is essential to make every effort to minimize the risks and then make decisions, based on an analysis of the best available information, to balance the remaining risks and rewards.

Possible benefits of programs that emphasize use of biomass to produce energy include:

a. Biomass to energy programs can contribute to the environmental quality of local areas as well as globally by:
    1. Reducing sulfur emissions caused by burning petroleum based fuels, thus contributing to the reduction in acid rain;
    2. Reducing carbon dioxide emissions, thus reducing the greenhouse effect resulting from fossil fuel combustion; (by using biomass to produce

electricity and transportation fuels, carbon dioxide stored by the plants during their growing season is recycled, upon emission, back into the crops of the next growing season, thus providing a short-term carbon dioxide closed loop and thereby creating a zero net carbon dioxide emission; reducing carbon monoxide); and

3. Improving combustion efficiency and increasing the octane rating of transportation fuels when gasoline is blended with 10% ethanol (carbon monoxide emissions is reduced by 10 to 30%) reducing volatile organic and aromatic hydrocarbon emissions (at blends greater than 10% ethanol); both potentially carcinogenic.

b. Reducing risks associated with imported oil, i.e. potential for oil spills.
c. Providing a means to reduce the problems associated with solid waste disposal and landfills.
d. Making available a locally produced soil supplement.
e. Contributing to the balance of payments on imports versus exports. The security position of Hawaii could be enhanced by offsetting the dependence on imported oil with locally produced and renewable energy. The state's balance of trade would be improved by reducing purchases of imported oil.

Possible costs or risks include:

a. Soil erosion on highly erodible lands.
b. Nutrient leaching resulting in declines in soil fertility.
c. Soil and chemical runoff possibly resulting in regional adverse water quality.
d. Adverse affects on infrastructure due to large trucks transporting biomass to the processing plant from the growing areas and fuel from the plant to the distribution outlets.
e. Improper storage of biomass resulting in spontaneous combustion or proliferation of pests and insects.

2. Biodiversity

In Hawaii, the stewardship of large parcels of land has been successfully managed for over 150 years by the agriculture industry. A program of sustainable agriculture on these lands has been accomplished over this period of time. Simply stated, successful stewardship of land involves the preservation of land and life over time. The Hawaii sugar plantations have certainly accomplished this. Lands that are being considered for the development of biomass energy programs in the state of Hawaii are the same lands which have been under cultivation for the past 150 years. If these lands are removed from agricultural practices, they run the risk of being developed in ways which may prove to be much less forgiving and sustainable. Thus, perhaps, adversely affecting the conservation of biological diversity of these areas. Many of these lands have served as a successful buffer zone between development and Hawaii's tropical rain forests.

B. REGULATIONS

The regulatory processes should be considered a tiered system with the traditional separation of federal, state, and county authorities. There are some instances where regulatory responsibilities overlap or are shared among the various regulatory agencies. This tends to complicate the permitting process and may obscure the identity of appropriate regulatory agencies and the procedural sequence in which one can best obtain the required approvals.

1. Federal

As a general rule, the federal government's regulatory role in the state of Hawaii applies to work in navigable waters, work in and around airports and related facilities, and the protection of wetlands. For a sustainable biomass energy project, the federal role would probably include review and approval of environmental documents and involvement with protecting the natural resources (air, water, land).

2. State

Activities regulated by the State of Hawaii focus on public health, welfare, and the management of natural and human resources.

3. County

The County of Hawaii regulates activities that are more directly concerned with land use, zoning, and development of facilities.

C. PERMITS AND APPROVALS

It is advisable for applicants to seek assistance to determine permit requirements among the three levels of government. With a better understanding of the broader regulatory requirements, one can also determine which approvals can be obtained concurrently to help streamline the permitting process.

To assist with streamlining the permitting process, the State of Hawaii designated the Office of State Planning (OSP) as the lead agency for implementation of a consolidated application process (CAP). The consolidated application process facilitates regulatory processing by providing a forum in which applicants may present and discuss their projects with regulatory agencies. Through this pre-application meeting, government agency representatives learn about the project and comment on the expected permit requirements, applicants can better plan and prepare for the permit process by establishing more accurate time frames, and the possibility for concurrent processing and combined public hearings can also be established.

Each county government in the state of Hawaii operates a Central Coordinating Agency (CCA) to assist applicants in the processing of county permits and approvals.

The Central Coordinating Agencies focus principally on county regulatory processes and the streamlining of interagency processes within the county. For the County of Hawaii, the CCA is its planning department.

Based on the preliminary investigation undertaken for this study, the possible number of federal, state and county permits and approvals have been estimated to be as high as 100 for a biomass energy facility (See Table VII-1). This could include as many as 75 different agencies which could be included in the review process. For an ethanol and/or electricity production facility built in conjunction with an existing sugar company facility, the actual numbers of permits and agencies are expected to be much less.

Table VII-1
Estimated Maximum Number of Permits and Agencies

	Federal	State of Hawaii	County of Hawaii	Total
No. Permits/Approvals	24	48	35	107
No. Agencies	20	30	25	75

1. Federal Permits

The primary federal agencies expected to be involved in the permitting process includes: Department of Energy (DOE), Environmental Protection Agency (EPA), and Department of Agriculture (DOA). In addition, there could be a number of secondary agencies that may also be involved such as the National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS).

2. State Permits

The primary State of Hawaii agencies expected to be involved in the review/approval process includes: Department of Health (DOH), Office of State Planning (OSP), and the Office of Environmental Quality Control (OEQC). In addition there could be a number of secondary agencies that may also be involved such as the Department of Land and Natural Resources (DLNR), Land Use Commission, and Department of Transportation (DOT).

3. County Permits

The primary county of Hawaii agencies expected to be involved in the permitting process includes: Planning Department, Department of Public Works, and the Fire Department. In addition there could be a number of secondary agencies that may also be involved such as the Engineering Department, Department of Water Supply, and Wastewater Department.

For a comprehensive list of federal, state, and county permits and approvals and the primary responsible agencies refer to Table VIII-2. [1] These tables were, in a large part, modified from a briefing document entitled "Energy Management and Permitting Analysis"[2] . Possible permits and agencies responsible have been organized into five broad categories:

1. Environmental Review,
2. Environmental Permits,
3. Construction & Operating Permits,
4. Land Use Permits, and
5. Utility Permits.

Table VII-2
List of Possible Permits and Approvals

CATEGORY	FEDERAL	STATE OF HAWAII	COUNTY OF HAWAII
Environmental Review	EPA/DOE - (1) NEPA EA/FONSI or EIS DOE - (1) Environmental Baseline Study	OEQC - (1) SOH EA/ND or EIS OSP - (1) Clearinghouse Review	Planning Department - (1) SOH EA or EIS Review
Environmental Permits	EPA - (1) PSD (3) Hazardous Waste Generator (3) TSD (1) Ocean Dumping Review (2) Injection Control Review COE - (2) Section 404 USFWS - (2) Endangered Species NMFS - (2) Clean Water Act (2) Marine Mammal Exemption (2) Endangered Species Park Service - (1) PSD (1) Visibility Analysis Coast Guard - (3) Notice-Submerged Cable (3) Notice-Cable Laying (3) Bridge/Causeway Permit	DOH - (1) PSD (1) Health Risk Assessment (2) Variance from Pollution Control (1) NPDES (1) Water Quality Certification (2) Injection Control Permit (2) Underground Storage Tank (2) Hazardous TSD Permit (1) SARA Reporting (2) Zone of Mixing Permit (2) Drinking Water Approval (2) Private Wastewater Permit OSP - (1) CZM Consistency	DPW - (2) Discharge of Water Permit (2) Industrial Wastewater Discharge Certificate

Table VII-2
List of Possible Permits and Approvals
(cont'd.)

CATEGORY	FEDERAL	STATE OF HAWAII	COUNTY OF HAWAII
Land Use Permits	**DOA, SCS -** (1) Prime Farmland (1) 1995 Farm Bill **FAA -** (3) Notice-Construction Within Airspace	**Land Use Commission -** (2) Special Use Permit (2) District Boundary Amendment **DLNR -** (2) Conservation District Use (2) Easement for Use of state Lands (2) Well Drilling/Modification (2) Groundwater Control Area (3) Stream Channel Alteration (2) Historic Site Review (3) Forest Reserve Special Permit (2) Wildlife Sanctuary Entry Permit (3) Closed Watershed Entry Permit (3) Natural Area Reserves (3) Geothermal Resource Subzone	**CCA -** (1) SMA Permit (2) Special Use Permit (3) Subdivision Permit (2) Flood Hazard Controls (2) Land Use Boundary Amendment (3) Development Plan Amendment (3) General Plan Amendment (2) Zoning Change **DPW -** (1) Grading, Grubbing, Excavating (1) Road Use/Modification Permit (2) Sewer Connection Permit (2) Flood Hazard District Permit (3) Subdivision Approval
Land Use Permits	**DOA, SCS -** (1) Prime Farmland (1) 1995 Farm Bill **FAA -** (3) Notice-Construction Within Airspace	**OSP -** (1) SMA Permit* **HCDA -** (2) Community Development Permit **DOT -** (3) Energy Corridor Lease (3) Airport Zone Land Use Permit	**Dept of Planning -** (2) Special Use Permit (1) SMA Permit (3) Shoreline Setback Variance (3) Subdivision Land Permit (3) Community Plan Amendment (2) Conditional Use Permit (3) Urban Land Use Classification (2) Historic District Application
Utility Permits	**FERC -** (1) Utility/QF Filings	**PUC -** (2) Transmission Line Approval (3) Special Order No. 6 Exemption (2) General Order No. 7 (2) Public Convenience /Necessity	**CCA -** (2) Public Utility Joint Venture

D. APPROVALS

As part of this study, an attempt was made to predict which permits and approvals would "Likely" (= "1"), "Possibly" (= "2"), or "Unlikely" (= "3") be required for an ethanol and/or electricity production facility located in the Hamakua/Hilo region of the Big Island. To address the broadest possible scenario, the following assumptions and information were used to make the predictions:

- The facility would be newly constructed (not a retrofit of existing factory).
- The facility would be of commercial size (25 million gals/year or 25 MW).
- Preliminary information was provided by OSP, OEQC, Hawaii Planning Department, HSC, HCPC, HELCO, HECO, HCDA, and DOA.
- Information from experience gained by PICHTR during the Biomass Gasifier Facility permitting process would be made available.
- Site may be located within a General Industrial District, so Special Use Permit (SUP) may not be required.
- Site would be located near or on existing HSC or HCPC factory site.

1. Electricity Versus Ethanol Option:

There are slight differences in the permitting requirements between a stand alone electricity facility, a stand alone ethanol facility, and an electricity/ethanol facility. The ethanol facility may require more permits relating to waste streams, SARA. Reporting of any hazardous chemicals, and a DOT permit for ethanol transportation. The electricity facility may have more air emission concerns, and therefore, may require more permits. Since there are relatively few differences between the two options, it is expected that a combination electricity/ethanol production facility would have similar permitting requirements to the two stand alone options.

Table VIII-3 summarizes all the permits and approvals that are considered to "likely" be required for a biomass energy facility in the Hamakua/Hilo region on the island of Hawaii. If the existing HSC or HCPC factory is retrofitted, the modified plant could possibly be 'grandfathered' under existing permits which would reduce the number of new permits required dramatically. Although this is possible, it is not likely due to recent environmental concerns associated with existing factories (i.e. HSC) and stricter environmental regulations today.

Table VII-3
Likely Permits and Approvals

CATEGORY	FEDERAL	STATE OF HAWAII	COUNTY OF HAWAII
Environ-mental Review	**EPA/DOE -** (1) NEPA EA/FONSI or EIS **DOE -** (1) Environmental Baseline Study	**OEQC -** (1) SOH EA/ND or EIS **OSP -** (1) Clearinghouse Review	**Planning Department -** (1) SOH EA or EIS Review
Environ-mental Permits	**EPA -** (1) PSD (1) Ocean Dumping Review **Park Service -** (1) PSD (1) Visibility Analysis	**DOH -** (1) PSD (1) Health Risk Assessment (1) NPDES (1) Water Quality Certification **OSP -** (1) CZM Consistency	**DPW -** (1) Discharge of Waters Permit (1) Industrial Wastewater Discharge Certificate
Construction & Operating Permits		**DOH -** (1) ATC (1) PTO (1) Allowable Noise Levels Permit **DLNR -** (1) Pressurized Vessel Permit **DOT -** (1) Ethanol Transportation	**CCA -** (1) Grading, Grubbing, Excavating (1) Building Permit **DPW -** (1) Building, Electrical, Plumbing **Fire Department -** (1) Combustible Liquid/Gas Tanks Installation/Use Permits
Land Use Permits	**DOA, SCS -** (1) Prime Farmland (1) 1995 Farm Bill	**OSP -** (1) SMA Permit*	**CCA -** (1) SMA Permit **DPW -** (1) Grading, Grubbing, Excavating (1) Road Use/Modification Permit **Dept of Planning -** (1) SMA Permit
Utility Permits	**FERC -** (1) Utility/QF Filings		

Figure VII -1
Permit Timing

ID	Name	Duration
1	PERMIT/ APPROVAL PROCESS	784d
2	SOH EA/EIS	650d
3	Site Selection	12w
4	EA/EIS Coordination Meetir	0d
5	Environmental Baseline Stuc	12w
6	Preliminary Design	52w
7	Consultation/Data Collecti	26w
8	Public Scoping Meeting	0d
9	Prepare EA/EIS PN Determir	12w
10	Submit EA/EIS PN Determinc	0d
11	Public Consultation Period	30ed
12	Prepare Draft EIS	52w
13	Submit/Distribute Draft EIS	0d
14	Public Comment Period	45ed
15	Prepare Final EIS	6w
16	Submit Final EIS	0d
17	Accepting Authority Review	30ed
18	Acceptance Notice Issued	0d
19	Legal Challenge Period	60ed
20	EIS Process Completed	0d
21	Federal EA/EIS	508d
22	Prepare EA/EIS NEPA Deterr	9w
23	Submit EA/EIS NEPA Determ	0d
24	Federal EIS Determination	60ed
25	Notice of Intent for Public M	0d
26	Federal EIS Scoping Meetin	0d
27	Prepare Implementation Pl	8w
28	Review Implementation Pla	30ed
29	Implementation Plan Appro	0d
30	Prepare Draft EIS	52w
31	Submit Draft EIS	0d
32	Public Comment Period	45ed
33	Prepare Final EIS	6w
34	Submit Final EIS	0d
35	Accepting Authority Review	30ed

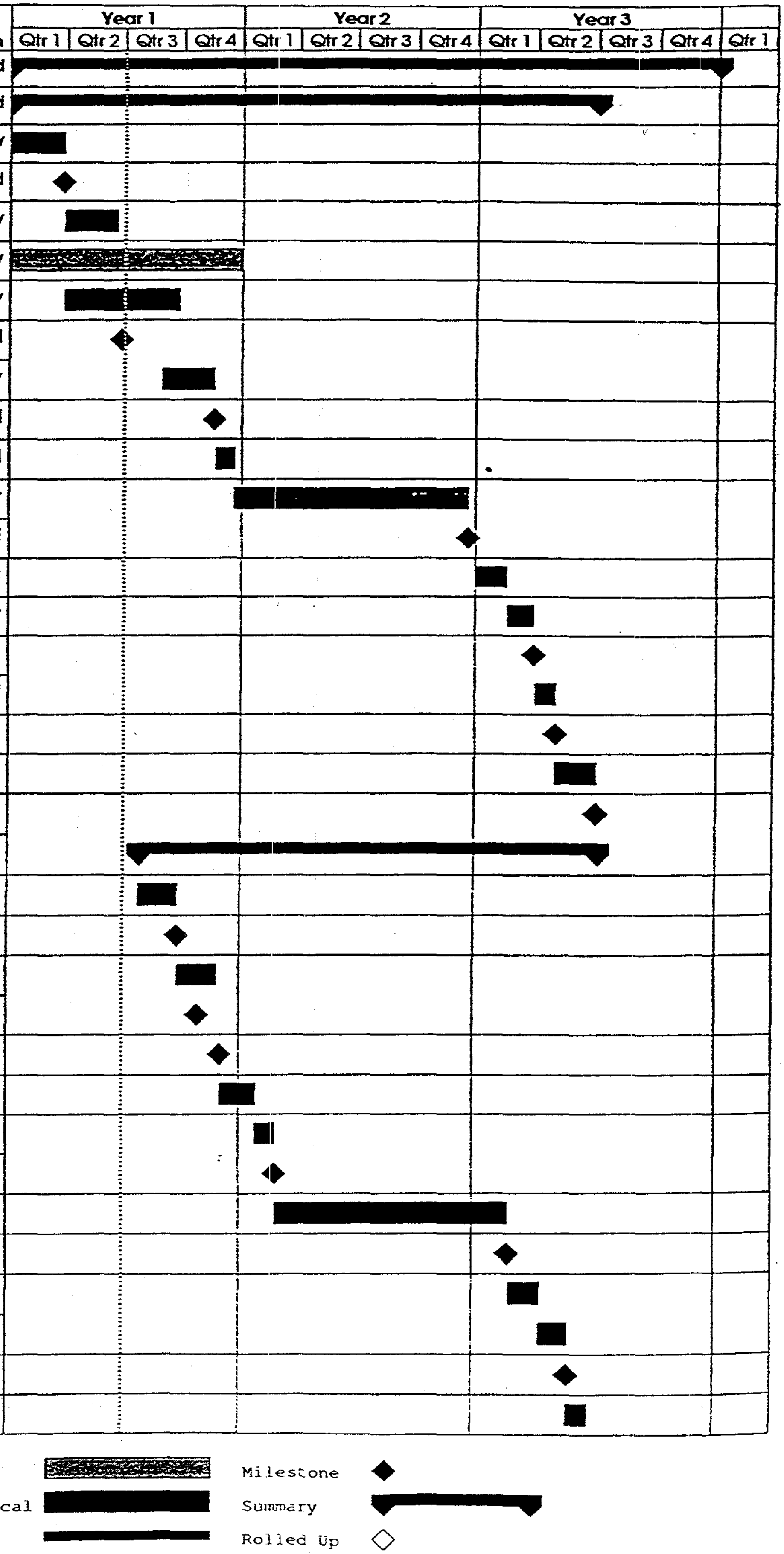
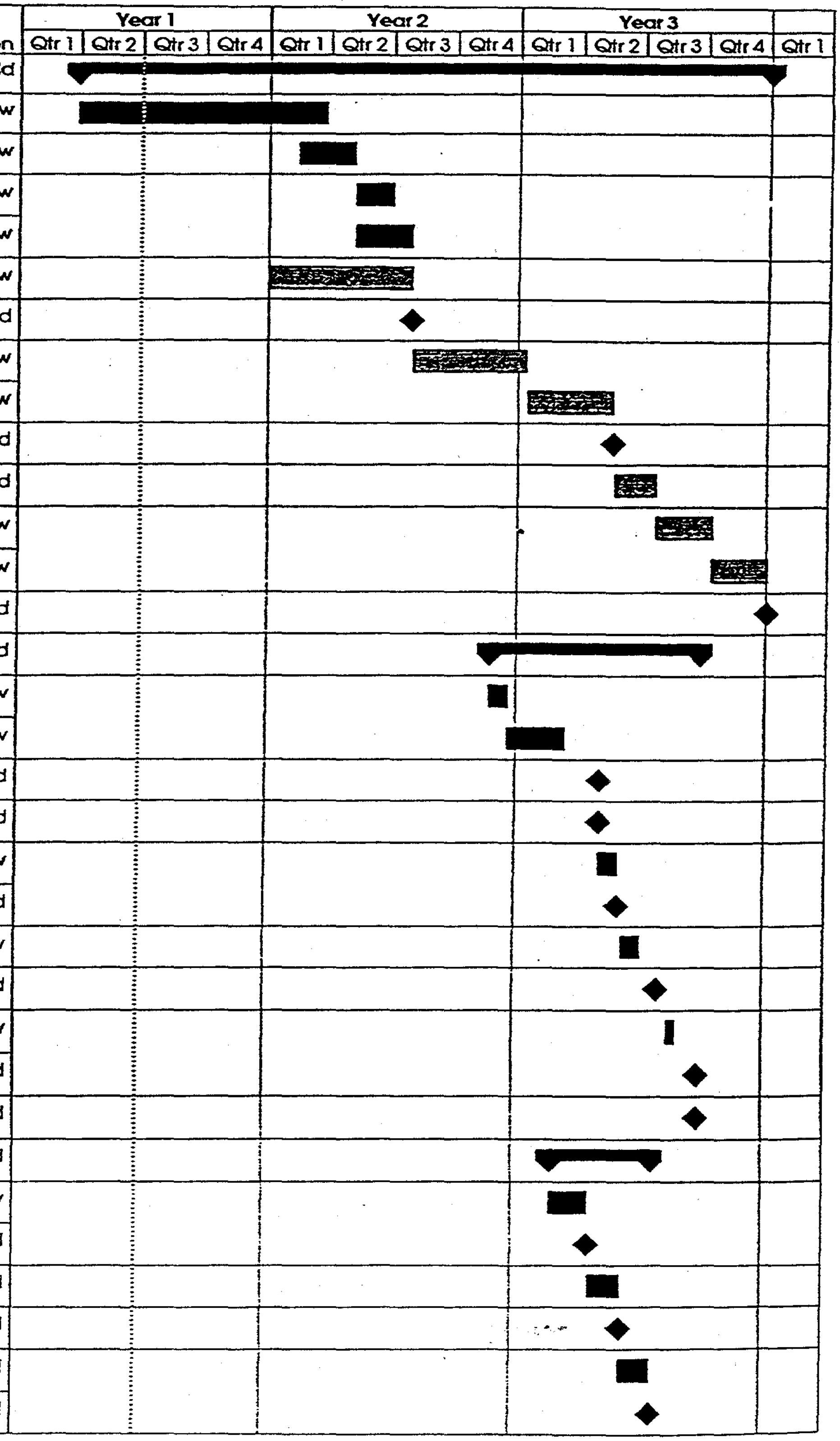


Figure VII -1
Permit Timing (continued)

ID	Name	Duration
37	ATC/PSD	724d
38	Met Data Collection	52w
39	Air Modeling/Emission Estim	12w
40	Visibility Analysis	8w
41	Health Risk Assesment	12w
42	Prepare Application	30w
43	Submit Application	0d
44	DOH, EPA, NPS, ...Review	24w
45	Prepare DOH Draft Permit	18w
46	DOH Draft Permit Issued	0d
47	Public Comment Period	60ed
48	Comment Response Period	12w
49	Prepare DOH Final Permit	12w
50	ATC Permit Issued	0d
51	SMA	221d
52	Determination of SMA Requ	4w
53	Prepare SMA Application	12w
54	Submit SMA Application	0d
55	Submit Final EIS to OSP	0d
56	Review of SMA Application	4w
57	Acceptance of Applicatior	0d
58	Notification of Public Hearir	4w
59	SMA Public Hearing	0d
60	Hearing Officer's Report	2w
61	OSP Determination on SMA	0d
62	SMA Use Permit Issued	0d
63	CZM	105d
64	Federal Agency Determina	8w
65	Consistency Determination	0d
66	OSP CZM Review	45ed
67	OSP Determination	0d
68	Federal Acceptance	45ed
69	CZM Permit Issued	0d



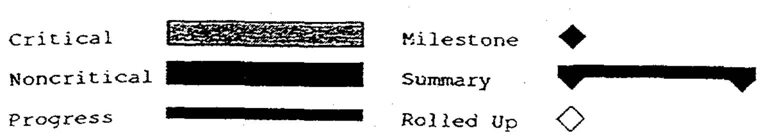


Figure VII -1
Permit Timing (continued)

ID	Name	Duration	Year 1				Year 2				Year 3				
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1
70	Water Quality Certification	152d													
71	Prepare WQC Application	6w													
72	Submit WQC Application	0d													
73	Review of WQC Applicatio	4w													
74	Public Notification	2w													
75	WQC Public Hearing	0d													
76	Determination on WQC	0d													
77	WQC Issued	0d													

Critical　Milestone
Noncritical　Summary
Progress　Rolled Up

E. RECOMMENDATIONS FOR SUCCESSFUL PERMITING

Based on PICHTR's experiences with the Biomass Gasifier Facility (BGF) and the precursory investigation of permitting issues for this Sustainable Biomass Energy Study, the following recommendations are believed to be appropriate for both a generic project/location and for a specific dedicated biomass energy production facility in the Hamakua/Hilo region of the Big Island:

- To insure that permits and approvals are obtained expediently, it is recommended that this work be started as soon as possible.

- To avoid duplication of effort, make as early as possible a determination of which federal, state, and county permits and approvals will be required for the proposed project.

- In order to avoid delays and confrontations with the general public, it is recommended that early and frequent consultations, meetings, and communications be initiated with community and environmental groups.

- It is also recommended that early and frequent consultations, meetings, and communications be initiated with federal, state, and county agencies. This is necessary to develop detailed planning, coordination of the permitting process, and verification that requirements are being met and concerns are being addressed.

- To streamline the complex permit/approval process, it is recommended that a coordinated effort be developed among all three levels of government (i.e., determine lead agency for duplicated documents, such as EA. or EIS, and prepare single comprehensive documents where possible, limit overlapped effort, combine public meetings and hearings, etc.). This will help minimize the delays and added costs often attributed to the regulatory requirements.

- Develop a detailed and integrated permit/approval schedule.

- Define and "fix" the proposed facility's design as early as possible. Avoid substantial design changes that might lead to requirements by certain agencies to submit new or revised documents.

- Pay particular attention to accurately preparing and completing all documents, otherwise significant delays in the permitting process could result. Try to anticipate all problems, concerns, and comments ahead of time and address them in the documents.

- Obtain, as early as possible, specifications for all input, output, and product streams (composition, quantity, etc.). This information is necessary to prepare documents such as ATC, EA./EIS, and HRA, and to determine if any special permits are required. If existing information is unavailable or unacceptable for proposed project, this would more than likely create a need to perform PDU-like testing. Unplanned testing would significantly impact the project schedule and costs and could impact what permits are required.

- Consider and investigate alternative sites and biomass conversion processes. This is especially important to meet EA/EIS requirements. If possible, try to get consensus from public, groups, and agencies on "best" site in advance. This may eliminate any need to obtain data for more than one site.

- Make every effort possible to develop and maintain good working relations with and the support of newspaper, magazine, radio, and television reporters.

- Avoid "negative/scary buzz" words, such as "experimental", "steam-explosion", and "acid", in project literature, verbal, and written communications.

- Expect the permits/approvals process to take time and money. Avoid the unrealistic assumption that "it will be easy". There is no such thing as a "one-stop" permitting (i.e., it took PICHTR two years to obtain the BGF Authority to Construct from the State Department of Health).

Specific References:

1. "An Applicant Guide to State Permits and Approvals for Land and Water Use Development", Hawaii Coastal Zone Management (CZM) Program, Department of Planning and Economic Development (CZM now regulated by Office of State Planning), June 1986.

2. "Energy Management and Permitting Analysis, Hawaii Integrated Energy Policy Development (HEP)" Briefing Document, RCG/Hagler, Bailly, Inc., October 4, 1991.

F. BENEFITS

1. Social Acceptability and Community Support

As indicated in the draft of the *Hilo-Hamakua Economic Development Plan,* preliminary "community vision" for the Hilo/Hamakua region, established through a series of community workshops, is one of integrated and diversified agriculture. It has been envisioned by members of the community that they would like to see small family farms run as interconnected operations which utilize recycling and multiple use self-sufficiency systems with coordinated planting, harvesting, processing and marketing efforts. They would like to see strong linkages established with the University of Hawaii's technical resources and field work. They would also like to see continued community development through grassroots planning processes. An integrated biomass energy program fits nicely with much of this community vision. An industry based on energy production from sustainable biomass would support the initial efforts and vision of community based economic development programs.

The opportunity to retain the agricultural base through the production of dedicated biomass feedstock supports and preserves the historic way of life in these rural communities. The development of this industry further supports rural economic development by strengthening and diversifying the economic base. Results of a study for the Southeastern Regional Biomass Energy Program showed significant potential to increase income and employment and improve the region's balance of trade through the use of biomass to energy programs. These programs diversified the regions economic base, while providing a means for retaining an economically sustainable agriculture based community.[3]

2. Employment

Hawaii County's residential population was approximately 130,500 (approximately 11% of The state's total) in 1992 and it is projected to be over 200,000 by the year 2010. The county of Hawaii's residential population is currently centered in two areas - South Hilo/Puna (approximately 65,000) and North Kona (approximately 25,000).[4]

The county of Hawaii accounts for about 9 percent of the state's total personal income. Total job count on the Big Island for January through June 1993 was 60,230. Total civilian labor force for the same period was 67,620. Historically, the county of Hawaii has been economically dependent upon agriculture. The agriculture industry directly accounts for roughly 10 percent of the Big Island employment.

The three regions most severely effected by the pending decline in the sugar industry on the island of Hawaii are; Hamakua (approximately 5,500 residents), North Hilo (approximately 1,500 residents), and Ka'u (approximately 4,500 residents). Hamakua Sugar Company employed approximately 750 people directly at full production. Mauna Kea Agribusiness Company employs approximately 450 people directly and Ka'u Sugar Company employs approximately 350 people directly.

Together, approximately 1550 people will lose their jobs, accounting for approximately 13 percent of the islands total job count.

The loss of these jobs will obviously have a severe direct affect on the economies of these rural areas and the county overall. The indirect multiplier effect will further depress the economic outlook. First Hawaiian Bank estimates an indirect income multiplier for the sugar industry to be approximately 1.3. That is, a $100 dollar direct contribution from the industry would, through successive re-spending, create another $30 additional dollars of contribution to the economy of the region.[5]

Assuming a biomass to ethanol industry developed, sustained agriculture would result in the establishment of ethanol refineries. An ethanol refinery would have economic advantages over a petroleum refinery. Petroleum refineries create about 1/2 to 1 full-time in-plant production job for every 1 million gallons of gasoline produced. Ethanol refineries employ 3-5 full-time people in-plant for every 1 million gallons of ethanol produced. If ethanol were to gain a 10 percent or 40 million gallon market share in Hawaii, the industry would create an additional 150-180 in-plant jobs. This may be nearly comparable to the in-plant jobs created in producing the 400 million gallons of gasoline Hawaii consumes. If ethanol were to replace 50 percent of the gasoline consumed in Hawaii the resulting industry could create more than 2,000 production jobs. In-plant jobs represent only one aspect of the economic benefits ethanol production brings rural communities. Equally important is the beneficial impact of keeping, in the producing region, millions of dollars in business spending.

3. Economic Advantages

A dollar spent on producing ethanol is largely spent inside the state while a significant amount of the dollar spent on producing gasoline leaves the state. For example, 45 to 55 cents of each gallon of gasoline represents the cost of crude oil, all of which leaves the state. On the other hand, at least 40 to 50 cents of the cost of producing a gallon of ethanol represents the cost of producing the biomass crop, all of which is grown within the state.

Studies of California's agricultural economy report a combined inter-industry multiplier of 2.5 or more, representing the multiple of farm revenues constituting total inter-industry effects on the state economy. In contrast, Hawaii's tourism multiplier is estimated to be 2.04. Because multipliers generally cluster around 2.0 for most industries, agriculture's higher multiplier typically means that investments in agricultural production generate economy-wide impacts at least 25 percent greater than that associated with other industries.[6]

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[1] Acronyms used in this table are presented in Appendix

[2] Prepared by RCG/Hagler, Bailly, Inc. (October 4, 1991).

[3] Source: Meridian Corporation. 1989. "Economic Impact of Industrial Wood Energy Use in the Southeast Region of the U.S.: Volume 1: Summary Report", Southeast Regional Biomass Energy Program, administered for the U.S. Department of Energy by the Tennessee Valley Authority, Muscle Shoals, Alabama.

[4] Source: Supplemental To Economic Indicators, First Hawaiian Bank. September/October 1993 and The State of Hawaii Data Book, 1990)

[5] Source: Supplement to Economic Indicators - First Hawaiian Bank, September/October 1993).

[6] Source: The Mason Research Foundation. Division of Simco Incorporated of U.S.A.Phase One Final Report. Chinese Tallow Tree Research. Growing Oil On Trees. June 30, 1992.)

VIII. MARKETS, PRODUCTS, & CO-PRODUCTS [TASK - 10]

The two primary products envisioned from a sustainable biomass energy facility are electricity and ethanol for use as a liquid transportation fuel. Potential markets for primary products, co-products, and potential higher value products which may result from conversion of biomass are outlined below. Emphasis has been given to local market potential.

A. MARKETS FOR ETHANOL

Liquid transportation fuels may be shipped between islands as well as out of state. Therefore, potential markets are located:

- on the island of Hawaii;
- on other islands (Maui, Lanai, Molokai, Oahu, Kauai) in the state;
- in the continental United States; and
- in other countries.

This section focuses on markets within Hawaii (1 and 2 above). Consideration of other markets may be warranted at a later date. However, they are not addressed here due to their complexity and sensitivity to fluctuations in commodities markets, international exchange rates, etc.

1. State Demand

Transportation fuels (primarily gasoline and diesel, with some propane) account for about 20% of the state's total petroleum demand. Gasoline represents about 94% of the ground transportation energy demand in the state. Use of gasoline in Hawaii ranges from 23 million gallons per year on Kauai, to 56 million gallons per year on the island of Hawaii, to over 250 million gallons per year on Oahu. In 1992, the statewide total was about 382 million gallons per year. Demand for ground transportation fuels is expected to continue and to increase.[1] Gasoline consumption by county is shown in Figure VIII-1.

2. Potential Markets for Fuel-Grade Ethanol

Ethanol may be used in the transportation fuel market in the following ways:

- In a 10% blend with gasoline, in existing vehicles;
- In the form of a gasoline additive such as ethyl tertiary butyl ether (ETBE) or tertiary amyl ethyl ether (TAEE), in existing vehicles;
- In an 85% blend with gasoline (85% ethanol, 15% gasoline) in specially-designed light duty vehicles (cars or vans); and

- As a "neat" fuel (100% ethanol) in specially-designed heavy duty vehicles (trucks or buses). Diesel fuel, which accounts for about six percent of the on-highway ground transportation energy demand in the state, is shown in Figure VIII-2.

Figure VIII-1

On-Highway Use of Gasoline, 1980-1992, by County

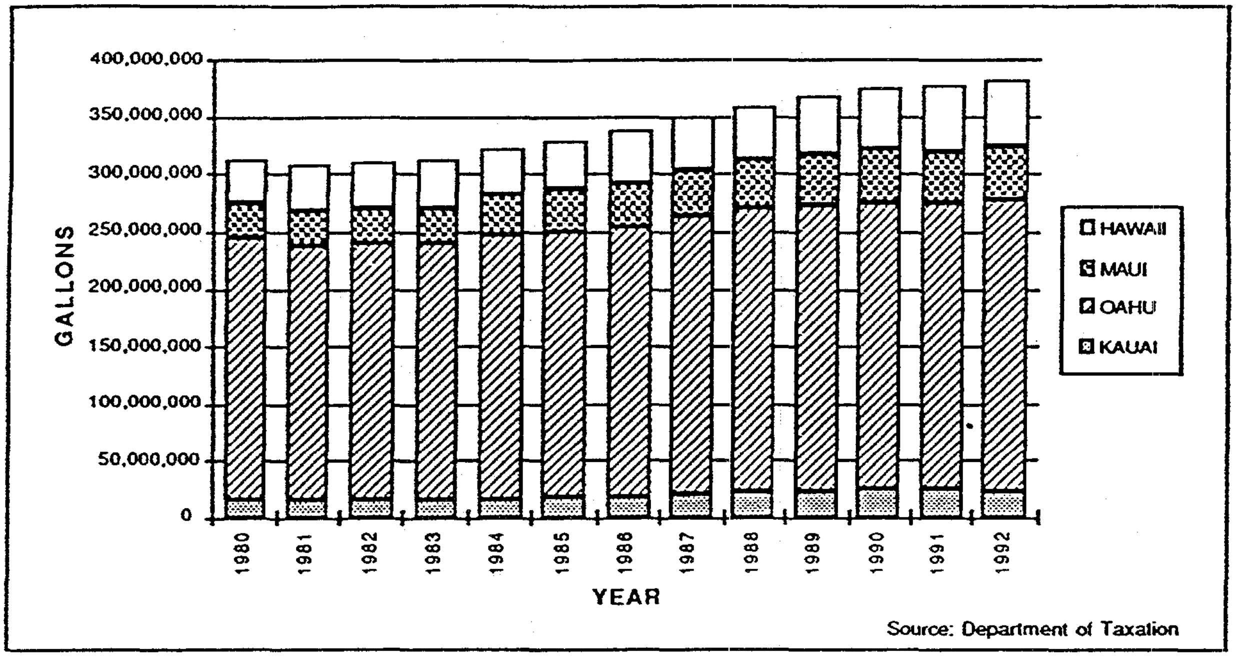
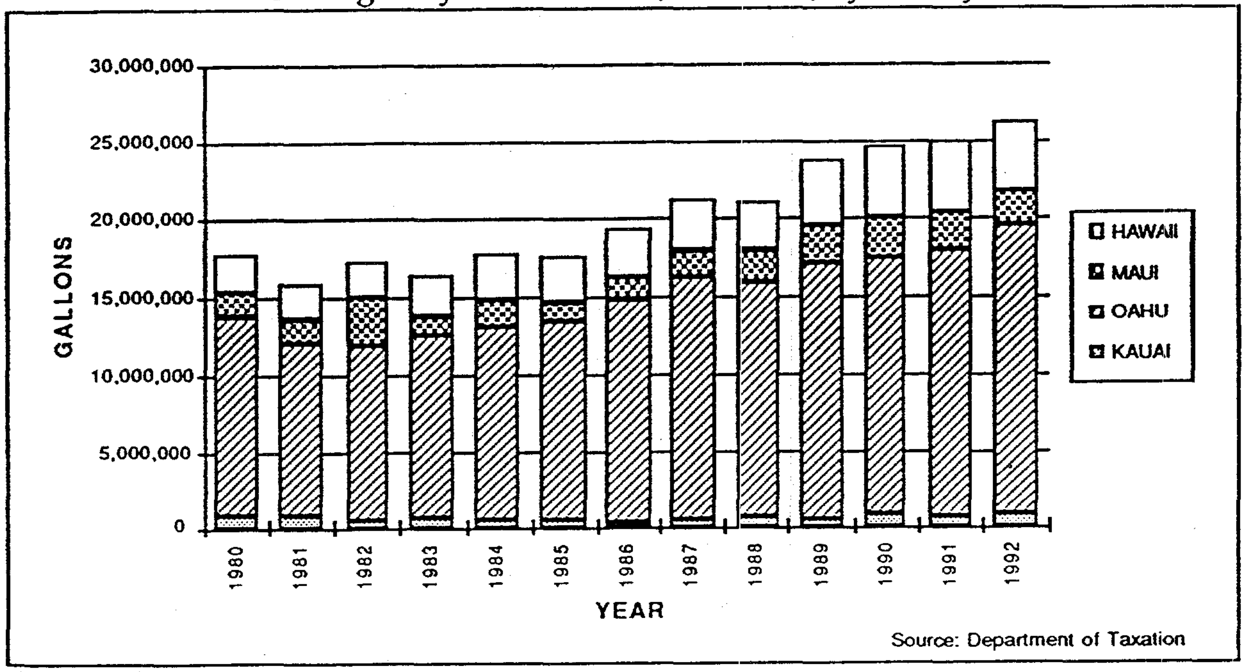


Figure VIII-2
On-Highway Use of Diesel, 1980-1992, by County



3. Theoretical Market Size and Market Constraints:

Each of the four uses outlined above are subject to the following constraints:

- Baseline demand for the traditional fuel;

- Availability of vehicles able to use the replacement product;
- Availability of the replacement product at a competitive price;
- Availability of the infrastructure necessary for distribution of the replacement product; and
- Willingness of the public to use the replacement product.

For the purpose of comparison, the above-listed uses and constraints, as well as theoretical market sizes, are shown in Table VIII-1.

Table VIII-1

Ethanol as a Transportation Fuel

	A. Baseline demand for the traditional fuel	B. Vehicles able to use the replacement product	C. Infrastructure for distribution of the replacement product	**Potential market size** (theoretical)
1. 10% ethanol	380 million gallons per year, x ≤ 10%	YES	YES	30 - 40 million gallons per year
2. ETBE or TAEE	380 million gallons per year	YES	YES	10 - 20 million gallons per year
3. 85% ethanol in light duty vehicles	380 million gallons per year	Vehicles commercially available.	Equipment commercially available.	480 million gallons per year
4. 100% ethanol in trucks, buses	25 million gallons per year	Vehicles commercially available.	Equipment commercially available.	50 million gallons per year

4. Practical Considerations:

The constraints to theoretical markets listed above introduce additional costs and complexity to each scenario. Costs (including shipping, infrastructure, and vehicle costs), benefits, and strategies are being addressed in the previously-referenced work in progress by the State Department of Business, Economic Development & Tourism on developing a "Transportation Energy Strategy".

Possible markets for ethanol fuel include: use as a transportation fuel, fuel additive, or as a fuel for electricity production. The potential market sizes, competition, and incentives for six possibilities are discussed briefly below. (For more detailed information on calculations and applications of tax credits and/or exemptions, see Appendix.)

a. As a blending agent (10%) with gasoline

1. **Market:** 382 million gallons of gasoline were sold in the state in 1992. A 10% blend with all gasoline would require about 38 million gallons per year.

2. **Competition:** 1) Locally-available gasolines; and 2) Ethanol from out of state

a. Locally-available gasolines

$ 0.85	rack price (approximately)
+ 0.09	retail overhead
+ 0.184	federal tax
+ 0.325	state and county fuel tax (Honolulu rate)
+ 0.039	state 4% tax
$ 1.49	retail gasoline price per gallon

Gasohol to compete with local gasoline:

$ 0.788	for 0.9 gallon $0.875 (unleaded regular + 2.5¢[2]) gasoline
+ 0.163	for 0.1 gallons ethanol (this is the maximum possible, which will still result in the same "bottom line" price to the consumer)
+ 0.09	retail overhead
+ 0.130	federal fuel tax
- 0.01	federal small producer credit (for facilities of less than 30 million gallons per year; credit applies only to the first 15 million gallons)
+ 0.004	federal income tax on credits
+ 0.325	state and county (Honolulu rate) fuel tax
+ 0.00	state excise tax (gasohol is exempt)
$ 1.49	retail gasohol price per gallon

(Ethanol would have to be produced for less than $1.63 per gallon.)

b. Ethanol from out of state:

Current prices for ethanol on the mainland range from $1.11 in South Dakota to $1.46 in the state of Washington.[3]

$1.10-$1.40/gal.	(approximate 5-year range);
+ 0.10-$0.20	shipping from West Coast to Hawaii (assumes parcel tanker shipments, includes terminal costs in Hawaii, does not include terminaling costs on the West Coast)
$1.20-$1.60/ethanol gal.	for Hawaii ethanol to compete with ethanol from out of state.

(Ethanol would have to be produced for less than $1.30 per gallon.)

3. Incentives:

5.4¢/fuel gal. federal excise tax (fuel tax) partial exemption
(See federal fuel tax amounts listed above:

gasoline,	$0.184 per gallon;
gasohol,	$0.130 per gallon;
= partial exemption for gasohol,	$0.054 per gallon);

10¢/ethanol gal. small producer federal income tax credit (minus a percentage because credit is taxable)

b. As a blending agent (10%) in unleaded mid-grade and premium gasoline

1. **Market:** About forty-two percent of the gasoline sold in Hawaii in 1992 was mid-grade and premium blends. A 10% blend with all mid-grade and premium gasolines would require about 17 million gallons of ethanol per year.

2. **Competition:**
1) Locally-available mid-grade and premium gasoline; and
2) Ethanol from out of state

a. Locally-available mid-grade and premium gasolines

$ 0.89	rack price (approximate)
+ 0.10	retail overhead
+ 0.184	federal tax
+ 0.325	state and county (Honolulu rate) fuel tax
+ 0.041	state 4% tax
$ 1.54	retail gasoline price per gallon

Maximum allowable cost of ethanol to compete with mid-grade and premium gasolines:

$ 0.788	for 0.9 gallon $0.875 (unleaded regular + 2.5¢) gasoline
+ 0.204	for 0.1 gallons ethanol at $2.04 per gallon
+ 0.10	retail overhead
+ 0.130	federal fuel tax
- 0.01	federal small producer credit (for facilities of less than 30 million gallons per year; credit applies only to the first 15 million gallons)
+ 0.004	federal income tax on credits
+ 0.325	state and county (Honolulu rate) fuel tax
+ 0.00	state excise tax (gasohol is exempt)
$ 1.54	retail gasohol price per gallon

(Ethanol would have to be produced for less than $2.04 per gallon.)

b. Ethanol from out of state: Same as a. 2.b. above.

3. Tax incentives: Same as a.3. above.

c. For use in light-duty flexible-fueled vehicles (FFV)

Most major auto manufacturers have designed special "flexible-fuel vehicles" which are capable of operating on mixtures of 85% alcohol and 15% gasoline. A mixture of 85% ethanol and 15% gasoline is known as "E85" and is considered an alternative fuel. The federal government has identified increased use of alternative fuels as a means to meet national energy security, economic, and environmental goals in both the Clean Air Act Amendments of 1990 and the National Energy Policy Act of 1992 (EPACT). As described in a Congressional Research Service Issue Brief:

> "The Energy Policy Act of 1992 sets a national goal of 30% penetration of nonpetroleum fuels in the light-duty vehicle market by 2010 and requires that, in sequence, the federal government, alternative fuels providers, state and local governments, and private fleets buy alternative fuel vehicles in percentages increasing over time. The Act also creates tax incentives for vehicle buyers and for alternative fuel service station operators."[4]

State government fleets are required to begin purchasing these vehicles in model year 1996. Ethanol is one of several alternative fuels. Other choices are methanol, liquefied petroleum gas (also commonly referred to as LPG or propane), natural gas, electricity, and biodiesel. Each of the fuels has benefits and disadvantages. It is unknown at this time what will be the demand for each of the alternative fuels (or for alternative fuels in general).

1. Market: Unknown. Based on a number of alternative-fueled vehicles purchased. Fuel use per vehicle: less than 500 gallons gasoline (694 gallons E85, containing 590 gallons ethanol) per year. A one million gallon per year facility would provide more than enough fuel for 1695 cars.[5] Theoretical maximum (if all gasoline-powered vehicles eventually used 85% ethanol) is projected to be more than 450 million gallons per year of ethanol. The current demand is zero.

2. Competition: 1. Locally-available gasolines; and
2. Ethanol from out of state

a. Locally-available gasoline

$ 0.85	rack price (approximate)
+ 0.09	retail overhead (approximate)
+ 0.184	federal tax
+ 0.325	state and county fuel tax (Honolulu rate)
+ 0.039	state 4% tax
$ 1.49	retail gasoline price per gallon

1.39 gallons E85 = 1 gallon gasoline. Since it takes more gallons of E85 to go the same distance, fuel cost per E85 gallon should be less. For fuel costs to be equivalent on a mile-for-mile basis, E85 retail price may not exceed $1.07 per gallon.

Maximum allowable cost of E85:

$ 0.1275	for 0.15 gallon gasoline (at 85¢/gallon gasoline)
+ 0.70	for 0.85 gallon ethanol (at 82¢/gallon ethanol)
+ 0.09	retail overhead
+ 0.184	federal fuel tax
- 0.459	federal tax credit
- 0.085	federal small producer credit
+ 0.19	federal income tax on credits
+ 0.325	state and county fuel tax
$ 1.07	per gallon E85

(Ethanol would have to be produced for less than $0.82 per gallon.)

b. Ethanol from out of state: Same as a. ii. b) above (less than $1.30 per gallon).

3. Incentives:

54¢/gal. federal income tax credit;

10¢/gal. small producer federal income tax credit (minus a percentage because credits are taxable);

Deductions for alternative fuel refueling facilities; and

Deductions for alternative fuel vehicles.

d. For use in buses

Ethanol-powered buses and trucks are in use in revenue service in several locations across the United States and in other countries (e.g. Brazil and France). Several federal programs have increased the use of alternative fuels in buses over the past several years. In 1988, the National Alternative Motor Fuels Act provided for transit agencies to begin to utilize alternative fuels in their fleets. In 1990, the Clean Air Act Amendments targeted particulate emissions from urban transit buses as an air pollution reduction objective. Alcohol fueled buses are one approach to reducing emissions of particulates. (Other options include advanced electronic engine controls, engine re-design, particulate traps, "clean diesel" fuels, catalytic converters, and various combinations of these systems.) The National Energy Policy Act of 1992 also contains provisions for alternatively-fueled buses.

Full-size transit buses which run on 100% ethanol[6] are available for approximately $40,000 more than for a regular bus (regular buses cost over $200,000).

1. Market: Unknown. Based on number of vehicles purchased. Current demand is zero. A 1 million gallon-per-year ethanol plant would provide enough fuel for about 35 buses. A 5 million gallon-per-year ethanol plant would provide enough fuel for about 178 buses.

2. Competition:
1) Locally-available diesel fuel; and
2) Ethanol from out of state

a. Locally-available diesel fuel[7]

$ 1.16	rack price (approximate)
0.00	federal tax
0.00	state and county fuel tax
$ 1.16	per gallon diesel

It takes approximately 1.8 gallons of ethanol to go as far as 1 gallon of diesel.[8] Since it takes more gallons of ethanol to go the same distance, fuel cost per ethanol gallon should be less. For fuel costs to be equivalent on a mile-for-mile basis, the total price of the E100 fuel should not be more than $0.69 per gallon.

Maximum allowable cost of ethanol to compete with diesel for use in transit buses:

$ 1.11	(1 gallon ethanol at $1.11 per gallon)
- 0.54	federal tax credit
- 0.10	federal small producer credit
+ 0.224	federal income tax on credit
$ 0.69	per gallon total price of E100 fuel

(Ethanol would have to be produced for less than $1.11 per gallon.)

b. Ethanol from out of state: Same as a. ii. b). above.

3. **Tax incentives:** Same as c.3. above.

e. As a feedstock in the production of ETBE (ethyl tertiary butyl ether)

Ethyl tertiary butyl ether (ETBE) is a gasoline additive made from ethanol and isobutylene. ETBE is an octane enhancer (raises the octane rating of the fuel) and an oxygenate (makes the fuel cleaner-burning). The November/December 1993 issue of *Fuel Reformulation* pegged the value of one gallon of ETBE at 130% the value of one gallon unleaded regular gasoline.

1. **Market:** If ETBE was blended into all mid-grade and premium gasolines at the rate of 17.2 per cent, demand for ethanol to make the ETBE would be about 12.5 million gallons per year.

2. **Competition:**
   1) Locally-available octane enhancers;
   2) ETBE or other octane enhancers from out of state;
   3) ETBE for export

a. Locally-available octane enhancers

Depends on refinery processes. If a competitive cost for ETBE is 130 percent of unleaded regular, ETBE cost per gallon would be $1.10.

$ 0.238	(0.68 gallons isobutylene[9] at approximately $0.35 per gallon[10])
+ 0.113	processing cost (estimated)
+ 0.928	ethanol cost (0.42 gallons ethanol at $2.20 per gallon)
- 0.2268	federal tax credit for ethanol used in ETBE
- 0.042	federal small producer credit
+ 0.094	federal income tax on credits
$ 1.10	ETBE

(Ethanol would have to be produced for less than $2.21 per gallon.)

b. ETBE or other octane enhancers from out of state

Depends on refinery processes. If a competitive cost for ETBE is 130 per cent of unleaded regular, and average price of unleaded regular is about 49 cents per gallon, ETBE could be shipped in for about 85 cents per gallon. However, the current situation with impending reformulated gasoline regulations – requiring lower vapor pressures (ETBE has a low vapor pressure), use of oxygenates (ETBE is an oxygenate) and a requirement for a certain percentage of oxygenates to be "renewable" (ETBE is usually made from ethanol which is considered "renewable") – may increase the value/price of ETBE.

c. ETBE for export

Depends on refinery processes. If unleaded regular on the mainland is about 49 cents, and a competitive cost for ETBE on the mainland is 130 per cent of unleaded regular (or about 64 cents), and shipping cost from Hawaii to the Mainland is about 10¢ per gallon, ETBE cost per gallon before shipping should be less than $0.54.

$ 0.238	(0.68 gallons isobutylene at approximately $0.35 per gallon)
+ 0.113	processing cost (estimated)
+ 0.354	ethanol cost (0.42 gallons ethanol at $0.84 per gallon)
- 0.2268	federal tax credit for ethanol used in ETBE
- 0.042	federal small producer credit
+ 0.094	federal income tax on credit
$ 0.53	ETBE

(Ethanol would have to be produced for less than $0.84 per gallon.)

f. For use in electricity generation

Electric utilities and combustion turbine manufacturers have evaluated the use of alcohols (methanol and ethanol) in combustion turbines. Combustion turbines operating on alcohols have shown higher efficiencies, longer operating life, and reduced emissions of NOx.[11]

1. Market: If ethanol is used in a 25,000 kW steam injected combustion turbine, fuel consumption is projected to be about 0.119 gallons per kilowatt-hour,[12] or almost 3000 gallons per hour at that operating rate. statewide electricity consumption in 1992 was over nine and one-half billion kWh.

2. Competition:
1) Conventional fossil fuels (fuel oil, diesel, and coal);
2) Direct combustion of biomass;
3) Other alternative energy sources for electricity generation.

Note that in the ethanol production process, lignin is a by-product which may also be burned to produce electricity. Although not explicitly valued in this section, its electricity production value may be included by reducing the projected ethanol price by the value of the lignin, then comparing that result to the target ethanol prices identified here.

a. Conventional fossil fuels

If #6 fuel oil is $18.00 per barrel, ethanol, competing with fuel oil, would have to be produced for not more than...

$ 0.22	(equivalent value per gallon ethanol on energy content basis)
+ 0.126	if electricity is generated from a "dedicated feedstock supply system," Federal credit of 1.5¢ per kilowatt-hour generated (8.4 kWh per gallon ethanol x 1.5 ¢/kWh = 12.6¢/gallon ethanol)
+ 0.54	federal income tax credit for ethanol used as fuel
+ 0.10	federal credit for small (less than 30 million gpy) producers
- 0.268	federal income tax on credits
$ 0.72	per gallon ethanol

(Ethanol would have to be produced for less than $0.72 per gallon.)

If diesel is $28.00 per barrel,

$ 0.40	(equivalent value per gallon ethanol on energy content basis)
+ 0.126	if electricity is generated from a "dedicated feedstock supply system," federal credit of 1.5¢ per kilowatt-hour generated (8.4 kWh per gallon ethanol x 1.5 ¢/kWh = 12.6¢/gallon ethanol)
+ 0.54	federal income tax credit for ethanol used as fuel
+ 0.10	federal credit for small (less than 30 million gpy) producers
- 0.268	federal income tax on credits
$ 0.87	per gallon ethanol

(Ethanol would have to be produced for less than $0.87 per gallon.)

If coal is $30.00 per ton,[13]

$ 0.11 (equivalent value per gallon ethanol on energy content basis, assuming coal at 21 million Btus per ton)

+ 0.126 if electricity is generated from a "dedicated feedstock supply system," Federal credit of 1.5¢ per kilowatt-hour generated (8.4 kWh per gallon ethanol x 1.5 ¢/kWh = 12.6¢/gallon ethanol)

+ 0.54 federal income tax credit for ethanol used as fuel

+ 0.10 federal credit for small (less than 30 million gpy) producers

- 0.268 federal income tax on credit

$ 0.61 per gallon ethanol

(Ethanol would have to be produced for less than $0.61 per gallon.)

b. Direct combustion of biomass

If biomass is $50.00 per ton dry matter,

$ 0.232 (equivalent value per gallon ethanol on energy content basis)

+ 0.00 If electricity is generated from a "dedicated feedstock supply system," Federal credit of 1.5 ¢ per kilowatt-hour generated. However, if biomass for direct combustion is also from a "dedicated feedstock supply system," it would be eligible for the credit as well so there would be no net advantage for ethanol with respect to this credit.

+ 0.54 Federal income tax credit for ethanol used as fuel

+ 0.10 Federal credit for small (less than 30 million gpy) producers

- 0.224 Federal income tax on credits

$ 0.65 per gallon ethanol

(Ethanol would have to be produced for less than $0.65 per gallon.)

g. Summary of potential markets for fuel ethanol

As illustrated above, and summarized in Table VIII-2 below, there are several potential markets for fuel ethanol. The "target price" for ethanol varies, according to the competition and applicable tax incentives, from as low as around 60 cents per gallon to over $1.50 per gallon.

Table VIII-2
Estimated "Competitive Price" For Fuel-Grade Ethanol
In Various Hawaii Applications

PRODUCT	VS:	% Ethanol By Volume In Primary Product	Competitive Retail Price for Primary Product (With ethanol cost added)	Estimated Retail Price for Primary Product (Without ethanol cost added)	Competitive Price for Quantity of Ethanol Used In Primary Product	Competitive Production Price Per Gallon of Ethanol
	-	%	$ per gallon	$ per gallon	$ per gallon	$ per gallon
Gasoline (all grades)	-	0 %	$1.49	$1.49	-	-
Gasoline (mid-grade & premium)	-	0 %	$1.54	$1.54	-	-
Ethanol shipped from the mainland	-	100 %	$1.30	-	$1.30	$1.30
Hawaii Gasohol	Gasoline (all grades)	10 %	$1.47	$1.30	$0.16	$1.63
Hawaii mid-grade & premium with ethanol	Gasoline (mid-grade & premium)	10 %	$1.54	$1.34	$0.20	$2.04
E85	Gasoline (all grades)	85 %	$1.07	$0.37	$0.69	$0.82
Diesel for use in city buses	-	0 %	$1.16	$1.16	-	-
E100	Diesel for use in city buses	100 %	$0.70	($0.42)	$1.11	$1.11
ETBE	Octane enhancers	42 %	$1.11	$0.18	$0.93	$2.21
Fuel oil (#6 distillate)	-	0 %	$0.43	$0.43	-	-
E100	Fuel oil (#6 distillate)	100%	$0.22	($0.50)	$0.72	$0.72
Diesel (#2 distillate)	-	0%	$0.67	$0.67	-	-
E100	Diesel (#2 distillate)	100%	$0.37	($0.50)	$0.87	$0.87
Coal	-	0%	$30.00	$30.00	-	-
E100	Coal	100%	$0.11	($0.50)	$0.61	$0.61

It was stated earlier that "...there are a variety of technologies that may produce ethanol, depending on amounts paid for feedstock, at costs ranging from less than $1.00 to over $3.00 per gallon." Since a portion of the projected range of sales prices is consistent with a portion of the projected range of production costs, this first-cut estimate indicates that ethanol production for certain markets may be economically feasible.

Ethanol is only one possible output from the biomass conversion systems described in this report. Revenues received from the sale of other by-products could help to pay for a portion of the feedstock and operating costs. In Chapter V, the "ethanol production cost" did not take into account potential returns from sale of by-products, and assumed that the only revenue coming into the system was from the sale of ethanol. Therefore, the ethanol price had to be set high enough to cover 100% of the costs. In certain cases, production and sale of co-products could reduce the ethanol sales price required for an economically feasible system.

Although it is beyond the scope of this project to evaluate the outputs from all possible combinations of feedstocks and technologies (once again, this would vary by site as well), Section C below provides a general discussion of possible co-products, markets and values.

B. MARKETS FOR ELECTRICITY

The Hilo/Hamakua region is grid-connected with the rest of the island of Hawaii. Therefore, the market for the product may be described as being the electrical demand of the island. The competitor for that market would be the existing and planned electrical generation capacity. Electrical demand projections are contained in the October, 1993 *Integrated Resource Planning Report* by Hawaii Electric Light Company (HELCO), and, are shown in Table VIII-3.

Table VIII-3
HELCO's 20-Year Preferred Plan as of October, 1993

Year	Forecast Peak (MW)	DSM Peak (MW)	System Capability	Reserve Margin (MW)	Reserve Margin (%)
1993	157	157.0	205.60	48.6	31.0
1994	165	164.4	197.60	33.2	20.2
1995	171	170.0	217.60	47.6	28.0
1996	177	174.0	217.75	43.8	25.1
1997	184	179.0	235.75	56.8	31.7
1998	191	183.0	222.00	39.0	21.3
1999	199	188.0	222.00	34.0	18.1
2000	207	193.0	239.20	46.2	23.9
2001	215	199.0	250.90	51.9	26.1
2002	224	205.0	250.90	45.9	22.4
2003	233	211.0	250.90	39.9	18.9
2004	242	217.0	250.90	33.9	15.6
2005	251	223.0	269.80	46.8	21.0
2006	261	230.0	262.30	32.3	14.0
2007	271	239.0	285.00	46.0	19.2
2008	283	248.0	285.00	37.0	14.9
2009	295	259.0	300.00	41.0	15.8
2010	308	269.0	300.00	31.0	11.5
2011	321	281.0	318.90	37.9	13.5
2012	334	292.0	341.60	49.6	17.0
2013	348	304.0	341.60	37.6	12.4

Source: *Integration Report* by Hawaii Electric Light Company, October, 1993.

Electrical supply projections (including generating capacity, retirements, and additions) are shown in Table VIII-4. These projections are subject to change, as HELCO is participating in an Integrated Resource Planning docket in which both demand and supply projections are under discussion.

Table VIII-4
HELCO's Planned Capacity Additions and Retirements

Date	Resource Description	Add (MW)	Retire (MW)
01 Jun. 1993	Puna Geothermal Venture	25.0	
03 Aug 1994	Hamakua (Hamakua contract revised from 10 to 8 MW for final harvest.)		8.0
01 Jul 1995	Combustion Turbine (CT) -4 (Scheduled install date.)	20.0	
01 Sep 1995	CT-5 (Scheduled install date. Required date 4/1/96.)	20.0	
31 Dec 1995	Waimea D-8, 9, 10		2.7
31 Dec 1995	Kanoelehua D-11		2
31 Dec 1995	Shipman 1		3.4
31 Dec 1995	Kanoelehua CT-1		9
31 Dec 1995	Waimea D-12		2.75
01 Oct 1997	Steam Turbine (ST) -7 (CT-4 & CT-5 to Dual Train Combined Cycle #1)	18.0	
31 Dec 1997	Waimea D-13 & 14, Kanoelehua D-15, 16		11.0
31 Dec 1998	Kanoelehua D-17		2.75
1999	Keahole D-18, 19		5.5
2000	Dual Train Combustion Turbine (DTCT) - Phase1 (A)	22.7	
2000	Keahole D-20, 21, 22, 23		11.0
2001	DTCT-PH2 (A)	22.7	
2005	DTST-PH3 (A) (DTCT-PH1(A) and DTCT-PH2 (A) to DTCC #2)	18.9	
2005	Shipman 3		7.5
2007	DTCT-PH1 (B)	22.7	
2008	Shipman 4		7.7
2009	DTCT-PH2 (B)	22.7	
2011	DTST-PH3(B) (DTCT-PH1(B) and DTCT-PH2(B) to DTCC #3)	18.9	
2012	DTCT-PH1 (C)	22.7	

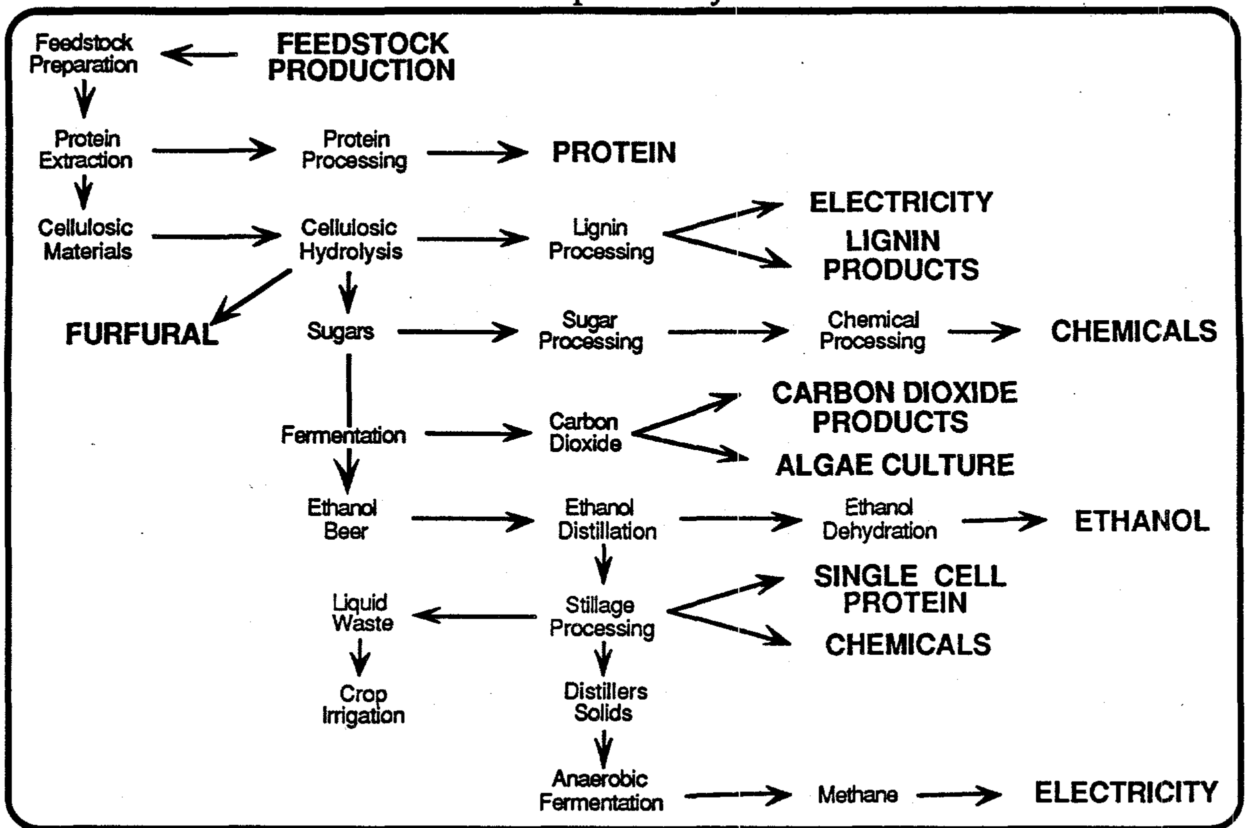
Source: *Integration Report* by Hawaii Electric Light Company, October, 1993.

As shown in Tables VIII-3 and VIII-4 above, the preferred size for capacity addition is between 18 and 25 MW. Capacity additions of this size are planned to occur approximately every two years (1995, 1997, 2000, 2001, 2005, 2007, 2009, 2011, and 2012).

C. MARKETS FOR CO-PRODUCTS AND BY-PRODUCTS

Each feedstock source and processing technology combination will produce slightly different outputs and co-products. For example, a feedstock with high levels of protein has potential to produce a high-protein animal feed supplement. A process with an overall lower energy demand, if combined with feedstocks high in lignin content, may produce greater quantities of electricity for sale to the utility. Figure VIII-3 illustrates a "Crop Refinery" concept.[14] This is analogous to an oil refinery which uses crude oil as a feedstock to produce a variety of refined products (gasoline, jet fuel, fuel oil, etc.). Revenues from all of the products contribute to the overall economic viability of the refinery.

Figure VIII-3
Crop Refinery



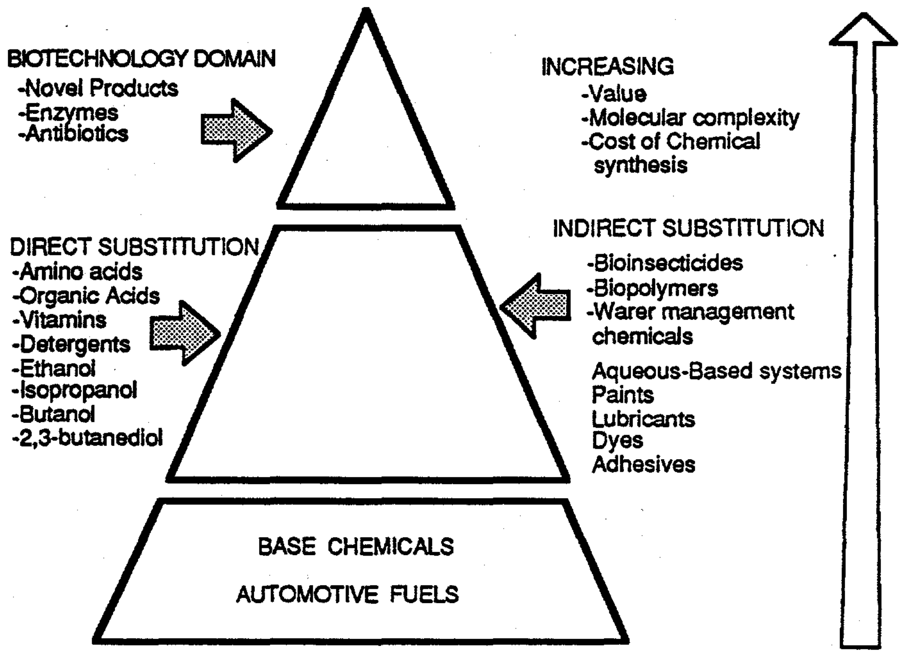
Modified from "An integrated forage crop refinery system" TVA Agriculture Research Branch. April 1985.

If an oil refinery considered itself simply an "oil to gasoline" production plant, tried to price its gasoline to cover all of the costs of the refining process, and disposed of the other products (jet fuel, diesel, fuel oil, etc.) as waste products, the process would be extremely inefficient, the price of gasoline would be very high, and the problems of disposing of the unused portions of the crude oil would be expected to be substantial.

The technology of agricultural refineries is still in its infancy and is driven by the need to increase the value added in the highly subsidized farm sector. Such refineries could bring a new layer of infrastructure between farm and industry. Each unit could serve a local region and would concentrate a range of raw feedstocks for further processing. The aim would be to develop new methods of growing and using biomass crops and organic wastes which would reduce operating costs and maximize the value of harvested material. Whole crop harvesting methods would be investigated to reduce waste and provide increased yields for use as feedstocks for processing.

A number of processes available today separate lignocellulose into its component fractions using organic solvents or steam explosion technologies. Cellulose would be separated out, leaving lignin and sugars as by-products for process energy and fermentation feedstocks. As this technology becomes commercially viable, a gradual process of substitution will take place, ultimately yielding a supply of co-products for use as fermentation feedstocks on a scale comparable with today's output of petrochemicals (See Figure VIII-4).

Figure VIII-4
Potential Product Development Through Commercial Substitution[15]



Developments in biotechnology will open new opportunities based initially on conventional sugar and starch crops. Potential products to emerge from this commercial application will include the following:

- Base Chemicals - Transportation Fuels - ETBE, MTBE, Carbon Dioxide;
- Base Products - Fertilizers, Soil Amendments, Biofeeds;
- Performance Chemicals - Intermediates;
- Direct Substitutions - Amino Acids, Organic Acids, Vitamins, Detergents, Ethanol, Isopropanol, Butanol;
- Indirect Substitutions - Bioinsecticides, Biopolymers, Water Management Chemicals, Paints, Lubricants, Dyes, Adhesives.
- Biotechnology Domain - Novel Products, Enzymes, Antibiotics

A discussion of "biomass to ethanol" may be, in its own way, as narrowly focused as the "oil to gasoline" production plant described above. Although actually designing the crop refinery outlined above is beyond the scope of this project, a general discussion of each of the possible by-products or co-products of such a system is provided below.

1. Protein

Some sources of lignocellulosic biomass (e.g. sorghum) can contain as much as 15% protein based on dry weight. This protein may be used in a marketable animal feed supplement. In a 1983 paper, Dale and others[16, 17] have pointed out that "protein is a valuable component of biomass that is currently neglected in current fuels and chemicals from biomass schemes." In this paper, Dale provided some representative data on crop composition, a summary of which is presented in Table VIII-5 below.

The material described is independent of the grain in the crop. For example, in this analysis, sorghum residue contains approximately 10% protein based on dry weight. A well-balanced plant protein is worth approximately $0.75 per pound. In this case, a ton of dry sorghum residue might contain 200 pounds of protein, for a total value of $150.00. If the extraction costs are reasonable, plant residues may be processed to provide protein for an animal feed industry. Protein is also contained in stillage from the fermentation process (see section on stillage).

Table VIII-5

Protein Content of Selected Plant Materials

Material	Cellulose (% by weight, dry basis)	Hemicellulose (% by weight, dry basis)	Lignin (% by weight, dry basis)	Protein (% by weight, dry basis)	Other (% by weight, dry basis)
Alfalfa (leaves)	22.2%	11.0%	5.2%	28.5%	33.1%
Alfalfa (stalks)	48.5%	6.5%	16.6%	10.5%	17.9%
Sorghum residue (leaves)	25.6%	40.0%	7.8%	10.4%	16.2%
Sorghum residue (stalks)	26.1%	31.1%	8.0%	9.3%	25.5%
Corn residue (leaves)	33.2%	31.1%	7.4%	7.1%	21.2%
Corn residue (stalks)	43.1%	10.5%	9.6%	3.4%	33.4%
Sudan grass (leaves)	35.8%	29.5%	10.9%	6.7%	17.1%
Sudan grass (stalks)	44.1%	21.3%	9.1%	5.1%	20.4%

2. Lignin

Lignin is a component of lignocellulosic biomass which generally passes through the biomass to ethanol conversion system unchanged. For a plant producing 25 million gallons per year of ethanol (using assumptions stated in Chapter V), lignin production would be about 100 tons per day. Lignin has an energy value that varies by source, from about 9,100 Btu's per pound of lignin from northern red oak to

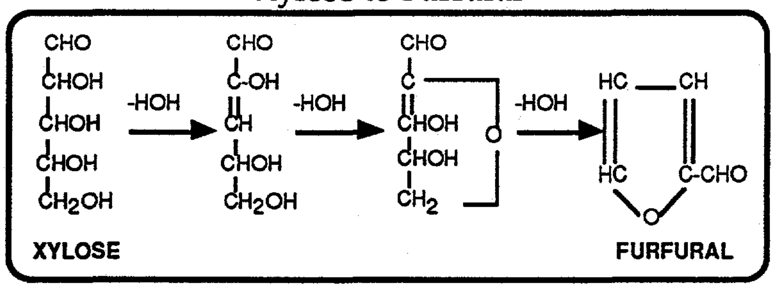
11,300 Btu's per pound of lignin from softwood.[18] Another reference quotes a heat content of 12,700 Btu's per pound of "milled wood lignin."[19]

Extraction of lignin in the processing of biomass to ethanol has the potential to provide a high energy compound for the production of process heat and generation of electrical energy. Lignin may also be processed to specialty polymers, electrically conducting polymers, or phenolic resins, which may be used as glues or binders in production of plywood and fiberboard.

3. Furfural

Hydrolysis of biomass can result in solubilizing or liberating the sugars that constitute cellulose and hemicellulose. Xylose, the primary sugar in hemicellulose, can be further processed in the presence of acid to furfural (See Figure VIII-4).

Figure VIII-5
Xylose to Furfural



This compound can be used as a selective solvent for refining high quality lubricating oils. Hydrogenation of furfural at 200°C produces furfural alcohol which can be refluxed to produce commercial resins. Furfural can also be used to produce low temperature adhesives and protective coating for wood. It also has application in the production of nylon.

4. Carbon dioxide

For every pound of ethanol produced, approximately one pound of carbon dioxide is produced from the fermentation process. For a 25 million gallon per year plant, carbon dioxide production would be about 250 tons per day.

a. Direct sale

Carbonation. Carbon dioxide has only limited market as a beverage carbonating agent in Hawaii.

Compression to make dry ice. Dry ice is used as a cooling agent in some industries.

b. Conversion to other products

Carbon dioxide may also be directed to the production of algae or methane.

5. Algae

In photosynthesis, plants and other chlorophyll containing organisms – including algae – use energy provided by sunlight to covert carbon dioxide to sugars. This is done by the reduction of CO_2 (removing oxygen and adding hydrogen).

$$6\ CO_2 + 6\ H_2O + \text{Light} \longrightarrow 6\ O_2 + C_6H_{12}O_6$$

carbon dioxide + water + sunlight ---------------> oxygen + sugar

As a result of photosynthesis, carbon dioxide (considered a pollutant) is converted to valuable oxygen and sugars that living forms use as a source of energy. CO_2 is utilized 100% by aquatic algae to produce biomass by photosynthesis. Appropriate selection of algae has the potential to produce pharmaceuticals, animal feed ingredients, and energy products.[20, 21, 22, 23, 24, 25] The abundance of sunlight available in Hawaii makes this possibility particularly intriguing.

6. Microbial Biomass

Yeast and other microorganisms that affect fermentation contain valuable nutrients including: nitrogen, phosphorous, potassium, and trace minerals. Fermentation (conversion of sugars to ethanol and carbon dioxide) is carried out by a variety of microorganisms. On a dry weight basis these microorganisms may contain up to 70% protein and a variety of vitamins and fatty acids . Processing produces a protein rich powder (sometimes referred to as single cell protein). Depending on species, these can be used as substitutes for soy protein or fish meal in formulating feeds for animals and aquatic species

7. Stillage

Fermentation (conversion of sugars to ethanol and carbon dioxide) is carried out by a variety of microorganisms. These microorganisms contain nitrogen, phosphorous, potassium, trace minerals, and, on a dry weight basis, may contain up to 70% protein and a variety of vitamins and fatty acids. Processing produces a protein rich powder (sometimes referred to as single cell protein). Depending on species these can be used as substitutes for soy protein or fish meal in formulating feeds for animals and aquatic species. Stillage may be anaerobically processed to produce methane.

8. Methane

Methane may be used for the generation of electricity or as a feedstock for production of other materials. Methane is not a direct product of the biomass to ethanol production process, but could be produced via anaerobic digestion of stillage and/or conversion of carbon dioxide. Proprietary designs of systems that have the capacity to convert CO_2 to methane have been developed at the experimental level.[26, 27, 28, 29, 30, 31, 32] As this technology continues to improve, methane from carbon dioxide may become an important source of energy for biomass conversion systems.

After microbial biomass is removed the resulting "beer" must be distilled. The liquid remaining is rich in nutrients and contains particulate material that must be disposed of or utilized. When combined with other organic wastes, this material is a particularly good substrate for anaerobic fermentation to produce methane. The resulting methane may be used for process heat or to produce electricity.

9. Electricity

a. Production

There are several possibilities for production of electricity within the plant: direct incineration of lignin, incineration of stillage (the stillage would have to be dried first), or use of methane (from anaerobic digestion of stillage and conversion of carbon dioxide) in natural gas engines or gas turbines.

b. Sale to utilities

Electricity not used in the plant may be sold to a local electric utility. The amount received in payment from the utility varies from island to island and between negotiated power purchase agreements. (A power purchase agreement is a contract between the independent power producer (IPP) and the utility.) An important factor in utility payments to IPPs is whether the contract is for firm power (available upon demand by the utility) or not. Another option would be to sell biomass-derived fuel (pellets, oils, etc.) to the utility for use in their own facilities, if a long-term contract could be worked out that was acceptable to both parties.

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1 Work in progress by the State Department of Business, Economic Development & Tourism on developing a "Transportation Energy Strategy"

2 According to 1990 correspondence from Pacific Resources, Inc., it would cost an additional 2 to 2.5 cents per gallon of gasoline to reduce the vapor pressure of the base gasoline for blending with ethanol.

3 "U.S. Market Fuel Ethanol." New Fuels Report. April 18, 1994. Volume 15, Number 6.

4 Congressional Research Service Issue Brief Number 93009, updated 01/01/94.

5 These estimates are for flexible-fueled vehicles. Dedicated vehicles would have better fuel economy.

6 "100% ethanol" and "E100" also refer to blends of 95% ethanol with 5% denaturant.

7 Assumes fuel used for a federally nontaxable purpose, such as by a state or local government.

8 U. S. Department of Energy. *Alternative Fuels Data Center Update.* Spring 1994. Volume 3, Issue 1.

9 Tshiteya, R. et al. 1991. Properties of Alcohol Transportation Fuels. Alcohol Fuels Reference Work #1. Prepared by Meridian Corporation for the U. S. Department of Energy.

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11 Electric Power Research Institute. 1980. AP-1712. "Test and Evaluation of Methanol in a Gas Turbine System;" and personal communication, General Electric representative M. Hirakami, 1992.

12 Based on a General Electric LM2500 combustion turbine running at 3600 RPM with shaft output of 31,200 HP.

13 This differs from the coal price ($60 per ton) assumed in Chapter III, due to the assumption that a utility which purchases coal for baseload power generation may face lower prices per ton than plantations replacing bagasse with coal.

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IX. CONCLUSIONS AND RECOMMENDATIONS

A. PERSPECTIVE

The primary focus of this evaluation was to determine if there is potential to use lands coming out of sugar production in the Hilo/Hamakua region to cultivate biomass to produce transportation fuel and/or electricity that would offset imports and generate employment opportunities. Based on a promising outcome, the intent of the project was to use this information to develop specific encouraging opportunities. Complications regarding land tenure and other issues have compromised the potential for any immediate actions to develop programs at the Hamakua sugar site. However, the conclusions of this effort do have general application to future activities in the Hilo/Hamakua region and throughout the state of Hawaii.

1. General Conclusions

There are a number of specific opportunities to develop biomass to energy businesses in Hawaii. These will be dependent on location, feedstock, technology, and product forms. **There are specific actions that need to be taken now, either from a perspective of technology development or financial arrangements, that could increase the possibility of these opportunities coming to fruition.** Conclusions emerging from this evaluation are as follows:

a. On a stand alone basis cultivation of crops as dedicated feedstocks for energy production in Hawaii is marginal at this time.

b. In order to be economically competitive for energy production in Hawaii biomass must be delivered at less than $50 per dry ton.

d. Multiple out put products are essential to the economic viability of any dedicated process.

c. Initially subsidies will be needed to establish infrastructure and sustain the energy industry.

e. The use of dedicated feedstocks holds promise when integrated with appropriate waste streams.

f. Further development of ethanol technology should be directed to constructing engineering development units for one or more technologies appropriate for promising feedstocks.

g. The Hamakua Sugar facilities are not practical as a biomass energy system, however many of the components have potential to be used in new systems.

h. The Hilo Coast processing Company should be considered for upgrading to augment the power supply on the island of Hawaii.

i. Coupling ethanol and electric production using advancing technologies such as saccharification of lignocellulosic material for ethanol and biomass gasification for electricity looks promising. However, this will require further evaluation and demonstration.

B. BIOMASS

There are a number of promising technologies for converting biomass to ethanol or electricity. Supplying cultivated biomass at a cost that is appropriate to producing marketable products at a competitive price appears to be the major constraint to establishing profitable energy businesses in Hawaii. Technologies to process lignocellulosic material are close to commercial development. The entire composition of each crop must be considered in an evaluation of its potential to be used for ethanol production.

This report reviewed seven technologies that were considered to have the potential to process crops and waste biomass to ethanol. The analysis was primarily based on information provided by the developers of the technology. The analyses resulted in similar cost projections. This similarity lends a degree of confidence that, as the technologies mature, ethanol production costs in Hawaii will fall within this range. Varieties of sugarcane and sweet sorghum were the crops with the greatest potential for ethanol production. Processing all available sugars from sugar or sorghum has the potential to produce about 3,000 gallons per harvested acre.

1. Gasoline Competition

In order to be competitive on a stand alone basis, ethanol derived from biomass must compete with the rack price of gasoline, about 90 cents per gallon. To achieve this level of economic performance, crops must be supplied at a cost of less than $50 per dry ton. Projections developed by HSPA and the sugar industry, indicated that the cost of delivering a dry ton of prepared cane for processing to ethanol and related products would be $31.35 per wet ton or $108 per dry ton for plantations operating on the island of Hawaii. At this cost, the price of producing ethanol from prepared cane would be approximately $2.70 per gallon. (Ethanol qualifies for a federal blender credit of 54 cents per gallon an additional small producer credit of 10 cents per gallon. A state 4% excise tax exemption is applicable to liquid fuels containing at least 10% biomass-based ethanol.) If existing federal and state tax credits of $1.03 were applied, the cost could be reduced to about $1.70. Use of lignin resulting from biomass processing to produce electricity and conversion of by-products to animal feeds, fertilizers, and other potential products, would be necessary to reduce the production cost to the equivalent of the rack price of gasoline.

In the short term, the perspective for cultivating crops as the sole source of biomass, to be processed to transportation fuel and/or electricity, is not particularly promising. However, there are numerous improvements that can be achieved through utilization of existing facilities, using waste products, and systems integration, that may establish an economically realistic basis for a biomass to energy industry in Hawaii in the future. Some of the more promising areas of opportunity include are discussed next.

2. Reducing Capital Costs

By retrofitting the sugar mills, capital expenditures may be kept to a minimum. Much of the equipment and infrastructure installed at the sugar mills has the potential to be used in the manufacture of ethanol and production of electricity. Use of these facilities can substantially reduce the capital costs as well as the time and expense of obtaining permits required to establish new operations.

3. Reducing Crop Production Costs and Improving Yields

Establishment of grower cooperatives to supply biomass to production plants reduces the substantial amount of administrative cost and overhead burden that is associated with the larger integrated plantation and sugar milling operations. Increasing biomass yields and harvestable sugar content by applying alternative production and harvesting technologies can be accomplished in the near term.

4. Using Wastewater for Irrigation

Wastewater contains significant amounts of nutrients for plant growth and provides a continuous supply of water that normally created a disposal problem. Using wastewater on cane may result in some decline in sugar production. However, the overall benefits in biomass production and other cost savings may more than offset the potential losses.

5. Using Waste as a Primary Source or to Augment Biomass Supplies

Using the green wastes as potential or lignocellulosic components of municipal solid waste that are abundant in Hawaii as feedstock. Almost 65% of the material in MSW has potential to be used as feedstock for ethanol production. Processing of the organic components in our current waste stream has the potential to produce between 10% and 20% of the annual transportation fuel requirements in the state. Diversion of these materials from the landfills could reduce the waste disposal problem, and could conceivably, result in the ethanol facility receiving tipping fees to accept these wastes.

6. Process Cost Reduction

The application of solar heating, drying, and distillation technology has the potential to reduce energy consumption.

Optimizing the production of ethanol with electricity generation and other coproducts, has the potential to improve cost performance.

Carbon dioxide, produced during fermentation, has the potential to be used to produce valuable algae species, by-products, or methane.

Development of fertilizer and animal feed ingredients using the microbial biomass produced in the fermentation process, has the potential to optimize overall economic performance of an integrated system.

C. ELECTRICITY

At current oil prices and current crop production costs, the opportunity to cultivate biomass as a dedicated feedstock for electricity production alone is not economically feasible. The most promising option appears to be a combination of biomass sources and processing technologies to reduce feedstock cost and produce the most valuable products.

As sources of biomass for electricity production, bagasse, tree, and/or grass crops that have moisture contents of less than 50%, offer the greatest potential to provide fuel for steam boilers or for gasification. Use of high BTU containing waste materials, offers the greatest potential to reduce the feedstock costs.

1. Future

Biomass to energy technology appropriate to Hawaii is still colored with a high degree of uncertainty. Indirectly, this report identified that there is a need for an "engineering scale" pre-commercial demonstration facility. Proceeding with a pre-commercial demonstration plant is essential to the demonstration of the economic feasibility of developing an industry in Hawaii. A concentrated effort by public, private, and government sources to move biomass technologies to a commercial reality in the state of Hawaii is required. This phase of development would provide necessary capital and operational costs required to ensure successful large scale commercial development.

D. IMPLEMENTATION

1. The Next Step

PICHTR has been awarded two contracts by the National Renewable Energy Laboratory (NREL) to identify the necessary steps and time required for project implementation. Included among these steps are: estimates of the extent and timing of all environmental approvals. Preliminary site specific business plans for pre-commercial demonstration facilities at C. Brewer's Ka'u plantation on the Big Island and AMFAC's Pioneer Mill on Maui will be used to determine the feasibility of commercial operations at these sites. If warranted, "pre-commercial demonstration facilities" will be built at these sites. The intent of this effort is to establish the "hard" capital and operating costs necessary to attract the business entities which are capable of ensuring successful full scale commercial development.

2. What Can The Government Do?

In the meantime, government can initiate actions to guarantee markets through legislation. This will keep existing assets intact to support this level of development by establishing:

- Tax Incentives,
- Mandates for blended fuels, and
- Financial assistance programs to leverage investment capital from interested private sector developers.

At the final meeting of the technical and advisory teams, a number of specific recommendations were made regarding government actions. The following general suggestion resulted in specific recommendations from the team members:

"It would be beneficial to create a list of actions that local, state, and federal elected officials could consider for implementation which would assist in the development process of this industry. They need to know which recommendations need to be implemented in order to help make this concept happen. With this information in hand, they would know what would be required of them should they choose to make a decision to try and bring about the development of this industry."

Specific recommendations made by the teams members included the following:

"The State should be providing tax credits for the generation of electricity from bagasse to support the industry. This would stop it from collapsing at this dramatic rate. By supporting this industry with temporary subsidies for electricity generated by bagasse, vast acreage's will remain in production at minimal cost to the State. When one considers the alternative, this would not represent that great of an expenditure. This would be a short term solution until we have the time to further develop the concepts presented in this report."

"We should direct our efforts to create tax incentives and credits to the existing industry rather than to blue sky scenarios that might have application someday."

"I have done a preliminary, back of the envelop, calculation based on the numbers in the report and have found that for a 40,000 acre facility, the subsidy required to swing the economics of the facility back to a break even point would only be about $1.6 million per year. Its not big bucks, in my opinion, to save plantations like that, especially when you consider the economic burden of the alternative that the State will be faced with."

"I would like to see a study done by the State on what the loss in revenues would be from the sugar companies that are going out of business; what they're going to be paying out in unemployment, and what its going to do to the overall economics of the State.

"I would like to suggest that we also make a recommendation to address the issue of a fair avoided cost rate; that we pay the sugar producing companies who generate

power a fair avoided cost rate; that we give recognition to the environmental pluses that come from the sugar industry; and that we consider environmental credits like what they are doing in Norway for keeping things green."

"A concept that I think makes sense is if we could work with the utilities and put combustion turbines in close association with the sugar mills and thereby be able to go combined cycle with the sugar operations. Under this concept, we could at least recover the heat for our operations. We should be working together..........There is no encouragement from the State to create this relationship."

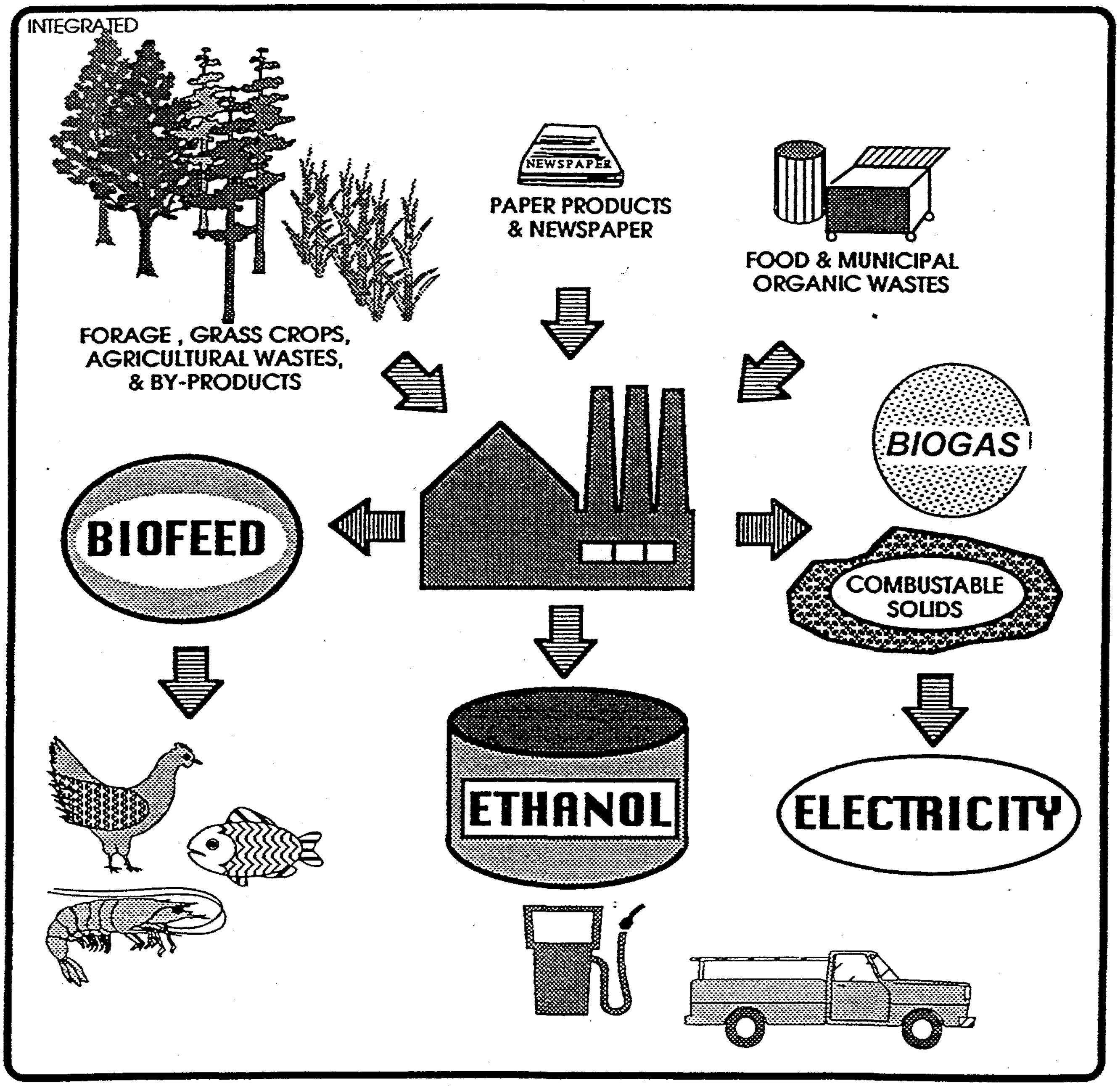
3. Concluding Remarks

The National Biomass Program and U.S. industry will create an industrial investment on the order of $25 billion dollars in advanced power generation facilities with about $5 billion of this going to rural communities to develop a biomass supply infrastructure. The benefits include an annual personal and corporate income that is projected to be approximately $6.2 billion per year by 2010, with about 300,000 persons employed in this renewable industry. With the creation of a strong U.S. industry, export markets will be opened up - markets that according to the Renewables Intensive Global Energy Scenario (RIGES) could produce 2606 TWh per year globally by 2025. Primary international market opportunities for biomass power are in tropical and subtropical countries where there are abundant underutilized or unutilized biomass wastes available for fuel. Hawaii is positioned to be a leader in both the development of biomass power and the export of this technology to other regions of the world.[1]

E. VISION FOR THE FUTURE - A HAWAII INTEGRATED BIOMASS ENERGY PROGRAM.

In addition to the specific recommendation there needs to be a common vision of integrated actions that can lead to an environmentally sensitive and economically positive outcome. Figure IX-1 provides a vision for such a program.

Figure X-1
A Vision For The Future - Hawaii Integrated Biomass Energy System



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[1]Electricity From Biomass - National Biomass Power Program Five-Year Plan (FY 1994 - FY 1998) Solar Thermal and Biomass Power Division, Office of Solar Energy Conversion, U.S. Department of Energy. April 1993.

APPENDIX

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	9/94 new	new Amak	sprAds
2	Island: Plantation	acres harvested	Prepared cane (tons)	Prepared cane (tons) (dry matter)	Prepared cane (dry matter) (%)	96 DA sugar (tons)	Final Molasses (tons) (wet basis)	Prepared cane (tons/acre) (wet basis)	Prepared cane (tons/acre) (dry basis)	96 DA sugar (tons/acre) (dry basis)	Final Molasses (tons/acre) (wet basis)	Molasses: yield per acre compared to state average	Bagasse Fiber (wet tons)	Bagasse Fiber (dry tons)	Bagasse Fiber (dry tons/acre)	Sugars in bagasse (tons/acre)	Sugars in Molasses (tons/acre)	Prepared cane yield, tons per acre per year (wet basis)	Prepared cane yield, tons per acre per year (dry basis)	Addt'l unburned cane fiber, tons per acre per year (dry basis)	Unburned cane yield, tons per acre per year (wet basis)	Unburned cane yield, tons per acre per year (dry basis)	Prepared cane yield per acre: % of state average	Sucrose yield per acre: % of state average	Sucrose yield per acre: % different from state average	Sucrose yield: maximum (+) deviation
3														52%						54%	115%					21.8%
4	Hawaii: Hamakua	14,509	1,681,162	418,992	25%	147,244	38,243	116	29	10.1	2.6	80.5%	449,049	233,505	16	0.4	1.3	48	12	4	55	16	103.7%	83.2%	-16.8%	
5	Hawaii: Hilo Coast Processing C	8,477	1,057,858	291,796	28%	108,489	26,474	125	34	12.8	3.1	95.4%	301,601	156,833	19	0.5	1.6	56	15	5	64	20	111.7%	105.0%	5.0%	
6	Hawaii: Ka'u Agribusiness Co.	5,687	685,038	196,226	29%	63,708	15,337	120	35	11.2	4.7	142.3%	225,349	117,181	21	0.5	2.4	43	12	6	49	18	107.8%	91.9%	-8.1%	
7																										
8	Total: Hawaii Island	28,673	3,423,858	907,014	26%	319,441	80,054	119	32	11.1	2.8		975,999	507,519	18	0.4	1.4	49	13	5	56	18				
9																										
10	Kauai: Kekaha Sugar	3,985	414,797	124,324	30%	50,410	13,384	104	31	12.6	3.4	102.6%	116,404	60,530	15	0.4	1.7	50	15	4	58	19	93.2%	103.8%	3.8%	
11	Kauai: Lihue	7,439	749,860	228,333	30%	82,586	19,884	101	31	11.1	2.7	81.7%	242,045	125,863	17	0.4	1.4	49	15	5	56	19	90.2%	91.1%	-8.9%	
12	Kauai: McBryde	6,001	499,915	147,266	29%	57,065	16,507	83	25	9.5	2.8	84.1%	141,719	73,694	12	0.3	1.4	40	12	3	46	15	74.6%	78.0%	-22.0%	
13	Kauai: Olokele	3,630	403,619	128,570	32%	51,990	12,567	111	35	14.3	3.5	105.8%	123,101	64,013	18	0.4	1.8	54	17	5	62	22	99.5%	117.5%	17.5%	
14																										
15	Total: Kauai Island	21,055	2,068,191	628,493	30%	242,051	62,342	98	30	11.5	3.0		623,269	324,100	15	0.4	1.5	47	14	4	54	18				
16																										
17	Maui: HC&S	18,478	2,020,191	616,993	31%	239,809	70,602	109	33	13.0	3.8	116.8%	589,581	306,582	17	0.4	2.0	52	16	4	60	20	97.9%	106.5%	6.5%	
18	Maui: Pioneer Mill	3,963	399,734	126,499	32%	49,712	15,148	101	32	12.5	3.8	116.8%	118,536	61,639	16	0.4	2.0	50	16	4	58	20	90.3%	102.9%	2.9%	
19																										
20	Total: Maui Island	22,441	2,419,925	743,492	31%	289,521	85,750	108	33	12.9	3.8		708,117	368,221	16	0.4	2.0	51	16	4	59	20				
21																										
22	Oahu: Oahu Sugar Co.	6,084	777,540	241,077	31%	90,297	24,557	128	40	14.8	4.0	123.3%	242,737	126,223	21	0.5	2.1	55	17	6	63	23	114.4%	121.7%	21.7%	
23	Oahu: Waialua Sugar Co.	4,776	585,013	174,699	30%	70,939	19,002	122	37	14.9	4.0	121.6%	162,996	84,758	18	0.4	2.0	46	14	5	53	19	109.7%	121.8%	21.8%	
24																										
25	Total: Oahu	10,860	1,362,553	415,776	31%	161,236	43,559	125	38	14.8	4.0		405,733	210,981	19	0.5	2.1	50	15	5	58	21				
26																										
27	1985 STATEWIDE TOTAL	83,029	9,274,527	2,694,775	29%	1,012,249	271,705	112	32	12.2	3.3		2,713,118	1,410,821	17	0.4	1.7	49	14	5	56	19				
28																										
29																										
30	Source:	Energy Report 23: HSPA unpublished data for calendar year 1985, and Kinoshita, 1994																								
31																	% moisture, burned cane		29%	moisture, unburned cane		33%				
32																				% moisture, leaves&trash	62%					
33	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985	1985
34	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991	1991

35	Island: Plantation	acres harvested	Field cane (tons) (wet basis)	Prepared cane (tons) (wet basis)	Net cane (tons) (wet basis)	96 DA sugar (tons) (dry basis)	Final Molasses (tons) (wet basis)	Field cane (tons/acre) (wet basis)	Prepared cane (tons/acre) (wet basis)	Net cane (tons/acre) (wet basis)	96 DA sugar (tons/acre) (dry basis)	Final Molasses (tons/acre) (wet basis)	Molasses: yield per acre compared to state average	Bagasse Fiber (dry tons)	Bagasse Fiber (dry tons/acre)	Sugars in bagasse (tons/acre)	Sugars in Molasses (tons/acre)	Prepared cane yield per acre: % of state average	Sucrose yield per acre: % of state average	Sucrose yield per acre: % different from state average	Sucrose yield: maximum (+) deviation	Sucrose yeild: maximum (-) deviation	Duplicate data (for graph):	Prepared cane yield per acre: % of state average	Sucrose yield per acre: % of state average	1991
36																				27.1%	-32.4%	A	149%	99%	1991
37	Hawaii: Hamakua	7,586	1,621,490	1,146,017	699,800	78,710	29,850	214	151	92	10.4	3.9	131.0%	153,517	20	0.5	2.0	148.8%	99.5%	-0.5%			B	112%	81%	1991
38	Hawaii: Hilo Coast Processing C	6,174	1,187,118	700,035	562,600	52,297	14,705	192	113	91	8.5	2.4	79.3%	101,491	16	0.4	1.2	111.7%	81.2%	-18.8%			C	115%	111%	1991
39	Hawaii: Ka'u Agribusiness Co.	4,374		509,601	463,499	50,818	15,391		117	106	11.6	3.5	117.1%	78,573	18	0.4	1.8	114.7%	111.4%	11.4%			D	101%	109%	1991
40																						E	73%	68%	1991
41	Total: Hawaii Island	18,134		2,355,653	1,725,899	181,825	59,946		130	95	10.0	3.3		333,581	18	0.5	1.7						F	73%	71%	1991
42																						G	113%	127%	1991
43	Kauai: Kekaha Sugar	3,588	532,671	369,278	285,171	40,770	11,480	148	103	79	11.4	3.2	106.5%	60,820	17	0.4	1.6	101.3%	109.0%	9.0%			H	95%	118%	1991
44	Kauai: Lihue	6,971	894,718	518,620	433,430	49,133	15,169	128	74	62	7.0	2.2	72.4%	74,996	11	0.3	1.1	•73.3%	67.6%	-32.4%			I	70%	79%	1991
45	Kauai: McBryde	5,209	647,064	387,323	342,615	38,478	11,617	124	74	66	7.4	2.2	74.2%	52,989	10	0.3	1.1	73.2%	70.8%	-29.2%			J	106%	116%	1991
46	Kauai: Olokele	3,629		416,484	365,428	48,089	13,625		115	101	13.3	3.8	125.0%	53,383	15	0.4	1.9	113.0%	127.1%	27.1%			K	85%	95%	1991
47																									1991
48	Total: Kauai Island	19,397		1,691,705	1,426,644	176,470	51,891		87	74	9.1	2.7		242,188	12	0.3	1.4									1991
49																									1991
50	Maui: HC&S	17,340	1,932,727	1,671,093	1,497,365	214,122	50,152	111	96	86	12.3	2.9	96.3%	241,701	14	0.3	1.5	94.9%	118.4%	18.4%						1991
51	Maui: Pioneer Mill	3,128		223,327	192,346	25,913	7,675		71	61	8.3	2.5	81.7%	36,013	12	0.3	1.3	70.3%	79.4%	-20.6%						1991
52																									1991
53	Total: Maui Island	20,468		1,894,420	1,689,711	240,035	57,827		93	83	11.7	2.8		277,714	14	0.3	1.4									1991
54																									1991
55	Oahu: Oahu Sugar Co.	5,632	825,939	608,960	536,698	68,265	22,172	147	108	95	12.1	3.9	131.1%	94,830	17	0.4	2.0	106.5%	116.2%	16.2%						1991
56	Oahu: Waialua Sugar Co.	5,808	740,267	500,916	466,511	57,505	16,744	127	86	80	9.9	2.9	96.0%	57,084	10	0.2	1.5	84.9%	94.9%	-5.1%						1991
57																									1991
58	Total: Oahu	11,440	1,566,206	1,109,876	1,003,209	125,770	38,916	137	97	88	11.0	3.4		151,914	13	0.3	1.7									1991
59																			acres harvest	acres in crop	REF #	res harve	op time (yr)		1991
60	1991 STATEWIDE TOTAL	69,439	1,566,206	7,051,654	5,845,463	724,100	208,580	23	102	84	10.4	3.0		1,005,397	14	0.4	1.5	ATEWIDE TOTAL		69,439	155,600.00	28	45%	2.24		1991
61	1990 STATEWIDE TOTAL	71,999	9,432,720	7,801,557	6,540,925	819,632	228,043		108	91	11.4	3.2		1,029,159	15	0.4	1.6	ATEWIDE TOTAL		71,999	162,000.00	p. 494	44%	2.25		1991
62																									1991
63	Source:	Energy Report 31: HSPA unpublished data for calendar year 1991																							1991

	C.	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X9/94	new new ham	k spreads	AA
68	YEAR	acres harvested	Prepared cane (tons)	96 DA sugar (tons)	Final molasses (tons) (wet basis)	Prepared cane (tons/acre) (wet basis)	96 DA sugar (tons/acre) (dry basis)	Final molasses (tons/acre) (wet basis)	Molasses solids (%)	Molasses solids (tons/acre)	Bagasse fiber (dry tons)	Bagasse fiber (tons/acre) (dry basis)	Sugars in bagasse (tons/acre)	Sugars in molasses (tons/acre)	Tons 96 DA sugar per (wet) ton prep cane	Prepared cane (tons/acre) (dry basis)	Prepared cane yield, tons per acre per year (wet basis)	Prepared cane yield, tons per acre per year (dry basis)	Add'l unburned cane fiber, tons per acre per year (dry basis)	Unburned cane yield, tons per acre per year (wet basis)	Unburned cane yield, tons per acre per year (dry basis)	Acres harvested	Acres in crop	% acres harvested	Crop time (yr)
69	1981	97,570	9,864,200	1,047,520	310,430	101	10.7	3.2	86%	2.7	1,506,180	14.9	0.4	1.7	0.106	28.3	45.6	12.8	3.6	52	16	97,570	216,100.00	45%	2.2
70	1982	89,260	9,932,300	982,910	287,190	111	11.0	3.2	86%	2.8	1,508,312	17.4	0.4	1.7	0.099	31.2	48.5	13.6	4.1	56	18	89,260	204,749.00	44%	2.3
71	1983	92,820	10,068,900	1,044,190	303,840	108	11.2	3.3	86%	2.8	1,550,848	15.6	0.4	1.7	0.104	29.7	51.8	14.2	4.0	60	18	92,820	194,258.00	48%	2.1
72	1984	89,540	9,641,086	1,061,814	314,187	108	11.9	3.5	86%	3.0	1,451,123	15.8	0.4	1.8	0.110	30.6	51.2	14.6	4.0	59	19	89,540	188,396.00	48%	2.1
73	1985	83,029	9,274,527	1,012,249	271,705	112	12.2	3.3	86%	2.8	1,410,821	17.0	0.4	1.7	0.109	32.0	49.4	14.1	4.1	57	18	83,029	187,858.00	44%	2.3
74	1986	83,584	9,791,865	1,042,452	290,422	117	12.5	3.5	85%	3.0	1,491,624	17.8	0.4	1.8	0.106	33.3	53.2	15.1	4.4	61	19	83,584	184,181.00	45%	2.2
75	1987	79,497	9,508,157	979,209	283,165	120	12.3	3.6	84%	3.0	1,463,732	18.4	0.5	1.8	0.103	33.7	52.5	14.8	4.4	60	19	79,497	180,966.00	44%	2.3
76	1988	78,862	8,916,462	928,195	274,155	113	11.8	3.5	84%	2.9	1,463,732	18.6	0.5	1.8	0.104	33.3	50.2	14.8	4.4	58	19	78,862	177,693.00	44%	2.3
77	1989	74,660	8,391,244	871,614	239,990	112	11.7	3.2	83%	2.7	1,283,668	17.2	0.4	1.6	0.104	31.5	49.1	13.8	4.1	56	18	74,660	170,813.00	44%	2.3
78	1990	71,999	7,801,557	819,632	228,043	108	11.4	3.2	83%	2.6	1,187,629	16.5	0.4	1.6	0.105	30.5	48.2	13.6	4.0	55	18	71,999	162,000.00	44%	2.3
79	1991	69,439	7,051,654	724,100	208,580	102	10.4	3.0	84%	2.5	1,101,245	15.9	0.4	1.5	0.103	28.8	45.3	12.9	3.8	52	17	69,439	155,600.00	45%	2.2
80	1992	61,734	6,510,501	652,304	201,754	105	10.6	3.3	84%	2.7	1,036,365	16.8	0.4	1.7	0.100	30.1	47.1	13.4	4.0	54	17	61,734	--	--	2.2
81	HIGH	97,570	10,068,900	1,061,814	314,187	120	12.5	3.6	86%	3.0	1,550,848	18.6	0.5	1.8	0.110	33.7	53	15.1	4.4	61	19	--	--	48%	2.3
82	LOW	61,734	6,510,501	652,304	201,754	101	10.4	3.0	83%	2.5	1,036,365	14.9	0.4	1.5	0.099	28.3	45	12.8	3.6	52	16	--	--	44%	2.1
83	AVERAGE	--	--	--	--	110	11.6	3.3	85%	2.8	--	16.8	0.4	1.7	0.104	31.1	49	14.0	4.1	57	18	--	--	45%	2.2
84	Tons sugar / ton prepared cane (	0.104461	tons molasses/ton prep cane (wet)			0.030																			
85																									

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
87	COMPOSITION	Sugarcane components (dry basis)	% Sucrose	% Cellulose	% Hemicellulose	% Lignin	% Other	CONVERSION EFFICIENCIES ASSUMED	LOW END OF RANGE	HIGH END OF RANGE	USED IN CALCULATIONS		tons from MSW in Hamakua	% of total	tons from MSW in N. Hilo	% of total
88	(SUCROSE,	Crop age (months)	24	24	24	24	24	Sucrose to glucose & fructose	99%	100%	99.5%	cellulose	1873	33%	521	33%
89	CELLULOSE,	Wet (fresh weight) or dry tons	dry	dry	dry	dry	dry	Cellulose to glucose	95%	100%	97.5%	hemicellulose	541	9%	150	9%
90	HEMICELLULOSE, &	Tops	0.0%	35.8%	21.4%	16.1%	26.7%	Hemicellulose to xylose	50%	90%	70.0%	lignin	948	17%	264	17%
91	LIGNIN)	Stalks	42.6%	21.8%	15.5%	11.5%	8.6%	Glucose to ethanol	95%	100%	97.5%	sum of above	3362	59%	935	59%
92	OF SUGARCANE STALKS	Trash	0.0%	35.8%	21.4%	16.1%	26.7%	Fructose to ethanol	95%	100%	97.5%	total reported	5728		1592	
93	& LEAVES	Stubble	42.6%	21.8%	15.5%	11.5%	8.6%	Xylose to ethanol	40%	90%	65.0%					source: Shleser draft report, 2/94
94		Roots						Sucrose to ethanol	94%	100%	97.0%					
95			tops & trash (leaves):	ref.	18			Cellulose to ethanol	90%	100%	95.1%					
96			stalks: bagasse + sucrose + molasses					Hemicellulose to ethanol	20%	81%	50.5%					
97																
98	Molasses $/ton (wet basis)	MOLASSES composition		Sucrose	Reducing Substances	Potassium Carbonate ash	Other carbonate ash	Other solids	Amino acids	Water	Total weight, wet basis	Total weight, dry basis				
99	$40	ref:	Weight, kg	352	168	44	74	187	36	139	1000	861				
100		27	% by weight, wet basis	35.2%	16.8%	4.4%	7.4%	18.7%	3.6%	13.9%	100.0%					
101		p.105	% by weight, dry basis	40.9%	19.5%	5.1%	8.6%	21.7%	4.2%			100.0%				
102				fermentable sugars =	60.4%											

	C	D	E	F	G	H	I	J	K
103		Experimental Yields (dry tons/gross acre/yr)	Estimated Commercial Yields (dry tons /gross acre/yr)	Estimated Commercial Yields (dry tons/net acre/yr)	Harvest Cycle (years)	Commercial Yields (dry tons gross yield/ harves			
104	BIOMASS CROP	dry tons/gross acre/yr	dry tons /gross acre/yr (2)	dry tons/net acre/yr (3)	years	dry tons gross yield/ harvest			
105	Sweet Sorghum (6 cult.; avg. 2 crops)	23.2	17.4	14.8	0.38	6.67			
106	Sweet Sorghum (MN 1500; 2 crops)	32.7	24.5	20.8	0.38	9.41			
107	Sorghum-Sudangrass	17.6	13.2	11.2	0.33	4.3			
108	Corn (Avg. 2 crops)	20	15	12.8	0.25	3.82			
109	Alfalfa (Avg. of 2 Experiments; 22 harvests)	11.8	8.9	7.5	0.08	0.73			
110	Napiergrass (Avg. 2 crops; 5 locations)	31.8	23.9	20.3	0.55	13.07			
111	Napiergrass (Avg. 7 crops; 1 location)	19.6	14.7	12.5	0.67	9.91			
112	Eucalyptus grandis (close spacing trial)	15.9	11.9	10.1	2	23.85			
113	Eucalyptus urophylla (close spacing trial)	18.6	14	11.9	2	27.9			
114	Acacia meamaii (close spacing trial)	17.1	12.8	10.9	2	25.65			
115	Eucalyptus grandis (large plots - Mt. View)	9.1	6.8	5.8	5	34.13			
116	Eucalyptus urophylla (large plots - Honokaa)	14.2	10.7	9.1	5	53.25			
117	Leucaena leucocephala (large plots - Maui)	11	8.3	7	5	41.25			
118	Leucaena leucocephala (large plots - Molokai)	9.6	7.2	6.1	5	36			
119	Eucalyptus urophylla (large plots - Kauai	7.8	5.9	5	5	29.25			
120	Sugarcane Maui (from HSPA Variety Tests) (4)	22.2	16.7	16.7	1.95	32.39			
121	Sugarcane Ka'u (from HSPA Variety Tests) (4)	16.7	12.5	12.5	2.33	29.17			
122	Sugarcane (5 locations; 2 harvests)	19.5	14.6	14.6					
123	Commercial Sugarcane (recovered biomass) (5)								
124	1981-1992 Average			14.0					
125	1981-1992 High			15.1					
126	1981-1992 Low			12.8					
127	Notes:								
128	(1) Information taken from HSPA experiments (1982-1993)								
129	Commercial Sugarcane Data obtained from HSPA report on annual sugar yield to the USDA,								
130	and unpublished HSPA reports. Alternative biomass yield data from reports to GACC and DBEDT.								
131	(2) Experimental Yields Discount (%)	25%							
132	(3) Gross to Net Acreage Conversion (%)	15%							
133	(4) Based on HSPA net acre (Sq. Ft.)	37,026							
134	(5) Includes sugar, fiber, soluble molasses solids								

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
136											BIOMASS MATERIAL:										
137	BIOMASS	Sweet Sorghum (6 cult.; avg. 2 crops)	Sweet Sorghum (MN 1500; 2 crops)	Napiergras s (Avg. 2 crops; 5 locations)	Napiergras s (Avg. 7 crops; 1 location)	Eucalyptus grandis (close spacing trial)	Eucalyptus grandis (large plots - Mt. View)	Eucalyptus urophylla (close spacing trial)	Eucalyptu s urophylla (large plots - Honokaa)	Eucalyptus urophylla (large plots - Kauai	Leucaena leucocephal a (large plots - Maui)	Leucaena leucoceph ala (large plots - Molokai)	Sugarcane Maui (from HSPA Variety Tests) (4)	Sugarcan e Ka'u (from HSPA Variety Tests) (4)	Sugarcane ("prepared cane")	Unburned sugarcan e	Newspaper	Municipal Solid Waste	Bagasse	Molasses	Sugarcane: leafy trash ususally burned
138	PARAMETERS														A		1144700	380929			B
139	Crop Production time (years)	0.38	0.38	0.55	0.67	2.00	5.00	2.00	5.00	5.00	5.00	5.00	1.95	2.33	2.23	2.23	n/a	n/a	2.23	2.23	2.23
140	Yield (wet tons/harvested acre)	19.06	26.89	46.68	35.39	47.70	68.26	55.80	106.50	58.50	82.50	72.00	107.97	97.23	109.82	116.74	n/a	n/a	31.73	3.30	16
141	Dry Matter (%)	35%	35%	28%	28%	50%	50%	50%	50%	50%	50%	50%	30%	30%	29%	33%	n/a	n/a	53%	85%	62%
142	Yield (dry tons/harvested acre)	6.67	9.41	13.07	9.91	23.85	34.13	27.90	53.25	29.25	41.25	36.00	32.39	29.17	31.91	39.00	5.72	1.90	16.82	2.80	9.90
143	Fermentable sugars (% dry weight)	34%	34%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	27%	43%	35%	0%	0%	3%	60%	0%
144	Cellulose (% dry weight)	36%	36%	32%	32%	38%	38%	38%	38%	38%	43%	43%	37%	37%	22%	27%	61%	33%	38%	0%	36%
145	Hemicellulose (% dry weight)	16%	16%	20%	20%	13%	13%	13%	13%	13%	14%	14%	14%	14%	16%	18%	16%	9%	27%	0%	21%
146	Lignin (% dry weight)	10%	10%	9%	9%	37%	37%	37%	37%	37%	25%	25%	15%	15%	11%	13%	21%	17%	20%	0%	16%
147	Other (% dry weight)	3%	3%	39%	39%	12%	12%	12%	12%	12%	18%	18%	9%	7%	9%	7%	2%	41%	13%	40%	27%
148	Sucrose (dry tons/acre)	2.29	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	8.00	13.58	13.58	0.00	0.00	0.42	1.69	0.00
149	Cellulose (dry tons/harvested acre)	2.41	3.40	4.18	3.17	9.06	12.97	10.60	20.24	11.12	17.74	15.48	11.98	10.79	6.96	10.51	3.49	0.62	6.39	0.00	3.54
150	Hemicellulose (dry tons/harvested acre)	1.10	1.55	2.61	1.98	3.10	4.44	3.63	6.92	3.80	5.78	5.04	4.53	4.08	4.95	7.07	0.92	0.18	4.54	0.00	2.12
151	Lignin (dry tons/harvested acre)	0.66	0.93	1.18	0.89	8.82	12.63	10.32	19.70	10.82	10.31	9.00	4.86	4.38	3.67	5.26	1.20	0.32	3.36	0.00	1.59
152	Glucose (dry tons/harvested acre)	3.81	5.37	4.53	3.44	9.82	14.05	11.49	21.92	12.04	19.22	16.77	17.17	15.88	14.66	18.49	3.78	0.67	7.14	0.89	3.84
153	Fructose (dry tons/harvested acre)	1.20	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.19	4.19	7.11	7.11	0.00	0.00	0.22	0.89	0.00
154	Xylose (dry tons/harvested acre)	0.87	1.23	2.08	1.58	2.47	3.53	2.89	5.51	3.02	4.59	4.01	3.61	3.25	3.94	5.62	0.73	0.14	3.61	0.00	1.68
155	Sugars, dry tons per acre per harvest	5.88	8.29	6.61	5.01	12.28	17.58	14.37	27.43	15.07	23.81	20.78	24.97	23.32	25.71	31.23	4.51	0.82	10.97	1.77	5.52
156	**Biomass Yield (dry tons / gross acre / year)**	17.6	24.6	23.6	14.8	11.9	6.8	14.0	10.7	5.9	8.3	7.2	16.6	12.6	14.3	17.5	5.7	1.9	7.6	1.3	4.4
157	**Biomass Yield (dry tons / net acre / year)**	14.6	20.6	20.3	12.6	10.1	5.6	11.9	9.1	5.0	7.0	6.1	16.7	12.6	12.2	14.9			6.4	1.1	3.8
158	Sugars - annual potential (tons/gross acre/year)	15.47	21.82	12.02	7.48	6.14	3.52	7.19	5.49	3.01	4.76	4.16	12.80	10.01	11.55	14.03			4.93	0.80	2.48
159	Tons sugars/dry ton biomass	0.88	0.88	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.58	0.58	0.77	0.80	0.81	0.80	0.79	0.43	0.65	0.63	0.56
160	Ethanol tons /ton sugar (.5 ton per ton)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
161	Ethanol (pounds/gal)	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58
162	Ethanol Potential (gallons / gross acre / harvest) (considering conversion efficiencies)	833	1,175	877	665	1,698	2,431	1,987	3,792	2,083	3,301	2,881	3,538	3,311	3,642	4,377	632	114	1,449	266	735
163	Ethanol Potential (gallons/gross acre/year)	2,191	3,091	1,594	992	849	486	993	758	417	660	576	1,814	1,421	1,636	1,967			651	119	330
164	Ethanol Gal/wet ton processed	43.69	43.69	18.78	18.78	35.61	35.61	35.61	35.61	35.61	40.01	40.01	32.77	34.05	33.16	37.49			45.66	80.45	
165	**Ethanol potential, gallons per dry ton processed (considering conversion efficiencies)**	124.82	124.82	67.08	67.08	71.21	71.21	71.21	71.21	71.21	80.03	80.03	109.22	113.50	114.13	112.22	110.49	59.91	86.15	94.93	74.28
166	Ethanol potential, tons ethanol / dry ton biomass	0.44	0.44	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.29	0.29	0.39	0.40	0.40	0.40	0.39	0.21	0.33	0.32	0.28
167	LIGNIN																				
168	Heat value(BTU/Ton)	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07
169	Heat value(BTU/lb)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
170	BTU/kWh	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000
171	KwH/dry ton biomass	227.47	227.47	207.69	207.69	853.85	853.85	853.85	853.85	853.85	576.92	576.92	346.15	346.15	265.08	311.15	484.62	381.93	461.54	0.00	371.54
172	Carbon Dioxide from Biomass																				
173	*CO2 t/dry t/harv ton biomass*	0.44	0.44	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.29	0.29	0.39	0.40	0.40	0.40	0.39	0.21	0.33	0.32	0.28
174	Theoretical ethanol maximum w/100% conversion at all steps (tons per dry ton biomass)	0.43	0.43	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.29	0.29	0.38	0.39	0.40	0.40	0.39	0.21	0.34	0.30	0.29

	C	D	E	F	G	H	I
136							
137	BIOMASS	=C105	=C106	=C110	=C111	=C112	=C115
138	PARAMETERS						
139	Crop Production time (years)	=G105	=G106	=G110	=G111	=G112	=G115
140	Yield (wet tons/harvested acre)	=D142/D141	=E142/E141	=F142/F141	=G142/G141	=H142/H141	=I142/I141
141	Dry Matter (%)	0.35	0.35	0.28	0.28	0.5	0.5
142	Yield (dry tons/harvested acre)	=H105	=H106	=H110	=H111	=H112	=H115
143	Fermentable sugars (% dry weight)	=0.12/D141	=0.12/E141	0	0	0	0
144	Cellulose (% dry weight)	=0.55*(1-D143)	=0.55*(1-E143)	0.32	0.32	0.38	0.38
145	Hemicellulose (% dry weight)	=0.25*(1-D143)	=0.25*(1-E143)	0.2	0.2	0.13	0.13
146	Lignin (% dry weight)	=0.15*(1-D143)	=0.15*(1-E143)	0.09	0.09	0.37	0.37
147	Other (% dry weight)	=1-(SUM(D143:D146))	=1-(SUM(E143:E146))	=1-(SUM(F143:F146))	=1-(SUM(G143:G146))	=1-(SUM(H143:H146))	=1-(SUM(I143:I146))
148	Sucrose (dry tons/acre)	=D142*D143	=E142*E143	=F142*F143	=G142*G143	=H142*H143	=I142*I143
149	Cellulose (dry tons/harvested acre)	=D142*D144	=E142*E144	=F142*F144	=G142*G144	=H142*H144	=I142*I144
150	Hemicellulose (dry tons/harvested acre)	=D142*D145	=E142*E145	=F142*F145	=G142*G145	=H142*H145	=I142*I145
151	Lignin (dry tons/harvested acre)	=D142*D146	=E142*E146	=F142*F146	=G142*G146	=H142*H146	=I142*I146
152	Glucose (dry tons/harvested acre)	=(D148*$L$88*$T$99)+(D149*$L$89*$S$99)	=(E148*$L$88*$T$99)+(E149*$L$89*$S$99)	=(F148*$L$88*$T$99)+(F149*$L$89*$S$99)	=(G148*$L$88*$T$99)+(G149*$L$89*$S$99)	=(H148*$L$88*$T$99)+(	=(I148*$L$88*$T$99)+(I149*$L8
153	Fructose (dry tons/harvested acre)	=D148*$L$88*$U$99	=E148*$L$88*$U$99	=F148*$L$88*$U$99	=G148*$L$88*$U$99	=H148*$L$88*$U$99	=I148*$L$88*$U$99
154	Xylose (dry tons/harvested acre)	=D150*$L$90*$X$99	=E150*$L$90*$X$99	=F150*$L$90*$X$99	=G150*$L$90*$X$99	=H150*$L$90*$X$99	=I150*$L$90*$X$99
155	Sugars, dry tons per acre per harvest	=SUM(D152:D154)	=SUM(E152:E154)	=SUM(F152:F154)	=SUM(G152:G154)	=SUM(H152:H154)	=SUM(I152:I154)
156	**Biomass Yield (dry tons / gross acre / year)**	=D142/D139	=E142/E139	=F142/F139	=G142/G139	=H142/H139	=I142/I139
157	**Biomass Yield (dry tons / net acre / year)**	=F105	=F106	=F110	=F111	=F112	=F115
158	Sugars - annual potential (tons/gross acre/year)	=D155/D139	=E155/E139	=F155/F139	=G155/G139	=H155/H139	=I155/I139
159	Tons sugars/dry ton biomass	=D155/D142	=E155/E142	=F155/F142	=G155/G142	=H155/H142	=I155/I142
160	Ethanol tons /ton sugar (.5 ton per ton)	0.5	0.5	0.5	0.5	0.5	0.5
161	Ethanol (pounds/gal)	6.58	6.58	6.58	6.58	6.58	6.58
162	Ethanol Potential (gallons / gross acre / harvest)	=((D152*$L91)+(D153*$K92)+(D154*$L93))*D	=((E152*$L91)+(E153*$K92)+(E154*$L93))*E	=((F152*$L91)+(F153*$K92)+(F154*$L93))*	=((G152*$L91)+(G153*$K92)+(G154*$L93))*	=((H152*$L91)+(H153*	=((I152*$L91)+(I153*$K92)+(I1
163	Ethanol Potential (gallons/gross acre/year)	=D162/D139	=E162/E139	=F162/F139	=G162/G139	=H162/H139	=I162/I139
164	Ethanol Gal/wet ton processed	=D162/D140	=E162/E140	=F162/F140	=G162/G140	=H162/H140	=I162/I140
165	**Ethanol potential, gallons per dry ton process**	=D162/D142	=E162/E142	=F162/F142	=G162/G142	=H162/H142	=I162/I142
166	Ethanol potential, tons ethanol / dry ton biomass	=(D155/D142)*0.5	=(E155/E142)*0.5	=(F155/F142)*0.5	=(G155/G142)*0.5	=(H155/H142)*0.5	=(I155/I142)*0.5
167	LIGNIN						
168	Heat value(BTU/Ton)	30000000	30000000	30000000	30000000	30000000	30000000
169	Heat value(BTU/lb)	=D168/2000	=E168/2000	=F168/2000	=G168/2000	=H168/2000	=I168/2000
170	BTU/kWh	13000	13000	13000	13000	13000	13000
171	KwH/dry ton biomass	=(2000*D146*D169)/D170	=(2000*E146*E169)/E170	=(2000*F146*F169)/F170	=(2000*G146*G169)/G170	=(2000*H146*H169)/H	=(2000*I146*I169)/I170
172	Carbon Dioxide from Biomass						
173	CO2 t/dry t/harv ton biomass	=D166	=E166	=F166	=G166	=H166	=I166
174	Theoretical ethanol maximum w/100% conversio	=((D148+D149+D150)/2)/D142	=((E148+E149+E150)/2)/E142	=((F148+F149+F150)/2)/F142	=((G148+G149+G150)/2)/G142	=((H148+H149+H150)/	=((I148+I149+I150)/2)/I142

	J	K	L	M	N	O	P	Q
136					BIOMASS MATERIAL			
137	=C113	=C116	=C119	=C117	=C118	=C120	=C121	Sugarcane ("prepared cane")
138								A
139	=G113	=G116	=G119	=G117	=G118	=G120	=G121	=AA83
140	=J142/J141	=K142/K141	=L142/L141	=M142/M141	=N142/N141	=O142/O141	=P142/P141	=H83
141	0.5	0.5	0.5	0.5	0.5	0.3	0.3	=U31
142	=H113	=H116	=H119	=H117	=H118	=H120	=H121	=Q140*Q141
143	0	0	0	0	0	=O148/O142	=P148/P142	=Q148/Q142
144	0.38	0.38	0.38	0.43	0.43	0.37	0.37	=(1-Q143)*U144
145	0.13	0.13	0.13	0.14	0.14	0.14	0.14	=(1-Q143)*U145
146	0.37	0.37	0.37	0.25	0.25	0.15	0.15	=(1-Q143)*U146
147	=1-(SUM(J143:J146))	=1-(SUM(K143:K146	=1-(SUM(L143:L146))	=1-(SUM(M143:M146))	=1-(SUM(N143:N146))	=1-(SUM(O143:O146))	=1-(SUM(P143:P146))	=1-SUM(Q143:Q146)
148	=J142*J143	=K142*K143	=L142*L143	=M142*M143	=N142*N143	8	8	=I83+O83+P83
149	=J142*J144	=K142*K144	=L142*L144	=M142*M144	=N142*N144	=O142*O144	=P142*P144	=Q142*Q144
150	=J142*J145	=K142*K145	=L142*L145	=M142*M145	=N142*N145	=O142*O145	=P142*P145	=Q142*Q145
151	=J142*J146	=K142*K146	=L142*L146	=M142*M146	=N142*N146	=O142*O146	=P142*P146	=Q142*Q146
152	=(J148*$L88*$T$99)+	=(K148*$L88*$T$99	=(L148*$L88*$T$99)+(L	=(M148*$L88*$T$99)+(M149*$L89*$S$99)	=(N148*$L88*$T$99)+(N149*$L89*$S$99)	=(O148*$L88*$T$99)+	=(P148*$L88*$T$99)+(P149*$L89*$S$99)	=(Q148*$L88*$T$99)+(Q149*$L89*$S$99)
153	=J148*$L88*$U$99	=K148*$L88*$U$99	=L148*$L88*$U$99	=M148*$L88*$U$99	=N148*$L88*$U$99	=O148*$L88*$U$99	=P148*$L88*$U$99	=Q148*$L88*$U$99
154	=J150*$L90*$X$99	=K150*$L90*$X$99	=L150*$L90*$X$99	=M150*$L90*$X$99	=N150*$L90*$X$99	=O150*$L90*$X$99	=P150*$L90*$X$99	=Q150*$L90*$X$99
155	=SUM(J152:J154)	=SUM(K152:K154)	=SUM(L152:L154)	=SUM(M152:M154)	=SUM(N152:N154)	=SUM(O152:O154)	=SUM(P152:P154)	=SUM(Q152:Q154)
156	=J142/J139	=K142/K139	=L142/L139	=M142/M139	=N142/N139	=O142/O139	=P142/P139	=Q142/Q139
157	=F113	=F116	=F119	=F117	=F118	=F120	=F121	=Q156*0.86
158	=J155/J139	=K155/K139	=L155/L139	=M155/M139	=N155/N139	=O155/O139	=P155/P139	=Q155/Q139
159	=J155/J142	=K155/K142	=L155/L142	=M155/M142	=N155/N142	=O155/O142	=P155/P142	=Q155/Q142
160	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
161	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58
162	=((J152*$L91)+(J153*	=((K152*$L91)+(K15	=((L152*$L91)+(L153*$K	=((M152*$L91)+(M153*$K92)+(M154*$L93	=((N152*$L91)+(N153*$K92)+(N154*$L93))	=((O152*$L91)+(O153*	=((P152*$L91)+(P153*$K92)+(P154*$L93))	=((Q152*$L91)+(Q153*$K92)+(Q154*$L93)
163	=J162/J139	=K162/K139	=L162/L139	=M162/M139	=N162/N139	=O162/O139	=P162/P139	=Q162/Q139
164	=J162/J140	=K162/K140	=L162/L140	=M162/M140	=N162/N140	=O162/O140	=P162/P140	=Q162/Q140
165	=J162/J142	=K162/K142	=L162/L142	=M162/M142	=N162/N142	=O162/O142	=P162/P142	=Q162/Q142
166	=(J155/J142)*0.5	=(K155/K142)*0.5	=(L155/L142)*0.5	=(M155/M142)*0.5	=(N155/N142)*0.5	=(O155/O142)*0.5	=(P155/P142)*0.5	=(Q155/Q142)*0.5
167								
168	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000
169	=J168/2000	=K168/2000	=L168/2000	=M168/2000	=N168/2000	=O168/2000	=P168/2000	=Q168/2000
170	13000	13000	13000	13000	13000	13000	13000	13000
171	=(2000*J146*J169)/J1	=(2000*K146*K169)/	=(2000*L146*L169)/L17	=(2000*M146*M169)/M170	=(2000*N146*N169)/N170	=(2000*O146*O169)/O	=(2000*P146*P169)/P170	=(2000*Q146*Q169)/Q170
172								
173	=J166	=K166	=L166	=M166	=N166	=O166	=P166	=Q166
174	=((J148+J149+J150)/2	=((K148+K149+K15	=((L148+L149+L150)/2)/	=((M148+M149+M150)/2)/M142	=((N148+N149+N150)/2)/N142	=((O148+O149+O150)/	=((P148+P149+P150)/2)/P142	=((Q148+Q149+Q150)/2)/Q142

	R	S	T	U	V	W
136						
137	Unburned sugarcane	Newspaper	Municipal Solid Waste	Bagasse	Molasses	Sugarcane: leafy trash ususally burned
138		1144700	380929			B
139	=Q139	n/a	n/a	=Q139	=Q139	=Q139
140	=R142/R141	n/a	n/a	=U142/U141	=J83	=W142/W141
141	=X31	n/a	n/a	0.53	=K83	=W32
142	39	=S138/200000	=T138/200000	=N83	=V140*V141	=(Q142-Q148)*0.54
143	=Q148/R142	0	0	0.025	=F102	=D90
144	=R149/R142	0.61	=O88	0.38	0	=E90
145	=R150/R142	0.16	=O89	0.27	0	=F90
146	=R151/R142	0.21	=O90	0.2	0	=G90
147	=1-(SUM(R143:R146))	=1-(SUM(S143:S146))	=1-(SUM(T143:T146))	=1-(SUM(U143:U146))	=1-SUM(V143:V146)	=1-SUM(W143:W146)
148	=Q148+W148	=S143*S142	=T143*T142	=U142*U143	=V143*V142	=W142*W143
149	=Q149+W149	=S144*S142	=T144*T142	=U142*U144	=V142*V144	=W142*W144
150	=Q150+W150	=S145*S142	=T145*T142	=U142*U145	=V142*V145	=W142*W145
151	=Q151+W151	=S146*S142	=T146*T142	=U142*U146	=V142*V146	=W142*W146
152	=(R148*$L88*$T$99)+(R149*$L89*$S$99)	=(S148*$L88*$T$99)+(S149*$L8	=(T148*$L88*$T$99)+(T149*$L8	=(U148*$L88*$T$99)+(U149*$L	=(V148*$L88*$T$99)+(V149*$L89*$S	=(W148*$L88*$T$99)+(W149*$L89*$S$99)
153	=R148*$L88*$U$99	=S148*$L88*$U$99	=T148*$L88*$U$99	=U148*$L88*$U$99	=V148*$L88*$U$99	=W148*$L88*$U$99
154	=R150*$L90*$X$99	=S150*$L90*$X$99	=T150*$L90*$X$99	=U150*$L90*$X$99	=V150*$L90*$X$99	=W150*$L90*$X$99
155	=SUM(R152:R154)	=SUM(S152:S154)	=SUM(T152:T154)	=SUM(U152:U154)	=SUM(V152:V154)	=SUM(W152:W154)
156	=R142/R139	=S142	=T142	=U142/U139	=V142/V139	=W142/W139
157	=R156*0.85			=U156*0.85	=V156*0.85	=W156*0.85
158	=R155/R139			=U155/U139	=V155/V139	=W155/W139
159	=R155/R142	=S155/S142	=T155/T142	=U155/U142	=V155/V142	=W155/W142
160	0.5	0.5	0.5	0.5	0.5	0.5
161	6.58	6.58	6.58	6.58	6.58	6.58
162	=((R152*$L91)+(R153*$K92)+(R154*$L93))	=((S152*$L91)+(S153*$K92)+(S	=((T152*$L91)+(T153*$K92)+(T	=((U152*$L91)+(U153*$K92)+(U	=((V152*$L91)+(V153*$K92)+(V154*$	=((W152*$L91)+(W153*$K92)+(W154*$L93
163	=R162/R139			=U162/U139	=V162/V139	=W162/W139
164	=R162/R140			=U162/U140	=V162/V140	
165	=R162/R142	=S162/S142	=T162/T142	=U162/U142	=V162/V142	=W162/W142
166	=(R155/R142)*0.5	=(S155/S142)*0.5	=(T155/T142)*0.5	=(U155/U142)*0.5	=(V155/V142)*0.5	=(W155/W142)*0.5
167						
168	30000000	30000000	30000000	30000000	30000000	30000000
169	=R168/2000	=S168/2000	=T168/2000	=U168/2000	=V168/2000	=W168/2000
170	13000	13000	13000	13000	13000	13000
171	=(2000*R146*R169)/R170	=(2000*S146*S169)/S170	=(2000*T146*T169)/T170	=(2000*U146*U169)/U170	=(2000*V146*V169)/V170	=(2000*W146*W169)/W170
172						
173	=R166	=S166	=T166	=U166	=V166	=W166
174	=((R148+R149+R150)/2)/R142	=((S148+S149+S150)/2)/S142	=((T148+T149+T150)/2)/T142	=((U148+U149+U150)/2)/U142	=((V148+V149+V150)/2)/V142	=((W148+W149+W150)/2)/W142

	C	D
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201	26	C. Brewer and Company, Ltd. 1981. Feasibility Study for Hilo Coast Processing Company. 11.4 Million Gallon Per Year Motor Fuel Grade Ethanol Plant.
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206	31	Chereminisoff et al. 1976. Woodwastes Utilization & Disposal.
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208	33	Falkehag, Ingemar. 1975. Lignin in Materials. *Printed in Proceedings of the Eighth Cellulose Conference.* Applied Polymer Symposia, No. 28.
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	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
210				DATA FOR CROP YIELD GRAPHS													
211	Data for graphs (all yields are in terms of dry tons per acre per year unless otherwise noted)	Sweet Sorghum (6 cult.; avg. 2 crops)	Sweet Sorghum (MN 1500; 2 crops)	Napiergrass (Avg. 2 crops; 5 locations)	Napiergrass (Avg. 7 crops; 1 location)	Eucalyptus grandis (close spacing trial)	Eucalyptus grandis (large plots - Mt. View)	Eucalyptus urophylla (close spacing trial)	Eucalyptus urophylla (large plots - Honokaa)	Eucalyptus urophylla (large plots - Kauai	Leucaena leucocephala (large plots - Maui)	Leucaena leucocephala (large plots - Molokai)	Sugarcane Maui (from HSPA Variety Tests) (4)	Sugarcane Ka'u (from HSPA Variety Tests) (4)	Sugarcane ("prepared cane")	Sugarcane: leafy trash usually burned	Unburned sugarcane
212	Wet weight (tons/acre/yr)	50	71	85	53	24	14	28	21	12	17	14	55	42	49	7	52
213	Dry matter (tons/acre/yr)	15	21	20	13	10	6	12	9	5	7	6	17	13	12	3.8	15
214	Potential ethanol yield (gallons/net acre/harvest)	708	998	745	565	1,444	2,066	1,689	3,223	1,771	2,806	2,449	3,007	2,814	3,095	625	3,720
215	Potential ethanol yield (gallons/net acre/year)	1,847	2,596	1,362	839	719	413	847	648	356	560	488	1,824	1,419	1,391	261	1,672
216		Sugarcane	Leucaena	Eucalyptus	Napiergrass	Sweet sorghum											
217	Upper Range of Experimental Yields (dry tons/gross acre/yr)	22	11	19	32	33		HSPA EST. COMM. YIELD (dry tons/acre/year)									
218	Upper Range of Estimated Commercial Yields (dry tons /gross acre/yr)	17	8	14	24	25											
219	Upper Range of Estimated Commercial Yields (dry tons/net acre/yr)	17	7	12	20	21											
220	Lower Range of Experimental Yields (dry tons/gross acre/yr)	17	10	8	20	23											
221	Lower Range of Estimated Commercial Yields (dry tons /gross acre/yr)	13	7	6	15	17											
222	Lower Range of Estimated Commercial Yields (dry tons/net acre/yr)	13	6	5	13	15											
223		NEWSPAPER	MUNICIPAL SOLID WASTE	MOLASSES	BAGASSE	UNBURNED CANE	PREPARED CANE	LEUCAENA	EUCALYPTUS	NAPIERGRASS	SWEET SORGHUM						
224	GALLONS ETHANOL PER DRY TON BIOMASS	110	60	95	86	112	114	80	71	67	125						
225		Sugarcane	Leucaena	Eucalyptus	Napier grass	Sweet sorghum											
226	From Upper Range of Experimental Yields (dry tons/gross acre/yr)	2534	880	1325	2133	4082											
227	From Upper Range of Estimated Commercial Yields (dry tons /gross acre/yr)	1906	664	997	1603	3058											
228	From Upper Range of Estimated Commercial Yields (dry tons/net acre/yr)	1963	560	847	1362	2596											
229	From Lower Range of Experimental Yields (dry tons/gross acre/yr)	1906	768	555	1315	2896											
230	From Lower Range of Estimated Commercial Yields (dry tons /gross acre/yr)	1427	576	420	986	2172											
231	From Lower Range of Estimated Commercial Yields (dry tons/net acre/yr)	1427	488	356	839	1847											

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
232															
233	Cost Center	Sugarcane (irrigated)			Napiergrass (irrigated)		Leucaena (irrigated)		Sugarcane (rainfed)			Eucalyptus (rainfed)		Napiergrass (rainfed)	
234	tons/acre/yr		16.0	%		18.0		10.0		14.0	%		8.5		15.0
235	Cost center	($/acre/yr)	($/ton)	of total cost	($/acre/yr)	($/ton)	($/acre/yr)	($/ton)	($/acre/yr)	($/ton)	of total cost	($/acre/yr)	($/ton)	($/acre/yr)	($/ton)
236	Landholding	$100	$6	8%	$100	$6	$100	$10	$100	$7	8%	$100	$12	$100	$7
237	Soil preparation	$53	$3	4%	$27	$2	$5	$1	$53	$4	2%	$49	$6	$27	$2
238	Planting/ratooning	$135	$8	10%	$67	$4	$16	$2	$135	$10	5%	$16	$2	$67	$4
239	Weed control	$92	$6	7%	$46	$3	$64	$6	$92	$7	4%	$41	$5	$46	$3
240	Irrigation	$260	$16	20%	$371	$21	$328	$33	$0	$0	30%	$0	$0	$0	$0
241	Fertilization	$115	$7	9%	$148	$8	$40	$4	$115	$8	12%	$40	$5	$148	$10
242	Other field	$179	$11	13%	$89	$5	$89	$9	$179	$13	7%	$30	$4	$89	$6
243	Harvesting	$123	$8	9%	$115	$6	$238	$24	$123	$9	9%	$251	$30	$115	$8
244	Hauling	$155	$10	12%	$180	$10	$36	$4	$155	$11	14%	$48	$6	$180	$12
245	G&A-Field	$121	$8	9%	$114	$6	$92	$9	$95	$7	9%	$58	$7	$90	$6
246	Research		$0	0%		$0		$0		$0	0%		$0		$0
247	Total delivered cost	$1,333	$83	100%	$1,257	$70	$1,008	$101	$1,047	$75	100%	$633	$74	$862	$57
248	Cost/ton		$83			$70		$101		$75			$74		$57
249	Cost per acre per harvest	$2,967			$691		$5,040		$2,330			$3,165		$474	
250															
251															
252															
253	tons sugar per wet ton prep. cane				0.1										
254	1981-92 avg. tons sugar per dry ton prep. cane				0.4										
255	1991 value of sugar per wet ton prep. cane				$38	assumes $360/ton raw sugar									
256	value of sugar in one dry ton prep. cane				$129										
257	1991 production cost per ton of sugar				$417	includes sugar factory costs. 1991 average, from HSPA 18th Annual News Media Briefing, 3/19/92									
258	1991 tons sugar per acre				10.4	1991 average yield, unpublished HSPA data									
259	average sugarcane production cost per acre (24 month harvest)				$4,348	includes sugar factory costs. 1991 average, calculated									
260	tons sugar per acre				11.5	1981-92 average yield									
261	sugarcane production cost per ton of sugar adjusted to 81-92 average				$379	1991 costs per ton sugar, adjusted for 1981-1992 average yields per acre									
262	cost per acre (24 month harvest)				$2,648	From Osgood & Dudley, above. Does not include sugar factory costs									
263	sugar processing costs per acre				$791	Based on Osgood & Dudley, plus Kinoshita est. cost after factory gate =						23%	of total raw sugar production cost		
264	sugar processing costs per ton sugar				$69	costs per acre adjusted for 1981-1992 av. sugar yield per acre									
265	sugar processing costs for sugar in one dry ton prepared cane				$25										
266					$300	costs per ton sugar, using Osgood & Dudley and 1981-92 average yields									
267					-21%	% diff compared to 1991 costs (adj. for 81-92 avg. yields)									
268															
269															

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	C	D	E	F	G	H	I	J	K	L	M
271	COMPONENT	Bagasse	R E F #	Molasses	Sugarcane ("prepared cane")	Sugarcane: leafy trash usually burned		Unburned sugarcane			
272	Tons (dry matter) per acre per harvest	16.8		2.8	31.9	9.9	2	39.0			
273	Est. max. cost per harvested acre	$0		$0	$3,918	$383		$4,301			
274	Estimated average cost per harvested acre	$0		$0	$2,648	$259	harvesting	$2,907			
275	Est. min. cost per harvested acre	$0		$0	$2,084	$204		$2,288			
276	Est. max. cost (dollars) per ton (dry matter)	$0.00	byproduct	$0	$123	$38.74		$110.29			
277	Est. average cost per ton (dry basis)	$0.00		$0	$83	$26.18		$74.55			
278	Est. min. cost (dollars) per ton (dry matter)	$0.00		$0	$65	$20.60		$58.66			
279	Cost to replace dry ton bagasse w/Diesel	$72.23	$32.00								
280	Cost to replace dry ton bagasse w/#6 oil	$42.28	$20.00								
281	Cost to replace dry ton bagasse w/Coal	$38.05	$60.00	32							
282	Estimated upper end of range, plant gate cost per dry ton	$72.23	16	$47.20	$122.80	$38.74		$110.29			
283	Estimated lower end of range, plant gate cost per dry ton	$38.05		$47.20	$65.31	$20.60		$58.66			
284	BIOMASS	Sugarcane	Leucaena	Eucalyptus	Napiergrass	Sweet sorghum	Newspaper	Municipal Solid Waste	Molasses	Bagasse	Unburned sugarcane
285	Cost per acre per year	$1,190	$1,008	$633	$1,060	$1,333	--	--	--	--	--
286	Estimated upper end of range, feedstock cost per dry ton	$95	$165	$127	$85	$90	$15	$25	$47	$72	$110
287	Estimated lower end of range, feedstock cost per dry ton	$69	$144	$53	$52	$64	$5	$0	$47	$38	$59
288	Estimated upper end of range, feedstock cost per potential ethanol gallon	$0.83	$2.06	$1.78	$1.26	$0.72	$0.14	$0.42	$0.50	$0.84	$0.98
289	Estimated lower end of range, feedstock cost per potential ethanol gallon	$0.61	$1.80	$0.75	$0.78	$0.51	$0.05	$0.00	$0.50	$0.44	$0.52
290		Cost per acre per year	Estimated upper end of range, feedstock cost per dry ton	Estimated lower end of range, feedstock cost per dry ton	Estimated upper end of range, feedstock cost per potential ethanol gallon	Estimated lower end of range, feedstock cost per potential ethanol gallon					
291	Sugarcane	$1,190.00	$95.20	$69.18	$0.83	$0.61					
292	Leucaena	$1,008.00	$165.25	$144.00	$2.06	$1.80					
293	Eucalyptus	$633.00	$126.60	$53.19	$1.78	$0.75					
294	Napiergrass	$1,059.50	$84.76	$52.19	$1.26	$0.78					
295	Sweet sorghum	$1,333.00	$90.07	$64.09	$0.72	$0.51					
296	Newspaper	--	$15.00	$5.00	$0.14	$0.05					
297	Municipal Solid Waste	--	$25.00	$0.00	$0.42	$0.00					
298	Molasses	--	$47.20	$47.20	$0.50	$0.50					
299	Bagasse	--	$72.23	$38.05	$0.84	$0.44					
300	Unburned sugarcane	--	$110.29	$58.66	$0.98	$0.52					

	C	D	E	F	G	H
302	INDEPENDENT VARIABLES		ref #	PG #	REALITY CHECK INFO	
303	Power Law Scaling Factor	0.7			FEEDSTOCK:	Sugarcane ("prepared cane")
304	Contingency	10%			TONS FERMENTABLE SUGAR PER TON BIOMASS	0.81
305	Start-up factor	5%			TONS ETHANOL PER TON BIOMASS, ASSUMING 100% OF SUGARS ARE FERMENTED:	0.41
306	Working Capital	7.50%			MAXIMUM THEORETICAL YIELD, GALLONS ETHANOL PER TON PREPARED CANE DRY MATTER:	125.15
307	Operating Days per Year	330				
308	Personnel Scaling Factor	0.9				
309	Property Tax & Insurance	1.50%				
310	**Biomass Cost/ton-**					
311	PROCESS COST ONLY (BIOMASS $0)	$0.00				
312	BIOMASS COST 1	$50.00			RESULTS OF REALITY CHECK:	% of theoretical
313	BIOMASS COST 2	$109.00			NREL SSF ESTIMATED BASE COSTS	73.8%
314	Denaturant Cost, $/gal	0.87			TVA ACID ESTIMATED BASE COSTS	63.6%
315	Denaturant Use	5.00%	26	p.12-4	STAKETECH ESTIMATED BASE COSTS	74.4%
316	Fringe Benefits	25%			BIOENERGY ESTIMATED BASE COSTS	72.2%
317	Depreciation period (yrs)	30			ARKENOL ESTIMATED BASE COSTS	72.7%
318	Salvage value (% of original value)	10%			PASZNER TECHNOLOGY ESTIMATED BASE COSTS	77.7%
319	Interest rate	0.00%			ASSUMPTION USED ABOVE IN "POTENTIAL ETHANOL GALLONS"	91.2%
320	Plant feedrate (dry tons per day)					
321	Ethanol Production (MM gal/yr)	5	PLANT SIZE 1			
322	Producing MM gal. per year-	25	PLANT SIZE 2			

	C	D	E	F	G	H	I	J	K	L	M	N
324							PROCESS COST ONLY (BIOMASS $0)					
325	NREL SSF ESTIMATED BASE COSTS						NREL SSF ESTIMATED BASE COSTS					
326	Plant feedrate (dry tons per day)		1900	Biomass Cost/ton-	$50.00		Plant feedrate (dry tons per day)		820		Ratio of orig. to proposed size-	0.43
327	Ethanol Production (MM gal/yr)		57.91			Ethanol Production (MM gal/yr)		25	Scaling of original data	0.56	Biomass Cost/ton-	$0.00
328	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
329	100	Biomass Preparation	$6.498	Biomass	$31,350.000	$0.541	100	Biomass Preparation	$3.609	Biomass	$0.000	$0.000
330	200	Pretreatment	$20.634	Chemicals			200	Pretreatment	$11.461	Chemicals		
331	210	Recycle & Recovery	$0.000	Denaturant	$2,200.000	$0.038	210	Recovery & Recycle	$0.000	Denaturant	$1,087.500	$0.044
332	300	Hydrolysis	$0.000	Acid	$0.000	$0.000	300	Hydrolysis	$0.000	Acid	$0.000	$0.000
333	400	Fermentation	$0.000	Ammonia	$0.000	$0.000	400	Fermentation (Unallocated)	$0.000	Ammonia	$0.000	$0.000
334	410	Hexose Fermentation	$20.235	Nutrients	$0.000	$0.000	410	Hexose Fermentation	$11.239	Nutrients	$0.000	$0.000
335	420	Pentose Fermentation	$5.643	Enzymes	$0.000	$0.000	420	Pentose Fermentation	$3.134	Enzymes	$0.000	$0.000
336	500	Distillation& Dehydration	$3.534	Yeast	$0.000	$0.000	500	Distillation & Dehydration	$1.963	Yeast	$0.000	$0.000
337	600	By-Product Preparation	$0.000	Other Chemicals	$7,740.000	$0.134	600	By-Product Preparation	$0.000	Other Chemicals	$3,341.392	$0.134
338	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	$41,290.000	$0.713	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	$4,428.892	$0.177
339	700	Product Storage & Denature	$2.850	Utilities			700	Product Storage & Denature	$1.583	Utilities		
340	800	Utilities & General	$0.000	Electricity/ Energy	($3,220.00)	($0.06)	800	Utilities & General	$0.000	Electricity/ Energy	($1,390.09)	($0.06)
341	810	Boiler	$18.020	Water	$120.000	$0.002	810	Boiler	$10.009	Water	$51.805	$0.002
342	820	Non-Boiler Utilities	$30.210	By-products	$400.000	$0.007	820	Non-Boiler Utilities	$16.780	By-products	$172.682	$0.007
343	830	Environmental	$3.734	VARIABLE COST TOTAL	$38,590.000	$0.666	830	Environmental	$2.074	VARIABLE COST TOTAL	$3,263.290	$0.131
344	840	Miscellaneous & Control	$5.786	GEN & ADMIN	$3,500.000	$0.060	840	Miscellaneous & Control	$3.213	GEN & ADMIN	$1,590.000	$0.064
345	900	Enzyme Production	$2.451				900	Enzyme Production	$1.361			
346				Operators	$3,237.000	$0.056				Operators	$1,519.884	$0.061
347		Total Installed Equipment	$119.594	Laborers	$2,130.000	$0.037	1000	Total Fixed Capital	$66.426	Laborers	$1,000.109	$0.040
348				Technicians	$447.000	$0.008				Technicians	$209.882	$0.008
349		Fixed Capital	$119.594	Maintenance	$1,704.000	$0.029	1010	Contingency	$6.643	Maintenance	$800.087	$0.032
350	10%	Miscellaneous	$11.959	Fringe Benefits	$1,879.500	$0.032	1020	Startup	$3.321	Fringe Benefits	$882.491	$0.035
351	5%	Start-up Costs	$5.980	TOTAL LABOR	$9,397.500	$0.162	1030	Working Capital	$4.982	TOTAL LABOR	$4,412.453	$0.176
352	7.50%	Working capital	$8.970	Property Tax & Insur.	$2,197.540	$0.038				Property Tax & Insur.	$1,220.583	$0.049
353				TOTAL CASH	$53,685.040	$0.927		TOTAL CAPITAL	$81.372	TOTAL CASH	$10,486.326	$0.419
354	sm=straight line depreciation	TOTAL CAPITAL	$146.503	Depreciation	$4,395.080	$0.076				Depreciation	$2,441.166	$0.098
355	db=real depreciation using fixed declining bal method			Interest	$0.000	$0.000				Interest	$0.000	$0.000
356												
357				TOTAL PRODUCTION	$58,080.119	$1.003				TOTAL PRODUCTION	$12,927.492	$0.517
358							Power Law Scaling Factor		0.7	PROCESS COST ONLY (BIOMASS $0)		$0.00
359							Contingency		10.00%	BIOMASS COST 1		$50.00
360							Start-up factor		5.00%	BIOMASS COST 2		$109.00
361							Working Capital		7.50%	Denaturant Cost, $/gal		$0.87
362							Operating Days per Year		330	Denaturant Use		5%
363							Personnel Scaling Factor		0.9	Fringe Benefits		25%
364							Property Tax & Insurance		1.50%	Depreciation period (yrs)		30

	I	J	K	L	M	N	O	P	Q	R	S	T
324	PROCESS COST ONLY (BIOMASS $0)						PROCESS COST ONLY (BIOMASS $0)					
325	NREL SSF ESTIMATED BASE COSTS						NREL SSF ESTIMATED BASE COSTS					
326	Plant feedrate (dry tons per day)		820		Ratio of orig. to proposed size-	0.43	Plant feedrate (dry tons per day)	164.05	Biomass Cost/ton-	$0.00	Ratio of orig. to proposed size-	0.09
327	Ethanol Production (MM gal/yr)	25	Scaling of original data	0.56	Biomass Cost/ton-	$0.00	Ethanol Production (MM gal/yr)	5			Scaling of original data	0.18
328	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
329	100	Biomass Preparation	$3.609	Biomass	$0.000	$0.000	100	Biomass Preparation	$1.170	Biomass	$0.000	$0.000
330	200	Pretreatment	$11.461	Chemicals			200	Pretreatment	$3.715	Chemicals		
331	210	Recovery & Recycle	$0.000	Denaturant	$1,087.500	$0.044	210	Recovery & Recycle	$0.000	Denaturant	$217.500	$0.044
332	300	Hydrolysis	$0.000	Acid	$0.000	$0.000	300	Hydrolysis	$0.000	Acid	$0.000	$0.000
333	400	Fermentation (Unallocated)	$0.000	Ammonia	$0.000	$0.000	400	Fermentation (Unallocated)	$0.000	Ammonia	$0.000	$0.000
334	410	Hexose Fermentation	$11.239	Nutrients	$0.000	$0.000	410	Hexose Fermentation	$3.643	Nutrients	$0.000	$0.000
335	420	Pentose Fermentation	$3.134	Enzymes	$0.000	$0.000	420	Pentose Fermentation	$1.016	Enzymes	$0.000	$0.000
336	500	Distillation & Dehydration	$1.963	Yeast	$0.000	$0.000	500	Distillation & Dehydration	$0.636	Yeast	$0.000	$0.000
337	600	By-Product Preparation	$0.000	Other Chemicals	$3,341.392	$0.134	600	By-Product Preparation	$0.000	Other Chemicals	$668.278	$0.134
338	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	$4,428.892	$0.177	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	$885.778	$0.177
339	700	Product Storage & Denature	$1.583	Utilities			700	Product Storage & Denature	$0.513	Utilities		
340	800	Utilities & General	$0.000	Electricity/ Energy	($1,390.09)	($0.06)	800	Utilities & General	$0.000	Electricity/ Energy	($278.02)	($0.06)
341	810	Boiler	$10.009	Water	$51.805	$0.002	810	Boiler	$3.244	Water	$10.361	$0.002
342	820	Non-Boiler Utilities	$16.780	By-products	$172.682	$0.007	820	Non-Boiler Utilities	$5.439	By-products	$34.536	$0.007
343	830	Environmental	$2.074	VARIABLE COST TOTAL	$3,263.290	$0.131	830	Environmental	$0.672	VARIABLE COST TOTAL	$652.658	$0.131
344	840	Miscellaneous & Control	$3.213	GEN & ADMIN	$1,590.000	$0.064	840	Miscellaneous & Control	$1.042	GEN & ADMIN	$373.529	$0.075
345	900	Enzyme Production	$1.361				900	Enzyme Production	$0.441			
346				Operators	$1,519.884	$0.061				Operators	$357.057	$0.071
347	1000	Total Fixed Capital	$66.426	Laborers	$1,000.109	$0.040	1000	Total Fixed Capital	$21.531	Laborers	$234.949	$0.047
348				Technicians	$209.882	$0.008				Technicians	$49.306	$0.010
349	1010	Contingency	$6.643	Maintenance	$800.087	$0.032	1010	Contingency	$2.153	Maintenance	$187.960	$0.038
350	1020	Startup	$3.321	Fringe Benefits	$882.491	$0.035	1020	Startup	$1.077	Fringe Benefits	$207.318	$0.041
351	1030	Working Capital	$4.982	TOTAL LABOR	$4,412.453	$0.176	1030	Working Capital	$1.615	TOTAL LABOR	$1,036.590	$0.207
352				Property Tax & Insur.	$1,220.583	$0.049				Property Tax & Insur.	$395.629	$0.079
353		TOTAL CAPITAL	$81.372	TOTAL CASH	$10,486.326	$0.419		TOTAL CAPITAL	$26.375	TOTAL CASH	$2,458.406	$0.492
354				Depreciation	$2,441.166	$0.098				Depreciation	$791.258	$0.158
355				Interest	$0.000	$0.000				Interest	$0.000	$0.000
356												
357				TOTAL PRODUCTION	$12,927.492	$0.517				TOTAL PRODUCTION	$3,249.664	$0.650
358	Power Law Scaling Factor		0.7	PROCESS COST ONLY (BIOMASS $0)		$0.00		Power Law Scaling Factor	0.7	COST ONLY (BIOMASS	$0.00	
359	Contingency		10.00%	BIOMASS COST 1		$50.00		Contingency	10.00%	BIOMASS COST 1	$50.00	
360	Start-up factor	.	5.00%	BIOMASS COST 2		$109.00		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
361	Working Capital		7.50%	Denaturant Cost, $/gal		$0.87		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
362	Operating Days per Year		330	Denaturant Use		5%		Operating Days per Year	330	Denaturant Use	5%	
363	Personnel Scaling Factor		0.9	Fringe Benefits		25%		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
364	Property Tax & Insurance		1.50%	Depreciation period (yrs)		30		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	I	J	K	L	M	N	O	P	Q	R	S	T
324	PROCESS COST ONLY (BIOMASS $0)						PROCESS COST ONLY (BIOMASS $0)					
325	NREL SSF ESTIMATED BASE COSTS						NREL SSF ESTIMATED BASE COSTS					
326	Plant feedrate (dry tons per day)		820		Ratio of orig. to proposed size-	0.43	Plant feedrate (dry tons per day)	164.05	Biomass Cost/ton-	$0.00	Ratio of orig. to proposed size-	0.09
327	Ethanol Production (MM gal/yr)	25	Scaling of original data	0.56	Biomass Cost/ton-	$0.00	Ethanol Production (MM gal/yr)	5			Scaling of original data	0.18
328	**AREA**	**CAPITAL COSTS**	**Million $**	**PRODUCTION COSTS**	**Thous $/Yr**	**$/gal**	**AREA**	**CAPITAL COSTS**	**Million $**	**PRODUCTION COSTS**	**Thous $/Yr**	**$/gal**
329	100	Biomass Preparation	$3.609	Biomass	$0.000	$0.000	100	Biomass Preparation	$1.170	Biomass	$0.000	$0.000
330	200	Pretreatment	$11.461	Chemicals			200	Pretreatment	$3.715	Chemicals		
331	210	Recovery & Recycle	$0.000	Denaturant	$1,087.500	$0.044	210	Recovery & Recycle	$0.000	Denaturant	$217.500	$0.044
332	300	Hydrolysis	$0.000	Acid	$0.000	$0.000	300	Hydrolysis	$0.000	Acid	$0.000	$0.000
333	400	Fermentation (Unallocated)	$0.000	Ammonia	$0.000	$0.000	400	Fermentation (Unallocated)	$0.000	Ammonia	$0.000	$0.000
334	410	Hexose Fermentation	$11.239	Nutrients	$0.000	$0.000	410	Hexose Fermentation	$3.643	Nutrients	$0.000	$0.000
335	420	Pentose Fermentation	$3.134	Enzymes	$0.000	$0.000	420	Pentose Fermentation	$1.016	Enzymes	$0.000	$0.000
336	500	Distillation & Dehydration	$1.963	Yeast	$0.000	$0.000	500	Distillation & Dehydration	$0.636	Yeast	$0.000	$0.000
337	600	By-Product Preparation	$0.000	Other Chemicals	$3,341.392	$0.134	600	By-Product Preparation	$0.000	Other Chemicals	$668.278	$0.134
338	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	$4,428.892	$0.177	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	$885.778	$0.177
339	700	Product Storage & Denature	$1.583	Utilities			700	Product Storage & Denature	$0.513	Utilities		
340	800	Utilities & General	$0.000	Electricity/ Energy	($1,390.09)	($0.06)	800	Utilities & General	$0.000	Electricity/ Energy	($278.02)	($0.06)
341	810	Boiler	$10.009	Water	$51.805	$0.002	810	Boiler	$3.244	Water	$10.361	$0.002
342	820	Non-Boiler Utilities	$16.780	By-products	$172.682	$0.007	820	Non-Boiler Utilities	$5.439	By-products	$34.536	$0.007
343	830	Environmental	$2.074	VARIABLE COST TOTAL	$3,263.290	$0.131	830	Environmental	$0.672	VARIABLE COST TOTAL	$652.658	$0.131
344	840	Miscellaneous & Control	$3.213	GEN & ADMIN	$1,590.000	$0.064	840	Miscellaneous & Control	$1.042	GEN & ADMIN	$373.529	$0.075
345	900	Enzyme Production	$1.361				900	Enzyme Production	$0.441			
346				Operators	$1,519.884	$0.061				Operators	$357.057	$0.071
347	1000	Total Fixed Capital	$66.426	Laborers	$1,000.109	$0.040	1000	Total Fixed Capital	$21.531	Laborers	$234.949	$0.047
348				Technicians	$209.882	$0.008				Technicians	$49.306	$0.010
349	1010	Contingency	$6.643	Maintenance	$800.087	$0.032	1010	Contingency	$2.153	Maintenance	$187.960	$0.038
350	1020	Startup	$3.321	Fringe Benefits	$882.491	$0.035	1020	Startup	$1.077	Fringe Benefits	$207.318	$0.041
351	1030	Working Capital	$4.982	TOTAL LABOR	$4,412.453	$0.176	1030	Working Capital	$1.615	TOTAL LABOR	$1,036.590	$0.207
352				Property Tax & Insur.	$1,220.583	$0.049				Property Tax & Insur.	$395.629	$0.079
353		TOTAL CAPITAL	$81.372	TOTAL CASH	$10,486.326	$0.419		TOTAL CAPITAL	$26.375	TOTAL CASH	$2,458.406	$0.492
354				Depreciation	$2,441.166	$0.098				Depreciation	$791.258	$0.158
355				Interest	$0.000	$0.000				Interest	$0.000	$0.000
356												
357				TOTAL PRODUCTION	$12,927.492	$0.517				TOTAL PRODUCTION	$3,249.664	$0.650
358	Power Law Scaling Factor		0.7	PROCESS COST ONLY (BIOMASS $0)		$0.00		Power Law Scaling Factor	0.7	PROCESS COST ONLY (BIOMASS $0)	$0.00	
359	Contingency		10.00%	BIOMASS COST 1		$50.00		Contingency	10.00%	BIOMASS COST 1	$50.00	
360	Start-up factor		5.00%	BIOMASS COST 2		$109.00		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
361	Working Capital		7.50%	Denaturant Cost, $/gal		$0.87		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
362	Operating Days per Year		330	Denaturant Use		5%		Operating Days per Year	330	Denaturant Use	5%	
363	Personnel Scaling Factor		0.9	Fringe Benefits		25%		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
364	Property Tax & Insurance		1.50%	Depreciation period (yrs)		30		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
324	BIOMASS COST 1						BIOMASS COST 1					
325	NREL SSF ESTIMATED BASE COSTS						NREL SSF ESTIMATED BASE COSTS					
326	Plant feedrate (dry tons per day)	820	Biomass Cost/ton-	$50.00	Ratio of orig. to proposed size-	0.43	Plant feedrate (dry tons per day)	164.05	Biomass Cost/ton-	$50.00	Ratio of orig. to proposed size-	0.09
327	Ethanol Production (MM gal/yr)	25	Scaling of original data	0.56			Ethanol Production (MM gal/yr)	5	Scaling of original data	0.18		
328	**AREA**	**CAPITAL COSTS**	**Million $**	**PRODUCTION COSTS**	**Thous $/Yr**	**$/gal**	**AREA**	**CAPITAL COSTS**	**Million $**	**PRODUCTION COSTS**	**Thous $/Yr**	**$/gal**
329	100	Biomass Preparation	$3.609	Biomass	$13,533.932	$0.541	100	Biomass Preparation	$1.170	Biomass	$2,706.786	$0.541
330	200	Pretreatment	$11.461	Chemicals			200	Pretreatment	$3.715	Chemicals		
331	210	Recovery & Recycle	$0.000	Denaturant	$1,087.500	$0.044	210	Recovery & Recycle	$0.000	Denaturant	$217.500	$0.044
332	300	Hydrolysis	$0.000	Acid	$0.000	$0.000	300	Hydrolysis	$0.000	Acid	$0.000	$0.000
333	400	Fermentation (Unalloca	$0.000	Ammonia	$0.000	$0.000	400	Fermentation (Unallocate	$0.000	Ammonia	$0.000	$0.000
334	410	Hexose Fermentation	$11.239	Nutrients	$0.000	$0.000	410	Hexose Fermentation	$3.643	Nutrients	$0.000	$0.000
335	420	Pentose Fermentation	$3.134	Enzymes	$0.000	$0.000	420	Pentose Fermentation	$1.016	Enzymes	$0.000	$0.000
336	500	Distillation & Dehydrati	$1.963	Yeast	$0.000	$0.000	500	Distillation & Dehydration	$0.636	Yeast	$0.000	$0.000
337	600	By-Product Preparation	$0.000	Other Chemicals	$3,341.392	$0.134	600	By-Product Preparation	$0.000	Other Chem	$668.278	$0.134
338	610	Stillage Evaporation	$0.000	RAW MATERIA	$17,962.824	$0.719	610	Stillage Evaporation	$0.000	RAW MATE	$3,592.565	$0.719
339	700	Product Storage & De	$1.583	Utilities			700	Product Storage & Dena	$0.513	Utilities		
340	800	Utilities & General	$0.000	Electricity/ Ener	($1,390.09)	($0.06)	800	Utilities & General	$0.000	Electricity/ E	($278.02)	($0.06)
341	810	Boiler	$10.009	Water	$51.805	$0.002	810	Boiler	$3.244	Water	$10.361	$0.002
342	820	Non-Boiler Utilities	$16.780	By-products	$172.682	$0.007	820	Non-Boiler Utilities	$5.439	By-products	$34.536	$0.007
343	830	Environmental	$2.074	VARIABLE COS	$16,797.222	$0.672	830	Environmental	$0.672	VARIABLE	$3,359.444	$0.672
344	840	Miscellaneous & Contr	$3.213	GEN & ADMIN	$1,590.000	$0.064	840	Miscellaneous & Control	$1.042	GEN & ADI	$373.529	$0.075
345	900	Enzyme Production	$1.361				900	Enzyme Production	$0.441			
346				Operators	$1,519.884	$0.061				Operators	$357.057	$0.071
347	1000	Total Fixed Capital	$66.426	Laborers	$1,000.109	$0.040	1000	Total Fixed Capital	$21.531	Laborers	$234.949	$0.047
348				Technicians	$209.882	$0.008				Technicians	$49.306	$0.010
349	1010	Contingency	$6.643	Maintenance	$800.087	$0.032	1010	Contingency	$2.153	Maintenanc	$187.960	$0.038
350	1020	Startup	$3.321	Fringe Benefits	$882.491	$0.035	1020	Startup	$1.077	Fringe Ben	$207.318	$0.041
351	1030	Working Capital	$4.982	TOTAL LABOR	$4,412.453	$0.176	1030	Working Capital	$1.615	OTAL LABO	$1,036.590	$0.207
352				Property Tax &	$1,220.583	$0.049				Property Ta	$395.629	$0.079
353		TOTAL CAPITAL	$81.372	TOTAL CASH	$24,020.258	$0.961		TOTAL CAPITAL	$26.375	TOTAL CA	$5,165.193	$1.033
354				Depreciation	$2,441.166	$0.098				Depreciatio	$791.258	$0.158
355				Interest	$0.000	$0.000				Interest	$0.000	$0.000
356												
357				TOTAL PRODU	$26,461.424	$1.058				TOTAL PR	$5,956.451	$1.191
358		Power Law Scaling Factor	0.7	PROCESS COS	$0.00	######		Power Law Scaling Factor	0.7	PROCESS	$0.00	
359		Contingency	10.00%	DMASS COST 1	$50.00	######		Contingency	10.00%	SS COST 1	$50.00	
360		Start-up factor	5.00%	DMASS COST 2	$109.00			Start-up factor	5.00%	SS COST 2	$109.00	
361		Working Capital	7.50%	urant Cost, $/gal	$0.87	$1.058		Working Capital	7.50%	Cost, $/gal	$0.87	
362		Operating Days per Year	330	Denaturant Use	5%			Operating Days per Year	330	aturant Use	5%	
363		Personnel Scaling Factor	0.9	Fringe Benefits	25%			Personnel Scaling Factor	0.9	ge Benefits	25%	

	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
324	BIOMASS COST 2						BIOMASS COST 2					
325	NREL SSF ESTIMATED BASE COSTS						NREL SSF ESTIMATED BASE COSTS					
326	Plant feedrate (dry tons per day)	820	Biomass Cost/ton-	$109.00	Ratio of orig. to proposed size-	0.43	Plant feedrate (dry tons per day)	164.05	Biomass Co	$109.00	Ratio of orig.	0.09
327	Ethanol Production (MM gal/yr)	25			Scaling of original data	0.56	Ethanol Production (MM gal/yr)	5	Scaling of ori	0.18		
328	**AREA**	**CAPITAL COSTS**	**Million $**	**PRODUCTIO N COSTS**	**Thous $/Yr**	**$/gal**	**AREA**	**CAPITAL COSTS**	**Million $**	**PRODUCTIO N COSTS**	**Thous $/Yr**	**$/gal**
329	100	Biomass Preparation	$3.609	Biomass	$29,503.972	$1.180	100	Biomass Preparation	$1.170	Biomass	$5,900.794	$1.180
330	200	Pretreatment	$11.461	Chemicals			200	Pretreatment	$3.715	Chemicals		
331	210	Recovery & Recycle	$0.000	Denaturant	$1,087.500	$0.044	210	Recovery & Recycle	$0.000	Denaturant	$217.500	$0.044
332	300	Hydrolysis	$0.000	Acid	$0.000	$0.000	300	Hydrolysis	$0.000	Acid	$0.000	$0.000
333	400	Fermentation (Unallocated)	$0.000	Ammonia	$0.000	$0.000	400	Fermentation (Unallocat	$0.000	Ammonia	$0.000	$0.000
334	410	Hexose Fermentation	$11.239	Nutrients	$0.000	$0.000	410	Hexose Fermentation	$3.643	Nutrients	$0.000	$0.000
335	420	Pentose Fermentation	$3.134	Enzymes	$0.000	$0.000	420	Pentose Fermentation	$1.016	Enzymes	$0.000	$0.000
336	500	Distillation & Dehydration	$1.963	Yeast	$0.000	$0.000	500	Distillation & Dehydratio	$0.636	Yeast	$0.000	$0.000
337	600	By-Product Preparation	$0.000	Other Chemica	$3,341.392	$0.134	600	By-Product Preparation	$0.000	Other Chemic	$668.278	$0.134
338	610	Stillage Evaporation	$0.000	RAW MATERI	$33,932.863	$1.357	610	Stillage Evaporation	$0.000	RAW MATERI	$6,786.573	$1.357
339	700	Product Storage & Denatur	$1.583	Utilities			700	Product Storage & Den	$0.513	Utilities		
340	800	Utilities & General	$0.000	Electricity/ Ene	($1,390.09)	($0.06)	800	Utilities & General	$0.000	Electricity/ Ene	($278.02)	($0.06)
341	810	Boiler	$10.009	Water	$51.805	$0.002	810	Boiler	$3.244	Water	$10.361	$0.002
342	820	Non-Boiler Utilities	$16.780	By-products	$172.682	$0.007	820	Non-Boiler Utilities	$5.439	By-products	$34.536	$0.007
343	830	Environmental	$2.074	VARIABLE CC	$32,767.262	$1.311	830	Environmental	$0.672	VARIABLE CC	$6,553.452	$1.311
344	840	Miscellaneous & Control	$3.213	GEN & ADMIN	$1,590.000	$0.064	840	Miscellaneous & Contro	$1.042	GEN & ADMIN	$373.529	$0.075
345	900	Enzyme Production	$1.361				900	Enzyme Production	$0.441			
346				Operators	$1,519.884	$0.061				Operators	$357.057	$0.071
347	1000	Total Fixed Capital	$66.426	Laborers	$1,000.109	$0.040	1000	Total Fixed Capital	$21.531	Laborers	$234.949	$0.047
348				Technicians	$209.882	$0.008				Technicians	$49.306	$0.010
349	1010	Contingency	$6.643	Maintenance	$800.087	$0.032	1010	Contingency	$2.153	Maintenance	$187.960	$0.038
350	1020	Startup	$3.321	Fringe Benefits	$882.491	$0.035	1020	Startup	$1.077	Fringe Benefit	$207.318	$0.041
351	1030	Working Capital	$4.982	TOTAL LABOR	$4,412.453	$0.176	1030	Working Capital	$1.615	TOTAL LABOR	$1,036.590	$0.207
352				Property Tax &	$1,220.583	$0.049				Property Tax &	$395.629	$0.079
353		**TOTAL CAPITAL**	$81.372	**TOTAL CASH**	$39,990.298	$1.600		**TOTAL CAPITAL**	$26.375	**TOTAL CASH**	$8,359.201	$1.672
354				Depreciation	$2,441.166	$0.098				Depreciation	$791.258	$0.158
355				Interest	$0.000	$0.000				Interest	$0.000	$0.000
356												
357				**TOTAL PROD**	$42,431.464	**$1.697**				**TOTAL PROD**	$9,150.459	**$1.830**
358		Power Law Scaling Factor	0.7	PROCESS CC	$0.00			Power Law Scaling Factor	0.7	PROCESS CC	$0.00	
359		Contingency	10.00%	MASS COST 1	$50.00			Contingency	10.00%	MASS COST 1	$50.00	
360		Start-up factor	5.00%	MASS COST 2	$109.00			Start-up factor	5.00%	MASS COST 2	$109.00	
361		Working Capital	7.50%	ant Cost, $/gal	$0.87			Working Capital	7.50%	ant Cost, $/gal	$0.87	
362		Operating Days per Year	330	enaturant Use	5%			Operating Days per Year	330	enaturant Use	5%	
363		Personnel Scaling Factor	0.9	Fringe Benefits	25%			Personnel Scaling Factor	0.9	Fringe Benefits	25%	

	AS	AT	AU	AV	AW	AX	AY
324							
325		COSTS AS PERCENTAGE OF TOTAL					
326		NREL SSF ESTIMATED BASE COSTS					
327			Ethanol Production (MM gal/yr)	57.91	Biomass Cost/ton-	$50.00	
328		AREA	CAPITAL COSTS	% of capital cost	PRODUCTION COSTS	Thous $/Yr	% of $/gallon cost
329		100	Biomass Preparation	4.4%	Biomass	1	54.0%
330		200	Pretreatment	14.1%	Chemicals	0	0.0%
331		210	Recycle & Recovery	0.0%	Denaturant	2200	3.8%
332		300	Hydrolysis	0.0%	Acid	0	0.0%
333		400	Fermentation	0.0%	Ammonia	0	0.0%
334		410	Hexose Fermentation	13.8%	Nutrients	0	0.0%
335		420	Pentose Fermentation	3.9%	Enzymes	0	0.0%
336		500	Distillation& Dehydration	2.4%	Yeast	0	0.0%
337		600	By-Product Preparation	0.0%	Other Chemicals	7740	13.3%
338		610	Stillage Evaporation	0.0%	RAW MATERIALS T	41290	71.1%
339		700	Product Storage & Denature	1.9%	Utilities	0	0.0%
340		800	Utilities & General	0.0%	Electricity/ Energy	-3220	-5.5%
341		810	Boiler	12.3%	Water	120	0.2%
342		820	Non-Boiler Utilities	20.6%	By-products	400	0.7%
343		830	Environmental	2.5%	VARIABLE COST T	38590	66.4%
344		840	Miscellaneous & Control	3.9%	GEN & ADMIN	3500	6.0%
345		900	Enzyme Production	1.7%			
346					Operators	3237	5.6%
347			Total Installed Equipment	81.6%	Laborers	2130	3.7%
348					Technicians	447	0.8%
349			Fixed Capital	81.6%	Maintenance	1704	2.9%
350		0.1	Miscellaneus	8.2%	Fringe Benefits	1880	3.2%
351		0.05	Start-up Costs	4.1%	TOTAL LABOR	9398	16.2%
352		0.075	Working capital	6.1%	Property Tax & Insur	2198	3.8%
353					TOTAL CASH	53685	92.4%
354			TOTAL CAPITAL	100.0%	Depreciation	4395	7.6%
355					Interest	0	0.0%
356							
357					TOTAL PRODUCTIO	58080	100.0%
358							
359							
360							
361							
362							
363							

	C	D	E	F	G	H
325	NREL SSI					
326	=$C$320		1900	=$C$310	=$D$312	
327	=$C$321		57.91			
328	**AREA**	**CAPITAL COSTS**	**Million $**	**PRODUCTION COSTS**	**Thous $/Yr**	**$/gal**
329	100	Biomass Preparation	=2.85*2.28	Biomass	=((E326*G326)*$D$307)/1000	=G329/(E327*1000)
330	200	Pretreatment	=2.85*7.24	Chemicals		
331	210	Recycle & Recovery	0	Denaturant	2200	=G331/(E327*1000)
332	300	Hydrolysis	0	Acid	0	=G332/(E327*1000)
333	400	Fermentation	0	Ammonia	0	=G333/(E327*1000)
334	410	Hexose Fermentation	=2.85*7.1	Nutrients	0	=G334/(E327*1000)
335	420	Pentose Fermentation	=2.85*1.98	Enzymes	0	=G335/(E327*1000)
336	500	Distillation& Dehydration	=2.85*1.24	Yeast	0	=G336/(E327*1000)
337	600	By-Product Preparation	0	Other Chemicals	7740	=G337/(E327*1000)
338	610	Stillage Evaporation	0	**RAW MATERIALS TOTAL**	=SUM(G329:G337)	=G338/(E327*1000)
339	700	Product Storage & Denature	=2.85*1	Utilities		
340	800	Utilities & General	0	Electricity/ Energy	-3220	=G340/(E327*1000)
341	810	Boiler	18.02	Water	120	=G341/(E327*1000)
342	820	Non-Boiler Utilities	=2.85*10.6	By-products	400	=G342/(E327*1000)
343	830	Environmental	=2.85*1.31	VARIABLE COST TOTAL	=SUM(G338:G342)	=G343/(E327*1000)
344	840	Miscellaneous & Control	=2.85*2.03	GEN & ADMIN	3500	=G344/(E327*1000)
345	900	Enzyme Production	=2.85*0.86			
346				Operators	3237	=G346/(E327*1000)
347		**Total Installed Equipment**	=SUM(E329:E346)	Laborers	2130	=G347/(E327*1000)
348				Technicians	447	=G348/(E327*1000)
349		Fixed Capital	=E347	Maintenance	1704	=G349/(E327*1000)
350	=D304	Miscellaneus	=E349*C350	Fringe Benefits	=N363*SUM(G346:G349)	=G350/(E327*1000)
351	=D305	Start-up Costs	=E349*C351	TOTAL LABOR	=SUM(G346:G350)	=G351/(E327*1000)
352	=D306	Working capital	=E349*C352	Property Tax & Insur.	=K364*E354*1000	=G352/(E327*1000)
353				**TOTAL CASH**	=G343+G344+G351+G352	=G353/(E327*1000)
354	sln=straight line	TOTAL CAPITAL	=SUM(E349:E353)	Depreciation	=SLN((E354*1000),($D$318*1000*E354),$D$317)	=G354/(E327*1000)
355	db=real deprecia			Interest	=E354*1000*$D$319	=G355/(E327*1000)
356						
357				**TOTAL PRODUCTION**	=G353+G354+G355	=G357/(E327*1000)

	I	J	K	L	M	N	O	P	Q	R	S	T
325	=$C325						=$C325					
326	=$C$320		=E326/E327*J327		Ratio of orig. to proposed siz	=J327/$E327	=$C$320	=K326/J327*P327	=$C$310	=S358	Ratio of orig. to proposed size-	=P327/$E327
327	=$C$321	=$D$322	Scaling of original da	=(J327/$E327)^K358	=$C$310	=N358	=$C$321	=$D$321			Scaling of original data	=(P327/$E327)^Q358
328	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
329	100	Biomass Preparation	=$E329*L327	Biomass	=K326*K362*N327/1000	=M329/(J327*1000)	100	Biomass Preparation	=$E329*T327	Biomass	=P326*Q362*R326/1000	=S329/(P327*1000)
330	200	Pretreatment	=$E330*L327	Chemicals			200	Pretreatment	=$E330*T327	Chemicals		
331	210	Recovery & Recycle	=$E331*L327	Denaturant	=J327*N361*N362*1000	=M331/(J327*1000)	210	Recovery & Recycle	=$E331*T327	Denaturant	=P327*S361*S362*1000	=S331/(P327*1000)
332	300	Hydrolysis	=$E332*L327	Acid	=$G332*N326	=M332/(J327*1000)	300	Hydrolysis	=$E332*T327	Acid	=$G332*T326	=S332/(P327*1000)
333	400	Fermentation (Unallocated)	=$E333*L327	Ammonia	=$G333*N326	=M333/(J327*1000)	400	Fermentation (Unallocated)	=$E333*T327	Ammonia	=$G333*T326	=S333/(P327*1000)
334	410	Hexose Fermentation	=$E334*L327	Nutrients	=$G334*N326	=M334/(J327*1000)	410	Hexose Fermentation	=$E334*T327	Nutrients	=$G334*T326	=S334/(P327*1000)
335	420	Pentose Fermentation	=$E335*L327	Enzymes	=$G335*N326	=M335/(J327*1000)	420	Pentose Fermentation	=$E335*T327	Enzymes	=$G335*T326	=S335/(P327*1000)
336	500	Distillation & Dehydration	=$E336*L327	Yeast	=$G336*N326	=M336/(J327*1000)	500	Distillation & Dehydration	=$E336*T327	Yeast	=$G336*T326	=S336/(P327*1000)
337	600	By-Product Preparation	=$E337*L327	Other Chemicals	=$G337*N326	=M337/(J327*1000)	600	By-Product Preparation	=$E337*T327	Other Chemicals	=$G337*T326	=S337/(P327*1000)
338	610	Stillage Evaporation	=$E338*L327	RAW MATERIALS TOTA	=SUM(M329:M337)	=M338/(J327*1000)	610	Stillage Evaporation	=$E338*T327	RAW MATERIALS TOTA	=SUM(S329:S337)	=S338/(P327*1000)
339	700	Product Storage & Denature	=$E339*L327	Utilities			700	Product Storage & Denature	=$E339*T327	Utilities		
340	800	Utilities & General	=$E340*L327	Electricity/ Energy	=$G340*N326	=M340/(J327*1000)	800	Utilities & General	=$E340*T327	Electricity/ Energy	=$G340*T326	=S340/(P327*1000)
341	810	Boiler	=$E341*L327	Water	=$G341*N326	=M341/(J327*1000)	810	Boiler	=$E341*T327	Water	=$G341*T326	=S341/(P327*1000)
342	820	Non-Boiler Utilities	=$E342*L327	By-products	=$G342*N326	=M342/(J327*1000)	820	Non-Boiler Utilities	=$E342*T327	By-products	=$G342*T326	=S342/(P327*1000)
343	830	Environmental	=$E343*L327	VARIABLE COST TOTA	=SUM(M338:M342)	=M343/(J327*1000)	830	Environmental	=$E343*T327	VARIABLE COST TOTA	=SUM(S338:S342)	=S343/(P327*1000)
344	840	Miscellaneous & Control	=$E344*L327	GEN & ADMIN	=1590*(J327/25)^K363	=M344/(J327*1000)	840	Miscellaneous & Control	=$E344*T327	GEN & ADMIN	=1590*(P327/25)^Q363	=S344/(P327*1000)
345	900	Enzyme Production	=$E345*L327				900	Enzyme Production	=$E345*T327			
346				Operators	=$G346*N326^K363	=M346/(J327*1000)				Operators	=$G346*T326^Q363	=S346/(P327*1000)
347	1000	Total Fixed Capital	=SUM(K328:K346)	Laborers	=$G347*(N326)^K363	=M347/(J327*1000)	1000	Total Fixed Capital	=SUM(Q328:Q346	Laborers	=$G347*(T326)^Q363	=S347/(P327*1000)
348				Technicians	=$G348*(N326)^K363	=M348/(J327*1000)				Technicians	=$G348*(T326)^Q363	=S348/(P327*1000)
349	1010	Contingency	=K347*K359	Maintenance	=$G349*(N326)^K363	=M349/(J327*1000)	1010	Contingency	=Q347*Q359	Maintenance	=$G349*(T326)^Q363	=S349/(P327*1000)
350	1020	Startup	=K347*K360	Fringe Benefits	=N363*SUM(M346:M349)	=M350/(J327*1000)	1020	Startup	=Q347*Q360	Fringe Benefits	=S363*SUM(S346:S349)	=S350/(P327*1000)
351	1030	Working Capital	=K347*K361	TOTAL LABOR	=SUM(M346:M350)	=M351/(J327*1000)	1030	Working Capital	=Q347*Q361	TOTAL LABOR	=SUM(S346:S350)	=S351/(P327*1000)
352				Property Tax & Insur.	=K364*K353*1000	=M352/(J327*1000)				Property Tax & Insur.	=Q364*Q353*1000	=S352/(P327*1000)
353		TOTAL CAPITAL	=SUM(K347:K352)	TOTAL CASH	=M343+M344+M351+M352	=M353/(J327*1000)		TOTAL CAPITAL	=SUM(Q347:Q352	TOTAL CASH	=S343+S344+S351+S352	=S353/(P327*1000)
354				Depreciation	=SLN((K353*1000),($D$318*	=M354/(J327*1000)				Depreciation	=SLN((Q353*1000),($D$318*1	=S354/(P327*1000)
355				Interest	=K353*1000*$D$319	=M355/(J327*1000)				Interest	=Q353*1000*$D$319	=S355/(P327*1000)
356												
357				TOTAL PRODUCTION	=M353+M354+M355	=M357/(J327*1000)				TOTAL PRODUCTION	=S353+S354+S355	=S357/(P327*1000)
358	Power Law		=$D$303	=$C$311		=$D$311		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
359	Contingenc		=$D$304	=$C$312		=$D$312		Contingency	=$D$304	=$C$312	=$D$312	
360	Start-up fa		=$D$305	=$C$313		=$D$313		Start-up factor	=$D$305	=$C$313	=$D$313	
361	Working C		=$D$306	Denaturant Cost, $/gal		=$D$314		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
362	Operating		=$D$307	Denaturant Use		=$D$315		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
363	Personnel		=$D$308	Fringe Benefits		=$D$316		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
364	Property T		=$D$309	=$C$317		=$D$317		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
324	=$C$31						=$C$3					
325	=$C$32						=$C32					
326	=$C$32	=P326/P327*V327	=$C$310	=Y359	Ratio of orig. to proposed siz	=V327/$E327	=$C$3	=V326/V327*AB327	=$C$310	=AE359	Ratio of orig. to proposed size-	=AB327/$E327
327	=$C$32	=$D$322	Scaling of original d	=(V327/$E327)^W358			=$C$3	=$D$321	Scaling of original	=(AB327/$E327)^AC		
328	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COS	Thous $/Yr	$/gal
329	100	Biomass Preparation	=$E329*X327	Biomass	=V326*W362*X326/1000	=Y329/(V327*100	100	Biomass Preparation	=$E329*AD327	Biomass	=AB326*AC362*AD326/1000	=AE329/(AB327*1000)
330	200	Pretreatment	=$E330*X327	Chemicals			200	Pretreatment	=$E330*AD327	Chemicals		
331	210	Recovery & Recycle	=$E331*X327	Denaturant	=V327*Y361*Y362*1000	=Y331/(V327*100	210	Recovery & Recycle	=$E331*AD327	Denaturant	=AB327*AE361*AE362*1000	=AE331/(AB327*1000)
332	300	Hydrolysis	=$E332*X327	Acid	=$G332*Z326	=Y332/(V327*100	300	Hydrolysis	=$E332*AD327	Acid	=$G332*AF326	=AE332/(AB327*1000)
333	400	Fermentation (Unallocated)	=$E333*X327	Ammonia	=$G333*Z326	=Y333/(V327*100	400	Fermentation (Unallocated)	=$E333*AD327	Ammonia	=$G333*AF326	=AE333/(AB327*1000)
334	410	Hexose Fermentation	=$E334*X327	Nutrients	=$G334*Z326	=Y334/(V327*100	410	Hexose Fermentation	=$E334*AD327	Nutrients	=$G334*AF326	=AE334/(AB327*1000)
335	420	Pentose Fermentation	=$E335*X327	Enzymes	=$G335*Z326	=Y335/(V327*100	420	Pentose Fermentation	=$E335*AD327	Enzymes	=$G335*AF326	=AE335/(AB327*1000)
336	500	Distillation & Dehydration	=$E336*X327	Yeast	=$G336*Z326	=Y336/(V327*100	500	Distillation & Dehydration	=$E336*AD327	Yeast	=$G336*AF326	=AE336/(AB327*1000)
337	600	By-Product Preparation	=$E337*X327	Other Chemicals	=$G337*Z326	=Y337/(V327*100	600	By-Product Preparation	=$E337*AD327	Other Chemicals	=$G337*AF326	=AE337/(AB327*1000)
338	610	Stillage Evaporation	=$E338*X327	RAW MATERIALS TOT	=SUM(Y329:Y337)	=Y338/(V327*100	610	Stillage Evaporation	=$E338*AD327	RAW MATERIALS T	=SUM(AE329:AE337)	=AE338/(AB327*1000)
339	700	Product Storage & Denature	=$E339*X327	Utilities			700	Product Storage & Denatur	=$E339*AD327	Utilities		
340	800	Utilities & General	=$E340*X327	Electricity/ Energy	=$G340*Z326	=Y340/(V327*100	800	Utilities & General	=$E340*AD327	Electricity/ Energy	=$G340*AF326	=AE340/(AB327*1000)
341	810	Boiler	=$E341*X327	Water	=$G341*Z326	=Y341/(V327*100	810	Boiler	=$E341*AD327	Water	=$G341*AF326	=AE341/(AB327*1000)
342	820	Non-Boiler Utilities	=$E342*X327	By-products	=$G342*Z326	=Y342/(V327*100	820	Non-Boiler Utilities	=$E342*AD327	By-products	=$G342*AF326	=AE342/(AB327*1000)
343	830	Environmental	=$E343*X327	VARIABLE COST TOT	=SUM(Y338:Y342)	=Y343/(V327*100	830	Environmental	=$E343*AD327	VARIABLE COST T	=SUM(AE338:AE342)	=AE343/(AB327*1000)
344	840	Miscellaneous & Control	=$E344*X327	GEN & ADMIN	=1590*(V327/25)^W363	=Y344/(V327*100	840	Miscellaneous & Control	=$E344*AD327	GEN & ADMIN	=1590*(AB327/25)^AC363	=AE344/(AB327*1000)
345	900	Enzyme Production	=$E345*X327				900	Enzyme Production	=$E345*AD327			
346				Operators	=$G346*Z326^W363	=Y346/(V327*100				Operators	=$G346*AF326^AC363	=AE346/(AB327*1000)
347	1000	Total Fixed Capital	=SUM(W328:W346	Laborers	=$G347*(Z326)^W363	=Y347/(V327*100	1000	Total Fixed Capital	=SUM(AC328:AC3	Laborers	=$G347*(AF326)^AC363	=AE347/(AB327*1000)
348				Technicians	=$G348*(Z326)^W363	=Y348/(V327*100				Technicians	=$G348*(AF326)^AC363	=AE348/(AB327*1000)
349	1010	Contingency	=W347*W359	Maintenance	=$G349*(Z326)^W363	=Y349/(V327*100	1010	Contingency	=AC347*AC359	Maintenance	=$G349*(AF326)^AC363	=AE349/(AB327*1000)
350	1020	Startup	=W347*W360	Fringe Benefits	=Y363*SUM(Y346:Y349)	=Y350/(V327*100	1020	Startup	=AC347*AC360	Fringe Benefits	=AE363*SUM(AE346:AE349)	=AE350/(AB327*1000)
351	1030	Working Capital	=W347*W361	TOTAL LABOR	=SUM(Y346:Y350)	=Y351/(V327*100	1030	Working Capital	=AC347*AC361	TOTAL LABOR	=SUM(AE346:AE350)	=AE351/(AB327*1000)
352				Property Tax & Insur.	=W364*W353*1000	=Y352/(V327*100				Property Tax & Insur	=AC364*AC353*1000	=AE352/(AB327*1000)
353		TOTAL CAPITAL	=SUM(W347:W352	TOTAL CASH	=Y343+Y344+Y351+Y352	=Y353/(V327*100		TOTAL CAPITAL	=SUM(AC347:AC3	TOTAL CASH	=AE343+AE344+AE351+AE352	=AE353/(AB327*1000)
354				Depreciation	=SLN((W353*1000),($D$318	=Y354/(V327*100				Depreciation	=SLN((AC353*1000),($D$318*1000*AC353),$D$317)	=AE354/(AB327*1000)
355				Interest	=W353*1000*$D$319	=Y355/(V327*100				Interest	=AC353*1000*$D$319	=AE355/(AB327*1000)
356												
357				TOTAL PRODUCTION	=Y353+Y354+Y355	=Y357/(V327*100				TOTAL PRODUCTI	=AE353+AE354+AE355	=AE357/(AB327*1000)
358		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	=Y338+Y340+Y34		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
359		Contingency	=$D$304	=$C$312	=$D$312	=Y338+Y340+Y34		Contingency	=$D$304	=$C$312	=$D$312	
360		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
361		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	=Z338+Z340+Z34		Working Capital	=$D$306	Denaturant Cost, $/g	=$D$314	
362		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
363		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
364		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
326	=$C$32(	=AB326/AB327*AH327	=$C$310	=AK360	Ratio of orig. to proposed size-	=AH327/$E327	=$C$32	=AH326/AH327*AN327	=$C$310	=AQ360	Ratio of orig. to proposed size-	=AN327/$E327
327	=$C$321	=$D$322			Scaling of original data	=(AH327/$E327)^AI358	=$C$32	=$D$321	Scaling of original d	=(AN327/$E327)^AO35		
328	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
329	100	Biomass Preparation	=$E329*AL327	Biomass	=AH326*AI362*AJ326/1000	=AK329/(AH327*1000)	100	Biomass Preparation	=$E329*AP327	Biomass	=AN326*AO362*AP326/1000	=AQ329/(AN327*1000)
330	200	Pretreatment	=$E330*AL327	Chemicals			200	Pretreatment	=$E330*AP327	Chemicals		
331	210	Recovery & Recycle	=$E331*AL327	Denaturant	=AH327*AK361*AK362*1000	=AK331/(AH327*1000)	210	Recovery & Recycle	=$E331*AP327	Denaturant	=AN327*AQ361*AQ362*1000	=AQ331/(AN327*1000)
332	300	Hydrolysis	=$E332*AL327	Acid	=$G332*AL326	=AK332/(AH327*1000)	300	Hydrolysis	=$E332*AP327	Acid	=$G332*AR326	=AQ332/(AN327*1000)
333	400	Fermentation (Unallocated)	=$E333*AL327	Ammonia	=$G333*AL326	=AK333/(AH327*1000)	400	Fermentation (Unallocated)	=$E333*AP327	Ammonia	=$G333*AR326	=AQ333/(AN327*1000)
334	410	Hexose Fermentation	=$E334*AL327	Nutrients	=$G334*AL326	=AK334/(AH327*1000)	410	Hexose Fermentation	=$E334*AP327	Nutrients	=$G334*AR326	=AQ334/(AN327*1000)
335	420	Pentose Fermentation	=$E335*AL327	Enzymes	=$G335*AL326	=AK335/(AH327*1000)	420	Pentose Fermentation	=$E335*AP327	Enzymes	=$G335*AR326	=AQ335/(AN327*1000)
336	500	Distillation & Dehydration	=$E336*AL327	Yeast	=$G336*AL326	=AK336/(AH327*1000)	500	Distillation & Dehydration	=$E336*AP327	Yeast	=$G336*AR326	=AQ336/(AN327*1000)
337	600	By-Product Preparation	=$E337*AL327	Other Chemicals	=$G337*AL326	=AK337/(AH327*1000)	600	By-Product Preparation	=$E337*AP327	Other Chemicals	=$G337*AR326	=AQ337/(AN327*1000)
338	610	Stillage Evaporation	=$E338*AL327	RAW MATERIALS TOT	=SUM(AK329:AK337)	=AK338/(AH327*1000)	610	Stillage Evaporation	=$E338*AP327	RAW MATERIALS TOT	=SUM(AQ329:AQ337)	=AQ338/(AN327*1000)
339	700	Product Storage & Denatu	=$E339*AL327	Utilities			700	Product Storage & Denature	=$E339*AP327	Utilities		
340	800	Utilities & General	=$E340*AL327	Electricity/ Energy	=$G340*AL326	=AK340/(AH327*1000)	800	Utilities & General	=$E340*AP327	Electricity/ Energy	=$G340*AR326	=AQ340/(AN327*1000)
341	810	Boiler	=$E341*AL327	Water	=$G341*AL326	=AK341/(AH327*1000)	810	Boiler	=$E341*AP327	Water	=$G341*AR326	=AQ341/(AN327*1000)
342	820	Non-Boiler Utilities	=$E342*AL327	By-products	=$G342*AL326	=AK342/(AH327*1000)	820	Non-Boiler Utilities	=$E342*AP327	By-products	=$G342*AR326	=AQ342/(AN327*1000)
343	830	Environmental	=$E343*AL327	VARIABLE COST TOT	=SUM(AK338:AK342)	=AK343/(AH327*1000)	830	Environmental	=$E343*AP327	VARIABLE COST TOT/	=SUM(AQ338:AQ342)	=AQ343/(AN327*1000)
344	840	Miscellaneous & Control	=$E344*AL327	GEN & ADMIN	=1590*(AH327/25)^AI363	=AK344/(AH327*1000)	840	Miscellaneous & Control	=$E344*AP327	GEN & ADMIN	=1590*(AN327/25)^AO363	=AQ344/(AN327*1000)
345	900	Enzyme Production	=$E345*AL327				900	Enzyme Production	=$E345*AP327			
346				Operators	=$G346*AL326^AI363	=AK346/(AH327*1000)				Operators	=$G346*AR326^AO363	=AQ346/(AN327*1000)
347	1000	Total Fixed Capital	=SUM(AI328:AI3	Laborers	=$G347*(AL326)^AI363	=AK347/(AH327*1000)	1000	Total Fixed Capital	=SUM(AO328:AO3	Laborers	=$G347*(AR326)^AO363	=AQ347/(AN327*1000)
348				Technicians	=$G348*(AL326)^AI363	=AK348/(AH327*1000)				Technicians	=$G348*(AR326)^AO363	=AQ348/(AN327*1000)
349	1010	Contingency	=AI347*AI359	Maintenance	=$G349*(AL326)^AI363	=AK349/(AH327*1000)	1010	Contingency	=AO347*AO359	Maintenance	=$G349*(AR326)^AO363	=AQ349/(AN327*1000)
350	1020	Startup	=AI347*AI360	Fringe Benefits	=AK363*SUM(AK346:AK349)	=AK350/(AH327*1000)	1020	Startup	=AO347*AO360	Fringe Benefits	=AQ363*SUM(AQ346:AQ349)	=AQ350/(AN327*1000)
351	1030	Working Capital	=AI347*AI361	TOTAL LABOR	=SUM(AK346:AK350)	=AK351/(AH327*1000)	1030	Working Capital	=AO347*AO361	TOTAL LABOR	=SUM(AQ346:AQ350)	=AQ351/(AN327*1000)
352				Property Tax & Insur.	=AI364*AI353*1000	=AK352/(AH327*1000)				Property Tax & Insur.	=AO364*AO353*1000	=AQ352/(AN327*1000)
353		TOTAL CAPITAL	=SUM(AI347:AI3	TOTAL CASH	=AK343+AK344+AK351+AK352	=AK353/(AH327*1000)		TOTAL CAPITAL	=SUM(AO347:AO3	TOTAL CASH	=AQ343+AQ344+AQ351+AQ3	=AQ353/(AN327*1000)
354				Depreciation	=SLN((AI353*1000),($D$318*10	=AK354/(AH327*1000)				Depreciation	=SLN((AO353*1000),($D$318*	=AQ354/(AN327*1000)
355				Interest	=AI353*1000*$D$319	=AK355/(AH327*1000)				Interest	=AO353*1000*$D$319	=AQ355/(AN327*1000)
356												
357				TOTAL PRODUCTION	=AK353+AK354+AK355	=AK357/(AH327*1000)				TOTAL PRODUCTION	=AQ353+AQ354+AQ355	=AQ357/(AN327*1000)
358		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
359		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
360		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
361		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
362		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
363		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
364		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	AT	AU	AV	AW	AX	AY
325	COSTS AS PERCENTAGE OF TOTAL					
326	NREL SSF ESTIMATED BASE COSTS					
327		Ethanol Production (MM gal/yr)	57.91	Biomass Cost/ton-	$50.00	
328	AREA	CAPITAL COSTS	% of capital cost	PRODUCTION COSTS	Thous $/Yr	% of $/gallon cost
329	100	Biomass Preparation	4.4%	Biomass	1	54.0%
330	200	Pretreatment	14.1%	Chemicals	0	0.0%
331	210	Recycle & Recovery	0.0%	Denaturant	2200	3.8%
332	300	Hydrolysis	0.0%	Acid	0	0.0%
333	400	Fermentation	0.0%	Ammonia	0	0.0%
334	410	Hexose Fermentation	13.8%	Nutrients	0	0.0%
335	420	Pentose Fermentation	3.9%	Enzymes	0	0.0%
336	500	Distillation& Dehydration	2.4%	Yeast	0	0.0%
337	600	By-Product Preparation	0.0%	Other Chemicals	7740	13.3%
338	610	Stillage Evaporation	0.0%	RAW MATERIALS T	41290	71.1%
339	700	Product Storage & Denature	1.9%	Utilities	0	0.0%
340	800	Utilities & General	0.0%	Electricity/ Energy	-3220	-5.5%
341	810	Boiler	12.3%	Water	120	0.2%
342	820	Non-Boiler Utilities	20.6%	By-products	400	0.7%
343	830	Environmental	2.5%	VARIABLE COST T	38590	66.4%
344	840	Miscellaneous & Control	3.9%	GEN & ADMIN	3500	6.0%
345	900	Enzyme Production	1.7%			
346				Operators	3237	5.6%
347		Total Installed Equipment	81.6%	Laborers	2130	3.7%
348				Technicians	447	0.8%
349		Fixed Capital	81.6%	Maintenance	1704	2.9%
350	0.1	Miscellaneus	8.2%	Fringe Benefits	1880	3.2%
351	0.05	Start-up Costs	4.1%	TOTAL LABOR	9398	16.2%
352	0.075	Working capital	6.1%	Property Tax & Insu	2198	3.8%
353				TOTAL CASH	53685	92.4%
354		TOTAL CAPITAL	100.0%	Depreciation	4395	7.6%
355				Interest	0	0.0%
356						
357				TOTAL PRODUCTI	58080	100.0%
358						

	I	J	K	L	M	N
365		PROCESS COST ONLY (BIOMASS $0)				
366		TVA ACID ESTIMATED BASE COSTS				
367	952	Plant feedrate (dry tons per day)		$0.00	Ratio of o	1.00
368	25	Ethanol Production (MM gal/yr)		1.00		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	1000$/Yr	$/gal
370	100	Biomass Preparation	$0.440	Biomass	0	$0.000
371	200	Pretreatment	$0.000	Chemicals		
372	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
373	300	Hydrolysis	$21.450	Acid	5,188	$0.208
374	400	Fermentation (Unallocated	$19.210	Ammonia	0	$0.000
375	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
376	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
377	500	Distillation & Dehydration	$12.820	Yeast	317	$0.013
378	600	By-Product Preparation	$0.000	Other Chemicals	3,099	$0.124
379	610	Stillage Evaporation	$2.970	RAW MATERIALS TOT	9,691	$0.388
380	700	Product Storage & Denatu	$1.634	Utilities		
381	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
382	810	Boiler	$13.400	Water	0	$0.000
383	820	Non-Boiler Utilities	$9.151	By-products	8,326	$0.333
384	830	Environmental	$0.000	VARIABLE COST TOT	18,017	$0.721
385	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
386	900	Enzyme Production	$0.000			
387				Operators	1,520	$0.061
388	1000	Total Fixed Capital	$81.075	Laborers	1,000	$0.040
389				Technicians	210	$0.008
390	1010	Contingency	$8.108	Maintenance	800	$0.032
391	1020	Startup	$4.054	Fringe Benefits	883	$0.035
392	1030	Working Capital	$6.081	TOTAL LABOR	4,413	$0.177
393				Property Tax & Insur.	1,490	$0.060
394		TOTAL CAPITAL	$99.317	TOTAL CASH	25,509	$1.020
395				Depreciation	2,980	$0.119
396				Interest	0	$0.000
397						
398				TOTAL PRODUCTION	28,489	$1.140
399		Power Law Scaling Factor	0.7	PROCESS COST ONL	$0.00	
400		Contingency	10.00%	BIOMASS COST 1	$50.00	
401		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
402		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
403		Operating Days per Year	330	Denaturant Use	5%	
404		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
405		Property Tax & Insurance	1.50%	epreciation period (yrs)	30	
406		PROCESS COST ONLY (BIOMASS $0)				
407	AFEX AMMONIA ESTIMATED BASE COSTS			Ratio of orig. to propos	1.00	
408		Plant feedrate (dry tons pe	863	Biomass Cost/ton-	$0.00	
409		Ethanol Production (MM g	25	Scaling of original data	1.00	
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
411	100	Biomass Preparation	$0.651	Biomass	0	$0.000
412	200	Pretreatment	$19.239	Chemicals		
413	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
414	300	Hydrolysis	$12.711	Acid	0	$0.000
415	400	Fermentation (Unallocated	$19.216	Ammonia	192	$0.008
416	410	Hexose Fermentation	$0.000	Nutrients	311	$0.012
417	420	Pentose Fermentation	$0.000	Enzymes	640	$0.026
418	500	Distillation & Dehydration	$12.687	Yeast	317	$0.013
419	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
420	610	Stillage Evaporation	$3.034	RAW MATERIALS TOT	2,577	$0.103
421	700	Product Storage & Denatu	$1.634	Utilities		
422	800	Utilities & General	$0.000	Electricity/ Energy	781	$0.031
423	810	Boiler	$12.337	Water	0	$0.000
424	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
425	830	Environmental	$0.000	VARIABLE COST TOT	3,358	$0.134
426	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
427	900	Enzyme Production	$10.888			
428				Operators	1,520	$0.061
429	1000	Total Fixed Capital	$101.548	Laborers	1,000	$0.040
430				Technicians	210	$0.008
431	1010	Contingency	$10.155	Maintenance	800	$0.032
432	1020	Startup	$5.077	Fringe Benefits	883	$0.035
433	1030	Working Capital	$7.616	TOTAL LABOR	4,413	$0.177
434				Property Tax & Insur.	1,866	$0.075
435		TOTAL CAPITAL	$124.396	TOTAL CASH	11,226	$0.449
436				Depreciation	3,732	$0.149
437				Interest	0	$0.000
438						
439				TOTAL PRODUCTION	14,958	$0.598
440		Power Law Scaling Factor	0.7	PROCESS COST ONL	$0.00	
441		Contingency	10.00%	BIOMASS COST 1	$50.00	
442		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
443		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
444		Operating Days per Year	330	Denaturant Use	5%	
445		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
446		Property Tax & Insurance	1.50%	epreciation period (yrs)	30	

	O	P	Q	R	S	T
365		PROCESS COST ONLY (BIOMASS $0)				
366		TVA ACID ESTIMATED BASE COSTS				
367	Plant	190.4	Biomass	$0.00	Ratio of ori	0.20
368	Ethan	5	Scaling of	0.32		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	$0.143	Biomass	0	$0.000
371	200	Pretreatment	$0.000	Chemicals		
372	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
373	300	Hydrolysis	$6.953	Acid	1,034	$0.208
374	400	Fermentation (Unalloc	$6.227	Ammonia	0	$0.000
375	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
376	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
377	500	Distillation & Dehydra	$4.155	Yeast	63	$0.013
378	600	By-Product Preparatio	$0.000	Other Chemicals	620	$0.124
379	610	Stillage Evaporation	$0.963	RAW MATERIALS TOTAL	1,936	$0.388
380	700	Product Storage & De	$0.530	Utilities		
381	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
382	810	Boiler	$4.343	Water	0	$0.000
383	820	Non-Boiler Utilities	$2.966	By-products	1,666	$0.333
384	830	Environmental	$0.000	VARIABLE COST TOTAL	3,603	$0.721
385	840	Miscellaneous & Cont	$0.000	GEN & ADMIN	374	$0.075
386	900	Enzyme Production	$0.000			
387				Operators	357	$0.071
388	1000	Total Fixed Capital	$26.279	Laborers	235	$0.047
389				Technicians	49	$0.010
390	1010	Contingency	$2.628	Maintenance	188	$0.038
391	1020	Startup	$1.314	Fringe Benefits	207	$0.041
392	1030	Working Capital	$1.971	TOTAL LABOR	1,037	$0.207
393				Property Tax & Insur.	483	$0.097
394		TOTAL CAPITAL	$32.192	TOTAL CASH	5,496	$1.099
395				Depreciation	966	$0.193
396				Return on Investment	0	$0.000
397						
398				TOTAL PRODUCTION	6,462	$1.292
399		Power Law Scaling Factor	0.7	PROCESS COST ONLY (	$0.00	
400		Contingency	10.00%	BIOMASS COST 1	$50.00	
401		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
402		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
403		Operating Days per Year	330	Denaturant Use	5%	
404		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
405		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
406		PROCESS COST ONLY (BIOMASS $0)				
407		AFEX AMMONIA ESTIMATED BASE COSTS				
408	Plant	172.6	Biomass	$0.00	Ratio of ori	0.20
409	Ethan	5	Scaling of	0.32		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	$0.211	Biomass	0	$0.000
412	200	Pretreatment	$6.236	Chemicals		
413	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
414	300	Hydrolysis	$4.120	Acid	0	$0.000
415	400	Fermentation (Unalloc	$6.229	Ammonia	38	$0.008
416	410	Hexose Fermentation	$0.000	Nutrients	62	$0.012
417	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
418	500	Distillation & Dehydra	$4.112	Yeast	63	$0.013
419	600	By-Product Preparatio	$0.000	Other Chemicals	6	$0.001
420	610	Stillage Evaporation	$0.983	RAW MATERIALS TOTA	515	$0.103
421	700	Product Storage & De	$0.530	Utilities		
422	800	Utilities & General	$0.000	Electricity/ Energy	156	$0.031
423	810	Boiler	$3.999	Water	0	$0.000
424	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
425	830	Environmental	$0.000	VARIABLE COST TOTAL	672	$0.134
426	840	Miscellaneous & Cont	$0.000	GEN & ADMIN	374	$0.075
427	900	Enzyme Production	$3.529			
428				Operators	357	$0.071
429	1000	Total Fixed Capital	$32.915	Laborers	235	$0.047
430				Technicians	49	$0.010
431	1010	Contingency	$3.291	Maintenance	188	$0.038
432	1020	Startup	$1.646	Fringe Benefits	207	$0.041
433	1030	Working Capital	$2.469	TOTAL LABOR	1,037	$0.207
434				Property Tax & Insur.	605	$0.121
435		TOTAL CAPITAL	$40.321	TOTAL CASH	2,687	$0.537
436				Depreciation	1,210	$0.242
437				Interest	0	$0.000
438						
439				TOTAL PRODUCTION	3,896	$0.779
440		Power Law Scaling Factor	0.7	PROCESS COST ONLY (	$0.00	
441		Contingency	10.00%	BIOMASS COST 1	$50.00	
442		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
443		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
444		Operating Days per Year	330	Denaturant Use	5%	
445		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
446		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	U	V	W	X	Y	Z
365		BIOMASS COST 1				
366		TVA ACID ESTIMATED BASE COSTS				
367	Plant fe	952	Biomass C	$50.00	Ratio of orig	1.00
368	Ethano	25	Scaling of c	1.00		
369	AREA	APITAL COST	Million $	RODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Prep	$0.440	Biomass	15,708	$0.628
371	200	Pretreatment	$0.000	Chemicals		
372	210	Recovery & R	$0.000	Denaturant	1,088	$0.044
373	300	Hydrolysis	$21.450	Acid	5,188	$0.208
374	400	Fermentation (	$19.210	Ammonia	0	$0.000
375	410	Hexose Ferme	$0.000	Nutrients	0	$0.000
376	420	Pentose Ferm	$0.000	Enzymes	0	$0.000
377	500	Distillation & D	$12.820	Yeast	317	$0.013
378	600	By-Product Pr	$0.000	Other Chemicals	3,099	$0.124
379	610	Stillage Evapo	$2.970	RAW MATERIALS T	25,399	$1.016
380	700	Product Storag	$1.634	Utilities		
381	800	Utilities & Gen	$0.000	Electricity/ Energy	0	$0.000
382	810	Boiler	$13.400	Water	0	$0.000
383	820	Non-Boiler Uti	$9.151	By-products	8,326	$0.333
384	830	Environmental	$0.000	VARIABLE COST TO	33,725	$1.349
385	840	Miscellaneous	$0.000	GEN & ADMIN	1,590	$0.064
386	900	Enzyme Produ	$0.000			
387				Operators	1,520	$0.061
388	1000	Total Fixed Ca	$81.075	Laborers	1,000	$0.040
389				Technicians	210	$0.008
390	1010	Contingency	$8.108	Maintenance	800	$0.032
391	1020	Startup	$4.054	Fringe Benefits	883	$0.035
392	1030	Working Capit	$6.081	TOTAL LABOR	4,413	$0.177
393				Property Tax & Insur.	1,490	$0.060
394		TOTAL CAPIT	$99.317	TOTAL CASH	41,217	$1.649
395				Depreciation	2,980	$0.119
396				Return on Investmen	0	$0.000
397						
398				TOTAL PRODUCTIO	44,197	$1.768
399		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
400		Contingency	10.00%	BIOMASS COST 1	$50.00	
401		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
402		Working Capital	7.50%	enaturant Cost, $/gal	$0.87	
403		Operating Days per Year	330	Denaturant Use	5%	
404		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
405		Property Tax & Insurance	1.50%	preciation period (yrs)	30	
406		BIOMASS COST 1				
407		AFEX AMMONIA ESTIMATED BASE COSTS				
408	Plant fe	863	Biomass C	$50.00	Ratio of ori	1.00
409	Ethano	25	Scaling of c	1.00		
410	AREA	APITAL COST	Million $	RODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Prep	$0.651	Biomass	14,240	$0.570
412	200	Pretreatment	$19.239	Chemicals		
413	210	Recovery & R	$0.000	Denaturant	1,088	$0.044
414	300	Hydrolysis	$12.711	Acid	0	$0.000
415	400	Fermentation (	$19.216	Ammonia	192	$0.008
416	410	Hexose Ferme	$0.000	Nutrients	311	$0.012
417	420	Pentose Ferm	$0.000	Enzymes	640	$0.026
418	500	Distillation & D	$12.687	Yeast	317	$0.013
419	600	By-Product Pr	$0.000	Other Chemicals	30	$0.001
420	610	Stillage Evapo	$3.034	RAW MATERIALS T	16,817	$0.673
421	700	Product Storag	$1.634	Utilities		
422	800	Utilities & Gen	$0.000	Electricity/ Energy	781	$0.031
423	810	Boiler	$12.337	Water	0	$0.000
424	820	Non-Boiler Util	$9.151	By-products	0	$0.000
425	830	Environmental	$0.000	VARIABLE COST TO	17,597	$0.704
426	840	Miscellaneous	$0.000	GEN & ADMIN	1,590	$0.064
427	900	Enzyme Produ	$10.868			
428				Operators	1,520	$0.061
429	1000	Total Fixed Ca	$101.548	Laborers	1,000	$0.040
430				Technicians	210	$0.008
431	1010	Contingency	$10.165	Maintenance	800	$0.032
432	1020	Startup	$5.077	Fringe Benefits	883	$0.035
433	1030	Working Capit	$7.616	TOTAL LABOR	4,413	$0.177
434				Property Tax & Insur.	1,866	$0.075
435		TOTAL CAPIT	$124.396	TOTAL CASH	25,466	$1.019
436				Depreciation	3,732	$0.149
437				Interest	0	$0.000
438						
439				TOTAL PRODUCTIO	29,198	$1.168
440		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
441		Contingency	10.00%	BIOMASS COST 1	$50.00	
442		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
443		Working Capital	7.50%	enaturant Cost, $/gal	$0.87	
444		Operating Days per Year	330	Denaturant Use	5%	
445		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
446		Property Tax & Insurance	1.50%	preciation period (yrs)	30	

	AA	AB	AC	AD	AE	AF
365		BIOMASS COST 1				
366		TVA ACID ESTIMATED BASE COSTS				
367	Plan	190.4	Biomass C	$50.00	Ratio of orig.	0.20
368	Eth	5	Scaling of	0.32		
369	RE	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	$0.143	Biomass	3,142	$0.628
371	200	Pretreatment	$0.000	Chemicals		
372	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
373	300	Hydrolysis	$6.953	Acid	1,034	$0.208
374	400	Fermentation (Unallocated)	$6.227	Ammonia	0	$0.000
375	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
376	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
377	500	Distillation & Dehydration	$4.155	Yeast	63	$0.013
378	600	By-Product Preparation	$0.000	Other Chemicals	620	$0.124
379	610	Stillage Evaporation	$0.963	RAW MATERIALS TOTA	5,080	$1.016
380	700	Product Storage & Denatu	$0.530	Utilities		
381	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
382	810	Boiler	$4.343	Water	0	$0.000
383	820	Non-Boiler Utilities	$2.966	By-products	1,665	$0.333
384	830	Environmental	$0.000	VARIABLE COST TOTA	6,745	$1.349
385	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
386	900	Enzyme Production	$0.000			
387				Operators	357	$0.071
388	###	Total Fixed Capital	$26.279	Laborers	235	$0.047
389				Technicians	49	$0.010
390	###	Contingency	$2.628	Maintenance	188	$0.038
391	###	Startup	$1.314	Fringe Benefits	207	$0.041
392	###	Working Capital	$1.971	TOTAL LABOR	1,037	$0.207
393				Property Tax & Insur.	483	$0.097
394		TOTAL CAPITAL	$32.192	TOTAL CASH	8,638	$1.728
395				Depreciation	966	$0.193
396				Return on Investment	0	$0.000
397						
398				TOTAL PRODUCTION	9,604	$1.921
399		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
400		Contingency	10.00%	BIOMASS COST 1	$50.00	
401		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
402		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
403		Operating Days per Year	330	Denaturant Use	5%	
404		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
405		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
406		BIOMASS COST 1				
407		AFEX AMMONIA ESTIMATED BASE COSTS				
408	Plan	172.6	Biomass C	$50.00	Ratio of orig.	0.20
409	Eth	5	Scaling of	0.32		
410	RE	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	$0.211	Biomass	2,848	$0.570
412	200	Pretreatment	$6.236	Chemicals		
413	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
414	300	Hydrolysis	$4.120	Acid	0	$0.000
415	400	Fermentation (Unallocated)	$6.229	Ammonia	38	$0.008
416	410	Hexose Fermentation	$0.000	Nutrients	62	$0.012
417	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
418	500	Distillation & Dehydration	$4.112	Yeast	63	$0.013
419	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
420	610	Stillage Evaporation	$0.983	RAW MATERIALS TOTA	3,363	$0.673
421	700	Product Storage & Denatu	$0.530	Utilities		
422	800	Utilities & General	$0.000	Electricity/ Energy	156	$0.031
423	810	Boiler	$3.999	Water	0	$0.000
424	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
425	830	Environmental	$0.000	VARIABLE COST TOTAL	3,519	$0.704
426	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
427	900	Enzyme Production	$3.529			
428				Operators	357	$0.071
429	###	Total Fixed Capital	$32.916	Laborers	235	$0.047
430				Technicians	49	$0.010
431	###	Contingency	$3.291	Maintenance	188	$0.038
432	###	Startup	$1.646	Fringe Benefits	207	$0.041
433	###	Working Capital	$2.469	TOTAL LABOR	1,037	$0.207
434				Property Tax & Insur.	605	$0.121
435		TOTAL CAPITAL	$40.321	TOTAL CASH	5,534	$1.107
436				Depreciation	1,210	$0.242
437				Interest	0	$0.000
438						
439				TOTAL PRODUCTION	6,744	$1.349
440		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
441		Contingency	10.00%	BIOMASS COST 1	$50.00	
442		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
443		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
444		Operating Days per Year	330	Denaturant Use	5%	
445		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
446		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AG	AH	AI	AJ	AK	AL
365	BIOMASS COST 2					
366	TVA ACID ESTIMATED BASE COSTS					
367	Plant	952	Biomass C	$109.00	Ratio of orig.	1.00
368	Ethan	25	Scaling of o	1.00		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	$0.440	Biomass	34,243	$1.370
371	200	Pretreatment	$0.000	Chemicals		
372	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
373	300	Hydrolysis	$21.450	Acid	5,188	$0.208
374	400	Fermentation (Unallocated)	$19.210	Ammonia	0	$0.000
375	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
376	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
377	500	Distillation & Dehydration	$12.820	Yeast	317	$0.013
378	600	By Product Preparation	$0.000	Other Chemicals	3,099	$0.124
379	610	Stillage Evaporation	$2.970	RAW MATERIALS TOTAL	43,934	$1.757
380	700	Product Storage & Denature	$1.634	Utilities		
381	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
382	810	Boiler	$13.400	Water	0	$0.000
383	820	Non-Boiler Utilities	$9.151	By-products	8,326	$0.333
384	830	Environmental	$0.000	VARIABLE COST TOTAL	52,260	$2.090
385	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
386	900	Enzyme Production	$0.000			
387				Operators	1,520	$0.061
388	1000	Total Fixed Capital	$81.075	Laborers	1,000	$0.040
389				Technicians	210	$0.008
390	1010	Contingency	$8.108	Maintenance	800	$0.032
391	1020	Startup	$4.054	Fringe Benefits	883	$0.035
392	1030	Working Capital	$6.081	TOTAL LABOR	4,413	$0.177
393				Property Tax & Insur.	1,490	$0.060
394		TOTAL CAPITAL	$99.317	TOTAL CASH	59,753	$2.390
395				Depreciation	2,980	$0.119
396				Return on Investment	0	$0.000
397						
398				TOTAL PRODUCTION	62,732	$2.509
399		Power Law Scaling Factor	0.7	PROCESS COST ONLY (	$0.00	
400		Contingency	10.00%	BIOMASS COST 1	$50.00	
401		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
402		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
403		Operating Days per Year	330	Denaturant Use	5%	
404		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
405		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
406	BIOMASS COST 2					
407	AFEX AMMONIA ESTIMATED BASE COSTS					
408	Plant	863	Biomass C	$109.00	Ratio of orig.	1.00
409	Ethan	25	Scaling of o	1.00		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	$0.651	Biomass	31,042	$1.242
412	200	Pretreatment	$19.239	Chemicals		
413	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
414	300	Hydrolysis	$12.711	Acid	0	$0.000
415	400	Fermentation (Unallocated)	$19.216	Ammonia	192	$0.008
416	410	Hexose Fermentation	$0.000	Nutrients	311	$0.012
417	420	Pentose Fermentation	$0.000	Enzymes	640	$0.026
418	500	Distillation & Dehydration	$12.687	Yeast	317	$0.013
419	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
420	610	Stillage Evaporation	$3.034	RAW MATERIALS TOTAL	33,619	$1.345
421	700	Product Storage & Denature	$1.634	Utilities		
422	800	Utilities & General	$0.000	Electricity/ Energy	781	$0.031
423	810	Boiler	$12.337	Water	0	$0.000
424	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
425	830	Environmental	$0.000	VARIABLE COST TOTAL	34,400	$1.376
426	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
427	900	Enzyme Production	$10.888			
428				Operators	1,520	$0.061
429	1000	Total Fixed Capital	$101.548	Laborers	1,000	$0.040
430				Technicians	210	$0.008
431	1010	Contingency	$10.155	Maintenance	800	$0.032
432	1020	Startup	$5.077	Fringe Benefits	883	$0.035
433	1030	Working Capital	$7.616	TOTAL LABOR	4,413	$0.177
434				Property Tax & Insur.	1,866	$0.075
435		TOTAL CAPITAL	$124.396	TOTAL CASH	42,268	$1.691
436				Depreciation	3,732	$0.149
437				Interest	0	$0.000
438						
439				TOTAL PRODUCTION	46,000	$1.840
440		Power Law Scaling Factor	0.7	PROCESS COST ONLY (	$0.00	
441		Contingency	10.00%	BIOMASS COST 1	$50.00	
442		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
443		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
444		Operating Days per Year	330	Denaturant Use	5%	
445		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
446		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AM	AN	AO	AP	AQ	AR
365	BIOMASS COST 2					
366	TVA ACID ESTIMATED BASE COSTS					
367	Plant fee	190.4	Biomass C	$109.00	Ratio of orig.	0.20
368	Ethanol	5	Scaling of	0.32		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	$0.143	Biomass	6,849	$1.370
371	200	Pretreatment	$0.000	Chemicals		
372	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
373	300	Hydrolysis	$6.963	Acid	1,038	$0.208
374	400	Fermentation (Unallocated)	$6.227	Ammonia	0	$0.000
375	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
376	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
377	500	Distillation & Dehydration	$4.155	Yeast	63	$0.013
378	600	By-Product Preparation	$0.000	Other Chemicals	620	$0.124
379	610	Stillage Evaporation	$0.963	RAW MATERIALS TOTAL	8,787	$1.757
380	700	Product Storage & Denature	$0.530	Utilities		
381	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
382	810	Boiler	$4.343	Water	0	$0.000
383	820	Non-Boiler Utilities	$2.966	By-products	1,665	$0.333
384	830	Environmental	$0.000	VARIABLE COST TOTAL	10,452	$2.090
385	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
386	900	Enzyme Production	$0.000			
387				Operators	357	$0.071
388	1000	Total Fixed Capital	$26.279	Laborers	235	$0.047
389				Technicians	49	$0.010
390	1010	Contingency	$2.628	Maintenance	188	$0.038
391	1020	Startup	$1.314	Fringe Benefits	207	$0.041
392	1030	Working Capital	$1.971	TOTAL LABOR	1,037	$0.207
393				Property Tax & Insur.	483	$0.097
394		TOTAL CAPITAL	$32.192	TOTAL CASH	12,345	$2.469
395				Depreciation	966	$0.193
396				Return on Investment	0	$0.000
397						
398				TOTAL PRODUCTION	13,311	$2.662
399		Power Law Scaling Factor	0.7	PROCESS COST ONLY (	$0.00	
400		Contingency	10.00%	BIOMASS COST 1	$50.00	
401		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
402		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
403		Operating Days per Year	330	Denaturant Use	5%	
404		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
405		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
406	BIOMASS COST 2					
407	AFEX AMMONIA ESTIMATED BASE COSTS					
408	Plant fee	172.6	Biomass C	$109.00	Ratio of orig.	0.20
409	Ethanol	5	Scaling of	0.32		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	$0.211	Biomass	6,208	$1.242
412	200	Pretreatment	$6.236	Chemicals		
413	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
414	300	Hydrolysis	$4.120	Acid	0	$0.000
415	400	Fermentation (Unallocated)	$6.229	Ammonia	38	$0.008
416	410	Hexose Fermentation	$0.000	Nutrients	62	$0.012
417	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
418	500	Distillation & Dehydration	$4.112	Yeast	63	$0.013
419	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
420	610	Stillage Evaporation	$0.983	RAW MATERIALS TOTAL	6,724	$1.345
421	700	Product Storage & Denature	$0.530	Utilities		
422	800	Utilities & General	$0.000	Electricity/ Energy	156	$0.031
423	810	Boiler	$3.999	Water	0	$0.000
424	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
425	830	Environmental	$0.000	VARIABLE COST TOTAL	6,880	$1.376
426	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
427	900	Enzyme Production	$3.529			
428				Operators	357	$0.071
429	1000	Total Fixed Capital	$32.915	Laborers	235	$0.047
430				Technicians	49	$0.010
431	1010	Contingency	$3.291	Maintenance	188	$0.038
432	1020	Startup	$1.646	Fringe Benefits	207	$0.041
433	1030	Working Capital	$2.469	TOTAL LABOR	1,037	$0.207
434				Property Tax & Insur.	605	$0.121
435		TOTAL CAPITAL	$40.321	TOTAL CASH	8,895	$1.779
436				Depreciation	1,210	$0.242
437				Interest	0	$0.000
438						
439				TOTAL PRODUCTION	10,105	$2.021
440		Power Law Scaling Factor	0.7	PROCESS COST ONLY (	$0.00	
441		Contingency	10.00%	BIOMASS COST 1	$50.00	
442		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
443		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
444		Operating Days per Year	330	Denaturant Use	5%	
445		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
446		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AS	AT	AU	AV	AW	AX	AY
365							
366		COSTS AS PERCENTAGE OF TOTAL					
367		TVA ACID ESTIMATED BASE COSTS					
368			Ethanol Production (MM gal/yr)	25	Biomass Cost/ton	$50.00	
369		AREA	CAPITAL COSTS	% of capital cos	RODUCTION COST	Thous $/Yr	of $/gallon co
370		100	Biomass Preparation	0.4%	Biomass	0	25.5%
371		200	Pretreatment	0.0%	Chemicals	0	0.0%
372		210	Recycle & Recovery	0.0%	Denaturant	86	0.2%
373		300	Hydrolysis	21.6%	Acid	5188	14.1%
374		400	Fermentation	19.3%	Ammonia	0	0.0%
375		410	Hexose Fermentation	0.0%	Nutrients	0	0.0%
376		420	Pentose Fermentation	0.0%	Enzymes	0	0.0%
377		500	Distillation & Dehydration	12.9%	Yeast	317	0.9%
378		600	By-Product Preparation	0.0%	Other Chemicals (Li	3099	8.4%
379		610	Stillage Evaporation	3.0%	RAW MATERIALS T	18110	49.1%
380		700	Product Storage & Denature	1.6%	Utilities	0	0.0%
381		800	Utilities & General	0.0%	Electricity/ Energy	0	0.0%
382		810	Boiler	13.5%	Water	0	0.0%
383		820	Non-Boiler Utilities	9.2%	By-products (Dispos	8326	22.6%
384		830	Environmental	0.0%	VARIABLE COST T	26436	71.6%
385		840	Miscellaneous & Control	0.0%	GEN & ADMIN	1590	4.3%
386		900	Enzyme Production	0.0%			
387					Operators	1520	4.1%
388			Total Installed Equipment	81.6%	Laborers	1000	2.7%
389					Technicians	210	0.6%
390			Fixed Capital	81.6%	Maintenance	800	2.2%
391		0.1	Miscellaneous	8.2%	Fringe Benefits	883	2.4%
392		0.05	Start-up Costs	4.1%	TOTAL LABOR	4413	12.0%
393		0.075	Working capital	6.1%	Property Tax & Insur	1490	4.0%
394					TOTAL CASH	33928	91.9%
395			TOTAL CAPITAL	100.0%	Depreciation	2980	8.1%
396					Interest	0	0.0%
397							
398					TOTAL PRODUCTI	36908	100.0%
399							
400							
401							
402							
403							
404							
405							
406							
407		COSTS AS PERCENTAGE OF TOTAL					
408		AFEX AMMONIA ESTIMATED BASE COSTS					
409			Ethanol Production (MM gal/yr)	25	Biomass Cost/ton	$50.00	
410		AREA	CAPITAL COSTS	% of capital co	RODUCTION COST	Thous $/Yr	of $/gallon co
411		100	Biomass Preparation	0.6%	Biomass	0	38.0%
412		200	Pretreatment	15.5%	Chemicals	0	0.0%
413		210	Recycle & Recovery	0.0%	Denaturant	86	0.4%
414		300	Hydrolysis	10.2%	Acid	0	0.0%
415		400	Fermentation	15.4%	Ammonia	192	0.9%
416		410	Hexose Fermentation	0.0%	Nutrients	311	1.4%
417		420	Pentose Fermentation	0.0%	Enzymes	640	2.8%
418		500	Distillation & Dehydration	10.2%	Yeast	317	1.4%
419		600	By-Product Preparation	0.0%	Other Chemicals	30	0.1%
420		610	Stillage Evaporation	2.4%	RAW MATERIALS T	10122	45.0%
421		700	Product Storage & Denature	1.3%	Utilities	0	0.0%
422		800	Utilities & General	0.0%	Electricity/ Energy	781	3.5%
423		810	Boiler	9.9%	Water	0	0.0%
424		820	Non-Boiler Utilities	7.4%	By-products	0	0.0%
425		830	Environmental	0.0%	VARIABLE COST T	10903	48.4%
426		840	Miscellaneous & Control	0.0%	GEN & ADMIN	1590	7.1%
427		900	Enzyme Production	8.8%			
428					Operators	1520	6.8%
429			Total Installed Equipmnt	81.6%	Laborers	1000	4.4%
430					Technicians	210	0.9%
431			Fixed Capital	81.6%	Maintenance	800	3.6%
432		0.1	Miscellaneous	8.2%	Fringe Benefits	883	3.9%
433		0.06	Start-up Costs	4.1%	TOTAL LABOR	4413	19.6%
434		0.075	Working capital	6.1%	Property Tax & Insur	1866	8.3%
435					TOTAL CASH	18771	83.4%
436			TOTAL CAPITAL	100.0%	Depreciation	3732	16.6%
437					Interest	0	0.0%
438							
439					TOTAL PRODUCTI	22503	100.0%
440							
441							
442							
443							
444							
445							
446							

	I	J	K	L	M	N
366	=$C366					
367	=D367/D	=$C$320		=M399	Ratio of orig. to prop	=I368/$D368
368	=$D$322	=$C$321		=(I368/$D368)^K399		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	1000$/Yr	$/gal
370	100	Biomass Preparation	=$E370*L368	Biomass	=I367*K403*L367/1	=M370/(I368*1000)
371	200	Pretreatment	=$E371*L368	Chemicals		
372	210	Recovery & Recycle	=$E372*L368	Denaturant	=I368*M402*M403*	=M372/(I368*1000)
373	300	Hydrolysis	=$E373*L368	Acid	=$G373*N367	=M373/(I368*1000)
374	400	Fermentation (Unallocated)	=$E374*L368	Ammonia	=$G374*N367	=M374/(I368*1000)
375	410	Hexose Fermentation	=$E375*L368	Nutrients	=$G375*N367	=M375/(I368*1000)
376	420	Pentose Fermentation	=$E376*L368	Enzymes	=$G376*N367	=M376/(I368*1000)
377	500	Distillation & Dehydration	=$E377*L368	Yeast	=$G377*N367	=M377/(I368*1000)
378	600	By-Product Preparation	=$E378*L368	Other Chemicals	=$G378*N367	=M378/(I368*1000)
379	610	Stillage Evaporation	=$E379*L368	RAW MATERIALS TOTAL	=SUM(M370:M378)	=M379/(I368*1000)
380	700	Product Storage & Denature	=$E380*L368	Utilities		
381	800	Utilities & General	=$E381*L368	Electricity/ Energy	=$G381*N367	=M381/(I368*1000)
382	810	Boiler	=$E382*L368	Water	=$G382*N367	=M382/(I368*1000)
383	820	Non-Boiler Utilities	=$E383*L368	By-products	=$G383*N367	=M383/(I368*1000)
384	830	Environmental	=$E384*L368	VARIABLE COST TOTAL	=SUM(M379:M383)	=M384/(I368*1000)
385	840	Miscellaneous & Control	=$E385*L368	GEN & ADMIN	=1590*(I368/25)^K4	=M385/(I368*1000)
386	900	Enzyme Production	=$E386*L368			
387				Operators	=$G387*N367*K40	=M387/(I368*1000)
388	1000	Total Fixed Capital	=SUM(K369:K387)	Laborers	=$G388*(N367)^K4	=M388/(I368*1000)
389				Technicians	=$G389*(N367)^K4	=M389/(I368*1000)
390	1010	Contingency	=K388*K400	Maintenance	=$G390*(N367)^K4	=M390/(I368*1000)
391	1020	Startup	=K388*K401	Fringe Benefits	=M404*SUM(M387:	=M391/(I368*1000)
392	1030	Working Capital	=K388*K402	TOTAL LABOR	=SUM(M387:M391)	=M392/(I368*1000)
393				Property Tax & Insur.	=K405*K394*1000	=M393/(I368*1000)
394		TOTAL CAPITAL	=SUM(K388:K393)	TOTAL CASH	=M384+M385+M39	=M394/(I368*1000)
395				Depreciation	=SLN((K394*1000),	=M395/(I368*1000)
396				Interest	=K394*1000*$D$31	=M396/(I368*1000)
397						
398				TOTAL PRODUCTION	=M394+M395+M39	=M398/(I368*1000)
399		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
400		Contingency	=$D$304	=$C$312	=$D$312	
401		Start-up factor	=$D$305	=$C$313	=$D$313	
402		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
403		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
404		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
405		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
406	=$C$311					
407	=$C407			Ratio of orig. to proposed s	=K409/$D409	
408		=$C$320	=D408/D409*K409	=$C$310	=M440	
409		=$C$321	=$D$322	Scaling of original data	=(K409/$D409)^K44	
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	=$E411*M409	Biomass	=K408*K444*M408/	=M411/(K409*1000)
412	200	Pretreatment	=$E412*M409	Chemicals		
413	210	Recovery & Recycle	=$E413*M409	Denaturant	=K409*M443*M444	=M413/(K409*1000)
414	300	Hydrolysis	=$E414*M409	Acid	=$G414*M407	=M414/(K409*1000)
415	400	Fermentation (Unallocated)	=$E415*M409	Ammonia	=$G415*M407	=M415/(K409*1000)
416	410	Hexose Fermentation	=$E416*M409	Nutrients	=$G416*M407	=M416/(K409*1000)
417	420	Pentose Fermentation	=$E417*M409	Enzymes	=$G417*M407	=M417/(K409*1000)
418	500	Distillation & Dehydration	=$E418*M409	Yeast	=$G418*M407	=M418/(K409*1000)
419	600	By-Product Preparation	=$E419*M409	Other Chemicals	=$G419*M407	=M419/(K409*1000)
420	610	Stillage Evaporation	=$E420*M409	RAW MATERIALS TOTAL	=SUM(M411:M419)	=M420/(K409*1000)
421	700	Product Storage & Denature	=$E421*M409	Utilities		
422	800	Utilities & General	=$E422*M409	Electricity/ Energy	=$G422*M407	=M422/(K409*1000)
423	810	Boiler	=$E423*M409	Water	=$G423*M407	=M423/(K409*1000)
424	820	Non-Boiler Utilities	=$E424*M409	By-products	=$G424*M407	=M424/(K409*1000)
425	830	Environmental	=$E425*M409	VARIABLE COST TOTAL	=SUM(M420:M424)	=M425/(K409*1000)
426	840	Miscellaneous & Control	=$E426*M409	GEN & ADMIN	=1590*(K409/25)^K	=M426/(K409*1000)
427	900	Enzyme Production	=$E427*M409			
428				Operators	=$G428*M407*K44	=M428/(K409*1000)
429	1000	Total Fixed Capital	=SUM(K410:K428)	Laborers	=$G429*(M407)^K4	=M429/(K409*1000)
430				Technicians	=$G430*(M407)^K4	=M430/(K409*1000)
431	1010	Contingency	=K429*K441	Maintenance	=$G431*(M407)^K4	=M431/(K409*1000)
432	1020	Startup	=K429*K442	Fringe Benefits	=M445*SUM(M428:	=M432/(K409*1000)
433	1030	Working Capital	=K429*K443	TOTAL LABOR	=SUM(M428:M432)	=M433/(K409*1000)
434				Property Tax & Insur.	=K446*K435*1000	=M434/(K409*1000)
435		TOTAL CAPITAL	=SUM(K429:K434)	TOTAL CASH	=M425+M426+M43	=M435/(K409*1000)
436				Depreciation	=SLN((K435*1000),	=M436/(K409*1000)
437				Interest	=K435*1000*$D$31	=M437/(K409*1000)
438						
439				TOTAL PRODUCTION	=M435+M436+M43	=M439/(K409*1000)
440		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
441		Contingency	=$D$304	=$C$312	=$D$312	
442		Start-up factor	=$D$305	=$C$313	=$D$313	
443		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
444		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
445		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
446		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	O	P	Q	R	S	T
365	=$C$311					
366	=$C366					
367	=$C$320	=I367/I368*P368	=$C$310	=S399	Ratio of orig. to propos	=P368/$D368
368	=$C$321	=$D$321	Scaling of original da	=(P368/$D368)^Q399		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	=$E370*R368	Biomass	=P367*Q403*R367/10	=S370/(P368*1000)
371	200	Pretreatment	=$E371*R368	Chemicals		
372	210	Recovery & Recycle	=$E372*R368	Denaturant	=P368*S402*S403*10	=S372/(P368*1000)
373	300	Hydrolysis	=$E373*R368	Acid	=$G373*T367	=S373/(P368*1000)
374	400	Fermentation (Unallocated)	=$E374*R368	Ammonia	=$G374*T367	=S374/(P368*1000)
375	410	Hexose Fermentation	=$E375*R368	Nutrients	=$G375*T367	=S375/(P368*1000)
376	420	Pentose Fermentation	=$E376*R368	Enzymes	=$G376*T367	=S376/(P368*1000)
377	500	Distillation & Dehydration	=$E377*R368	Yeast	=$G377*T367	=S377/(P368*1000)
378	600	By-Product Preparation	=$E378*R368	Other Chemicals	=$G378*T367	=S378/(P368*1000)
379	610	Stillage Evaporation	=$E379*R368	RAW MATERIALS TOTAL	=SUM(S370:S378)	=S379/(P368*1000)
380	700	Product Storage & Denature	=$E380*R368	Utilities		
381	800	Utilities & General	=$E381*R368	Electricity/ Energy	=$G381*T367	=S381/(P368*1000)
382	810	Boiler	=$E382*R368	Water	=$G382*T367	=S382/(P368*1000)
383	820	Non-Boiler Utilities	=$E383*R368	By-products	=$G383*T367	=S383/(P368*1000)
384	830	Environmental	=$E384*R368	VARIABLE COST TOTAL	=SUM(S379:S383)	=S384/(P368*1000)
385	840	Miscellaneous & Control	=$E385*R368	GEN & ADMIN	=1590*(P368/25)^Q40	=S385/(P368*1000)
386	900	Enzyme Production	=$E386*R368			
387				Operators	=$G387*T367^Q404	=S387/(P368*1000)
388	1000	Total Fixed Capital	=SUM(Q369:Q387)	Laborers	=$G388*(T367)^Q404	=S388/(P368*1000)
389				Technicians	=$G389*(T367)^Q404	=S389/(P368*1000)
390	1010	Contingency	=Q388*Q400	Maintenance	=$G390*(T367)^Q404	=S390/(P368*1000)
391	1020	Startup	=Q388*Q401	Fringe Benefits	=S404*SUM(S387:S39	=S391/(P368*1000)
392	1030	Working Capital	=Q388*Q402	TOTAL LABOR	=SUM(S387:S391)	=S392/(P368*1000)
393				Property Tax & Insur.	=Q405*Q394*1000	=S393/(P368*1000)
394		TOTAL CAPITAL	=SUM(Q388:Q393)	TOTAL CASH	=S384+S385+S392+S	=S394/(P368*1000)
395				Depreciation	=SLN((Q394*1000),($I	=S395/(P368*1000)
396				Return on Investment	=Q394*1000*$D$319	=S396/(P368*1000)
397						
398				TOTAL PRODUCTION	=S394+S395+S396	=S398/(P368*1000)
399		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
400		Contingency	=$D$304	=$C$312	=$D$312	
401		Start-up factor	=$D$305	=$C$313	=$D$313	
402		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
403		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
404		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
405		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
406	=$C$311					
407	=$C407					
408	=$C$320	=K408/K409*P409	=$C$310	=S440	Ratio of orig. to propos	=P409/$D409
409	=$C$321	=$D$321	Scaling of original da	=(P409/$D409)^Q440		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	=$E411*R409	Biomass	=P408*Q444*R408/10	=S411/(P409*1000)
412	200	Pretreatment	=$E412*R409	Chemicals		
413	210	Recovery & Recycle	=$E413*R409	Denaturant	=P409*S443*S444*10	=S413/(P409*1000)
414	300	Hydrolysis	=$E414*R409	Acid	=$G414*T408	=S414/(P409*1000)
415	400	Fermentation (Unallocated)	=$E415*R409	Ammonia	=$G415*T408	=S415/(P409*1000)
416	410	Hexose Fermentation	=$E416*R409	Nutrients	=$G416*T408	=S416/(P409*1000)
417	420	Pentose Fermentation	=$E417*R409	Enzymes	=$G417*T408	=S417/(P409*1000)
418	500	Distillation & Dehydration	=$E418*R409	Yeast	=$G418*T408	=S418/(P409*1000)
419	600	By-Product Preparation	=$E419*R409	Other Chemicals	=$G419*T408	=S419/(P409*1000)
420	610	Stillage Evaporation	=$E420*R409	RAW MATERIALS TOTAL	=SUM(S411:S419)	=S420/(P409*1000)
421	700	Product Storage & Denature	=$E421*R409	Utilities		
422	800	Utilities & General	=$E422*R409	Electricity/ Energy	=$G422*T408	=S422/(P409*1000)
423	810	Boiler	=$E423*R409	Water	=$G423*T408	=S423/(P409*1000)
424	820	Non-Boiler Utilities	=$E424*R409	By-products	=$G424*T408	=S424/(P409*1000)
425	830	Environmental	=$E425*R409	VARIABLE COST TOTAL	=SUM(S420:S424)	=S425/(P409*1000)
426	840	Miscellaneous & Control	=$E426*R409	GEN & ADMIN	=1590*(P409/25)^Q44	=S426/(P409*1000)
427	900	Enzyme Production	=$E427*R409			
428				Operators	=$G428*T408^Q445	=S428/(P409*1000)
429	1000	Total Fixed Capital	=SUM(Q410:Q428)	Laborers	=$G429*(T408)^Q445	=S429/(P409*1000)
430				Technicians	=$G430*(T408)^Q445	=S430/(P409*1000)
431	1010	Contingency	=Q429*Q441	Maintenance	=$G431*(T408)^Q445	=S431/(P409*1000)
432	1020	Startup	=Q429*Q442	Fringe Benefits	=S445*SUM(S428:S43	=S432/(P409*1000)
433	1030	Working Capital	=Q429*Q443	TOTAL LABOR	=SUM(S428:S432)	=S433/(P409*1000)
434				Property Tax & Insur.	=Q446*Q435*1000	=S434/(P409*1000)
435		TOTAL CAPITAL	=SUM(Q429:Q434)	TOTAL CASH	=S425+S426+S433+S	=S435/(P409*1000)
436				Depreciation	=SLN((Q435*1000),($I	=S436/(P409*1000)
437				Interest	=Q435*1000*$D$319	=S437/(P409*1000)
438						
439				TOTAL PRODUCTION	=S435+S436+S437	=S439/(P409*1000)
440		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
441		Contingency	=$D$304	=$C$312	=$D$312	
442		Start-up factor	=$D$305	=$C$313	=$D$313	
443		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
444		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
445		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
446		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	U	V	W	X	Y	Z
365	=$C$312					
366	=$C366					
367	=$C$320	=P367/P368*V368	=$C$310	=Y400	Ratio of orig. to propose	=V368/$D368
368	=$C$321	=$D$322	Scaling of original data	=(V368/$D368)^W399		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	=$E370*X368	Biomass	=V367*W403*X367/100	=Y370/(V368*100
371	200	Pretreatment	=$E371*X368	Chemicals		
372	210	Recovery & Recycle	=$E372*X368	Denaturant	=V368*Y402*Y403*100	=Y372/(V368*100
373	300	Hydrolysis	=$E373*X368	Acid	=$G373*Z367	=Y373/(V368*100
374	400	Fermentation (Unallocated)	=$E374*X368	Ammonia	=$G374*Z367	=Y374/(V368*100
375	410	Hexose Fermentation	=$E375*X368	Nutrients	=$G375*Z367	=Y375/(V368*100
376	420	Pentose Fermentation	=$E376*X368	Enzymes	=$G376*Z367	=Y376/(V368*100
377	500	Distillation & Dehydration	=$E377*X368	Yeast	=$G377*Z367	=Y377/(V368*100
378	600	By-Product Preparation	=$E378*X368	Other Chemicals	=$G378*Z367	=Y378/(V368*100
379	610	Stillage Evaporation	=$E379*X368	RAW MATERIALS TOTAL	=SUM(Y370:Y378)	=Y379/(V368*100
380	700	Product Storage & Denature	=$E380*X368	Utilities		
381	800	Utilities & General	=$E381*X368	Electricity/ Energy	=$G381*Z367	=Y381/(V368*100
382	810	Boiler	=$E382*X368	Water	=$G382*Z367	=Y382/(V368*100
383	820	Non-Boiler Utilities	=$E383*X368	By-products	=$G383*Z367	=Y383/(V368*100
384	830	Environmental	=$E384*X368	VARIABLE COST TOTAL	=SUM(Y379:Y383)	=Y384/(V368*100
385	840	Miscellaneous & Control	=$E385*X368	GEN & ADMIN	=1590*(V368/25)^W404	=Y385/(V368*100
386	900	Enzyme Production	=$E386*X368			
387				Operators	=$G387*Z367^W404	=Y387/(V368*100
388	1000	Total Fixed Capital	=SUM(W369:W387)	Laborers	=$G388*(Z367)^W404	=Y388/(V368*100
389				Technicians	=$G389*(Z367)^W404	=Y389/(V368*100
390	1010	Contingency	=W388*W400	Maintenance	=$G390*(Z367)^W404	=Y390/(V368*100
391	1020	Startup	=W388*W401	Fringe Benefits	=Y404*SUM(Y387:Y39	=Y391/(V368*100
392	1030	Working Capital	=W388*W402	TOTAL LABOR	=SUM(Y387:Y391)	=Y392/(V368*100
393				Property Tax & Insur.	=W405*W394*1000	=Y393/(V368*100
394		TOTAL CAPITAL	=SUM(W388:W393)	TOTAL CASH	=Y384+Y385+Y392+Y3	=Y394/(V368*100
395				Depreciation	=SLN((W394*1000),($D	=Y395/(V368*100
396				Return on Investment	=W394*1000*$D$319	=Y396/(V368*100
397						
398				TOTAL PRODUCTION	=Y394+Y395+Y396	=Y398/(V368*100
399		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
400		Contingency	=$D$304	=$C$312	=$D$312	
401		Start-up factor	=$D$305	=$C$313	=$D$313	
402		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
403		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
404		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
405		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
406	=$C$312					
407	=$C407					
408	=$C$320	=P408/P409*V409	=$C$310	=Y441	Ratio of orig. to propose	=V409/$D409
409	=$C$321	=$D$322	Scaling of original data	=(V409/$D409)^W440		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	=$E411*X409	Biomass	=V408*W444*X408/100	=Y411/(V409*100
412	200	Pretreatment	=$E412*X409	Chemicals		
413	210	Recovery & Recycle	=$E413*X409	Denaturant	=V409*Y443*Y444*100	=Y413/(V409*100
414	300	Hydrolysis	=$E414*X409	Acid	=$G414*Z408	=Y414/(V409*100
415	400	Fermentation (Unallocated)	=$E415*X409	Ammonia	=$G415*Z408	=Y415/(V409*100
416	410	Hexose Fermentation	=$E416*X409	Nutrients	=$G416*Z408	=Y416/(V409*100
417	420	Pentose Fermentation	=$E417*X409	Enzymes	=$G417*Z408	=Y417/(V409*100
418	500	Distillation & Dehydration	=$E418*X409	Yeast	=$G418*Z408	=Y418/(V409*100
419	600	By-Product Preparation	=$E419*X409	Other Chemicals	=$G419*Z408	=Y419/(V409*100
420	610	Stillage Evaporation	=$E420*X409	RAW MATERIALS TOTAL	=SUM(Y411:Y419)	=Y420/(V409*100
421	700	Product Storage & Denature	=$E421*X409	Utilities		
422	800	Utilities & General	=$E422*X409	Electricity/ Energy	=$G422*Z408	=Y422/(V409*100
423	810	Boiler	=$E423*X409	Water	=$G423*Z408	=Y423/(V409*100
424	820	Non-Boiler Utilities	=$E424*X409	By-products	=$G424*Z408	=Y424/(V409*100
425	830	Environmental	=$E425*X409	VARIABLE COST TOTAL	=SUM(Y420:Y424)	=Y425/(V409*100
426	840	Miscellaneous & Control	=$E426*X409	GEN & ADMIN	=1590*(V409/25)^W445	=Y426/(V409*100
427	900	Enzyme Production	=$E427*X409			
428				Operators	=$G428*Z408^W445	=Y428/(V409*100
429	1000	Total Fixed Capital	=SUM(W410:W428)	Laborers	=$G429*(Z408)^W445	=Y429/(V409*100
430				Technicians	=$G430*(Z408)^W445	=Y430/(V409*100
431	1010	Contingency	=W429*W441	Maintenance	=$G431*(Z408)^W445	=Y431/(V409*100
432	1020	Startup	=W429*W442	Fringe Benefits	=Y445*SUM(Y428:Y43	=Y432/(V409*100
433	1030	Working Capital	=W429*W443	TOTAL LABOR	=SUM(Y428:Y432)	=Y433/(V409*100
434				Property Tax & Insur.	=W446*W435*1000	=Y434/(V409*100
435		TOTAL CAPITAL	=SUM(W429:W434)	TOTAL CASH	=Y425+Y426+Y433+Y4	=Y435/(V409*100
436				Depreciation	=SLN((W435*1000),($D	=Y436/(V409*100
437				Interest	=W435*1000*$D$319	=Y437/(V409*100
438						
439				TOTAL PRODUCTION	=Y435+Y436+Y437	=Y439/(V409*100
440		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
441		Contingency	=$D$304	=$C$312	=$D$312	
442		Start-up factor	=$D$305	=$C$313	=$D$313	
443		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
444		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
445		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
446		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
447	=$C$312					

	AA	AB	AC	AD	AE	AF
366	=$C366					
367	=$C$32	=V367/V368*AB368	=$C$310	=AE400	Ratio of orig. to proposed s	=AB368/$D368
368	=$C$32	=$D$321	Scaling of original dat	=(AB368/$D368)^AC399		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	=$E370*AD368	Biomass	=AB367*AC403*AD367/10	=AE370/(AB368*100
371	200	Pretreatment	=$E371*AD368	Chemicals		
372	210	Recovery & Recycle	=$E372*AD368	Denaturant	=AB368*AE402*AE403*10	=AE372/(AB368*100
373	300	Hydrolysis	=$E373*AD368	Acid	=$G373*AF367	=AE373/(AB368*100
374	400	Fermentation (Unallocated)	=$E374*AD368	Ammonia	=$G374*AF367	=AE374/(AB368*100
375	410	Hexose Fermentation	=$E375*AD368	Nutrients	=$G375*AF367	=AE375/(AB368*100
376	420	Pentose Fermentation	=$E376*AD368	Enzymes	=$G376*AF367	=AE376/(AB368*100
377	500	Distillation & Dehydration	=$E377*AD368	Yeast	=$G377*AF367	=AE377/(AB368*100
378	600	By-Product Preparation	=$E378*AD368	Other Chemicals	=$G378*AF367	=AE378/(AB368*100
379	610	Stillage Evaporation	=$E379*AD368	RAW MATERIALS TOTAL	=SUM(AE370:AE378)	=AE379/(AB368*100
380	700	Product Storage & Denature	=$E380*AD368	Utilities		
381	800	Utilities & General	=$E381*AD368	Electricity/ Energy	=$G381*AF367	=AE381/(AB368*100
382	810	Boiler	=$E382*AD368	Water	=$G382*AF367	=AE382/(AB368*100
383	820	Non-Boiler Utilities	=$E383*AD368	By-products	=$G383*AF367	=AE383/(AB368*100
384	830	Environmental	=$E384*AD368	VARIABLE COST TOTAL	=SUM(AE379:AE383)	=AE384/(AB368*100
385	840	Miscellaneous & Control	=$E385*AD368	GEN & ADMIN	=1590*(AB368/25)^AC404	=AE385/(AB368*100
386	900	Enzyme Production	=$E386*AD368			
387				Operators	=$G387*AF367^AC404	=AE387/(AB368*100
388	1000	Total Fixed Capital	=SUM(AC369:AC387	Laborers	=$G388*(AF367)^AC404	=AE388/(AB368*100
389				Technicians	=$G389*(AF367)^AC404	=AE389/(AB368*100
390	1010	Contingency	=AC388*AC400	Maintenance	=$G390*(AF367)^AC404	=AE390/(AB368*100
391	1020	Startup	=AC388*AC401	Fringe Benefits	=AE404*SUM(AE387:AE3	=AE391/(AB368*100
392	1030	Working Capital	=AC388*AC402	TOTAL LABOR	=SUM(AE387:AE391)	=AE392/(AB368*100
393				Property Tax & Insur.	=AC405*AC394*1000	=AE393/(AB368*100
394		**TOTAL CAPITAL**	=SUM(AC388:AC393	**TOTAL CASH**	=AE384+AE385+AE392+A	=AE394/(AB368*100
395				Depreciation	=SLN((AC394*1000),(D	=AE395/(AB368*100
396				Return on Investment	=AC394*1000*$D$319	=AE396/(AB368*100
397						
398				**TOTAL PRODUCTION**	**=AE394+AE395+AE396**	**=AE398/(AB368*100**
399		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
400		Contingency	=$D$304	=$C$312	=$D$312	
401		Start-up factor	=$D$305	=$C$313	=$D$313	
402		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
403		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
404		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
405		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
406	=$C$31					
407	=$C407					
408	=$C$32	=V408/V409*AB409	=$C$310	=AE441	Ratio of orig. to proposed s	=AB409/$D409
409	=$C$32	=$D$321	Scaling of original dat	=(AB409/$D409)^AC440		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	=$E411*AD409	Biomass	=AB408*AC444*AD408/10	=AE411/(AB409*100
412	200	Pretreatment	=$E412*AD409	Chemicals		
413	210	Recovery & Recycle	=$E413*AD409	Denaturant	=AB409*AE443*AE444*10	=AE413/(AB409*100
414	300	Hydrolysis	=$E414*AD409	Acid	=$G414*AF408	=AE414/(AB409*100
415	400	Fermentation (Unallocated)	=$E415*AD409	Ammonia	=$G415*AF408	=AE415/(AB409*100
416	410	Hexose Fermentation	=$E416*AD409	Nutrients	=$G416*AF408	=AE416/(AB409*100
417	420	Pentose Fermentation	=$E417*AD409	Enzymes	=$G417*AF408	=AE417/(AB409*100
418	500	Distillation & Dehydration	=$E418*AD409	Yeast	=$G418*AF408	=AE418/(AB409*100
419	600	By-Product Preparation	=$E419*AD409	Other Chemicals	=$G419*AF408	=AE419/(AB409*100
420	610	Stillage Evaporation	=$E420*AD409	RAW MATERIALS TOTAL	=SUM(AE411:AE419)	=AE420/(AB409*100
421	700	Product Storage & Denature	=$E421*AD409	Utilities		
422	800	Utilities & General	=$E422*AD409	Electricity/ Energy	=$G422*AF408	=AE422/(AB409*100
423	810	Boiler	=$E423*AD409	Water	=$G423*AF408	=AE423/(AB409*100
424	820	Non-Boiler Utilities	=$E424*AD409	By-products	=$G424*AF408	=AE424/(AB409*100
425	830	Environmental	=$E425*AD409	VARIABLE COST TOTAL	=SUM(AE420:AE424)	=AE425/(AB409*100
426	840	Miscellaneous & Control	=$E426*AD409	GEN & ADMIN	=1590*(AB409/25)^AC445	=AE426/(AB409*100
427	900	Enzyme Production	=$E427*AD409			
428				Operators	=$G428*AF408^AC445	=AE428/(AB409*100
429	1000	Total Fixed Capital	=SUM(AC410:AC428	Laborers	=$G429*(AF408)^AC445	=AE429/(AB409*100
430				Technicians	=$G430*(AF408)^AC445	=AE430/(AB409*100
431	1010	Contingency	=AC429*AC441	Maintenance	=$G431*(AF408)^AC445	=AE431/(AB409*100
432	1020	Startup	=AC429*AC442	Fringe Benefits	=AE445*SUM(AE428:AE4	=AE432/(AB409*100
433	1030	Working Capital	=AC429*AC443	TOTAL LABOR	=SUM(AE428:AE432)	=AE433/(AB409*100
434				Property Tax & Insur.	=AC446*AC435*1000	=AE434/(AB409*100
435		**TOTAL CAPITAL**	=SUM(AC429:AC434	**TOTAL CASH**	=AE425+AE426+AE433+A	=AE435/(AB409*100
436				Depreciation	=SLN((AC435*1000),(D	=AE436/(AB409*100
437				Interest	=AC435*1000*$D$319	=AE437/(AB409*100
438						
439				**TOTAL PRODUCTION**	**=AE435+AE436+AE437**	**=AE439/(AB409*100**
440		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
441		Contingency	=$D$304	=$C$312	=$D$312	
442		Start-up factor	=$D$305	=$C$313	=$D$313	
443		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
444		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
445		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
446		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	AG	AH	AI	AJ	AK	AL
366	=$C366					
367	=$C$320	=AB367/AB368*AH368	=$C$310	=AK401	Ratio of orig. to proposed s	=AH368/$D368
368	=$C$321	=$D$322	Scaling of original data	=(AH368/$D368)^AI399		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	=$E370*AJ368	Biomass	=AH367*AI403*AJ367/100(	=AK370/(AH368*10
371	200	Pretreatment	=$E371*AJ368	Chemicals		
372	210	Recovery & Recycle	=$E372*AJ368	Denaturant	=AH368*AK402*AK403*10(	=AK372/(AH368*10
373	300	Hydrolysis	=$E373*AJ368	Acid	=$G373*AL367	=AK373/(AH368*10
374	400	Fermentation (Unallocated)	=$E374*AJ368	Ammonia	=$G374*AL367	=AK374/(AH368*10
375	410	Hexose Fermentation	=$E375*AJ368	Nutrients	=$G375*AL367	=AK375/(AH368*10
376	420	Pentose Fermentation	=$E376*AJ368	Enzymes	=$G376*AL367	=AK376/(AH368*10
377	500	Distillation & Dehydration	=$E377*AJ368	Yeast	=$G377*AL367	=AK377/(AH368*10
378	600	By-Product Preparation	=$E378*AJ368	Other Chemicals	=$G378*AL367	=AK378/(AH368*10
379	610	Stillage Evaporation	=$E379*AJ368	RAW MATERIALS TOTAL	=SUM(AK370:AK378)	=AK379/(AH368*10
380	700	Product Storage & Denature	=$E380*AJ368	Utilities		
381	800	Utilities & General	=$E381*AJ368	Electricity/ Energy	=$G381*AL367	=AK381/(AH368*10
382	810	Boiler	=$E382*AJ368	Water	=$G382*AL367	=AK382/(AH368*10
383	820	Non-Boiler Utilities	=$E383*AJ368	By-products	=$G383*AL367	=AK383/(AH368*10
384	830	Environmental	=$E384*AJ368	VARIABLE COST TOTAL	=SUM(AK379:AK383)	=AK384/(AH368*10
385	840	Miscellaneous & Control	=$E385*AJ368	GEN & ADMIN	=1590*(AH368/25)^AI404	=AK385/(AH368*10
386	900	Enzyme Production	=$E386*AJ368			
387				Operators	=$G387*AL367^AI404	=AK387/(AH368*10
388	1000	Total Fixed Capital	=SUM(AI369:AI387)	Laborers	=$G388*(AL367)^AI404	=AK388/(AH368*10
389				Technicians	=$G389*(AL367)^AI404	=AK389/(AH368*10
390	1010	Contingency	=AI388*AI400	Maintenance	=$G390*(AL367)^AI404	=AK390/(AH368*10
391	1020	Startup	=AI388*AI401	Fringe Benefits	=AK404*SUM(AK387:AK39	=AK391/(AH368*10
392	1030	Working Capital	=AI388*AI402	TOTAL LABOR	=SUM(AK387:AK391)	=AK392/(AH368*10
393				Property Tax & Insur.	=AI405*AI394*1000	=AK393/(AH368*10
394		**TOTAL CAPITAL**	=SUM(AI388:AI393)	**TOTAL CASH**	=AK384+AK385+AK392+A	=AK394/(AH368*10
395				Depreciation	=SLN((AI394*1000),($D$3	=AK395/(AH368*10
396				Return on Investment	=AI394*1000*$D$319	=AK396/(AH368*10
397						
398				**TOTAL PRODUCTION**	=AK394+AK395+AK396	=AK398/(AH368*10
399		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
400		Contingency	=$D$304	=$C$312	=$D$312	
401		Start-up factor	=$D$305	=$C$313	=$D$313	
402		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
403		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
404		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
405		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
406	=$C$313					
407	=$C407					
408	=$C$320	=AB408/AB409*AH409	=$C$310	=AK442	Ratio of orig. to proposed s	=AH409/$D409
409	=$C$321	=$D$322	Scaling of original data	=(AH409/$D409)^AI440		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	=$E411*AJ409	Biomass	=AH408*AI444*AJ408/100(	=AK411/(AH409*10
412	200	Pretreatment	=$E412*AJ409	Chemicals		
413	210	Recovery & Recycle	=$E413*AJ409	Denaturant	=AH409*AK443*AK444*10(	=AK413/(AH409*10
414	300	Hydrolysis	=$E414*AJ409	Acid	=$G414*AL408	=AK414/(AH409*10
415	400	Fermentation (Unallocated)	=$E415*AJ409	Ammonia	=$G415*AL408	=AK415/(AH409*10
416	410	Hexose Fermentation	=$E416*AJ409	Nutrients	=$G416*AL408	=AK416/(AH409*10
417	420	Pentose Fermentation	=$E417*AJ409	Enzymes	=$G417*AL408	=AK417/(AH409*10
418	500	Distillation & Dehydration	=$E418*AJ409	Yeast	=$G418*AL408	=AK418/(AH409*10
419	600	By-Product Preparation	=$E419*AJ409	Other Chemicals	=$G419*AL408	=AK419/(AH409*10
420	610	Stillage Evaporation	=$E420*AJ409	RAW MATERIALS TOTAL	=SUM(AK411:AK419)	=AK420/(AH409*10
421	700	Product Storage & Denature	=$E421*AJ409	Utilities		
422	800	Utilities & General	=$E422*AJ409	Electricity/ Energy	=$G422*AL408	=AK422/(AH409*10
423	810	Boiler	=$E423*AJ409	Water	=$G423*AL408	=AK423/(AH409*10
424	820	Non-Boiler Utilities	=$E424*AJ409	By-products	=$G424*AL408	=AK424/(AH409*10
425	830	Environmental	=$E425*AJ409	VARIABLE COST TOTAL	=SUM(AK420:AK424)	=AK425/(AH409*10
426	840	Miscellaneous & Control	=$E426*AJ409	GEN & ADMIN	=1590*(AH409/25)^AI445	=AK426/(AH409*10
427	900	Enzyme Production	=$E427*AJ409			
428				Operators	=$G428*AL408^AI445	=AK428/(AH409*10
429	1000	Total Fixed Capital	=SUM(AI410:AI428)	Laborers	=$G429*(AL408)^AI445	=AK429/(AH409*10
430				Technicians	=$G430*(AL408)^AI445	=AK430/(AH409*10
431	1010	Contingency	=AI429*AI441	Maintenance	=$G431*(AL408)^AI445	=AK431/(AH409*10
432	1020	Startup	=AI429*AI442	Fringe Benefits	=AK445*SUM(AK428:AK43	=AK432/(AH409*10
433	1030	Working Capital	=AI429*AI443	TOTAL LABOR	=SUM(AK428:AK432)	=AK433/(AH409*10
434				Property Tax & Insur.	=AI446*AI435*1000	=AK434/(AH409*10
435		**TOTAL CAPITAL**	=SUM(AI429:AI434)	**TOTAL CASH**	=AK425+AK426+AK433+A	=AK435/(AH409*10
436				Depreciation	=SLN((AI435*1000),($D$3	=AK436/(AH409*10
437				Interest	=AI435*1000*$D$319	=AK437/(AH409*10
438						
439				**TOTAL PRODUCTION**	**=AK435+AK436+AK437**	**=AK439/(AH409*10**
440		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
441		Contingency	=$D$304	=$C$312	=$D$312	
442		Start-up factor	=$D$305	=$C$313	=$D$313	
443		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
444		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
445		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
446		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	AM	AN	AO	AP	AQ	AR
366	=$C366					
367	=$C$320	=AH367/AH368*AN368	=$C$310	=AQ401	Ratio of orig. to proposed s	=AN368/$D368
368	=$C$321	=$D$321	Scaling of original data	=(AN368/$D368)^AO399		
369	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
370	100	Biomass Preparation	=$E370*AP368	Biomass	=AN367*AO403*AP367/1(	=AQ370/(AN368*1000)
371	200	Pretreatment	=$E371*AP368	Chemicals		
372	210	Recovery & Recycle	=$E372*AP368	Denaturant	=AN368*AQ402*AQ403*1	=AQ372/(AN368*1000)
373	300	Hydrolysis	=$E373*AP368	Acid	=$G373*AR367	=AQ373/(AN368*1000)
374	400	Fermentation (Unallocated)	=$E374*AP368	Ammonia	=$G374*AR367	=AQ374/(AN368*1000)
375	410	Hexose Fermentation	=$E375*AP368	Nutrients	=$G375*AR367	=AQ375/(AN368*1000)
376	420	Pentose Fermentation	=$E376*AP368	Enzymes	=$G376*AR367	=AQ376/(AN368*1000)
377	500	Distillation & Dehydration	=$E377*AP368	Yeast	=$G377*AR367	=AQ377/(AN368*1000)
378	600	By-Product Preparation	=$E378*AP368	Other Chemicals	=$G378*AR367	=AQ378/(AN368*1000)
379	610	Stillage Evaporation	=$E379*AP368	RAW MATERIALS TOTAL	=SUM(AQ370:AQ378)	=AQ379/(AN368*1000)
380	700	Product Storage & Denature	=$E380*AP368	Utilities		
381	800	Utilities & General	=$E381*AP368	Electricity/ Energy	=$G381*AR367	=AQ381/(AN368*1000)
382	810	Boiler	=$E382*AP368	Water	=$G382*AR367	=AQ382/(AN368*1000)
383	820	Non-Boiler Utilities	=$E383*AP368	By-products	=$G383*AR367	=AQ383/(AN368*1000)
384	830	Environmental	=$E384*AP368	VARIABLE COST TOTAL	=SUM(AQ379:AQ383)	=AQ384/(AN368*1000)
385	840	Miscellaneous & Control	=$E385*AP368	GEN & ADMIN	=1590*(AN368/25)^AO404	=AQ385/(AN368*1000)
386	900	Enzyme Production	=$E386*AP368			
387				Operators	=$G387*AR367*AO404	=AQ387/(AN368*1000)
388	1000	Total Fixed Capital	=SUM(AO369:AO387)	Laborers	=$G388*(AR367)^AO404	=AQ388/(AN368*1000)
389				Technicians	=$G389*(AR367)^AO404	=AQ389/(AN368*1000)
390	1010	Contingency	=AO388*AO400	Maintenance	=$G390*(AR367)^AO404	=AQ390/(AN368*1000)
391	1020	Startup	=AO388*AO401	Fringe Benefits	=AQ404*SUM(AQ387:AQ	=AQ391/(AN368*1000)
392	1030	Working Capital	=AO388*AO402	TOTAL LABOR	=SUM(AQ387:AQ391)	=AQ392/(AN368*1000)
393				Property Tax & Insur.	=AO405*AO394*1000	=AQ393/(AN368*1000)
394		TOTAL CAPITAL	=SUM(AO388:AO393)	TOTAL CASH	=AQ384+AQ385+AQ392+	=AQ394/(AN368*1000)
395				Depreciation	=SLN((AO394*1000),(D	=AQ395/(AN368*1000)
396				Return on Investment	=AO394*1000*$D$319	=AQ396/(AN368*1000)
397						
398				TOTAL PRODUCTION	=AQ394+AQ395+AQ396	=AQ398/(AN368*1000)
399		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
400		Contingency	=$D$304	=$C$312	=$D$312	
401		Start-up factor	=$D$305	=$C$313	=$D$313	
402		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
403		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
404		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
405		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
406	=$C$313					
407	=$C407					
408	=$C$320	=AH408/AH409*AN409	=$C$310	=AQ442	Ratio of orig. to proposed s	=AN409/$D409
409	=$C$321	=$D$321	Scaling of original data	=(AN409/$D409)^AO440		
410	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
411	100	Biomass Preparation	=$E411*AP409	Biomass	=AN408*AO444*AP408/1(	=AQ411/(AN409*1000)
412	200	Pretreatment	=$E412*AP409	Chemicals		
413	210	Recovery & Recycle	=$E413*AP409	Denaturant	=AN409*AQ443*AQ444*1	=AQ413/(AN409*1000)
414	300	Hydrolysis	=$E414*AP409	Acid	=$G414*AR408	=AQ414/(AN409*1000)
415	400	Fermentation (Unallocated)	=$E415*AP409	Ammonia	=$G415*AR408	=AQ415/(AN409*1000)
416	410	Hexose Fermentation	=$E416*AP409	Nutrients	=$G416*AR408	=AQ416/(AN409*1000)
417	420	Pentose Fermentation	=$E417*AP409	Enzymes	=$G417*AR408	=AQ417/(AN409*1000)
418	500	Distillation & Dehydration	=$E418*AP409	Yeast	=$G418*AR408	=AQ418/(AN409*1000)
419	600	By-Product Preparation	=$E419*AP409	Other Chemicals	=$G419*AR408	=AQ419/(AN409*1000)
420	610	Stillage Evaporation	=$E420*AP409	RAW MATERIALS TOTAL	=SUM(AQ411:AQ419)	=AQ420/(AN409*1000)
421	700	Product Storage & Denature	=$E421*AP409	Utilities		
422	800	Utilities & General	=$E422*AP409	Electricity/ Energy	=$G422*AR408	=AQ422/(AN409*1000)
423	810	Boiler	=$E423*AP409	Water	=$G423*AR408	=AQ423/(AN409*1000)
424	820	Non-Boiler Utilities	=$E424*AP409	By-products	=$G424*AR408	=AQ424/(AN409*1000)
425	830	Environmental	=$E425*AP409	VARIABLE COST TOTAL	=SUM(AQ420:AQ424)	=AQ425/(AN409*1000)
426	840	Miscellaneous & Control	=$E426*AP409	GEN & ADMIN	=1590*(AN409/25)^AO445	=AQ426/(AN409*1000)
427	900	Enzyme Production	=$E427*AP409			
428				Operators	=$G428*AR408*AO445	=AQ428/(AN409*1000)
429	1000	Total Fixed Capital	=SUM(AO410:AO428)	Laborers	=$G429*(AR408)^AO445	=AQ429/(AN409*1000)
430				Technicians	=$G430*(AR408)^AO445	=AQ430/(AN409*1000)
431	1010	Contingency	=AO429*AO441	Maintenance	=$G431*(AR408)^AO445	=AQ431/(AN409*1000)
432	1020	Startup	=AO429*AO442	Fringe Benefits	=AQ445*SUM(AQ428:AQ	=AQ432/(AN409*1000)
433	1030	Working Capital	=AO429*AO443	TOTAL LABOR	=SUM(AQ428:AQ432)	=AQ433/(AN409*1000)
434				Property Tax & Insur.	=AO446*AO435*1000	=AQ434/(AN409*1000)
435		TOTAL CAPITAL	=SUM(AO429:AO434)	TOTAL CASH	=AQ425+AQ426+AQ433+	=AQ435/(AN409*1000)
436				Depreciation	=SLN((AO435*1000),(D	=AQ436/(AN409*1000)
437				Interest	=AO435*1000*$D$319	=AQ437/(AN409*1000)
438						
439				TOTAL PRODUCTION	=AQ435+AQ436+AQ437	=AQ439/(AN409*1000)
440		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
441		Contingency	=$D$304	=$C$312	=$D$312	
442		Start-up factor	=$D$305	=$C$313	=$D$313	
443		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
444		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
445		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
446		Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	I	J	K	L	M	N
447	PROCESS COST ONLY (BIOMASS $0)					
448	STAKETECH ESTIMATED BASE COSTS					
449	Plant f	814	Biomass C	$0.00	Ratio of or	1.00
450	Ethanc	25	Scaling of	1.00		
451	AREA	CAPITAL COSTS	Million $	RODUCTION COST	Thous $/Y	$/gal
452	100	Biomass Preparation	$0.450	Biomass	0	$0.000
453	200	Pretreatment	$18.673	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
455	300	Hydrolysis	$12.709	Acid	0	$0.000
456	400	Fermentation (Unallocated	$19.217	Ammonia	37	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	642	$0.026
459	500	Distillation & Dehydration	$12.479	Yeast	317	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
461	610	Stillage Evaporation	$2.805	RAW MATERIALS T	2,113	$0.085
462	700	Product Storage & Denatu	$1.635	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$12.572	Water	0	$0.000
465	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST T	2,113	$0.085
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
468	900	Enzyme Production	$0.000			
469				Operators	1,520	$0.061
470	1000	Total Fixed Capital	$89.691	Laborers	1,000	$0.040
471				Technicians	210	$0.008
472	1010	Contingency	$8.969	Maintenance	800	$0.032
473	1020	Startup	$4.485	Fringe Benefits	883	$0.035
474	1030	Working Capital	$8.727	TOTAL LABOR	4,413	$0.177
475				Property Tax & Insur	1,648	$0.066
476		TOTAL CAPITAL	$109.871	TOTAL CASH	9,764	$0.391
477				Depreciation	3,296	$0.132
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTI	13,060	$0.522
481		Power Law Scaling Factor	0.7	PROCESS COST O	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	enaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	reciation period (yrs)	30	

	O	P	Q	R	S	T
447	PROCESS COST ONLY (BIOMASS $0)					
448	STAKETECH ESTIMATED BASE COSTS					
449	Plant	162.8	Biomass	$0.00	Ratio of o	0.20
450	Ethan	5	Scaling of	0.32		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
452	100	Biomass Preparation	$0.146	Biomass	0	$0.000
453	200	Pretreatment	$6.053	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
455	300	Hydrolysis	$4.119	Acid	0	$0.000
456	400	Fermentation (Unallocate	$6.229	Ammonia	7	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
459	500	Distillation & Dehydration	$4.045	Yeast	63	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
461	610	Stillage Evaporation	$0.900	RAW MATERIALS TOT	423	$0.085
462	700	Product Storage & Dena	$0.530	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$4.075	Water	0	$0.000
465	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TOTA	423	$0.085
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
468	900	Enzyme Production	$0.000			
469				Operators	357	$0.071
470	1000	Total Fixed Capital	$29.072	Laborers	235	$0.047
471				Technicians	49	$0.010
472	1010	Contingency	$2.907	Maintenance	188	$0.038
473	1020	Startup	$1.454	Fringe Benefits	207	$0.041
474	1030	Working Capital	$2.180	TOTAL LABOR	1,037	$0.207
475				Property Tax & Insur.	534	$0.107
476		TOTAL CAPITAL	$35.613	TOTAL CASH	2,367	$0.473
477				Depreciation	1,068	$0.214
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTION	3,435	$0.687
481		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	U	V	W	X	Y	Z	AA
447	BIOMASS COST 1						
448	STAKETECH ESTIMATED BASE COSTS						
449	Plant	814	Biomass C	$50.00	Ratio of or	1.00	Plant
450	Ethan	25	Scaling of	1.00			Ethan
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA
452	100	Biomass Preparation	$0.450	Biomass	13,431	$0.537	100
453	200	Pretreatment	$18.673	Chemicals			200
454	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044	210
455	300	Hydrolysis	$12.709	Acid	0	$0.000	300
456	400	Fermentation (Unallocat	$19.217	Ammonia	37	$0.001	400
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000	410
458	420	Pentose Fermentation	$0.000	Enzymes	642	$0.026	420
459	500	Distillation & Dehydratior	$12.479	Yeast	317	$0.013	500
460	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001	600
461	610	Stillage Evaporation	$2.805	RAW MATERIALS TO	15,544	$0.622	610
462	700	Product Storage & Dena	$1.635	Utilities			700
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000	800
464	810	Boiler	$12.572	Water	0	$0.000	810
465	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000	820
466	830	Environmental	$0.000	VARIABLE COST TO	15,544	$0.622	830
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064	840
468	900	Enzyme Production	$0.000				900
469				Operators	1,520	$0.061	
470	1000	Total Fixed Capital	$89.691	Laborers	1,000	$0.040	1000
471				Technicians	210	$0.008	
472	1010	Contingency	$8.969	Maintenance	800	$0.032	1010
473	1020	Startup	$4.485	Fringe Benefits	883	$0.035	1020
474	1030	Working Capital	$8.727	TOTAL LABOR	4,413	$0.177	1030
475				Property Tax & Insur.	1,648	$0.066	
476		TOTAL CAPITAL	$109.871	TOTAL CASH	23,195	$0.928	
477				Depreciation	3,296	$0.132	
478				Interest	0	$0.000	
479							
480				TOTAL PRODUCTIO	26,491	$1.060	
481		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00		
482		Contingency	10.00%	BIOMASS COST 1	$50.00		
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00		
484		Working Capital	7.50%	)enaturant Cost, $/gal	$0.87		
485		Operating Days per Year	330	Denaturant Use	5%		
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%		
487		Property Tax & Insurance	1.50%	preciation period (yrs)	30		

	AB	AC	AD	AE	AF
447	BIOMASS COST 1				
448	STAKETECH ESTIMATED BASE COSTS				
449	162.8	Biomass (	$50.00	Ratio of or	0.20
450	5	Scaling of	0.32		
451	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
452	Biomass Preparation	$0.146	Biomass	2,686	$0.537
453	Pretreatment	$6.053	Chemicals		
454	Recovery & Recycle	$0.000	Denaturant	218	$0.044
455	Hydrolysis	$4.119	Acid	0	$0.000
456	Fermentation (Unallocated	$6.229	Ammonia	7	$0.001
457	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	Pentose Fermentation	$0.000	Enzymes	128	$0.026
459	Distillation & Dehydration	$4.045	Yeast	63	$0.013
460	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
461	Stillage Evaporation	$0.909	RAW MATERIALS TO	3,109	$0.622
462	Product Storage & Denat	$0.530	Utilities		
463	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	Boiler	$4.075	Water	0	$0.000
465	Non-Boiler Utilities	$2.966	By-products	0	$0.000
466	Environmental	$0.000	VARIABLE COST TO	3,109	$0.622
467	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
468	Enzyme Production	$0.000			
469			Operators	357	$0.071
470	Total Fixed Capital	$29.072	Laborers	235	$0.047
471			Technicians	49	$0.010
472	Contingency	$2.907	Maintenance	188	$0.038
473	Startup	$1.454	Fringe Benefits	207	$0.041
474	Working Capital	$2.180	TOTAL LABOR	1,037	$0.207
475			Property Tax & Insur.	534	$0.107
476	TOTAL CAPITAL	$35.613	TOTAL CASH	5,053	$1.011
477			Depreciation	1,068	$0.214
478			Interest	0	$0.000
479					
480			TOTAL PRODUCTIO	6,122	$1.224
481	Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
482	Contingency	10.00%	BIOMASS COST 1	$50.00	
483	Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484	Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485	Operating Days per Year	330	Denaturant Use	5%	
486	Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487	Property Tax & Insurance	1.50%	preciation period (yrs)	30	

	AG	AH	AI	AJ	AK	AL
447	BIOMASS COST 2					
448	STAKETECH ESTIMATED BASE COSTS					
449	Plant	814	Biomass C	$109.00	Ratio of ori	1.00
450	Ethan	25	Scaling of o	1.00		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
452	100	Biomass Preparation	$0.450	Biomass	29,280	$1.171
453	200	Pretreatment	$18.673	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
455	300	Hydrolysis	$12.709	Acid	0	$0.000
456	400	Fermentation (Unallocated	$19.217	Ammonia	37	#VALUE!
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	642	$0.026
459	500	Distillation & Dehydration	$12.479	Yeast	317	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
461	610	Stillage Evaporation	$2.805	RAW MATERIALS TOTA	31,393	$1.256
462	700	Product Storage & Denat	$1.635	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$12.572	Water	0	$0.000
465	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TOTA	31,393	$1.256
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
468	900	Enzyme Production	$0.000			
469				Operators	1,520	$0.061
470	1000	Total Fixed Capital	$89.691	Laborers	1,000	$0.040
471				Technicians	210	$0.008
472	1010	Contingency	$8.969	Maintenance	800	$0.032
473	1020	Startup	$4.485	Fringe Benefits	883	$0.035
474	1030	Working Capital	$6.727	TOTAL LABOR	4,413	$0.177
475				Property Tax & Insur.	1,648	$0.066
476		TOTAL CAPITAL	$109.871	TOTAL CASH	39,043	$1.562
477				Depreciation	3,296	$0.132
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTION	42,339	$1.694
481		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AM	AN	AO	AP	AQ	AR
447	BIOMASS COST 2					
448	STAKETECH ESTIMATED BASE COSTS					
449	Plant f	162.8	Biomass C	$109.00	Ratio of ori	0.20
450	Ethan	5	Scaling of	0.32		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
452	100	Biomass Preparation	$0.146	Biomass	5,856	$1.171
453	200	Pretreatment	$6.053	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
455	300	Hydrolysis	$4.119	Acid	0	$0.000
456	400	Fermentation (Unallocated)	$6.229	Ammonia	7	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
459	500	Distillation & Dehydration	$4.045	Yeast	63	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
461	610	Stillage Evaporation	$0.909	RAW MATERIALS TOTAL	6,279	$1.256
462	700	Product Storage & Denatur	$0.530	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$4.075	Water	0	$0.000
465	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TOTAL	6,279	$1.256
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
468	900	Enzyme Production	$0.000			
469				Operators	357	$0.071
470	1000	Total Fixed Capital	$29.072	Laborers	235	$0.047
471				Technicians	49	$0.010
472	1010	Contingency	$2.907	Maintenance	188	$0.038
473	1020	Startup	$1.454	Fringe Benefits	207	$0.041
474	1030	Working Capital	$2.180	TOTAL LABOR	1,037	$0.207
475				Property Tax & Insur.	534	$0.107
476		TOTAL CAPITAL	$35.613	TOTAL CASH	8,223	$1.645
477				Depreciation	1,068	$0.214
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTION	9,291	$1.858
481		Power Law Scaling Factor	0.7	PROCESS COST ONLY (B	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AS	AT	AU	AV	AW	AX	AY
447							
448		COSTS AS PERCENTAGE OF TOTAL					
449		STAKETECH ESTIMATED BASE COSTS					
450			Ethanol Production (MM gal/yr)	25	Biomass Cost/ton-	$50.00	
451		AREA	CAPITAL COSTS	% of capital cos	RODUCTION COST	Thous $/Yr	of $/gallon c
452		100	Biomass Preparation	0.4%	Biomass	0	38.2%
453		200	Pretreatment	17.0%	Chemicals	0	0.0%
454		210	Recycle & Recovery	0.0%	Denaturant	1088	5.2%
455		300	Hydrolysis	11.6%	Acid	0	0.0%
456		400	Fermentation	17.5%	Ammonia	37	0.2%
457		410	Hexose Fermentation	0.0%	Nutrients	0	0.0%
458		420	Pentose Fermentation	0.0%	Enzymes	642	3.0%
459		500	Distillation& Dehydration	11.4%	Yeast	317	1.5%
460		600	By-Product Preparation	0.0%	Other Chemicals	30	0.1%
461		610	Stillage Evaporation	2.6%	RAW MATERIALS T	10173	48.2%
462		700	Product Storage & Denature	1.5%	Utilities	0	0.0%
463		800	Utilities & General	0.0%	Electricity/ Energy	0	0.0%
464		810	Boiler	11.4%	Water	0	0.0%
465		820	Non-Boiler Utilities	8.3%	By-products	0	0.0%
466		830	Environmental	0.0%	VARIABLE COST T	10173	48.2%
467		840	Miscellaneous & Control	0.0%	GEN & ADMIN	1590	7.5%
468		900	Enzyme Production	0.0%			
469					Operators	1520	7.2%
470			Total Installed Equipment	81.6%	Laborers	1000	4.7%
471					Technicians	210	1.0%
472			Fixed Capital	81.6%	Maintenance	800	3.8%
473		0.1	Miscellaneous	8.2%	Fringe Benefits	883	4.2%
474		0.05	Start-up Costs	4.1%	TOTAL LABOR	4413	20.9%
475		0.075	Working capital	6.1%	Property Tax & Insu	1648	7.8%
476					TOTAL CASH	17823	84.4%
477			TOTAL CAPITAL	100.0%	Depreciation	3296	15.6%
478					Interest	0	0.0%
479							
480					TOTAL PRODUCTI	21119	100.0%
481							
482							
483							
484							
485							
486							
487							

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447		PROCESS COST ONLY (BIOMASS $0)				
448		STAKETECH ESTIMATED BASE COSTS				
449	Plant I	814	Biomass (	$0.00	Ratio of d	1.00
450	Ethanol	25	Scaling of	1.00		
451	AREA	CAPITAL COSTS	Million $	RODUCTION COST	Thous $/Y	$/gal
452	100	Biomass Preparation	$0.450	Biomass	0	$0.000
453	200	Pretreatment	$18.673	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
455	300	Hydrolysis	$12.709	Acid	0	$0.000
456	400	Fermentation (Unallocated	$19.217	Ammonia	37	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	642	$0.026
459	500	Distillation & Dehydration	$12.479	Yeast	317	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
461	610	Stillage Evaporation	$2.805	RAW MATERIALS T	2,113	$0.085
462	700	Product Storage & Denatu	$1.635	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$12.572	Water	0	$0.000
465	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST T	2,113	$0.085
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
468	900	Enzyme Production	$0.000			
469				Operators	1,520	$0.061
470	1000	Total Fixed Capital	$89.691	Laborers	1,000	$0.040
471				Technicians	210	$0.008
472	1010	Contingency	$8.969	Maintenance	800	$0.032
473	1020	Startup	$4.485	Fringe Benefits	883	$0.035
474	1030	Working Capital	$6.727	TOTAL LABOR	4,413	$0.177
475				Property Tax & Insur	1,648	$0.066
476		TOTAL CAPITAL	$109.871	TOTAL CASH	9,764	$0.391
477				Depreciation	3,296	$0.132
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTI	13,060	$0.522
481		Power Law Scaling Factor	0.7	PROCESS COST O	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	enaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	reciation period (yrs)	30	
488		PROCESS COST ONLY (BIOMASS $0)				
489		BIOENERGY ESTIMATED BASE COSTS				
490	Plant I	838	Biomass (	$0.00	Ratio of d	1.00
491	Ethanol	25	Scaling of	1.00		
492	AREA	CAPITAL COSTS	Million $	RODUCTION COST	Thous $/Y	$/gal
493	100	Biomass Preparation	$0.640	Biomass	0	$0.000
494	200	Pretreatment	$18.830	Chemicals		
495	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
496	300	Hydrolysis	$15.280	Acid	0	$0.000
497	400	Fermentation (Unallocated	$22.820	Ammonia	202	$0.008
498	410	Hexose Fermentation	$0.000	Nutrients	1,053	$0.042
499	420	Pentose Fermentation	$0.000	Enzymes	673	$0.027
500	500	Distillation & Dehydration	$12.190	Yeast	317	$0.013
501	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
502	610	Stillage Evaporation	$6.280	RAW MATERIALS T	3,362	$0.134
503	700	Product Storage & Denatu	$1.634	Utilities		
504	800	Utilities & General	$0.000	Electricity/ Energy	950	$0.038
505	810	Boiler	$12.810	Water	0	$0.000
506	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
507	830	Environmental	$0.000	VARIABLE COST T	4,312	$0.172
508	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
509	900	Enzyme Production	$4.410			
510				Operators	1,520	$0.061
511	1000	Total Fixed Capital	$104.045	Laborers	1,000	$0.040
512				Technicians	210	$0.008
513	1010	Contingency	$10.405	Maintenance	800	$0.032
514	1020	Startup	$5.202	Fringe Benefits	883	$0.035
515	1030	Working Capital	$7.803	TOTAL LABOR	4,413	$0.177
516				Property Tax & Insur	1,912	$0.076
517		TOTAL CAPITAL	$127.455	TOTAL CASH	12,227	$0.489
518				Depreciation	3,824	$0.153
519				Interest	0	$0.000
520						
521				TOTAL PRODUCTI	16,050	$0.642
522		Power Law Scaling Factor	0.7	PROCESS COST O	$0.00	
523		Contingency	10.00%	BIOMASS COST 1	$50.00	
524		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
525		Working Capital	7.50%	enaturant Cost, $/gal	$0.87	
526		Operating Days per Year	330	Denaturant Use	5%	
527		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
528		Property Tax & Insurance	1.50%	reciation period (yrs)	30	
529		PROCESS COST ONLY (BIOMASS $0)				

	O	P	Q	R	S	T
447		PROCESS COST ONLY (BIOMASS $0)				
448		STAKETECH ESTIMATED BASE COSTS				
449	Plant	162.8	Biomass	$0.00	Ratio of d	0.20
450	Ethan	5	Scaling of	0.32		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
452	100	Biomass Preparation	$0.146	Biomass	0	$0.000
453	200	Pretreatment	$6.053	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
455	300	Hydrolysis	$4.119	Acid	0	$0.000
456	400	Fermentation (Unallocate	$6.229	Ammonia	7	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
459	500	Distillation & Dehydration	$4.045	Yeast	63	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
461	610	Stillage Evaporation	$0.909	RAW MATERIALS TO	423	$0.085
462	700	Product Storage & Dena	$0.530	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$4.075	Water	0	$0.000
465	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TOT	423	$0.085
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
468	900	Enzyme Production	$0.000			
469				Operators	357	$0.071
470	1000	Total Fixed Capital	$29.072	Laborers	235	$0.047
471				Technicians	49	$0.010
472	1010	Contingency	$2.907	Maintenance	186	$0.038
473	1020	Startup	$1.454	Fringe Benefits	207	$0.041
474	1030	Working Capital	$2.180	TOTAL LABOR	1,037	$0.207
475				Property Tax & Insur.	534	$0.107
476		TOTAL CAPITAL	$35.613	TOTAL CASH	2,367	$0.473
477				Depreciation	1,068	$0.214
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTION	3,435	$0.687
481		Power Law Scaling Factor	0.7	PROCESS COST ONL	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	epreciation period (yrs)	30	
488		PROCESS COST ONLY (BIOMASS $0)				
489		BIOENERGY ESTIMATED BASE COSTS				
490	Plant	167.6	Biomass	$0.00	Ratio of d	0.20
491	Ethan	5	Scaling of	0.32		
492	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
493	100	Biomass Preparation	$0.207	Biomass	0	$0.000
494	200	Pretreatment	$6.103	Chemicals		
495	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
496	300	Hydrolysis	$4.953	Acid	0	$0.000
497	400	Fermentation (Unallocate	$7.397	Ammonia	40	$0.008
498	410	Hexose Fermentation	$0.000	Nutrients	211	$0.042
499	420	Pentose Fermentation	$0.000	Enzymes	135	$0.027
500	500	Distillation & Dehydration	$3.951	Yeast	63	$0.013
501	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
502	610	Stillage Evaporation	$2.036	RAW MATERIALS TO	672	$0.134
503	700	Product Storage & Dena	$0.530	Utilities		
504	800	Utilities & General	$0.000	Electricity/ Energy	190	$0.038
505	810	Boiler	$4.152	Water	0	$0.000
506	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
507	830	Environmental	$0.000	VARIABLE COST TOT	862	$0.172
508	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
509	900	Enzyme Production	$1.429			
510				Operators	357	$0.071
511	1000	Total Fixed Capital	$33.724	Laborers	235	$0.047
512				Technicians	49	$0.010
513	1010	Contingency	$3.372	Maintenance	188	$0.038
514	1020	Startup	$1.686	Fringe Benefits	207	$0.041
515	1030	Working Capital	$2.529	TOTAL LABOR	1,037	$0.207
516				Property Tax & Insur.	620	$0.124
517		TOTAL CAPITAL	$41.312	TOTAL CASH	2,892	$0.578
518				Depreciation	1,239	$0.248
519				Interest	0	$0.000
520						
521				TOTAL PRODUCTION	4,132	$0.826
522		Power Law Scaling Factor	0.7	PROCESS COST ONL	$0.00	
523		Contingency	10.00%	BIOMASS COST 1	$50.00	
524		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
525		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
526		Operating Days per Year	330	Denaturant Use	5%	
527		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
528		Property Tax & Insurance	1.50%	epreciation period (yrs)	30	
529		PROCESS COST ONLY (BIOMASS $0)				

	U	V	W	X	Y	Z
447		BIOMASS COST 1				
448		STAKETECH ESTIMATED BASE COSTS				
449	Plant	814	Biomass C	$50.00	Ratio of o	1.00
450	Ethan	25	Scaling of	1.00		
451	AREA	CAPITAL COSTS	Million $	RODUCTION COSTS	Thous $/Y	$/gal
452	100	Biomass Preparation	$0.450	Biomass	13,431	$0.537
453	200	Pretreatment	$18.673	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
455	300	Hydrolysis	$12.709	Acid	0	$0.000
456	400	Fermentation (Unallocate	$19.217	Ammonia	37	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	642	$0.026
459	500	Distillation & Dehydration	$12.479	Yeast	317	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
461	610	Stillage Evaporation	$2.805	RAW MATERIALS TO	15,544	$0.622
462	700	Product Storage & Dena	$1.635	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$12.572	Water	0	$0.000
465	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TO	15,544	$0.622
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
468	900	Enzyme Production	$0.000			
469				Operators	1,520	$0.061
470	1000	Total Fixed Capital	$89.691	Laborers	1,000	$0.040
471				Technicians	210	$0.008
472	1010	Contingency	$8.969	Maintenance	800	$0.032
473	1020	Startup	$4.485	Fringe Benefits	883	$0.035
474	1030	Working Capital	$6.727	TOTAL LABOR	4,413	$0.177
475				Property Tax & Insur.	1,648	$0.066
476		TOTAL CAPITAL	$109.871	TOTAL CASH	23,195	$0.928
477				Depreciation	3,296	$0.132
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTIO	26,491	$1.060
481		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	preciation period (yrs)	30	
488		BIOMASS COST 1				
489		BIOENERGY ESTIMATED BASE COSTS				
490	Plant	838	Biomass C	$50.00	Ratio of o	1.00
491	Ethan	25	Scaling of	1.00		
492	AREA	CAPITAL COSTS	Million $	RODUCTION COSTS	Thous $/Y	$/gal
493	100	Biomass Preparation	$0.640	Biomass	13,827	$0.553
494	200	Pretreatment	$18.830	Chemicals		
495	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
496	300	Hydrolysis	$15.280	Acid	0	$0.000
497	400	Fermentation (Unallocate	$22.820	Ammonia	202	$0.008
498	410	Hexose Fermentation	$0.000	Nutrients	1,053	$0.042
499	420	Pentose Fermentation	$0.000	Enzymes	673	$0.027
500	500	Distillation & Dehydration	$12.190	Yeast	317	$0.013
501	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
502	610	Stillage Evaporation	$6.280	RAW MATERIALS TO	17,189	$0.688
503	700	Product Storage & Dena	$1.634	Utilities		
504	800	Utilities & General	$0.000	Electricity/ Energy	950	$0.038
505	810	Boiler	$12.810	Water	0	$0.000
506	820	Non-Boiler Utilities	$9.151	By-products	0	$0.000
507	830	Environmental	$0.000	VARIABLE COST TO	18,139	$0.726
508	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
509	900	Enzyme Production	$4.410			
510				Operators	1,620	$0.061
511	1000	Total Fixed Capital	$104.045	Laborers	1,000	$0.040
512				Technicians	210	$0.008
513	1010	Contingency	$10.405	Maintenance	800	$0.032
514	1020	Startup	$5.202	Fringe Benefits	883	$0.035
515	1030	Working Capital	$7.803	TOTAL LABOR	4,413	$0.177
516				Property Tax & Insur.	1,912	$0.076
517		TOTAL CAPITAL	$127.455	TOTAL CASH	26,054	$1.042
518				Depreciation	3,824	$0.153
519				Interest	0	$0.000
520						
521				TOTAL PRODUCTIO	29,877	$1.195
522		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
523		Contingency	10.00%	BIOMASS COST 1	$50.00	
524		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
525		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
526		Operating Days per Year	330	Denaturant Use	5%	
527		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
528		Property Tax & Insurance	1.50%	preciation period (yrs)	30	
529		BIOMASS COST 1				

	AA	AB	AC	AD	AE	AF
447		BIOMASS COST 1				
448		STAKETECH ESTIMATED BASE COSTS				
449	Plant	162.8	Biomass (	$50.00	Ratio of or	0.20
450	Ethan	5	Scaling of	0.32		
451	AREA	CAPITAL COSTS	Million $	RODUCTION COSTS	Thous $/Y	$/gal
452	100	Biomass Preparation	$0.146	Biomass	2,686	$0.537
453	200	Pretreatment	$6.053	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
455	300	Hydrolysis	$4.119	Acid	0	$0.000
456	400	Fermentation (Unallocated	$6.229	Ammonia	7	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
459	500	Distillation & Dehydration	$4.045	Yeast	63	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
461	610	Stillage Evaporation	$0.909	RAW MATERIALS TO	3,109	$0.622
462	700	Product Storage & Denat	$0.530	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$4.075	Water	0	$0.000
465	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TO	3,109	$0.622
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
468	900	Enzyme Production	$0.000			
469				Operators	357	$0.071
470	1000	Total Fixed Capital	$29.072	Laborers	235	$0.047
471				Technicians	49	$0.010
472	1010	Contingency	$2.907	Maintenance	186	$0.038
473	1020	Startup	$1.454	Fringe Benefits	207	$0.041
474	1030	Working Capital	$2.180	TOTAL LABOR	1,037	$0.207
475				Property Tax & Insur.	534	$0.107
476		TOTAL CAPITAL	$35.613	TOTAL CASH	5,053	$1.011
477				Depreciation	1,068	$0.214
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTIO	6,122	$1.224
481		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	preciation period (yrs)	30	
488		BIOMASS COST 1				
489		BIOENERGY ESTIMATED BASE COSTS				
490	Plant	167.6	Biomass (	$50.00	Ratio of or	0.20
491	Ethar	5	Scaling of	0.32		
492	AREA	CAPITAL COSTS	Million $	RODUCTION COSTS	Thous $/Y	$/gal
493	100	Biomass Preparation	$0.207	Biomass	2,765	$0.553
494	200	Pretreatment	$6.103	Chemicals		
495	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
496	300	Hydrolysis	$4.953	Acid	0	$0.000
497	400	Fermentation (Unallocated	$7.397	Ammonia	40	$0.008
498	410	Hexose Fermentation	$0.000	Nutrients	211	$0.042
499	420	Pentose Fermentation	$0.000	Enzymes	135	$0.027
500	500	Distillation & Dehydration	$3.951	Yeast	63	$0.013
501	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
502	610	Stillage Evaporation	$2.036	RAW MATERIALS TO	3,438	$0.688
503	700	Product Storage & Denat	$0.530	Utilities		
504	800	Utilities & General	$0.000	Electricity/ Energy	190	$0.038
505	810	Boiler	$4.152	Water	0	$0.000
506	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
507	830	Environmental	$0.000	VARIABLE COST TO	3,628	$0.726
508	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
509	900	Enzyme Production	$1.429			
510				Operators	357	$0.071
511	1000	Total Fixed Capital	$33.724	Laborers	235	$0.047
512				Technicians	49	$0.010
513	1010	Contingency	$3.372	Maintenance	188	$0.038
514	1020	Startup	$1.686	Fringe Benefits	207	$0.041
515	1030	Working Capital	$2.529	TOTAL LABOR	1,037	$0.207
516				Property Tax & Insur.	620	$0.124
517		TOTAL CAPITAL	$41.312	TOTAL CASH	5,658	$1.132
518				Depreciation	1,239	$0.248
519				Interest	0	$0.000
520						
521				TOTAL PRODUCTIO	6,897	$1.379
522		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
523		Contingency	10.00%	BIOMASS COST 1	$50.00	
524		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
525		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
526		Operating Days per Year	330	Denaturant Use	5%	
527		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
528		Property Tax & Insurance	1.50%	preciation period (yrs)	30	
529		BIOMASS COST 1				

	AG	AH	AI	AJ	AK	AL
447			BIOMASS COST 2			
448			STAKETECH ESTIMATED BASE COSTS			
449	Plant	814	Biomass C	$109.00	Ratio of orig	1.00
450	Ethan	25	Scaling of o	1.00		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
452	100	Biomass Preparation	$0.450	Biomass	29,280	$1.171
453	200	Pretreatment	$18.673	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
455	300	Hydrolysis	$12.709	Acid	0	$0.000
456	400	Fermentation (Unallocated	$19.217	Ammonia	37	#VALUE!
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	642	$0.026
459	500	Distillation & Dehydration	$12.479	Yeast	317	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
461	610	Stillage Evaporation	$2.805	RAW MATERIALS TOTA	31,393	$1.256
462	700	Product Storage & Denatu	$1.635	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$12.572	Water	0	$0.000
465	820	Non Boiler Utilities	$9.151	By products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TOTA	31,393	$1.256
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
468	900	Enzyme Production	$0.000			
469				Operators	1,520	$0.061
470	1000	Total Fixed Capital	$89.691	Laborers	1,000	$0.040
471				Technicians	210	$0.008
472	1010	Contingency	$8.969	Maintenance	800	$0.032
473	1020	Startup	$4.485	Fringe Benefits	883	$0.035
474	1030	Working Capital	$6.727	TOTAL LABOR	4,413	$0.177
475				Property Tax & Insur.	1,648	$0.066
476		TOTAL CAPITAL	$109.871	TOTAL CASH	39,043	$1.562
477				Depreciation	3,296	$0.132
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTION	42,339	$1.694
481		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
488			BIOMASS COST 2			
489			BIOENERGY ESTIMATED BASE COSTS			
490	Plant	838	Biomass C	$109.00	Ratio of orig	1.00
491	Ethan	25	Scaling of o	1.00		
492	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
493	100	Biomass Preparation	$0.640	Biomass	30,143	$1.206
494	200	Pretreatment	$18.630	Chemicals		
495	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
496	300	Hydrolysis	$15.280	Acid	0	$0.000
497	400	Fermentation (Unallocated	$22.820	Ammonia	202	$0.008
498	410	Hexose Fermentation	$0.000	Nutrients	1,053	$0.042
499	420	Pentose Fermentation	$0.000	Enzymes	673	$0.027
500	500	Distillation & Dehydration	$12.190	Yeast	317	$0.013
501	600	By-Product Preparation	$0.000	Other Chemicals	30	$0.001
502	610	Stillage Evaporation	$6.280	RAW MATERIALS TOTA	33,505	$1.340
503	700	Product Storage & Denatu	$1.634	Utilities		
504	800	Utilities & General	$0.000	Electricity/ Energy	950	$0.038
505	810	Boiler	$12.810	Water	0	$0.000
506	820	Non Boiler Utilities	$9.151	By products	0	$0.000
507	830	Environmental	$0.000	VARIABLE COST TOTA	34,455	$1.378
508	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
509	900	Enzyme Production	$4.410			
510				Operators	1,520	$0.061
511	1000	Total Fixed Capital	$104.045	Laborers	1,000	$0.040
512				Technicians	210	$0.008
513	1010	Contingency	$10.405	Maintenance	800	$0.032
514	1020	Startup	$5.202	Fringe Benefits	883	$0.035
515	1030	Working Capital	$7.803	TOTAL LABOR	4,413	$0.177
516				Property Tax & Insur.	1,912	$0.076
517		TOTAL CAPITAL	$127.455	TOTAL CASH	42,369	$1.695
518				Depreciation	3,824	$0.153
519				Interest	0	$0.000
520						
521				TOTAL PRODUCTION	46,183	$1.848
522		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
523		Contingency	10.00%	BIOMASS COST 1	$50.00	
524		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
525		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
526		Operating Days per Year	330	Denaturant Use	5%	
527		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
528		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
529			BIOMASS COST 2			

	AM	AN	AO	AP	AQ	AR
447			BIOMASS COST 2			
448			STAKETECH ESTIMATED BASE COSTS			
449	Plant	162.8	Biomass C	$109.00	Ratio of ori	0.20
450	Ethan	5	Scaling of	0.32		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
452	100	Biomass Preparation	$0.146	Biomass	5,856	$1.171
453	200	Pretreatment	$6.063	Chemicals		
454	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
455	300	Hydrolysis	$4.119	Acid	0	$0.000
456	400	Fermentation (Unallocated)	$6.229	Ammonia	7	$0.001
457	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
458	420	Pentose Fermentation	$0.000	Enzymes	128	$0.026
459	500	Distillation & Dehydration	$4.045	Yeast	63	$0.013
460	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
461	610	Stillage Evaporation	$0.909	RAW MATERIALS TOTAL	6,279	$1.256
462	700	Product Storage & Denatur	$0.530	Utilities		
463	800	Utilities & General	$0.000	Electricity/ Energy	0	$0.000
464	810	Boiler	$4.075	Water	0	$0.000
465	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
466	830	Environmental	$0.000	VARIABLE COST TOTAL	6,279	$1.256
467	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
468	900	Enzyme Production	$0.000			
469				Operators	357	$0.071
470	1000	Total Fixed Capital	$29.072	Laborers	235	$0.047
471				Technicians	49	$0.010
472	1010	Contingency	$2.907	Maintenance	188	$0.038
473	1020	Startup	$1.454	Fringe Benefits	207	$0.041
474	1030	Working Capital	$2.180	TOTAL LABOR	1,037	$0.207
475				Property Tax & Insur.	534	$0.107
476		TOTAL CAPITAL	$35.613	TOTAL CASH	8,223	$1.645
477				Depreciation	1,068	$0.214
478				Interest	0	$0.000
479						
480				TOTAL PRODUCTION	9,291	$1.858
481		Power Law Scaling Factor	0.7	PROCESS COST ONLY (B	$0.00	
482		Contingency	10.00%	BIOMASS COST 1	$50.00	
483		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
484		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
485		Operating Days per Year	330	Denaturant Use	5%	
486		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
487		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
488			BIOMASS COST 2			
489			BIOENERGY ESTIMATED BASE COSTS			
490	Plant	167.6	Biomass C	$109.00	Ratio of ori	0.20
491	Ethan	5	Scaling of	0.32		
492	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
493	100	Biomass Preparation	$0.207	Biomass	6,029	$1.206
494	200	Pretreatment	$6.103	Chemicals		
495	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
496	300	Hydrolysis	$4.953	Acid	0	$0.000
497	400	Fermentation (Unallocated)	$7.397	Ammonia	40	$0.008
498	410	Hexose Fermentation	$0.000	Nutrients	211	$0.042
499	420	Pentose Fermentation	$0.000	Enzymes	135	$0.027
500	500	Distillation & Dehydration	$3.951	Yeast	63	$0.013
501	600	By-Product Preparation	$0.000	Other Chemicals	6	$0.001
502	610	Stillage Evaporation	$2.036	RAW MATERIALS TOTAL	6,701	$1.340
503	700	Product Storage & Denatur	$0.530	Utilities		
504	800	Utilities & General	$0.000	Electricity/ Energy	190	$0.038
505	810	Boiler	$4.152	Water	0	$0.000
506	820	Non-Boiler Utilities	$2.966	By-products	0	$0.000
507	830	Environmental	$0.000	VARIABLE COST TOTAL	6,891	$1.378
508	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
509	900	Enzyme Production	$1.429			
510				Operators	357	$0.071
511	1000	Total Fixed Capital	$33.724	Laborers	235	$0.047
512				Technicians	49	$0.010
513	1010	Contingency	$3.372	Maintenance	188	$0.038
514	1020	Startup	$1.686	Fringe Benefits	207	$0.041
515	1030	Working Capital	$2.529	TOTAL LABOR	1,037	$0.207
516				Property Tax & Insur.	620	$0.124
517		TOTAL CAPITAL	$41.312	TOTAL CASH	8,921	$1.784
518				Depreciation	1,239	$0.248
519				Interest	0	$0.000
520						
521				TOTAL PRODUCTION	10,160	$2.032
522		Power Law Scaling Factor	0.7	PROCESS COST ONLY (B	$0.00	
523		Contingency	10.00%	BIOMASS COST 1	$50.00	
524		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
525		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
526		Operating Days per Year	330	Denaturant Use	5%	
527		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
528		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	
529			BIOMASS COST 2			

AS	AT	AU	AV	AW	AX	AY
			COSTS AS PERCENTAGE OF TOTAL			
			STAKETECH ESTIMATED BASE COSTS			
		Ethanol Production (MM gal/yr)	25	Biomass Cost/ton	$50.00	
	AREA	CAPITAL COSTS	% of capital cos	PRODUCTION COST	Thous $/Yr	of $/gallon c
	100	Biomass Preparation	0.4%	Biomass	0	38.2%
	200	Pretreatment	17.0%	Chemicals	0	0.0%
	210	Recycle & Recovery	0.0%	Denaturant	1088	5.2%
	300	Hydrolysis	11.6%	Acid	0	0.0%
	400	Fermentation	17.5%	Ammonia	37	0.2%
	410	Hexose Fermentation	0.0%	Nutrients	0	0.0%
	420	Pentose Fermentation	0.0%	Enzymes	642	3.0%
	500	Distillation& Dehydration	11.4%	Yeast	317	1.5%
	600	By-Product Preparation	0.0%	Other Chemicals	30	0.1%
	610	Stillage Evaporation	2.6%	RAW MATERIALS T	10173	48.2%
	700	Product Storage & Denature	1.5%	Utilities	0	0.0%
	800	Utilities & General	0.0%	Electricity/ Energy	0	0.0%
	810	Boiler	11.4%	Water	0	0.0%
	820	Non-Boiler Utilities	8.3%	By-products	0	0.0%
	830	Environmental	0.0%	VARIABLE COST T	10173	48.2%
	840	Miscellaneous & Control	0.0%	GEN & ADMIN	1590	7.5%
	900	Enzyme Production	0.0%			
				Operators	1520	7.2%
		Total Installed Equipment	81.6%	Laborers	1000	4.7%
				Technicians	210	1.0%
		Fixed Capital	81.6%	Maintenance	800	3.8%
	0.1	Miscellaneous	8.2%	Fringe Benefits	883	4.2%
	0.05	Start-up Costs	4.1%	TOTAL LABOR	4413	20.9%
	0.075	Working capital	6.1%	Property Tax & Insur	1648	7.8%
				TOTAL CASH	17823	84.4%
		TOTAL CAPITAL	100.0%	Depreciation	3296	15.6%
				Interest	0	0.0%
				TOTAL PRODUCTI	21119	100.0%
			COSTS AS PERCENTAGE OF TOTAL			
			BIOENERGY ESTIMATED BASE COSTS			
		Ethanol Production (MM gal/yr)	25	Biomass Cost/ton	$50.00	
	AREA	CAPITAL COSTS	% of capital cos	PRODUCTION COST	Thous $/Yr	of $/gallon c
	100	Biomass Preparation	0.5%	Biomass	0	34.1%
	200	Pretreatment	14.8%	Chemicals	0	0.0%
	210	Recycle & Recovery	0.0%	Denaturant	1088	4.5%
	300	Hydrolysis	12.0%	Acid	0	0.0%
	400	Fermentation	17.9%	Ammonia	202	0.8%
	410	Hexose Fermentation	0.0%	Nutrients	1053	4.3%
	420	Pentose Fermentation	0.0%	Enzymes	673	2.8%
	500	Distillation& Dehydration	9.6%	Yeast	317	1.3%
	600	By-Product Preparation	0.0%	Other Chemicals	30	0.1%
	610	Stillage Evaporation	4.9%	RAW MATERIALS T	11660	47.9%
	700	Product Storage & Denature	1.3%	Utilities	0	0.0%
	800	Utilities & General	0.0%	Electricity/ Energy	950	3.9%
	810	Boiler	10.1%	Water	0	0.0%
	820	Non-Boiler Utilities	7.2%	By-products	0	0.0%
	830	Environmental	0.0%	VARIABLE COST T	12611	51.8%
	840	Miscellaneous & Control	0.0%	GEN & ADMIN	1590	6.5%
	900	Enzyme Production	3.5%			
				Operators	1520	6.2%
		Total Installed Equipment	81.6%	Laborers	1000	4.1%
				Technicians	210	0.9%
		Fixed Capital	81.6%	Maintenance	800	3.3%
	0.1	Miscellaneous	8.2%	Fringe Benefits	883	3.6%
	0.05	Start-up Costs	4.1%	TOTAL LABOR	4413	18.1%
	0.075	Working capital	6.1%	Property Tax & Insur	1912	7.9%
				TOTAL CASH	20525	84.3%
		TOTAL CAPITAL	100.0%	Depreciation	3824	15.7%
				Interest	0	0.0%
				TOTAL PRODUCTI	24349	100.0%

	I	J	K	L	M	N
529	PROCESS COST ONLY (BIOMASS $0)					
530	ARKENOL ESTIMATED BASE COSTS					
531	Plant I	833	Biomass (	$0.00	Ratio of c	1.00
532	Ethanc	25	Scaling of	1.00		
533	AREA	CAPITAL COSTS	Million $	RODUCTION COST	hous $/Y	$/gal
534	100	Biomass Preparation	$2.806	Biomass	0	$0.000
535	200	Pretreatment	$0.000	Chemicals		
536	210	Recovery & Recycle	$20.270	Denaturant	1,088	$0.044
537	300	Hydrolysis	$10.250	Acid	315	$0.013
538	400	Fermentation (Unallocated	$5.611	Ammonia	0	$0.000
539	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
540	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
541	500	Distillation & Dehydration	$11.924	Yeast	100	$0.004
542	600	By-Product Preparation	$0.000	Other Chemicals	13,206	$0.528
543	610	Stillage Evaporation	$0.000	RAW MATERIALS T	14,709	$0.588
544	700	Product Storage & Denatu	$1.403	Utilities		
545	800	Utilities & General	$0.000	Electricity/ Energy	8,865	$0.355
546	810	Boiler	$2.104	Water	0	$0.000
547	820	Non-Boiler Utilities	$4.208	By-products	(6,506)	($0.26)
548	830	Environmental	$0.000	VARIABLE COST T	17,068	$0.683
549	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
550	900	Enzyme Production	$0.000			
551				Operators	511	$0.020
552	1000	Total Fixed Capital	$58.576	Laborers	458	$0.018
553				Technicians	197	$0.008
554	1010	Contingency	$5.858	Maintenance	72	$0.003
555	1020	Startup	$2.929	Fringe Benefits	310	$0.012
556	1030	Working Capital	$4.393	TOTAL LABOR	1,548	$0.062
557				Property Tax & Insur	1,076	$0.043
558		TOTAL CAPITAL	$71.756	TOTAL CASH	21,279	$0.851
559				Depreciation	2,153	$0.086
560				Interest	0	$0.000
561						
562				TOTAL PRODUCTI	23,432	$0.937
563		Power Law Scaling Factor	0.7	PROCESS COST O	$0.00	
564		Contingency	10.00%	BIOMASS COST 1	$50.00	
565		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
566		Working Capital	7.50%	enaturant Cost, $/gal	$0.87	
567		Operating Days per Year	330	Denaturant Use	5%	
568		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
569		Property Tax & Insurance	1.50%	reciation period (yrs)	30	
570	PROCESS COST ONLY (BIOMASS $0)					
571	PASZNER TECHNOLOGY ESTIMATED BASE COSTS					
572	Plant I	779	Biomass (	$0.00	Ratio of c	1.50
573	Ethanc	25	Scaling of	1.33		
574	AREA	CAPITAL COSTS	Million $	RODUCTION COST	hous $/Y	$/gal
575	100	Biomass Preparation	$2.455	Biomass	0	$0.000
576	200	Pretreatment	$21.518	Chemicals		
577	210	Recovery & Recycle	$3.069	Denaturant	1,088	$0.044
578	300	Hydrolysis	$6.675	Acid	389	$0.016
579	400	Fermentation (Unallocated	$2.685	Ammonia	0	$0.000
580	410	Hexose Fermentation	$0.000	Nutrients	130	$0.005
581	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
582	500	Distillation & Dehydration	$5.371	Yeast	331	$0.013
583	600	By-Product Preparation	$1.841	Other Chemicals	1,236	$0.049
584	610	Stillage Evaporation	$0.000	RAW MATERIALS T	3,174	$0.127
585	700	Product Storage & Denatu	$1.228	Utilities		
586	800	Utilities & General	$1.995	Electricity/ Energy	4,932	$0.197
587	810	Boiler	$18.414	Water	0	$0.000
588	820	Non-Boiler Utilities	$0.000	By-products	0	$0.000
589	830	Environmental	$0.000	VARIABLE COST T	8,106	$0.324
590	840	Miscellaneous & Control	$6.560	GEN & ADMIN	1,590	$0.064
591	900	Enzyme Production	$0.000			
592				Operators	1,584	$0.063
593	1000	Total Fixed Capital	$71.812	Laborers	1,042	$0.042
594				Technicians	219	$0.009
595	1010	Contingency	$7.181	Maintenance	833	$0.033
596	1020	Startup	$3.591	Fringe Benefits	919	$0.037
597	1030	Working Capital	$5.386	TOTAL LABOR	4,597	$0.184
598				Property Tax & Insur	1,320	$0.053
599		TOTAL CAPITAL	$87.970	TOTAL CASH	15,612	$0.624
600				Depreciation	2,639	$0.106
601				Interest	0	$0.000
602						
603				TOTAL PRODUCTI	18,251	$0.730
604		Power Law Scaling Factor	0.7	PROCESS COST O	$0.00	
605		Contingency	10.00%	BIOMASS COST 1	$50.00	
606		Start up factor	5.00%	BIOMASS COST 2	$109.00	
607		Working Capital	7.50%	enaturant Cost, $/gal	$0.87	
608		Operating Days per Year	330	Denaturant Use	5%	
609		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
610		Property Tax & Insurance	1.50%	reciation period (yrs)	30	

	O	P	Q	R	S	T
529	PROCESS COST ONLY (BIOMASS $0)					
530	ARKENOL ESTIMATED BASE COSTS					
531	Plant	166.6	Biomass	$0.00	Ratio of c	0.20
532	Ethan	5	Scaling of	0.32		
533	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	hous $/Y	$/gal
534	100	Biomass Preparation	$0.910	Biomass	0	$0.000
535	200	Pretreatment	$0.000	Chemicals		
536	210	Recovery & Recycle	$6.570	Denaturant	218	$0.044
537	300	Hydrolysis	$3.322	Acid	63	$0.013
538	400	Fermentation (Unallocate	$1.819	Ammonia	0	$0.000
539	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
540	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
541	500	Distillation & Dehydration	$3.865	Yeast	20	$0.004
542	600	By-Product Preparation	$0.000	Other Chemicals	2,641	$0.528
543	610	Stillage Evaporation	$0.000	RAW MATERIALS TO	2,942	$0.588
544	700	Product Storage & Dena	$0.455	Utilities		
545	800	Utilities & General	$0.000	Electricity/ Energy	1,773	$0.355
546	810	Boiler	$0.682	Water	0	$0.000
547	820	Non-Boiler Utilities	$1.364	By-products	(1,302)	($0.26)
548	830	Environmental	$0.000	VARIABLE COST TOT	3,413	$0.683
549	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
550	900	Enzyme Production	$0.000			
551				Operators	120	$0.024
552	1000	Total Fixed Capital	$18.986	Laborers	108	$0.022
553				Technicians	46	$0.009
554	1010	Contingency	$1.899	Maintenance	17	$0.003
555	1020	Startup	$0.949	Fringe Benefits	73	$0.015
556	1030	Working Capital	$1.424	TOTAL LABOR	364	$0.073
557				Property Tax & Insur.	349	$0.070
558		TOTAL CAPITAL	$23.256	TOTAL CASH	4,499	$0.900
559				Depreciation	698	$0.140
560				Interest	0	$0.000
561						
562				TOTAL PRODUCTION	5,197	$1.039
563		Power Law Scaling Factor	0.7	PROCESS COST ONL	$0.00	
564		Contingency	10.00%	BIOMASS COST 1	$50.00	
565		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
566		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
567		Operating Days per Year	330	Denaturant Use	5%	
568		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
569		Property Tax & Insurance	1.50%	epreciation period (yrs)	30	
570	PROCESS COST ONLY (BIOMASS $0)					
571	PASZNER TECHNOLOGY ESTIMATED BASE COSTS					
572	Plant	155.795116	Biomass	$0.00	Ratio of c	0.30
573	Ethan	5	Scaling of	0.43		
574	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	hous $/Y	$/gal
575	100	Biomass Preparation	$0.796	Biomass	0	$0.000
576	200	Pretreatment	$6.976	Chemicals		
577	210	Recovery & Recycle	$0.995	Denaturant	218	$0.044
578	300	Hydrolysis	$2.164	Acid	78	$0.016
579	400	Fermentation (Unallocate	$0.870	Ammonia	0	$0.000
580	410	Hexose Fermentation	$0.000	Nutrients	26	$0.005
581	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
582	500	Distillation & Dehydration	$1.741	Yeast	66	$0.013
583	600	By-Product Preparation	$0.597	Other Chemicals	247	$0.049
584	610	Stillage Evaporation	$0.000	RAW MATERIALS TO	635	$0.127
585	700	Product Storage & Dena	$0.398	Utilities		
586	800	Utilities & General	$0.647	Electricity/ Energy	986	$0.197
587	810	Boiler	$5.969	Water	0	$0.000
588	820	Non-Boiler Utilities	$0.000	By-products	0	$0.000
589	830	Environmental	$0.000	VARIABLE COST TOT	1,621	$0.324
590	840	Miscellaneous & Control	$2.126	GEN & ADMIN	374	$0.075
591	900	Enzyme Production	$0.000			
592				Operators	372	$0.074
593	1000	Total Fixed Capital	$23.277	Laborers	245	$0.049
594				Technicians	51	$0.010
595	1010	Contingency	$2.328	Maintenance	196	$0.009
596	1020	Startup	$1.164	Fringe Benefits	216	$0.043
597	1030	Working Capital	$1.746	TOTAL LABOR	1,080	$0.216
598				Property Tax & Insur.	428	$0.086
599		TOTAL CAPITAL	$28.514	TOTAL CASH	3,502	$0.700
600				Depreciation	855	$0.171
601				Interest	0	$0.000
602						
603				TOTAL PRODUCTION	4,358	$0.872
604		Power Law Scaling Factor	0.7	PROCESS COST ONL	$0.00	
605		Contingency	10.00%	BIOMASS COST 1	$50.00	
606		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
607		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
608		Operating Days per Year	330	Denaturant Use	5%	
609		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
610		Property Tax & Insurance	1.50%	epreciation period (yrs)	30	

	U	V	W	X	Y	Z
529	BIOMASS COST 1					
530	ARKENOL ESTIMATED BASE COSTS					
531	Plant	833	Biomass C	$50.00	Ratio of o	1.00
532	Ethan	25	Scaling of	1.00		
533	AREA	CAPITAL COSTS	Million $	RODUCTION COSTS	hous $/Y	$/gal
534	100	Biomass Preparation	$2.806	Biomass	13,745	$0.550
535	200	Pretreatment	$0.000	Chemicals		
536	210	Recovery & Recycle	$20.270	Denaturant	1,088	$0.044
537	300	Hydrolysis	$10.250	Acid	315	$0.013
538	400	Fermentation (Unallocat	$5.611	Ammonia	0	$0.000
539	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
540	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
541	500	Distillation & Dehydration	$11.924	Yeast	100	$0.004
542	600	By-Product Preparation	$0.000	Other Chemicals	13,206	$0.528
543	610	Stillage Evaporation	$0.000	RAW MATERIALS TC	28,453	$1.138
544	700	Product Storage & Dena	$1.403	Utilities		
545	800	Utilities & General	$0.000	Electricity/ Energy	8,865	$0.355
546	810	Boiler	$2.104	Water	0	$0.000
547	820	Non-Boiler Utilities	$4.208	By-products	(6,506)	($0.26)
548	830	Environmental	$0.000	VARIABLE COST TO	30,610	$1.232
549	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
550	900	Enzyme Production	$0.000			
551				Operators	511	$0.020
552	1000	Total Fixed Capital	$58.576	Laborers	458	$0.018
553				Technicians	197	$0.008
554	1010	Contingency	$5.858	Maintenance	72	$0.003
555	1020	Startup	$2.929	Fringe Benefits	310	$0.012
556	1030	Working Capital	$4.393	TOTAL LABOR	1,548	$0.062
557				Property Tax & Insur.	1,076	$0.043
558		TOTAL CAPITAL	$71.756	TOTAL CASH	35,024	$1.401
559				Depreciation	2,153	$0.086
560				Interest	0	$0.000
561						
562				TOTAL PRODUCTIO	37,177	$1.487
563		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
564		Contingency	10.00%	BIOMASS COST 1	$50.00	
565		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
566		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
567		Operating Days per Year	330	Denaturant Use	5%	
568		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
569		Property Tax & Insurance	1.50%	preciation period (yrs)	30	
570	BIOMASS COST 1					
571	PASZNER TECHNOLOGY ESTIMATED BASE COSTS					
572	Plant	779	Biomass C	$50.00	Ratio of o	1.50
573	Ethan	25	Scaling of	1.33		
574	AREA	CAPITAL COSTS	Million $	RODUCTION COSTS	hous $/Y	$/gal
575	100	Biomass Preparation	$2.455	Biomass	12,853	$0.514
576	200	Pretreatment	$21.518	Chemicals		
577	210	Recovery & Recycle	$3.069	Denaturant	1,088	$0.044
578	300	Hydrolysis	$6.675	Acid	389	$0.016
579	400	Fermentation (Unallocat	$2.685	Ammonia	0	$0.000
580	410	Hexose Fermentation	$0.000	Nutrients	130	$0.005
581	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
582	500	Distillation & Dehydration	$5.371	Yeast	331	$0.013
583	600	By-Product Preparation	$1.841	Other Chemicals	1,236	$0.049
584	610	Stillage Evaporation	$0.000	RAW MATERIALS TC	16,027	$0.641
585	700	Product Storage & Den	$1.228	Utilities		
586	800	Utilities & General	$1.995	Electricity/ Energy	4,932	$0.197
587	810	Boiler	$18.414	Water	0	$0.000
588	820	Non-Boiler Utilities	$0.000	By-products	0	$0.000
589	830	Environmental	$0.000	VARIABLE COST TO	20,959	$0.838
590	840	Miscellaneous & Control	$6.560	GEN & ADMIN	1,590	$0.064
591	900	Enzyme Production	$0.000			
592				Operators	1,584	$0.063
593	1000	Total Fixed Capital	$71.812	Laborers	1,042	$0.042
594				Technicians	219	$0.009
595	1010	Contingency	$7.181	Maintenance	833	$0.033
596	1020	Startup	$3.591	Fringe Benefits	919	$0.037
597	1030	Working Capital	$5.386	TOTAL LABOR	4,597	$0.184
598				Property Tax & Insur.	1,320	$0.053
599		TOTAL CAPITAL	$87.970	TOTAL CASH	28,465	$1.139
600				Depreciation	2,639	$0.106
601				Interest	0	$0.000
602						
603				TOTAL PRODUCTIO	31,104	$1.244
604		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
605		Contingency	10.00%	BIOMASS COST 1	$50.00	
606		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
607		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
608		Operating Days per Year	330	Denaturant Use	5%	
609		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
610		Property Tax & Insurance	1.50%	preciation period (yrs)	30	

	AA	AB	AC	AD	AE	AF
529	BIOMASS COST 1					
530	ARKENOL ESTIMATED BASE COSTS					
531	Plant	166.6	Biomass (	$50.00	Ratio of o	0.20
532	Ethan	5	Scaling of	0.32		
533	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	hous $/Y	$/gal
534	100	Biomass Preparation	$0.910	Biomass	2,749	$0.550
535	200	Pretreatment	$0.000	Chemicals		
536	210	Recovery & Recycle	$6.570	Denaturant	218	$0.044
537	300	Hydrolysis	$3.322	Acid	63	$0.013
538	400	Fermentation (Unallocated	$1.819	Ammonia	0	$0.000
539	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
540	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
541	500	Distillation & Dehydration	$3.865	Yeast	20	$0.004
542	600	By-Product Preparation	$0.000	Other Chemicals	2,641	$0.528
543	610	Stillage Evaporation	$0.000	RAW MATERIALS TO	5,691	$1.138
544	700	Product Storage & Denal	$0.455	Utilities		
545	800	Utilities & General	$0.000	Electricity/ Energy	1,773	$0.355
546	810	Boiler	$0.682	Water	0	$0.000
547	820	Non-Boiler Utilities	$1.364	By-products	(1,302)	($0.26)
548	830	Environmental	$0.000	VARIABLE COST TO	6,182	$1.232
549	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
550	900	Enzyme Production	$0.000			
551				Operators	120	$0.024
552	1000	Total Fixed Capital	$18.986	Laborers	108	$0.022
553				Technicians	46	$0.009
554	1010	Contingency	$1.899	Maintenance	17	$0.003
555	1020	Startup	$0.949	Fringe Benefits	73	$0.015
556	1030	Working Capital	$1.424	TOTAL LABOR	364	$0.073
557				Property Tax & Insur.	349	$0.070
558		TOTAL CAPITAL	$23.256	TOTAL CASH	7,246	$1.450
559				Depreciation	698	$0.140
560				Interest	0	$0.000
561						
562				TOTAL PRODUCTIO	7,946	$1.589
563		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
564		Contingency	10.00%	BIOMASS COST 1	$50.00	
565		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
566		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
567		Operating Days per Year	330	Denaturant Use	5%	
568		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
569		Property Tax & Insurance	1.50%	preciation period (yrs)	30	
570	BIOMASS COST 1					
571	PASZNER TECHNOLOGY ESTIMATED BASE COSTS					
572	Plant	155.795116	Biomass (	$50.00	Ratio of or	0.30
573	Ethan	5	Scaling of	0.43		
574	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
575	100	Biomass Preparation	$0.796	Biomass	2,571	$0.514
576	200	Pretreatment	$6.976	Chemicals		
577	210	Recovery & Recycle	$0.995	Denaturant	218	$0.044
578	300	Hydrolysis	$2.164	Acid	78	$0.016
579	400	Fermentation (Unallocated	$0.870	Ammonia	0	$0.000
580	410	Hexose Fermentation	$0.000	Nutrients	26	$0.005
581	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
582	500	Distillation & Dehydration	$1.741	Yeast	66	$0.013
583	600	By-Product Preparation	$0.597	Other Chemicals	247	$0.049
584	610	Stillage Evaporation	$0.000	RAW MATERIALS TC	3,205	$0.641
585	700	Product Storage & Denal	$0.398	Utilities		
586	800	Utilities & General	$0.647	Electricity/ Energy	986	$0.197
587	810	Boiler	$5.969	Water	0	$0.000
588	820	Non-Boiler Utilities	$0.000	By-products	0	$0.000
589	830	Environmental	$0.000	VARIABLE COST TO	4,192	$0.838
590	840	Miscellaneous & Control	$2.126	GEN & ADMIN	374	$0.075
591	900	Enzyme Production	$0.000			
592				Operators	372	$0.074
593	1000	Total Fixed Capital	$23.277	Laborers	245	$0.049
594				Technicians	51	$0.010
595	1010	Contingency	$2.328	Maintenance	196	$0.009
596	1020	Startup	$1.164	Fringe Benefits	216	$0.043
597	1030	Working Capital	$1.746	TOTAL LABOR	1,080	$0.216
598				Property Tax & Insur.	428	$0.086
599		TOTAL CAPITAL	$28.514	TOTAL CASH	6,073	$1.215
600				Depreciation	855	$0.171
601				Interest	0	$0.000
602						
603				TOTAL PRODUCTIO	6,928	$1.386
604		Power Law Scaling Factor	0.7	PROCESS COST ON	$0.00	
605		Contingency	10.00%	BIOMASS COST 1	$50.00	
606		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
607		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
608		Operating Days per Year	330	Denaturant Use	5%	
609		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
610		Property Tax & Insurance	1.50%	preciation period (yrs)	30	

	AG	AH	AI	AJ	AK	AL
528	BIOMASS COST 2					
530	ARKENOL ESTIMATED BASE COSTS					
531	Plant	833	Biomass C	$109.00	Ratio of orig	1.00
532	Ethan	25	Scaling of o	1.00		
533	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
534	100	Biomass Preparation	$2.806	Biomass	29,963	$1.199
535	200	Pretreatment	$0.000	Chemicals		
536	210	Recovery & Recycle	$20.270	Denaturant	1,088	$0.044
537	300	Hydrolysis	$10.250	Acid	315	$0.013
538	400	Fermentation (Unallocated	$5.611	Ammonia	0	$0.000
539	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
540	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
541	500	Distillation & Dehydration	$11.924	Yeast	100	$0.004
542	600	By Product Preparation	$0.000	Other Chemicals	13,206	$0.528
543	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTA	44,672	$1.787
544	700	Product Storage & Denatu	$1.403	Utilities		
545	800	Utilities & General	$0.000	Electricity/ Energy	8,865	$0.355
546	810	Boiler	$2.104	Water	0	$0.000
547	820	Non Boiler Utilities	$4.208	By products	(6,508)	($0.26)
548	830	Environmental	$0.000	VARIABLE COST TOTAL	47,029	$1.881
549	840	Miscellaneous & Control	$0.000	GEN & ADMIN	1,590	$0.064
550	900	Enzyme Production	$0.000			
551				Operators	511	$0.020
552	1000	Total Fixed Capital	$58.576	Laborers	458	$0.018
553				Technicians	197	$0.008
554	1010	Contingency	$5.858	Maintenance	72	$0.003
555	1020	Startup	$2.929	Fringe Benefits	310	$0.012
556	1030	Working Capital	$4.393	TOTAL LABOR	1,548	$0.062
557				Property Tax & Insur.	1,076	$0.043
558		TOTAL CAPITAL	$71.756	TOTAL CASH	51,242	$2.050
559				Depreciation	2,153	$0.086
560				Interest	0	$0.000
561						
562				TOTAL PRODUCTION	53,395	$2.136
563		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
564		Contingency	10.00%	BIOMASS COST 1	$50.00	
565		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
566		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
567		Operating Days per Year	330	Denaturant Use	5%	
568		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
569		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AM	AN	AO	AP	AQ	AR
528	BIOMASS COST 2					
530	ARKENOL ESTIMATED BASE COSTS					
531	Plant	166.6	Biomass C	$109.00	Ratio of ori	0.20
532	Ethan	5	Scaling of	0.32		
533	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
534	100	Biomass Preparation	$0.910	Biomass	5,993	$1.199
535	200	Pretreatment	$0.000	Chemicals		
536	210	Recovery & Recycle	$6.670	Denaturant	218	$0.044
537	300	Hydrolysis	$3.322	Acid	63	$0.013
538	400	Fermentation (Unallocated)	$1.819	Ammonia	0	$0.000
539	410	Hexose Fermentation	$0.000	Nutrients	0	$0.000
540	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
541	500	Distillation & Dehydration	$3.865	Yeast	20	$0.004
542	600	By-Product Preparation	$0.000	Other Chemicals	2,641	$0.528
543	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	8,934	$1.787
544	700	Product Storage & Denatur	$0.455	Utilities		
545	800	Utilities & General	$0.000	Electricity/ Energy	1,773	$0.355
546	810	Boiler	$0.682	Water	0	$0.000
547	820	Non-Boiler Utilities	$1.364	By-products	(1,302)	($0.26)
548	830	Environmental	$0.000	VARIABLE COST TOTAL	9,406	$1.881
549	840	Miscellaneous & Control	$0.000	GEN & ADMIN	374	$0.075
550	900	Enzyme Production	$0.000			
551				Operators	120	$0.024
552	1000	Total Fixed Capital	$18.986	Laborers	108	$0.022
553				Technicians	46	$0.009
554	1010	Contingency	$1.899	Maintenance	17	$0.003
555	1020	Startup	$0.949	Fringe Benefits	73	$0.015
556	1030	Working Capital	$1.424	TOTAL LABOR	364	$0.073
557				Property Tax & Insur.	349	$0.070
558		TOTAL CAPITAL	$23.258	TOTAL CASH	10,492	$2.098
559				Depreciation	698	$0.140
560				Interest	0	$0.000
561						
562				TOTAL PRODUCTION	11,189	$2.238
563		Power Law Scaling Factor	0.7	PROCESS COST ONLY (B	$0.00	
564		Contingency	10.00%	BIOMASS COST 1	$50.00	
565		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
566		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
567		Operating Days per Year	330	Denaturant Use	5%	
568		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
569		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AT	AU	AV	AW	AX	AY
530	COSTS AS PERCENTAGE OF TOTAL					
531	ARKENOL ESTIMATED BASE COSTS					
532		Ethanol Production (MM gal/yr)	25	Biomass Cost/ton	$50.00	
533	AREA	CAPITAL COSTS	% of capital cos	PRODUCTION COST	Thous $/Yr	of $/gallon c
534	100	Biomass Preparation	3.9%	Biomass	0	22.2%
535	200	Pretreatment	0.0%	Chemicals	0	0.0%
536	210	Recycle & Recovery	28.2%	Denaturant	886	3.0%
537	300	Hydrolysis	14.3%	Acid	315	1.1%
538	400	Fermentation	7.8%	Ammonia	0	0.0%
539	410	Hexose Fermentation	0.0%	Nutrients	0	0.0%
540	420	Pentose Fermentation	0.0%	Enzymes	0	0.0%
541	500	Distillation& Dehydration	16.6%	Yeast	100	0.3%
542	600	By-Product Preparation	0.0%	Other Chemicals	13206	44.2%
543	610	Stillage Evaporation	0.0%	RAW MATERIALS T	21153	70.8%
544	700	Product Storage & Denature	2.0%	Utilities	0	0.0%
545	800	Utilities & General	0.0%	Electricity/ Energy	8865	29.7%
546	810	Boiler	2.9%	Water	0	0.0%
547	820	Non-Boiler Utilities	5.9%	By-products	-6508	-21.8%
548	830	Environmental	0.0%	VARIABLE COST T	23510	78.7%
549	840	Miscellaneous & Control	0.0%	GEN & ADMIN	1590	5.3%
550	900	Enzyme Production	0.0%			
551				Operators	511	1.7%
552		Total Installed Equipment	81.6%	Laborers	458	1.5%
553				Technicians	197	0.7%
554		Fixed Capital	81.6%	Maintenance	72	0.2%
555	0.1	Miscellaneous	8.2%	Fringe Benefits	310	1.0%
556	0.05	Start-up Costs	4.1%	TOTAL LABOR	1548	5.2%
557	0.075	Working capital	6.1%	Property Tax & Insur	1076	3.6%
558				TOTAL CASH	27724	92.8%
559		TOTAL CAPITAL	100.0%	Depreciation	2153	7.2%
560				Interest	0	0.0%
562				TOTAL PRODUCTI	29877	100.0%

	AG	AH	AI	AJ	AK	AL
570	BIOMASS COST 2					
571	PASZNER TECHNOLOGY ESTIMATED BASE COSTS					
572	Plant	779	Biomass C	$109.00	Ratio of orig	1.50
573	Ethan	25	Scaling of o	1.33		
574	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
575	100	Biomass Preparation	$2.455	Biomass	28,020	$1.121
576	200	Pretreatment	$21.518	Chemicals		
577	210	Recovery & Recycle	$3.069	Denaturant	1,088	$0.044
578	300	Hydrolysis	$6.675	Acid	389	#VALUE!
579	400	Fermentation (Unallocated	$2.685	Ammonia	0	#VALUE!
580	410	Hexose Fermentation	$0.000	Nutrients	130	$0.005
581	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
582	500	Distillation & Dehydration	$5.371	Yeast	331	$0.013
583	600	By Product Preparation	$1.841	Other Chemicals	1,236	$0.049
584	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTA	31,194	$1.248
585	700	Product Storage & Denat	$1.228	Utilities		
586	800	Utilities & General	$1.995	Electricity/ Energy	4,932	$0.197
587	810	Boiler	$18.414	Water	0	$0.000
588	820	Non Boiler Utilities	$0.000	By products	0	$0.000
589	830	Environmental	$0.000	VARIABLE COST TOTAL	36,126	$1.445
590	840	Miscellaneous & Control	$6.560	GEN & ADMIN	1,590	$0.064
591	900	Enzyme Production	$0.000			
592				Operators	1,584	$0.063
593	1000	Total Fixed Capital	$71.612	Laborers	1,042	$0.042
594				Technicians	219	$0.009
595	1010	Contingency	$7.161	Maintenance	833	$0.033
596	1020	Startup	$3.591	Fringe Benefits	919	$0.037
597	1030	Working Capital	$5.386	TOTAL LABOR	4,597	$0.184
598				Property Tax & Insur.	1,320	$0.053
599		TOTAL CAPITAL	$87.970	TOTAL CASH	43,632	$1.745
600				Depreciation	2,639	$0.106
601				Interest	0	$0.000
602						
603				TOTAL PRODUCTION	46,271	$1.851
604		Power Law Scaling Factor	0.7	PROCESS COST ONLY	$0.00	
605		Contingency	10.00%	BIOMASS COST 1	$50.00	
606		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
607		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
608		Operating Days per Year	330	Denaturant Use	5%	
609		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
610		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AM	AN	AO	AP	AQ	AR
570	BIOMASS COST 2					
571	PASZNER TECHNOLOGY ESTIMATED BASE COSTS					
572	Plant	155.795115	Biomass C	$109.00	Ratio of ori	0.30
573	Ethan	5	Scaling of	0.43		
574	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Y	$/gal
575	100	Biomass Preparation	$0.796	Biomass	5,604	$1.121
576	200	Pretreatment	$6.975	Chemicals		
577	210	Recovery & Recycle	$0.995	Denaturant	218	$0.044
578	300	Hydrolysis	$2.164	Acid	78	$0.016
579	400	Fermentation (Unallocated)	$0.870	Ammonia	0	$0.000
580	410	Hexose Fermentation	$0.000	Nutrients	26	$0.005
581	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
582	500	Distillation & Dehydration	$1.741	Yeast	66	$0.013
583	600	By-Product Preparation	$0.597	Other Chemicals	247	$0.049
584	610	Stillage Evaporation	$0.000	RAW MATERIALS TOTAL	6,239	$1.248
585	700	Product Storage & Denatur	$0.398	Utilities		
586	800	Utilities & General	$0.647	Electricity/ Energy	986	$0.197
587	810	Boiler	$5.969	Water	0	$0.000
588	820	Non-Boiler Utilities	$0.000	By-products	0	$0.000
589	830	Environmental	$0.000	VARIABLE COST TOTAL	7,225	$1.445
590	840	Miscellaneous & Control	$2.126	GEN & ADMIN	374	$0.075
591	900	Enzyme Production	$0.000			
592				Operators	372	$0.074
593	1000	Total Fixed Capital	$23.277	Laborers	245	$0.049
594				Technicians	51	$0.010
595	1010	Contingency	$2.328	Maintenance	196	$0.039
596	1020	Startup	$1.164	Fringe Benefits	216	$0.043
597	1030	Working Capital	$1.746	TOTAL LABOR	1,080	$0.216
598				Property Tax & Insur	428	$0.086
599		TOTAL CAPITAL	$28.514	TOTAL CASH	9,106	$1.821
600				Depreciation	855	$0.171
601				Interest	0	$0.000
602						
603				TOTAL PRODUCTION	9,962	$1.892
604		Power Law Scaling Factor	0.7	PROCESS COST ONLY (B	$0.00	
605		Contingency	10.00%	BIOMASS COST 1	$50.00	
606		Start-up factor	5.00%	BIOMASS COST 2	$109.00	
607		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
608		Operating Days per Year	330	Denaturant Use	5%	
609		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
610		Property Tax & Insurance	1.50%	Depreciation period (yrs)	30	

	AT	AU	AV	AW	AX	AY
571	COSTS AS PERCENTAGE OF TOTAL					
572	PASZNER TECHNOLOGY ESTIMATED BASE COSTS					
573		Ethanol Production (MM gal/yr)	17	Biomass Cost/ton	$50.00	
574	AREA	CAPITAL COSTS	% of capital cos	PRODUCTION COST	Thous $/Yr	of $/gallon c
575	100	Biomass Preparation	2.8%	Biomass	0	6.3%
576	200	Pretreatment	24.5%	Chemicals	0	0.0%
577	210	Recycle & Recovery	3.5%	Denaturant	60	0.5%
578	300	Hydrolysis	7.6%	Acid	260	2.0%
579	400	Fermentation	3.1%	Ammonia	0	0.0%
580	410	Hexose Fermentation	0.0%	Nutrients	87	0.7%
581	420	Pentose Fermentation	0.0%	Enzymes	0	0.0%
582	500	Distillation& Dehydration	6.1%	Yeast	222	1.7%
583	600	By-Product Preparation	2.1%	Other Chemicals	827	6.4%
584	610	Stillage Evaporation	0.0%	RAW MATERIALS T	2264	17.5%
585	700	Product Storage & Denature	1.4%	Utilities	0	0.0%
586	800	Utilities & General	2.3%	Electricity/ Energy	3299	25.6%
587	810	Boiler	20.9%	Water	0	0.0%
588	820	Non-Boiler Utilities	0.0%	By-products	0	0.0%
589	830	Environmental	0.0%	VARIABLE COST T	5563	43.1%
590	840	Miscellaneous & Control	7.5%	GEN & ADMIN	1153	8.9%
591	900	Enzyme Production	0.0%			
592				Operators	1103	8.5%
593		Total Installed Equipment	81.6%	Laborers	725	5.6%
594				Technicians	152	1.2%
595		Fixed Capital	81.6%	Maintenance	580	4.5%
596	0.1	Miscellaneous	8.2%	Fringe Benefits	640	5.0%
597	0.05	Start-up Costs	4.1%	TOTAL LABOR	3201	24.8%
598	0.075	Working capital	6.1%	Property Tax & Insur	996	7.7%
599				TOTAL CASH	10913	84.6%
600		TOTAL CAPITAL	100.0%	Depreciation	1992	15.4%
601				Interest	0	0.0%
603				TOTAL PRODUCTI	12904	100.0%

	I	J	K	L	M	N	O	P	Q	R	S	T
447	=$C$311						=$C$311					
448	=$C448						=$C448					
449	=$C$320	=D449/D450*J450	=$C$310	=M481	Ratio of orig. to pro	=J450/$D450	=$C$320	=J449/J450*P450	=$C$310	=S481	Ratio of orig. to pro	=P450/$D450
450	=$C$321	=$D$322	Scaling of original dat	=(J450/$D450)^K481			=$C$321	=$D$321	Scaling of original d	=(P450/$D450)^Q481		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
452	100	Biomass Preparation	=$E452*L450	Biomass	=J449*K485*L449/	=M452/(J450*100	100	Biomass Preparation	=$E452*R450	Biomass	=P449*Q485*R449	=S452/(P450*1000
453	200	Pretreatment	=$E453*L450	Chemicals			200	Pretreatment	=$E453*R450	Chemicals		
454	210	Recovery & Recycle	=$E454*L450	Denaturant	=J450*M484*M485	=M454/(J450*100	210	Recovery & Recycle	=$E454*R450	Denaturant	=P450*S484*S485	=S454/(P450*1000
455	300	Hydrolysis	=$E455*L450	Acid	=$G455*N449	=M455/(J450*100	300	Hydrolysis	=$E455*R450	Acid	=$G455*T449	=S455/(P450*1000
456	400	Fermentation (Unallocated)	=$E456*L450	Ammonia	=$G456*N449	=M456/(J450*100	400	Fermentation (Unallocated)	=$E456*R450	Ammonia	=$G456*T449	=S456/(P450*1000
457	410	Hexose Fermentation	=$E457*L450	Nutrients	=$G457*N449	=M457/(J450*100	410	Hexose Fermentation	=$E457*R450	Nutrients	=$G457*T449	=S457/(P450*1000
458	420	Pentose Fermentation	=$E458*L450	Enzymes	=$G458*N449	=M458/(J450*100	420	Pentose Fermentation	=$E458*R450	Enzymes	=$G458*T449	=S458/(P450*1000
459	500	Distillation & Dehydration	=$E459*L450	Yeast	=$G459*N449	=M459/(J450*100	500	Distillation & Dehydration	=$E459*R450	Yeast	=$G459*T449	=S459/(P450*1000
460	600	By-Product Preparation	=$E460*L450	Other Chemicals	=$G460*N449	=M460/(J450*100	600	By-Product Preparation	=$E460*R450	Other Chemicals	=$G460*T449	=S460/(P450*1000
461	610	Stillage Evaporation	=$E461*L450	RAW MATERIALS TOTAL	=SUM(M452:M460)	=M461/(J450*100	610	Stillage Evaporation	=$E461*R450	RAW MATERIALS TOTAL	=SUM(S452:S460)	=S461/(P450*1000
462	700	Product Storage & Denature	=$E462*L450	Utilities			700	Product Storage & Denature	=$E462*R450	Utilities		
463	800	Utilities & General	=$E463*L450	Electricity/ Energy	=$G463*N449	=M463/(J450*100	800	Utilities & General	=$E463*R450	Electricity/ Energy	=$G463*T449	=S463/(P450*1000
464	810	Boiler	=$E464*L450	Water	=$G464*N449	=M464/(J450*100	810	Boiler	=$E464*R450	Water	=$G464*T449	=S464/(P450*1000
465	820	Non-Boiler Utilities	=$E465*L450	By-products	=$G465*N449	=M465/(J450*100	820	Non-Boiler Utilities	=$E465*R450	By-products	=$G465*T449	=S465/(P450*1000
466	830	Environmental	=$E466*L450	VARIABLE COST TOTAL	=SUM(M461:M465)	=M466/(J450*100	830	Environmental	=$E466*R450	VARIABLE COST TOTAL	=SUM(S461:S465)	=S466/(P450*1000
467	840	Miscellaneous & Control	=$E467*L450	GEN & ADMIN	=1590*(J450/25)^K	=M467/(J450*100	840	Miscellaneous & Control	=$E467*R450	GEN & ADMIN	=1590*(P450/25)^(	=S467/(P450*1000
468	900	Enzyme Production	=$E468*L450				900	Enzyme Production	=$E468*R450			
469				Operators	=$G469*N449^K48	=M469/(J450*100				Operators	=$G469*T449^Q48	=S469/(P450*1000
470	1000	Total Fixed Capital	=SUM(K451:K469)	Laborers	=$G470*(N449)^K4	=M470/(J450*100	1000	Total Fixed Capital	=SUM(Q451:Q469)	Laborers	=$G470*(T449)^Q4	=S470/(P450*1000
471				Technicians	=$G471*(N449)^K4	=M471/(J450*100				Technicians	=$G471*(T449)^Q4	=S471/(P450*1000
472	1010	Contingency	=K470*K482	Maintenance	=$G472*(N449)^K4	=M472/(J450*100	1010	Contingency	=Q470*Q482	Maintenance	=$G472*(T449)^Q4	=S472/(P450*1000
473	1020	Startup	=K470*K483	Fringe Benefits	=M486*SUM(M469	=M473/(J450*100	1020	Startup	=Q470*Q483	Fringe Benefits	=S486*SUM(S469	=S473/(P450*1000
474	1030	Working Capital	=K470*K484	TOTAL LABOR	=SUM(M469:M473)	=M474/(J450*100	1030	Working Capital	=Q470*Q484	TOTAL LABOR	=SUM(S469:S473)	=S474/(P450*1000
475				Property Tax & Insur.	=K487*K476*1000	=M475/(J450*100				Property Tax & Insur.	=Q487*Q476*1000	=S475/(P450*1000
476		TOTAL CAPITAL	=SUM(K470:K475)	TOTAL CASH	=M466+M467+M47	=M476/(J450*100		TOTAL CAPITAL	=SUM(Q470:Q475)	TOTAL CASH	=S466+S467+S47	=S476/(P450*1000
477				Depreciation	=SLN((K476*1000)	=M477/(J450*100				Depreciation	=SLN((Q476*1000)	=S477/(P450*1000
478				Interest	=K476*1000*$D$3	=M478/(J450*100				Interest	=Q476*1000*$D$3	=S478/(P450*1000
479												
480				TOTAL PRODUCTION	=M476+M477+M47	=M480/(J450*100				TOTAL PRODUCTION	=S476+S477+S47	=S480/(P450*1000
481		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
482		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
483		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
484		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
485		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
486		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
487		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
488	=$C$311						=$C$311					
489	=$C489						=$C489					
490	=$C$320	=D490/D491*J491	=$C$310	=M522	Ratio of orig. to pro	=J491/$D491	=$C$320	=J490/J491*P491	=$C$310	=S522	Ratio of orig. to pro	=P491/$D491
491	=$C$321	=$D$322	Scaling of original dat	=(J491/$D491)^K522			=$C$321	=$D$321	Scaling of original d	=(P491/$D491)^Q522		
492	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
493	100	Biomass Preparation	=$E493*L491	Biomass	=J490*K526*L490/	=M493/(J491*100	100	Biomass Preparation	=$E493*R491	Biomass	=P490*Q526*R490	=S493/(P491*1000
494	200	Pretreatment	=$E494*L491	Chemicals			200	Pretreatment	=$E494*R491	Chemicals		
495	210	Recovery & Recycle	=$E495*L491	Denaturant	=J491*M525*M526	=M495/(J491*100	210	Recovery & Recycle	=$E495*R491	Denaturant	=P491*S525*S526	=S495/(P491*1000
496	300	Hydrolysis	=$E496*L491	Acid	=$G496*N490	=M496/(J491*100	300	Hydrolysis	=$E496*R491	Acid	=$G496*T490	=S496/(P491*1000
497	400	Fermentation (Unallocated)	=$E497*L491	Ammonia	=$G497*N490	=M497/(J491*100	400	Fermentation (Unallocated)	=$E497*R491	Ammonia	=$G497*T490	=S497/(P491*1000
498	410	Hexose Fermentation	=$E498*L491	Nutrients	=$G498*N490	=M498/(J491*100	410	Hexose Fermentation	=$E498*R491	Nutrients	=$G498*T490	=S498/(P491*1000
499	420	Pentose Fermentation	=$E499*L491	Enzymes	=$G499*N490	=M499/(J491*100	420	Pentose Fermentation	=$E499*R491	Enzymes	=$G499*T490	=S499/(P491*1000
500	500	Distillation & Dehydration	=$E500*L491	Yeast	=$G500*N490	=M500/(J491*100	500	Distillation & Dehydration	=$E500*R491	Yeast	=$G500*T490	=S500/(P491*1000
501	600	By-Product Preparation	=$E501*L491	Other Chemicals	=$G501*N490	=M501/(J491*100	600	By-Product Preparation	=$E501*R491	Other Chemicals	=$G501*T490	=S501/(P491*1000
502	610	Stillage Evaporation	=$E502*L491	RAW MATERIALS TOTAL	=SUM(M493:M501)	=M502/(J491*100	610	Stillage Evaporation	=$E502*R491	RAW MATERIALS TOTAL	=SUM(S493:S501)	=S502/(P491*1000
503	700	Product Storage & Denature	=$E503*L491	Utilities			700	Product Storage & Denature	=$E503*R491	Utilities		
504	800	Utilities & General	=$E504*L491	Electricity/ Energy	=$G504*N490	=M504/(J491*100	800	Utilities & General	=$E504*R491	Electricity/ Energy	=$G504*T490	=S504/(P491*1000
505	810	Boiler	=$E505*L491	Water	=$G505*N490	=M505/(J491*100	810	Boiler	=$E505*R491	Water	=$G505*T490	=S505/(P491*1000
506	820	Non-Boiler Utilities	=$E506*L491	By-products	=$G506*N490	=M506/(J491*100	820	Non-Boiler Utilities	=$E506*R491	By-products	=$G506*T490	=S506/(P491*1000
507	830	Environmental	=$E507*L491	VARIABLE COST TOTAL	=SUM(M502:M506)	=M507/(J491*100	830	Environmental	=$E507*R491	VARIABLE COST TOTAL	=SUM(S502:S506)	=S507/(P491*1000
508	840	Miscellaneous & Control	=$E508*L491	GEN & ADMIN	=1590*(J491/25)^K	=M508/(J491*100	840	Miscellaneous & Control	=$E508*R491	GEN & ADMIN	=1590*(P491/25)^(	=S508/(P491*1000
509	900	Enzyme Production	=$E509*L491				900	Enzyme Production	=$E509*R491			
510				Operators	=$G510*N490^K52	=M510/(J491*100				Operators	=$G510*T490^Q52	=S510/(P491*1000
511	1000	Total Fixed Capital	=SUM(K492:K510)	Laborers	=$G511*(N490)^K5	=M511/(J491*100	1000	Total Fixed Capital	=SUM(Q492:Q510)	Laborers	=$G511*(T490)^Q5	=S511/(P491*1000
512				Technicians	=$G512*(N490)^K5	=M512/(J491*100				Technicians	=$G512*(T490)^Q5	=S512/(P491*1000
513	1010	Contingency	=K511*K523	Maintenance	=$G513*(N490)^K5	=M513/(J491*100	1010	Contingency	=Q511*Q523	Maintenance	=$G513*(T490)^Q5	=S513/(P491*1000
514	1020	Startup	=K511*K524	Fringe Benefits	=M527*SUM(M510	=M514/(J491*100	1020	Startup	=Q511*Q524	Fringe Benefits	=S527*SUM(S510	=S514/(P491*1000
515	1030	Working Capital	=K511*K525	TOTAL LABOR	=SUM(M510:M514)	=M515/(J491*100	1030	Working Capital	=Q511*Q525	TOTAL LABOR	=SUM(S510:S514)	=S515/(P491*1000
516				Property Tax & Insur.	=K528*K517*1000	=M516/(J491*100				Property Tax & Insur.	=Q528*Q517*1000	=S516/(P491*1000
517		TOTAL CAPITAL	=SUM(K511:K516)	TOTAL CASH	=M507+M508+M51	=M517/(J491*100		TOTAL CAPITAL	=SUM(Q511:Q516)	TOTAL CASH	=S507+S508+S51	=S517/(P491*1000
518				Depreciation	=SLN((K517*1000)	=M518/(J491*100				Depreciation	=SLN((Q517*1000)	=S518/(P491*1000
519				Interest	=K517*1000*$D$3	=M519/(J491*100				Interest	=Q517*1000*$D$3	=S519/(P491*1000
520												
521				TOTAL PRODUCTION	=M517+M518+M51	=M521/(J491*100				TOTAL PRODUCTION	=S517+S518+S51	=S521/(P491*1000
522		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
523		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
524		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
525		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
526		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
527		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
528		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
447	=$C$312						=$C$312					
448	=$C448						=$C448					
449	=$C$320	=P449/P450*V450	=$C$310	=Y482	Ratio of orig. to prop	=V450/$D450	=$C$320	=V449/V450*AB450	=$C$310	=AE482	Ratio of orig. to proposed s	=AB450/$D450
450	=$C$321	=$D$322	Scaling of original data	=(V450/$D450)*W481			=$C$321	=$D$321	Scaling of original dat	=(AB450/$D450)*AC481		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
452	100	Biomass Preparation	=$E452*X450	Biomass	=V449*W485*X449/	=Y452/(V450*1000)	100	Biomass Preparation	=$E452*AD450	Biomass	=AB449*AC485*AD449/10	=AE452/(AB450*1000)
453	200	Pretreatment	=$E453*X450	Chemicals			200	Pretreatment	=$E453*AD450	Chemicals		
454	210	Recovery & Recycle	=$E454*X450	Denaturant	=V450*Y484*Y485*1	=Y454/(V450*1000)	210	Recovery & Recycle	=$E454*AD450	Denaturant	=AB450*AE484*AE485*10	=AE454/(AB450*1000)
455	300	Hydrolysis	=$E455*X450	Acid	=$G455*Z449	=Y455/(V450*1000)	300	Hydrolysis	=$E455*AD450	Acid	=$G455*AF449	=AE455/(AB450*1000)
456	400	Fermentation (Unallocated)	=$E456*X450	Ammonia	=$G456*Z449	=Y456/(V450*1000)	400	Fermentation (Unallocated)	=$E456*AD450	Ammonia	=$G456*AF449	=AE456/(AB450*1000)
457	410	Hexose Fermentation	=$E457*X450	Nutrients	=$G457*Z449	=Y457/(V450*1000)	410	Hexose Fermentation	=$E457*AD450	Nutrients	=$G457*AF449	=AE457/(AB450*1000)
458	420	Pentose Fermentation	=$E458*X450	Enzymes	=$G458*Z449	=Y458/(V450*1000)	420	Pentose Fermentation	=$E458*AD450	Enzymes	=$G458*AF449	=AE458/(AB450*1000)
459	500	Distillation & Dehydration	=$E459*X450	Yeast	=$G459*Z449	=Y459/(V450*1000)	500	Distillation & Dehydration	=$E459*AD450	Yeast	=$G459*AF449	=AE459/(AB450*1000)
460	600	By-Product Preparation	=$E460*X450	Other Chemicals	=$G460*Z449	=Y460/(V450*1000)	600	By-Product Preparation	=$E460*AD450	Other Chemicals	=$G460*AF449	=AE460/(AB450*1000)
461	610	Stillage Evaporation	=$E461*X450	RAW MATERIALS TOTAL	=SUM(Y452:Y460)	=Y461/(V450*1000)	610	Stillage Evaporation	=$E461*AD450	RAW MATERIALS TOTA	=SUM(AE452:AE460)	=AE461/(AB450*1000)
462	700	Product Storage & Denature	=$E462*X450	Utilities			700	Product Storage & Denature	=$E462*AD450	Utilities		
463	800	Utilities & General	=$E463*X450	Electricity/ Energy	=$G463*Z449	=Y463/(V450*1000)	800	Utilities & General	=$E463*AD450	Electricity/ Energy	=$G463*AF449	=AE463/(AB450*1000)
464	810	Boiler	=$E464*X450	Water	=$G464*Z449	=Y464/(V450*1000)	810	Boiler	=$E464*AD450	Water	=$G464*AF449	=AE464/(AB450*1000)
465	820	Non-Boiler Utilities	=$E465*X450	By-products	=$G465*Z449	=Y465/(V450*1000)	820	Non-Boiler Utilities	=$E465*AD450	By-products	=$G465*AF449	=AE465/(AB450*1000)
466	830	Environmental	=$E466*X450	VARIABLE COST TOTAL	=SUM(Y461:Y465)	=Y466/(V450*1000)	830	Environmental	=$E466*AD450	VARIABLE COST TOTAL	=SUM(AE461:AE465)	=AE466/(AB450*1000)
467	840	Miscellaneous & Control	=$E467*X450	GEN & ADMIN	=1590*(V450/25)^W	=Y467/(V450*1000)	840	Miscellaneous & Control	=$E467*AD450	GEN & ADMIN	=1590*(AB450/25)^AC486	=AE467/(AB450*1000)
468	900	Enzyme Production	=$E468*X450				900	Enzyme Production	=$E468*AD450			
469				Operators	=$G469*Z449^W48	=Y469/(V450*1000)				Operators	=$G469*AF449^AC486	=AE469/(AB450*1000)
470	1000	Total Fixed Capital	=SUM(W451:W469)	Laborers	=$G470*(Z449)^W4	=Y470/(V450*1000)	1000	Total Fixed Capital	=SUM(AC451:AC469	Laborers	=$G470*(AF449)^AC486	=AE470/(AB450*1000)
471				Technicians	=$G471*(Z449)^W4	=Y471/(V450*1000)				Technicians	=$G471*(AF449)^AC486	=AE471/(AB450*1000)
472	1010	Contingency	=W470*W482	Maintenance	=$G472*(Z449)^W4	=Y472/(V450*1000)	1010	Contingency	=AC470*AC482	Maintenance	=$G472*(AF449)^AC486	=AE472/(AB450*1000)
473	1020	Startup	=W470*W483	Fringe Benefits	=Y486*SUM(Y469:Y	=Y473/(V450*1000)	1020	Startup	=AC470*AC483	Fringe Benefits	=AE486*SUM(AE469:AE4	=AE473/(AB450*1000)
474	1030	Working Capital	=W470*W484	TOTAL LABOR	=SUM(Y469:Y473)	=Y474/(V450*1000)	1030	Working Capital	=AC470*AC484	TOTAL LABOR	=SUM(AE469:AE473)	=AE474/(AB450*1000)
475				Property Tax & Insur.	=W487*W476*1000	=Y475/(V450*1000)				Property Tax & Insur.	=AC487*AC476*1000	=AE475/(AB450*1000)
476		TOTAL CAPITAL	=SUM(W470:W475)	TOTAL CASH	=Y466+Y467+Y474+	=Y476/(V450*1000)		TOTAL CAPITAL	=SUM(AC470:AC475	TOTAL CASH	=AE466+AE467+AE474+A	=AE476/(AB450*1000)
477				Depreciation	=SLN((W476*1000),	=Y477/(V450*1000)				Depreciation	=SLN((AC476*1000),(D	=AE477/(AB450*1000)
478				Interest	=W476*1000*$D$31	=Y478/(V450*1000)				Interest	=AC476*1000*$D$319	=AE478/(AB450*1000)
479												
480				TOTAL PRODUCTION	=Y476+Y477+Y478	=Y480/(V450*1000)				TOTAL PRODUCTION	=AE476+AE477+AE478	=AE480/(AB450*1000)
481		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
482		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
483		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
484		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
485		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
486		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
487		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
488	=$C$312						=$C$312					
489	=$C489						=$C489					
490	=$C$320	=P490/P491*V491	=$C$310	=Y523	Ratio of orig. to prop	=V491/$D491	=$C$320	=V490/V491*AB491	=$C$310	=AE523	Ratio of orig. to proposed s	=AB491/$D491
491	=$C$321	=$D$322	Scaling of original data	=(V491/$D491)*W522			=$C$321	=$D$321	Scaling of original dat	=(AB491/$D491)*AC522		
492	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
493	100	Biomass Preparation	=$E493*X491	Biomass	=V490*W526*X490/	=Y493/(V491*1000)	100	Biomass Preparation	=$E493*AD491	Biomass	=AB490*AC526*AD490/10	=AE493/(AB491*1000)
494	200	Pretreatment	=$E494*X491	Chemicals			200	Pretreatment	=$E494*AD491	Chemicals		
495	210	Recovery & Recycle	=$E495*X491	Denaturant	=V491*Y525*Y526*1	=Y495/(V491*1000)	210	Recovery & Recycle	=$E495*AD491	Denaturant	=AB491*AE525*AE526*10	=AE495/(AB491*1000)
496	300	Hydrolysis	=$E496*X491	Acid	=$G496*Z490	=Y496/(V491*1000)	300	Hydrolysis	=$E496*AD491	Acid	=$G496*AF490	=AE496/(AB491*1000)
497	400	Fermentation (Unallocated)	=$E497*X491	Ammonia	=$G497*Z490	=Y497/(V491*1000)	400	Fermentation (Unallocated)	=$E497*AD491	Ammonia	=$G497*AF490	=AE497/(AB491*1000)
498	410	Hexose Fermentation	=$E498*X491	Nutrients	=$G498*Z490	=Y498/(V491*1000)	410	Hexose Fermentation	=$E498*AD491	Nutrients	=$G498*AF490	=AE498/(AB491*1000)
499	420	Pentose Fermentation	=$E499*X491	Enzymes	=$G499*Z490	=Y499/(V491*1000)	420	Pentose Fermentation	=$E499*AD491	Enzymes	=$G499*AF490	=AE499/(AB491*1000)
500	500	Distillation & Dehydration	=$E500*X491	Yeast	=$G500*Z490	=Y500/(V491*1000)	500	Distillation & Dehydration	=$E500*AD491	Yeast	=$G500*AF490	=AE500/(AB491*1000)
501	600	By-Product Preparation	=$E501*X491	Other Chemicals	=$G501*Z490	=Y501/(V491*1000)	600	By-Product Preparation	=$E501*AD491	Other Chemicals	=$G501*AF490	=AE501/(AB491*1000)
502	610	Stillage Evaporation	=$E502*X491	RAW MATERIALS TOTAL	=SUM(Y493:Y501)	=Y502/(V491*1000)	610	Stillage Evaporation	=$E502*AD491	RAW MATERIALS TOTA	=SUM(AE493:AE501)	=AE502/(AB491*1000)
503	700	Product Storage & Denature	=$E503*X491	Utilities			700	Product Storage & Denature	=$E503*AD491	Utilities		
504	800	Utilities & General	=$E504*X491	Electricity/ Energy	=$G504*Z490	=Y504/(V491*1000)	800	Utilities & General	=$E504*AD491	Electricity/ Energy	=$G504*AF490	=AE504/(AB491*1000)
505	810	Boiler	=$E505*X491	Water	=$G505*Z490	=Y505/(V491*1000)	810	Boiler	=$E505*AD491	Water	=$G505*AF490	=AE505/(AB491*1000)
506	820	Non-Boiler Utilities	=$E506*X491	By-products	=$G506*Z490	=Y506/(V491*1000)	820	Non-Boiler Utilities	=$E506*AD491	By-products	=$G506*AF490	=AE506/(AB491*1000)
507	830	Environmental	=$E507*X491	VARIABLE COST TOTAL	=SUM(Y502:Y506)	=Y507/(V491*1000)	830	Environmental	=$E507*AD491	VARIABLE COST TOTAL	=SUM(AE502:AE506)	=AE507/(AB491*1000)
508	840	Miscellaneous & Control	=$E508*X491	GEN & ADMIN	=1590*(V491/25)^W	=Y508/(V491*1000)	840	Miscellaneous & Control	=$E508*AD491	GEN & ADMIN	=1590*(AB491/25)^AC527	=AE508/(AB491*1000)
509	900	Enzyme Production	=$E509*X491				900	Enzyme Production	=$E509*AD491			
510				Operators	=$G510*Z490^W527	=Y510/(V491*1000)				Operators	=$G510*AF490^AC527	=AE510/(AB491*1000)
511	1000	Total Fixed Capital	=SUM(W492:W510)	Laborers	=$G511*(Z490)^W5	=Y511/(V491*1000)	1000	Total Fixed Capital	=SUM(AC492:AC510	Laborers	=$G511*(AF490)^AC527	=AE511/(AB491*1000)
512				Technicians	=$G512*(Z490)^W5	=Y512/(V491*1000)				Technicians	=$G512*(AF490)^AC527	=AE512/(AB491*1000)
513	1010	Contingency	=W511*W523	Maintenance	=$G513*(Z490)^W5	=Y513/(V491*1000)	1010	Contingency	=AC511*AC523	Maintenance	=$G513*(AF490)^AC527	=AE513/(AB491*1000)
514	1020	Startup	=W511*W524	Fringe Benefits	=Y527*SUM(Y510:Y	=Y514/(V491*1000)	1020	Startup	=AC511*AC524	Fringe Benefits	=AE527*SUM(AE510:AE5	=AE514/(AB491*1000)
515	1030	Working Capital	=W511*W525	TOTAL LABOR	=SUM(Y510:Y514)	=Y515/(V491*1000)	1030	Working Capital	=AC511*AC525	TOTAL LABOR	=SUM(AE510:AE514)	=AE515/(AB491*1000)
516				Property Tax & Insur.	=W528*W517*1000	=Y516/(V491*1000)				Property Tax & Insur.	=AC528*AC517*1000	=AE516/(AB491*1000)
517		TOTAL CAPITAL	=SUM(W511:W516)	TOTAL CASH	=Y507+Y508+Y515+	=Y517/(V491*1000)		TOTAL CAPITAL	=SUM(AC511:AC516	TOTAL CASH	=AE507+AE508+AE515+A	=AE517/(AB491*1000)
518				Depreciation	=SLN((W517*1000),	=Y518/(V491*1000)				Depreciation	=SLN((AC517*1000),(D	=AE518/(AB491*1000)
519				Interest	=W517*1000*$D$31	=Y519/(V491*1000)				Interest	=AC517*1000*$D$319	=AE519/(AB491*1000)
520												
521				TOTAL PRODUCTION	=Y517+Y518+Y519	=Y521/(V491*1000)				TOTAL PRODUCTION	=AE517+AE518+AE519	=AE521/(AB491*1000)
522		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
523		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
524		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
525		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
526		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
527		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
528		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
447	=$C$313						=$C$31					
448	=$C448						=$C448					
449	=$C$320	=AB449/AB450*AH450	=$C$310	=AK483	Ratio of orig. to proposed	=AH450/$D450	=$C$32	=AH449/AH450*AN450	=$C$310	=AO483	Ratio of orig. to propos	=AN450/$D450
450	=$C$321	=$D$322	Scaling of original d	=(AH450/$D450)*AI481			=$C$32	=$D$321	Scaling of origin	=(AN450/$D450)*AO481		
451	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
452	100	Biomass Preparation	=$E452*AJ450	Biomass	=AH449*AI485*AJ449/10	=AK452/(AH450*1000)	100	Biomass Preparation	=$E452*AP450	Biomass	=AN449*AO485*AP44	=AO452/(AN450*1000)
453	200	Pretreatment	=$E453*AJ450	Chemicals			200	Pretreatment	=$E453*AP450	Chemicals		
454	210	Recovery & Recycle	=$E454*AJ450	Denaturant	=AH450*AK484*AK485*1	=AK454/(AH450*1000)	210	Recovery & Recycle	=$E454*AP450	Denaturant	=AN450*AO484*AO48	=AO454/(AN450*1000)
455	300	Hydrolysis	=$E455*AJ450	Acid	=$G455*AL449	=AK455/(AH450*1000)	300	Hydrolysis	=$E455*AP450	Acid	=$G455*AR449	=AO455/(AN450*1000)
456	400	Fermentation (Unallocated)	=$E456*AJ450	Ammonia	=$G456*AL449	=AK457/(AH451*1000)	400	Fermentation (Unallocated)	=$E456*AP450	Ammonia	=$G456*AR449	=AO456/(AN450*1000)
457	410	Hexose Fermentation	=$E457*AJ450	Nutrients	=$G457*AL449	=AK457/(AH450*1000)	410	Hexose Fermentation	=$E457*AP450	Nutrients	=$G457*AR449	=AO457/(AN450*1000)
458	420	Pentose Fermentation	=$E458*AJ450	Enzymes	=$G458*AL449	=AK458/(AH450*1000)	420	Pentose Fermentation	=$E458*AP450	Enzymes	=$G458*AR449	=AO458/(AN450*1000)
459	500	Distillation & Dehydration	=$E459*AJ450	Yeast	=$G459*AL449	=AK459/(AH450*1000)	500	Distillation & Dehydration	=$E459*AP450	Yeast	=$G459*AR449	=AO459/(AN450*1000)
460	600	By Product Preparation	=$E460*AJ450	Other Chemicals	=$G460*AL449	=AK460/(AH450*1000)	600	By Product Preparation	=$E460*AP450	Other Chemicals	=$G460*AR449	=AO460/(AN450*1000)
461	610	Stillage Evaporation	=$E461*AJ450	RAW MATERIALS TOTAL	=SUM(AK452:AK460)	=AK461/(AH450*1000)	610	Stillage Evaporation	=$E461*AP450	RAW MATERIALS TOTAL	=SUM(AO452:AO460)	=AO461/(AN450*1000)
462	700	Product Storage & Denaturd	=$E462*AJ450	Utilities			700	Product Storage & Denature	=$E462*AP450	Utilities		
463	800	Utilities & General	=$E463*AJ450	Electricity/ Energy	=$G463*AL449	=AK463/(AH450*1000)	800	Utilities & General	=$E463*AP450	Electricity/ Energy	=$G463*AR449	=AO463/(AN450*1000)
464	810	Boiler	=$E464*AJ450	Water	=$G464*AL449	=AK464/(AH450*1000)	810	Boiler	=$E464*AP450	Water	=$G464*AR449	=AO464/(AN450*1000)
465	820	Non Boiler Utilities	=$E465*AJ450	By-products	=$G465*AL449	=AK465/(AH450*1000)	820	Non Boiler Utilities	=$E465*AP450	By-products	=$G465*AR449	=AO465/(AN450*1000)
466	830	Environmental	=$E466*AJ450	VARIABLE COST TOTAL	=SUM(AK461:AK465)	=AK466/(AH450*1000)	830	Environmental	=$E466*AP450	VARIABLE COST TOTAL	=SUM(AO461:AO465)	=AO466/(AN450*1000)
467	840	Miscellaneous & Control	=$E467*AJ450	GEN & ADMIN	=1590*(AH450/25)*AI486	=AK467/(AH450*1000)	840	Miscellaneous & Control	=$E467*AP450	GEN & ADMIN	=1590*(AN450/25)*AO	=AO467/(AN450*1000)
468	900	Enzyme Production	=$E468*AJ450				900	Enzyme Production	=$E468*AP450			
469				Operators	=$G469*AL449*AI486	=AK469/(AH450*1000)				Operators	=$G469*AR449*AO48	=AO469/(AN450*1000)
470	1000	Total Fixed Capital	=SUM(AI451:AI469	Laborers	=$G470*(AL449)*AI486	=AK470/(AH450*1000)	1000	Total Fixed Capital	=SUM(AO451:A	Laborers	=$G470*(AR449)*AO4	=AO470/(AN450*1000)
471				Technicians	=$G471*(AL449)*AI486	=AK471/(AH450*1000)				Technicians	=$G471*(AR449)*AO4	=AO471/(AN450*1000)
472	1010	Contingency	=AI470*AI482	Maintenance	=$G472*(AL449)*AI486	=AK472/(AH450*1000)	1010	Contingency	=AO470*AO482	Maintenance	=$G472*(AR449)*AO4	=AO472/(AN450*1000)
473	1020	Startup	=AI470*AI483	Fringe Benefits	=AK486*SUM(AK469:AK	=AK473/(AH450*1000)	1020	Startup	=AO470*AO483	Fringe Benefits	=AO486*SUM(AO469:	=AO473/(AN450*1000)
474	1030	Working Capital	=AI470*AI484	TOTAL LABOR	=SUM(AK469:AK473)	=AK474/(AH450*1000)	1030	Working Capital	=AO470*AO484	TOTAL LABOR	=SUM(AO469:AO473)	=AO474/(AN450*1000)
475				Property Tax & Insur.	=AI487*AI476*1000	=AK475/(AH450*1000)				Property Tax & Insur.	=AO487*AO476*1000	=AO475/(AN450*1000)
476		TOTAL CAPITAL	=SUM(AI470:AI475	TOTAL CASH	=AK466+AK467+AK474+	=AK476/(AH450*1000)		TOTAL CAPITAL	=SUM(AO470:A	TOTAL CASH	=AO466+AO467+AO4	=AO476/(AN450*1000)
477				Depreciation	=SLN((AI476*1000),(D	=AK477/(AH450*1000)				Depreciation	=SLN((AO476*1000),(	=AO477/(AN450*1000)
478				Interest	=AI476*1000*$D$319	=AK478/(AH450*1000)				Interest	=AO476*1000*$D$319	=AO478/(AN450*1000)
479												
480				TOTAL PRODUCTION	=AK476+AK477+AK478	=AK480/(AH450*1000)				TOTAL PRODUCTION	=AO476+AO477+AO4	=AO480/(AN450*1000)
481		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
482		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
483		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
484		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
485		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
486		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
487		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
488	=$C$313						=$C$31					
489	=$C489						=$C489					
490	=$C$320	=AB490/AB491*AH491	=$C$310	=AK524	Ratio of orig. to proposed	=AH491/$D491	=$C$32	=AH490/AH491*AN491	=$C$310	=AO524	Ratio of orig. to propos	=AN491/$D491
491	=$C$321	=$D$322	Scaling of original d	=(AH491/$D491)*AI522			=$C$32	=$D$321	Scaling of origin	=(AN491/$D491)*AO522		
492	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
493	100	Biomass Preparation	=$E493*AJ491	Biomass	=AH490*AI526*AJ490/10	=AK493/(AH491*1000)	100	Biomass Preparation	=$E493*AP491	Biomass	=AN490*AO526*AP49	=AO493/(AN491*1000)
494	200	Pretreatment	=$E494*AJ491	Chemicals			200	Pretreatment	=$E494*AP491	Chemicals		
495	210	Recovery & Recycle	=$E495*AJ491	Denaturant	=AH491*AK525*AK526*1	=AK495/(AH491*1000)	210	Recovery & Recycle	=$E495*AP491	Denaturant	=AN491*AO525*AO52	=AO495/(AN491*1000)
496	300	Hydrolysis	=$E496*AJ491	Acid	=$G496*AL490	=AK496/(AH491*1000)	300	Hydrolysis	=$E496*AP491	Acid	=$G496*AR490	=AO496/(AN491*1000)
497	400	Fermentation (Unallocated)	=$E497*AJ491	Ammonia	=$G497*AL490	=AK497/(AH491*1000)	400	Fermentation (Unallocated)	=$E497*AP491	Ammonia	=$G497*AR490	=AO497/(AN491*1000)
498	410	Hexose Fermentation	=$E498*AJ491	Nutrients	=$G498*AL490	=AK498/(AH491*1000)	410	Hexose Fermentation	=$E498*AP491	Nutrients	=$G498*AR490	=AO498/(AN491*1000)
499	420	Pentose Fermentation	=$E499*AJ491	Enzymes	=$G499*AL490	=AK499/(AH491*1000)	420	Pentose Fermentation	=$E499*AP491	Enzymes	=$G499*AR490	=AO499/(AN491*1000)
500	500	Distillation & Dehydration	=$E500*AJ491	Yeast	=$G500*AL490	=AK500/(AH491*1000)	500	Distillation & Dehydration	=$E500*AP491	Yeast	=$G500*AR490	=AO500/(AN491*1000)
501	600	By-Product Preparation	=$E501*AJ491	Other Chemicals	=$G501*AL490	=AK501/(AH491*1000)	600	By-Product Preparation	=$E501*AP491	Other Chemicals	=$G501*AR490	=AO501/(AN491*1000)
502	610	Stillage Evaporation	=$E502*AJ491	RAW MATERIALS TOTAL	=SUM(AK493:AK501)	=AK502/(AH491*1000)	610	Stillage Evaporation	=$E502*AP491	RAW MATERIALS TOTAL	=SUM(AO493:AO501)	=AO502/(AN491*1000)
503	700	Product Storage & Denaturd	=$E503*AJ491	Utilities			700	Product Storage & Denature	=$E503*AP491	Utilities		
504	800	Utilities & General	=$E504*AJ491	Electricity/ Energy	=$G504*AL490	=AK504/(AH491*1000)	800	Utilities & General	=$E504*AP491	Electricity/ Energy	=$G504*AR490	=AO504/(AN491*1000)
505	810	Boiler	=$E505*AJ491	Water	=$G505*AL490	=AK505/(AH491*1000)	810	Boiler	=$E505*AP491	Water	=$G505*AR490	=AO505/(AN491*1000)
506	820	Non Boiler Utilities	=$E506*AJ491	By-products	=$G506*AL490	=AK506/(AH491*1000)	820	Non Boiler Utilities	=$E506*AP491	By-products	=$G506*AR490	=AO506/(AN491*1000)
507	830	Environmental	=$E507*AJ491	VARIABLE COST TOTAL	=SUM(AK502:AK506)	=AK507/(AH491*1000)	830	Environmental	=$E507*AP491	VARIABLE COST TOTAL	=SUM(AO502:AO506)	=AO507/(AN491*1000)
508	840	Miscellaneous & Control	=$E508*AJ491	GEN & ADMIN	=1590*(AH491/25)*AI527	=AK508/(AH491*1000)	840	Miscellaneous & Control	=$E508*AP491	GEN & ADMIN	=1590*(AN491/25)*AO	=AO508/(AN491*1000)
509	900	Enzyme Production	=$E509*AJ491				900	Enzyme Production	=$E509*AP491			
510				Operators	=$G510*AL490*AI527	=AK510/(AH491*1000)				Operators	=$G510*AR490*AO52	=AO510/(AN491*1000)
511	1000	Total Fixed Capital	=SUM(AI492:AI510	Laborers	=$G511*(AL490)*AI527	=AK511/(AH491*1000)	1000	Total Fixed Capital	=SUM(AO492:A	Laborers	=$G511*(AR490)*AO5	=AO511/(AN491*1000)
512				Technicians	=$G512*(AL490)*AI527	=AK512/(AH491*1000)				Technicians	=$G512*(AR490)*AO5	=AO512/(AN491*1000)
513	1010	Contingency	=AI511*AI523	Maintenance	=$G513*(AL490)*AI527	=AK513/(AH491*1000)	1010	Contingency	=AO511*AO523	Maintenance	=$G513*(AR490)*AO5	=AO513/(AN491*1000)
514	1020	Startup	=AI511*AI524	Fringe Benefits	=AK527*SUM(AK510:AK	=AK514/(AH491*1000)	1020	Startup	=AO511*AO524	Fringe Benefits	=AO527*SUM(AO510:	=AO514/(AN491*1000)
515	1030	Working Capital	=AI511*AI525	TOTAL LABOR	=SUM(AK510:AK514)	=AK515/(AH491*1000)	1030	Working Capital	=AO511*AO525	TOTAL LABOR	=SUM(AO510:AO514)	=AO515/(AN491*1000)
516				Property Tax & Insur.	=AI528*AI517*1000	=AK516/(AH491*1000)				Property Tax & Insur.	=AO528*AO517*1000	=AO516/(AN491*1000)
517		TOTAL CAPITAL	=SUM(AI511:AI516	TOTAL CASH	=AK507+AK508+AK515+	=AK517/(AH491*1000)		TOTAL CAPITAL	=SUM(AO511:A	TOTAL CASH	=AO507+AO508+AO5	=AO517/(AN491*1000)
518				Depreciation	=SLN((AI517*1000),(D	=AK518/(AH491*1000)				Depreciation	=SLN((AO517*1000),(	=AO518/(AN491*1000)
519				Interest	=AI517*1000*$D$319	=AK519/(AH491*1000)				Interest	=AO517*1000*$D$319	=AO519/(AN491*1000)
520												
521				TOTAL PRODUCTION	=AK517+AK518+AK519	=AK521/(AH491*1000)				TOTAL PRODUCTION	=AO517+AO518+AO5	=AO521/(AN491*1000)
522		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
523		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
524		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
525		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
526		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
527		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
528		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
529	=$C$312						=$C$312					
530	=$C530						=$C530					
531	=$C$320	=P531/P532*V532	=$C$310	=Y564	Ratio of orig. to prop	=V532/$D532	=$C$320	=V531/V532*AB532	=$C$310	=AE564	Ratio of orig. to proposed s	=AB532/$D532
532	=$C$321	=$D$322	Scaling of origina	=(V532/$D532)*W563			=$C$321	=$D$321	Scaling of original dat	=(AB532/$D532)*AC563		
533	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
534	100	Biomass Preparation	=$E534*X532	Biomass	=V531*W567*X531/	=Y534/(V532*1000)	100	Biomass Preparation	=$E534*AD532	Biomass	=AB531*AC567*AD531/10	=AE534/(AB532*1000)
535	200	Pretreatment	=$E535*X532	Chemicals			200	Pretreatment	=$E535*AD532	Chemicals		
536	210	Recovery & Recycle	=$E536*X532	Denaturant	=V532*Y566*Y567*1	=Y536/(V532*1000)	210	Recovery & Recycle	=$E536*AD532	Denaturant	=AB532*AE566*AE567*10	=AE536/(AB532*1000)
537	300	Hydrolysis	=$E537*X532	Acid	=$G537*Z531	=Y537/(V532*1000)	300	Hydrolysis	=$E537*AD532	Acid	=$G537*AF531	=AE537/(AB532*1000)
538	400	Fermentation (Unallocated)	=$E538*X532	Ammonia	=$G538*Z531	=Y538/(V532*1000)	400	Fermentation (Unallocated)	=$E538*AD532	Ammonia	=$G538*AF531	=AE538/(AB532*1000)
539	410	Hexose Fermentation	=$E539*X532	Nutrients	=$G539*Z531	=Y539/(V532*1000)	410	Hexose Fermentation	=$E539*AD532	Nutrients	=$G539*AF531	=AE539/(AB532*1000)
540	420	Pentose Fermentation	=$E540*X532	Enzymes	=$G540*Z531	=Y540/(V532*1000)	420	Pentose Fermentation	=$E540*AD532	Enzymes	=$G540*AF531	=AE540/(AB532*1000)
541	500	Distillation & Dehydration	=$E541*X532	Yeast	=$G541*Z531	=Y541/(V532*1000)	500	Distillation & Dehydration	=$E541*AD532	Yeast	=$G541*AF531	=AE541/(AB532*1000)
542	600	By-Product Preparation	=$E542*X532	Other Chemicals	=$G542*Z531	=Y542/(V532*1000)	600	By-Product Preparation	=$E542*AD532	Other Chemicals	=$G542*AF531	=AE542/(AB532*1000)
543	610	Stillage Evaporation	=$E543*X532	RAW MATERIALS TOTAL	=SUM(Y534:Y542)	=Y543/(V532*1000)	610	Stillage Evaporation	=$E543*AD532	RAW MATERIALS TOTA	=SUM(AE534:AE542)	=AE543/(AB532*1000)
544	700	Product Storage & Denaturd	=$E544*X532	Utilities			700	Product Storage & Denature	=$E544*AD532	Utilities		
545	800	Utilities & General	=$E545*X532	Electricity/ Energy	=$G545*Z531	=Y545/(V532*1000)	800	Utilities & General	=$E545*AD532	Electricity/ Energy	=$G545*AF531	=AE545/(AB532*1000)
546	810	Boiler	=$E546*X532	Water	=$G546*Z531	=Y546/(V532*1000)	810	Boiler	=$E546*AD532	Water	=$G546*AF531	=AE546/(AB532*1000)
547	820	Non-Boiler Utilities	=$E547*X532	By-products	=$G547*Z531	=Y547/(V532*1000)	820	Non-Boiler Utilities	=$E547*AD532	By-products	=$G547*AF531	=AE547/(AB532*1000)
548	830	Environmental	=$E548*X532	VARIABLE COST TOTAL	=SUM(Y543:Y547)	=Y548/(V532*1000)	830	Environmental	=$E548*AD532	VARIABLE COST TOTAL	=SUM(AE543:AE547)	=AE548/(AB532*1000)
549	840	Miscellaneous & Control	=$E549*X532	GEN & ADMIN	=1590*(V532/25)*W	=Y549/(V532*1000)	840	Miscellaneous & Control	=$E549*AD532	GEN & ADMIN	=1590*(AB532/25)*AC568	=AE549/(AB532*1000)
550	900	Enzyme Production	=$E550*X532				900	Enzyme Production	=$E550*AD532			
551				Operators	=$G551*Z531*W568	=Y551/(V532*1000)				Operators	=$G551*AF531*AC568	=AE551/(AB532*1000)
552	1000	Total Fixed Capital	=SUM(W533:W5	Laborers	=$G552*(Z531)^W56	=Y552/(V532*1000)	1000	Total Fixed Capital	=SUM(AC533:AC551	Laborers	=$G552*(AF531)^AC568	=AE552/(AB532*1000)
553				Technicians	=$G553*(Z531)^W56	=Y553/(V532*1000)				Technicians	=$G553*(AF531)^AC568	=AE553/(AB532*1000)
554	1010	Contingency	=W552*W564	Maintenance	=$G554*(Z531)^W56	=Y554/(V532*1000)	1010	Contingency	=AC552*AC564	Maintenance	=$G554*(AF531)^AC568	=AE554/(AB532*1000)
555	1020	Startup	=W552*W565	Fringe Benefits	=Y568*SUM(Y551:Y	=Y555/(V532*1000)	1020	Startup	=AC552*AC565	Fringe Benefits	=AE568*SUM(AE551:AE5	=AE555/(AB532*1000)
556	1030	Working Capital	=W552*W566	TOTAL LABOR	=SUM(Y551:Y555)	=Y556/(V532*1000)	1030	Working Capital	=AC552*AC566	TOTAL LABOR	=SUM(AE551:AE555)	=AE556/(AB532*1000)
557				Property Tax & Insur.	=W569*W558*1000	=Y557/(V532*1000)				Property Tax & Insur.	=AC569*AC558*1000	=AE557/(AB532*1000)
558		TOTAL CAPITAL	=SUM(W552:W5	TOTAL CASH	=Y548+Y549+Y556+	=Y558/(V532*1000)		TOTAL CAPITAL	=SUM(AC552:AC557	TOTAL CASH	=AE548+AE549+AE556+A	=AE558/(AB532*1000)
559				Depreciation	=SLN((W558*1000),	=Y559/(V532*1000)				Depreciation	=SLN((AC558*1000),(D	=AE559/(AB532*1000)
560				Interest	=W558*1000*$D$31	=Y560/(V532*1000)				Interest	=AC558*1000*$D$319	=AE560/(AB532*1000)
561												
562				TOTAL PRODUCTION	=Y558+Y559+Y560	=Y562/(V532*1000)				TOTAL PRODUCTION	=AE558+AE559+AE560	=AE562/(AB532*1000)
563		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
564		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
565		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
566		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
567		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
568		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
569		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
570	=$C$312						=$C$312					
571	=$C571						=$C571					
572	=$C$320	=P572/P573*V573	=$C$310	=Y605	Ratio of orig. to prop	=V573/$D573	=$C$320	=V572/V573*AB573	=$C$310	=AE605	Ratio of orig. to proposed s	=AB573/$D573
573	=$C$321	=$D$322	Scaling of origina	=(V573/$D573)*W604			=$C$321	=$D$321	Scaling of original dat	=(AB573/$D573)*AC604		
574	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
575	100	Biomass Preparation	=$E575*X573	Biomass	=V572*W608*X572/	=Y575/(V573*1000)	100	Biomass Preparation	=$E575*AD573	Biomass	=AB572*AC608*AD572/10	=AE575/(AB573*1000)
576	200	Pretreatment	=$E576*X573	Chemicals			200	Pretreatment	=$E576*AD573	Chemicals		
577	210	Recovery & Recycle	=$E577*X573	Denaturant	=V573*Y607*Y608*1	=Y577/(V573*1000)	210	Recovery & Recycle	=$E577*AD573	Denaturant	=AB573*AE607*AE608*10	=AE577/(AB573*1000)
578	300	Hydrolysis	=$E578*X573	Acid	=$G578*Z572	=Y578/(V573*1000)	300	Hydrolysis	=$E578*AD573	Acid	=$G578*AF572	=AE578/(AB573*1000)
579	400	Fermentation (Unallocated)	=$E579*X573	Ammonia	=$G579*Z572	=Y579/(V573*1000)	400	Fermentation (Unallocated)	=$E579*AD573	Ammonia	=$G579*AF572	=AE579/(AB573*1000)
580	410	Hexose Fermentation	=$E580*X573	Nutrients	=$G580*Z572	=Y580/(V573*1000)	410	Hexose Fermentation	=$E580*AD573	Nutrients	=$G580*AF572	=AE580/(AB573*1000)
581	420	Pentose Fermentation	=$E581*X573	Enzymes	=$G581*Z572	=Y581/(V573*1000)	420	Pentose Fermentation	=$E581*AD573	Enzymes	=$G581*AF572	=AE581/(AB573*1000)
582	500	Distillation & Dehydration	=$E582*X573	Yeast	=$G582*Z572	=Y582/(V573*1000)	500	Distillation & Dehydration	=$E582*AD573	Yeast	=$G582*AF572	=AE582/(AB573*1000)
583	600	By-Product Preparation	=$E583*X573	Other Chemicals	=$G583*Z572	=Y583/(V573*1000)	600	By-Product Preparation	=$E583*AD573	Other Chemicals	=$G583*AF572	=AE583/(AB573*1000)
584	610	Stillage Evaporation	=$E584*X573	RAW MATERIALS TOTAL	=SUM(Y575:Y583)	=Y584/(V573*1000)	610	Stillage Evaporation	=$E584*AD573	RAW MATERIALS TOTA	=SUM(AE575:AE583)	=AE584/(AB573*1000)
585	700	Product Storage & Denaturd	=$E585*X573	Utilities			700	Product Storage & Denature	=$E585*AD573	Utilities		
586	800	Utilities & General	=$E586*X573	Electricity/ Energy	=$G586*Z572	=Y586/(V573*1000)	800	Utilities & General	=$E586*AD573	Electricity/ Energy	=$G586*AF572	=AE586/(AB573*1000)
587	810	Boiler	=$E587*X573	Water	=$G587*Z572	=Y587/(V573*1000)	810	Boiler	=$E587*AD573	Water	=$G587*AF572	=AE587/(AB573*1000)
588	820	Non-Boiler Utilities	=$E588*X573	By-products	=$G588*Z572	=Y588/(V573*1000)	820	Non-Boiler Utilities	=$E588*AD573	By-products	=$G588*AF572	=AE588/(AB573*1000)
589	830	Environmental	=$E589*X573	VARIABLE COST TOTAL	=SUM(Y584:Y588)	=Y589/(V573*1000)	830	Environmental	=$E589*AD573	VARIABLE COST TOTAL	=SUM(AE584:AE588)	=AE589/(AB573*1000)
590	840	Miscellaneous & Control	=$E590*X573	GEN & ADMIN	=1590*(V573/25)*W	=Y590/(V573*1000)	840	Miscellaneous & Control	=$E590*AD573	GEN & ADMIN	=1590*(AB573/25)*AC609	=AE590/(AB573*1000)
591	900	Enzyme Production	=$E591*X573				900	Enzyme Production	=$E591*AD573			
592				Operators	=$G592*Z572*W609	=Y592/(V573*1000)				Operators	=$G592*AF572*AC609	=AE592/(AB573*1000)
593	1000	Total Fixed Capital	=SUM(W574:W5	Laborers	=$G593*(Z572)^W60	=Y593/(V573*1000)	1000	Total Fixed Capital	=SUM(AC574:AC592	Laborers	=$G593*(AF572)^AC609	=AE593/(AB573*1000)
594				Technicians	=$G594*(Z572)^W60	=Y594/(V573*1000)				Technicians	=$G594*(AF572)^AC609	=AE594/(AB573*1000)
595	1010	Contingency	=W593*W605	Maintenance	=$G595*(Z572)^W60	=Y595/(V573*1000)	1010	Contingency	=AC593*AC605	Maintenance	=$G595*(AF572)^AC609	=AE595/(AB573*1000)
596	1020	Startup	=W593*W606	Fringe Benefits	=Y609*SUM(Y592:Y	=Y596/(V573*1000)	1020	Startup	=AC593*AC606	Fringe Benefits	=AE609*SUM(AE592:AE5	=AE596/(AB573*1000)
597	1030	Working Capital	=W593*W607	TOTAL LABOR	=SUM(Y592:Y596)	=Y597/(V573*1000)	1030	Working Capital	=AC593*AC607	TOTAL LABOR	=SUM(AE592:AE596)	=AE597/(AB573*1000)
598				Property Tax & Insur.	=W610*W599*1000	=Y598/(V573*1000)				Property Tax & Insur.	=AC610*AC599*1000	=AE598/(AB573*1000)
599		TOTAL CAPITAL	=SUM(W593:W5	TOTAL CASH	=Y589+Y590+Y597+	=Y599/(V573*1000)		TOTAL CAPITAL	=SUM(AC593:AC598	TOTAL CASH	=AE589+AE590+AE597+A	=AE599/(AB573*1000)
600				Depreciation	=SLN((W599*1000),(	=Y600/(V573*1000)				Depreciation	=SLN((AC599*1000),(D	=AE600/(AB573*1000)
601				Interest	=W599*1000*$D$31	=Y601/(V573*1000)				Interest	=AC599*1000*$D$319	=AE601/(AB573*1000)
602												
603				TOTAL PRODUCTION	=Y599+Y600+Y601	=Y603/(V573*1000)				TOTAL PRODUCTION	=AE599+AE600+AE601	=AE603/(AB573*1000)
604		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
605		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
606		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
607		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
608		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
609		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
610		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
529	=$C$313						=$C$31					
530	=$C530						=$C530					
531	=$C$320	=AB531/AB532*AH532	=$C$310	=AK566	Ratio of orig. to proposed	=AH532/$D532	=$C$32	=AH531/AH532*AN532	=$C$310	=AO566	Ratio of orig. to propos	=AN532/$D532
532	=$C$321	=$D$322	Scaling of original d	=(AH532/$D532)^AI563			=$C$32	=$D$321	Scaling of origin	=(AN532/$D532)^AO563		
533	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
534	100	Biomass Preparation	=$E534*AJ532	Biomass	=AH531*AI567*AJ531/10	=AK534/(AH532*1000)	100	Biomass Preparation	=$E534*AP532	Biomass	=AN531*AO567*AP53	=AO534/(AN532*1000)
535	200	Pretreatment	=$E535*AJ532	Chemicals			200	Pretreatment	=$E535*AP532	Chemicals		
536	210	Recovery & Recycle	=$E536*AJ532	Denaturant	=AH532*AK566*AK567*1	=AK536/(AH532*1000)	210	Recovery & Recycle	=$E536*AP532	Denaturant	=AN532*AO566*AO56	=AO536/(AN532*1000)
537	300	Hydrolysis	=$E537*AJ532	Acid	=$G537*AL531	=AK537/(AH532*1000)	300	Hydrolysis	=$E537*AP532	Acid	=$G537*AR531	=AO537/(AN532*1000)
538	400	Fermentation (Unallocated)	=$E538*AJ532	Ammonia	=$G538*AL531	=AK538/(AH532*1000)	400	Fermentation (Unallocated)	=$E538*AP532	Ammonia	=$G538*AR531	=AO538/(AN532*1000)
539	410	Hexose Fermentation	=$E539*AJ532	Nutrients	=$G539*AL531	=AK539/(AH532*1000)	410	Hexose Fermentation	=$E539*AP532	Nutrients	=$G539*AR531	=AO539/(AN532*1000)
540	420	Pentose Fermentation	=$E540*AJ532	Enzymes	=$G540*AL531	=AK540/(AH532*1000)	420	Pentose Fermentation	=$E540*AP532	Enzymes	=$G540*AR531	=AO540/(AN532*1000)
541	500	Distillation & Dehydration	=$E541*AJ532	Yeast	=$G541*AL531	=AK541/(AH532*1000)	500	Distillation & Dehydration	=$E541*AP532	Yeast	=$G541*AR531	=AO541/(AN532*1000)
542	600	By Product Preparation	=$E542*AJ532	Other Chemicals	=$G542*AL531	=AK542/(AH532*1000)	600	By Product Preparation	=$E542*AP532	Other Chemicals	=$G542*AR531	=AO542/(AN532*1000)
543	610	Stillage Evaporation	=$E543*AJ532	RAW MATERIALS TOTAL	=SUM(AK534:AK542)	=AK543/(AH532*1000)	610	Stillage Evaporation	=$E543*AP532	RAW MATERIALS TOTAL	=SUM(AO534:AO542)	=AO543/(AN532*1000)
544	700	Product Storage & Denature	=$E544*AJ532	Utilities			700	Product Storage & Denature	=$E544*AP532	Utilities		
545	800	Utilities & General	=$E545*AJ532	Electricity/ Energy	=$G545*AL531	=AK545/(AH532*1000)	800	Utilities & General	=$E545*AP532	Electricity/ Energy	=$G545*AR531	=AO545/(AN532*1000)
546	810	Boiler	=$E546*AJ532	Water	=$G546*AL531	=AK546/(AH532*1000)	810	Boiler	=$E546*AP532	Water	=$G546*AR531	=AO546/(AN532*1000)
547	820	Non-Boiler Utilities	=$E547*AJ532	By-products	=$G547*AL531	=AK547/(AH532*1000)	820	Non-Boiler Utilities	=$E547*AP532	By-products	=$G547*AR531	=AO547/(AN532*1000)
548	830	Environmental	=$E548*AJ532	VARIABLE COST TOTAL	=SUM(AK543:AK547)	=AK548/(AH532*1000)	830	Environmental	=$E548*AP532	VARIABLE COST TOTAL	=SUM(AO543:AO547)	=AO548/(AN532*1000)
549	840	Miscellaneous & Control	=$E549*AJ532	GEN & ADMIN	=1590*(AH532/25)^AI568	=AK549/(AH532*1000)	840	Miscellaneous & Control	=$E549*AP532	GEN & ADMIN	=1590*(AN532/25)^AC	=AO549/(AN532*1000)
550	900	Enzyme Production	=$E550*AJ532				900	Enzyme Production	=$E550*AP532			
551				Operators	=$G551*AL531^AI568	=AK551/(AH532*1000)				Operators	$G551*AR531^AO56	AO551/(AN532*1000)
552	1000	Total Fixed Capital	=SUM(AI533:AI551	Laborers	=$G552*(AL531)^AI568	=AK552/(AH532*1000)	1000	Total Fixed Capital	=SUM(AO533:A	Laborers	$G552*(AR531)^AO5	AO552/(AN532*1000)
553				Technicians	=$G553*(AL531)^AI568	=AK553/(AH532*1000)				Technicians	$G553*(AR531)^AO5	AO553/(AN532*1000)
554	1010	Contingency	=AI552*AI564	Maintenance	=$G554*(AL531)^AI568	=AK554/(AH532*1000)	1010	Contingency	AO552*AO564	Maintenance	=$G554*(AR531)^AO5	=AO554/(AN532*1000)
555	1020	Startup	=AI552*AI565	Fringe Benefits	=AK568*SUM(AK551:AK	=AK555/(AH532*1000)	1020	Startup	=AO552*AO565	Fringe Benefits	=AO568*SUM(AO551:	=AO555/(AN532*1000)
556	1030	Working Capital	=AI552*AI566	TOTAL LABOR	=SUM(AK551:AK555)	=AK556/(AH532*1000)	1030	Working Capital	=AO552*AO566	TOTAL LABOR	=SUM(AO551:AO555)	=AO556/(AN532*1000)
557				Property Tax & Insur.	=AI569*AI558*1000	=AK557/(AH532*1000)				Property Tax & Insur.	=AO569*AO558*1000	=AO557/(AN532*1000)
558		TOTAL CAPITAL	=SUM(AI552:AI557	TOTAL CASH	=AK548+AK549+AK556+	=AK558/(AH532*1000)		TOTAL CAPITAL	=SUM(AO552:A	TOTAL CASH	=AO548+AO549+AO5	=AO558/(AN532*1000)
559				Depreciation	=SLN((AI558*1000),(D	=AK559/(AH532*1000)				Depreciation	=SLN((AO558*1000),(	=AO559/(AN532*1000)
560				Interest	=AI558*1000*$D$319	=AK560/(AH532*1000)				Interest	=AO558*1000*$D$319	=AO560/(AN532*1000)
561												
562				TOTAL PRODUCTION	=AK558+AK559+AK560	=AK562/(AH532*1000)				TOTAL PRODUCTION	=AO558+AO559+AO5	=AO562/(AN532*1000)
563		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
564		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
565		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
566		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
567		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
568		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
569		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	
570	=$C$313						=$C$31					
571	=$C571						=$C571					
572	=$C$320	=AB572/AB573*AH573	=$C$310	=AK606	Ratio of orig. to proposed	=AH573/$D573	=$C$32	=AH572/AH573*AN573	=$C$310	=AO606	Ratio of orig. to propos	=AN573/$D573
573	=$C$321	=$D$322	Scaling of original d	=(AH573/$D573)^AI604			=$C$32	=$D$321	Scaling of origin	=(AN573/$D573)^AO604		
574	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal	AREA	CAPITAL COSTS	Million $	PRODUCTION COSTS	Thous $/Yr	$/gal
575	100	Biomass Preparation	=$E575*AJ573	Biomass	=AH572*AI608*AJ572/10	=AK575/(AH573*1000)	100	Biomass Preparation	=$E575*AP573	Biomass	=AN572*AO608*AP57	=AO575/(AN573*1000)
576	200	Pretreatment	=$E576*AJ573	Chemicals			200	Pretreatment	=$E576*AP573	Chemicals		
577	210	Recovery & Recycle	=$E577*AJ573	Denaturant	=AH573*AK607*AK608*1	=AK577/(AH573*1000)	210	Recovery & Recycle	=$E577*AP573	Denaturant	=AN573*AO607*AO60	=AO577/(AN573*1000)
578	300	Hydrolysis	=$E578*AJ573	Acid	=$G578*AL572	=AK578/(AH573*1000)	300	Hydrolysis	=$E578*AP573	Acid	=$G578*AR572	=AO578/(AN573*1000)
579	400	Fermentation (Unallocated)	=$E579*AJ573	Ammonia	=$G579*AL572	=AK581/(AH575*1000)	400	Fermentation (Unallocated)	=$E579*AP573	Ammonia	=$G579*AR572	=AO579/(AN573*1000)
580	410	Hexose Fermentation	=$E580*AJ573	Nutrients	=$G580*AL572	=AK580/(AH573*1000)	410	Hexose Fermentation	=$E580*AP573	Nutrients	=$G580*AR572	=AO580/(AN573*1000)
581	420	Pentose Fermentation	=$E581*AJ573	Enzymes	=$G581*AL572	=AK581/(AH573*1000)	420	Pentose Fermentation	=$E581*AP573	Enzymes	=$G581*AR572	=AO581/(AN573*1000)
582	500	Distillation & Dehydration	=$E582*AJ573	Yeast	=$G582*AL572	=AK582/(AH573*1000)	500	Distillation & Dehydration	=$E582*AP573	Yeast	=$G582*AR572	=AO582/(AN573*1000)
583	600	By Product Preparation	=$E583*AJ573	Other Chemicals	=$G583*AL572	=AK583/(AH573*1000)	600	By-Product Preparation	=$E583*AP573	Other Chemicals	=$G583*AR572	=AO583/(AN573*1000)
584	610	Stillage Evaporation	=$E584*AJ573	RAW MATERIALS TOTAL	=SUM(AK575:AK583)	=AK584/(AH573*1000)	610	Stillage Evaporation	=$E584*AP573	RAW MATERIALS TOTAL	=SUM(AO575:AO583)	=AO584/(AN573*1000)
585	700	Product Storage & Denature	=$E585*AJ573	Utilities			700	Product Storage & Denature	=$E585*AP573	Utilities		
586	800	Utilities & General	=$E586*AJ573	Electricity/ Energy	=$G586*AL572	=AK586/(AH573*1000)	800	Utilities & General	=$E586*AP573	Electricity/ Energy	=$G586*AR572	=AO586/(AN573*1000)
587	810	Boiler	=$E587*AJ573	Water	=$G587*AL572	=AK587/(AH573*1000)	810	Boiler	=$E587*AP573	Water	=$G587*AR572	=AO587/(AN573*1000)
588	820	Non-Boiler Utilities	=$E588*AJ573	By-products	=$G588*AL572	=AK588/(AH573*1000)	820	Non-Boiler Utilities	=$E588*AP573	By-products	=$G588*AR572	=AO588/(AN573*1000)
589	830	Environmental	=$E589*AJ573	VARIABLE COST TOTAL	=SUM(AK584:AK588)	=AK589/(AH573*1000)	830	Environmental	=$E589*AP573	VARIABLE COST TOTAL	=SUM(AO584:AO588)	=AO589/(AN573*1000)
590	840	Miscellaneous & Control	=$E590*AJ573	GEN & ADMIN	=1590*(AH573/25)^AI609	=AK590/(AH573*1000)	840	Miscellaneous & Control	=$E590*AP573	GEN & ADMIN	=1590*(AN573/25)^AC	=AO590/(AN573*1000)
591	900	Enzyme Production	=$E591*AJ573				900	Enzyme Production	=$E591*AP573			
592				Operators	=$G592*AL572^AI609	=AK592/(AH573*1000)				Operators	=$G592*AR572^AO60	=AO592/(AN573*1000)
593	1000	Total Fixed Capital	=SUM(AI574:AI592	Laborers	=$G593*(AL572)^AI609	=AK593/(AH573*1000)	1000	Total Fixed Capital	=SUM(AO574:A	Laborers	=$G593*(AR572)^AO6	=AO593/(AN573*1000)
594				Technicians	=$G594*(AL572)^AI609	=AK594/(AH573*1000)				Technicians	=$G594*(AR572)^AO(	=AO594/(AN573*1000)
595	1010	Contingency	=AI593*AI605	Maintenance	=$G595*(AL572)^AI609	=AK595/(AH573*1000)	1010	Contingency	=AO593*AO605	Maintenance	=$G595*(AR572)^AO6	=AO595/(AN573*1000)
596	1020	Startup	=AI593*AI606	Fringe Benefits	=AK609*SUM(AK592:AK	=AK596/(AH573*1000)	1020	Startup	=AO593*AO606	Fringe Benefits	=AO609*SUM(AO592:	=AO596/(AN573*1000)
597	1030	Working Capital	=AI593*AI607	TOTAL LABOR	=SUM(AK592:AK596)	=AK597/(AH573*1000)	1030	Working Capital	=AO593*AO607	TOTAL LABOR	=SUM(AO592:AO596)	=AO597/(AN573*1000)
598				Property Tax & Insur.	=AI610*AI599*1000	=AK598/(AH573*1000)				Property Tax & Insur.	=AO610*AO599*1000	=AO598/(AN573*1000)
599		TOTAL CAPITAL	=SUM(AI593:AI598	TOTAL CASH	=AK589+AK590+AK597+	=AK599/(AH573*1000)		TOTAL CAPITAL	=SUM(AO593:A	TOTAL CASH	=AO589+AO590+AO5	=AO599/(AN573*1000)
600				Depreciation	=SLN((AI599*1000),(D	=AK600/(AH573*1000)				Depreciation	=SLN((AO599*1000),(	=AO600/(AN573*1000)
601				Interest	=AI599*1000*$D$319	=AK601/(AH573*1000)				Interest	=AO599*1000*$D$319	=AO601/(AN573*1000)
602												
603				TOTAL PRODUCTION	=AK599+AK600+AK601	=AK603/(AH573*1000)				TOTAL PRODUCTION	=AO599+AO600+AO6	=AO603/(AN573*1000)
604		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
605		Contingency	=$D$304	=$C$312	=$D$312			Contingency	=$D$304	=$C$312	=$D$312	
606		Start-up factor	=$D$305	=$C$313	=$D$313			Start-up factor	=$D$305	=$C$313	=$D$313	
607		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
608		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
609		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
610		Property Tax & Insurance	=$D$309	=$C$317	=$D$317			Property Tax & Insurance	=$D$309	=$C$317	=$D$317	

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
611								Biomass cost per ton (dry basis) =	$0.00					Biomass cost per ton (dry basis) =	$50.00		Biomass cost per ton (dry basis) =	$109.00	
612						Process		25	Million gpy facility		5	Million gpy facility		Million gpy:	25	5	Million gpy:	25	5
613	PROCESS			Title of Table in Appendix		reference	PROCESS	Capital	Unit Cost	Biomass	Capital	Unit Cost	Biomass	PROCESS	Unit Cost	Unit Cost	PROCESS	Unit Cost	Unit Cost
614						number		(MM$)	$/ Gal	tons/ day	(MM$)	$/ Gal	tons/day		$/ Gal	$/ Gal		$/ Gal	$/ Gal
615	Simultaneous saccharification and fermentation			NREL SSF ESTIMATED BASE COSTS		1.	Simultaneous saccharification and fermentation	$81	$0.52	820	$26	$0.65	164	1.	$1.06	$1.19	1.	$1.70	$1.83
616	Concentrated acid hydrolysis, neutralization and fermentation			TVA ACID ESTIMATED BASE COSTS		2.	Concentrated acid hydrolysis, neutralization and fermentation	$99	$1.14	952	$32	$1.29	190	2.	$1.77	$1.92	2.	$2.51	$2.66
617	Ammonia disruption hydrolysis and fermentation			AFEX AMMONIA ESTIMATED BASE COSTS		3.	Ammonia disruption hydrolysis and fermentation	$124	$0.60	863	$40	$0.78	173	3.	$1.17	$1.35	3.	$1.84	$2.02
618	Steam disruption, hydrolysis and fermentation			STAKETECH ESTIMATED BASE COSTS		4.	Steam disruption, hydrolysis and fermentation	$110	$0.52	814	$36	$0.69	163	4.	$1.06	$1.22	4.	$1.69	$1.86
619	Acid disruption and transgenic microorganism fermentation (Quadrex)			BIOENERGY ESTIMATED BASE COSTS		5.	Acid disruption and transgenic microorganism fermentation (Quadrex)	$127	$0.64	838	$41	$0.83	168	5.	$1.20	$1.38	5.	$1.85	$2.03
620	Concentrated acid hydrolysis, acid recycle and fermentation			ARKENOL ESTIMATED BASE COSTS		6.	Concentrated acid hydrolysis, acid recycle and fermentation	$72	$0.94	833	$23	$1.04	167	6.	$1.49	$1.59	6.	$2.14	$2.24
621	Acidified acetone extraction, hydrolysis and fermentation			PASZNER TECHNOLOGY ESTIMATED BASE COSTS		7.	Acidified acetone extraction, hydrolysis and fermentation	$88	$0.73	779	$29	$0.87	156	7.	$1.24	$1.39	7.	$1.85	$1.99

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
611								Biomass	=K622					Biomass cost	=Q623		=P611	=T624	
612						Process		=J327	Million gpy fac		=P327	=K612		Million gpy:	=V327	=AB327	=P612	=AH327	=AN327
613	PROCESS			Title of Tab		reference	=C613	Capital	Unit Cost	Biomass	Capital	Unit Cost	Biomass	=C613	Unit Cost	Unit Cost	=P613	Unit Cost	Unit Cost
614						number		(MM$)	$/ Gal	tons/day	(MM$)	$/ Gal	tons/day		$/ Gal	$/ Gal		$/ Gal	$/ Gal
615	Simultaneous saccharification and fermentation			=$C325		1	=C615	=K353	=N357	=K326	=O353	=T357	=P326	=H615	=Z357	=AF357	=P615	=AL357	=AR357
616	Concentrated acid hydrolysis, neutralization and fermentation			=$C366		2	=C616	=K394	=N398	=I367	=O394	=T398	=P367	=H616	=Z398	=AF398	=P616	=AL398	=AR398
617	Ammonia disruption hydrolysis and fermentation			=$C407		3	=C617	=K435	=N439	=K408	=O435	=T439	=P408	=H617	=Z439	=AF439	=P617	=AL439	=AR439
618	Steam disruption, hydrolysis and fermentation			=$C448		4	=C618	=K476	=N480	=J449	=O476	=T480	=P449	=H618	=Z480	=AF480	=P618	=AL480	=AR480
619	Acid disruption and transgenic microorganism fermentation (C			=$C489		5	=C619	=K517	=N521	=J490	=O517	=T521	=P490	=H619	=Z521	=AF521	=P619	=AL521	=AR521
620	Concentrated acid hydrolysis, acid recycle and fermentation			=$C530		6	=C620	=K558	=N562	=J531	=O558	=T562	=P531	=H620	=Z562	=AF562	=P620	=AL562	=AR562
621	Acidified acetone extraction, hydrolysis and fermentation			=$C571		7	=C621	=K599	=N603	=J572	=O599	=T603	=P572	=H621	=Z603	=AF603	=P621	=AL603	=AR603

	C	D	E	F	G	H
626						
627	TRADITIONAL FERMENTATION					
628	Plant feedrate (dry tons per day)	1456	Biomass	$0.00		
629	Ethanol Production (MM gal/yr)	25				
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	$3.609	Biomass	$0	$0.000
632	200	Pretreatment		Chemicals		
633	210	Recycle & Recovery		Denaturant	$1,088	$0.044
634	300	Hydrolysis		Acid	$0	$0.000
635	400	Fermentation		Ammonia	$0	$0.000
636	410	Hexose Fermentation	$5.620	Nutrients	$0	$0.000
637	420	Pentose Fermentation		Enzymes	$0	$0.000
638	500	Distillation & Dehydration		Yeast	$0	$0.000
639	600	By-Product Preparation		Other Chem	$3,341	$0.134
640	610	Stillage Evaporation		RAW MATE	$4,429	$0.177
641	700	Product Storage & Denat	$1.683	Utilities		
642	800	Utilities & General		Electricity E	($1,390)	($0.06)
643	810	Boiler	$10.009	Water	$52	$0.002
644	820	Non-Boiler Utilities	$16.780	By-products	$173	$0.007
645	830	Environmental	$2.074	VARIABLE (	$3,264	$0.131
646	840	Miscellaneous & Control	$3.213	GEN & ADM	$1,590	$0.064
647	900	Enzyme Production				
648				Operators	$1,620	$0.061
649		Total Installed Equipme	$42.688	Laborers	$750	$0.030
650				Technicians	$157	$0.006
651		Fixed Capital	$42.888	Maintenance	$800	$0.032
652	10%	Miscellaneous	$4.289	Fringe Bene	$807	$0.032
653	5%	Start-up Costs	$2.144	TOTAL LAB	$4,034	$0.161
654	7.50%	Working capital	$3.217	Property Ta	$788	$0.032
655				TOTAL CAS	$9,676	$0.387
656		TOTAL CAPITAL	$52.638	Depreciation	######	$0.063
657				Interest	$0.000	$0.000
658						
659				TOTAL PRO	$11,252	$0.450
660						
661						
662						
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666						

	I	J	K	L	M	N
626	PROCESS COST ONLY (BIOMASS $0)					
627	TRADITIONAL FERMENTATION					
628	Plant feedrate (dry tons per day)	1456	Biomass Cost/ton-	$0.00	Ratio of orig. to proposed size-	1.00
629	Ethanol Production (MM gal/yr)	25	Scaling of original data	1.00		
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	$3.609	Biomass	0	$0.000
632	200	Pretreatment	$0.000	Chemicals		
633	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
634	300	Hydrolysis	$0.000	Acid	0	$0.000
635	400	Fermentation (Unallocated)	$0.000	Ammonia	0	$0.000
636	410	Hexose Fermentation	$5.620	Nutrients	0	$0.000
637	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
638	500	Distillation & Dehydration	$0.000	Yeast	0	$0.000
639	600	By-Product Preparation	$0.000	Other Chemicals	3,341	$0.134
640	610	Stillage Evaporation	$0.000	RAW MATERIAL	4,429	$0.177
641	700	Product Storage & Denatur	$1.683	Utilities		
642	800	Utilities & General	$0.000	Electricity Energ	(1,390)	($0.06)
643	810	Boiler	$10.009	Water	52	$0.002
644	820	Non-Boiler Utilities	$16.780	By-products	173	$0.007
645	830	Environmental	$2.074	VARIABLE COS	3,264	$0.131
646	840	Miscellaneous & Control	$3.213	GEN & ADMIN	1,590	$0.064
647	900	Enzyme Production	$0.000			
648				Operators	750	$0.030
649	1000	Total Fixed Capital	$42.688	Laborers	157	$0.006
650				Technicians	800	$0.032
651	1010	Contingency	$4.289	Maintenance	807	$0.032
652	1020	Startup	$2.144	Fringe Benefits	629	$0.025
653	1030	Working Capital	$3.217	TOTAL LABOR	3,143	$0.126
654				Property Tax & I	788	$0.032
655		TOTAL CAPITAL	$52.638	TOTAL CASH	8,784	$0.351
656				Depreciation	0	$0.000
657				Interest	0	$0.000
658						
659				TOTAL PRODU	8,784	$0.351
660		Power Law Scaling Factor	0.7	PROCESS COST ONLY (BIOMASS $0)	$0.00	
661		Contingency	10.00%	BIOMASS COST 1	$0.00	
662		Start-up factor	5.00%	BIOMASS COST 2	$0.00	
663		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
664		Operating Days per Year	330	Denaturant Use	5%	
665		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
666		Property Tax & Insurance	1.50%	Capital Charge, %/yr	0%	

	O	P	Q	R	S	T
626	PROCESS COST ONLY (BIOMASS $0)					
627	TRADITIONAL FERMENTATION					
628	Plant feedrate (dry tons per day)	291	Biomass Cost/ton-	$0.00	Ratio of orig. to proposed size-	0.20
629	Ethanol Production (MM gal/yr)	5	Scaling of original data	0.32		
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	$1.170	Biomass	0	$0.000
632	200	Pretreatment	$0.000	Chemicals		
633	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
634	300	Hydrolysis	$0.000	Acid	0	$0.000
635	400	Fermentation (Unallocated)	$0.000	Ammonia	0	$0.000
636	410	Hexose Fermentation	$1.822	Nutrients	0	$0.000
637	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
638	500	Distillation & Dehydration	$0.000	Yeast	0	$0.000
639	600	By-Product Preparation	$0.000	Other Chemicals	668	$0.134
640	610	Stillage Evaporation	$0.000	MATERIALS	886	$0.177
641	700	Product Storage & Denatur	$0.613	Utilities		
642	800	Utilities & General	$0.000	Electricity Energy	(278)	($0.06)
643	810	Boiler	$3.244	Water	10	$0.002
644	820	Non-Boiler Utilities	$5.439	By-products	35	$0.007
645	830	Environmental	$0.672	VARIABLE COST TOTAL	653	$0.131
646	840	Miscellaneous & Control	$1.041	GEN & ADMIN	374	$0.075
647	900	Enzyme Production	$0.000			
648				Operators	178	$0.036
649	1000	Total Fixed Capital	$13.901	Laborers	37	$0.007
650				Technicians	188	$0.038
651	1010	Contingency	$1.390	Maintenance	190	$0.038
652	1020	Startup	$0.695	Fringe Benefits	148	$0.030
653	1030	Working Capital	$1.043	TOTAL LABOR	738	$0.148
654				Property Tax & Insur.	256	$0.051
655		TOTAL CAPITAL	$17.029	TOTAL CASH	2,020	$0.404
656				Depreciation	0	$0.000
657				Interest	0	$0.000
658						
659				TOTAL PRODUC	2,020	$0.404
660		Power Law Scaling Factor	0.7	PROCESS COST ONLY (BIOMASS $0)	$0.00	
661		Contingency	10.00%	BIOMASS COST 1	$0.00	
662		Start-up factor	5.00%	BIOMASS COST 2	$0.00	
663		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
664		Operating Days per Year	330	Denaturant Use	5%	
665		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
666		Property Tax & Insurance	1.50%	Capital Charge, %/yr	0%	

	U	V	W	X	Y	Z
626	BIOMASS COST 1					
627	TRADITIONAL FERMENTATION					
628	Plant feedrate (dry tons per day)	1456	Biomass Cost/ton-	$0.00	Ratio of orig. to proposed size-	1.00
629	Ethanol Production (MM gal/yr)	25	Scaling of original data	1.00		
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	$3.609	Biomass	0	$0.000
632	200	Pretreatment	$0.000	Chemicals		
633	210	Recovery & Recycle	$0.000	Denaturant	1,088	$0.044
634	300	Hydrolysis	$0.000	Acid	0	$0.000
635	400	Fermentation (Unallocated)	$0.000	Ammonia	0	$0.000
636	410	Hexose Fermentation	$5.620	Nutrients	0	$0.000
637	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
638	500	Distillation & Dehydration	$0.000	Yeast	0	$0.000
639	600	By-Product Preparation	$0.000	Other Chemicals	3,341	$0.134
640	610	Stillage Evaporation	$0.000	RAW MATERIALS	4,429	$0.177
641	700	Product Storage & Denatur	$1.683	Utilities		
642	800	Utilities & General	$0.000	Electricity/ Energy	(1,390)	($0.06)
643	810	Boiler	$10.009	Water	52	$0.002
644	820	Non-Boiler Utilities	$16.780	By-products	173	$0.007
645	830	Environmental	$2.074	VARIABLE COST T	3,264	$0.131
646	840	Miscellaneous & Control	$3.213	GEN & ADMIN	1,590	$0.064
647	900	Enzyme Production	$0.000			
648				Operators	750	$0.030
649	1000	Total Fixed Capital	$42.688	Laborers	157	$0.006
650				Technicians	800	$0.032
651	1010	Contingency	$4.289	Maintenance	807	$0.032
652	1020	Startup	$2.144	Fringe Benefits	629	$0.025
653	1030	Working Capital	$3.217	TOTAL LABOR	3,143	$0.126
654				Property Tax & Insu	788	$0.032
655		TOTAL CAPITAL	$52.638	TOTAL CASH	8,784	$0.351
656				Depreciation	0	$0.000
657				Interest	0	$0.000
658						
659				TOTAL PRODUCT	8,784	$0.351
660		Power Law Scaling Factor	0.7	PROCESS COST ONLY (BIOMASS $0)	$0.00	
661		Contingency	10.00%	BIOMASS COST 1	$0.00	
662		Start-up factor	5.00%	BIOMASS COST 2	$0.00	
663		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
664		Operating Days per Year	330	Denaturant Use	5%	
665		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
666		Property Tax & Insurance	1.50%	Capital Charge, %/yr	0%	

	AA	AB	AC	AD	AE	AF
626	BIOMASS COST 1					
627	TRADITIONAL FERMENTATION					
628	Plant feedrate (dry tons per day)	291	Biomass Cost/ton-	$0.00	Ratio of orig. to proposed size-	0.20
629	Ethanol Production (MM gal/yr)	5	Scaling of original data	0.32		
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	$1.170	Biomass	0	$0.000
632	200	Pretreatment	$0.000	Chemicals		
633	210	Recovery & Recycle	$0.000	Denaturant	218	$0.044
634	300	Hydrolysis	$0.000	Acid	0	$0.000
635	400	Fermentation (Unallocated)	$0.000	Ammonia	0	$0.000
636	410	Hexose Fermentation	$1.822	Nutrients	0	$0.000
637	420	Pentose Fermentation	$0.000	Enzymes	0	$0.000
638	500	Distillation & Dehydration	$0.000	Yeast	0	$0.000
639	600	By-Product Preparation	$0.000	Other Chemicals	668	$0.134
640	610	Stillage Evaporation	$0.000	RAW MATERIAL	886	$0.177
641	700	Product Storage & Denatur	$0.613	Utilities		
642	800	Utilities & General	$0.000	Electricity/ Ener	(278)	($0.06)
643	810	Boiler	$3.244	Water	10	$0.002
644	820	Non-Boiler Utilities	$5.439	By-products	35	$0.007
645	830	Environmental	$0.672	VARIABLE COS	653	$0.131
646	840	Miscellaneous & Control	$1.041	GEN & ADMIN	374	$0.076
647	900	Enzyme Production	$0.000			
648				Operators	176	$0.036
649	1000	Total Fixed Capital	$13.901	Laborers	37	$0.007
650				Technicians	168	$0.036
651	1010	Contingency	$1.390	Maintenance	190	$0.036
652	1020	Startup	$0.696	Fringe Benefits	148	$0.030
653	1030	Working Capital	$1.043	TOTAL LABOR	738	$0.148
654				Property Tax & I	255	$0.051
655		TOTAL CAPITAL	$17.029	TOTAL CASH	2,020	$0.404
656				Depreciation	0	$0.000
657				Interest	0	$0.000
658						
659				TOTAL PRODU	2,020	$0.404
660		Power Law Scaling Factor	0.7	PROCESS COST ONLY (BIOMASS $0)	$0.00	
661		Contingency	10.00%	BIOMASS COST 1	$0.00	
662		Start-up factor	5.00%	BIOMASS COST 2	$0.00	
663		Working Capital	7.50%	Denaturant Cost, $/gal	$0.87	
664		Operating Days per Year	330	Denaturant Use	5%	
665		Personnel Scaling Factor	0.9	Fringe Benefits	25%	
666		Property Tax & Insurance	1.50%	Capital Charge, %/yr	0%	

	C	D	E	F	G	H	I	J	K	L	M	N
626							=$C$31					
627	TRADIT						=$C627					
628	=$C$32(	=((D629*1000000)/K664)/(((H5+H	=$C$310	0			=$C$32(	=D628/D629*J629	=$C$310	=M660	Ratio of orig. to proposed	=J629/$D629
629	=$C$32	25					=$C$32	=$D$322	Scaling of origi	=(J629/$D629)^K660		
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	3.609	Biomass	=((D628*F628)*$D$307)/1000	=G631/(D629*1000)	100	Biomass Preparation	=$E631*L629	Biomass	=J628*K664*L628/1000	=M631/(J629*100
632	200	Pretreatment		Chemicals			200	Pretreatment	=$E632*L629	Chemicals		
633	210	Recycle & Recovery		Denaturant	=D629*M663*M664*1000	=G633/(D629*1000)	210	Recovery & Recycle	=$E633*L629	Denaturant	=J629*M663*M664*1000	=M633/(J629*100
634	300	Hydrolysis		Acid	0	=G634/(D629*1000)	300	Hydrolysis	=$E634*L629	Acid	=$G634*N628	=M634/(J629*100
635	400	Fermentation		Ammonia	0	=G635/(D629*1000)	400	Fermentation (Unallocated)	=$E635*L629	Ammonia	=$G635*N628	=M635/(J629*100
636	410	Hexose Fermentation	5.62	Nutrients	0	=G636/(D629*1000)	410	Hexose Fermentation	=$E636*L629	Nutrients	=$G636*N628	=M636/(J629*100
637	420	Pentose Fermentation		Enzymes	0	=G637/(D629*1000)	420	Pentose Fermentation	=$E637*L629	Enzymes	=$G637*N628	=M637/(J629*100
638	500	Distillation& Dehydration		Yeast	0	=G638/(D629*1000)	500	Distillation & Dehydration	=$E638*L629	Yeast	=$G638*N628	=M638/(J629*100
639	600	By-Product Preparation		Other Chemicals	3341	=G639/(D629*1000)	600	By-Product Preparation	=$E639*L629	Other Chemicals	=$G639*N628	=M639/(J629*100
640	610	Stillage Evaporation		RAW MATERIALS TOTA	=SUM(G631:G639)	=G640/(D629*1000)	610	Stillage Evaporation	=$E640*L629	RAW MATERIALS TOTAL	=SUM(M631:M639)	=M640/(J629*100
641	700	Product Storage & Denature	1.583	Utilities			700	Product Storage & Denature	=$E641*L629	Utilities		
642	800	Utilities & General		Electricity/ Energy	-1390	=G642/(D629*1000)	800	Utilities & General	=$E642*L629	Electricity/ Energy	=$G642*N628	=M642/(J629*100
643	810	Boiler	10.009	Water	52	=G643/(D629*1000)	810	Boiler	=$E643*L629	Water	=$G643*N628	=M643/(J629*100
644	820	Non-Boiler Utilities	16.78	By-products	173	=G644/(D629*1000)	820	Non-Boiler Utilities	=$E644*L629	By-products	=$G644*N628	=M644/(J629*100
645	830	Environmental	2.074	VARIABLE COST TOTA	=SUM(G640:G644)	=G645/(D629*1000)	830	Environmental	=$E645*L629	VARIABLE COST TOTAL	=SUM(M640:M644)	=M645/(J629*100
646	840	Miscellaneous & Control	3.213	GEN & ADMIN	1590	=G646/(D629*1000)	840	Miscellaneous & Control	=$E646*L629	GEN & ADMIN	=1590*(J629/25)^K665	=M646/(J629*100
647	900	Enzyme Production					900	Enzyme Production	=$E647*L629			
648				Operators	1520	=G648/(D629*1000)				Operators	=$G649*N628^K665	=M648/(J629*100
649		Total Installed Equipment	=SUM(E631:E647)	Laborers	750	=G649/(D629*1000)	1000	Total Fixed Capital	=$E649*L629	Laborers	=$G650*(N628)^K665	=M649/(J629*100
650				Technicians	157	=G650/(D629*1000)				Technicians	=$G651*(N628)^K665	=M650/(J629*100
651		Fixed Capital	=E649	Maintenance	800	=G651/(D629*1000)	1010	Contingency	=K649*K661	Maintenance	=$G652*(N628)^K665	=M651/(J629*100
652	=K661	Miscellaneous	=E651*C652	Fringe Benefits	807	=G652/(D629*1000)	1020	Startup	=K649*K662	Fringe Benefits	=M665*SUM(M648:M651	=M652/(J629*100
653	=K662	Start-up Costs	=E651*C653	TOTAL LABOR	=SUM(G648:G652)	=G653/(D629*1000)	1030	Working Capital	=K649*K663	TOTAL LABOR	=SUM(M648:M652)	=M653/(J629*100
654	=K663	Working capital	=E651*C654	Property Tax & Insur.	=K666*E656*1000	=G654/(D629*1000)				Property Tax & Insur.	=K666*K655*1000	=M654/(J629*100
655				TOTAL CASH	=G645+G646+G653+G654	=G655/(D629*1000)		TOTAL CAPITAL	=SUM(K649:K	TOTAL CASH	=M645+M646+M653+M6	=M655/(J629*100
656		TOTAL CAPITAL	=SUM(E651:E655)	Depreciation	=SLN((E656*1000),($D$318*1000*E656),$D$317	=G656/(D629*1000)				Depreciation	=SLN((K656*1000),(D	=M656/(J629*100
657				Interest	=E656*1000*$D$319	=G657/(D629*1000)				Interest	=K656*1000*$D$319	=M657/(J629*100
658												
659				TOTAL PRODUCTION	=G655+G656+G657	=G659/(D629*1000)				TOTAL PRODUCTION	=M655+M656+M657	=M659/(J629*100
660								Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
661								Contingency	=$D$304	=$C$312	=F628	
662								Start-up factor	=$D$305	=$C$313	=F628	
663								Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
664								Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
665								Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
666								Property Tax & Insurance	=$D$309	Capital Charge, %/yr	=$D$319	

	O	P	Q	R	S	T	U	V	W	X	Y	Z
626	=$C$311						=$C$312					
627	=$C627						=$C627					
628	=$C$320	=J628/J629*P629	=$C$310	=S660	Ratio of orig. to proposed	=P629/$D629	=$C$320	=P628/P629*V629	=$C$310	=Y661	Ratio of orig. to proposed size-	=V629/$D629
629	=$C$321	=$D$321	Scaling of orig	=(P629/$D629)^Q660			=$C$321	=$D$322	Scaling of origin	=(V629/$D629)^W660		
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	=$E631*R629	Biomass	=P628*Q664*R628/1000	=S631/(P629*100	100	Biomass Preparation	=$E631*X629	Biomass	=V628*W664*X628/1000	=Y631/(V629*1000)
632	200	Pretreatment	=$E632*R629	Chemicals			200	Pretreatment	=$E632*X629	Chemicals		
633	210	Recovery & Recycle	=$E633*R629	Denaturant	=P629*S663*S664*1000	=S633/(P629*100	210	Recovery & Recycle	=$E633*X629	Denaturant	=V629*Y663*Y664*1000	=Y633/(V629*1000)
634	300	Hydrolysis	=$E634*R629	Acid	=$G634*T628	=S634/(P629*100	300	Hydrolysis	=$E634*X629	Acid	=$G634*Z628	=Y634/(V629*1000)
635	400	Fermentation (Unallocated)	=$E635*R629	Ammonia	=$G635*T628	=S635/(P629*100	400	Fermentation (Unallocated)	=$E635*X629	Ammonia	=$G635*Z628	=Y635/(V629*1000)
636	410	Hexose Fermentation	=$E636*R629	Nutrients	=$G636*T628	=S636/(P629*100	410	Hexose Fermentation	=$E636*X629	Nutrients	=$G636*Z628	=Y636/(V629*1000)
637	420	Pentose Fermentation	=$E637*R629	Enzymes	=$G637*T628	=S637/(P629*100	420	Pentose Fermentation	=$E637*X629	Enzymes	=$G637*Z628	=Y637/(V629*1000)
638	500	Distillation & Dehydration	=$E638*R629	Yeast	=$G638*T628	=S638/(P629*100	500	Distillation & Dehydration	=$E638*X629	Yeast	=$G638*Z628	=Y638/(V629*1000)
639	600	By-Product Preparation	=$E639*R629	Other Chemicals	=$G639*T628	=S639/(P629*100	600	By-Product Preparation	=$E639*X629	Other Chemicals	=$G639*Z628	=Y639/(V629*1000)
640	610	Stillage Evaporation	=$E640*R629	RAW MATERIALS TOTAL	=SUM(S631:S639)	=S640/(P629*100	610	Stillage Evaporation	=$E640*X629	RAW MATERIALS TOTAL	=SUM(Y631:Y639)	=Y640/(V629*1000)
641	700	Product Storage & Denature	=$E641*R629	Utilities			700	Product Storage & Denature	=$E641*X629	Utilities		
642	800	Utilities & General	=$E642*R629	Electricity/ Energy	=$G642*T628	=S642/(P629*100	800	Utilities & General	=$E642*X629	Electricity/ Energy	=$G642*Z628	=Y642/(V629*1000)
643	810	Boiler	=$E643*R629	Water	=$G643*T628	=S643/(P629*100	810	Boiler	=$E643*X629	Water	=$G643*Z628	=Y643/(V629*1000)
644	820	Non-Boiler Utilities	=$E644*R629	By-products	=$G644*T628	=S644/(P629*100	820	Non-Boiler Utilities	=$E644*X629	By-products	=$G644*Z628	=Y644/(V629*1000)
645	830	Environmental	=$E645*R629	VARIABLE COST TOTAL	=SUM(S640:S644)	=S645/(P629*100	830	Environmental	=$E645*X629	VARIABLE COST TOTAL	=SUM(Y640:Y644)	=Y645/(V629*1000)
646	840	Miscellaneous & Control	=$E646*R629	GEN & ADMIN	=1590*(P629/25)^Q665	=S646/(P629*100	840	Miscellaneous & Control	=$E646*X629	GEN & ADMIN	=1590*(V629/25)^W665	=Y646/(V629*1000)
647	900	Enzyme Production	=$E647*R629				900	Enzyme Production	=$E647*X629			
648				Operators	=$G649*T628^Q665	=S648/(P629*100				Operators	=$G649*Z628^W665	=Y648/(V629*1000)
649	1000	Total Fixed Capital	=$E649*R629	Laborers	=$G650*(T628)^Q665	=S649/(P629*100	1000	Total Fixed Capital	=$E649*X629	Laborers	=$G650*(Z628)^W665	=Y649/(V629*1000)
650				Technicians	=$G651*(T628)^Q665	=S650/(P629*100				Technicians	=$G651*(Z628)^W665	=Y650/(V629*1000)
651	1010	Contingency	=Q649*Q661	Maintenance	=$G652*(T628)^Q665	=S651/(P629*100	1010	Contingency	=W649*W661	Maintenance	=$G652*(Z628)^W665	=Y651/(V629*1000)
652	1020	Startup	=Q649*Q662	Fringe Benefits	=S665*SUM(S648:S651)	=S652/(P629*100	1020	Startup	=W649*W662	Fringe Benefits	=Y665*SUM(Y648:Y651)	=Y652/(V629*1000)
653	1030	Working Capital	=Q649*Q663	TOTAL LABOR	=SUM(S648:S652)	=S653/(P629*100	1030	Working Capital	=W649*W663	TOTAL LABOR	=SUM(Y648:Y652)	=Y653/(V629*1000)
654				Property Tax & Insur.	=Q666*Q655*1000	=S654/(P629*100				Property Tax & Insur.	=W666*W655*1000	=Y654/(V629*1000)
655		TOTAL CAPITAL	=SUM(Q649:(	TOTAL CASH	=S645+S646+S653+S65	=S655/(P629*100		TOTAL CAPITAL	=SUM(W649:W	TOTAL CASH	=Y645+Y646+Y653+Y654	=Y655/(V629*1000)
656				Depreciation	=SLN((Q656*1000),(D	=S656/(P629*100				Depreciation	=SLN((W656*1000),($D$318*1000*W656),$D$317)	=Y656/(V629*1000)
657				Interest	=Q656*1000*$D$319	=S657/(P629*100				Interest	=W656*1000*$D$319	=Y657/(V629*1000)
658												
659				TOTAL PRODUCTION	=S655+S656+S657	=S659/(P629*100				TOTAL PRODUCTION	=Y655+Y656+Y657	=Y659/(V629*1000)
660		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311			Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
661		Contingency	=$D$304	=$C$312	=F628			Contingency	=$D$304	=$C$312	=F628	
662		Start-up factor	=$D$305	=$C$313	=F628			Start-up factor	=$D$305	=$C$313	=F628	
663		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314			Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
664		Operating Days per Year	=$D$307	Denaturant Use	=$D$315			Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
665		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316			Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
666		Property Tax & Insurance	=$D$309	Capital Charge, %/yr	=$D$319			Property Tax & Insurance	=$D$309	Capital Charge, %/yr	=$D$319	

	AA	AB	AC	AD	AE	AF
626	=$C$31					
627	=$C627					
628	=$C$32	=V628/V629*AB629	=$C$310	=AE661	Ratio of orig. to proposed size-	=AB629/$D629
629	=$C$32	=$D$321	Scaling of original data	=(AB629/$D629)^AC660		
630	AREA	CAPITAL COSTS	MM$	PRODUCTION COSTS	$M/Yr	$/gal
631	100	Biomass Preparation	=$E631*AD629	Biomass	=AB628*AC664*AD628/1000	=AE631/(AB629*1000)
632	200	Pretreatment	=$E632*AD629	Chemicals		
633	210	Recovery & Recycle	=$E633*AD629	Denaturant	=AB629*AE663*AE664*1000	=AE633/(AB629*1000)
634	300	Hydrolysis	=$E634*AD629	Acid	=$G634*AF628	=AE634/(AB629*1000)
635	400	Fermentation (Unallocated)	=$E635*AD629	Ammonia	=$G635*AF628	=AE635/(AB629*1000)
636	410	Hexose Fermentation	=$E636*AD629	Nutrients	=$G636*AF628	=AE636/(AB629*1000)
637	420	Pentose Fermentation	=$E637*AD629	Enzymes	=$G637*AF628	=AE637/(AB629*1000)
638	500	Distillation & Dehydration	=$E638*AD629	Yeast	=$G638*AF628	=AE638/(AB629*1000)
639	600	By-Product Preparation	=$E639*AD629	Other Chemicals	=$G639*AF628	=AE639/(AB629*1000)
640	610	Stillage Evaporation	=$E640*AD629	RAW MATERIALS TOTAL	=SUM(AE631:AE639)	=AE640/(AB629*1000)
641	700	Product Storage & Denatur	=$E641*AD629	Utilities		
642	800	Utilities & General	=$E642*AD629	Electricity/ Energy	=$G642*AF628	=AE642/(AB629*1000)
643	810	Boiler	=$E643*AD629	Water	=$G643*AF628	=AE643/(AB629*1000)
644	820	Non-Boiler Utilities	=$E644*AD629	By-products	=$G644*AF628	=AE644/(AB629*1000)
645	830	Environmental	=$E645*AD629	VARIABLE COST TOTAL	=SUM(AE640:AE644)	=AE645/(AB629*1000)
646	840	Miscellaneous & Control	=$E646*AD629	GEN & ADMIN	=1590*(AB629/25)^AC665	=AE646/(AB629*1000)
647	900	Enzyme Production	=$E647*AD629			
648				Operators	=$G649*AF628^AC665	=AE648/(AB629*1000)
649	1000	Total Fixed Capital	=$E649*AD629	Laborers	=$G650*(AF628)^AC665	=AE649/(AB629*1000)
650				Technicians	=$G651*(AF628)^AC665	=AE650/(AB629*1000)
651	1010	Contingency	=AC649*AC661	Maintenance	=$G652*(AF628)^AC665	=AE651/(AB629*1000)
652	1020	Startup	=AC649*AC662	Fringe Benefits	=AE665*SUM(AE648:AE651)	=AE652/(AB629*1000)
653	1030	Working Capital	=AC649*AC663	TOTAL LABOR	=SUM(AE648:AE652)	=AE653/(AB629*1000)
654				Property Tax & Insur.	=AC666*AC655*1000	=AE654/(AB629*1000)
655		TOTAL CAPITAL	=SUM(AC649:AC654)	TOTAL CASH	=AE645+AE646+AE653+AE654	=AE655/(AB629*1000)
656				Depreciation	=SLN((AC656*1000),($D$318*10	=AE656/(AB629*1000)
657				Interest	=AC656*1000*$D$319	=AE657/(AB629*1000)
658						
659				TOTAL PRODUCTION	=AE655+AE656+AE657	=AE659/(AB629*1000)
660		Power Law Scaling Factor	=$D$303	=$C$311	=$D$311	
661		Contingency	=$D$304	=$C$312	=F628	
662		Start-up factor	=$D$305	=$C$313	=F628	
663		Working Capital	=$D$306	Denaturant Cost, $/gal	=$D$314	
664		Operating Days per Year	=$D$307	Denaturant Use	=$D$315	
665		Personnel Scaling Factor	=$D$308	Fringe Benefits	=$D$316	
666		Property Tax & Insurance	=$D$309	Capital Charge, %/yr	=$D$319	

	C	D	E	F	G	H	I	J	K	L	M	N	O	P
667	ENERGY VALUES (BTU)	Fiber (ton dry matter)	#2 Diesel (Bbl)	#6 fuel oil (Bbl)	Coal (ton)	Lignin (ton)	lignin ref							
668	oil & coal ref: USDOE/EIA | Btu	16,800,000	5,900,000	6,300,000	21,000,000	20,714,000	34	PRODUCING SUGAR, BAGASSE, AND MOLASSES						
669	Efficiency of conversion to steam	65%	82%	82%	82%	82%	<--(lignin: est.)							
670	Assumed reduction in retrievable sucrose yield when harvest without open field burning	4%	Factors (Bbl or ton per dry ton bagasse)	Total cost per wet ton prep cane to 96 DA sugar	Field costs = ___% of total per wet ton	Field costs per wet ton prep cane	Factory costs per wet ton prep cane	SCENARIO	BASELINE	SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE AND MOLASSES (BUSINESS-AS-USUAL)				
671	ETHANOL $/GALLON	$1.30	V	$38.47	76%	$29.14	$9.33	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
672	#2 DIESEL (BARREL)	$32.00	2.28	island plantation				SUGAR INDUSTRY PRODUCTS						
673	#6 FUEL OIL (BARREL)	$16.00	2.11					Prepared Cane (wet tons)	123.0	$29.14	$3,585			
674	COAL (TON)	$60.00	0.63	by sugar plantations,	% of total sugar elect. sales	Est. avg. retail value (¢/kWh) sugar electricity	Est. avg. wholesale ¢/kWh, sugar, '91	Leaves & tops (wet tons) not counted in prep. cane	0	--	--			
675	LIGNIN (TON)	--	0.64			$0.13		Sucrose (dry tons)	12.2	$94.40	$791	$360.00	$4,377	
676	Reduction factor for processing unburned leafy trash	0.60				Weighted factors	$0.050	Bagasse (wet tons)	37.2	--	--	$17.50	$651	
677	1991 avg. residential electricity rate,¢/kWh	Kauai	$0.14	100.12	23%	0.032	$0.052	Molasses (wet tons)	3.0	--	--	$40.00	$118	
678	1991 Oahu ¢/kWh	Oahu	$0.09	45.45	11%	0.010	$0.036							
679	1991 Maui (Island) ¢/kWh	Maui Island	$0.12	104.68	24%	0.030	$0.046							
680	1991 Hawaii ¢/kWh	Hawaii	$0.14	160.98	42%	0.058	$0.053	TOTAL			$4,376		$5,146	
681								PROFIT/LOSS PER ACRE						$769
682														
683	SCENARIO	5	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH (LEAFY TRASH USED FOR ELECTRICITY GENERATION)					SCENARIO	6	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, LEAFY TRASH (TO ELECTRICITY), AND ETHANOL (MOLASSES TO ETHANOL)				
684	MATERIAL	TONS/ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
685	SUGAR INDUSTRY PRODUCTS							SUGAR INDUSTRY PRODUCTS						
686	Prepared Cane (wet tons)	123.0	$29.14	$3,585				Prepared Cane (wet tons)	123.0	$29.14	$3,585			
687	Leaves & tops (wet tons) not counted in prep. cane	15.9	$24.18	$383	$15.28	$242		Leaves & tops (wet tons) not counted in prep. cane	15.9	$24.18	$383	$15.28	$242	
688	Sucrose (dry tons)	11.7	$67.78	$791	$360.00	$4,202		Sucrose (dry tons)	11.7	$67.78	$791	$360.00	$4,202	
689	Bagasse (wet tons)	37.2	--	--	$17.50	$651		Bagasse (wet tons)	37.2	--	--	$17.50	$651	
690	Molasses (wet tons)	3.0	--	--	$40.00	$118		Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
691														
692														
693	TOTAL			$4,760		$5,213		TOTAL			$4,887		$5,404	
694	PROFIT/LOSS PER ACRE						$453	PROFIT/LOSS PER ACRE						$537
695														

	C	D	E	F	G	H	I	J	K	L	M	N	O	P
696	SCENARIO	10	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT COAL PRICE (SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					SCENARIO	11	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT #6 FUEL OIL PRICE (BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)				
697	MATERIAL	TONS/ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE	MATERIAL	TONS (BBLS) /ACRE	COST PER TON (BBL)	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
698	SUGAR INDUSTRY PRODUCTS							SUGAR INDUSTRY PRODUCTS						
699	Prepared Cane (wet tons)	123.0	$29.14	$3,585	$0	$0		Prepared Cane (wet tons)	123.0	$29.14	$3,585			
700	Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383	$0	$0		Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383			
701	Sucrose to ethanol	11.7	$67.78	$699	$212.59	$2,481		Sucrose (dry tons)	11.7	$67.78	$791	$360.00	$4,202	
702	Bagasse replaced by tons coal	7.0	$60.00	$423	--	$470.13		Bagasse (wet tons) (replaced by #6 fuel oil) Bbls	23.5	$16.00	$376	--	$622	
703	Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309		Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
704	Bagasse & unburned leafy trash (dry tons) to ethanol	29.6	$42.50	$1,258	$85.00	$2,517		Bagasse & unburned leafy trash (dry tons) to ethanol	29.6	$42.50	$1,258	$85.00	$2,517	
705	Recovered lignin (dry tons) to energy	5.5	--	--	--	see coal		Recovered lignin (dry tons) to energy	5.5	--	--	--	see fuel oil	
706	TOTAL			$6,455		$5,777		TOTAL			$6,501		$7,649	
707	PROFIT/LOSS PER ACRE						($678)	PROFIT/LOSS PER ACRE						$1,149

	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
667														
668	PRODUCING SUGAR, BAGASSE,							PRODUCING SUGAR						
669	AND ETHANOL							AND ETHANOL						
670	SCENARIO	2	SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, AND ETHANOL (MOLASSES TO ETHANOL)					SCENARIO	3	SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT COAL PRICE (BAGASSE AND MOLASSES TO ETHANOL)				
671	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	LOSS PER	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
672	SUGAR INDUSTRY PRODUCTS							SUGAR INDUSTRY PRODUCTS						
673	Prepared Cane (wet tons)	123.0	$29.14	3585.4				Prepared Cane (wet tons)	123.0	$29.14	$3,585			
674	Leaves & tops (wet tons) not counted in prep. cane	0	--	--				Leaves & tops (wet tons) not counted in prep. cane	0	--	--			
675	Sucrose (dry tons)	12.2	$94.40	791.0	$360.00	$4,377		Sucrose (dry tons)	12.2	$94.40	$791	$360.00	$4,377	
676	Bagasse (wet tons)	37.2	--	--	$17.50	$651		Bagasse replaced by tons coal	8.6	$60.00	$517	--	$470	
677	Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309		Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
678								Bagasse (dry tons) to ethanol	19.7	$44.55	$878	$111.99	$2,208	
679								Recovered lignin (dry tons) to energy	3.9	--	--	--	see coal	
680	TOTAL			$4,483		$5,337		TOTAL			$5,878		$7,364	
681	PROFIT/LOSS PER ACRE						$853	PROFIT/LOSS PER ACRE						$1,485
682														
683	SCENARIO	7	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, MOLASSES, AND ETHANOL (UNBURNED LEAFY TRASH TO ETHANOL)					SCENARIO	8	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, AND ETHANOL (MOLASSES AND UNBURNED LEAFY TRASH TO ETHANOL)				
684	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	LOSS PER	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
685	SUGAR INDUSTRY PRODUCTS							SUGAR INDUSTRY PRODUCTS						
686	Prepared Cane (wet tons)	123.0	$29.14	$3,585				Prepared Cane (wet tons)	123.0	$29.14	$3,585			
687	Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383	--	--		Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383			
688	Sucrose (dry tons)	11.7	$67.78	$791	$360.00	$4,202		Sucrose (dry tons)	11.7	$67.78	$791	$360.00	$4,202	
689	Bagasse (wet tons)	37.2	--	--	$17.50	$651		Bagasse (wet tons)	37.2	--	--	$17.50	$651	
690	Molasses (wet tons)	3.0	--	--	$40.00	$118		Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
691	Unburned leafy trash (dry tons) to ethanol	9.9	$38.41	$380	$96.57	$956		Unburned leafy trash (dry tons) to ethanol	9.9	38.4	380.1	96.6	$956	
692	Recovered lignin (dry tons) to energy	2.0	--	--	$63.46	$126		Recovered lignin (dry tons) to energy	2.0	--	--	63.5	125.6	
693	TOTAL			$5,140		$6,052		TOTAL			$5,247		$6,117	
694	PROFIT/LOSS PER ACRE						$912	PROFIT/LOSS PER ACRE						$870
695														

	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
696	SCENARIO	12	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT #6 FUEL OIL PRICE (SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					SCENARIO	13	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT #2 DIESEL PRICE (BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)				
697	MATERIAL	TONS (BBLS) /ACRE	COST PER TON (BBL)	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE	MATERIAL	TONS (BBLS) /ACRE	COST PER TON (BBL)	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
698	SUGAR INDUSTRY PRODUCTS							SUGAR INDUSTRY PRODUCTS						
699	Prepared Cane (wet tons)	123.0	$29.14	$3,585				Prepared Cane (wet tons)	123.0	$29.14	$3,585			
700	Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383				Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383			
701	Sucrose to ethanol	11.7	$67.78	$699	$212.59	$2,481		Sucrose (dry tons)	11.7	$67.78	$791	$360.00	$4,202	
702	Bagasse (wet tons) (replaced by #6 fuel oil) Bbls	23.5	$16.00	$376	--	$821.71		Bagasse (wet tons) (replaced by #2 diesel) Bbls	25.1	$32.00	$802	--	$682	
703	Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309		Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
704	Bagasse & unburned leafy trash (dry tons) to ethanol	29.6	$42.50	$1,258	$85.00	$2,517		Bagasse & unburned leafy trash (dry tons) to ethanol	29.6	$42.50	$1,258	$85.00	$2,517	
705	Recovered lignin (dry tons) to energy	5.5	--	--	--	see fuel oil		Recovered lignin (dry tons) to energy	5.5	--	--	--	e diesel oil	
706	TOTAL			$6,408		$5,929		TOTAL			$6,927		$7,710	
707	PROFIT/LOSS PER ACRE						($479)	PROFIT/LOSS PER ACRE						$782

	AE	AF	AG	AH	AI	AJ	AK
667							
668	PRODUCING						
669	ETHANOL ONLY						
670	SCENARIO	4	SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT COAL PRICE (SUGAR, BAGASSE, AND MOLASSES TO ETHANOL)				
671	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
672	SUGAR INDUSTRY PRODUCTS						
673	Prepared Cane (wet tons)	123.0	$29.14	$3,585			
674	Leaves & tops (wet tons) not counted in prep. cane	0	--	--			
675	Sucrose to ethanol	12.2	$57.46	$699	$212.59	$2,585	
676	Bagasse replaced by tons coal	8.6	$60.00	$517	--	$470.13	
677	Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
678	Bagasse (dry tons) to ethanol	19.7	$44.55	$878	$111.99	$2,208	
679	Recovered lignin (dry tons) to energy	3.9	--	--	--	see coal	
680	TOTAL			$5,786		$5,572	
681	PROFIT/LOSS PER ACRE						($214)
682							
683	SCENARIO	9	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT COAL PRICE (BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)				
684	MATERIAL	TONS/ ACRE	COST PER TON	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
685	SUGAR INDUSTRY PRODUCTS						
686	Prepared Cane (wet tons)	123.0	$29.14	$3,585			
687	Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383			
688	Sucrose (dry tons)	11.7	$67.78	$791	$360.00	$4,202	
689	Bagasse replaced by tons coal	7.0	$60.00	$423	--	$470	
690	Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
691	Bagasse & unburned leafy trash (dry tons) to ethanol	29.6	$42.50	$1,258	$85.00	$2,517	
692	Recovered lignin (dry tons) to energy	5.5	--	--	--	see coal	
693	TOTAL			$6,548		$7,498	
694	PROFIT/LOSS PER ACRE						$950
695							

	AE	AF	AG.	AH	AI	AJ	AK
696	SCENARIO	14	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT #2 DIESEL PRICE (SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)				
697	MATERIAL	TONS (BBLS) /ACRE	COST PER TON (BBL)	COST PER ACRE	VALUE PER TON	VALUE PER ACRE	PROFIT / LOSS PER ACRE
698	SUGAR INDUSTRY PRODUCTS						
699	Prepared Cane (wet tons)	123.0	$29.14	$3,585			
700	Unburned leafy trash (wet tons) -- to ethanol	15.9	$24.18	$383			
701	Sucrose to ethanol	11.7	$67.78	$699	$212.59	$2,481	
702	Bagasse (wet tons) (replaced by #2 diesel) Bbls	25.1	32.0	$802	--	$682	
703	Molasses (wet tons) to ethanol	3.0	$36.21	$107	$104.59	$309	
704	Bagasse & unburned leafy trash (dry tons) to ethanol	29.6	$42.50	$1,258	$85.00	$2,517	
705	Recovered lignin (dry tons) to energy	5.5	--	--	--	see diesel oil	
706	TOTAL			$6,835		$5,989	
707	PROFIT/LOSS PER ACRE						($846)

	C	D	E	F	G	H	I	J	K
667	ENERGY VALUES (BT	Fiber (ton dry m	#2 Diesel (Bbl)	#6 fuel oil (Bbl)	Coal (ton)	Lignin (ton)	lignin ref		
668	oil & coal ref: USDOE/E	=8400*2000	5900000	6300000	21000000	=((9111+10620+113	=C209	PRODUCING SUGAR, BAG	
669	Efficiency of conversion	0.65	0.82	0.82	0.82	=G669	<--(lignin: est.)		
670	Assumed reduction in r	0.04	Factors (Bbl or ton	Total cost per wet ton prep	Field costs = ___% of tota	Field costs per wet to	Factory costs	SCENARIO	=C709
671	ETHANOL $/GALLON	1.3	V	=D758	=H932	=F671*G671	=F671*(1-G67	MATERIAL	TONS/ACRE
672	#2 DIESEL (BARREL)	=E279	=(D668*D669)/(E66	(from Big Island plantation (				SUGAR INDUSTRY PRODU	
673	#6 FUEL OIL (BARREL	16	=(D668*D669)/(F66					Prepared Cane (wet tons)	=(E5+E6)/(D5+D6)
674	COAL (TON)	=E281	=(D668*D669)/(G6	Million kWh generated by s	=AF35	Est. avg. retail value	Est. avg. whol	Leaves & tops (wet tons) not	0
675	LIGNIN (TON)	--	=(D668*D669)/(H6			=H677+H678+H679		Sucrose (dry tons)	=(H5+H6)/(D5+D6)
676	Reduction factor for pro	0.6				Weighted factors	=AK43	Bagasse (wet tons)	=(O5+O6)/(D5+D6)
677	1991 avg. residential el	Kauai	0.13571	=AE48	=AF48	=E677*G677	=(I676/H675)*	Molasses (wet tons)	=(I5+I6)/(D5+D6)
678	*1991 Oahu ¢/kWh*	*Oahu*	*0.09354*	=AE58	=AF58	=E678*G678	=(I676/H675)*		
679	1991 Maui (island) ¢/kW	Maui Island	0.1237	=AE53	=AF53	=E679*G679	=(I676/H675)*		
680	1991 Hawaii ¢/kWh	Hawaii	0.13857	=AE41	=AF41	=E680*G680	=(I676/H675)*	TOTAL	
681								PROFIT/LOSS PER ACRE	
682									
683	=J670	=C713	=E713					=C683	=C714
684	=J671	=K671	=L671	=M671	=N671	=O671	=P671	=C684	=D684
685	=J672							=C685	
686	=J673	=K673	=L673	=M673				=C686	=D686
687	=J674	=W140	=H276*W141	=E687*D687	=W141*AK52*D676*I676	=D687*G687		=C687	=D687
688	=J675	=K675*(1-D670	=F688/D688	=M675	=N675	=D688*G688		=C688	=D688
689	=J676	=K676	=L676	=M676	=N676	=D689*G689		=C689	=D689
690	=J677	=K677	=L677	=M677	=N677	=D690*G690		=Q677	=R677
691									
692									
693	=J680			=SUM(F686:F691)		=SUM(H686:H691)		=Q680	
694	=J681						=H693-F693	=Q681	
695									
696	=AE683	=C718	=E718					=AE683	=C719
697	=AE684	=AF684	=AG684	=AH684	=AI684	=AJ684	=AK684	=AE684	TONS (BBLS)/ACRE
698	=AE685							=AE685	
699	=AE686	=AF686	=AG686	=AH686	=AI686	=D699*G699		=AE686	=AF686
700	=AE687	=AF687	=AG687	=AH687	=AI687	=D700*G700		=AE687	=AF687
701	=AE675	=D688	=E688	=AH675	=AI675	=D701*G701		=AE688	=AF688
702	=AE689	=AF689	=AG689	=AH689	=AI689	=AJ689		Bagasse (wet tons) (replaced	=((K676*U141)-(K705/E
703	=AE690	=AF690	=AG690	=AH690	=AI690	=D703*G703		=AE690	=AF690
704	=AE691	=AF691	=AG691	=AH691	=AI691	=D704*G704		=AE691	=AF691
705	=AE692	=AF692	=AG692	=AH692	=AI692	=AJ692		=AE692	=AF692
706	=AE693			=SUM(F699:F705)		=SUM(H699:H705)		=AE693	
707	=AE694						=H706-F706	=AE694	
708	SCENARIOS	Island assumed						=P671	RESULTS OF NUMBER

	L	M	N	O	P	Q	R	S	T	U	V	W
667												
668						PRODUCING SUG/						
669						AND ETHANOL						
670	=E709					=J670	=C710	=E710				
671	COST PER TON	COST PER ACRE	VALUE PE	VALUE PER ACRE	PROFIT / LOS	=J671	=K671	=L671	=M671	=N671	=O671	=P671
672						=J672						
673	=H671	=K673*L673				=J673	=K673	=L673	=M673			
674	--	--				=J674	=K674	=L674	=M674			
675	=I671*(K673/K675)	=G263	=AK38	=K675*N675		=J675	=K675	=L675	=M675	=N675	=R675*U675	
676	--	--	=U141*(((A	=N676*K676		=J676	=K676	=L676	=M676	=N676	=R676*U676	
677	--	--	=B99	=K677*N677		Molasses (wet tons)	=K677	=H659*V164	=S677*R677	=D671*V164	=R677*U677	
678												
679												
680		=SUM(M673:M678)		=SUM(O673:O678)		=J680			=SUM(T673:T678)		=SUM(V673:V678)	
681					=O680-M680	=J681						=V680-T680
682												
683	=E714					=C683	=C715	=E715				
684	=E684	=F684	=G684	=H684	=I684	=C684	=D684	=E684	=F684	=G684	=H684	=I684
685						=C685						
686	=E686	=F686				=C686	=D686	=E686	=F686			
687	=E687	=F687	=G687	=H687		Unburned leafy tras	=D687	=E687	=F687	--	--	
688	=E688	=F688	=G688	=H688		=C688	=D688	=E688	=F688	=G688	=R688*U688	
689	=E689	=F689	=G689	=H689		=C689	=D689	=E689	=F689	=G689	=R689*U689	
690	=S677	=T677	=U677	=V677		=C690	=D690	=E690	=F690	=G690	=R690*U690	
691						Unburned leafy tras	=R687*W141	=N357*W165	=S691*R691	=W165*D671	=R691*U691	
692						=AE679	=R691*U146	--	--	=(AK52/E675)*I676	=R692*U692	
693		=SUM(M686:M691)		=SUM(O686:O691)		=C693			=SUM(T686:T692)		=SUM(V686:V692)	
694					=O693-M693	=C694						=V693-T693
695												
696	=E719					=J696	=C720	=E720				
697	COST PER TON (BBL)	=AH684	=AI684	=AJ684	=AK684	=J697	=K697	=L697	=M697	=N697	=O697	=P697
698						=J698						
699	=AG686	=AH686				=J699	=K699	=L699	=M699			
700	=AG687	=AH687				=J700	=K700	=L700	=M700			
701	=AG688	=AH688	=AI688	=K701*N701		=C701	=D701	=E701	=F701	=G701	=R701*U701	
702	=D673	=L702*K702	=AI689	=(O676/I676)*I679		=J702	=K702	=L702	=M702	=N702	=O702	
703	=AG690	=AH690	=AI690	=K703*N703		=J703	=K703	=L703	=M703	=N703	=R703*U703	
704	=AG691	=AH691	=G704	=K704*N704		=J704	=K704	=L704	=M704	=N704	=R704*U704	
705	=AG692	=AH692	=AI692	see fuel oil		=J705	=K705	=L705	=M705	=N705	=O705	
706		=SUM(M699:M705)		=SUM(O699:O705)		=J706			=SUM(T699:T705)		=SUM(V699:V705)	
707					=O706-M706	=J707						=V706-T706
708	GALLONS ETHANOL PRODU(											

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
667													
668	PRODUC							PRODUCI					
669	AND ETH							ETHANOL					
670	=Q670	=C711	=E711					=X670	=C712	=E712			
671	=Q671	=R671	=S671	=T671	=U671	=V671	=W671	=X671	=Y671	=Z671	=AA671	=AB671	=AC671
672	=Q672							=X672					
673	=Q673	=R673	=S673	=T673				=X673	=Y673	=Z673	=AA673		
674	=Q674	0	--	--				=X674	0	--	--		
675	=Q675	=R675	=S675	=T675	=U675	=Y675*AB675		Sucrose to	=Y675	=((T99*V99	=AG675*AF675	=((T99*V99)+(U99*	=AF675*AI675
676	Bagasse	=((K676*U141)-	=D674	=Z676*Y676	--	=(O676/I676)*I678		=X676	=Y676	=Z676	=AA676	=AB676	=AC676
677	=Q677	=R677	=S677	=T677	=U677	=Y677*AB677		=X677	=Y677	=Z677	=AA677	=AB677	=AF677*AI677
678	Bagasse	=K676*U141	=N357*U1	=Z678*Y678	=U165*D671	=AB678*Y678		=X678	=Y678	=Z678	=AA678	=AB678	=AI678*AF678
679	Recovere	=Y678*U146	--	--	--	see coal		=X679	=Y679	=Z679	=AA679	=AB679	=AC679
680	=Q680			=SUM(AA673:AA679)		=SUM(AC673:AC679)		=X680			=SUM(AH673:AH679)		=SUM(AJ673:AJ679)
681	=Q681						=AC680-AA680	=X681					
682													
683	=Q683	=C716	=E716					=X683	=C717	=E717			
684	=Q684	=R684	=S684	=T684	=U684	=V684	=W684	=X684	=Y684	=Z684	=AA684	=AB684	=AC684
685	=Q685							=X685					
686	=Q686	=R686	=S686	=T686				=X686	=Y686	=Z686	=AA686		
687	=Q687	=R687	=S687	=T687				=X687	=Y687	=Z687	=AA687		
688	=Q688	=R688	=S688	=T688	=U688	=Y688*AB688		=X688	=Y688	=Z688	=AA688	=AB688	=AF688*AI688
689	=Q689	=R689	=S689	=T689	=U689	=Y689*AB689		=X676	=((K676*U141)-	=Z676	=AF689*AG689	=AB676	=AC676
690	=Q677	=R677	=S677	=T677	=U677	=Y690*AB690		=X690	=Y690	=Z690	=AA690	=AB690	=AF690*AI690
691	=Q691	=R691	=S691	=T691	=U691	=Y691*AB691		Bagasse &	=(D687*W141)-	=((W165*R	=AG691*AF691	=AG691/T357*D67	=AF691*AI691
692	=Q692	=R692	=S692	=T692	=U692	=V692		=X679	=(K676*U141*U	=Z679	=AA679	=AB679	=AC679
693	=Q693			=SUM(AA686:AA691)		=SUM(AC686:AC691)		=X693			=SUM(AH686:AH692)		=SUM(AJ686:AJ692)
694	=Q694						=AC693-AA693	=X694					
695													
696	=J696	=C721	=E721					=Q696	=C722	=E722			
697	=J697	=K697	=L697	=M697	=N697	=O697	=P697	=Q697	=R697	=S697	=T697	=U697	=V697
698	=J698							=Q698					
699	=J699	=K699	=L699	=M699				=Q699	=R699	=S699	=T699		
700	=J700	=K700	=L700	=M700				=Q700	=R700	=S700	=T700		
701	=J701	=K701	=L701	=M701	=N701	=Y701*AB701		=Q701	=R701	=S701	=T701	=U701	=AF701*AI701
702	Bagasse (	=((K676*U141)-	=D672	=Z702*Y702	=N702	=(O676/I676)*I677		=X702	=Y702	=Z702	=AA702	=AB702	=AC702
703	=J703	=K703	=L703	=M703	=N703	=Y703*AB703		=Q703	=R703	=S703	=T703	=U703	=AF703*AI703
704	=J704	=K704	=L704	=M704	=N704	=Y704*AB704		=Q704	=R704	=S704	=T704	=U704	=AF704*AI704
705	=J705	=K705	=L705	=M705	=N705	see diesel oil		=Q705	=Y705	=Z705	=AA705	=AB705	=AC705
706	=J706			=SUM(AA699:AA705)		=SUM(AC699:AC705)		=Q706			=SUM(AH699:AH705)		=SUM(AJ699:AJ705)
707	=J707						=AC706-AA706	=Q707					
708													

	AK
667	
668	
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670	
671	=AD671
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675	
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680	
681	=AJ680-AH680
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683	
684	=AD684
685	
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688	
689	
690	
691	
692	
693	
694	=AJ693-AH693
695	
696	
697	=W697
698	
699	
700	
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702	
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705	
706	
707	=AJ706-AH706
708	

	C	D	E	F	G	H	I	J	K	L
708	SCENARIOS	Island assumed						PROFIT / LOSS PER ACRE	RESULTS OF NUMBERED SCENARIO RUNS: $/HARVESTED ACRE INCREASE OR DECREASE COMPARED TO BASELINE	GALLONS ETHANOL PRODUCED PER ACRE
709	BASELINE	State average	**SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE AND MOLASSES (BUSINESS-AS-USUAL)**					$769	**$0**	0
710	2	State average	SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, AND ETHANOL (MOLASSES TO ETHANOL)					$853	**$84**	237
711	3	Oahu	SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT COAL PRICE (BAGASSE AND MOLASSES TO ETHANOL)					$1,485	**$716**	1,936
712	4	Oahu	SUGAR COMPANY HARVESTING W/OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT COAL PRICE (SUGAR, BAGASSE, AND MOLASSES TO ETHANOL)					($214)	**($984)**	3,924
713	5	State average	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH (LEAFY TRASH USED FOR ELECTRICITY GENERATION)					$453	**($316)**	0
714	6	State average	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, LEAFY TRASH (TO ELECTRICITY), AND ETHANOL (MOLASSES TO ETHANOL)					$537	**($232)**	237
715	7	State average	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, MOLASSES, AND ETHANOL (UNBURNED LEAFY TRASH TO ETHANOL)					$912	**$143**	735
716	8	State average	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR, BAGASSE, AND ETHANOL (MOLASSES AND UNBURNED LEAFY TRASH TO ETHANOL)					$870	**$101**	973
717	9	Oahu	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT COAL PRICE (BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					$950	**$181**	2,174
718	10	Oahu	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT COAL PRICE (SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					($678)	**($1,447)**	4,082
719	11	Maui	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT #6 FUEL OIL PRICE (BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					$1,149	**$379**	2,174
720	12	Maui	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT #6 FUEL OIL PRICE (SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					($479)	**($1,249)**	4,082
721	13	Kauai/ Hawaii	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING SUGAR AND ETHANOL; BAGASSE VALUED AT #2 DIESEL PRICE (BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					$782	**$13**	2,174
722	14	Kauai/ Hawaii	SUGAR COMPANY HARVESTING WITHOUT OPEN FIELD BURNING; PRODUCING ETHANOL; BAGASSE VALUED AT #2 DIESEL PRICE (SUGAR, BAGASSE, MOLASSES, AND UNBURNED LEAFY TRASH TO ETHANOL)					($846)	**($1,615)**	4,082

	C	D	E	F	G
743	**CONSTANTS**				
744	Lbs/ton	2,000	2,000		
745	Lignin BTU/pound (dry)	10,357			
746	BTU/kWh (theoretical)	3,412			
747	Oil (BTU/ No.6 barrel)	6,300,000			
748	Hours per year	8760			
749					
750					
751					
752	**GENERAL SUGAR PARAMETERS**	**PREPARED CANE PER HARVESTED ACRE**	**BAGASSE PER HARVESTED ACRE**		
753	Crop Production time (years)	2.23	2.23		
754	Wet tons/harv. acre	123.04	37.20	'85 (avg. yr)	
755	Prep cane cost per harv. acre (field & prep)	$3,585.36	-	'91, 2 BI plantns	HCPC & Kau
756	Prep cane cost/ton after washing (wet weight)	$29.14			
757	Total cost per harv. acre (plus factory, etc.)	$4,732.98			
758	Total cost/ton (wet weight)	$38.47			
759	Dry Wgt (%)	28%	52%		
760	Dry weight (tons/harv. acre)	34.46	19.35		
761	Prep cane cost/ton (dry weight)	$104.06			
762	Yield (dry tons/harvested acre)	34.46	19.35		
763	Sucrose (% dw)	43%	3%		
764	Sucrose (total dry tons/harvested acre)	14.67	0.58	includes non-recovered sucrose	
765	Sugar Sales Price ($ per ton)	$360.00		'91 price	
766	Sugar Production Cost ($ per ton)	$389.31		'91 prices; '85 (avg. yr) tonnage	
767	Bagasse Fiber (dry tons/harv acre)	18.77	18.77		
768	Bagasse % Dry Weight	52%	52%		
769	Bagasse Wet tons / harv acre	37.20	37.20		
770	Bagasse Value ($/wet ton)		$16.00		
771	Molasses from Prepared cane (tons/acre)	2.95		'85 (avg. yr)	
772	Molasses value ($/ton)	$40.00			
773	Sugar Content of molasses	60%			
774	Sugar in molasses tons/acre	1.78			
775	Sucrose produced/tons harv acre	12.16	0.58	Sucrose in prep cane column = marketable s	
776	Cellulose (% dw in prepared cane)	22%	38%		
777	Hemicellulose (% dw in prepared cane)	16%	27%		
778	Lignin (% dw in prepared cane)	11%	20%		
779	Cellulose (tons/harvested acre)	7.52	7.35		
780	Hemicellulose tons/harv acre	5.34	5.22		
781	Lignin tons/harvested acre	3.96	3.87		
782	Glucose (tons/harvested acre)	14.51	8.27		
783	Fructose(tons/harvested acre)	6.37	0.30		
784	Xylose (tons/harvested acre)	4.25	4.15		
785	FERMENTABLE SUGARS POT. (tons/harv acre)	25.13	12.73		
786	SUGAR-ANNUAL POTENTIAL (tons/acre/year)	11.29	5.72		
787	TONS SUGARS/DRY TON BIOMASS	0.73	0.66		
788	Ethanol tons /ton sugar (theoretical)	*0.50*	*0.50*		
789	Ethanol (pounds/gal)	*6.58*	*6.58*		
790	Potential ethanol (tons/harv acre)	12.56	6.36		
791	Potential ethanol (gallons/harv acre)	3,819	1,934		
792	Estimated ethanol (gallons/harv acre)	0	0		
793	TOTAL ethanol theoretical pot. (gal/harv acre)	**3,819**	**1,934**		
794	Sucrose to ethanol-conversion efficiency	97%	97%		
795	Converted sugars-conversion efficiency	65%	65%		
796	Estimated ethanol, w/convers. effic. (gal./harvested acre)	3,499	1,674		
797	Estimated ethanol w/convers. effic. (gal./ton ferm sugars)	139.22	131.56		
798	Ethanol potential, w/convers. effic. (gal./acre/year)	1,572	752		
799	Ethanol gal/wet ton processed	28.44	45.01		
800	Ethanol gal/dry ton processed	101.54	86.55		
801	Ethanol Sales Price per gallon	$0.90	$0.90		
802	Efficiency of oil to steam	82%			
803	Btu steam per bbl #6 oil	5,166,000			
804	BTU/lb steam (600 psi-750°F)	1,425			
805	Lbs steam (600 psi-750°F) produced per BBl #6 oil	3,625			
806	Btu in steam required to produce 1 kWh	8250		derived from Pioneer Mill	
807	lbs steam to produce 1 kWh	5.79			
808	kWh per Bbl oil	626.1818182			
809	Electricity Generation Cost /kWh	$0.037			
810	Payment from utility for electricity/kWh	$0.05			
811	**Yields /ton prepared cane(wet)**				
812	DA 96 sugar (tons /ton prep cane)	0.10			
813	Bagasse wet tons /ton prep cane	0.30			
814	Lignin tons /ton prep cane	0.03			
815	ethanol gal /ton prep cane (w/convers. effic.)	28.44			
816	Btus from bagasse in 1 ton prep cane	2,562,313			
817	**Energy Required For Factory Operations**				
818	Tons Prepared Cane Processed Per Hour (tons)	325		Charly's 1990 cogen report, Hamakua diag.	

	C	D	E	F	G
819	Energy Available From Burning Lignin:				
820	Pounds of Lignin/ton prep cane	64.33			
821	BTU's per Pound of Lignin	10,357			
822	BTU's from Lignin/ton prep cane (Btu's)	666,313			
823	BTU Production From Lignin Per Hour (Btu's)	216,551,651			
824	Lbs of Steam From Lignin Per Hour (lbs)	124,595			
825	kWh's from lignin/ton prep cane (kWh)	66			
826	Energy Available From Burning Bagasse:				
827	BTU from Bagasse/ton prep cane (Btu's)	2,562,313			
828	BTU Production From bagasse Per Hour (Btu's)	832,751,637			
829	Lbs of Steam (600 psi-750°F) From Bagasse Per Hour (lbs)	379,800			
830	Energy Production (in kWh equiv) (kWh)	65,611			
831	Energy prod. (in kWh equiv)/ton prep cane (kWh)	202		calculated from above	
832	kWh per ton prep cane	78	from cell $D$838		
833	kWh for sale per ton prep cane	54	from cell $D$837	from HSPA reports	
834	Steam (600 psi-750°F) Req'd For Operations (lbs/hr)	379,800		Charly's 1990 cogen rept	
835	Baseline reported total Btus in steam, per yr	2,309,000,000,000	20	hours per day	
836	Baseline, reported kWh used, kWh/yr	27,630,000	311	days per year	
837	Baseline, reported kWh sold, kWh/yr	62,060,000		Hamakua 1991	
838	Baseline, reported kWh total per year	89,690,000		Hamakua 1991	
839	Baseline, est Btus in steam used for electricity/yr	739,942,500,000			
840	Baseline est. steam (600 psi-750°F) production, lbs/yr	2,362,356,000	from cell $D$834		
841	Baseline, reported steam (600 psi-750°F) needed, lbs/yr	1,620,130,663	from cell $D$835		
842	Baseline, biomass Btus needed, per yr	3,552,307,692,308			
843	Baseline, tons prep cane for biomass Btus, per yr	1,386,368		1991 tons, Hamakua: 1146017	
844	**Ethanol production via SSF, using bagasse**				
845	BTU's Req For SSF Ethanol (Btu's fr. steam per gal eth)	18,058		Stone paper	
846	BTU's Req For SSF Ethanol (Btu per ton prep cane)	513,491			
847	Btus from Steam req for SSF ethanol (Btu/hr)	166,884,710			
848	Steam req (lbs/hr) for SSF ethanol per hour	117,096			
849	Steam required (lbs/hr) for normal operation plus SSF	496,896	HNEI COGENERATION IN SUGAR IND		
850	Steam Available From Burning Lignin (lbs/hr)	124,595			
851	Steam Shortage For Overall Plan Operations (lbs/hr)	372,301			
852	Oil Required For Shortfall (bbl/hr)	103			
853	Cost of #6 Oil Per Barrel	$16.00			
854	Cost of oil to make up factory shortage per hour	$1,643.36			
855	Cost of Oil Required to Make Up Shortage ($/ton prep cane)	$5.06			
856					
857	**Electricity Generation, Retrofit Option**				
858	Efficiency Rating (Retrofit Option)	21%			
859	Capacity Factor	71%	same as baseline		
860	Gross Electricity Generation Retrofit Option (MW)	35.3			
861	Auxiliary power load (MW)	3.53			
862	Steam production req'd for retrofit electricity generation (Btu/hr)	565,197,560			
863	Increased Btu in steam over baseline (Btu/hr)	23,908,996			
864	Field and Factory Load (MW)	3.5			
865	Net plant power (MW)	28			
866	Annual gross electricity production	219,566			
867	Annual electricity export, kWh	175,839			
868	Tons cane per day for all loads	2,179			
869	Tons cane per day for electricity for sale	1,372			
870	kWh produced for sale per ton prep cane	128			
871					
872	**Electricity Generation, Gasifier Option**				
873	Efficiency Rating (gassifier Option)	31%	20	hours per day	
874	Capacity Factor	71%	250	days per year	
875	Gross Electricity Generation Retrofit Option (MW)	29.0			
876	Auxiliary power load (MW)	2.83			
877	Steam production req'd for retrofit electricity generation (Btu/hr)	319,187,097			
878	Increased Btu in steam over baseline (Btu/hr)	(222,101,467)			
879	Field and Factory Load (MW)	3.50			
880	Net plant power (MW)	23			
881	Annual gross electricity production	180,380			
882	Annual electricity export, kWh	141,007			
883	Tons cane per day for all loads	1,143.00			
884	Tons cane per day for electricity for sale	775			
885	kWh produced for sale per ton prep cane	181.99			
886					
887					
888					

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741	**ASSUMPTIONS FOR THESE PROJECTIONS**		
742			
743	**CONSTANTS**		
744	Lbs/ton	2000	2000
745	Lignin BTU/pound (dry)	=H668/2000	
746	BTU/kWh (theoretical)	3412	
747	Oil (BTU/ No.6 barrel)	=F668	
748	Hours per year	=365*24	
749			
750			
751			
752	**GENERAL SUGAR PARAMETERS**	**PREPARED CANE PER HARVESTED ACRE**	**BAGASSE PER HARVESTED ACRE**
753	Crop Production time (years)	=AA83	=AA83
754	Wet tons/harv. acre	=(E5+E6)/(D5+D6)	=(O5+O6)/(D5+D6)
755	Prep cane cost per harv. acre (field & prep)	3585.36	
756	Prep cane cost/ton after washing (wet weight)	=D755/D754	
757	Total cost per harv. acre (plus factory, etc.)	=D755/H932	
758	Total cost/ton (wet weight)	=D757/D754	
759	Dry Wgt (%)	=(F5+F6)/(E5+E6)	=(P5+P6)/(O5+O6)
760	Dry weight (tons/harv. acre)	=D754*D759	=E754*E759
761	Prep cane cost/ton (dry weight)	=D756/D759	
762	Yield (dry tons/harvested acre)	=D754*D759	=E760
763	Sucrose (% dw)	=Q143	0.03
764	Sucrose (total dry tons/harvested acre)	=D762*D763	=E762*E763
765	Sugar Sales Price ($ per ton)	=AK38	
766	Sugar Production Cost ($ per ton)	=(D755/H932)/((H5+H6)/(D5+D6))	
767	Bagasse Fiber (dry tons/harv acre)	=E762-E764	=E760-E764
768	Bagasse % Dry Weight	=E759	=E759
769	Bagasse Wet tons / harv acre	=E754	=E754
770	Bagasse Value ($/wet ton)		16
771	Molasses from Prepared cane (tons/acre)	=(I5+I6)/(D5+D6)	
772	Molasses value ($/ton)	=B99	
773	Sugar Content of molasses	=V143	
774	Sugar in molasses tons/acre	=D771*D773	
775	Sucrose produced/tons harv acre	=(H5+H6)/(D5+D6)	=E764
776	Cellulose (% dw in prepared cane)	=Q144	=U144
777	Hemicellulose (% dw in prepared cane)	=Q145	=U145
778	Lignin (% dw in prepared cane)	=Q146	=U146
779	Cellulose (tons/harvested acre)	=D762*D776	=E762*E776
780	Hemicellulose tons/harv acre	=D762*D777	=E762*E777
781	Lignin tons/harvested acre	=D762*D778	=E762*E778
782	Glucose (tons/harvested acre)	=(D775*$L$88*$T$99)+(D779*$L$89*$S$99)	=(E775*$L$88*$T$99)+(E779*$L$89*S
783	Fructose(tons/harvested acre)	=D775*$L$88*$U$99	=E775*$L$88*$U$99
784	Xylose (tons/harvested acre)	=D780*$L$90*$X$99	=E780*$L$90*$X$99
785	FERMENTABLE SUGARS POT. (tons/harv acre)	=SUM(D782:D784)	=SUM(E782:E784)
786	SUGAR-ANNUAL POTENTIAL (tons/acre/year)	=D785/D753	=E785/E753
787	TONS SUGARS/DRY TON BIOMASS	=D785/D760	=E785/E760
788	Ethanol tons /ton sugar (theoretical)	*0.5*	*0.5*
789	Ethanol (pounds/gal)	*6.58*	*6.58*
790	Potential ethanol (tons/harv acre)	=D785*D788	=E785*E788
791	Potential ethanol (gallons/harv acre)	=D790*D744/D789	=E790*D744/E789
792	Estimated ethanol (gallons/harv acre)	=D791*B792	=E791*B792
793	TOTAL ethanol theoretical pot. (gal/harv acre)	**=((D785*D788)*D744)/D789**	**=((E785*E788)*D744)/E789**
794	Sucrose to ethanol-conversion efficiency	=L94	=L94
795	Converted sugars-conversion efficiency	=L93	=L93
796	Estimated ethanol, w/convers. effic. (gal./harvested acre)	**=((((D782+D783)*D788*D794)+(D784*D788*D795))***	**=((((E782+E783)*E788*E794)+(E784*E78**
797	Estimated ethanol w/convers. effic. (gal./ton ferm sugars)	=D796/D785	=E796/E785
798	Ethanol potential, w/convers. effic. (gal./acre/year)	=D796/D753	=E796/E753
799	Ethanol gal/wet ton processed	=D796/D754	=E796/E754
800	Ethanol gal/dry ton processed	=D796/D762	=E796/E762
801	Ethanol Sales Price per gallon	0.9	0.9
802	Efficiency of oil to steam	=F669	
803	Btu steam per bbl #6 oil	=D747*D802	
804	BTU/lb steam (600 psi-750°F)	1425.19369155403	
805	Lbs steam (600 psi-750°F) produced per BBl #6 oil	=D803/D804	
806	Btu in steam required to produce 1 kWh	8250	
807	lbs steam to produce 1 kWh	=D806/D804	
808	kWh per Bbl oil	=D803/D806	
809	Electricity Generation Cost /kWh	=((E953*C975)-E971)/E970	
810	Payment from utility for electricity/kWh	0.05	
811	**Yields /ton prepared cane(wet)**		
812	DA 96 sugar (tons /ton prep cane)	=D775/D754	
813	Bagasse wet tons /ton prep cane	=D769/D754	
814	Lignin tons /ton prep cane	=D781/D754	
815	ethanol gal /ton prep cane (w/convers. effic.)	=D796/D754	
816	Btus from bagasse in 1 ton prep cane	=(E767/D754)*D668	
817	**Energy Required For Factory Operations**		
818	Tons Prepared Cane Processed Per Hour (tons)	325	

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819	Energy Available From Burning Lignin:		
820	Pounds of Lignin/ton prep cane	=D814*2000	
821	BTU's per Pound of Lignin	=H668/2000	
822	BTU's from Lignin/ton prep cane (Btu's)	=D820*D821	
823	BTU Production From Lignin Per Hour (Btu's)	=D822*D818	
824	Lbs of Steam From Lignin Per Hour (lbs)	=D823*H669/D804	
825	kWh's from lignin/ton prep cane (kWh)	=D824/D807/D818	
826	Energy Available From Burning Bagasse:		
827	BTU from Bagasse/ton prep cane (Btu's)	=D816	
828	BTU Production From bagasse Per Hour (Btu's)	=D827*D818	
829	Lbs of Steam (600 psi-750°F) From Bagasse Per Hour (lbs)	=D828*D669/D804	
830	Energy Production (in kWh equiv) (kWh)	=D829/D807	
831	Energy prod. (in kWh equiv)/ton prep cane (kWh)	=D830/D818	
832	kWh per ton prep cane	=D838/F37	="from cell "&CELL("address",D838)
833	kWh for sale per ton prep cane	=D837/F37	="from cell "&CELL("address",D837)
834	Steam (600 psi-750°F) Req'd For Operations (lbs/hr)	=288600+83600+7600	
835	Baseline reported total Btus in steam, per yr	=1855000000000+454000000000	20
836	Baseline, reported kWh used, kWh/yr	=AD37*1000000	311
837	Baseline, reported kWh sold, kWh/yr	=AE37*1000000	
838	Baseline, reported kWh total per year	=D836+D837	
839	Baseline, est Btus in steam used for electricity/yr	=D838*D806	
840	Baseline est. steam (600 psi-750°F) production, lbs/yr	=D834*E835*E836	="from cell "&CELL("address",D834)
841	Baseline, reported steam (600 psi-750°F) needed, lbs/yr	=D835/D804	="from cell "&CELL("address",D835)
842	Baseline, biomass Btus needed, per yr	=D841*D804/D669	
843	Baseline, tons prep cane for biomass Btus, per yr	=D842/D816	
844	**Ethanol production via SSF, using bagasse**		
845	BTU's Req For SSF Ethanol (Btu's fr. steam per gal eth)	=((8.25+7.83+4.35+0.74)/4)*D746	
846	BTU's Req For SSF Ethanol (Btu per ton prep cane)	=D845*D796/D754	
847	Btus from Steam req for SSF ethanol (Btu/hr)	=D846*D818	
848	Steam req (lbs/hr) for SSF ethanol per hour	=D847/D804	
849	Steam required (lbs/hr) for normal operation plus SSF	=D848+D829	HNEI COGENERATION IN SUGAR IND
850	Steam Available From Burning Lignin (lbs/hr)	=D824	
851	Steam Shortage For Overall Plan Operations (lbs/hr)	=D849-D850	
852	Oil Required For Shortfall (bbl/hr)	=D851/D805	
853	Cost of #6 Oil Per Barrel	=D673	
854	Cost of oil to make up factory shortage per hour	=D852*D853	
855	Cost of Oil Required to Make Up Shortage ($/ton prep cane)	=D854/D818	
856			
857	**Electricity Generation, Retrofit Option**		
858	Efficiency Rating (Retrofit Option)	0.2131	
859	Capacity Factor	=(E836*E835)/(365*24)	same as baseline
860	Gross Electricity Generation Retrofit Option (MW)	35.3	
861	Auxiliary power load (MW)	3.53	
862	Steam production req'd for retrofit electricity generation (Btu/hr)	=D860*1000*D746/D858	
863	Increased Btu in steam over baseline (Btu/hr)	=D862-(D834*D804)	
864	Field and Factory Load (MW)	3.5	
865	Net plant power (MW)	=D860-D861-D864	
866	Annual gross electricity production	=D860*D859*365*24	
867	Annual electricity export, kWh	=D865*E835*E836	
868	Tons cane per day for all loads	2179	
869	Tons cane per day for electricity for sale	=(D746/D858)*D866/(D668*E767/D754)	
870	kWh produced for sale per ton prep cane	=D867/D869	
871			
872	**Electricity Generation, Gasifier Option**		
873	Efficiency Rating (gassifier Option)	0.31	20
874	Capacity Factor	=(E836*E835)/(365*24)	250
875	Gross Electricity Generation Retrofit Option (MW)	29	
876	Auxiliary power load (MW)	2.83	
877	Steam production req'd for retrofit electricity generation (Btu/hr)	=D875*1000*D746/D873	
878	Increased Btu in steam over baseline (Btu/hr)	=D877-(D834*D804)	
879	Field and Factory Load (MW)	3.5	
880	Net plant power (MW)	=D875-D876-D879	
881	Annual gross electricity production	=D875*D874*365*24	
882	Annual electricity export, kWh	=D880*E835*E836	
883	Tons cane per day for all loads	1143	
884	Tons cane per day for electricity for sale	=(D746/D873)*D881/(D668*E767/D754)	
885	kWh produced for sale per ton prep cane	=D882/D884	
886			
887			

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742	ESTIMATED INCOME FROM OPERATIONS PER HARVESTED ACRE				
743	Prepared Cane to Sugar & Molasses, Bagasse to Electricity (Business As Usual) Scenario 1			Scenario 1	
744	Total Cane Costs =	$38	/wet ton		
745			COST OF	VALUE OF	
746		YIELD	OPERATIONS	PRODUCT	NET VALUE
747		tons, kWh	$ per ton of	$ per ton, kWh	$ per
748		or gallons	prepared cane	or gallon	harvested acre
749	REVENUES				
750	DA96 Sugar (tons/harvested acre)	12.16		$360.00	$4,377
751	Molasses (tons/harvested acre)	2.95		$40.00	$118
752	Ethanol-SF (gals/harvested acre)	0		$0.90	$0
753	Ethanol-SSF (gals/harvested acre)	0		$0.90	$0
754	Electricity sold (kWh/harvested acre)	8,181		$0.05	$409
755	TOTAL REVENUES				$4,904
756	COSTS				
757	Prepared Cane (wet tons)	123.04			
758	Cultivation		$18.96		(2,332)
759	Harvesting/Hauling		$3.31		(407)
760	Cleaning/Shredding		$2.17		(268)
761	Diffusion/Dewatering		$0.29		(36)
762	Waste Disposal		$0.01		(2)
763	Boiling House/Sugar Processing		$1.62		(199)
764	Ethanol Production (SSF)				0
765	Ethanol Production (SF)				0
766	Additional Fuel Costs				0
767	Electricity production		$2.69		(331)
768	Other Factory		$3.40		(418)
769	G&A		$5.80		(714)
770	TOTAL COSTS OF OPERATIONS		$38.25		($4,706)
771	TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				$197
772					
773		YIELD		VALUE	NET VALUE
774		gallons		$ per gal	$ per
775		or kWh		or kWh	harvested acre
776	CREDITS				
777	Federal Small Producer Credit	0		$0.10	$0
778	State Indigenous Fuels Production Cr	0		$0.00	$0
779					
780	Ethanol Tax Credits				$0
781	Dedicated Feedstock Electric Credit	0		$0.015	$0
782	Electricity Tax Credits				$0
783	TOTAL CREDITS				$0
784	TOTAL VALUE WITH CREDITS				$197
785					
786			Scenario 2		
787	ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE				Scenario 2
788	Prepared Cane to Sugar & Molasses, Bagasse to Ethanol by SSF, Lignin to Electricity				
789	Total Cane Costs =	$38	/wet ton		
790			COST OF	VALUE OF	NET
791		YIELD	OPERATIONS	PRODUCT	VALUE
792		tons, kWh	$ per ton of	$ per ton, kWh	$ per
793		or gallons	prepared cane	or gallon	harvested acre
794	REVENUES				
795	DA96 Sugar (tons/harvested acre)	12.16		$360.00	$4,377
796	Molasses (tons/harvested acre)	2.95		$40.00	$118
797	Ethanol-SF (gals/harvested acre)	0		$0.90	$0
798	Ethanol-SSF (gals/harvested acre)	1,674		$0.90	$1,507
799	Electricity (kWh/harvested acre)	8,161		$0.05	$409
800	TOTAL REVENUES				$6,411
801	COSTS OF OPERATIONS				
802	Prepared Cane (wet tons)	123.04			
803	Cultivation		$18.96		(2,332)
804	Harvesting/Hauling		$3.31		(407)
805	Cleaning/Shredding		$2.17		(268)
806	Diffusion/Dewatering		$0.29		(36)
807	Waste Disposal		$0.01		(2)
808	Boiling House/Sugar Processing		$1.62		(199)
809	Ethanol Production (SSF)		$7.79		(959)
810	Ethanol Production (SF)				0
811	Additional Fuel Costs		$5.06		(622)
812	Electricity production		$2.69		(331)
813	Other Factory		$3.40		(418)
814	G&A		$5.80		(714)
815	TOTAL COSTS		$51.10		($6,288)
816	TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				$123
817		YIELD		VALUE	NET VALUE
818		gallons		$ per gal	$ per
819		or kWh		or kWh	harvested acre
820	CREDITS				
821	Federal Small Producer Credit	1,674		$0.10	$167
822	State Indigenous Fuels Production Cr	1,674		$0.00	$0
823					
824	Ethanol Tax Credits				$167
825	Dedicated Feedstock Electric Credit	0		$0.015	$0
826	Electricity Tax Credits				$0
827	TOTAL CREDITS				$167
828	TOTAL VALUE WITH CREDITS				$291

N	O	P	Q	R	S
	ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE				
	Sugar Company Harvesting With Open Field Burning (Scenario 1A)				
	Sugarcane Processed To Sugar and Molasses/Bagasse Burned for Electricity				
	(Business As Usual/Conventional Steam Combustion Option)				
		YIELD	COST OF	VALUE OF	NET
		KWh or tons	OPERATIONS	PRODUCT	VALUE
		per harvested acre	$/ton Prep cane	$/ton or kWh	$/harv. acre
	REVENUES				
	96DA Sugar (tons per harvested acre)	12.16		$360.00	4,377
	Molasses (tons per harvested acre)	2.95		$40.00	118
	Electricity Sales (kWh's/harv. acre)	95,332		$0.05	4,767
	Total Revenues				$9,261
	COSTS OF OPERATIONS				
	Prep Cane (wet tons)	123.04			
	Cultivation		$18.96		(2,332)
	Harvesting/Hauling		$3.31		(407)
	Cleaning/Shredding		$2.17		(268)
	Diffusion		$0.14		(17)
	Dewatering		$0.15		(18)
	Waste Disposal		$0.01		(2)
	Boiling House/Processing		$1.62		(199)
	Electricity Production		$2.69		(331)
	Other Factory		$3.40		(418)
	G&A Costs		$5.80		(714)
	Total Costs		$38.25		($4,706)
	TOTAL INCOME FROM OPERATIONS (per acre)				$4,555
		YIELD		VALUE	NET VALUE
		gallons		$ per gal	$ per
		or kWh		or kWh	harvested acre
	CREDITS/EXEMPTIONS				
	DFS Electric Credit	0		0.015	$0
	Electricity Tax Credits				$0
	TOTAL VALUE WITH CREDITS				$4,565
			Scenario 1B		
	ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE				
	Sugar Company Harvesting With Open Field Burning (Scenario 1B)				
	Sugarcane Processed To Sugar and Molasses/ Bagasse Burned for Electricity				Scenario 1B
	(Business As Usual/Inclusion of Retrofit Option)				
		YIELD	COST OF	VALUE OF	NET
		KWh or	OPERATIONS	PRODUCT	VALUE
		tons	$/ton Prep cane	$/ton or kWh	$/harv. acre
	REVENUES				
	96DA Sugar (tons per harv. acre)	12.16		$360.00	4,377
	Molasses (tons per harvested acre)	2.95		$40.00	118
	Electricity Sales (kWh's/harv. acre)	15,769		$0.05	788
	Total Revenues				$5,283
	COSTS OF OPERATIONS				
	Prepared Cane (tons/harvested acre)	123.04			
	Cultivation		$18.96		(2,332)
	Harvesting/Hauling		$3.31		(407)
	Cleaning/Shredding		$2.17		(268)
	Diffusion		$0.14		(17)
	Dewatering		$0.15		(18)
	Waste Disposal		$0.01		(2)
	Boiling House/Processing		$1.62		(199)
	Electricity Production		$2.81		(345)
	Other Factory		$3.40		(418)
	G&A Costs		$5.80		(714)
	Total Costs		$38.37		($4,721)
	TOTAL INCOME FROM OPERATIONS (per acre)				$561.92
		YIELD		VALUE	NET VALUE
		gallons		$ per gal	$ per
		or kWh		or kWh	harvested acre
	CREDITS/EXEMPTIONS				
	DFS Electric Credit	0		0.015	$0
	Electricity Tax Credits				$0
	TOTAL VALUE WITH CREDITS				$562

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829					
830			Scenario 3		
831	ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE				
832	Prepared Cane to Ethanol by Simple Fermentation, Bagasse to Electricity				
833	Total Cane Costs =	$38	/wet ton		
834			COST OF	VALUE OF	
835		YIELD	OPERATIONS	PRODUCT	NET VALUE
836		tons, kWh	$ per ton of	$ per ton, kWh	$ per
837		or gallons	prepared cane	or gallon	harvested acre
838	REVENUES				
839	DA96 Sugar (tons/harvested acre)	0.00		$360.00	0
840	Molasses (tons/harvested acre)	2.95		$40.00	118
841	Ethanol-SF (gals/harvested acre)	1,793		$0.90	1,613
842	Ethanol-SSF (gals/harvested acre)	0		$0.90	0
843	Electricity (kWh/harvested acre)	8,181		$0.05	409
844	TOTAL REVENUES				$2,141
845	COSTS OF OPERATIONS				
846	Prepared Cane (wet tons/cost)	123.04			
847	Cultivation		$18.96		(2,332)
848	Harvesting/Hauling		$3.31		(407)
849	Cleaning/Shredding		$2.17		(268)
850	Diffusion/Dewatering		$0.29		(36)
851	Waste Disposal		$0.01		(2)
852	Boiling House/Sugar Processing		$1.62		(199)
853	Ethanol Production (SSF)				0
854	Ethanol Production (SF)		$6.88		(847)
855	Additional Fuel Costs				0
856	Electricity production		$2.69		(331)
857	Other Factory		$3.40		(418)
858	G&A		$5.80		(714)
859	TOTAL COSTS		$45.13		($5,553)
860	TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				($3,413)
861		YIELD		VALUE	NET VALUE
862		gallons		$ per gal	$ per
863		or kWh		or kWh	harvested acre
864	CREDITS				
865	Federal Small Producer Credit	1,793		$0.10	$179
866	State Indigenous Fuels Production Cr	1,793		$0.00	$0
867					
868	Ethanol Tax Credits				$179
869	Dedicated Feedstock Electric Credit	0		$0.015	$0
870	Electricity Tax Credits				$0
871	TOTAL CREDITS				$179
872	TOTAL VALUE WITH CREDITS				($3,233)
873					
874			Scenario 4		
875	ESTIMATED INCOME FROM OPERATIONS PER HARVESTED ACRE				
876	Prepared Cane to Ethanol by SF, Bagasse to Ethanol by SSF, Lignin to Electricity				Scenario,4
877	Total Cane Costs =	$38	/wet ton		
878			COST OF	VALUE OF	
879		YIELD	OPERATIONS	PRODUCT	NET VALUE
880		tons, kWh	$ per ton of	$ per ton, kWh	$ per
881		or gallons	prepared cane	or gallon	harvested acre
882	REVENUES				
883	DA96 Sugar (tons/harvested acre)	0.00		$360.00	0
884	Molasses (tons/harvested acre)	2.95		$40.00	118
885	Ethanol-SF (gals/harvested acre)	1,793		$0.90	1,613
886	Ethanol-SSF (gals/harvested acre)	1,674		$0.90	1,507
887	Electricity (kWh/harvested acre)	8,181		$0.05	409
888	TOTAL REVENUES				$3,647
889	COSTS OF OPERATIONS				
890	Prepared Cane (wet tons/cost)	123.04			
891	Cultivation		$18.96		(2,332)
892	Harvesting/Hauling		$3.31		(407)
893	Cleaning/Shredding		$2.17		(268)
894	Diffusion/Dewatering		$0.29		(36)
895	Waste Disposal		$0.01		(2)
896	Boiling House/Sugar Processing		$1.62		(199)
897	Ethanol Production (SSF)		$7.79		(959)
898	Ethanol Production (SF)		$6.88		(847)
899	Additional Fuel Costs		$5.06		(622)
900	Electricity production		$2.90		(357)
901	Other Factory		$3.40		(418)
902	G&A		$5.80		(714)
903	TOTAL COSTS		$58.20		($7,161)
904	TOTAL INCOME FROM OPERATIONS (Per Harvested Acre)				($3,513)
905		YIELD		VALUE	NET VALUE
906		gallons		$ per gal	$ per
907		or kWh		or kWh	harvested acre
908	CREDITS				
909	Federal Small Producer Credit	3,467		$0.10	$347
910	State Indigenous Fuels Production Cr	3,467		$0.00	$0
911					
912	Ethanol Tax Credits				$347
913	Dedicated Feedstock Electric Credit	0		$0.015	$0
914	Electricity Tax Credits				$0
915	TOTAL CREDITS				$347
916	TOTAL VALUE WITH CREDITS				($3,167)
917					

O	P	Q	R	S
		Scenario 1C		
ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED ACRE				
Sugar Company Harvesting With Open Field Burning (Senario 1C)				
Sugarcane Processed To Sugar and Molasses/ Bagasse Burned for Electricity				Scenario 1C
(Business As Usual/Inclusion of Gasifier Option)				
	YIELD	COST OF	VALUE OF	NET
	KWh or	OPERATIONS	PRODUCT	VALUE
	tons	$/ton Prep cane	$/ton or kWh	$/harv. acre
REVENUES				
960A Sugar (tons per harv. acre)	12.16		$360.00	4,377
Molasses (tons per harvested acre)	2.96		$40.00	118
Electricity Sales (kWh's/harv.acre)	22,391		$0.05	1,120
Total Revenues				$5,614
COSTS OF OPERATIONS				
Prepared Cane (tons/harv. acre)	123.04			
Cultivation		$18.96		(2,332)
Harvesting/Hauling		$3.31		(407)
Cleaning/Shredding		$2.17		(268)
Diffusion		$0.14		(17)
Dewatering		$0.15		(18)
Drying		$0.20		(25)
Waste Disposal		$0.01		(2)
Boiling House/Processing		$1.62		(199)
Electricity Production		$2.90		(357)
Other Factory		$3.40		(418)
G&A Costs		$5.80		(714)
Total Costs		$38.67		($4,757)
TOTAL INCOME FROM OPERATIONS (per acre)				$857
	YIELD		VALUE	NET VALUE
	gallons		$ per gal	$ per
	or kWh		or kWh	harvested acre
CREDITS/EXEMPTIONS				
DFS Electric Credit	22,391		0.015	$336
Electricity Tax Credits				$336
TOTAL VALUE WITH CREDITS				$1,183

	I	J	K	L	M	N	O	P	Q	R	S
742	ESTIMATED INCOME FROM OPERATIO						ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED				
743	Prepared Cane to Sugar & Molasses, Bag			Scenario 1			Sugar Company Harvesting With Open Field Burning (Scenario 1A)				
744	Total Cane Costs =	=$D$758	/wet ton				Sugarcane Processed To Sugar and Molasses/Bagasse Burned for				Scenario 1A
745			COST OF	VALUE OF			(Business As Usual/Conventional Steam Combustion Option)				
746		YIELD	OPERATIONS	PRODUCT	NET VALUE			YIELD	COST OF	VALUE OF	NET
747		tons, kWh	$ per ton of	$ per ton, kWh	$ per			KWh or tons	OPERATIONS	PRODUCT	VALUE
748		or gallons	prepared cane	or gallon	harvested acre			per harvested acr	$/ton Prep cane	$/ton or kWh	$/harv. acre
749	REVENUES						REVENUES				
750	DA96 Sugar (tons/harvested acre)	=$D$775		=$D$765	=L750*J750		96DA Sugar (tons per harvested acre)	=$D$775		=$D$765	=R750*P750
751	Molasses (tons/harvested acre)	=$D$771		=$D$772	=L751*J751		Molasses (tons per harvested acre)	=$D$771		=$D$772	=(R751*P751)
752	Ethanol-SF (gals/harvested acre)	0		=$D$801	=L752*J752		Electricity Sales (kWh's/harv. acre)	=D884*P755		=$D$810	=R752*P752
753	Ethanol-SSF (gals/harvested acre)	0		=$D$801	=L753*J753		Total Revenues				=SUM(S750:S752)
754	Electricity sold (kWh/harvested acre)	=$D$837/D		=$D$810	=L754*J754		COSTS OF OPERATIONS				
755	TOTAL REVENUES				=SUM(M750:M754)		Prep Cane (wet tons)	=$D$754			
756	COSTS						Cultivation		=$J$744*$G$933		=-(Q756*P755)
757	Prepared Cane (wet tons)	=$D$754					Harvesting/Hauling		=$J$744*$G$936		=-(Q757*P755)
758	Cultivation		=$J$744*$G$933		=-(K758*J757)		Cleaning/Shredding		=$J$744*$G$941		=-(Q758*P755)
759	Harvesting/Hauling		=$J$744*$G$938		=-(K759*J757)		Diffusion		=$J$744*$E$1037		=-(Q759*P755)
760	Cleaning/Shredding		=$J$744*$G$941		=-(K760*J757)		Dewatering		=$J$744*$E$1038		=-(Q760*P755)
761	Diffusion/Dewatering		=$J$744*$G$942		=-(K761*J757)		Waste Disposal		=$J$744*$G$943		=-(Q761*P755)
762	Waste Disposal		=$J$744*$G$943		=-(K762*J757)		Boiling House/Processing		=$J$744*$G$949		=-(Q762*P755)
763	Boiling House/Sugar Processing		=$J$744*$G$949		=-(K763*J757)		Electricity Production		=K767		=-(Q763*P755)
764	Ethanol Production (SSF)				=-(K764*J757)		Other Factory		=$J$744*$G$958		=-(Q764*P755)
765	Ethanol Production (SF)				=-(K765*J757)		G&A Costs		=$J$744*$G$966		=-(Q765*P755)
766	Additional Fuel Costs				=-(K766*J757)		Total Costs		=SUM(O756:O765)		=SUM(S755:S765)
767	Electricity production		=E970/C973*D809		=-(K767*J757)		TOTAL INCOME FROM OPERATIONS (per acre)				=S753+S766
768	Other Factory		=$J$744*$G$958		=-(K768*J757)						
769	G&A		=$J$744*$G$966		=-(K769*J757)			YIELD		VALUE	NET VALUE
770	TOTAL COSTS OF OPERATIONS		=SUM(K758:K769)		=SUM(M757:M769)			gallons		$ per gal	$ per
771	TOTAL INCOME FROM OPERATIONS (P				=M770+M755			or kWh		or kWh	harvested acre
772							CREDITS/EXEMPTIONS				
773		YIELD		VALUE	NET VALUE		DFS Electric Credit	0		0.015	=R773*P773
774		gallons		$ per gal	$ per		Electricity Tax Credits				=S773
775		or kWh		or kWh	harvested acre		TOTAL VALUE WITH CREDITS				=S767+S774
776	CREDITS										
777	Federal Small Producer Credit	=J753		0.1	=L777*J777				Scenario 1B		
778	State Indigenous Fuels Production Credit	=J753		0	=L778*J778		ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED				
779							Sugar Company Harvesting With Open Field Burning (Scenario 1B)				
780	Ethanol Tax Credits				=SUM(M777:M779)		Sugarcane Processed To Sugar and Molasses/ Bagasse Burned for				Scenario 1B
781	Dedicated Feedstock Electric Credit	0		0.015	=L781*J781		(Business As Usual/Inclusion of Retrofit Option)				
782	Electricity Tax Credits				=M781			YIELD	COST OF	VALUE OF	NET
783	TOTAL CREDITS				=M782+M780			KWh or	OPERATIONS	PRODUCT	VALUE
784	TOTAL VALUE WITH CREDITS				=M783+M771			tons	$/ton Prep cane	$/ton or kWh	$/harv. acre
785							REVENUES				
786			Scenario 2				96DA Sugar (tons per harv. acre)	=$D$775		=$D$765	=R786*P786
787	ESTIMATE OF INCOME FROM OPERATI				Scenario 2		Molasses (tons per harvested acre)	=$D$771		=$D$772	=(R787*P787)
788	Prepared Cane to Sugar & Molasses, Bag						Electricity Sales (kWh's/harv. acre)	=D870*P791		=$D$810	=R788*P788
789	Total Cane Costs =	=$D$758	/wet ton				Total Revenues				=SUM(S786:S788)
790			COST OF	VALUE OF	NET		COSTS OF OPERATIONS				
791		YIELD	OPERATIONS	PRODUCT	VALUE		Prepared Cane (tons/harvested acre)	=$D$754			
792		tons, kWh	$ per ton of	$ per ton, kWh	$ per		Cultivation		=$J$744*$G$933		=-(O792*P791)
793		or gallons	prepared cane	or gallon	harvested acre		Harvesting/Hauling		=$J$744*$G$938		=-(O793*P791)
794	REVENUES						Cleaning/Shredding		=$J$744*$G$941		=-(O794*P791)
795	DA96 Sugar (tons/harvested acre)	=$D$775		=$D$765	=L796*J795		Diffusion		=$J$744*$E$1037		=-(O795*P791)
796	Molasses (tons/harvested acre)	=$D$771		=$D$772	=L796*J796		Dewatering		=$J$744*$E$1038		=-(O796*P791)
797	Ethanol-SF (gals/harvested acre)	0		=$D$801	=L797*J797		Waste Disposal		=$J$744*$G$943		=-(O797*P791)
798	Ethanol-SSF (gals/harvested acre)	=$E$796		=$D$801	=L798*J798		Boiling House/Processing		=$J$744*$G$949		=-(O798*P791)
799	Electricity (kWh/harvested acre)	=$D$837/D		=$D$810	=L799*J799		Electricity Production		=D1078		=-(O799*P791)
800	TOTAL REVENUES				=SUM(M795:M799)		Other Factory		=$J$744*$G$958		=-(O800*P791)
801	COSTS OF OPERATIONS						G&A Costs		=$J$744*$G$966		=-(O801*P791)
802	Prepared Cane (wet tons)	=$D$754					Total Costs		=SUM(O792:O801)		=SUM(S791:S801)
803	Cultivation		=$J$744*$G$933		=-(K803*J802)		TOTAL INCOME FROM OPERATIONS (per acre)				=S789+S802
804	Harvesting/Hauling		=$J$744*$G$938		=-(K804*J802)						
805	Cleaning/Shredding		=$J$744*$G$941		=-(K805*J802)			YIELD		VALUE	NET VALUE
806	Diffusion/Dewatering		=$J$744*$G$942		=-(K806*J802)			gallons		$ per gal	$ per
807	Waste Disposal		=$J$744*$G$943		=-(K807*J802)			or kWh		or kWh	harvested acre
808	Boiling House/Sugar Processing		=$J$744*$G$949		=-(K808*J802)		CREDITS/EXEMPTIONS				
809	Ethanol Production (SSF)		=($N$357-$N$340)*		=-(K809*J802)		DFS Electric Credit	0		0.015	=R809*P809
810	Ethanol Production (SF)				=-(K810*J802)		Electricity Tax Credits				=S809
811	Additional Fuel Costs		=$D$855		=-(K811*J802)		TOTAL VALUE WITH CREDITS				=S803+S810
812	Electricity production		=K767		=-(K767*J802)						
813	Other Factory		=$J$744*$G$958		=-(K813*J802)						
814	G&A		=$J$744*$G$966		=-(K814*J802)						
815	TOTAL COSTS		=SUM(K803:K814)		=SUM(M802:M814)						
816	TOTAL INCOME FROM OPERATIONS (P				=M815+M800						
817		YIELD		VALUE	NET VALUE						
818		gallons		$ per gal	$ per						
819		or kWh		or kWh	harvested acre						
820	CREDITS										
821	Federal Small Producer Credit	=SUM(J797:J		0.1	=L821*J821						
822	State Indigenous Fuels Production Credit	=SUM(J797:J		0	=L822*J822						
823											
824	Ethanol Tax Credits				=SUM(M821:M823)						
825	Dedicated Feedstock Electric Credit	0		0.015	=L825*J825						
826	Electricity Tax Credits				=M825						
827	TOTAL CREDITS				=M826+M824						
828	TOTAL VALUE WITH CREDITS				=M816+M827						

9/94 new new hamak spreads

	I	J	K	L	M	N	O	P	Q	R	S
829											
830			Scenario 3				ESTIMATE OF INCOME FROM OPERATIONS PER HARVESTED		Scenario 1C		
831	ESTIMATE OF INCOME FROM OPERATI						Sugar Company Harvesting With Open Field Burning (Senario 1C)				
832	Prepared Cane to Ethanol by Simple Ferm						*Sugarcane Processed To Sugar and Molasses/ Bagasse Burned for*				Scenario 1C
833	Total Cane Costs =	=$D$758	/wet ton				(Business As Usual/Inclusion of Gasifier Option)				
834			COST OF	VALUE OF				YIELD	COST OF	VALUE OF	NET
835		YIELD	OPERATIONS	PRODUCT	NET VALUE			KWh or	OPERATIONS	PRODUCT	VALUE
836		tons, kWh	$ per ton of	$ per ton, kWh	$ per			tons	$/ton Prep cane	$/ton or kWh	$/harv. acre
837		or gallons	prepared cane	or gallon	harvested acre		REVENUES				
838	REVENUES						96DA Sugar (tons per harv. acre)	=$D$775		=$D$765	=R838*P838
839	DA96 Sugar (tons/harvested acre)	0		=$D$765	=L839*J839		Molasses (tons per harvested acre)	=$D$771		=$D$772	=(R839*P839)
840	Molasses (tons/harvested acre)	=$D$771		=$D$772	=L840*J840		Electricity Sales (kWh's/harv.acre)	=D885*P843		=$D$810	=R840*P840
841	Ethanol-SF (gals/harvested acre)	=(D775*D786		=$D$801	=L841*J841		Total Revenues				=SUM(S838:S840)
842	Ethanol-SSF (gals/harvested acre)	0		=$D$801	=L842*J842		COSTS OF OPERATIONS				
843	Electricity (kWh/harvested acre)	=$D$837/D		=$D$810	=L843*J843		Prepared Cane (tons/harv. acre)	=$D$754			
844	TOTAL REVENUES				=SUM(M839:M843)		Cultivation		=$J$744*$G$933		=-(Q844*$P$843)
845	COSTS OF OPERATIONS						Harvesting/Hauling		=$J$744*$G$938		=-(Q845*$P$843)
846	Prepared Cane (wet tons/cost)	=$D$754					Cleaning/Shredding		=$J$744*$G$941		=-(Q846*$P$843)
847	Cultivation		=$J$744*$G$933		=-(K847*J846)		Diffusion		=$J$744*$E$1037		=-(Q847*$P$843)
848	Harvesting/Hauling		=$J$744*$G$938		=-(K848*J846)		Dewatering		=$J$744*$E$1038		=-(Q848*$P$843)
849	Cleaning/Shredding		=$J$744*$G$941		=-(K849*J846)		Drying		=F1097		=-(Q849*$P$843)
850	Diffusion/Dewatering		=$J$744*$G$942		=-(K850*J846)		Waste Disposal		=$J$744*$G$943		=-(Q850*$P$843)
851	Waste Disposal		=$J$744*$G$943		=-(K851*J846)		Boiling House/Processing		=$J$744*$G$949		=-(Q851*$P$843)
852	Boiling House/Sugar Processing		=$J$744*$G$949		=-(K852*J846)		Electricity Production		=$J$744*$G$953		=-(Q852*$P$843)
853	Ethanol Production (SSF)				=-(K853*J846)		Other Factory		=$J$744*$G$958		=-(Q853*$P$843)
854	Ethanol Production (SF)		=(H659-H642)*$J$7		=-(K854*J846)		G&A Costs		=$J$744*$G$966		=-(Q854*$P$843)
855	Additional Fuel Costs				=-(K855*J846)		Total Costs		=SUM(Q844:Q854)		=SUM(S843:S854)
856	Electricity production		=K767		=-(K856*J846)		TOTAL INCOME FROM OPERATIONS (per acre)				=S841+S855
857	Other Factory		=$J$744*$G$958		=-(K857*J846)						
858	G&A		=$J$744*$G$966		=-(K858*J846)			YIELD		VALUE	NET VALUE
859	TOTAL COSTS		=SUM(K847:K858)		=SUM(M846:M858)			gallons		$ per gal	$ per
860	TOTAL INCOME FROM OPERATIONS (P				=M859+M844			or kWh		or kWh	harvested acre
861		YIELD		VALUE	NET VALUE		CREDITS/EXEMPTIONS				
862		gallons		$ per gal	$ per		DFS Electric Credit	=P840		0.015	=R862*P862
863		or kWh		or kWh	harvested acre		Electricity Tax Credits				=S862
864	CREDITS						TOTAL VALUE WITH CREDITS				=S856+S863
865	Federal Small Producer Credit	=SUM(J841:J		0.1	=L865*J865						
866	State Indigenous Fuels Production Credit	=SUM(J841:J		0	=L866*J866		Summary of ethanol scenarios				
867							=K742	=I743			
868	*Ethanol Tax Credits*				=SUM(M865:M867)		=M771	per acre	no tax credits		
869	Dedicated Feedstock Electric Credit	0		0.015	=L869*J869		=M784	=P868	with tax credits		
870	Electricity Tax Credits				=M869		=K786	=I788			
871	TOTAL CREDITS				=M870+M868		=M816	=P868	=O868		
872	TOTAL VALUE WITH CREDITS				=M860+M871		=M828	=P868	=O869		
873							=K830	=I832			
874			Scenario 4				=M860	=P868	=O868		
875	ESTIMATED INCOME FROM OPERATIO						=M872	=P868	=O869		
876	Prepared Cane to Ethanol by SF, Bagasse				Scenario,4		=K874	=I876			
877	Total Cane Costs =	=$D$758	/wet ton				=M904	=P868	=O868		
878			COST OF	VALUE OF			=M916	=P868	=O869		
879		YIELD	OPERATIONS	PRODUCT	NET VALUE						
880		tons, kWh	$ per ton of	$ per ton, kWh	$ per		Summary of electricity scenarios				
881		or gallons	prepared cane	or gallon	harvested acre		=O741	=O743			
882	REVENUES							=O744			
883	DA96 Sugar (tons/harvested acre)	0		=$D$765	=L883*J883			=O745			
884	Molasses (tons/harvested acre)	=$D$771		=$D$772	=L884*J884		=S767	without tax credit			
885	Ethanol-SF (gals/harvested acre)	=J841		=$D$801	=L885*J885		=S775	with tax credit			
886	Ethanol-SSF (gals/harvested acre)	=J796		=$D$801	=L886*J886						
887	Electricity (kWh/harvested acre)	=$D$837/D		=$D$810	=L887*J887						
888	TOTAL REVENUES				=SUM(M883:M887)		=O777	=O779			
889	COSTS OF OPERATIONS							=O780			
890	Prepared Cane (wet tons/cost)	=$D$754						=O781			
891	Cultivation		=$J$744*$G$933		=-(K891*J890)		=S803	=P884			
892	Harvesting/Hauling		=$J$744*$G$938		=-(K892*J890)		=S811	=P885			
893	Cleaning/Shredding		=$J$744*$G$941		=-(K893*J890)						
894	Diffusion/Dewatering		=$J$744*$G$942		=-(K894*J890)						
895	Waste Disposal		=$J$744*$G$943		=-(K895*J890)		=O829	=O831			
896	Boiling House/Sugar Processing		=$J$744*$G$949		=-(K896*J890)			=O832			
897	Ethanol Production (SSF)		=K809		=-(K897*J890)			=O833			
898	Ethanol Production (SF)		=K854		=-(K898*J890)			=P884			
899	Additional Fuel Costs		=$D$855		=-(K899*J890)			=P885			
900	Electricity production		=$J$744*$G$953		=-(K900*J890)						
901	Other Factory		=$J$744*$G$958		=-(K901*J890)						
902	G&A		=$J$744*$G$966		=-(K902*J890)						
903	TOTAL COSTS		=SUM(K891:K902)		=SUM(M890:M902)						
904	TOTAL INCOME FROM OPERATIONS (P				=M903+M888						
905		YIELD		VALUE	NET VALUE						
906		gallons		$ per gal	$ per						
907		or kWh		or kWh	harvested acre						
908	CREDITS										
909	Federal Small Producer Credit	=SUM(J885:J		0.1	=L909*J909						
910	State Indigenous Fuels Production Credit	=SUM(J885:J		0	=L910*J910						
911											
912	Ethanol Tax Credits				=SUM(M909:M911)						
913	Dedicated Feedstock Electric Credit	0		0.015	=L913*J913						
914	Electricity Tax Credits				=M913						
915	TOTAL CREDITS				=M914+M912						
916	TOTAL VALUE WITH CREDITS				=M904+M915						
917											