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Hawai'i Military Biofuels Crop Program
Baseline Island and Biofuels Report
Hawai'i Island

Prepared for:

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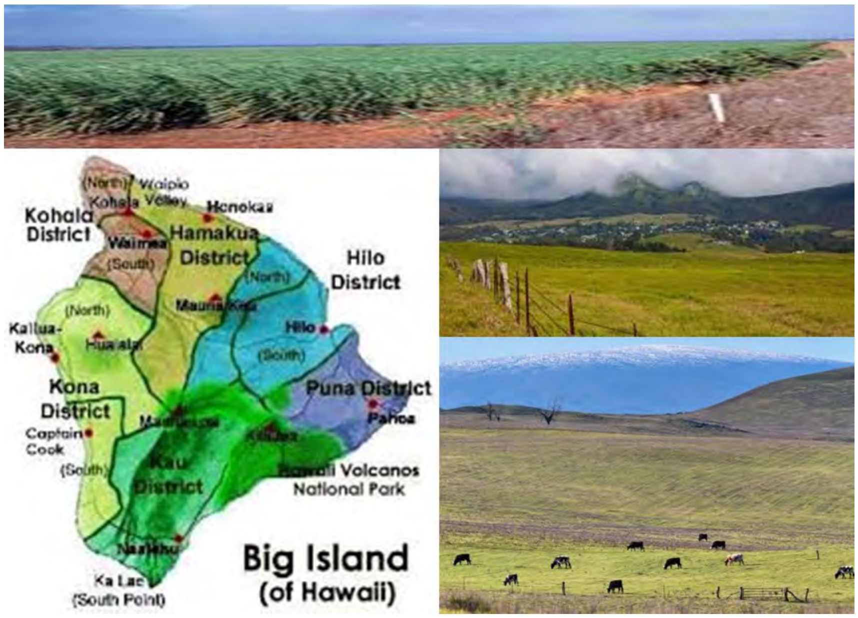

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Statement of Work Task 1

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Executive Summary

The Hawaii Island crop testing plan builds upon the progress made in the Hawaii Military Biofuel Crop (HMBC) demonstration project and will explore the use of sunflowers as a large scale crop with the interest being the development of fuels from local renewable sources. This study provides an overview of the agriculture potential on Hawaii Island, along with a description of the test plots and an overview of the initial test plot growing plan.

Hawaii Island has significant potential for crop production. The island has 1,184,599 acres designated for agriculture. The vast majority of the lands are currently in pasture or fallow. Historically over 80,000 acres were used for sugar cane, and over 40,000 acres in Waimea/South Kohala are suitable for growing sunflower with an investment in infrastructure. It is anticipated that the year round growing season will allow for 2 growing cycles with roughly 100 days of rest for each parcel. The growing cycle for sunflower is largely dependent on solar energy, so each crop will be roughly 120 days from germination to harvest. Initial research indicates that the best planting will be achieved with 27,000 seeds per acre, and produce roughly 1800 lbs of seed and 24 tons of silage per acre. The seed are expected to produce 800 lbs of oil and 1000 pounds of seedcake. These predictions will be tested in the initial crop growth tests. If correct, a 5,000,000 gallon biofuel plant could be supported with roughly 25,000 acres.

Sunflowers have been selected as there is potential to use the entire biomass to create energy and other products. This results in the potential for lower costs for the energy components. In the case of sunflower three markets would be oil for liquid fuels (F-76, biodiesel), silage as feedstock for synthetic gas production and conversion to electricity or fuel, and seedcake for livestock feeds. The specific products are:

<u>BIOMASS</u>

- Vegetable Oil for sale as either a fuel feedstock or as an oil for use in cooking

- Seedcake for sale as livestock feed

- Pelletized silage for use in the gasification plant. Any production exceeding the capacity of the gasification plant will be sold to other biomass users on the Island and in the State.

<u>FUEL</u>

- Aviation fuel for the commercial and Department of Defense Markets

- Transportation Fuels as needed for the local vehicle market

- Methane for the local heating and electrical generation markets

RELATED PRODUCTS

- Ash and fertilizer byproducts from the gasification process

- Glycerin and fertilizer from the biodiesel process

In order to determine the best potential regions on the island for ramping up to commercial scale production, the project has identified the following regions on which to develop 1 acre test sites:

1) North Kohala at Sea Level and at 1500 ft. altitude

2) South Kohala at 3000 ft. altitude ranging from 25 inch to 40 inch annual rainfall

3) Hamakua Coast in the vicinity of Honakaa and North Hilo

4) Puna District

The overall work plan is summarized below. The first step will be to develop, plant, raise and harvest test crops on the 1 acre test sites.

Work Plan Timeline – 9 Months

Months 1-3	Months 4-6	Months 7-9
1. HI Island Biofuel Crop Potential Report **2. Crop Regional Land Identification** **3. Crop Commercialization Site Selection**	**4. Potential Fuel & Byproduct Options from Biomass** **5. Economics Assessment Report** **6. Site Preparation & Development**	**7. Supply Chain Plan** **8. Agriculture Process Infrastructure Plan**
1. Develop & provide survey of suitable lands available for biofuels crop, irrigation potential & estimate of total fuels potential from idle agriculture lands. 2. High Probability Site Selection Report. 3. Site Selection Report. 4. Review TRL 7-9 options for crop specific conversion of non-oil biomass (silage) to fuels to include advanced biofuels, syngas, methane, methane byproducts & hydrogen.	5. Report with additionally include additional economic options such as livestock feed. Identify potential revenue streams for byproducts such as livestock feed, pellitized biomass and cooking oils. Report will evaluate opportunity to reduce cost of fuels. 6. Site Preparation Development Plan. 7. Site Specific Irrigation Engineering Plan. 8. Completed Permits and Lease Report. 9. Site Specific 3-year Crop Commercialization Plans.	10. Operational Flow Chart including jobs provided & Pathway to Commercialization plan. 11. Develop & provide comprehensive plan for equipment & infrastructure to support commercial cultivation & processing of biofuel crops. 12. Jatropha crop viability assessment.

Each site will be developed to identify a select set of key evaluation metrics. These metrics are designed to identify the most likely regions for future expansion to commercial scale. The most important determination is the cost per ton to grow the crops. Not too distant from the primary goal is the need to create a crop growth system that improves the land and allows for long-term maintenance of the supply chain. The key evaluation features will be:

1) Irrigation requirement per acre
2) Fertilizer requirement per acre
3) Rate of growth
4) Crop loss per acre
5) Time required for cover/rotation crops to restore land
6) Infrastructure cost per acre

The following are the selected test sites

1) North Kohala Low Altitude – 500 ft.
2) North Kohala Medium Altitude – 1500 ft.
3) Waimea Dry Side DHHL – 2880 ft.
4) Waimea Mid-range rainfall DHHL – 3100 ft.
5) Waimea Wet Side – 3000 ft.
6) Hamakua Mid-altitude – 2500 ft.
7) North Hilo – 800 ft.
8) Puna low altitude – 650 ft.
9) Puna mid altitude – 900 ft.

This report outlines the baseline information from which the site selection will be finalized.

1. Project Summary

1.1 Overview

1.1.1 Historical Perspective

Figure 1. Pre-Contact Estimated Food Production Areas

Figure 1: Historic Land Use for Hawaii Island from the

Baseline Study for Food Self-Sufficiency (UH-Hilo 2012)

From first settlement until the mid-1800's Hawaii Island was the critical agricultural island in the State. The island produced food for all the residents, which is currently estimated to be somewhere between 400,000 and 1,000,000. Beginning the mid-1800's sugarcane became a dominant crop in Hawaii, along with pineapple, and drove a significant shift towards large mono-crop agriculture. This industry remained on the Island until 1994 when the last of the plantations left the island. Following the collapse of the industry, much of the land was purchased by the Bishop Estate and other smaller trusts. Many government programs were put in place to create new industry with little success. The lands on the Hamakua Coast have, in large part, been planted in Eucalyptus with over 19,000 acres still in the timber.

Another trade that opened land for agriculture was the strong Sandalwood trade with India and China that lasted from 1811 through the early 1830's. This trade destroyed the Sandalwood forests, and left over 100,000 acres of land on Hawaii Island that were converted to ranching. Much of this acreage was in the Waimea region, and now is held by two major landholders, the Department of Hawaiian Home Lands and Parker Ranch.

Prior to the arrival of Europeans, South and North Kohala had extensive agricultural production. The region was seen as a breadbasket. For this study a member of a long-time Waimea Hawaiian Family, Robert Lindsey, was interviewed about the history of the region. Mr. Lindsey is now the Chairman of the Office of Hawaiian Affairs, the State agency responsible for the physical and historic wellbeing of Native Hawaiians.

Robert Lindsey:
"Waimea Nui; our 'aina momona' (a place of abundance) is traditionally agriculture focused place nestled in the lee of the Kohala foothills and the shadow of Mauna Kea Mountain. Waimea Nui is our Canaan, 'our Promise Land of milk and honey.'

Our people settled this 'wahi pana' (sacred place) many, many centuries ago. They came from Hawai'iki guided by the stars, winds, birds and currents in great sea faring canoes bringing with them our ancient gods, protocols, ethics, values, principles, folkways, and mores. They were proud, industrious and hardworking. And in this most isolated corner *of the world's vastest ocean, our people established a 'lei' (a wreath worn around the neck) of chiefdoms that has endured and flourished across time.*

In 1778, the Explorer James Cook stumbled upon us when searching for the Northwest Passage. James Cook came from a culture of "Guns, Germs and Steel" whereas our culture was built on stone and fiber. And with his arrival, the well-kept secret of Hawai'i was gone forever; he opened our shores to the world and put us on a path to globalization. James Cook was the beginning of category 5 force changes that would sweep through our homeland, a homeland that was once described by Mark Twain as the "most beautiful of islands anchored in any ocean."

In 1810 our Warrior Chief Kamehameha Paiea accomplished what others had tried but failed to achieve: he unified our islands (Kauai being the exception). In November 1819, the 'Keepers of The Ancient Ways' and the 'Advocates for Change' resolved their differences in the Battle of Kuamo'o, with the traditionalists on the losing side. In April 1820 (six months later) the first boatload of New England missionaries arrived at Kamakahonu, Kailua-Kona. Some say it was destiny, a void existed, the God of Abraham and Isaac made landfall and filled the existing abyss.

The 19th Century was the 'Pacific Century' and Hawai'i was at its epicenter. The "Sandwich Islands", as Hawai'i was known at the time, served as a replenishing station for ships pursuing commerce (whaling, sandalwood) and plying trade between West and East (the Americas, Europe and Asia). More changes would take our islands by storm, our populace would be decimated by foreign maladies, our 'Ali'i' (Chiefs) would face a continuing struggle against nations lusting after our geographic position in the Pacific (Monroe Doctrine and Manifest Destiny), and within the islands sugar' became 'King' and pineapple its 'Queen.' The significant events include:

- *1831 Lahainaluna School established; western education formalized in the Kingdom of Hawai'i.*
- *1839 first printing of Bible in Hawaiian, French Admiral La Place threatens to bombard Honolulu if the harassment of French Catholics is not stopped by Kamehameha III.; Chief's Children School established with instruction provided by American missionaries.*
- *1840 First Hawaiian Constitution adopted based on Hawaiian and Western principles.*
- *1843 Lord Paulet seizes Hawai'i for England. Admiral Thomas restores Hawai'i's sovereignty that same year.*
- *1848 the Great 'Mahele' (Division), land ownership replaces our indigenous land system whose essence was "the land was chief and we are its servants," we are caretakers not possessors of land; Parker Ranch is established.*
- *1876 Reciprocity Treaty negotiated with U.S. for use of Pearl Harbor Basin as a coaling Station.*

- *1878 telephone service installed at Iolani Palace.*
- *1883 King Kalakaua and Queen Kapiolani are coronated in Honolulu.*
- *1887 Bayonet Constitution proclaimed by Reform Party; King Kalakaua's powers diminished greatly as a result.*
- *1891 Kalakaua dies and is succeeded by his sister Lili'uokalani.*
- *1893 Liliuokalani overthrown by American businessman, U.S. Minister Stevens and U.S. Marines.*
- *1894 Republic of Hawai'i established.*
- *1898 Kingdom of Hawai'i annexed to the United States via Newlands Resolution, majority of Hawaiians voted against annexation.*
- *1900 Hawai'i becomes U.S. Territory.*
- *1920 Hawaiian Homes Commission Act passes out of the U.S. Congress.*
- *1943 Waimea is a major training center for U.S. Marines (2nd & 5th Divisions) participating in the Pacific Campaign against Japan (Tinian, Saipan and Iwo Jima), electrical and domestic water systems were introduced to our paniolo town.*
- *1959 Hawai'i becomes 50th State of the American Union' and responsibility for carrying out the mandates of the Hawaiian Homes Act is passed from the Federal to newly formed State Government and the Department of Hawaiian Home Lands (1960).*
- *1970 Hawaiian Renaissance spreads across the Hawaiian Archipelago.*
- *1978 Constitutional Amendment creates the Office of Hawaiian Affairs, a quasi-State Agency "to better conditions for Hawaiian people.*

Like our ancestors, we the beneficiaries of Waimea Nui are proud, industrious and hard working. Despite all the changes which have rolled across our homeland over centuries, we choose to see our 'glass as being half full' and filling all the time. We are not bitter or chagrined about the history of our past. We are poised to take these events and turn them into future opportunities for our people.

We need to 'Holomua' (move forward), no longer as victims but as victors through a noble and worthy effort to resurrect and reform our nation in a contemporary context: repair our spirits, bring back some of what was lost that was good and blend that with the best of this Global and New World we reside in today. Waimea Nui provides us that 'on ramp' to the future, a future built on aloha, compassion, selflessness and goodwill. For the good of our people and all who call Hawai'i home, this is what we must and will do. The days of handouts and free lunches are 'pau' (gone). We live in a hand up world, where we must do for ourselves, where we must do more with less and less with less, and where we can share what we learn with others around the world. Building on our tradition of agriculture with sunflowers."

1.1.2 Objectives of Baseline Test

The baseline report serves to document the research conducted to determine the best sites for the test crops. In preparation for the test, the Hawaii Biofuels team has conducted site surveys of over 30 potential sites across the island. Many of the sites had aspects that appeared viable, but were eliminated because they would not provide suitable results. The site survey narrowed down the sites based on the following criteria:

1) Ability to expand beyond the test site to larger acreage. The minimum expansion size is 50 acres.

2) Rainfall which enabled reduced irrigation, but did not exceed the plants water requirements

3) Soils which had not been stripped of nutrients by either erosion, sugarcane production, or excessive rainfall.

4) Existing infrastructure supports access to the site with required equipment.

5) Lands are diverse enough to represent the majority of suitable land on the island. This required several sites to be eliminated as they were too similar in environment and soil condition. Elevation is a key discriminator.

6) Land with slopes of less than 1% to reduce costs of land preparation.

For the test, the team held a series of discussions with mainland sunflower farmers and seed companies. The specific objective has been to identify the appropriate varieties to pursue. For the test oil production is the key factor, with overall biomass production being a secondary issue. Additional criteria were suitability for Hawaiian soils, resistance to organic herbicides, maturity rate, and resistance to winds. For the test three varieties were recommended and selected.

1) Cobalt II - Clearfield, high oleic, early maturity
2) Hornet - Clearfield, high oleic, medium-full maturity
3) Camaro II - Clearfield, NuSun (midoleic), medium maturity

As part of the seed identification process it was determined that seed size should either be 3 or 4. This is due to the soil and sun conditions, with this seed size being ideally suited for produce growth and for seed spacing of 27,000 per acre.

Finally the sites that have been selected are flat and surrounded by lands that can be tilled if needed. The test will be conducted using no-till as the primary means to determine if this is adequate to enable crop growth.

1.1.3 Phase One Test Sites

The following sites have been selected for the test. They are listed from North to South, which is the primary mechanism for property identification on Hawaii Island. The sites range from North Kohala to Puna.

Figure 2: Hawaii Island Regions

The following are the selected test sites

1) North Kohala Low Altitude
    a. 500 ft. altitude
    b. Available irrigation from County sources
    c. Land has been in pasture
    d. 20 inch annual rainfall
    e. Equivalent land in area: 325 acres
2) North Kohala Medium Altitude
    a. 1500 ft. altitude
    b. Available irrigation from Watt Water Tunnel overflow
    c. Land has been in pasture
    d. 25 inch annual rainfall
    e. Equivalent land in area: 460 acres

3) Waimea Dry Side DHHL
    a. 2880 ft. altitude
    b. Available irrigation from State Agriculture
    c. Land has been in agriculture
    d. 25 inch annual rainfall
    e. Equivalent land in area: 12,750 acres
4) Waimea Mid-range rainfall DHHL
    a. 3150 ft. altitude
    b. Available irrigation from State Agriculture
    c. Land has been in agriculture
    d. 30 inch annual rainfall
    e. Equivalent land in area: 7,650 acres
5) Waimea Wet Side
    a. 3100 ft. altitude
    b. Available irrigation from State Agriculture
    c. Land has been in pasture
    d. 45 inch annual rainfall
    e. Equivalent land in area: 5,150 acres
6) Hamakua Mid-altitude
    a. 2500 ft. altitude
    b. Available irrigation from State Agriculture
    c. Land has been in pasture
    d. 60 inch annual rainfall
    e. Equivalent land in area: 3,900 acres
7) North Hilo
    a. 1100 ft. altitude
    b. Available irrigation from on-site irrigation ditch
    c. Land has been in agriculture
    d. 75 inch annual rainfall
    e. Equivalent land in area: 650 acres
8) Puna low altitude
    a. 650 ft. altitude
    b. Available irrigation from State Agriculture
    c. Land has been agriculture
    d. 80 inch annual rainfall
    e. Equivalent land in area: 7,000 acres
9) Puna mid altitude
    a. 900 ft. altitude
    b. Available irrigation from State Agriculture
    c. Land has been in agriculture
    d. 75 inch annual rainfall
    e. Equivalent land in area: 2,500 acres

1.2 Farming Test Concept

The test crops will be planted in 9 rows with seed spacing that will match a 27,000 acre rate in each row. The rows will have wider than normal separation to allow testing. Each row will be divided into 3 separate irrigation zones; a) no irrigation b) moderate irrigation, and c) standard irrigation. Each of those subzones will be further subdivided into 3 fertilizer levels; a) no fertilizer, b) low fertilizer, and c) standard fertilizer. Because of the substantial difference in annual rainfall in these regions, some may not require watering at all, others will use one heavy watering during planting, or as is required for the higher rainfall/lower soil areas.

1.3 Sunflower for Biofuels

Introduction

Sunflower, one of the most common oilseed crops, can be easily incorporated into the local cropping systems, and produce added benefits such as enhanced soil health and increased biodiversity in the rotation. (Oilseed production in the northeast: March 2010) According to the USDA national agricultural statistical service, there were 1.6 million acres of oilseed sunflowers harvested in the United States in 2012. (Tennessee State University. Bioenergy- Sunflower for biodiesel prod. 2014)

Hitting closer to home, according to a November report produced by the Hawaii Agricultural Research Center for the State Department of Agriculture, 150 million gallons of biodiesel per year represents 55% of diesel used in the state in 2004.

Capacity for biofuel

Biodiesel is a clean burning renewable fuel made through a chemical process which converts oils and fats of natural origin into fatty acid methyl esters. Biodiesel is a direct replacement for fossil diesel fuel in vehicles and power generators. Reducing the United States' fuel consumption would mean biofuels over time would make up a larger portion of overall transportation fuel.

The production of biodiesel in the US was almost 1.8 billion gallons in 2014. This equates to 0.7% of the total US transportation fuel use. The United States production expanded from 215 million gallons in 2011 to 1.1 billion gallons in 2012. Installed capacity is generally listed as 1.5 to 2 times the current production. There are currently 159 companies working to produce advanced biofuel in the United States and Canada. Not only has the Department of Defense (DoD) invested heavily in advanced biofuel projects, but also the military is the nation's single largest consumer of fuels. Much individual analysis' reveals slow and steady growth for the advanced biofuel industry. (Advanced biofuel report 2013)

Commercial users such as the maritime, aviation, construction and electric power industries consume most diesel fuel in Hawai'i. In 2014 about 3% of all diesel vehicles in the state are powered by biodiesel, which today generally costs 20-30 cents more than conventional diesel, though biodiesel was cheaper during much of 2013.

Growing

Sunflowers germinate when the soil temperature is between 50-55 degrees Fahrenheit. A general rule of thumb is to plant the seed double the depth that the size they are. Cold and wet soil at planting can delay the lower germination, which can often increase susceptibility of the developing seed and shoot to fungal pathogens. Being able to identify sunflower growth stages is important when attempting to identify diseases and pests, many of which affect the plant at only specific development stages. The vegetative phase is denoted with a V, followed by the number of true leaves greater than 2" long- for example V-4 describes when the plant has 4 true leaves, and V-10 when the plant has 10 true leaves. The reproductive phase is denoted with an R, followed by a number that represents stages of flower development and maturation. Significant milestones in this phase are R2 (immature bud formed), R5 (flowering), and R9 (physiological maturity).

When the seed reaches physiological maturity, the receptacle tissue in the head is generally still too wet to allow harvest with a combine. Dry down of the receptacle is dependent on weather conditions. Quickening dry-down of the plant with desiccants such as glyphosate is a common practice in the Great Plains, and can help avoid crop loses to birds by getting the seed out of the field before the peak of the migratory bird season. Applying a desiccant can hasten sunflower harvest by 20 days.

Sunflower development is particularly dependent on accumulation of growing degree-days (GDDs), which influences the rate of maturation of the seed. Full maturation of the seed requires about 2500 heat units, depending on the variety. Hawaii has a steady 12-hour growing time on average. Many varieties of sunflower are well suited for warmer southern climates. (Cooperative extension service or the NRCS 2007)

In Maui farmers grow the sunflowers (up to 4 inches) in a container, water in the AM and keep the soil moist. The sunflowers have deep roots, so they plant the sunflowers in the ground at 4 inches, plant 1-3 inches deep and 3-4 inches apart from each other. The sunflowers need 6-8 hours of sun a day. They should be watered only around base because they can develop powdery mildew if water gets on leaves. Sunflowers are considered full grown when the head droops and petals drop off and back of sunflower head turns brown. The small black seeds have the oil variety. Lastly, Maui has reported 28-32,000 plants yield per acre.

The Farmer's Almanac reported that sunflowers like sandy and loamy soil that is well drained. They claim it is a higher holding water crop that prefers neutral to alkaline/basic soil of a pH of 6-7.5 and little to no wind. They recommend preparing the bed as such: dig down 2 feet, 3 feet across, loosen soil so it isn't too compact. Once planting, put the plants 20-30 inches apart and once the plant is established then water once a week with several gallons of water. Also they reveal that sunflowers are heavy feeders so they need manure, especially during initial planting for strong roots. Gardening tips from the Farmer's Almanac would be to hand pick bugs (they are prone to slugs), pull off yellow leaves, fertilization biweekly, stake the stalk if needs. To fertilize they advise using nitrogen amounts of 90-105 pounds of nitrogen per acre and phosphorus and potassium should be applied if soil tests are below medium values. Lye should be applied if pH is 6 or less. (http://www.almanac.com/plant/sunflowers)

The University of Tennessee has shown the research on sunflowers that in early development, the heads track the sun so sunflowers are planted North to South rows so that the plants will lean into the 30 inch row spaces rather than into each other which could cause seed loss. They have mentioned that grass-type weeds can be managed once sunflowers have germinated using herbicides containing clethodim or sethoxydim. Broadleaf weeds can only be managed using tillage between rows up to the 4-6-leaf stage. They also noticed that wet periods might cause fungal issues. They established that the seeds are mature when the back of the flower head is yellow, and when it is brown it can usually be harvested. To harvest the seed should have 18-20% moisture or less when harvesting and a conventional grain combine with a sunflower head attachments can be used. (Tennessee State University

Bioenergy- Sunflower for biodiesel production 2014)

Pollination:

Interestingly, some studies have shown that sunflowers that are out-crossed with other flowers by insect pollinators have higher yields and higher seed oil contents. Many of the insect pests that present significant economic problems in the Northeast United States appear at the same time that pollinators become important; spraying insecticides becomes problematic in those situations.

Soils and fertility

Sunflowers are best suited for well-drained soils that have good water-holding capacity (i.e. high organic matter and good soil structure). Sunflowers are exceptional scavengers of soil nutrients because of their extremely long taproots. In deep soil, sunflowers are able to access nutrients from between three and four feet, far below the profile of corn and hay.

Nutrient application

To produce optimal yields of sunflowers, 100 to 150 lbs of Nitrogen per acre are required. Adapting Nitrogen applications to specific field management conditions is crucial to maximize yield and quality. Essentially, the amount of Nitrogen fertilizer or other organic amendment will depend on your yield goal, soil type, and past year's fertility practices. Taking a nitrate sample (pre-side dress nitrate test, PSNT) to a two-foot depth will help guide actual Nitrogen needs of the crop during the growing season.

Sunflowers also require relatively low levels of Phosphorus and Potassium. Standard soil tests will estimate available Phosphorus and Potassium in the soil. The testing laboratory will provide recommendations. However, as a recommendation, soils testing high to very high in Phosphorus and Potassium will require no additional input of these nutrients. If soil test levels are low to medium, 60-100 lbs. of Phosphorus or Potassium per acre will be required to produce a sunflower crop.

Oil content and quality

Oilseed sunflower seeds generally contain about 40% oil and 20% protein. The typical percentage of oil extracted from the seed is 40%. 90-day hybrid varieties have the highest percent yield and are the most pest resistant. There are two kinds of oilseed sunflowers that produce oils with different proportions of linoleic and oleic fatty acids, and therefore have different market potentials. Traditional oilseed sunflowers tend to have high in oleic and low oleic fatty acid levels, which makes them a good multipurpose seed. These seeds typically enter the birdseed market, but also can used for biofuel production. High oleic varieties, such as those with the NuSun trait, contain a minimum of 55% oleic fatty acids, and are in high demand for the food industry for use as frying oil. These oils are also good for use as cold-pressed raw oil.

There are 3 different types of oilseed: Linoleic is used to be widespread for low saturated fat content (11% saturated fat). It is 69% polyunsaturated fat and 20%

monounsaturated fat. NuSun or mid- oleic is a predominant oilseed sunflower currently grown (estimated at 85% to 90% of oilseed sunflower acres grown in 2007), the seeds contain less saturated fat than linoleic types (<10% saturated fat and 65% monounsaturated fat). High oleic is low in saturated fats like NuSun, but higher monounsaturated fat content than Nu Sun (82% vs. 65%). High oleic oil is currently grown by contract based on consumer demand. Oils high in unsaturated fats (NuSun or high oleic) may be best for biodiesel quality because their chemical structures can help reduce coagulation in fuel lines under cold temp. (Tennessee State University Bioenergy- Sunflower for biodiesel production. 2014)

Seed size and quality

Sunflower seeds are assigned sizes between 1 and 5, where 1 is the largest and 5 is the smallest; for oilseed sunflowers, sizes 2, 3 and 4 are most common.

Herbicide tolerance

There are currently two herbicide tolerance traits available for sunflower hybrids (Clearfield and ExpressSun). Clearfield sunflowers, which are resistant to imazamox which can be used to control broadleaf weeds. Clearfield has been selected for the tests.

Planting practices

One of the most common production problems in sunflower fields across the country is planter error and leads to long skips or clusters in fields and subsequent increased weed pressure and yield losses. Many of these errors can be avoided with seedbed preparation and planter calibration.

In conventional tillage situations, field preparation is very similar to preparation for corn, which generally includes moldboard and/or chisel plowing, followed by secondary tillage to break up large clods and even out the seedbed. Incorporation of pre-plant herbicides can occur at this point as well.

Equipment Recommendations for planting

Sunflowers should be planted with corn planters or air seeders. Seed meters that use a finger pickup system often have interchangeable finger pickup wheels, and sunflower-specific fingers can be purchased relatively inexpensively. Metering systems that employ a vacuum seed plate also have sunflower specific plates (both flat plates and cell plates) that accommodate the unique shape of sunflower seeds. These basic adjustments provide huge improvements in seed spacing, which corresponds directly to increased yield. Double eliminators also exist in some finger pickup meters. One additional finding is that a combination of talc and graphite greatly improved seed flow through the planter, resulting in better seed placement.

Row spacing

The standard row spacing operated on 30-inch rows. Where some flexibility exists and fungal diseases are less threatening, narrowing the rows while maintaining the total population would achieve a more even distribution of plants across the field and can result in higher yields.

The most effective tool against pests of all kinds is a carefully planned rotation of sunflowers with grass and other broadleaf crops. Virtually every production guide in the United States recommends rotations that call for sunflowers to be planted in a field once every three to five years. Also by altering the time during the season when the sunflower reaches each stage, these sorts of pests can be avoided.

Higher yielding crops like safflower, mustards and sunflower have significant rotational benefits. For example, deep safflower and sunflower roots help break up hardpan and improve soil tilth. Canola and rapeseed can make soil nutrients available for succeeding years' crops. Oil-yielding brassicas such as mustards, canola and rapeseed help reduce soil borne diseases and pathogens.

Rapeseed, mustard and canola should not be grown within 5 years of sunflower rotation. Sunflower is susceptible to scherotinia and should be grown once every 5 years. Should not raise in short rotation with crucifers. (ATTRA Biodiesel: the sustainability dimensions 2010)

Cooperative extension service or the natural resources conservation service (NRCS) may have information of specific oilseed crops that can be raised in certain locations and the best rotations for soil-building and pest suppression benefits. (ATTRA Biodiesel: the sustainability dimensions 2010)

Management of insect pests

Banded sunflower moth is currently the most problematic insect pest in sunflower fields in Vermont. It is extremely widespread, and overwinters in the soils and field margins. The best management option is a good rotation where successive crops are located far enough from each other that the number of moths that can move between the fields is limited. Deep fall plowing after sunflower harvest has also been shown to reduce emergence of the adults by up to 80%, but that strategy can be costly to fuel and time, and is not practical for every field. Recent research suggests that delaying planting date to early June may also reduce banded sunflower moth incidence and severity.

The banded sunflower moth damage results in empty seed hulls, where the larvae have eaten the contents and then exited through the hole at the top of the seed. Loose webbing reveals presence of the larvae over the top of the florets in the area where the larvae are eating seeds. The banded sunflower moth favors field edges, especially where there are grassy and shrubby field margins.

The sunflower midge is another detrimental insect to the sunflower population. They feed on tissue between the bracts and the head, slowly migrating into the center of the head as the florets mature. The initial result is dead tissue along the edges. As the maggots migrate into the head, their feeding causes the head to cup toward the center, and seeds will not develop properly. However, where sunflower midge does exist in high populations, significant percentages of the flowers (10-15%) can be cupped strongly enough to reduce seed development and complicate harvesting.

Biological controls

Keeping beneficial insects in sunflower fields can be extremely effective against insect pests; ladybeetles, lacewings, and hoverflies (syrphid flies) all have predatory stages, and feed on problematic insects. The only actively applied biological agent for pest management is Contans, a fungus that parasitizes the dormant fungal bodies of Sclerotinia.

Sunflower diseases

The Sclerotinia group of fungal diseases is particularly devastating in all crops it insects, and sunflowers are no exception. Verticillium is another common fungal disease in vegetables, but not identified in the Northeast's sunflowers to date. While downy mildew can be a serious problem in sunflowers, especially in a wet climate, the advent and use of resistant hybrids has greatly diminished the potential that downy mildew can cause serious economic crop loss. Get DMRs, downy mildew resistant hybrids when you can.

Cultural controls

The best tool for managing Sclerotinia is a well-planned rotation that employs crops that are not susceptible (i.e. grasses) and long periods between successive sunflower crops. For disease-free fields, sunflower should be planted no more than every 4 years in the same field, with other Sclerotinia-susceptible drops making only rare appearances. A cultural control to deter birds is to select varieties of sunflower that have large and flat enough heads to fully bend over as much as the plant dries so the birds cannot reach the seeds. Some producers have also opted to deal with the amount of crop that a bird flock eats by planting additional acres of sunflowers.

Chemical controls

The most common seed treatment is a combination of the following three fungicides: mefenoxam, azoxystrobin, and fludioxonil. Most of the herbicides that are registered for use in sunflowers should be applied pre-planting, and many have strict guidelines about incorporation.

Major week pests: Broadleaves

The best conventional weed control strategies involve pre-plant herbicides followed by several cultivations to eliminate weeds. Tineweeding can be effective in sunflower fields to reduce grass weed pressure. Cultivation with a rear-mounted tineweeder at both 6 (pre-emergence) and 12 (post emergence) days after planting can provide weed control similar in effectiveness to herbicide.

Sunflower bird pests

Cannons, squawk boxes, scarecrows, eyespot balloons, and shiny ribbons can be effective for short periods of time. However, birds will become accustomed to each of these tactics fairly quickly; they need to be moved regularly and used in combinations in order to stay unpredictable.

Harvesting practices

Seed harvested before the head is dry will cause the wet tissue to clog up and combine, the seed will not thresh out of the head easily, and the trash will not separate well from the seed. Harvested too late, the seed will break in the combine, have poor oil content, and not yield as well.

Plant maturity and seed moisture content

In general, sunflower seeds need to be somewhere below 20% moisture in order to harvest with a combine. To test this, flex the seed head; the seeds should appear somewhat loose, but not so loose that they fall out immediately.

As the population of sunflowers in a field increases, head width decreases, and drying time is shortened. At harvest time, moisture remains higher in sunflower stands with wider heads, or lower populations.

Harvest populations between 28,000 and 30,000 plants per acre have been shown to provide the greatest yields in recent University of Vermont (UVM) Extension trials. Additionally, populations between 28,000 and 30,000 plants per acre produce sunflower head sizes that are small enough to dry well, but large enough to encourage bending over to protect seeds from birds.

Seed cleaning and drying

Cleaning seed before storage is critical to maintaining the quality of the seed and oil over the long term. If the sunflower crop is harvested above 12% moisture, the seed must be dried to bring the moisture down to a point where it can be stored without unnecessary risk of spoilage and reduced oil content. The target moisture for seed storage is between 9% and 12%- the drier end of the range is better for seed stored into the winter, while the wetter end of the spectrum is adequate for shorter-term storage (on the order of weeks). Seed below 6% moisture loses oil content very quickly and can plug up the press, requiring constant maintenance.

Seed storage

Once the sunflower seed has gone into the grain bin for storage, producers should perform weekly checks for seed heating and for condensation on the bin walls and ceiling until the crop has cooled to below freezing. There should be no light or heat in the seed storage bin.

As a recap: The harvesting should be done when the seed is below 20% moisture and the seed should be stored at 9% moisture and less than 110 degrees Fahrenheit. More moisture than 9% then the seed can get moldy. If the moisture is less than 9% then the seed can make oil extraction difficult. Drying seed quickly and controlling the moisture can be a difficult once the seed is harvested. (Biodiesel.org)

Pressing

The seed needs to be clean and dry. The temperature of the oil needs to be watched- it cannot be too hot or too cold; the optimum temperature should be 104 degrees Fahrenheit. To make sure the biofuel is the most capable it can be, run processing through a 2nd time and keep seed and equipment warm. The shells have to be removed before pressing and can be used as animal feed.

One pound of glycerine is a co-product for each 10 pounds of biofuel made, which can have monetary benefits of its own. Glycerine can be used as fuel itself or as a base for soap. The fuel can be used instead of kerosene, home heating fuel can be mixed with up to 50% of glycerine. The methanol needs to be removed first and can be reused in itself. Other uses for glycerine can be compost, fertilizer and feedstock. (Biodiesel.org)

Storage of biofuel:

Settling the oil after it is pressed cleans it, and an additional cleansing can be done running the oil through a 300 micron filter. Tanks may be made of aluminum, steel, Teflon, or fluorinated polyethylene or polypropylene. Fiberglass is sometimes used, but should be approached with caution since some resins are not compatible with biodiesel. (Biodiesel handling and fuel quality, ATTRA publication 2007)

Feedstock

Feedstock, or another by-product of biofuel, has many advantages of its own. It can be fed to animals and also can be used as compost. Sunflower seed cake is not suitable for people, but it makes a good addition to chicken, pig or cattle feed. It is quite high in crude protein, but contains very few carbohydrates. It should be used as a feed additive, not a feed by itself.

It is tricky to get the oil out of the seed if you do not have a proper pressing machine. If you use an efficient machine you could result with up to 518 pounds of oil per acre (40% oil content with a yield of 1300-2000 pounds of seed per acre). In a 4-year (2004-2007) field trial conducted by the University of Tennessee, average yields were 1296 lbs. seed per acre. In other words, sunflower production yields about 50 lbs more per acre than soybeans. (www.dickinson.edu/departments/sustainabilitybiodiesel.html)

Benefits of cooking with Sunflower oil

Linoleic, high-oleic and mid-oleic sunflower oils each contain different amounts of unsaturated and saturated fats. Despite nutritional differences arising from their fat contents, all of these oils are healthy. They have a very high smoke point and are suitable for a variety of cooking applications, contain very little saturated fat and provide more than one-third of your daily intake of the antioxidant vitamin E in 1 tablespoon.

All vegetable oils begin to emit smoke and become inedible if heated above a certain temperature. Heating oils beyond this temperature changes their flavor, color and aroma and also increases their content of cancer-promoting free radicals. Sunflower oil varieties have smoke points ranging from 440 to 450 degrees Fahrenheit. Because of this, they are suitable for nearly all cooking applications -- including searing, browning, stir-frying, deep-frying, baking, oven-cooking and low-temperature preparations, such as for sauces and salad dressings.

Linoleic, or regular, sunflower oil is primarily a polyunsaturated fatty acid, which accounts for 48.3 to 74 percent of the oil's total fats. Monounsaturated fats are the next largest contributor at 14 to 39.4 percent. The saturated palmitic fatty acid adds another 5 to 7.6 percent and other saturated fatty acids each account for 1.5 percent or less. This combination of high polyunsaturated fats and low saturated fats promotes healthy cholesterol levels, as polyunsaturated fats lower total cholesterol levels and help to break down cholesterol deposits in your blood vessels. Replacing saturated fats with polyunsaturated varieties helps to lower your risk of coronary heart disease. Despite these benefits, the high polyunsaturated fat content of linoleic sunflower oil greatly reduces its shelf life.

High-oleic sunflower oils contain much higher concentrations of monounsaturated fats than regular sunflower oil, with 75 to 90.7 percent of their total fats coming from monounsaturated fats. Polyunsaturated fats account for an additional 2.1 to 17 percent, palmitic acid adds 2.6 to 5 percent and other saturated fatty acids account for about 1.6 percent. Similar to regular sunflower oil, this oil's low-saturated, high-unsaturated fat content promotes healthy blood-cholesterol levels. As monounsaturated fats have no impact on coronary heart disease, high-oleic sunflower oils are not as healthy as regular sunflower oil. However, the high monounsaturated fat content of high-oleic sunflower oil gives it the longest shelf life of any sunflower oil.

Mid-oileic sunflower oils contain a balance of polyunsaturated and monounsaturated fats. The fat content of these oils is 43.1 to 71.8 percent monounsaturated, 18.7 to 45.3 percent polyunsaturated, 4 to 5.5 percent palmitic acid and about 1 percent of other saturated fatty acids. This balance of unsaturated fats lends mid-oleic sunflower oil the cardiovascular health benefits of polyunsaturated fats and the longer shelf life of monounsaturated fats -- making it the healthiest of the three varieties of sunflower oil.
(http://healthyeating.sfgate.com/sunflower-oil-healthy-4508.html)

History of renewable fuels

First generation biofuels are derived from food crops such as corn and soybeans. Second generation fuels, commonly referred to as cellulosic fuels, are made from non- food plants, trees or agricultural residues. Algae and other aquatic species produce oils for the 3rd generation biofuels such as jet fuel and sophisticated biodiesels.

Biofuel crop production basics:

The Small Oilseed Processing briefing in May 2007 recommends the following equipment needed for oilseed processing:

Seed prep equipment
Mechanical extractor
Power source for the extractor
Seed storage bin
Meal storage bin
Pumps, filters and plumbing for oil storage

Specific equipment for pressing recommendations:
Bropro refiner $10,000, $2,500 shipping- installation, and hook up
(Journey to4ever.org)

To make fuel from the oil:
2 liters methanol
10 liters veg. oil
35 g NaOH or KOH

It is suggested to measure lye quickly to minimize absorbing the moisture from air and to mix it with methanol in a heatproof glass bottle. Then use a warm new oil to mix, this is better than adding a sodium methoxide solution. The solution then needs to be stirred with drill for 1 hour and to be left overnight to settle. The next day siphon off 10 liters of biodiesel as the final product, while having up to 2 liters of glycerin by-product.

Oil storage tanks

There is caution that farm based processors need to assess current crop yields and costs to determine whether or not an oilseed crop is a viable option for their crop rotations. The end product of oilseed processing produces two products, oil and seed. Oilseed meal is generally used as a feed product for livestock. The oil has a variety of uses, including human consumption, bio-fuels, bio-lubricants, cosmetics, and many other applications. You could also rent the oil to restaurants then take it back and make fuel out of it. (Small Oilseed Processing: briefing may 2007)

Energy usage

PBS announced in 2007 that for every 1 energy unit of fossil fuel used, 3.2 units are gained using biofuel. Rootstock.coop reported for every $1 growing you get $6 in meal and oil and 1 gallon of fuel results in 8-9 gallons of biofuel. The National Center for Appropriate Technology states that 1 unit needed gives 4.5 units of energy. Compared to ethanol and petroleum diesel; biodiesel provides an energy yield of 3.2 (soybean oil), bioethanol provides an energy yield of 1.34, petrodiesel provides an energy yield of .843, and petrogas provides an energy yield of 0.805 (www.ncat.org/special/oilseeds.nrcs.report.06.01.09.pdf)

Advantages and disadvantages to Biofuel

There is an abundant of advantages to using biofuel. The most economical is that engines do not need to be modified in order to use biofuel. Environmentally biofuel creates 78%

lower carbon dioxide into the atmosphere. Biofuel is made from domestically produced and renewable agricultural products, mainly vegetable oil or animal fat and it is essentially non-toxic and biodegradable. Biofuel, in general, has a high flash point (over 300 degrees) and is difficult to light on fire with a match.

Biofuel reduces emissions of many toxic air pollutant and it functions as an excellent fuel lubricant and performs similarly to low sulfur diesel with regards to power, torque, and fuel consumption. Biodiesel has excellent solvent properties and can be used as a cleaning agent and paint remover. It can remove the paint on the side of your car or tractor if you splash it around while filling the tank. In fact, it can even dissolve concrete. (Biodiesel use handling, and fuel quality, ATTRA publication 2007)

The disadvantages of using biofuel are mostly economical. The price (to date) is more expensive to petrofuel. This is largely due to subsidies to oil companies. If the same subsidies could be given to biofuel companies also it would greatly make biofuel a comparable fuel to be used. Bio-jet fuels could provide long-range price stability and maybe even lower ticket prices. The advanced biofuel report 2013 testifies that in order to operate at full capacity, operating expenses, which depend primarily on feedstock prices, must remain low. Operating costs include feedstock costs and are related to productivity per unit of feedstock. Novozymes, an enzyme developer, reports that the costs of cellulosic ethanol production per gallon have decreased approximately 50% since 2007, from $4-8 to $2-3.5. Bloomsberg estimates the minimum price at which cellulosic ethanol could be sold profitably as $3.65/gallon and declining to $2.54/gallon by 2016.

Another disadvantage is that biofuel cannot be used in the cold weather and it also has a low shelf life (6 months). There are questions if an engine would still obtain the manufacturer warranties. Lastly is also a slight issue of having a lower energy content when using biofuel in an engine. On average, B100 has about 80% less energy content (BTU per gallon). Some authorities recommend setting the injection timing back by two to three degrees from top dead center. This will sometimes cause the engine to run quieter, although it may also slightly reduce your power. There is also a query of softening fuel lines: besides rubber, other valuable materials identified by the National biodiesel board include polypropylene, polyvinyl, and tygon. If the engine is using biodiesel blends higher than B20, the engine oil may need to be changed more frequently and in order to prevent microbial growth, you should drain any water from the bottom of your fuel tank on a regular basis

<u>Biodiesel Use handling, and fuel quality</u>

Straight vegetable oil is not compatible with any modern diesel engine and must not be used. The oil must be converted to biodiesel. The specification for biodiesel in the US is ASTM D6751. Fuel meeting this specification can be used either neat (100% biodiesel) or blended with fossil diesel. Oxidative stability additives allow extended storage of biodiesel. The Cold Soak Filtration Test assures the absence of minor impurities that would otherwise increase filter clogging.

<u>Government</u>

There is a Hawaii state mandate that 20% of its electricity production will come from renewable sources by 2020. Ultimately companies would prefer to have a fuel supply from locally grown biofuel feedstock. The agricultural department report believes Hawaii could probably produce enough biodiesel feedstock to reduce imported diesel by 20%, but also said it could take five to ten years to determine the best crops and locations for farming. The renewable fuels standard of the energy independence and security act of 2007 definition includes these concepts with advanced biofuels having at least 50% less lifecycle greenhouse gas emissions when compared to gasoline produced in 2005. (Advanced biofuel report. 2013)

Congress established the renewable fuel standard as part of the energy policy act in 2005. Expanded in 2007, the renewable fuel standard (RFS) is a federal renewable fuel volume mandate. The total renewable fuel mandate is 36 billion gallons of ethanol equivalent by 2022, but Environment Protection Agency (EPA) has the authority to adjust this mandate as needed. Minnesota, for example, requires B10 be blended for summer months and B5 for the remainder of the year.www.bq9000.com

Biodiesel: Economic contributions

America's biodiesel industry will add $24 billion to the US economy between 2005 and 2015, assuming biodiesel growth reaches 1.6 billion gallons of annual production by 2015. It will keep 13.6 billion in America that would otherwise be spent on foreign oil. For every billion dollars spent on foreign oil, America lost 10,000-25,000 jobs. Jobs would be increased to 20,300 by 2016 for workers in just the biofuel industry alone. (Advanced biofuel report 2013)

Biodiesel: environmental and safety information

In June 2000, representatives of the US Congress announced that biodiesel had become the first and only alternative fuel to have successfully completed the Tier I and Tier II Health Effects testing requirements of the clean air act amendments of 1990. The biodiesel industry invested more than two million dollars and 4 years into the health effects testing program with the goal of setting biodiesel apart from other alternative fuels and increasing consumer confidence in biodiesel.

Biodiesel in nontoxic. The acute oral LD 50 (lethal dose) is greater than 17.4-g/Kg-body weight. By comparison table salt is nearly 10x more toxic. A 24-hour human patch test indicated that undiluted biodiesel produced very mild irritation. The irritation was less than the result produced by a 4% soap and water solution.

Biodiesel degrades about four times faster than petroleum diesel. Within 28 days, pure biodiesel degrades 85-88% in water. Dextrose (a test sugar used as the positive control when testing biodegradability) degraded at the same rate. Blending biodiesel with diesel fuel accelerates its biodegradability. For example, blends of 20% biodiesel and 80% diesel fuel degrade twice as fast as #2 diesel alone.

The ozone smog forming potential hydrocarbon exhaust emissions from biodiesel is 50% less. The exhaust emissions of carbon monoxide from biodiesel are 50% lower. The exhaust emissions of particulate matter are 30% lower. The exhaust emissions of sulfur oxides and sulfates are completely eliminated. The exhaust emissions of aromatic compounds known as PAH and nPAH compounds (suspected of causing cancer) are reduced 95% for biodiesel compared to diesel.

The Navy leads the clean fuel initiatives, with a goal to replace half its consumption of a petroleum fuels with alternatives by 2020. This is backed by a joint agreement from the Navy, DOE, and USDA to provide $510 million over a 3-year period for the development of advanced biofuels. (Advanced biofuel report 2013)

Other Projects

There are over $600 million in active federal grants to advanced biofuel projects since 2008, $940 in loan guarantees. The DoD was able to announce $16 million in contracts to 3 advanced biofuel projects in May 2013. Biomass research and development grants for feedstock development, bio based product development, and development analysis. E2 and Cleantech group have tracked over $783 million in loan guarantees and grants provided by the USDA alone since 2008.

One strategy for securing new venture capital is to develop partnerships with large interested parties, such as oil companies or fuel purchasers. For example, Sapphire energies have secured Tesoro, a fuel refiner, as a customer for its algae based crude oil.

Another strategy is partnering with companies that may wish to provide exclusive use of waste feedstock. Dynamic fuels, funded as a joint venture of Tyson Foods, and Syntroleum, uses the waste fats from Tyson and delivers fuel to Syntroleum. Some companies may partner with automotive manufacturers for research, testing, and investments. (Advanced biofuel report 2013) Another example is the Mixed Alcohol Synthesis project that has their plant in Soperton, Georgia. They plan to convert syngas building blocks to make methanol and ethanol chemically via mixed alcohol synthesis (MAS).

The Navy is testing camelina-based biofuels in these “Green Hornets” at Patuxent River Naval Air Station for their forthcoming Great Green Carrier Group that is planned to be operational in 2016. Also by 2016 the US Air Force is gearing up to have 50% of its high performance JP-8 jet fuel come from green sources. They have developed the ammonia fiber expansion (AFEX) process, which cooks cellulosic biomass at 100 degrees C with concentrated ammonia under pressure. Feedstocks are heated above 700 degrees Celsius inside a pressurized chamber with limited oxygen, turning them into a gas. Scientists and engineers are working on new applications to handle biomass, sorted municipal solid waste and other renewable or recyclable feedstocks. A high temperature/high pressure/no oxygen process is pyrolysis. Here, however, the temperatures are lower than gasification (300-600 degrees C) and the adjustable temperature and reaction rates contribute to product composition. (ProQuest biodiesel refinery planned Dec. 2014)

Methane produced from anaerobic digestion of manure may also be an option. Anaerobic digesters break down or digest organic matter without oxygen to produce methane and other gases and co-products that are useful on the farm. This gas mixture is commonly referred to as biogas or digester gas. Biogas is combustible and normally consists of 50-60% methane. Biogas can be burned in an engine to generate bio-power and thermal energy or processed further into other fuel types such as methanol. Refined biogas can be used compressed natural gas (CNG) and liquefied natural gas (LNG) in automobiles,

among other uses. The by-products from anaerobic digestion can be used as soil amendments and liquid fertilizers. (National sustainable agricultural information service: An introduction to bioenergy: feedstocks, processes and products. 2010)
Also see ATTRA publication Anaerobic Digestion of Animal Wastes: factors to consider.

Biofuel compliance

Fuel produced in Hawaii by Big Island Biodiesel is distilled biodiesel. Every lot is tested for compliance to the ASTM D6751 specification. Oxidative stablility additive is used on all fuel. The current feedstocks are used cooking oil, brown grease, trap grease, jatropha, and other virgin oils.

2. Hawaii Island Agriculture Capacity

2.1 Background

Hawai'i Island is uniquely positioned to be a field laboratory for sustainable innovation for the world. It is one of the few places in the world that contains nearly all the climates in which agriculture is prevalent, and most of the major renewable energy sources are possible on this relatively small land mass. It is the largest and the southeastern-most of the Hawaiian Islands, a chain of volcanic islands in the North Pacific Ocean. With an area of 4,028 square miles (10,430 km^2), it is larger than all of the other islands in the archipelago combined and is the largest island in the United States. In greatest dimension, the island is 93 miles (150 km) across and comprises 62% of the Hawaiian Islands' land area. The two largest mountains on the island reach over 13,000 ft. tall. As of the 2010 Census the population on Hawai'i Island was 185,079.

There are significant unused land, sovereign lands, remote and urban communities, very high technology communities co-located with impoverished multi-lingual immigrant communities and extreme environments all under the legal intellectual property protections of US law. Replicating this diversity would require monitoring projects spread over more than a thousand miles on the US mainland, where on Hawai'i Island a centrally located Institute can leverage any of these assets within a 100 mile radius, in a single county.

Hawai'i Island also boasts unique human resources. The astronomy community attracts many of the world's most accomplished astronomers, physicists, and mathematicians to the Island regularly. The unique biota of the island and surrounding ocean has drawn world-class environmental scientists to the island, and the presence of one of the world's most active volcanoes has attracted geological scientists to become island residents. The diversity of renewable energy resources draws experts from around the world, and the Island's population has a range of farmers and ranchers. The collapse of the plantation economy has left behind a culture used to integrating languages, cultures, and peoples from diverse backgrounds, learning from practices, but retaining diets and agriculture practices from their pasts. This diversity of education, talent, culture, language, and history enable the ability to not only test technologies and practices, but also to understand the powerful influence of culture on the implementation of ideas.

Historically the people of the State of Hawai'i have, out of necessity, grown and raised all their own food. While returning to this level of self-sufficiency is unlikely, the agriculture industry can return to providing enough produce, meats, and basic nutrition to provide for 1,000,000 or more people. This level dramatically reduces the need to import food on a routine basis, keeping the economic activity related to foods in the State. As importantly this level of production can ensure that the State can have at least subsistence level nutrition for all its citizens in the event of emergency, reducing or eliminating the current shortfall of more than 2,000,000 meals per day needed to sustain the State in emergency.

Hawai'i Island, with many thousands of acres of available farmland, excess water, and renewable energy resources, is well suited to be the predominant food source for the State. This will take a significant investment of financial and human resources, but the fundamental resources needed to achieve the State's goals are in place.

Historical Waimea Forest /Agriculture

There are many accounts of the Waimea region as being intensively cultivated and densely inhabited by thousands people and native birds.

Cultivated crops included but not limited to: Kalo (taro, colocasia esculenta), kukui (candle-nut, aleurites moluccana), maiʻa (banana, musa xparadisiaca, kō (sugarcane, saccharum officinarum), uhi (yam, Dioscorea batatas), pia (arrowroot, Tacca leontopetaloides),ʻuala, (sweet potato, ipomoea batatas) ʻawa (Piper methysticum) ʻōhiʻaʻai (mountain apple, kapa malaccensis).

Plants cultivated in the Lālāmilo and lower Puʻukapu ʻili, at a slightly lower elevation consist of ʻulu (breadfruit, Artocarpus atilis), Tī leaves (Ti, Cordyline fruticosa), Hala (pandanus, pandanus odoratissimus), and Niu (coconut, cocos nucifera). Other cultivations included the main source for making clothing (kapa), from the bark of the wauke plant (paper, mulberry (Broussonetia papyrifera). In addition to food sources these two plants māmaki (Pipturus) and ʻulu were also cultivated for kapa. The people of this region are still cultivating these plants. An extensive irrigation system was used in prehistoric times until the early 1900's. It is still evident today, water flows from the top of Mauna a Kea down through the farm lands of Waimea and out to the sea at Kawaihae or feeding the loʻi of Waipiʻo Valley.

Once, Waimea's hillsides and mountains were covered by forests of sandalwood, but the rapid and brief exploitation of the sandalwood trade lead to its demise. The introduction and expansions of cattle and sheep ranching lead to deforestation leaving Waimea to be largely replaced by pasturelands. Within these pasturelands sat many agriculture fields, specifically in the lands of Puʻukapu and Lālāmilo. The Māhele testimonies describe many parcels of land awards including house and agricultural lots. These testimonies included references to kīhāpai, paukū, loʻi, and kōʻele, evidence that agriculture was prevalent in the Waimea region. A sugar mill was established on the lands of Līhuʻe, Lālāmilo in 1827. It was powered my mules, and operated till the 1840ʻs (Doyle, 1953: 50-51)

In the 1840's, food was in great demand in the booming population of the California Gold Rush. Here in Waimea the farmers responded by cultivating many different crops for export. Irish and sweet potatoes were sold to the California markets by the barrels (Doyle, 1953:153).

Waimea farmers increased production of potatoes and introduced crops like watermelons, onions, cabbages, figs and beans. Other vegetables, along with sugar, molasses and coffee were also cultivated for export. The natives also venture into the Waimea forests reserves to gather the pulu, yellow wool of the base of the hāpuʻu leaf stalks (Cibotium spp.). It was used to stuff mattresses and pillows (Pukui & Elbert, 1986: 354). This boom didn't last long as the demand diminished quickly. 1860 Lyons wrote:

> The Pulu business is becoming a failure. Demand for Irish potatoes is exceedingly small. The foreign population on whom the native are very much dependent for money is constantly fluctuating (Doyle 1953: 182).

Strategic Alignment

Biofuels production has direct impact on two of the State's highest priorities, food security and energy security, which are as very high priority for the Federal government. Identifying an approach that targets both priorities from an integrated process affords the highest chance of sustainable success. The Biofuel Test Crop team has developed strong relationships with senior government officials, and will leverage those relationships to identify the alignment of the strategic partnership with the priorities of the leadership. Articulating the value of the plan in a comprehensive, integrated fashion, building on the Hawaii Island 21st Century Economy Roadmap, enables the team to garner the support of appropriate officials. This support streamlines development timelines and costs.

Previous Study Results

Oʻahu based Hawaii Military Biofuels Crop Project – Summary of Results
This project has shown that oilseed crops can be grown in Hawaii to support both the State and military energy security and clean energy goals. It has also shown that in the short term, taking advantage of waste oilseed agriculture already available within the state, such as culled macadamia nuts and kukui nuts, may be a serendipitous discovery that could lead to a significant biodiesel feedstock supply.

There is a large untapped capacity to produce local biodiesel from agriculture in Hawaii. In order to reach a price point at parity or less compared to fossil diesel fuel, co-products and value- added side streams are required. Pacific Biodiesel Technologies has been working on co-product development for several years, and the HMBC project has aided in this ongoing research. Installed capacity currently exists in Hawaii to convert vegetable oils to biodiesel. The HMBC project focuses on increasing Hawaii-sourced feedstock while reducing costs for renewable fuel usage. A successful model will include State and Federal governments working with private landowners, farmers and ranchers to create large-scale production in a fully sustainable collaboration. Crop production costs will be paid by utilizing 80-100% of the crop for various products such as biofuel feedstock, livestock meal, biomass for gasification, etc.

The information to determine whether these types of crops can be grown in thousand-acre or even hundred-acre blocks requires additional crop trials to demonstrate commercial scale cost effectiveness. The fact that both seed processing and biodiesel processing are currently available on the Big Island make oilseed production more economic today compared too many other start- up technologies. A subsequent phase of this project, with larger acreage and a fully commercial sized crushing mill, is expected to demonstrate even better economic feasibility and also has the potential to expand capacity of the Big Island Biodiesel (BIB) fuel production plant due to the relative ease of processing virgin crop oils versus the extensive pre-processing system required to process waste vegetable oils and animal fats. By replacing the current yellow and brown grease imports at BIB with local biofuel crop oil, it is estimated by PBT that the refinery capacity could increase from 5.5 mgy to 7-10 mgy.

Through the efforts of this project, the initial steps for a viable energy security feedstock have been identified. A long-term robust farming industry creating both food and fuel in Hawaii is within reach. Working with other local interests on the Big Island, including the State of Hawaii Department of Agriculture, Rivertop Solutions, the Veterans-to-Farmers program, the livestock industry and the University of Hawaii, PBT hopes to have the next funded demonstration phase lead to full commercialization within 5 years. The resulting sustainable system will secure much of the military's in-state renewable fuel requirements while creating a self-sufficient green economy model for Hawaii.

Crops to be tested

Sunflower

Description:	*Helianthus annuus L.*; Annual plant, sunflowers have big, daisylike flower faces of bright yellow petals (and occasionally red) and brown centers that ripen into heavy heads filled with seeds. Tall and course, the plants have creeping or tuberous roots and large, bristly leaves.
Uses:	Biofuel, cooking oil, edible seeds, meal for livestock feeds
Soils:	Variety of soil conditions; best in well-drained soils with high water-holding capacity. Sandy, Loamy pH: Neutral, alkaline
Climate:	However, sunflower is considered a drought tolerant crop and has a deeper root system than most crops.
Irrigation:	Drier regions often need at least supplemental irrigation for best yields.
Insects and Pests:	Cutworms, palestriped flea beetle, sunflower beetle, sunflower bud moth, longhorned beetle, sunflower stem weevil, thistle caterpillar, sunflower midge, sunflower seed weevil, sunflower moth, banded sunflower moth, lygus bug, sunflower headclipping weevil, various bird species
Pest Management:	*Biological Controls:* Beneficial insects, Beneficial pathogens, resistant cultivars. *Cultural Controls:* Crop rotation, modified cultural practices, Trapping. *Chemical Controls:* Pesticides, Attractants, Repellents, Pheromones
Weed Control:	Both chemical and cultural management practices are common, especially in the first four weeks of growth. Once established, sunflowers complete relatively well with weeds.
Disease:	sclerotinia diseases and downy mildew
Planting Preparation:	Most common: Tilling the land, spraying herbicide when planting the seed to eliminate competitiors until a canopy is established. Alternatively: No till practices have been used; instead of herbicide spray some use a tineweeder.
Data Source:	National Sunflower Growers: Sunflower Production Guide. http://www.sunflowernsa.com/uploads/resources/121/sunflower_production_handbook_2007.pdf Extension.org: http://www.extension.org/pages/29605/sunflowers-for-biofuel-production#.VD7zESj6KPE

Safflower (time and resources permitting)

Description:	*Carthamus tinctorius L;* Annual broad-leaved plant known to be drought tolerant. Thistle-like, with a main stem and a number of branches. It stands 1 to 4 feet tall at maturity. Its taproot can penetrate 8 to 10 feet depending on subsoil temperature and moisture
Uses:	Biofuel, food grade oil, meal for livestock (24% protein), and birdseed
Soils:	A wide range of soils; best are deep, fertile, well-drained soils; tolerant of soil salinity than small grains because of its deep roots. Do not plant safflower in poorly drained or cool, wet soils. Cool, wet soil delays uniform emergence.
Climate:	Lower rainfall areas ideal for growing safflower. Sun loving crop, and high temperatures and bright sunny days speed development. Though moisture is important at planting, plants need dry atmospheric conditions during flowering and seed filling for proper head set.
Insects:	Few insect problems with safflower. Wireworms and cutworms can damage seedlings. Grasshoppers and lygus bugs also can damage the crop
Pest Managemen t:	Both cultural and chemical forms of control are common
Weed Control:	Poor competitor with weeds, especially in the early stages of growth, when it has not started branching. Important to eliminate weeds before you plant the crop. Tillage is common to keep down weed growth.
Disease:	In higher than normal rainfall, fungal diseases such as Phytophthora root rot, Alternaria leaf spot (Alternaria cartharmi), Pseudomonas bacterial blight (P. syringae), and Sclerotinia rot can cause serious losses. Fusarium and Verticillium wilts and Botrytis head rot can also cause serious losses
Planting Preparation:	A moist, firm, weed- free seedbed is required. Safflower doesn’t do well when there is soil crusting. Light harrowing of the seedbed helps loosen soil for seeding.
Data Source:	Oregon State University Extension Services: http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/20205/em8792-e.pdf

Potential Crops already ruled out

Though Camelina presented as a great option for a dual-use crop as both feed and fuels, having 29% crude protein, it proved less viable as option. The seed size is much smaller which may make it more difficult to effectively press out the oil. Because the oil output was less than optimal, it was ruled out as a commercially viable option.

Conventional Techniques

The standard approach to preparing the soil, and planting the sunflower generally involves tilling, then spraying the land with pesticides while the seeds are germinating in the soil. We will be assessing alternative techniques that seek to use no-till approaches which have been shown to improve long term soil health.

Sustainability and Improved Techniques

There are numerous techniques and alternative supply options that can be used to improve the resilience and sustainability of crop production. Focusing on creating a biofuels production system, from planting through processing and distribution that prioritize not only growth of crops but also sustainment of the environment to support future growth ensures longevity of the entire industry. This is especially important in Hawaii, a highly isolated environment, being able to sustain these operations locally, depending less on imports to sustain biofuels production in Hawaii has important security implications.

General Approach

Though there is less focus on the systemic alternatives at this small scale because the priority is assessing the general range of climates available on Hawaii Island and potential growing areas. Even now in the initial planning process, a permaculture expert and university faculty are part of the advisement team to compile and evaluate alternative planting techniques and growing practices. Some of the early areas of interest focus on production practices that both improve the growing areas and surrounding environments.

For example, common to Hawaii are heavy rains that can cause high rates of sedimentation, this not only washes away valuable topsoil, it also, but also high rates of sedimentation damage coral reefs; knowing this, the team is working on no till techniques and using other plantings to reduce and where possible, eliminate sediment from washing down stream. Other efforts focus on shifting away from monoculture to avoid severe pest issues and integrating agroforestry and diversified agriculture to improve the production system health and the economic stability.

Also being assessed is the potential to use local inputs as sources for fertilizers and integrated pest management. This will build on the early assessment of compost and biochar used in the O’ahu trials.

Alternative Materials and Supplies

The early HMBC Oahu based crop trials showed a substantial increase in plant growth when biochar was used, especially in nutrient depleted soils. Compost also proved to yield nearly double the production in both vegetative growth and seed production compared to the control not receiving compost. Both of these will continued to be tested

2.2 History and Current Conditions

2.2.1 Historic Use

Hawaii Island trails the State in average income, access to health care, access to emergency services and shelters. The island also mimics the State in that the vast majority of food and energy has to be imported. Any demographics for the region reflect the broader community, and the homestead itself has more acute versions of each. This need is set against some of the most rapid growth in the State. In fact the population of South Kohala, as an example, is projected to nearly double between 2000 and 2020.

Table 2.6 Population Projections

Area	2000 Population	2020 Projection A	2020 Projection B	2020 Projection C
South Kohala	13,131	23,947	24,426	26,625
Co. of Hawai'i	148,677	213,452	217,718	237,323

Source: County of Hawai'i Planning Department

Figure 2: Hawai'i County Population Projections

The largest industry on the island for decades was sugarcane, with peaks as high as 80,000 acres in production on the island. That production began to decline in the 1970's and was eliminated in 1994. The remaining lands have been converted to pasture, timber and left fallow. These lands were primarily along the coasts, and represent one of the two primary opportunities for expansion.

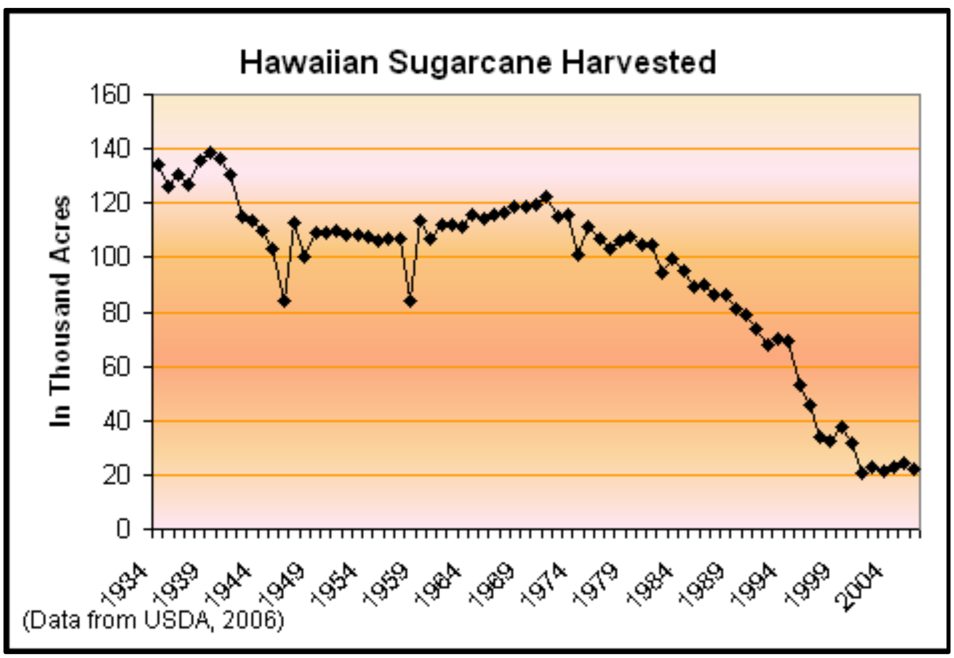


Figure 3: USDA Historic Agriculture Lands

The second opportunity is lands that have previously been forest and ranch land, which now lay largely fallow. The states ranching industry has also been in decline, with more than 200,000 less acres in production now than during peak years. Restoring the ranching industry is a key goal of the program through the creation of low cost livestock feed. These lands can support significant expansion of the growth of sunflower as it will be also help rebuild the industry.

2.2.2 Current Agriculture Lands

The below figures indicate the lands that are most likely candidates for the tests. The lands on the southern side of the island have promise for growing, but lack the access to labor and have difficult logistics and so are considered a lower priority. The primary lands under consideration are the stretch from North Kohala to Puna. In these lands alone there are roughly 40,000 acres of land that have the capacity to support long term sunflower growth.

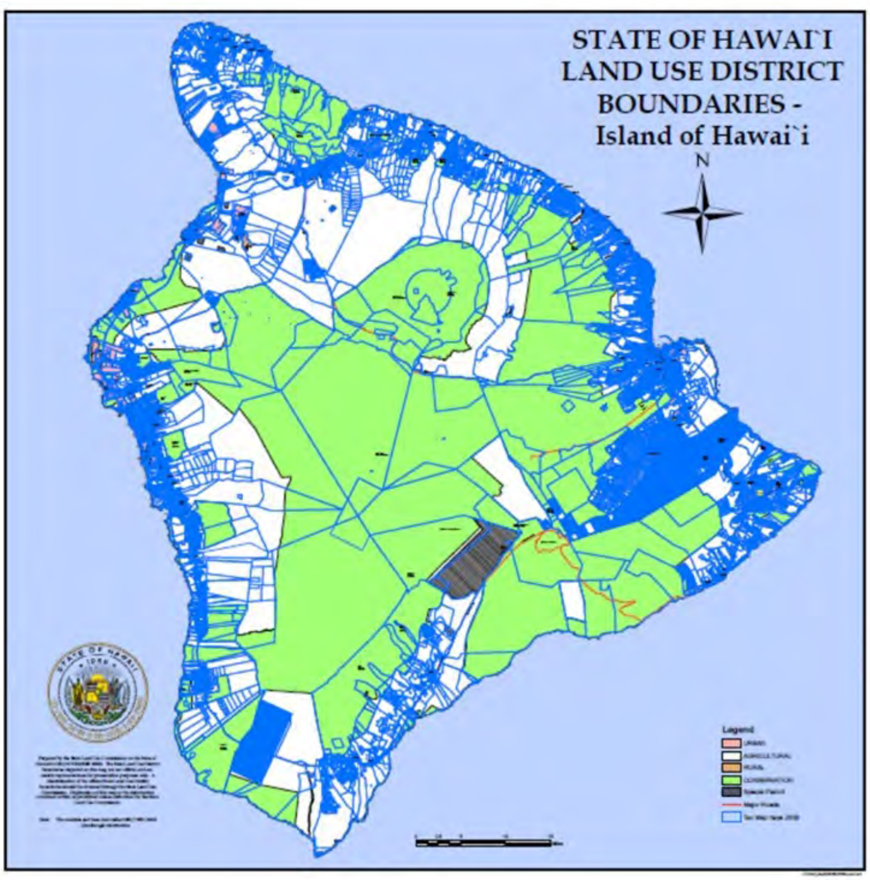


Figure 4: State Land Use Districts for Hawaii Island

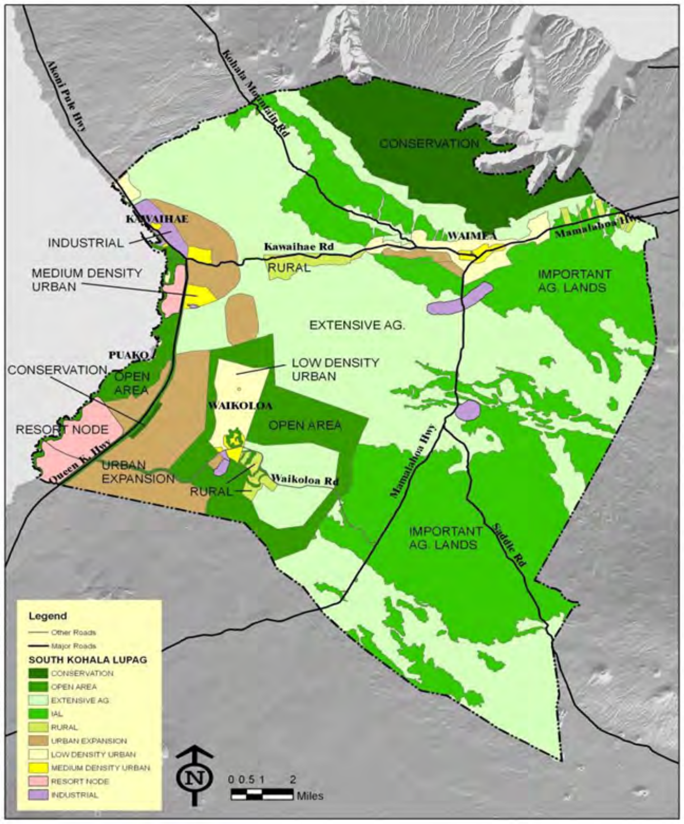


Figure 5: Current Agriculture Lands in Hawaii

The total land inventory on the island is sufficient to produce silage and oils which can support roughly 15,000,000 gallons per year of biofuels production. This production would support the ranching community as well.

Table 2.2 State Land Use Districts Acreage by County Districts in 2000

Districts	Agricultural	Conservation	Rural	Urban	Total
Puna	175,104	138,563	146	6,329	320,142
South Hilo	70,695	169,493	0	12,814	253,002
North Hilo	53,587	120,110	71	608	174,376
Hämäkua	162,729	235,805	13	1,041	399,588
North Kohala	64,713	13,187	16	2,434	80,350
South Kohala	**150,426**	**15,356**	**53**	**10,608**	**176,443**
North Kona	158,853	188,331	477	17,787	365,448
South Kona	110,749	35,051	31	845	146,676
Ka’u	237,743	422,239	0	1,801	661,783
Total	1,184,599	1,338,135	807	54,267	2,577,808

Figure 6: Existing Land Inventories

2.2.3 Current Irrigation and Water Availability

Irrigation water has two primary sources on the Island. Ditch systems collect and carry surface water from the streams in the mountains, and ground water wells and tunnels. The ditch systems currently leak or transport 30,000,000 gallons per day of water which is unused by the agriculture community. Sunflower requires an average of 1000 gallons per day across the growing cycle, though the daily usage varies greatly. The ground water is estimated to have sustainable yields across the selected growing regions of over 150,000,000 gallons per day. The water resources, while available, require significant investment to develop. This investment is in all segments of the system from source through storage to distribution. Initial estimates are that water can economically be developed to support any acreage needed for expansion.

Figure 6: University of Hawaii-Hilo Water Source Data

2.2.4 Current Processing Infrastructure

There is an initial need for processing of the sunflowers. Currently the island has a small operating crushing mill owned by Pacific Biodiesel Technologies next door to the Big Island Biodiesel processing facility in Keaau, Hawaii. The mill has the capacity to crush any material produced during the test and create a powdered seed cake. Future expansion will require the construction of a large scale pellet mill.

3.1 Physical and Environmental Attributes

3.1.1 Soils

The terrain consists of ash-covered lava flows from between 65,000 to 250,000 years ago (Wolfe and Morris 1996). The majority of the soil on the project site is classified by the U.S. Natural Resources Conservation Service (formerly Soil Conservation Service) as being in the Waimea very fine sandy loam (383), a well-drained soil usually found on slopes of 3 to 12 percent. The surface layer is typically about six inches thick with subsoil of about 44 inches in depth. The surface can be extremely stony in places. Permeability is moderately rapid, runoff is slow and erosion hazard slight. Also found in the area are Kikoni series, predominately Kikoni very fine sandy loam (487), and Kikoni medial silt loam (493), soils with similar characteristics. Listed below are the NRCS official series descriptions for both the Waimea and Kikoni series. Included below the descriptions is a table of permeability rates of the soil in centimeter per hour and per minute that correspond with the classes used for conservation and agricultural measurements.

While testing will provide detailed information on the soils at each site, the general soils in the region are:

WAIMEA SERIES

The Waimea series consists of deep, well drained soils that formed in material weathered from volcanic ash underlain by andesite and basalt. Waimea soils are on ash fields and have slopes of 6 to 20 percent. Mean annual rainfall is about 762 millimeters (30 inches) and mean annual temperature is about 16 degrees C (60 degrees F).

TAXONOMIC CLASS: *Medial, amorphic, isothermic Humic Haplustands*

TYPICAL PEDON: *Waimea medial silt loam, on a south facing, slightly concave, 17 percent slope, under grasses, at an elevation of 991 meters (3,250 feet). (Colors are for moist soils unless otherwise noted. All textures are "apparent field textures". When described August 10, 2003 the soil was dry throughout.)*

A1--*0 to 5 centimeters (0 to 2 inches); very dark brown (7.5YR 2/2) medial silt loam, dark brown (7.5YR 3/3) dry; weak very fine and fine granular structure; loose, very friable, nonsticky and nonplastic; nonsmeary; many very fine and fine roots; many fine interstitial and irregular pores; neutral (pH 7.0); abrupt smooth boundary. (5 to 15 centimeters {2 to 6 inches} thick)*

A2--*5 to 18 centimeters (2 to 7 inches); dark brown (7.5YR 3/2) medial very fine sandy loam, dark brown (7.5YR 3/4) dry; massive; loose, very friable, nonsticky and nonplastic; nonsmeary; many very fine and fine roots; common very fine interstitial pores; neutral (pH 7.3); clear smooth boundary. (13 to 23 centimeters {5 to 9 inches} thick)*

AB--*18 to 43 centimeters (7 to 17 inches); dark brown (7.5YR 3/3) cobbly medial loam, brown (7.5YR 4/4) dry; massive; loose, very friable, nonsticky and nonplastic; nonsmeary; many very fine and fine roots; common very fine interstitial pores; 5 percent gravel and 10 percent cobbles;*

slightly alkaline (pH 7.5); gradual wavy boundary. (25 to 38 centimeters {10 to 15 inches} thick)

Bw1--*43 to 79 centimeters (17 to 31 inches); dark brown (7.5YR 3/3) cobbly medial silt loam, brown (7.5YR 4/4) dry; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; nonsmeary; many very fine and fine roots; many very fine and fine tubular pores; 5 percent gravel, 10 percent cobbles, and 10 percent stones; slightly alkaline (pH 7.5); gradual wavy boundary. (31 to 38 centimeters {12 to 15 inches} thick)*

Bw2--*79 to 107 centimeters (31 to 42 inches); dark brown (7.5YR 3/3) cobbly medial silt loam, brown (7.5YR 4/4) dry; weak fine and medium subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; weakly smeary; many very fine and fine roots; many very fine and fine tubular pores; 20 percent cobbles and 10 percent stones; slightly alkaline (pH 7.6); abrupt wavy boundary. (28 to 38 centimeters {11 to 15 inches} thick)*

2R--*107 centimeters (42 inches}; hard, moderately weathered basalt.*

TYPE LOCATION: *Island of Hawaii, Hawaii County, Hawaii; at the intersection of highways 250 and 19 west of Waimea, turn northwest and drive upslope about 3.3 miles on Highway 250. Pedon is located about 120 meters (394 feet) east of highway at elevation 991 meters (3,250 feet).*

Kamuela Quadrangle; lat. 20 degrees 03 minutes 18.0 seconds N. and long. 155 degrees 44 minutes 40.0 seconds W. Old Hawaiian datum.

RANGE IN CHARACTERISTICS: *Depth to bedrock: 102 to 152 centimeters (40 to 60 inches).
Coarse fragments: 0 to 25 percent of the pedon.
Mean annual soil temperature: 17 to 22 degrees C (59 to 64 degrees F).*

*A and A/B horizons
Value: 2 or 3 moist, 3 or 4 dry.
Chroma: 2 or 3 moist, 2 to 4 dry.
Texture: nonstony to stony, medial very fine sandy loam, silt loam or loam
Structure: Weak to moderate granular, or massive.
Soil reaction: slightly acid or slightly alkaline (pH 6.1 to 7.8).*

*Bw horizons
Value: 3 or 4 moist or dry
Chroma: 2 to 4 moist or dry.
Texture: Cobbly medial silt loam or loam.
Consistence: Nonsticky or slightly sticky and nonplastic or slightly plastic.
Smeariness: Nonsmeary or weakly smeary. Experience*

COMPETING SERIES: *These are the Kamakoa, Kamaoa, Kapapala, Kikoni, Kiolakaa, and Kula series. Kamakoa are alluvial soils with fine to coarse sand and gravel in the control section. Kamaoa soils have strong structure in the A horizon and have a silty clay loam Bw horizon that is slightly to moderately plastic. Kapapala soils have an ashy coarse sand C horizon. Kikoni soils have strong granular structure in the A horizon and strong subangular blocky structure in the 2Bw horizon. Kiolakaa soils are moderately deep (50 to 102 centimeters {20 to 40 inches}) to bedrock. Kula soils have silty clay loam texture in the 2B horizons.*

GEOGRAPHIC SETTING: *Waimea soils are on mid elevation, leeward slopes of Mauna Kea and Kohala volcanoes at elevations from 610 to 1830 meters (2000 to 6000 feet). These soils are* *on all hillslope positions of nearly level to moderately steep lava flows that are greater than 65,000 years old. Slope gradients range from 6 to 20 percent. The soils formed in basic volcanic*

ash over andesitic or basaltic lava. The mean annual rainfall ranges from 510 to 1270 millimeters (20 to 50 inches), with most of the rainfall occurring from October through April. The mean annual pan evaporation ranges from 1780 to 2030 millimeters (70 to 80 inches). The mean annual air temperature ranges from 14 to 19 degrees C (57 to 66 degrees F). The mean summer soil temperature and the mean winter soil temperature differ by less than 6 degrees C (11 degrees F). Strong winds are common and summers are droughty.

GEOGRAPHICALLY ASSOCIATED SOILS: *These are the Puu Pa, Kemole, and the competing Kamakoa series. Puu Pa and Kemole soils are medial-skeletal.*

DRAINAGE AND PERMEABILITY: *Well drained. Runoff is low to high. Permeability is moderately rapid.*

USE AND VEGETATION: *Used for livestock grazing. Natural vegetation is kikuyugrass (Pennisetum clandestinum), bermudagrass (Cynodon dactylon), cactus (Opuntia megacantha), and mountain dandelion (Taraxacum vulgare).*

DISTRIBUTION AND EXTENT: *North and South Kohala Districts, Island of Hawaii; MLRA 160. The soils are of moderate extent.*

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: *Davis, California*

SERIES ESTABLISHED: *Soil Survey, Territory of Hawaii, 1949.*

REMARKS: *Soil moisture - dry in some or all parts for short intermittent periods totaling 90 or more days during the months of April through October in most years (Ustic moisture regime).*
Diagnostic horizons and features recognized in this pedon are:
Mollic epipedon - from 0 to 107 centimeters (0 to 42 inches) (all horizons).
Andic soil properties - from 0 to 107 centimeters (0 to 42 inches) (all horizons).
Lithic contact - at 107 centimeters (42 inches) (2R horizon).

Edit Log: 8/10/04 Classification revised due to changes in Soil Taxonomy. Old classification: Medial, isothermic Typic Eutrandepts. Competing series updated. MRK. OSED scanned by SSQA. Last revised by state on 5/78.

ADDITIONAL DATA: *SSIR No. 29, HAWAII, pp. 45-47, 1976.*

National Cooperative Soil Survey
U.S.A.

KIKONI SERIES

The Kikoni series consists of deep, well drained soils that formed in basic volcanic ash overlying \`a\`a lava. Kikoni soils are on ash fields and have slopes of 0 to 12 percent. The mean annual rainfall is about 1020 millimeters (40 inches) and mean annual temperature is about 19 degrees C. (65 degrees F.)

TAXONOMIC CLASS: *Medial, amorphic, isothermic Humic Haplustands*

TYPICAL PEDON: *Kikoni medial very fine sandy loam - pasture. (Colors are for moist soil unless otherwise noted. All textures are "apparent field textures.")*

A--*0 to 15 centimeters (0 to 6 inches); very dark brown (7.5YR 2/2) medial very fine sandy loam, dark brown (7.5YR 3/2) dry; strong fine and medium granular structure; soft, friable, nonsticky and nonplastic; many fine roots; many very fine and fine interstitial pores; neutral (pH 7.2); abrupt smooth boundary. (13 to 18 centimeters {5 to 7 inches} thick)*

Bw1--*15 to 28 centimeters (6 to 11 inches); dark brown (7.5YR 3/3) medial very fine sandy loam, dark yellowish brown (10YR 4/4) dry; massive; soft, very friable, nonsticky and nonplastic; many fine roots; many very fine and fine tubular pores; pockets of white colored material which may be remnants of old land snails; neutral (pH 7.3); gradual smooth boundary. (10 to 15 centimeters {4 to 6 inches} thick)*

Bw2--*28 to 38 centimeters (11 to 15 inches); dark brown (7.5YR 3/2) medial very fine sandy loam, dark yellowish brown (10YR 4/4) dry; massive; soft, very friable, nonsticky and nonplastic; many very fine roots; many very fine and fine tubular pores; common pockets of strong fine subangular blocky structure; slightly alkaline (pH 7.5); gradual smooth boundary. (15 to 23 centimeters {6 to 9 inches} thick)*

Bw3--*38 to 64 centimeters (15 to 25 inches); dark brown (7.5YR 3/3) medial very fine sandy loam, brown (7.5YR 4/4) dry; massive, with pockets of strong fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine roots; many fine and medium tubular pores; slightly alkaline (pH 7.8); gradual smooth boundary. (13 to 20 centimeters {5 to 8 inches} thick)*

2Bw--*64 to 127 centimeters (25 to 50 inches); dark reddish brown (5YR 3/2) gravelly medial silt loam, very dark brown (10YR 2/2) dry; strong very fine and fine subangular blocky structure; extremely hard, firm, nonsticky and slightly plastic; common very fine roots; many very fine and fine tubular pores; common pockets of dark yellowish brown (10YR 3/4) which is similar to above horizon; 17 gravel-size basalt fragments; slightly alkaline (pH 7.4); abrupt wavy boundary. (51 to 76 centimeters {20 to 30 inches} thick)*

3C--*127 to 152 centimeters (5O to 60 inches); cobbles with soil material from above filling the interstices. 75 percent cobbles and 10 percent stones from `a`a lava.*

TYPE LOCATION: *Island of Hawaii, Hawaii; Kukuihaele Quadrangle - 20 degrees 0 minutes 44 seconds north latitude and 115 degrees 36 minutes 8 seconds west longitude; about 3 miles southeast of the Extension Service office in Kamuela and about 5 yards south of the Mana Road on Parker Ranch.*

RANGE IN CHARACTERISTICS:
Depth to unconforming bedrock is greater than 152 centimeters (60 inches).

The solum has hue of 10YR through 5YR.

The B horizon
Value and chroma of 2 through 4 moist.

Texture ranges from medial very fine sandy loam to medial silt loam. Consistence of the lower 2Bw horizon is weakly smeary toward the wetter limits of the series.

COMPETING SERIES: *These are the Kamakoa, Kamaoa, Kapapala, Kula, Kiolakaa, and Waimea series. Kamakoa soils are alluvial soils. Kamaoa soils lack a buried B horizon with strong structure. Kapapala are on Mauna Loa Volcano. Kula soils have weak structure in the A horizon and moderate structure in the upper part of the B horizon. Kiolakaa soils are moderately deep to bedrock. Waimea soils have weak structure in the A horizon and lack a buried B horizon.*

GEOGRAPHIC SETTING: *The Kikoni soils are on intermediate leeward ash fields on Mauna Kea and Kohala mountain slopes. Slope is 0 to 12 percent. Elevation ranges from 792 to 1,097 meters (2,600 to 3,600 feet). The soils formed in basic volcanic ash. Annual rainfall is 635 to 1,270 millimeters (25 to 50 inches). Mean annual temperature is 19 degrees C. (66 degrees F.); average January temperature is 12 degrees c. (54 degrees F.) and that of July is 17 degrees C. (62 degrees F.)*

GEOGRAPHICALLY ASSOCIATED SOILS: *These are the Hanipoe, Maile, and the competing Waimea soils. Hanipoe soils have a weak granular A horizon and weak subangular blocky structure in the B horizon. Maile soils are hydrous silty clay loam in the control section.*

DRAINAGE AND PERMEABILITY: *Well drained; slow runoff; moderately rapid permeability.*

USE AND VEGETATION: *These soils are used mainly for pasture with a few acres in truck crops. Natural vegetation is mainly bermudagrass (Cynodon dactylon), rattailgrass (Sporobolus capensis), kikuyugrass (Pennisetum clandestinum) and hilograss (Paspalum conjugatum).*

DISTRIBUTION AND EXTENT: *This series occurs on the northwestern section of the island of Hawaii. MLRA 160. It is about 11,000 acres in extent.*

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: *Davis, California*

SERIES ESTABLISHED: *Island of Hawaii, Hawaii, 1971.*

REMARKS: *Diagnostic horizons and features (11th edition, Keys to Soil Taxonomy) recognized in this pedon are:*
Andic soil properties - from the soil surface to 127 centimeters (50 inches).
Mollic epipedon - from the soil surface to 15 centimeters (6 inches).
Soil moisture-usually moist, but dry in some or all parts for short intermittent periods totaling 90 days or more (Ustic moisture regime).

OSED scanned by SSQA. Last revised by state on 5/78.

National Cooperative Soil Survey
U.S.A.
https://soilseries.sc.egov.usda.gov/OSD_Docs/K/KIKONI.ht

Soil permeability classes for agriculture and conservation

Soil permeability classes	Permeability rates[1]	
	cm/hour	cm/day
Very slow	Less than 0.13	Less than 3
Slow	0.13 - 0.3	3 - 12
Moderately slow	0.5 - 2.0	12 - 48
Moderate	2.0 - 6.3	48 - 151
Moderately rapid	6.3 - 12.7	151 - 305
Rapid	12.7 - 25	305 - 600
Very rapid	More than 25	More than 600

3.1.2 Slope

All of the sites were selected because they had 0.5% and 1%. Small portions of the sites may contain slightly steeper slopes, but none severe enough to present erosion hazards, and only spanning a distance of no more than a few hundered feet.

3.1.3 Rainfall

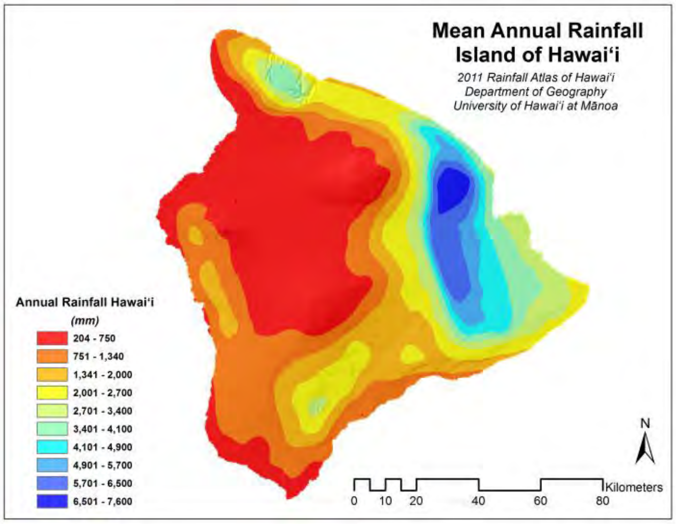


Figure 6: University of Hawai'i Rainfall Map

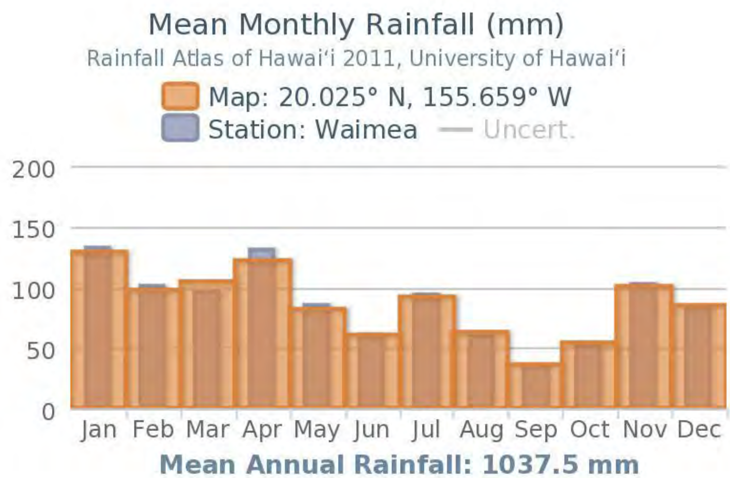
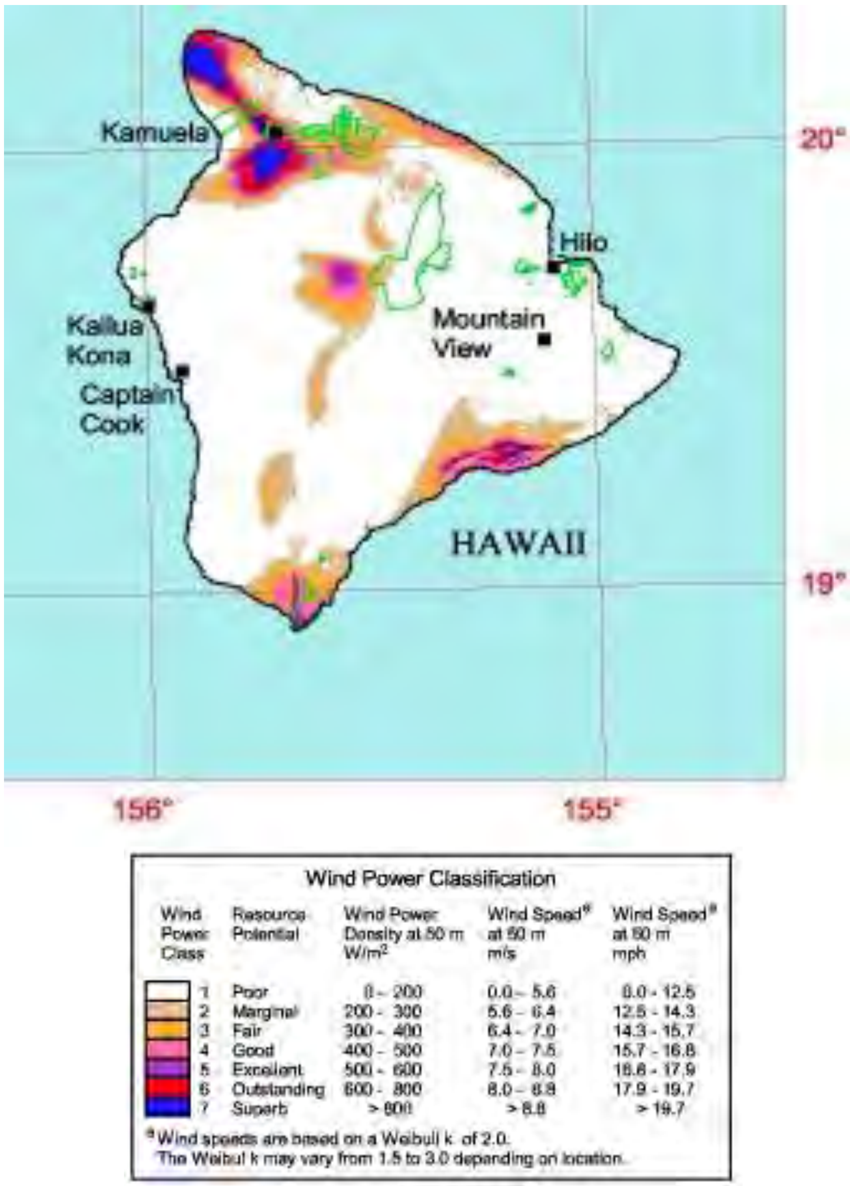


Figure 7: Monthly Rainfall Levels

Light rain and fog are common in this area of Kohala, with an average annual rainfall of about 35 inches or 103 centimeters (U.H. Hilo-Geography 1998:57). The majority of rainfall occurs between December and April. The southern regions have heavier rainfall.

3.1.4 Climate



Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	> 800	> 8.8	> 19.7

[a] Wind speeds are based on a Weibull k of 2.0.
The Weibul k may vary from 1.5 to 3.0 depending on location.

Figure 8: Wind Map of Hawai'i Island

The weather on the east side is typically temperate with frequent drizzles. Average daily temperature maximums reach 75 degrees and averages lows around 65 degrees. Winds can range from 3 to 14 knots, which are predominately northeast trade winds, but in the winter can sometimes be replaced by westerly Kona-side winds. Winds may require growing wind breaks,

3.2 Infrastructure Assessment (existing and planned infrastructure capacity both on and off site)

3.2.1 Water

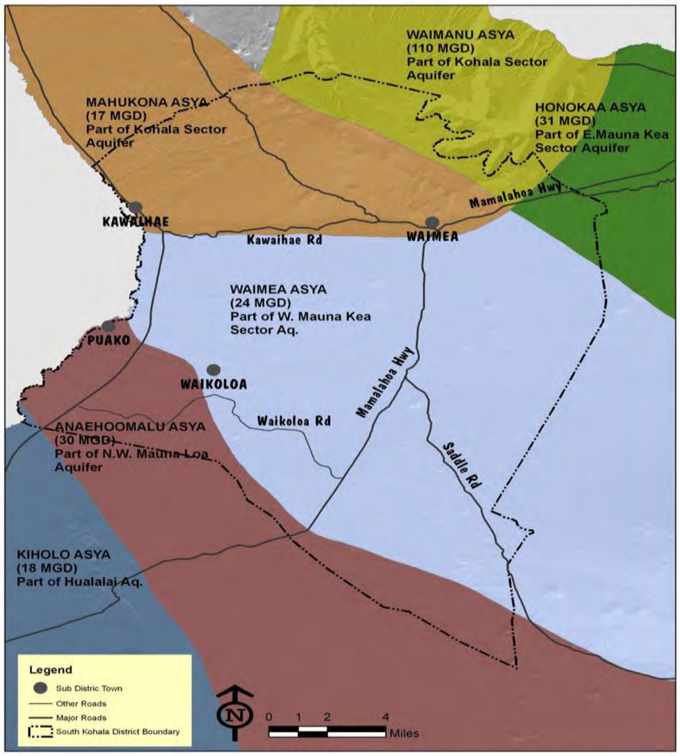


Figure 11: County of Hawaii Watershed Regional Map

The Hawaii County Water Use and Development Plan Update of 2010 provides the best reference for the water available in the region. The Waimea and Waimanu aquifers systems have a sustainable yield of 134 million gallons per day between them, with current use of that yield at roughly 11.5 million gallons per day. While the water system has damage, the resource will not be affected adversely by the addition of the facilities on the 161 acre parcel. Currently, we estimate that the completed facility will use roughly 125,000 gallons per day of agriculture water, and 6,000 gallons per day of potable water.

An aquifer's '**Sustainable Yield**' refers to the *estimated* maximum amount of water that the aquifer can safely produce. Extracting amounts of water greater than the sustainable yield may irreparably damage the aquifer. It should be emphasized that sustainable yield numbers are only *estimates*.

These estimates should not be considered as the exact amount of groundwater that can be safely utilized. In many regions with high sustainable yield numbers, groundwater cannot be utilized because it would not be economically feasible to install water systems to deliver water to users.

Current water usage, as detailed in Table 2.12 from the South Kohala Community Development Plan, includes water use from County Department of Water Supply (DWS) systems, private water systems, agricultural use, and irrigation use, including use of reclaimed waste water and water use from domestic rain catchments. Table 2.12 distinguishes between current water use with agricultural water use and current water use without agricultural water use. As can be seen in the table, agricultural water use accounts for a significant percentage of current water use in most Aquifer System Area's (ASYA). It is also important to note that current use for the aquifer system areas of Waimanu, Mahukona, and Anaehoÿomalu, includes users from outside the district of South Kohala as well. The Waimea aquifer is the only system that exclusively serves South Kohala.

Table 2.12 South Kohala Aquifer System Areas (all numbers in MGD)

ASYA	Developmental Stage	Sustainable Yield (SY)	DWS Water System Use	Private System Water Use	Total Water Use w/Agriculture	Total Water Use w/o Agriculture
Waimanu	Potential Use	**110**	0.08	0.00	0.34	0.10
Mahukona	Currently Used	**17**	0.95	0.68	3.94	1.69
Waimea	Currently Used	**24**	2.17	4.56	11.05	7.71
Anaeho'omalu	Currently Used	**30**	2.14	0.00	8.15	7.97

Zoning Designation	Average Daily Demand
RESIDENTIAL:	
Single Family or Duplex	400 gals/unit
Multi-Family Low Rise	400 gals/unit
Multi-Family High Rise	400 gals/unit
COMMERCIAL:	
Commercial Only	3000 gals/acre
RESORT:	400 gals/unit or 17,000 gal/acre*
LIGHT INDUSTRY:	4000 gals/acre
SCHOOLS, PARKS:	4000 gals/acre or 60 gals/student
AGRICULTURE:	3400 gals/acre**

* Resort ADD of 17,000 gal/acre based on ADD for Maui.
** Agriculture ADD based on AWUDP.

3.2.2 Road

Each of the selected sites has road access without any requirement for additional investment. Many of the pasture lands which can serve as expansion regions will require the construction of new roads. These roads will require the capacity to handle 10 ton loads, but will not require paving. Likely each will be built with 4 inch base coarse and gravel.

3.2.3 Energy

One of the key elements of the processing is the cost of electricity. During the testing phase the energy content of the silage will be evaluated. As facilities for crushing and pelletizing are developed, it will be critical to co-develop renewable energy systems that can reduce the cost. These systems will be site specific, but may include gasification systems that will use the silage as fuel. This will enable the development of a self-sustaining system, and reduce further any dependence on fossil fuel in the supply chain.

3.3 Siting Considerations and Regional Consistency

3.3.1 Consistent with Existing Site Conditions

The primary siting concerns are consistency with existing zoning and permitting requirements. In 2013, the Hawaii State Legislature passed Act 203, now formally HRS 46-88. This law opened up the size and structures that can be developed on agriculture land without a permit. Act 203 changed the regulations to allow grading and grubbing as required, as well as construction of processing facilities up to 8000 sq ft. with only the need to submit a document of compliance. All of the land surrounding the sites are currently zoned agriculture, and some have been registerd in the States Important Agriculture Lands registry, which ensures the land will remain in agriculture.

The sites were also selected because they are in agriculture communities, and so are consistent with all the community development plans.

3.3.2 Potential for Expansion

The negotiations with each of the land owners included future expansion as a point of discussion. Hawaii Island is unlikely to create thousand acre farming plots, and so the expansion will be built around 50 to 100 acre plots. This is well suited to the year round growing cycle, which will allow weekly harvesting. This will also allow for the use of smaller scale planting and harvesting equipment suited to the size of parcel. At full scale production that would require harvesting two 100 acre parcels four days per week.

It is anticipated the test sites will provide sufficient information to allow for scale up to meet that demand.

4. Resources and References

Resources:
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www.rockingz.com
www.attra.ncat.org/farm_energy/biodiesel.html
www.ampc.montana.edu/energy information.html
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https://utextension.tennesee.edu/publications/Documents/SP721.pdf
www.funflowernsa.com
www.ncat.org 1-800-275-6228
sanangelo.tamu.edu/extension/agronomy/agronomy-publications/sunflower-production-guide/
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www.biofuelcanada.ca
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www.ampc.montana.edu/briefings/briefing88.pdf
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marwaha@tamu.edu
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www.biodiesel.org/resources/fuelfactsheets/default.shtm
www.biodiesel.org/buyingbiodiesel/guide
www.uiweb.uidoho.edu/bioenergy/BiodieselEd/publication/02.pdf
www. Biodieslel.org/resources/reportsdatabase/reports/gen/19980701_gen-097.pdf
www.sarep.ucdavis.edu/cgi-bin/ccrop.exe
www.ncat.org/special/oilseeds.php
www.uiweb.uidaho.edu/bioenergy
http://journeytoforever.org/biodiesel.html
www.veggievan.org
www.biodieselSMARTER.org
www.eere.energy.gov/biomass
http://www.almanac.com/plant/sunflowers
www.ncat.org/special/oilseeds.nrcs.report.06.01.09.pdf
http://healthyeating.sfgate.com/sunflower-oil-healthy-4508.html

References for Biofuels

Robert Wellington- Blue Earth Biofuels. Maui

Pioneer Hi-bed international research center- Kauai

Michael Cooney- U of H School of ocean and earth science and tech. expertise in biofuels on Oahu

Pacific Biodiesel in 2011 manages the HI military Biofuels crop demo. Project: 2.4 mill. Grant – in collaboration with Big Island Biodiesel

Christian and Jamie Twigg-Smith- HI pure plant oil farm

NRCS- Natural resources conservation service may have information on what crops are well adapted to the region

National Biodiesel board- gives where there are filling stations

Emergent project in HI

***Imperium Renewables Hawaii

*** Bioearth fuels -Maui.

Attachment A
Cultural and Archeological Assessment

1. *Introduction*

1.1 Archival and Historical Resources

This compendium includes oral histories, historical records, journals, books including references, but not limited to — land use records, including Hawaiian Land Commission Award (LCA) records from the M hele (Land Division) of 1848; Boundary Commission Testimonies and Survey records of the Kingdom and Territory of Hawaiʻi (ca. 1873-1903); and historical texts authored or compiled by — D. Malo (1951); S. Kamakau (1961, 1964, 1976, and 1991); Wm. Ellis (1963); A. Fornander (1916-1919 and 1996); G. Bowser (1880); T. Thrum (1908); J.F.G. Stokes and T. Dye (1991); J. W. Coulter (1931); E. Doyle (1953); M. Beckwith (1970); and Handy and Handy with Pukui (1972). Importantly, this study also includes several native accounts from Hawaiian language newspapers, and it includes historical records authored by eighteenth and nineteenth century visitors to the region.

1.2 Hawaiian Land Concepts and Resource Management Practices

The Island of Hawaiʻi originally contained six chiefdoms. These six chiefdoms were in existence by the 16th century when Liloa the dynastic founder of the Island's chiefs were in rule. These chiefdoms are Hāmākua, Hilo, Kaʻū, Puna, Kona, and Kohala. (Kamakau, 1961:1) Proceeding Liloaʻs death the dynasty branched into two powerful lines or houses; the Mahi chiefs, in rule over Kohala, Kona, and Kaʻū and the ʻI chiefs, in rule over Hāmākua, Hilo and Puna. These two family houses fought continually nearing 300 years, both sides in conquest to unify Hawaiʻi's Island chiefdoms. This feat of unfication was eventually accomplished by the great Kamehmeha I in the late 18th century. These same geographic division of land within the chiefdoms became known as the moku ʻāina (districts) of the Island of Hawaiʻi. These six moku ʻāina still remain today (Barrère :25).

The Island as a whole is referred to as a Mokupuni (Island), then divided into Moku ʻĀina (districts). Within these Moku ʻĀina are ʻokana (sub-districts) e.g. Kohala Waho or Kohala Hema (South Kohala). In the ʻokana is a Kalana (land division) e.g. Waimea. Within the Kalana are Ahupuaʻa (Single administrative land divisions running from the mountains to the sea) containing a Konohiki (The headman of the Ahupuaʻa). In the Ahupuaʻa are ʻili (Strips of land, sections, subdivisions), many under the ongoing care of different families, some granted to particular families. Within the ʻili are many more divisions of land, becoming geographically smaller.

A) Moʻo, a long strip of arable land with an ʻili
B) Loʻi, an irrageted taro flat
C) Paukū, parcels of wet taro land, smaller than a moʻo
D) Kihapai, garden, farm, small piece of cultivated land, other than a loʻi, that are primarily farmed for the tenant
E) Koʻele/ Hakuʻone, parcels that are farmed for the Chief and the Konohiki (Handy & Handy, 1972: 54)

The text below is from David Malo, explaining the concepts of land division:

> "Ke Kapa ana i ko loko mau inoa o ka moku. Ua kapa aku ka poe kahiko inoa no ko ka mokupuni mau mea ma ko lakou nana ana a kupono ko lakou manao ana, elua inoa i kapa ia ma ka mokupuni, he moku ka inoa, he aina kahi inoa, ma ka moku ana ia ke kai ua kapa ia he moku, a ma ka noho ana a kanaka, ua kapa ia he aina ka inoa. O ka mokupuni, oia ka mea nui e like me Hawaii, Maui a me keia pae moku apau. Ua Mahele ia i mau apana maloko o ka mokupuni o kela mau apana i mahele ia, ua kapa ia he moku oloko e like me Kona ma Hawaii a me Hana ma Maui, a me na mea like ae ma keia mau moku. A ua mahele hou ia mau apana hou ua kapa ia aku ia he okana kahi inoa he kalana kahi inoa, he poko maloko ia o ka okana. A ua mahele hou ia mau apana hou malalo iho o keia mau apana, ua kapa ia aku ia he Ahupuaa, aka malalo o ke Ahupuaa, ua kapa ia he Ili aina. A ua mahele ia malalo o ka Ili aina na moo aina a malalo o ka moo aina na pauku aina a malalo o na pauku aina na kihapai malaila i mahele ia na Koele, na hakuone, na kuakua." (Malo, 1987: 13-14)

1.3 **General Location**

Many historical accounts refer to land sections like Puʻukapu, Lalamilo, and ʻŌuli, in Waimea as separate ahupuaʻa and in other accounts refer to it as ʻili ʻāina or ʻili kūpono, especially those listed in the Māhele- Boundry/ Land Commission Award books. For clarity, in this review they will be referred to as ʻili.

The Waimea Nui project site is located in the Moku ʻĀina of Kohala on the Island of Hawaiʻi. Further, it is located in the ʻOkana of Kohala Waho and in the Kalana of Waimea, specifically located in the ʻili of Puʻukapu.

1.4 **Purposed Site Project**

The project area is a grazing pastureland once used by Parker Ranch, until their lease ended in the 1980ʻs. This area was named "Christmas" by the paniolo who built a paddock there. After use by Parker Ranch, the area reverted to the Department of Hawaiian Homes, and according to the DHHL Waimea Nui Regional Plan, it is designated for community use and general agriculture, though today lessees of Pu‘ukapu use the land for grazing cattle.

Stories of the naming of this area and ranching life are documented. Fencing was a continuous and important part of ranch work throughout the years and only a few highlights are touched on in a story that reflects the loyalty and perseverance of the fence crew.

> Mr. Carter and his men worked all one day, surveying, staking and fencing a large paddock near the headquarters of the Ranch. Late that evening, while still in his office, Mr. Carter was approached by his fence foreman who said, "Kalikimaka all pan". Mr. Carter then realized that the day was Christmas (Kalikimaka), a fact he had lost sight of in his desire to complete the job, but he appreciated the humor of the subtle rebuke and retained the name for the paddock. (Brundage, 1971)

The designated area of study is situated between and next to many different ‘ili sections. The lands near this area were discussed in the above passage on Kalikimaka paddock. Because this property falls on the boundary area inter-joining the many surrounding ‘ili, distinguishing precisely where the boundaries lie is challenging. Some of the surrounding ‘ili are Pukalani, Paulama. Noho‘āina, ‘Ala‘ōhi‘a, Pauweanui, Po‘okanaka, and Historic Preservation Division contacted as outlined in Hawai‘i Administrative Rules 13§13-275-12.

2.2 **Land Boundaries of Pu‘ukapu, Waimea, South Kohala**

Taken from (Maly, 1999: 90-93) which was adapted from the Boundary Commission Testimony:

Volume A – 1, No. 2
Rex vs. George Davis
Boundary Dispute
Waikoloa nui Ili of Waimea – Hawaii.
Testimony taken August 8th and 9th 1865 at Waimea-Hawaii.

Davis' Witnesses:	Rex Witnesses :
1. Mi 1st	1. Kaolulu
2. Ehu	2. Kuupele
3. Kuehu	3. Kanakaole
4. Kalua	4. Moluhi
5. Moolau	5. Kanehailua
6. Kuahine	6. Kahakauwila
7. Wahahee	7. Kualehelehe

George Davis claims that Waikoloa, as he had heard, begins at Puaapilau, thence down the road from Hāmākua to Waimea, to Puʻu Ohikona, thence to Paakai nui, thence to Ouli, the land of Keoniana, and along the boundary of Ouli to the sea shore at Kaihumoku, thence along the shore to Lalamilo; thence to Keaha [Keahaaha], thence to Keakolono [i.e., Keahuolono], on the boundary of Kona; then along the boundary of Kona to Kaohe, then along the boundary of Kaohe to Kemoli [Kemole], thence to Kupaha.

Ehu – sworn: I am *kamaaina* of Puukapu. I was born in Waimea. I know the boundary from my own and my father's knowledge. Commence at Puaapilau, thence to Napamakani, thence to Paakainui, thence to Kapuulepo, thence to Kapalihalapepe, thence to Puuainako, thence to Kalalakoa.

I knew Kahanapilo w. wife of George Davis-she was not *konohiki* of the ilis on Waikoloa – nor of Waimea – I was in Kona when she died.

I am *kamaaina* of Puukapu only – Kainea was the *Konohiki* when I lived there. There was no *pili* grass on that land – my father was not a bird catcher, he used to *mahiai* [farm]. Waikoloa was the land that had the birds – the boundary as stated is the boundary from the time of Kamehameha first.

Cross – Kainea was *Konohiki* in the time of Kalaimoku – Kainea is dead. Waikoloa is an *ahupuaa* of Waimea, which is a *Kalana*, with eight divisions. I only know about Waikoloa. – I have been on to Pukalani – Nohoaina and Paulama – they join Waikoloa, but do not run far out. – Pukalani joins Puukapu. Nohoaina joins Pukalani, and Paulama joins Waikoloa. Puukapu is a division of Waimea. – Pukalani belonged to Kamehameha and he gave it to his man Kekoikumoku. Nohoaina belonged to the chiefs of Waimea, Kupapaulu. Paulama belonged to Kupapaulu. – Puukapu belonged to Kalaimoku. (I do not know the present owners). I do not know who was the *Konohiki* before Kainea. Wahahee – sworn. – I am *kamaaina* of the King's land Puukapu – I was born there. Commence at Puaapilau, thence to Pooholua, thence to Leohu, thence to Paakainui, thence to Kapuulepo, that is all I know.
Puulepo is close to Pukalani, which land joins Puukapu. – My parents showed me the boundary. – My mother belonged at Puukapu, my father was from Napuu [page 6]. Nohoaina joins Pukalani, Paulama joins Nohoaina, and Waikoloa joins Paulama. Pukalani belonged to Kamehameha fourth. – Nohoaina and Paulama to the same; also Puukapu; and I suppose they descended to Kamehameha V.

Cross. – I do not know the boundary of Paulama and Waikoloa. – I heard that Waikoloa was divided. –there are two Waikoloa's, they lie side by side. I do not know the adjoining lands to Waikoloa, except Paulama on the *mauka* side. – I heard that Waikoloa joins Napuu. – I have not heard that Paulama joins Napuu.– all the *pili* belonged to Waikoloa.

Mi 1st – sworn: I live on Waikoloa – I am a *kamaaina* of the lands in dispute. The name of the large land is Waimea – I am a witness for George Davis, and also for the Rex. – Waimea is a *Kalana*. – which is the same as an island divided in to districts. – there are eight *Okana* in Waimea. In those *Okana* are those lands said to extend out (*hele mawaho*). These lands came in to the possession of Kamehameha I who said to Kupapaulu, go and look out to of the large lands running to the sea, for John Young and Isaac Davis. Kupapaulu went to Keawekuloa, the *haku aina*, who said if we give Waikoloa to the foreigners they will get Kalahuipua [Kalahuipuaa] and Anaiomalu [Anaehoomalu] (two lands at the beach) then your master will have no fish. So they kept the sea lands and gave Waikoloa to Isaac Davis. John Young asked my parents if it was a large land they said, the black *aa* was Napuu, and the good land Waimea.

They kept all the valuable part of the lands, and gave the poor land outside to Isaac Davis. They kept Puukapu, Pukalani, Nohoaina, Kukuiula (above the church), and Paulama; and gave Waikoloa to Isaac Davis. The other Waikoloa, this side of the stream dividing them, was the King's. It comes down along the stream by Mr. Lyon's, then along the ditch, then along the wall of Puuloa, to Ahuli on the King's land, to the round hill, Uleiokapihe, and is cut off here by Davis' Waikoloa. – The wall was the boundary below, between Waikoloa of Isaac Davis and the land of the King, Kamehameha I. The latter built it by Kauliakamoa; to keep the cattle off from the King's land. The boundary runs to Liuliu, and the *pili* was all South, on Davis' land; then I know along an old road, Puupa, Waikoloa being South and Waimea North of the road, then to Kaniku. That is all I know.

Cross. – My parents heard the command of Kamehameha I to Kupapaulu, and they told me, and also about John Young's asking about the land. I never heard that Puukapu, Nohoaina, Pukalani, and Paulama extended out to the *pili*. A road divided the land of the King and that of I. Davis.

Waikoloa. – The wall was built to keep off the cattle, and to mark the land. The church is on the King's land. When Kalama measured Waikoloa he took in the church, I heard. – I went with Kalama some of the time. Kalama said leave the old boundary and make a straight boundary, so I left them, lest Davis' land would go to the King. – The boundary as I know it is from the English school house along a hollow, to the ditch near to Hoomaloo; thence to *puu* Makeokeo;
Thence to hills outside of Ahuli. The church is on Paulama which joins Waikoloa.

I know the boundary of Paulama it does not reach Napuu. I know the *mauka* boundary of Waikoloa and Puukapu. Puukapu extends to Puulepo, then goes in (*maloko*). [page 7]

Kuahine – sworn: I am *kamaaina* at Lihue. I know the boundaries of Waikoloa; viz. from Koananai to Puuokaa, to Kekio, to Pahoa, which are cut off from Waikoloa, and are cut off by it; the are all divisions of the *Okana* Lihue. Liuliu is an old road, forms the boundary between Waikoloa and the *ahupuaa* to Puuwaawaa, where the road divides, one goes to the sea shore, and the other goes along the boundary, along the *pili* to Kepani; thence to Keahu a Lono – Waikoloa being *mauka* of the road. – My father, who was *luna* [overseer] of the land Lihue, told me the boundary.

Cross. – Kahanapilo w. was *Konohiki* of Waikoloa – it descended from her parents, and from her husband, Hueu, this is from my knowledge.

I know about the wall built, my father was *luna* at the time. – I was large at the time, and could carry stones. – Kupapaulu and Keawekuloa were the Konohikis of the land. – I never saw Kamehameha I. – but I was born before his death. I was a babe when Kiholo was built [built ca. 1810].

I know Waikoloa first, it goes to the mound near Ahuli… [page 8]

Witness, Moʻolau – presented testimony similar to the above; notes that he was born at Kïholo, and that he helped to build the boundary wall referenced by Mi, above (pages 8-9).

Volume A No. 1 No. 2
For the King

Kaolulu sworn – I am *kamaaina* of the lands in dispute from one end to the other. I was born on Ouli, and have lived on different parts of the lands. Commence at Kohiaina, the head of Waikoloa, thence to Waikalehua, thence to Kapele, thence to Alaanui, thence to Alaohia, thence to Keakualapalapa, thence to Kulanapahu, thence to Kaopapa, thence to Keanakii, thence to
Kahoalapiko, the *makai* boundary is from Puupanui to Puuakowai, thence to Kilohana, thence to Puuokaa, thence to Waikoloa, thence to Puuohu, this is the boundary of Waikoloa nui of George Davis.

Cross. – Puupanui is the corner *makai*. – This description begins at Paulama. Puuhuluhulu is the land *makai* of Waikoloa; and also Kaleikumikiau; Puupili; Pahoa; Kekio; 2 Puuokaa; and Waikoloa are King's lands adjoining. I know about the wall; I could carry stones then; in the time of Kamehameha I. I know the boundary of Waimea. – Commence at Puukapu, the head of the land. Waikoloa is an *ili* of the *Ahupuaa* Waimea, as I have heard.

Waikoloa first reaches Napuu at Puupanui. – The two Waikoloas joined *mauka*. The King's Waikoloa reaches Puuokaa, which is cut off by Davis' Waikoloa. Davis' Waikoloa does not reach Puukeekee, nor Waikii.

The land from here down to the sea is Waimea, which has divisions. Paulama is adjoining Napuu; so is Nohoaina. Paulama and Waikoloa meet Napii at Kahooalapiko. Kahanapilo w. was never *Konohiki* of any land but Waiauia. [page 9]

Witness, Kuupele – testified that he was born at Puuanahulu. "I know the wall – it was built to keep off the cattle from the cultivated land. I could carry stones – it was after Kiholo in the time of Kamehameha I…" (pages 9-10)

Kanehailua – sworn — I am *kamaaina* of Waimea. I know the boundary of Waikoloa and the King's land. Paulama joins Waikoloa. Commence at the woods, at Kohiaina, thence to Puakalehua, thence to Kapele, thence to Alaanui, thence to Alaohia, thence to Kekualapalapa, thence to Kulanapahu, thence to Keanakii, thence to Kahoopapale, thence to Kahooalapiko.
Puuanahulu cuts off Paulama here. Nohoaina joins Paulama from the woods to Napuu. That is what I know of the boundary *mauka* of Waikoloa. The *makai* boundary is from Puupaha to Puuakowai, thence to Kilohana, also adjoining Puuokaa and Kamakeokeo, to the settlement of Mr. Lyons *ma* [folks].

Waikoloa of the King joins *makai*; then comes Pahoa first and second. Puupili, Kalaeokumikiau, Puuhuluhulu, Kaleohai, Kokiapuueo, Paaina, Opuokopukini, Kaluaana, Papuaa, Wailoa, and Mahoe, which is the *kahawai* [stream] of Puuiki. All of these are the King's lands. Waikoloa is an *ili* of Waimea *Ahupuaa*; as are also these other lands. Waimea is an *Okana*…

Cross: Puuhinai is the *makai* corner of Waikoloa of George Davis on the boundary of Kona. Puupaha is the corner of the King's Waikoloa. Puupili joins Napuu, so does also Kalaeokumikiau. Kapaakea is the name of the palce where Puupili joins Napuu. The Hooneene gulch is where the land joins Napuu.Puuhuluhulu joins Napuu at Halolo gulch. Kaleohai joins Napuu. Kokiapuueo joins Napuu. These are all the lands that join Kona. [page 10]…

…The boundaries of Waikoloa nui as decided by the Commissioners of Boundaries at Waimea – Hawaii, August tenth 1865.

Commencing at Kohiaina run to Waiakalehua, to Kapele Alaanui, Alaohia, Keakualapalapa, Kulanapahu, Kaopapa, Keanakii, Kahoopapale, Kahooalapiko, then along Napuu to Puupaha; then along the King's land to Puakowai, Kilohana, Puuokaa, Makeokeo, Waikoloa, to Puuohu, and to commencement, as given by Kaolulu, Kuupele, Kanehailua, and Kahakauwila.

P. Cummings
F.S. Lyman. [page 12]

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2.3 **Historical Waimea Forest /Agriculture**

There are many accounts of the Waimea region as being intensively cultivated and densely inhabited by thousands people and native birds.

Cultivated crops included but not limited to: Kalo (taro, colocasia esculenta), kukui (candle-nut, aleurites moluccana), maiʻa (banana, musa xparadisiaca, kō (sugarcane, saccharum officinarum), uhi (yam, Dioscorea batatas), pia (arrowroot, Tacca leontopetaloides),ʻuala, (sweet potato, ipomoea batatas) ʻawa (Piper methysticum) ʻōhiʻaʻai (mountain apple, eugenia malaccensis).

Plants cultivated in the Lālāmilo and lower Puʻukapu ʻili, at a slightly lower elevation consist of ʻulu (breadfruit, Artocarpus atilis), Tī leaves (Ti, Cordyline fruticosa), Hala (pandanus, pandanus odoratissimus), and Niu (coconut, cocos nucifera). Other cultivations included the main source for making clothing (kapa), from the bark of the wauke plant (paper, mulberry (Broussonetia papyrifera) . In addition to food sources these two plants māmaki (Pipturus) and ʻulu were also cultivated for kapa. The people of this region are still cultivating these plants. An extensive irrigation system was used in prehistoric times until the early 1900's. It is still evident today, water flows from the top of Mauna a Kea down through the farm lands of Waimea and out to the sea at Kawaihae or feeding the loʻi of Waipiʻo Valley.

Once, Waimea's hillsides and mountains were covered by forests of sandalwood, but the rapid and brief exploitation of the sandalwood trade lead to its demise. The introduction and expansions of cattle and sheep ranching lead to deforestation leaving Waimea to be largely replaced by pasturelands. Within these pasturelands sat many agriculture fields, specifically in the lands of Puʻukapu and Lālāmilo. The Māhele testimonies describe many parcels of land awards including house and agricultural lots. These testimonies included references to kīhāpai, paukū, loʻi, and kōʻele, evidence that agriculture was prevalent in the Waimea region. A sugar mill was established on the lands of Līhuʻe, Lālāmilo in 1827. It was powered my mules, and operated till the 1840ʻs (Doyle, 1953: 50-51)

In the 1840's, food was in great demand in the booming population of the California Gold Rush. Here in Waimea the farmers responded by cultivating many different crops for export. Irish and sweet potatoes were sold to the California markets by the barrels (Doyle, 1953:153).

Waimea farmers increased production of potatoes and introduced crops like watermelons, onions, cabbages, figs and beans. Other vegetables, along with sugar, molasses and coffee were also cultivated for export. The natives also venture into the Waimea forests reserves to gather the pulu, a yellow wool of the base of the hāpuʻu leaf stalks (Cibotium spp.). It was used to stuff mattresses and pillows (Pukui & Elbert, 1986: 354). This boom didn't last long as the demand diminished quickly. 1860 Lyons wrote:

> The Pulu business is becoming a failure. Demand for Irish potatoes is exceedingly small. The foreign population on whom the native are very much dependent for money is constantly fluctuating (Doyle 1953: 182).

2. ***Historic Accounts of Waimea, South Kohala***

2.1 **Hoʻopiliahae**

Keawe-nui-a-Umi, grandson of Liloa, who founded the Hawaiʻi island dynasty, took as one of his wives Hoʻopiliahae, daughter of Hae-a-pae who was the high priest to Umi-a-Liloa. From this union came Umi-o-ka-lani, an ancestor to the great Luahine, Palena and Mahi families of Kohala. She was a high-ranking chiefess, descendant of the goddess/chiefess Wao and from a long line of Kahuna (priest). She deeply cared for her people and during her rein she was revered and beloved by all.

Next to the lands of Keoniki and Kauniho are the ahupuaʻa of Lanikepu and Ouli. In these hills and surrounding the back of the area was once lush forest. A heiau was built there, the only heiau ever founded, dedicated and consecrated by a woman, the High Chiefess Hoʻopiliahae, an ancestor of both the Sovereigns of Hawaiʻi and the ruling High Chiefs of Waimea. Bearing the name Haleʻino, translating to meaning the house of storm; this heiau is positioned on a nexus where five different rains fall and many different elements converge, joining forces to make distinctly weather stormy. Each individual wall is named for the type of rain that falls upon its side. Hoʻopiliahae had five children and named them after the rains of this Heiau.

Haleʻino noted for the red rain and the vivid rainbow symbols of the sacredness of this locality, it was exclusively for girls of the age of purity who performed the duties of dedicating and participating in the different ceremonies, in which the spirit of love, purity of body and mind was imbued; also the science of healing was taught, thus consecrating their lives for the betterment of others. These woman learned to become midwives and traditional healers, and were respected by all (Henriques, n.d.).

Today, Haleʻino still stands as a monumental reminder of the High Chiefess Hoʻopiliahae and the many young women that dedicated their lives to the spiritual, physical and mental well being of the Hawaiian people. Though hiding in blades grass, its foundations still remain completely intact. This is a wahi pana, a sacred site; the only one of it's kind.

2.2 **Kaʻōanaʻeha**

Below these hills in the ahupuaʻa of ʻŌuli was one of the home of the High Chiefess Kaʻōanaʻeha, grandmother of Queen Emma, wife to Kamehameha IV. There upon the landscape sat a koʻele of kalo and uʻala that fed the royal court of Kaʻōanaʻeha. Being the daughter of Chiefess Kalikookalani and Chief Keliʻimaikaʻi the only full-blooded brother of Kamehameha I, she was of high rank and thus born under the royal taboos. She married the sailor John Young in 1805, and the two lived in Makahuna, Kawaihae.

> John Young and Isaac Davis would have been killed had not Kaʻōanaʻeha, a high lady, fallen in love with Young and by her intercession with the King saved the lives of both sailors. Kaʻōanaʻeha was the most beautiful woman on the island of Owhyhee (Hawaiʻi) and was the admiration of all the sailors who visited

> Karakakooa Bay (Kealakekua). She was the only daughter of Keliʻimaiki, the favorite brother of the great King, Kamehameha I. John Young and Kaoanaeha were soon married. King Kamehameha appreciated the superior talents of the white men and made them high chiefs (New York Times, 1886).

She defied the Christianity of her husband, and was similar to Princess Ruth Keʻelikōlani in turning down Western ways. For example, after Young died in 1835 she took as her new name Mele Kuamoʻo, after the battle of Kuamoʻo where her brother Kekuaokalani, defended the kapu system, and was killed leading the rebel forces against those of Kamehameha II in 1819. (Kanahele, 1999: 46)

According Laura Judd, Kaʻōanaʻeha, the wife of John young and neice of Kamehameha, preferred life in the Hawaiian manner. She chose to live in a hale pili, a grass hut.

> … got up at midnight, and went down to the grass house of Mrs. Young, which was neat and comfortable. She is a noble woman. She lives in native style; one of the sons is with the king, and the daughters are in the train of the princess (Judd 1928: 36)

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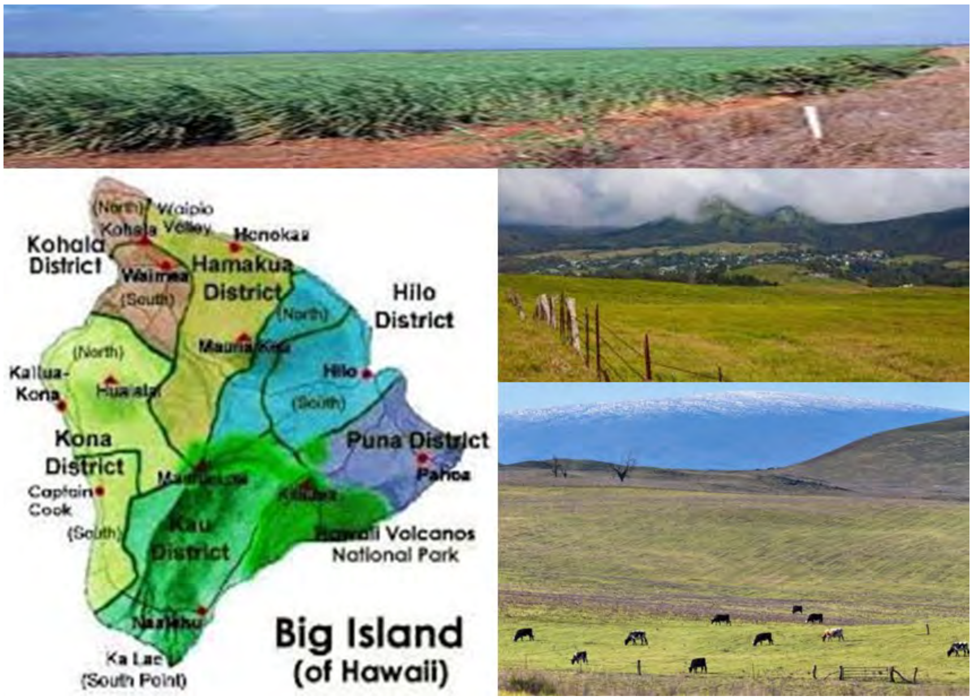
Hawaii Military Biofuels Crop Program
Hawaii Island

Task 2
Biofuels Technology Inventory



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PACIFIC BIODIESEL TECHNOLOGIES

Deliverable 2
TABLE OF CONTENTS

1. Overview: Support the Deputy Assistant Secretary of the Navy for Energy (DASN-E) in the development, operation, and oversight of the Hawaii Military Biofuel Crop Program (HMBCP). The HMBCP will provide an operations sensitive assessment of the capacity for the local production of fuels and biomass to support military operations in Hawaii and in forward operating regions.

Purpose: To rapidly transition the Hawaii Military Biofuels Crop program from Oahu to the Big Island in support of congressional, Navy and USDA interest in establishing a biofuels commercialization program. The program will support the Navy/USDA Farm to Fleet Initiative, and is sponsored by the Secretary of the Navy.

Team: The research team is led by Pacific Biodiesel, Rivertop Energy Solutions, and the University of Hawaii at Hilo.

Goals: The specific goals include:

1) Complete all preliminary work required to enable a running start of a potential new program for a mid FY 16 start.
2) Provide stand-alone assessment of the capacity of Hawaii Island to support biofuels using the multi-use crop approach established in the HMBC Program.
3) Identify five (5) sites, with potential for a combined minimum of 1,000 acres for use in the new program.
4) Provide a comprehensive set of analysis regarding the economic, technical, and infrastructure viability regarding the production of biofuels in Hawaii.
5) Provide an evaluation of technologies which can be used to convert locally sourced biomass for installations and forward operating bases (FOBs).

This study will provide an evaluation of technologies which can be used to convert locally sourced biomass for installations and FOBs with the primary goal being to accelerate a **community-based effort** to develop **economically feasible** and **sustainable large scale renewable fuel/energy** capacity to support commercial and military customers in Hawaii and in CONUS.

Price competitive fuels are created by allowing farming operations to secure three revenue streams from the biomass grown – 1) oil for liquid fuels; 2) silage as a biomass feedstock; and 3) seedcake for livestock feeds. In addition, the silage can be further diversified to create carbon byproducts that will enhance the farmers' revenue stream.

The primary focus of this study is to determine the optimal revenue stream for an integrated biofuel crop production in order to facilitate cost effective fuels and biomass production. An integrated systems approach has never been previously implemented in optimizing biofuel production. Only the economic merits of the biofuel producing components have been addressed when analyzing and comparing to more conventional fuel production systems.

Phase I of this study is to identify commercially available technologies. A follow on Phase II of the study will determine optimal revenue streams for an integrated biofuel crop production in order to facilitate cost effective fuels and biomass production.

2. Types of Non-Combustion Biomass Conversion Technologies:

There are two types of non-combustion biomass conversion technologies – thermochemical and biochemical.

Thermochemical conversion utilizes high heat processes to convert the organic fraction to synthesis gas or fuel gas. The three major types of thermochemical processes include: 1) gasification; 2) pyrolysis; and 3) pyrolysis gasifier.

Gasification prefers feedstock with low moisture content, such as organics (i.e. paper and other carbon based materials), and readily decomposable organics (i.e. plastics and rubber). The primary products are fuel gases (CO, CH_4, H_2) or Synthesis Gas. Secondary products include fuels, chemicals, and electricity. Solid residues remaining include organic ash, metals, ceramics, glass, and stones.

Pyrolysis prefers feedstock with low moisture content, such as (dry) organics (i.e.carbon based materials, sludge, and plastics). The primary products include fuel gases (CO_2, CO, CH_4, H_2) or Synthesis Gas, and pyrolitic liquids and tars. Secondary products include electricity and some fuels. Solid residues include carbonaceous char, ash, metals, glass, ceramic and stones.

Pyrolysis/Gasifier prefers low moisture organic feedstock, such as carbon based materials, sludge, and plastics. The primary products include fuel gases (CO_2, CO, CH_4, H_2) or Synthesis Gas. Secondary products include electricity and some fuels. Solid residues include carbonaceous char, ash, metals, glass, ceramic and stones.

Biochemical conversion employs biological and chemical breakdown of organic materials to produce gas, alcohols, or other chemical products. There are two major types of biochemical conversion technologies: 1) anaerobic digestion; and 2) fermentation.

Anaerobic digestion utilizes readily biodegradable components as feedstock, such as food waste, green waste, and paper. Plastics and rubber cannot be converted. Woody and ligneous materials are difficult to process. The primary products include biogas (CO_2 and CH_4) and ethanol. Secondary products include heat, power, solvents, acids, and other bio-based chemicals for refining and soil amendment. Solid residues can include inorganics, metals, glass, and undegraded/unprocessed biomass.

<u>Fermentation</u> utilizes the same feedstock as anaerobic digestion. The primary product is ethanol. Secondary products include heat and other bio-based chemicals for refining and soil amendment. Solid residue includes inorganics, metals, glass, and undegraded/unprocessed biomass.

Table 1 provides a matrix of various commercially available technologies which can be used to convert locally sourced biomass for installations and forward operating bases (FOBs).

3 Technology Providers:

3.1 Advanced Pyrolysis System (APS-IP)

The Advanced Pyrolysis System (APS) is a patented waste-to-energy (WtE) technology develop.ed and tested over a period of more than 15 years in the US. The technology allows for a variety of feedstock materials, including municipal solid waste (MSW), agricultural waste, medical waste, wood, tires, toxic chemicals, sludge, and other materials to be cleanly converted to carbon and gas. The APS gasification technology is different from other systems. APS chemically decomposes waste into carbon and synthesis fuel gas (syngas) through a process called pyrolysis. Pyrolysis is the application of high heat in the absence of oxygen. The process requires no incineration or burning of the waste. APS does not create ash or toxic pollutants that are serious environmental concerns with incineration and competing WTE techniques.

The syngas that is created by APS is very similar to clean burning and environmentally friendly natural gas. The APS technology allows highly efficient combustion of the syngas within the system design. The heat that is generated is recycled to sustain the pyrolysis reaction and produce clean renewable electricity. Such complete combustion improves the efficiency of waste-to-energy project economics.

The APS technology complies with emissions regulations. APS is permitted in California, where the emissions standards are some the most stringent in the US, and is consistent with strict European Union (EU) emission requirements.

The APS 8 ton per day WtE plant in operation in Sacramento, California

The APS 40 ton per day WtE system.

3.2 Alternative Energy Solutions Intl Inc. (AESI)

AESIs' units operate from a differentiated process whereby solid fuels are first gasified and then combusted in the same device; referred to as Vertically Integrated Gasification and Combustion. Simply burning biomass is less complete than burning produced syngas which is why gasification followed by combustion is a better approach and it reduces issues related to emissions.

Biomass fuels are carbon neutral, and can be obtained at costs that are increasingly lower than oil, propane and natural gas. Through gasification, biomass fuels can be derived from many different sources, including waste streams, enabling low to negative cost fuel use. Solid fuel biomass gasifiers can be integrated into mechanical system configurations no matter the industry or market segment, either replacing or appending existing system operations.

Based on a technology developed over 50 years ago by Uniconfort, an ISO 9001 company, and now exclusively fabricated by AESI in the United States, the GLOBAL Series accommodates biomass fuel diversity, composition, and moisture content.

AESI GLOBAL Series

3.3 BIOFerm Energy Systems

BIOFerm™ Energy Systems provides anaerobic digestion technology for energy generation and waste management to North American operations. The BIOFerm™ technology utilizes anaerobic digestion to harness biogas rising from fermenting organics—food waste, manure, biosolids, etc.—converting it into green energy, heat, fuel, and more.

BIOFerm™ offers a range of anaerobic digestion technology: from low to high solids and from industrial-sized to small-scale, including the following four systems:

The BIOFerm™ Dry Fermentation System

The BIOFerm™ system is a batch type system that uses the principle of dry fermentation anaerobic digestion in the mesophillic temperature range. The BIOFerm™ dry fermentation process is well suited for solid waste materials that have a solids content of 25-35%.

The dry digester utilizes a batch-system approach and can accept most any stackable waste, including large items (i.e. whole watermelons) and contaminated waste streams (i.e. non-organic items). There is no need for a pumpable waste stream and there are no moving internal parts.

The BIOFerm™ Dry Fermentation System is ideal for operations with large amounts of food waste, yard clippings, dry manure on bedding and other high-solid organic waste. It is best suited for operations that process organic waste with a moisture content of less than 75%.

EUCOlino – The Small Scale Digester System

The compact, small scale EUCOlino system uses organic waste to create energy through anaerobic digestion. It is ideal for any operation with a limited amount of biomass or small footprint, and has the ability to process a variety of feedstocks.

The feedstock versatility and small size of the system make it ideal for an extreme range of operations. It is a pre-assembled container unit that is shipped from the supplier as a complete plug-and-play system. The EUCOlino system is characterized by low investment costs and small space requirements.

The different system components include: the digester tank with mixer, the technology container with CHP, pumps, desulfurization, mixer motor and plant controls, a feeder for solid substrates (optional) and pre-digestion separator to thicken the manure to a higher solids content (optional).

COCCUS®

COCCUS® is a complete mix anaerobic digester designed to run at the mesophilic temperature range. It is designed for input materials with low solids content (between 8 – 12%). The tank is a reinforced concrete design with 2 or 3 large REMEX® paddle mixers. The drive motor of the mixer is mounted onto the outside wall of COCCUS® so that only the polyamide bearings are located inside the fermenter. The tank is heated through hydronic heating installed onto the interior tank wall. Biological desulfurization is integrated into the wooden roof structure of the gas storage which provides for a cost effective removal of a large part of the hydrogen sulfide.

EUCO® Plant System

EUCO® is a plug flow digester with agitation that is designed to run at the mesophillic temperature range. The steel tank has a rectangular footprint and has a horizontal paddle mixer than runs the full length of the tank. The mixer is powered by planetary drive units at both ends. The tank is heated through the horizontal mixer shaft. Solid material is loaded into the tank via the PASCO® feeder system. Liquid feedstock is pumped from a CALIX reception pit.

3.4 Brienergy

While converting carbon-based material into ethanol, the Brienergy (BRI) Renewable Energy Process will:

- Make possible the consistent, low-cost co-production of ethanol and electrical energy, while assisting municipalities in dealing with the disposal of urban wastes and sewage sludge, and the proliferation of landfills.

- Dispose of such organic materials as municipal solid waste, agricultural residues, animal wastes, used tires and plastics.
- Provide an alternative to landfills and extend by up to 80% the useful lives of those currently in use.
- Respond to government mandates that call for the introduction of renewable fuels and the generation of “green” power.
- Utilize waste resources to produce fuel-grade ethanol priced competitively priced with gasoline.
- Improve the environment by reducing greenhouse gas emissions from such sources as fossil fuels, landfill gas (methane), internal combustion automobile engines, coal-fired power plants and the decomposition of urban wastes, dead trees and agricultural residues.
- Dispose of organic wastes with minimal ground, air or water emissions.

3.5 Changing World Technologies

Changing World Technologies, Inc. (CWT) develops alternative fuels and specialty chemicals. It converts organic and inorganic wastes, fats, bones, greases, and feathers into oils, gases, carbons, metals, and ash through its thermal conversion process. The company’s renewable oil is used for refrigeration, telecommunications, electricity generation, and potable water applications. It serves food, mixed plastics, and municipal solid waste markets. The company was founded in 1997 and is based in West Hempstead, New York. Changing World Technologies, Inc. operates as a subsidiary of RDX Technologies Corporation.

CWT was started primarily to develop and commercialize the thermal depolymerization (TDP) technology, now referred to by the company as "Thermal Conversion Process" or TCP. The process produces Renewable Diesel Fuel Oil (RDO) from agricultural wastes, including Fats Oils and Greases (FOG), Dissolved Air Flotations (DAF), waste greases, offal, animal carcasses and other organic-rich wastes.

In 2011, the EPA designated CWT’s Renewable Diesel Fuel Oil (RDO), currently produced in the Missouri facility, as both a biomass based diesel and Advanced Biofuel under the EPA’s Renewable Fuel Standards Program (RFS). This designation qualifies CWT’s RDO for assigned Renewable Identification Numbers (RINs).

In April 2013, CWT was acquired by a Canadian firm, Ridgeline Energy Services, based in Calgary, Canada

3.6 Concord Blue

Concord Blue uses a patented technology called steam thermolysis to convert nearly any waste material into clean, renewable energy. Concord Blue’s method relies on heat transfer instead of incineration—producing high quality syngas with no flame and no pollution.

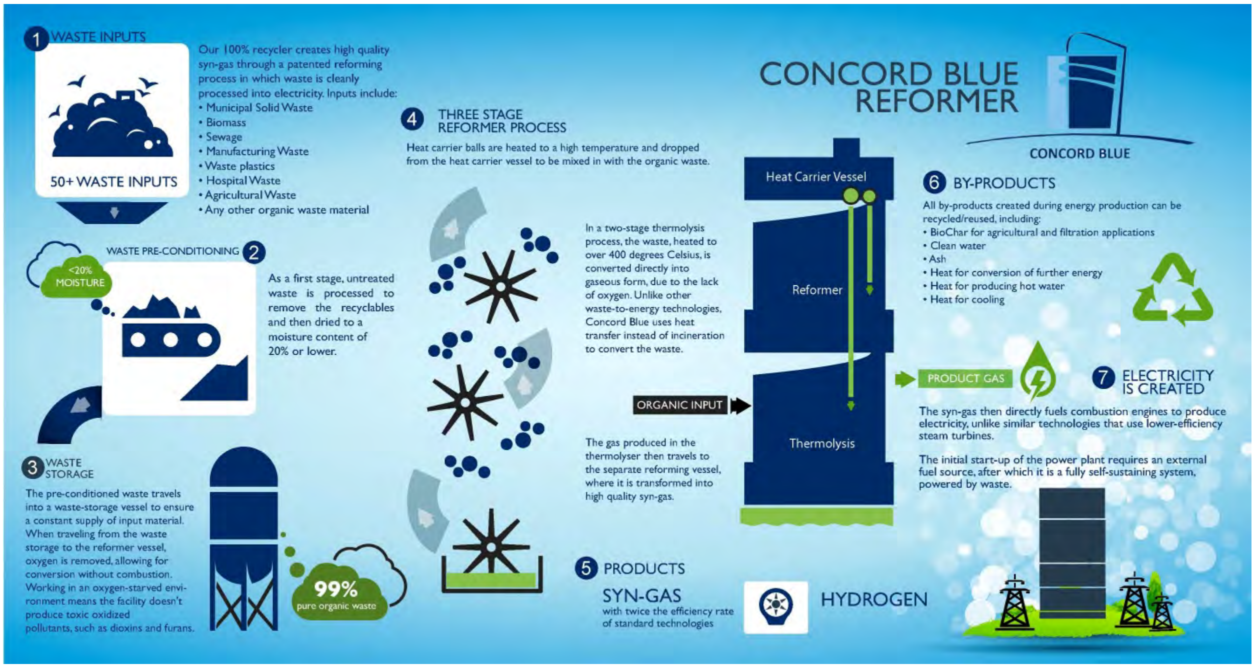
Concord Blue utilizes a closed-loop system sustained by the byproducts it creates, producing its own energy so that no additional fuel is needed once the process begins. Because Concord Blue's technology allows the tower and waste inputs to be heated in an oxygen-starved environment, their facilities cannot produce toxic oxidized pollutants, such as dioxins and furans. With no need for costly add-on scrubbers to clean emissions, their process is environmentally friendly and cost-effective.

Concord Blue's technology offers flexibility in feedstock, end product, and scale. Waste streams can include municipal solid waste, biomass, sewage, manufacturing waste, plastic waste, hospital waste, and any other organic material. Regardless of the input type, they offer a wide range of output choices, such as syngas, electricity, liquid fuels, and hydrogen. Byproducts include biochar, clean water, ash, heat for conversion of energy, heat for producing hot water, and heat for cooling.

Their technology is flexible in three ways—feedstock, end product and scale. Their process can scale up and down. Regardless of the feedstock used, they offer a variety of options for the type of output produced. Because they use a closed-loop system that creates its own energy, their facilities generate a number of byproducts with minimal pollutants and unusable materials.

Their process creates clean energy utilizing a variety of waste streams, including municipal solid waste, biomass, sewage, manufacturing waste, plastic waste, hospital waste, agricultural and livestock waste, slaughter waste, and any other organic waste material.

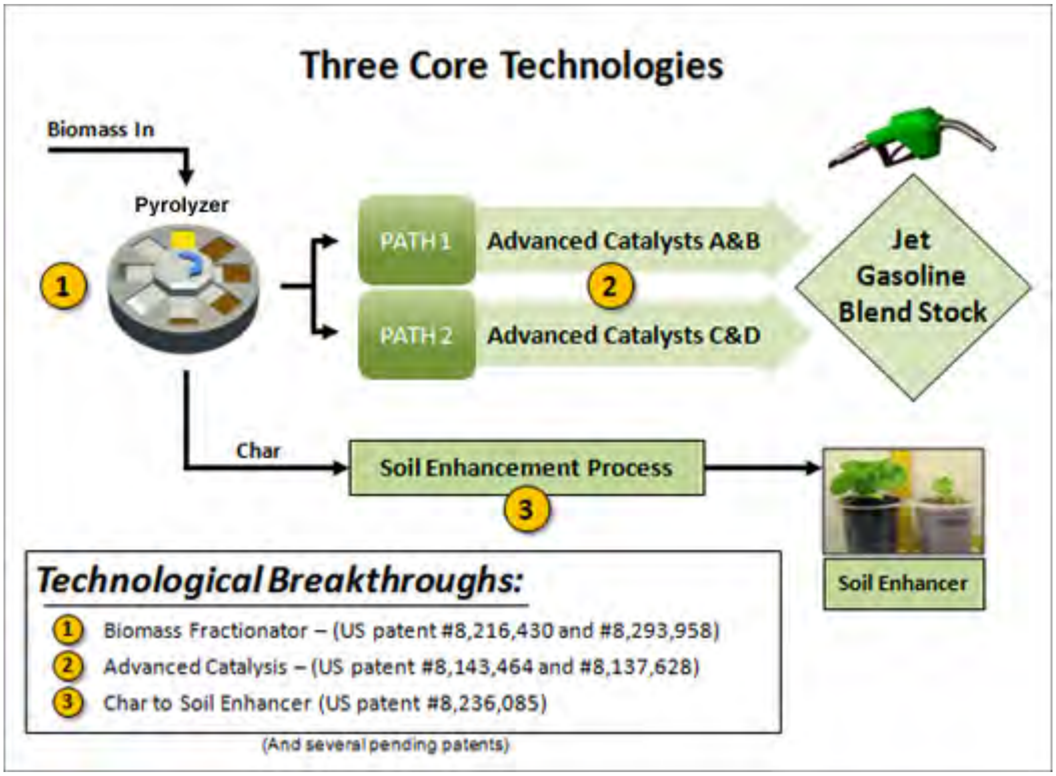
Their patented technology produces energy sources such as syngas, electricity, liquid fuels, and hydrogen. In addition, their process creates many byproducts, including biochar, clean water, ash (used in fertilizer and construction), heat for conversion of energy, heat for producing hot water, and heat for cooling (water or air conditioning).



3.7 Cool Planet Energy Systems

Even though they come from a different source, Cool Planet's gasoline, diesel, and jet fuel blendstocks can be blended into the current fuel supply to reduce CO_2 from the air without sacrificing performance or increasing prices at the pump.

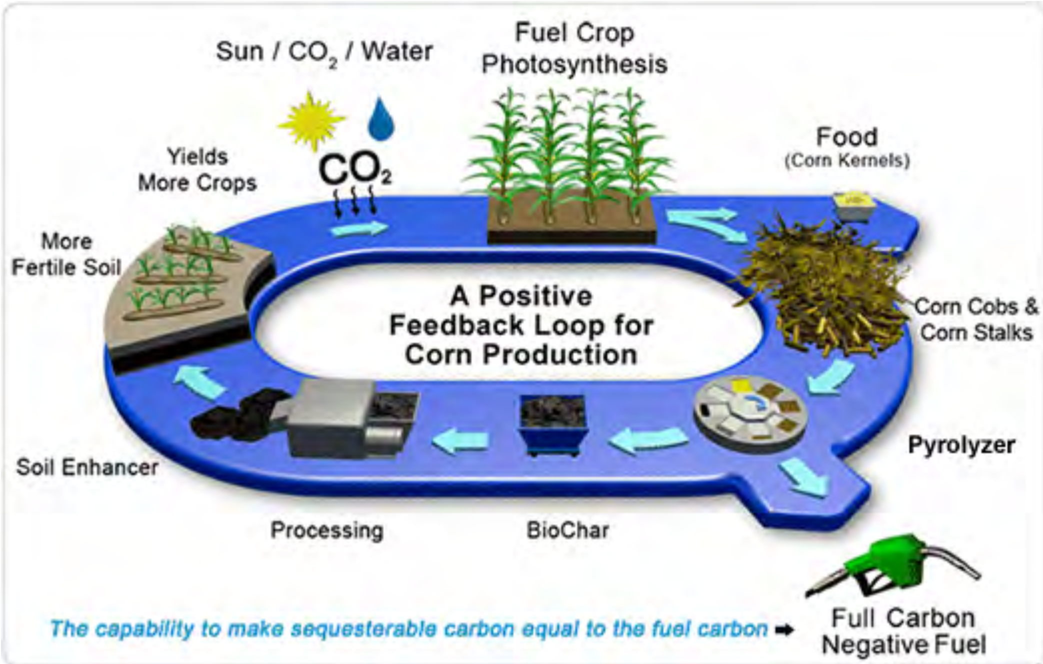
The company's fuels create greener gasoline and diesel that are the same, high-octane hydrocarbons that is powering vehicles today. They have undergone testing inside real vehicles and are ready for use at the pump without any changes to current vehicle fleet or fuel infrastructure.



Cool Planet's patented technology is comprised of three core components:

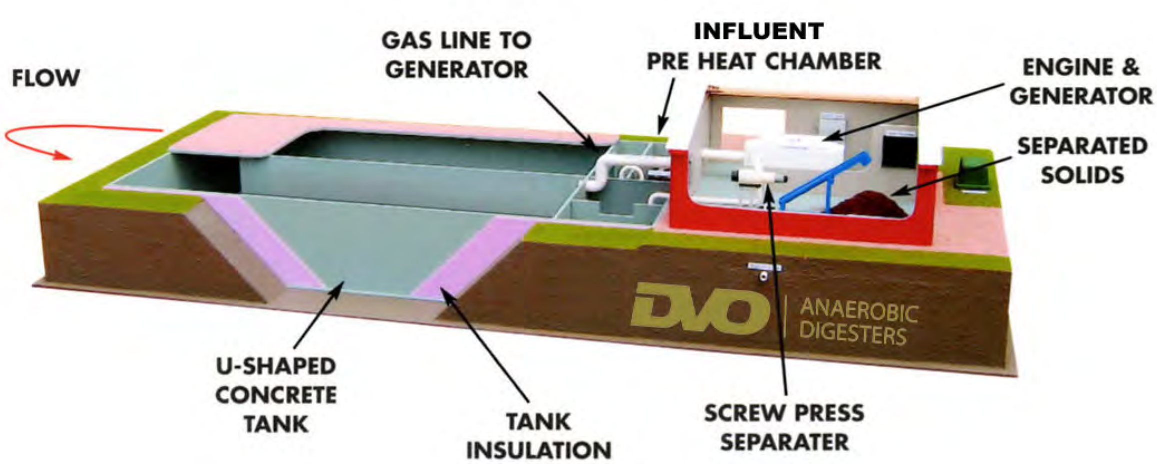
- ***Biomass Pyrolysis:*** Biomass is processed through a mechanical system that uses pressure and heat to create streams of useful hydrocarbon components. Cool Planet's sources of biomass include corn stover, wood chips, and non-food energy crops such as miscanthus.
- ***Catalytic Conversion:*** Cool Planet has developed a number of proprietary catalytic conversion processes to convert these hydrocarbon components into different types of fuels. One of their catalytic conversion processes creates a high-octane gasoline blend stock that can be used in today's standard automobiles requiring no change to existing conventional fuel distribution systems.
- ***Carbon Capture:*** Once the useful components for fuel have been removed, the biofractionation captures the leftover plant matter in a solid carbon form called biochar. This excess carbon is highly porous and has beneficial water and nutrient retaining capabilities. By creating renewable fuel and sequestering the biochar in the ground as a soil enhancer, they permanently remove atmospheric CO_2 for hundreds of years.

Due to the company's patented technology and biochar products, their green fuels have the capability to be carbon negative.



3.8 DVO Inc.

The patented two-stage digester converts manure and other organic wastes into three byproducts: a biogas, which can be burned in a genset or turbine to create electricity or scrubbed to make natural gas (i.e. CNG for transportation fuels); a biosolid, used as a bedding for cows or as a soil amendment; and a liquid stream that is non-odorous and can be applied as a fertilizer to growing crops.



DVO's anaerobic digester can process a variety of commercial and agricultural waste streams – including municipal separated organics, wasted food and food processing waste, and animal manures from dairy, swine, and poultry operations. Many other types of organic wastes can be digested in DVO's digester, such as fats, oils, sugars, starches, etc.

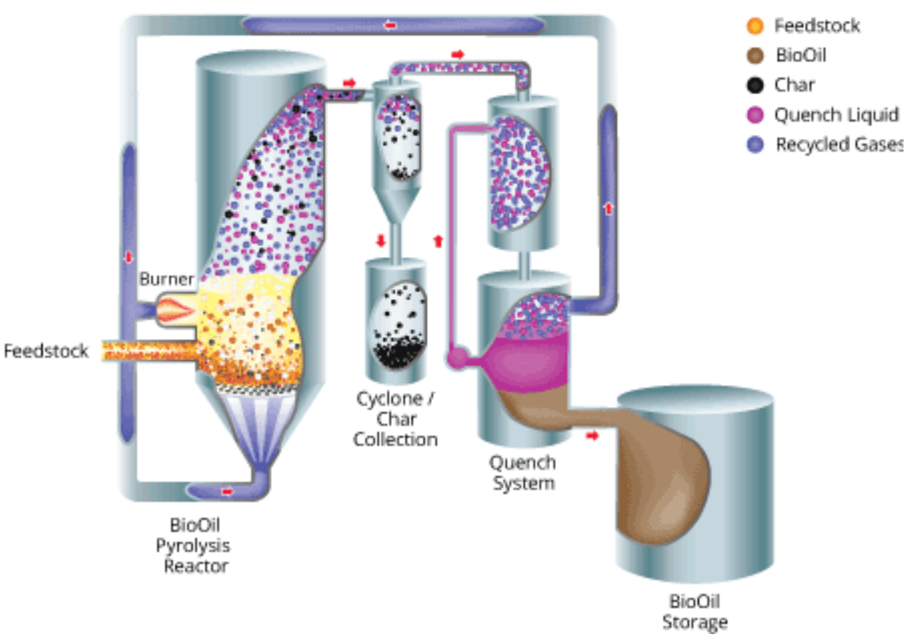
The system can be implemented at agri-businesses with organic wastes such as meat packing plants, dairy plants, and vegetable processors, as well as municipal sewage treatment plants and other waste treatment facilities.

Their digesters are designed to be operated by the owner/farmer, are simple to maintain and are optimized for reliability.

3.9 Dynamotive Energy Systems

Dynamotives' patented fast pyrolysis process involves the rapid heating of a biomass feedstock in the absence of oxygen.

Prepared feedstock (<10% moisture and 1-2 mm particle size) is fed into the bubbling fluid bed reactor, which is heated to 450-500°C in the absence of oxygen. This is lower than other pyrolysis systems and therefore has the benefit of higher overall energy conversion efficiency. The feedstock flashes and vaporizes, like throwing droplets of water onto a hot frying pan. The resulting gases pass into a cyclone where solid particles (char) are extracted. The gases enter a quench tower where they are quickly cooled using BioOil already made in the process. The BioOil condenses and falls into the product tank, while non-condensable gases are returned to the reactor as fuel to maintain process heating. The entire reaction from injection to quenching takes only two seconds.

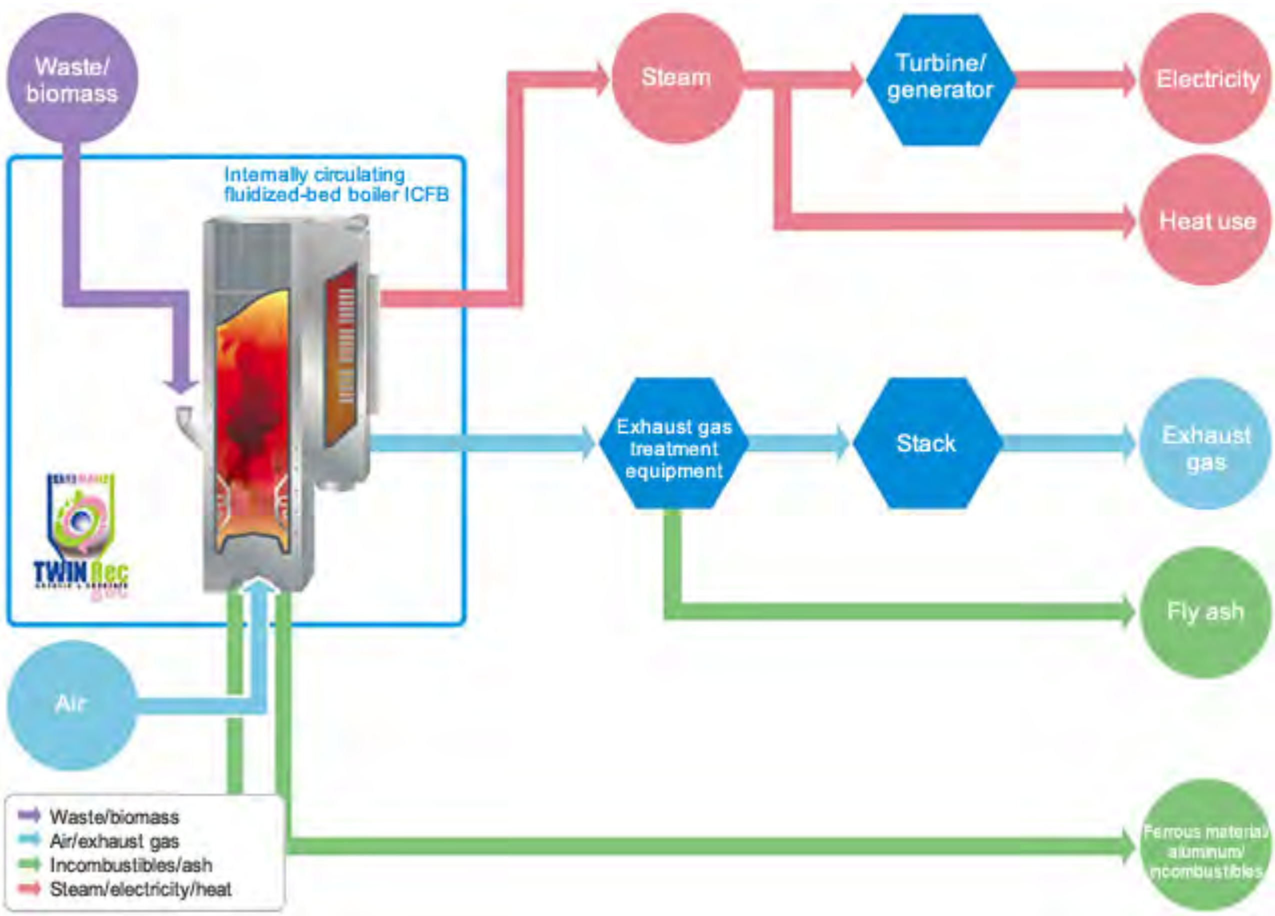


Three products are produced: BioOil (60-75% by weight); char (15-20% by weight); and non-condensable gases (10-20% by weight). Yields vary depending on the feedstock composition. A fourth product, BioOil Plus, can be produced by adding back the separated char into the BioOil, in a finely ground form of about 8 microns in size.

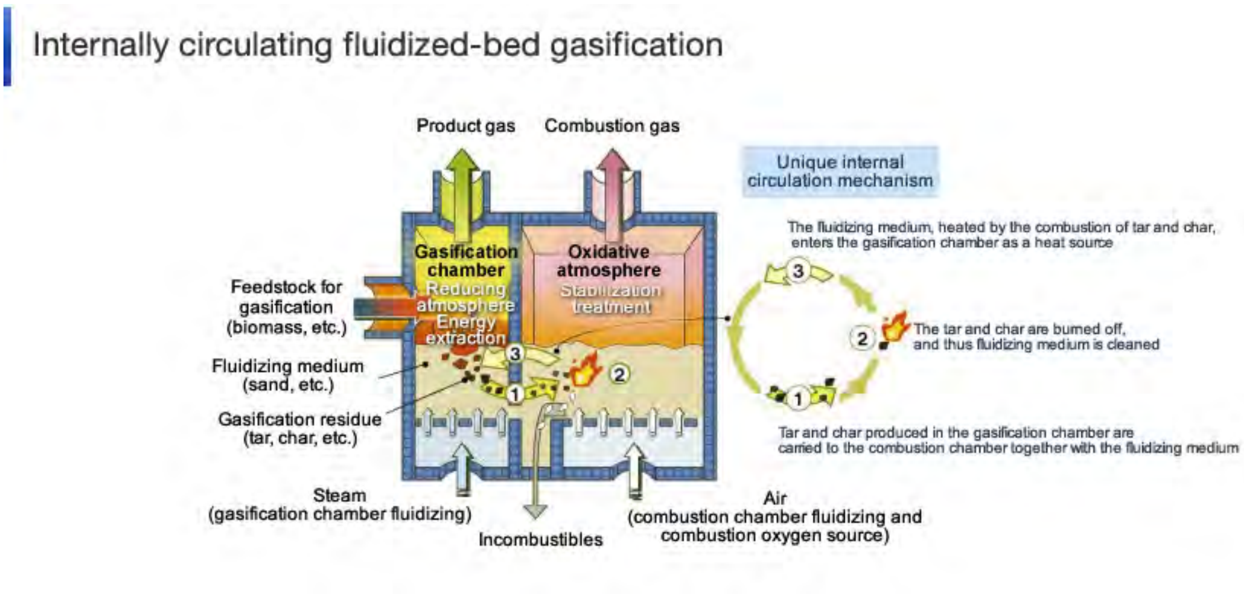
3.10 Ebara Environmental Plant Co. (EBARA)

EBARA's internally circulating fluidized-bed boiler is suited to biomass power plant applications, since it can stably incinerate a wide range of fuels like biomass, coal, waste plastic and discarded tires. A heat recovery chamber, in which in-bed heat transfer tubes are equipped, is arranged separately from the main combustion chamber to protect the heat transfer tubes from corrosion and erosion while enabling efficient energy recovery. EBARA's original heat transfer control function can dynamically control live steam flow while keeping stable combustion temperature, so that the system can quickly adapt to fluctuation of fuel properties and load demand, also at partial load condition.

The interior of the furnace is kept at negative pressure by balanced draft operation. This means that fuel does not need to be finely crushed, and there are no worries about leakage of combustion gases. Fuel incombustibles can stably be discharged from furnace bottom by the internal circulating function which is originally developed by EBARA.



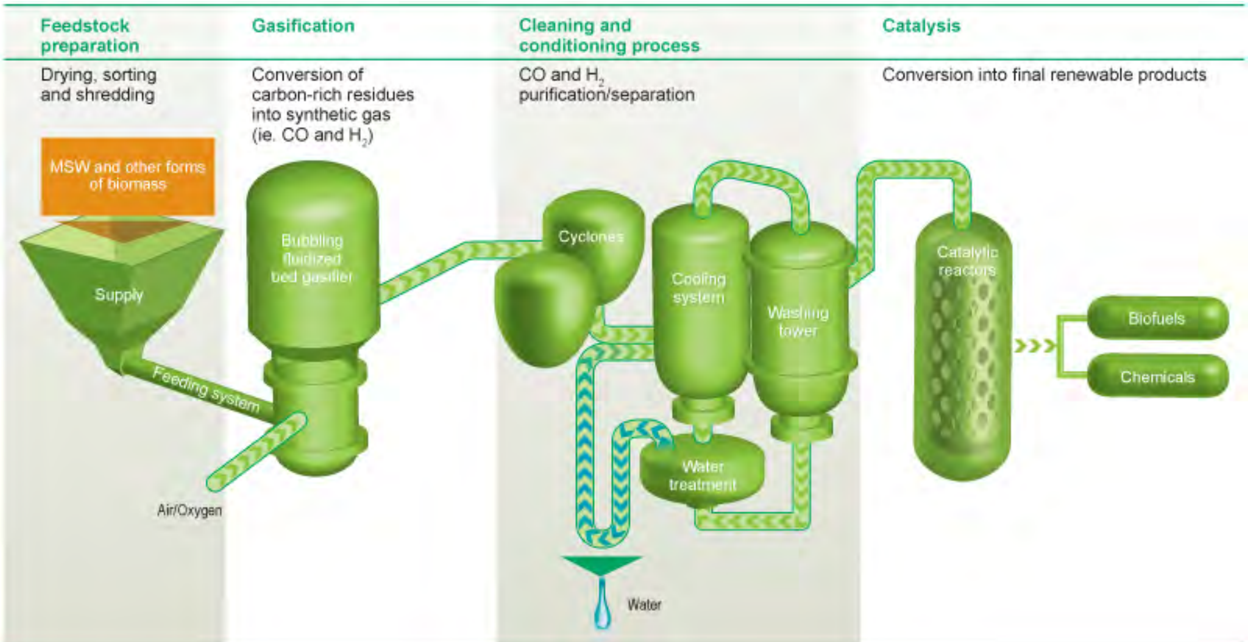
The internally circulating fluidized-bed gasification system (ICFG) is developed to recover high-calorific fuel gas, consisting mainly of hydrocarbons, from low-grade materials like biomass. The product gas can be used as an alternative energy to fossil fuels. The ICFG can be integrated to existing industrial processes with massive energy consumption to realize a system for utilization of biomass and waste energy as an alternative fuel for manufacturing industries.



3.11 Enerkem

Enerkem's proprietary thermochemical process converts waste into biofuels and chemicals. Enerkem's clean technology platform is a 4-step thermochemical process that consists of:

1. feedstock preparation
2. gasification
3. cleaning and conditioning of syngas
4. catalytic synthesis

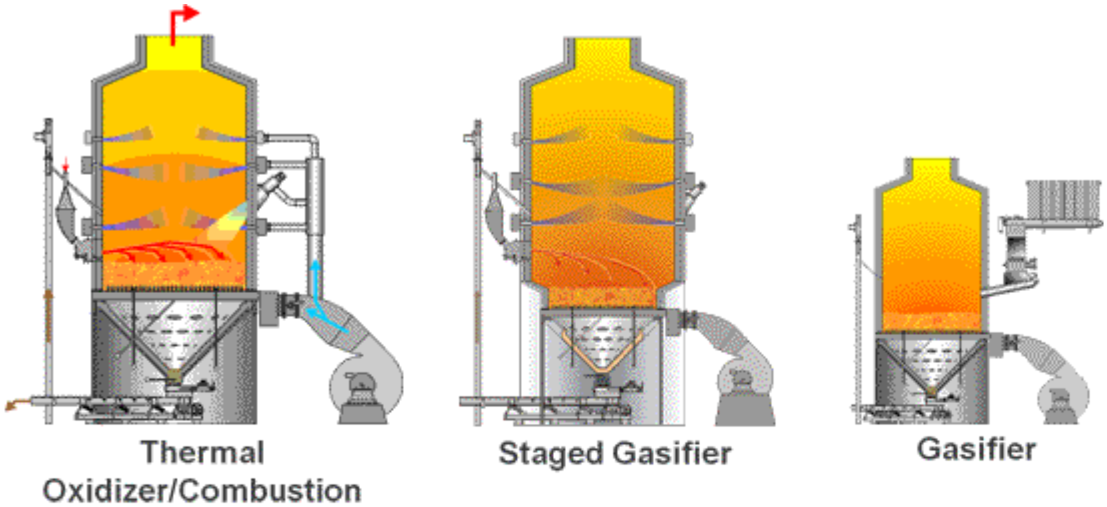


Enerkem converts mixed waste and residues into a pure synthesis gas (or syngas) which is suitable for the production of biofuels and chemicals using proven, well-established and commercially available catalysts. With its proprietary technology platform, the company is able to chemically recycle the carbon molecules from non-recyclable waste into a number of products.

Enerkem's primary focus is the commercial production of cellulosic ethanol. Its process first requires the production of methanol as a chemical building block for the production of ethanol. Enerkem can also sell its methanol as an end-product, or use it as a key intermediate to produce other renewable chemicals. Enerkem has validated its technology over 10 years using municipal solid waste from several municipalities, as well as a broad range of residues. Enerkem's process uses relatively low temperatures and pressures, which reduces energy requirements and costs. Enerkem's green chemistry provides a source of clean energy as well as a sustainable alternative to landfill and incineration.

3.12 Energy Products of Idaho (EPI/Outotec)

In December 2011, Outotec strengthened its portfolio of energy and environmental technologies by acquiring all interests in Energy Products of Idaho Limited Partnership Limited Partnership (referred to as 'EPI') in Coeur d'Alene, US. Outotec has solutions for a number of applications depending on fuel and other project requirements.



Outotec offers biomass and residue fuels (e.g. waste, sludge) applications as well as conventional fuels (e.g. coal, oil shale etc.) applications using both circulating and stationary fluidized bed technology.

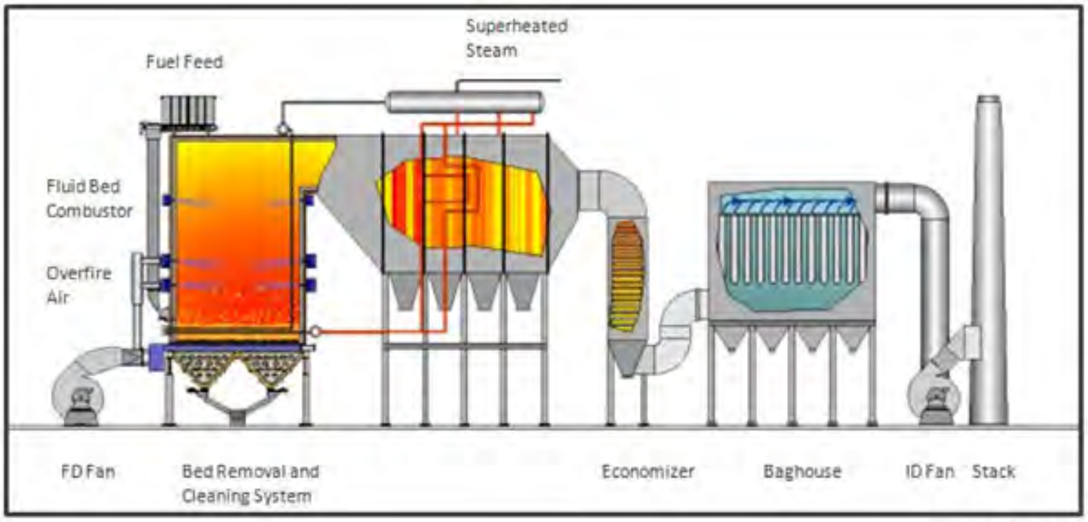
Outotec's fluidized bed combustion technology is an environmentally friendly solution for the generation of energy and the disposal of solid wastes. The key to Outotec's technology combusting difficult waste fuel is the proprietary bed recycle system. Outotec offers uniform bed drawdown, integrated air cooling and automatic cleaning and reinjection of the bed material. This feature enables Outotec systems to operate on fuels with significant quantities with a size up to 4 inch (100mm) non-combustible tramp material (contaminants such as rocks, metal etc.). In grate style systems, tramp material and ash slag can cause significant problems requiring a shutdown to correct. In other fluidized bed systems, tramp material can build to the point that fluidization is no longer possible, allowing clinkers to form. In these competing systems, a shutdown is thus required to clean out the accumulation.

The turbulence in the combustor vapor space combined with the tumultuous scouring effect and thermal inertia of the bed material provide for complete, controlled and uniform combustion. These factors are vital to maximizing thermal efficiency, minimizing char formation, and controlling emissions. The high efficiency of a fluidized bed combustor makes it particularly well suited to problematic fuels with low energy value and high moisture characteristics. Outotec systems have consistently achieved high combustion efficiencies. In a typical unit, the carbon burnout percentage within the combustor is well in excess of 99%.

The high combustion efficiency of a fluidized bed results in a reduced amount of inorganic material in the ash. The remaining larger material consists mainly of non-combustibles, such as rocks and wire contained in the fuel, and coarse sand like neutral particles. Low combustion temperatures in the fluidized bed minimize the formation of toxic materials that may end up in the ash. Ash samples from Outotec systems have consistently been tested nontoxic, and in many instances the ash is sold as input for other products such as cement.

Outotec's fluidized bed systems have demonstrated the ability to operate under a wide range of load conditions. The thermal "fly-wheel" effect of the bed material allows swings in moisture and heating content of the fuel to be absorbed by the system without negative impact. Conversely, the low fuel inventory present in the unit makes it very responsive to varying loads. The fluidized bed also maintains efficiency during system turndown. The operating flexibility demonstrated by existing units has proven valuable for customers to take advantage of utility incentive programs for generation that follows electric demand.

The lack of moving parts in a fluidized bed reduces maintenance costs and down time. Outotec units have achieved high operating availabilities and have kept operating costs relatively low given the difficult fuels being used.



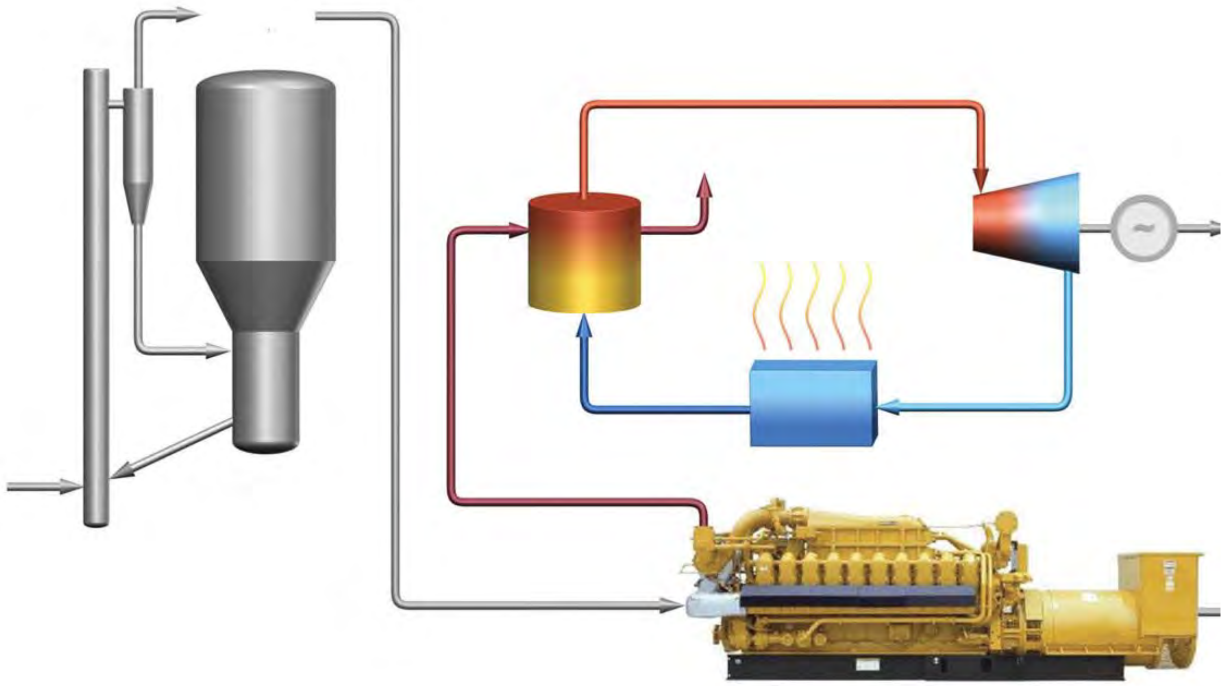
3.13 Envergent Technologies

Envergent Technologies offers an advanced technology called rapid thermal processing (RTP). RTP is used to convert cellulosic biomass feedstock, usually forestry or agricultural residuals, into RTP green fuel—a light, pourable, clean-burning liquid. This liquid provides a sustainable, cost-effective and virtually carbon-neutral alternative for process heat, power generation and, with further refining, transportation fuels.

This RTP technology is a fast thermal process in which biomass, usually forest residuals or agricultural by-products, is rapidly heated to approximately 500°C in the absence of oxygen. A circulating transported fluidized bed reactor system; similar to the one used in the Honeywell UOP's Fluid Catalytic Cracking (FCC) technology, is at the heart of the process.

A tornado of hot sand vaporizes the biomass, which is then rapidly quenched, typically yielding 65wt% to 75wt% RTP green fuel. This pourable liquid can then be used as a fuel for industrial heat or electrical generation, or it eventually can be further upgraded to produce transportation fuels.

RTP also produces char and a non-condensable gas, both of which can be used to provide process energy in the reheater to maintain the RTP process and/or in the dryer to condition the biomass.



RTP plus Diesel ORC Combined Cycle. This assumes that the primary power production generator set (GenSet - the diesel engine generator) is followed by an Organic Rankine Cycle ("ORC") heat engine in a combined cycle configuration. This combined cycle configuration uses an ORC rather than a classic steam cycle to produce additional power, and represents the highest power conversion efficiency.

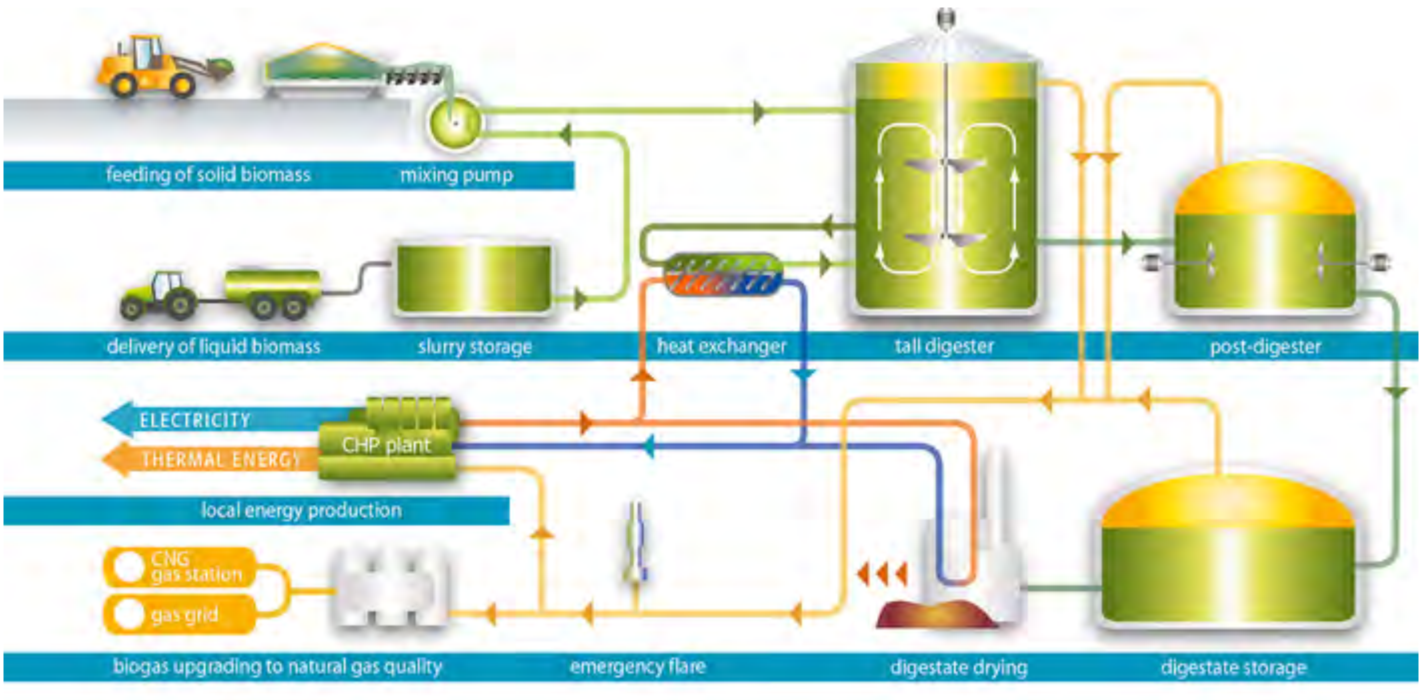
3.14 FARMATIC

FARMATIC offers turnkey solutions and custom services for biogas projects in agricultural, industrials, and communal application. FARMATIC has designed, constructed and commissioned turnkey biogas plants since the early 1990s. They are an Engineering, Procurement, Construction contractor (EPCC) that specializes in plant sizes up to 5 MW.

In addition to turnkey biogas plants, FARMATIC supplies individual components such as specialized storage solutions, digesters, thermal storage systems, digestate dryers, agitators and heat exchangers from their own designs.

When planned optimally, agricultural biogas plants perfectly fit into farming and soil nutrition cycles. The anaerobic digestion of manure, agricultural byproducts, and energy crops not only provides electricity and usable heat – it also produces a high quality organic fertilizer and soil conditioner. The nutrients contained in the substrate are broken down during the biogas conversion, thereby increasing the fertilizer quality of the digested product on the arable land. Plants can access the nutrients in digestate much easier than in untreated manure.

Each FARMATIC biogas plant is custom-tailored to the customer specifications and to the feedstocks available locally. All their plant's components consist of industrial grade materials that are highly resistant to corrosion.



Schematic of an Agricultural Biogas Plant

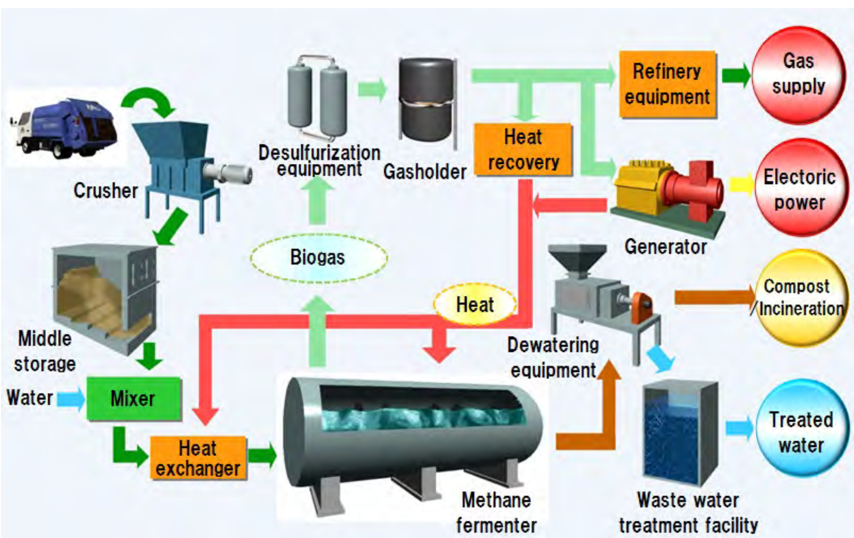
3.15 Hitachi-Zosen Corporation

Solid organic waste such as raw garbage, pruned branches and paper, is converted via methane fermentation to biomass, a green energy source. Since 1996, Hitachi Zosen has been utilizing technology from Axpo Kompogas (formerly Buhler), a leading supplier of methane fermentation solutions in Europe. The Hitz Kompogas System is a dry methane fermentation system that uses organic matter (biomass extracted through pre-processing of general combustible waste) to create biogas with approximately 60% methane content. The recovered biogas has a variety of applications such as use in gas engines, high efficiency power generation such as fuel batteries, fuel for automobiles, and city gas supplies.

Pilot plant in Kyoto

The system uses a combustible waste pre-processor to collect biomass material that can be converted into energy. It does not require any modifications to the existing waste collection setup. Key features of the Hitz Kompogas System are listed below.

1. Converts raw garbage into biomass and fermentation residue into compost simultaneously.
2. Accredited by the Japan Waste Management Association in 2001 as a waste methane fermentation system in line with technical inspection and verification procedures.
3. Biomass-derived biogas represents a renewable energy source that reduces CO2 emissions.



3.16 International Environmental Solutions (IES)

International Environmental Solutions Corp. (IES) engages in converting biomass and plastic wastes into electric energy and marketable products using a set of non-combustion thermochemical and biochemical technologies. It also produces components, such as thermal oxidizers, dust collectors, and wet scrubbers.

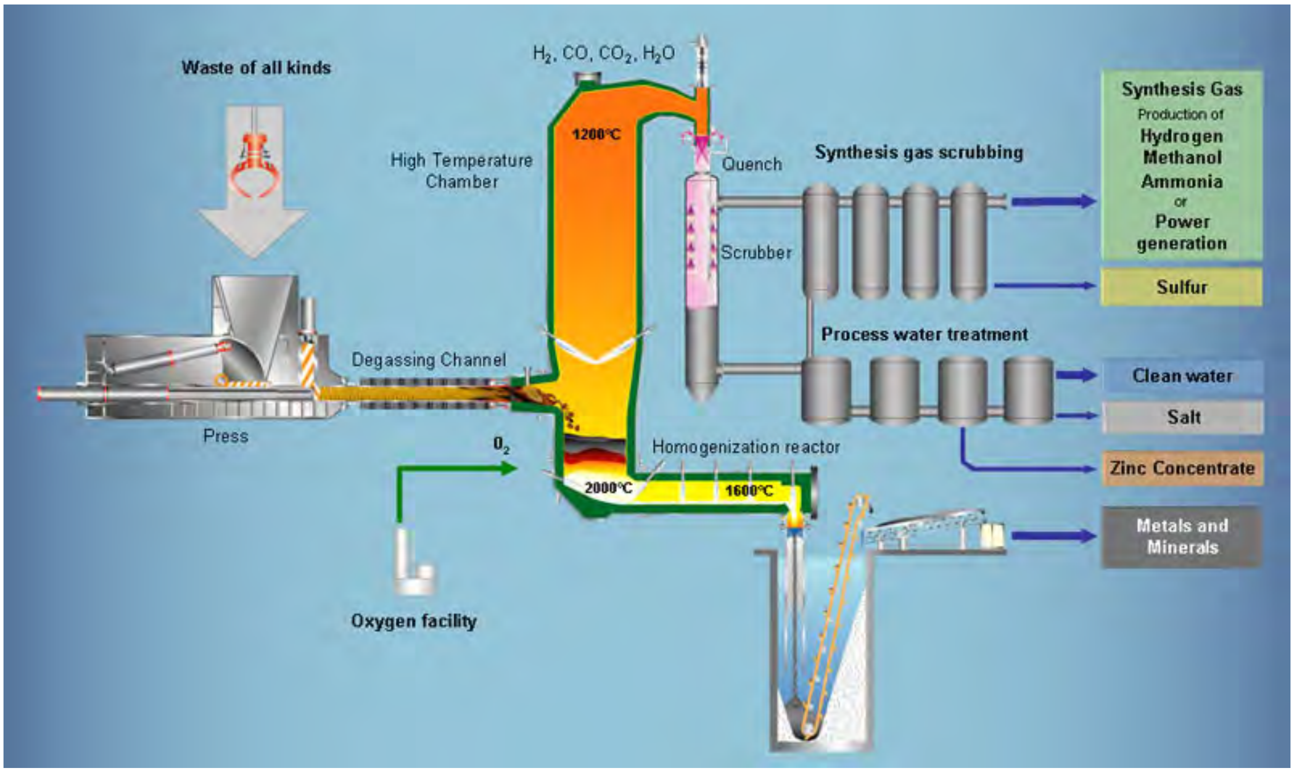
IES' Advanced Pyrolysis Systems (AP) are capable of converting numerous waste streams -- municipal solid waste (MSW), medical and industrial waste, sewage sludge and others -- into useful electrical or thermal energy with very few emissions. The process of pyrolysis uses very high heat to decompose organic wastes into synthetic gases and a carbon residue. The gases are then cleaned and combusted to produce steam, which can be used to meet onsite process needs, and also converted to electricity through a steam turbine. Because the process uses heat instead of combustion to convert the waste into energy, the resulting emissions are much lower than other waste-to-energy technologies. The only remaining solids are fly ash -- which is captured -- and a carbon char, which comprises less than 10% of the original waste volume and can often be sold as an inert binder, filler, or landfill cover material. Finally, the AP System is modular, can run on a wide variety of fuels, and can change fuels with only minor controls adjustments.

IES uses a pyrolytic process, which applies high temperatures (from 1,200°F to 1,800°F) indirectly to a retort chamber, which houses an environment free of flame and oxygen. Inside, hydrocarbons and other waste components are converted into gases and basic elemental solids via destructive distillation and molecular decomposition. All of the off-gases are diverted to a thermal oxidizer operating at 2,250°F for conversion to carbon dioxide, oxygen, and water vapor. The remaining solid residues passing out of the retort are typically carbon, sterile sands, and fixed, non-leachable metals. Waste materials are fed through airlocks to the horizontal retort chamber, which houses a proprietary rotating auger. IES has designed a three-arch, triangular chamber, which uses the upper portion to transport the generated gases to the thermal oxidizer, while the two bottom arches contain a suspended twin-rotary screw (auger) with paddle flights that convey the waste through the retort as pyrolysis occurs. Another set of airlocks is positioned at the "solids discharge" end of the retort chamber to prevent the introduction of oxygen.

IES Advanced Pyrolytic Systems are designed for trouble-free operation and minimal down-time. IES Advanced Pyrolytic Systems, in addition to destroying waste materials, facilitate the cost-effective use of all processing by-products. For example, the heat from the thermal oxidizer can be routed to waste-heat boilers to produce process steam or electricity via steam turbine generators. Solid residues, depending on composition, can often be recycled, sold as commodities, or formed into construction material.

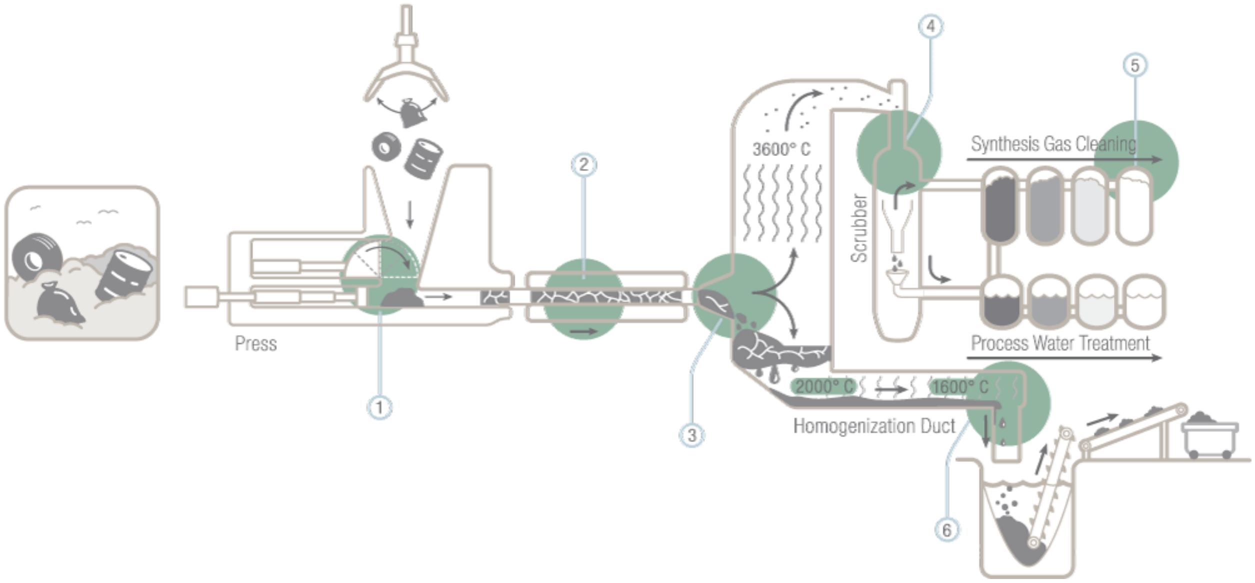
3.17 Interstate Waste Technologies (IWT)

IWT has identified a process that transforms municipal solid waste into usable raw materials, with no toxic emissions. Their Thermoselect process utilizes gasification to recycle 100% of waste into an energy rich syngas that can be used to generate electricity or to manufacture clean diesel, hydrogen fuel, and other recycled products.



IWT has identified a proven process that transforms waste into clean energy and commercially useful recycled products with no air emissions or process water discharges.

The Thermoselect technology transforms the energy content of waste from which they can generate multiple sources of clean energy. Other components of the waste become useful recycled products. Nothing remains to be landfilled. The Thermoselect process does not incorporate incineration technology. By carefully controlling oxygen levels in the process, they ensure that no combustion takes place. Utilizing the patented gasification process, the Thermoselect system recycles all types of waste, including MSW, commercial, industrial and medical waste, tires, E-waste and municipal sludges.



The Thermoselect process produces synthesis gas (syngas) which can be used to generate:

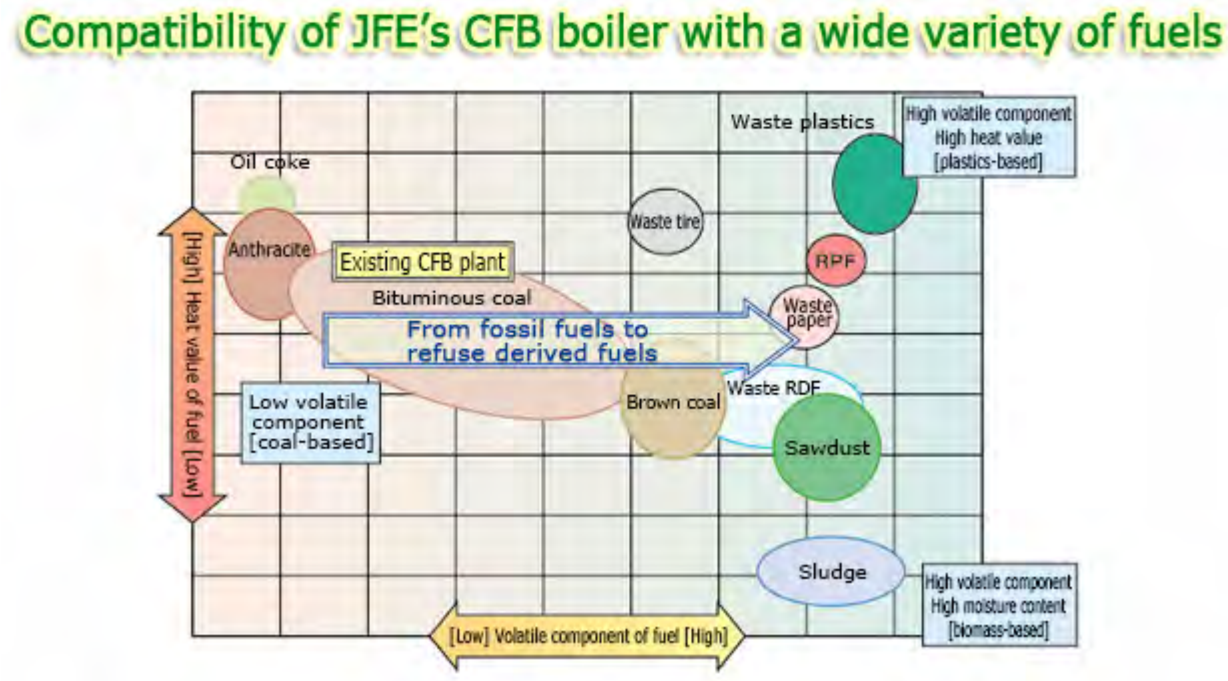
- A cleaner source of electricity
- Clean burning fuels, such as clean diesel fuel
- Hydrogen to power the future "hydrogen economy"

3.18 JFE Engineering

Conventional boilers are often only suitable for fossil fuels such as high-grade charcoal, oil and gas. JFE's circulating fluidized bed (CFB) boiler is capable of burning not only low-grade charcoal, biomass, sludge and sawdust, but a wide variety of fuels including industrial waste, such as waste plastics and tires.

JFE's CFB boiler burns a blended fuel of biomass and coal. Conventional boilers are only suitable for fossil fuels, such as high-grade charcoal, oil, and gas, whereas JFE's CFB boiler is compatible not only with low-grade charcoal, biomass, sludge, and sawdust, but a wide variety of fuels, including industrial waste such as waste plastics and tires.

JFE's CFB Boiler offers the advantage of reduction in fuel-related expenditures while yielding reduced CO2 emissions through the utilization of biomass.



3.19 KiOR

KiOR has developed a proprietary technology platform to convert sustainable, low-cost, non-food biomass into a hydrocarbon-based renewable crude oil. Using standard refining equipment, the company processes its renewable crude into gasoline and diesel blendstocks that can utilize the existing transportation fuel infrastructure for use in vehicles on the road today.

The company's technology platform combines its proprietary catalyst systems with a process based on existing Fluid Catalytic Cracking (FCC) technology, a standard process used for over 60 years in oil refining. The efficiency of KiOR's process, called Biomass Fluid Catalytic Cracking (BFCC), and the proven nature of catalytic cracking technologies, allow for cost advantages, including lower capital and operating costs, versus traditional biofuels producers.

KiOR processes its renewable crude oil in a conventional hydrotreater, which is a standard process unit used in oil refineries, into gasoline and diesel blendstocks that can be combined with existing fossil-based fuels and used in vehicles on the road today.

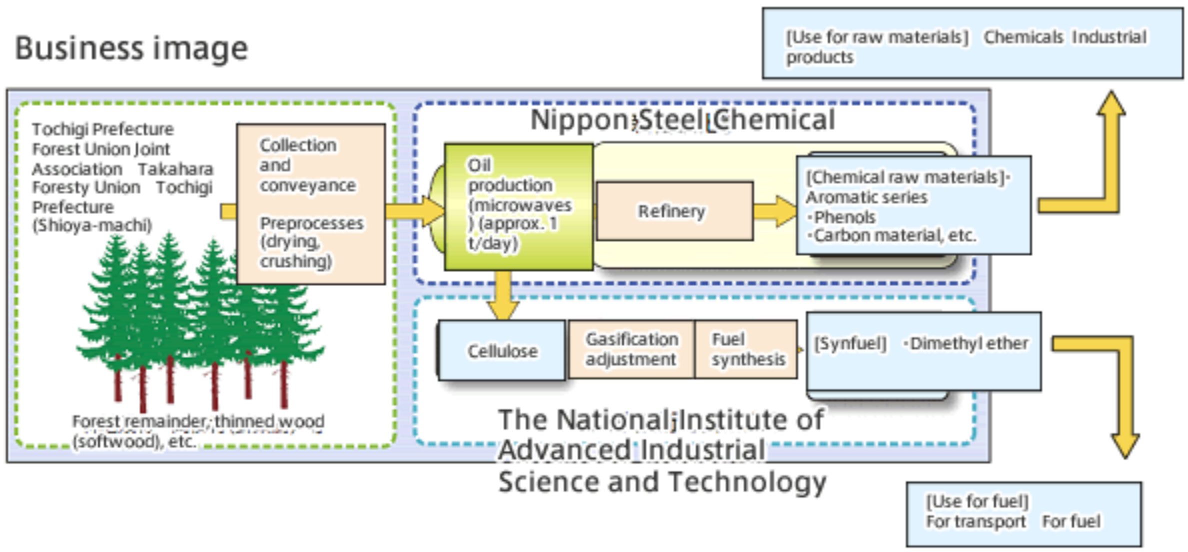
KiOR's first commercial scale production facility in Columbus, Mississippi, which began shipping cellulosic fuels in early 2013.

3.20 Nippon Steel & Sumitomo Metal (NSSM)

Nippon Steel and Sumitomo Metal (NSSM) utilizes biomass energy from the mixed combustion of woody biomass and coal. They utilize two techniques to process forest residue. NSSM is engaged in the utilization of forest off-cuts through the two techniques of biomass energy and bio-oil production.

Bio-oil production technology using microwaves:

- Nippon Steel & Sumikin Chemical (NSSMC) is proceeding with the research and development of a system for using microwaves to produce chemical raw materials and petroleum-substitute fuel from unused forest resources, such as thinnings.
- NSSMC is executing this project in cooperation with the Tochigi Prefecture Forest Union Joint Association, commissioned by the Forestry Agency for a "forest resources utilization-type new business creation project."



Bio-oil production demonstration facility

Features of this technology:

- Microwaves can liquefy wood powder over a short time period.
- Can use various wood materials relatively in a coarsely crushed status as a raw material.
- The obtained liquefied material (bio-oil) contains the components of chemical material and can also be used as liquid fuel.
- The manufacturing process is simple and eco-friendly.

The Nippon Steel & Sumitomo Metal (NSSM) Kamaishi Steel Works (hereafter referred to as Kamaishi Works) is a system that uses the Ministry of Economy, Trade and Industry subsidy system to promote the utilization of biomass resources for 'local production for local consumption' in a cooperative effort between government, forestry enterprises and manufacturers under the Kamaishi City Green System Creation Project. Specifically, the Kamaishi Works combusts coal in combination with thinned wood and forest remainders, which are wood biomass resources, and aims at saving energy by reducing the usage of coal, which is imported fossil fuel, and greenhouse gas mitigation. The mixing combustion ratio is 2% by weight until March 2011. The reduction in CO_2 emissions is estimated to be 7,000 tons/year using 5,000 tons/year of wood biomass.

The Kamaishi Works is adopting biomass energy.

3.21 ENTECH Renewable Energy Solutions

ENTECH Pyrolytic Gasification Systems utilizes third generation combustion technology to gasify biomass and waste and convert it into a combustible gas mixture referred to as “syngas” at 1,400 degrees Celsius, resulting in a clean, high temperature off-gas that is low in NOx, CO particulate, volatile organic compounds (VOCs), and other pollution compounds. The system’s energy recovery unit harnesses the heat energy generated (not from burning biomass or waste, but from firing the syngas produced by the pyrolytic gasification process) and puts it to use for power generation (cogeneration), or for manufacturing and plant processes (steam or hot water generation).

WtGas is the core technology of the Entech-Tru-RES™. It’s based upon a low temperature gasification process that converts waste from its solid to gaseous form of syngas, so that it can be fired to generate energy; with emissions that are cleaner than firing of any fossil fuel.

The heart of the WtGas system is the syngas production stage, where the ENTECH™ Pyrolytic Gasification Chamber:

- Receives the waste or biomass and subjects it to low temperature-substoichiometric gasification; so as to heat and convert it into methane like gases high in CO, CH_4 & C_nH_n hydrocarbons, which are referred to as syngas.
- The process is around 1/20th the air input and around 1/50th the velocity and turbulence of conventional combustion, which maximizes the volatility of the syngas, plus minimizes entrainment of pollution concerns into it.
- This results in the syngas being a relatively clean gas that's available for immediate utilization without further refining or treatment.
- The feedstock of the gasification process is subjected to regular churning and stoking by the ENTECH™ Churning, Stoking & Distribution System so as to expose all matter to the actual gasification process.
- The feedstock is processed over a period of around 16-24 hours to ensure complete gasification.

The WtGas system key to energy efficient and environmentally superior utilization of the syngas is the ENTECH™ SynGas Burner, which:

- Receives the syngas and fires it instead of fossil fuel.
- Adopts conventional high efficiency / low NOx burner design with staged processes of pre-mixing to LEL, ignition and oxidation.
- The burner staged process also results high DRE (destruction rate efficiency) of POP's (principle organic pollutants) such as VOC's, PAH's, nitro-PAH's and dioxins.
- With the syngas containing negligible pollution concerns and the firing of the syngas achieved at high efficiency and high DRE; the resulting off-gas consists primarily of CO_2 and water vapor.

The syngas produced by the WtGas system is fired to power boilers and like devices to produce steam and/or electricity. After firing the off-gas, it is subjected to cleansing via an air quality control system, with resulting emissions complying with worldwide emission regulatory requirements.

3.22 PRM Energy Systems Inc.

The PRME® Gasification Technology is a fixed bed, up-draft, sub-stoichiometric, multi-zoned gasification air and staged combustion air system. PRME® Gasification Systems are available in a wide range of sizes to gasify from 20 – 2,000 tons per day input.

A complete PRME® Gasification System includes a fuel metering bin; solids infeed control; multi-zoned gasification air; the KC Reactor®; staged combustion air combustion chamber; water cooled ash discharge conveyors; utility piping; and instrumentation/electronic controls to provide complete automatic or manual operation. Then, depending, on the customers' needs, the syngas produced will be fully combusted for heat applications, partially combusted in a staged configuration for steam applications, or cleaned and conditioned for other uses, such as electrical generation through internal combustion engine gensets.

The versatility, modularity, and ruggedness of the PRME gasifier make it suitable for energy development in remote areas of developing countries, as well as developed nations. This conclusion is supported by a joint project between PRME and Citizens Power and Light Company of Boston, MA, to study the feasibility of private sector development of biomass to electricity projects in India. This study was co-funded by Winrock International and USAID.

Typical Applications of the Technology

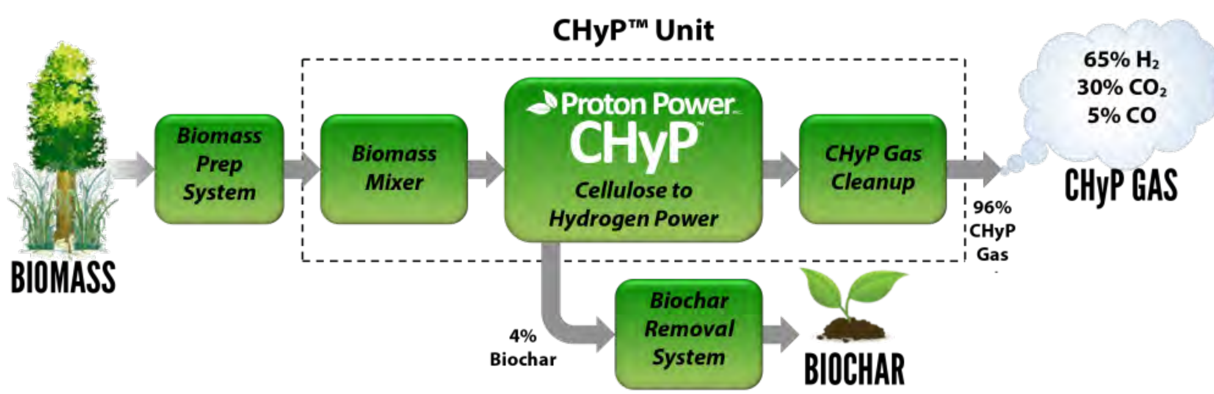
Gasification of the following:	To Produce:
• green or dry wood waste • agricultural residues • paper mill sludge • waste water treatment sludge • processed municipal solid waste (RDF)	• heat for the direct firing of dry kilns • steam to generate electricity for use or sale • steam for industrial process steam • gas for I/C Engine/gensets • gas for co-firing of utility boilers • heat for direct firing of thermal oxidizers • lower waste disposal cost

One model KC 8 gasification system installed to generate 1MW of electrical power. The system is operated on wood fuel and/or distillery residue. The syngas is cooled, cleaned and burned in an EneriaCat engine-genset. The system was installed in the spring of 2006.

3.23 Proton Power, Inc. (PPI)

Proton Power, Inc. (PPI) is all about hydrogen - using biomass to make inexpensive hydrogen, which they convert to energy such as synthetic fuels, electricity and heat.

Proton Power, Inc. (PPI) has developed a patented renewable energy system that produces inexpensive hydrogen on demand from biomass and waste sources. This core technology, referred to as Cellulose to Hydrogen Power (CHyP), is ideal for clean energy applications such as distributed or central-station electrical power generation, hydrogen production, or producing synthetic fuels such as renewable gasoline, diesel, and aviation fuel. Co-products are biochar, a soil amendment, and water. PPI has successfully tested a wide variety of biomasses in its CHyP system, including switchgrass, various kinds of sawdust, and processed municipal solid waste.



The hydrogen produced from the CHyP system can be used in various clean energy applications including:

- Supplement for existing diesel fuel generators with up to 60% of diesel usage eliminated
- CHyP syngas can be burned directly in natural gas generators to make electricity
- Drop-in ready renewable diesel and other synthetic fuels
- Demolition and construction debris power generation binds toxic materials into non-leachable form and reduces volume going into landfills by 96%

Available sizes of 250 kWe, 500 kWe, 1000 kWe, and 2000 kWe allow scalability.

The CHyP system provides advantages over standard energy options:

- A high yield of 65% hydrogen in CHyP syngas leads to low hydrogen cost
- Biomass can have 45% moisture content which eliminates the drying step
- Tars and particulates are virtually eliminated; no need for expensive and energy-intensive syngas clean-up process
- Higher power density than many other syngases
- The process is carbon neutral or negative
- The systems are scalable upward from 250 kWh to suit the application
- The cellulosic fuel is renewable and sustainable
- Small footprint facilitates remote locations
- Continuous operation makes good economic sense
- CHyP system can provide many energy uses: heat, electricity, and synthetic fuels

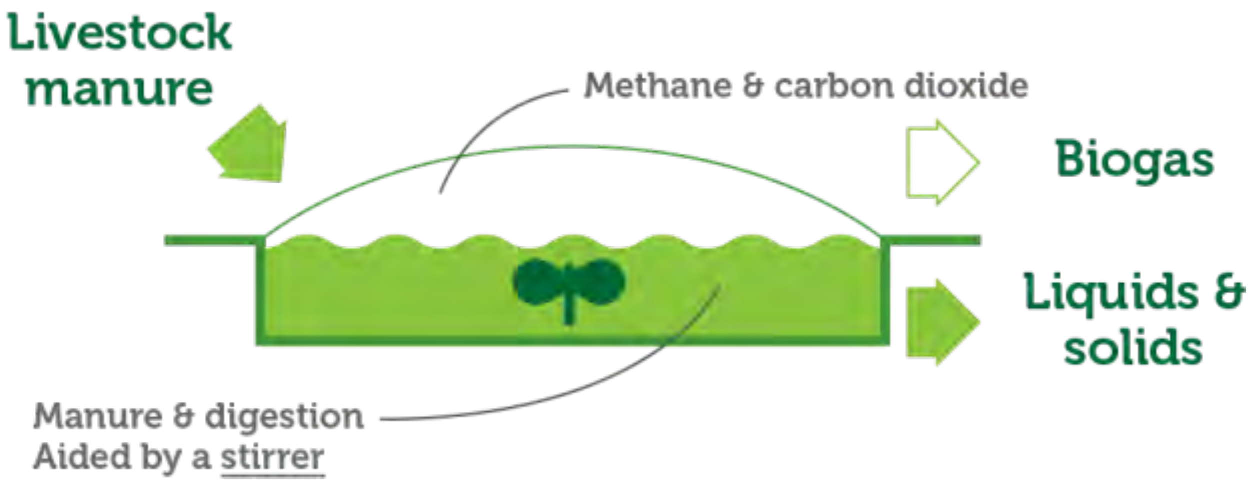
3.24 RCM Digesters

RCM’s proven technology maximizes the production of biogas through systems that are efficient, easy to operate, and durable.

RCM’s digester types include:

- Complete Mix
- Heated, Stirred, Lined
- Covered Lagoon
- Plug Flow

Complete Mix



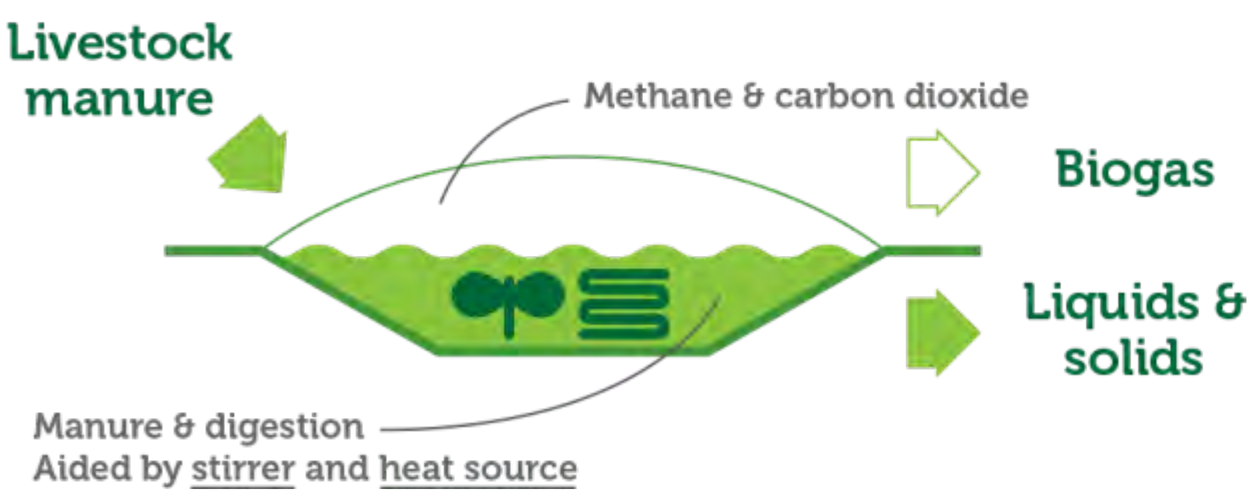
Complete Mix is a technologically advanced system designed to maximize the quantity and the quality of biogas production. The optimized anaerobic process also results in biological stabilization of the effluent and odor control.

Complete Mix digesters produce biogas from a variety of organic wastes that have a total solid content of 3 to 10 percent. To enhance energy production, the waste is headed and mixed to maintain a high level of bacteria. An impermeable material covers the top of the vessel to keep the biogas from escaping.

The components of a Complete Mix system generally include:

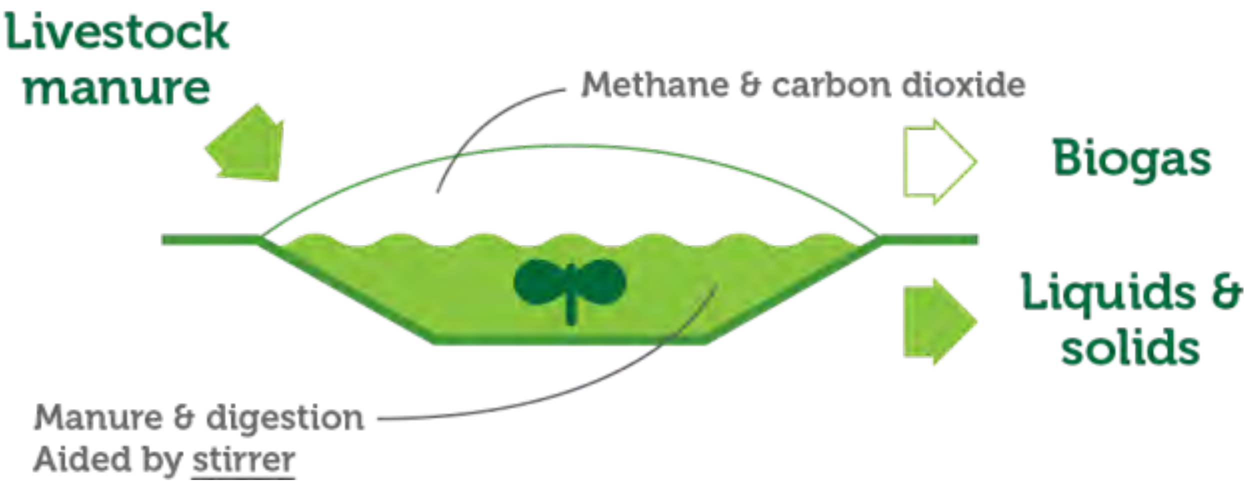
- a mix tank
- a digester tank with mixing, heating and biogas recovery systems
- an effluent storage structure
- a biogas utilization system

Heated, Stirred, Lined



The Heated, Stirred, Lined reactor is a hybrid system that begins with a covered lagoon, with the addition of lining and a heating and mixing system. This digester is designed for scraped or pull-plug pig or dairy waste in moderate climates. The system is able to handle varying manure flows, and is relatively inexpensive to build and operate.

Covered Lagoon



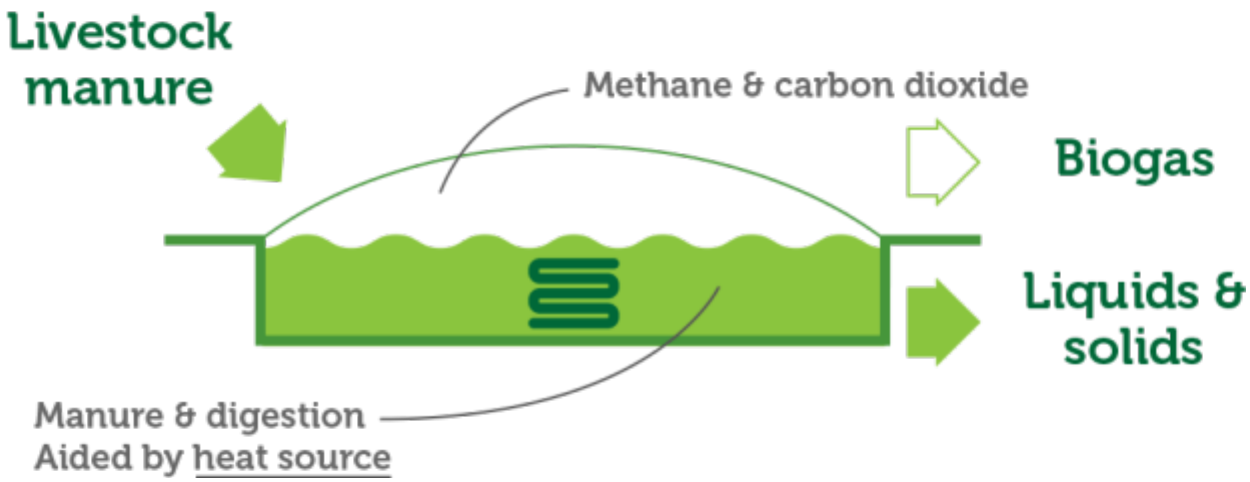
These digesters produce biogas at ambient temperatures from diluted manure with less than 2% solids. To trap biogas, an impermeable cover floats on top of a lagoon filled with flush manure. Covered lagoons are used for energy production in warm climates but are limited to odor control in colder climates.

A covered lagoon system consists of:

- a solids separator
- one or more lagoons
- a floating lagoon cover
- a biogas utilization system

The most successful arrangement includes two connected lagoons that separate the biological treatment for biogas production from the storage of manure used for land application.

Plug Flow



This digester is an unmixed, heated, rectangular tank that digests raw livestock manure from dairy farms. Manure is collected by scraping and fed into the digester, where it degrades as it travels through the tank. To capture the biogas, an impermeable material covers the top of the tank.

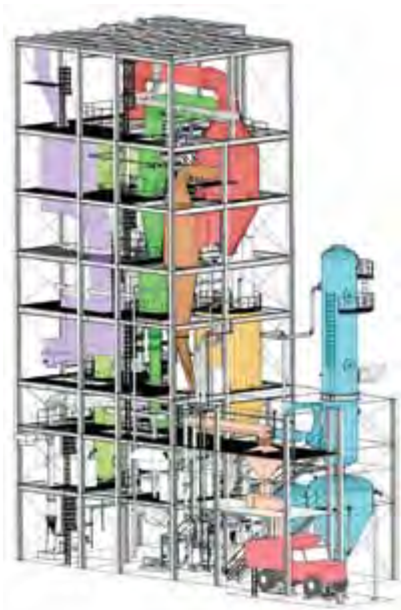
The system generally consists of:

- a mix tank
- a digester tank with heat exchanger and biogas recovery system
- an effluent storage structure
- a biogas utilization system

Unlike covered lagoon systems, plug flow digesters are optimized to produce energy in any climate. Digested dairy solids can be separated and sold as a new product.

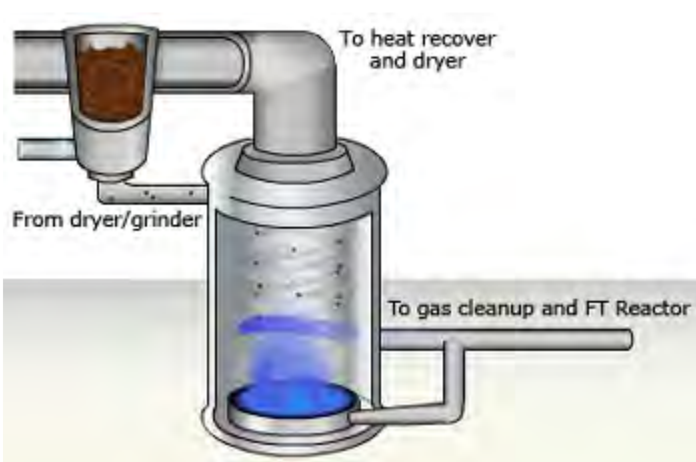
3.25 Rentech-Clearfuels

Rentech-SilvaGas Biomass Gasification Process is a patented, commercially proven, gasification technology with over $100 million invested in technology and assets. The gasifier can process a wide variety of cellulosic feedstocks to produce syngas. The syngas can be used to produce renewable power or it can be processed through their Rentech Process or other third-party fuel conversion technologies to produce drop-in, certified, renewable fuels. The gasifier has successfully operated in Burlington, VT for over 2 years in partnership with the Department of Energy (DOE), National Renewable Energy Laboratory (NREL) and Battelle Columbus Laboratory.



Rentech-SilvaGas Gasifier

The Rentech-ClearFuels biomass gasification technology produces hydrogen as well as syngas from cellulosic feedstocks through the use of a High Efficiency Hydrothermal Reformer (HEHTR). The syngas can be used to produce renewable power or be processed through Rentech's technology or other third-party fuel conversion technology to produce renewable drop-in fuels. The Rentech-ClearFuels technology has operated at pilot scale in excess of 10,000 hours and multiple third parties, including Idaho National Laboratory and Hawaii Natural Energy Institute, which have independently validated the results of the pilot scale data. The Rentech-ClearFuels technology has been proven at demonstration scale at Rentech's Energy Technology Center in Commerce City, CO through a $23 million grant received from the U.S. Department of Energy under the American Recovery and Reinvestment Act.



Rentech-ClearFuels Gasification Process

3.26 Schmack Biogas

Schmack Biogas's core competence lies with the fermentation of energy plants and agricultural waste products, such as slurry and solid manure. The cornerstone of their biogas plants are their "standard plant systems". Their product range covers from 185 kWel to 20 MW gas feed-in plants – all in the form of comprehensive systems.

EUCO® Titan
The EUCO® Titan plant system has experienced on-going development since the company's formation and has been optimized specifically for the fermentation of sustainable raw materials. Its high level of efficiency makes it attractive, not only to agricultural enterprises, but also to investors, energy suppliers and city departments of works, all of whom bank on this leading technology.

EUCO® MONO
The EUCO® Mono plant system was specifically developed to ferment substances with a high proportion of dry matter such as grass, maize and solid manure, for example. It is distinguished by its particularly compact design. Contrary to all other plant systems, no circular digester is used; instead a "horizontal"digester (plug-flow digester) is employed.

COCCUS® Titan
As a minimum, the COCCUS® Titan plant system comprises a classic circular digester. It is primarily recommended for large industrial plants, predominantly where substances with a low proportion of dry matter are fermented.

COCCUS® Farm
The German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, or EEG), updated in 2010, encourages the construction of smaller biogas plants in the agricultural sector that utilize a minimum proportion of slurry as a fermentation substance. This prompted Schmack Biogas to develop the small COCCUS® Farm system. High industrial standards, usually applied by Schmack to larger system builds, were brought to bear in the development and realization of this smaller system. The COCCUS® Farm plant system is the right choice where material of low energy density and low proportion of dry matter is usually available such as, for example, beef and pig slurry.

Biogas plant Fischbach. COCCUS® Farm 185 Agricultural plant: Installed electrical output: 185 kW. Fermentation matter: Beef slurry, grass, silage, maize silage, solid pig manure. Commissioning: December 2009

3.27 Sundrop Fuels

Sundrop Fuels, Inc. is a privately-held advanced biofuels company with corporate headquarters in Longmont, Colorado. The company is preparing to launch construction in Central Louisiana of its inaugural fuels facility, a production plant representing the first phase in Sundrop Fuels' path toward providing a renewable, drop-in biogasoline.

Unlike other biofuels production methods that typically burn considerable amounts of feedstock to generate the heat necessary for conversion, Sundrop Fuels adds hydrogen and heat from clean-burning, American natural gas to create a process that converts virtually all of the biomaterial used into actual liquid fuel. This allows Sundrop Fuels to compete directly with petroleum products by delivering to the market a renewable advanced biofuel for an estimated unsubsidized cost of about $2 per gallon.

At the center of its advanced biofuels production is the Sundrop Fuels proprietary, ultra-high temperature, pressurized, bioreforming system. Inside a specially-designed thermochemical reactor, biomass is quickly converted, and then combined with hydrogen from clean-burning natural gas, to create a renewable feed stream – the key ingredient for biogasoline that is 100% compatible with today's combustion engines and transportation fuels infrastructure. Sundrop Fuels first converts this renewable feed into methanol using a syngas-to-methanol process, and then creates “green gasoline” using a commercially-established methanol-to-gasoline (MTG) fuels synthesis.

Sundrop Fuels’ bioreforming production method is unique from conventional biomass gasification in that it uses indirect radiation heat transfer to rapidly drive the extremely high temperatures needed to create the renewable gas feed, which is then processed to create liquid advanced cellulosic biofuel. Using natural gas, temperatures inside the Sundrop Fuels radiation-driven bioreformer reach more 1,400 degrees Celsius (2,552 degrees Fahrenheit) – hotter than lava flowing from a volcano.

By steadily maintaining these ultra-high temperatures to drive the endothermic bioreforming reaction, the Sundrop Fuels process operates at an extraordinary high-efficiency, producing more yield of renewable liquid fuel per ton of biomass feedstock than any other production method.

The Sundrop Fuels biogasoline production path significantly reduces greenhouse gas emissions as compared to the production of conventional petroleum fuels. Every gallon of Sundrop Fuels drop-in cellulosic advanced biofuel will generate Renewable Identification Number (RIN) credits under the U.S. Renewable Fuel Standard (RFS).

Sundrop Fuels is currently in the engineering design stage for its inaugural production facility located just outside of Alexandria, Louisiana – the first operational milestone in the company’s path toward becoming a mass-scale provider of renewable, drop-in biogasoline. When fully operational, Sundrop Fuels’ first facility will produce 15,000 barrels per day of finished, 87-octane gasoline. It will also represent the world’s largest commercial production of cellulosic advanced biofuel using methanol-to-gasoline (MTG) technology, which was originally demonstrated as a commercially available process in the 1980s.

How it works.

1. Cellulosic biomass material is delivered by entrained flow into Sundrop Fuels’ proprietary ultra-high temperature pressurized bioreforming system, which converts the material. Natural gas is used to power the radiation-driven bioreforming reactor, generating temperatures of more than 1,400 degrees Celsius (2,552 degrees Fahrenheit).

2. Hydrogen-rich natural gas is added after bioreforming to allow for a two-to-one hydrogen-to-carbon ratio – the chemical make-up necessary for transportation fuels that can be used in today’s internal combustion engines. This combination of converted biomass and additional hydrogen creates a renewable feed that is the key ingredient for Sundrop Fuels drop-in biogasoline.

3. The renewable feed is converted into methanol using a commercially available catalyst process.

4. Using a well-established commercial fuels synthesis process, the methanol that was created from the renewable feed is then made into in ready-to-use “green gasoline” – or more easily referred to as biogasoline.

5. The Sundrop Fuels high-octane, drop-in biogasoline, is blended and ultimately delivered to the marketplace through the nation’s existing pipeline and distribution infrastructure.

3.28 Westinghouse Plasma

A Westinghouse Plasma Corp. plasma gasifier will convert a wide variety of waste streams into a clean syngas which can be further altered to create other forms of energy.

A plasma gasifier is an oxygen starved vessel where various feedstocks can be gasified using the very high temperatures achievable with plasma. Rather than being combusted, the heat breaks the feedstock down into elements like hydrogen and simple compounds like carbon monoxide and water. The gas that is created is called synthesis gas or “syngas”.

The syngas created in the gasifier, which contains dust (particulates) and other undesirable elements like mercury, undergoes a clean-up process to make it suitable for conversion into other forms of energy including power, heat and liquid fuels. The syngas clean-up process is tailored to meet the requirements of each project. In most cases, especially where municipal solid waste (MSW) is the feedstock, the syngas clean-up will include particulate removal, sulphur removal, and mercury/heavy metals removal.

Plasma gasification differs from non-plasma gasification in one key area – temperature. The temperatures inside a Westinghouse Plasma Corp. gasifier reach over 3000 °C. The higher temperatures inside their plasma gasifier results in the complete destruction of tars. Non plasma gasifiers typically operate between 800 and 900 °C and cannot eliminate tars during operations. As it is very difficult to remove tars downstream of a gasifier, the utility of the syngas produced by non-plasma gasifiers is very limited. Syngas produced by non-plasma gasifiers can be burned immediately to produce power, but it cannot be conditioned for use in gas turbines, reciprocating engines, or for conversion into liquid fuels.

In summary, a Westinghouse Plasma Corp. plasma gasifier enables the conversion of difficult feedstocks like MSW into a clean syngas that is suitable for use in advanced conversion technologies such as high efficiency gas turbines or next generation liquid fuels technologies.

Waste to Liquids

Syngas, created through the gasification of waste, contains the building blocks for the production of liquid fuels such as diesel, jet fuel, ethanol, methanol and propanol.

Coskata, the owner of technology that converts syngas to ethanol completed a successful multi-year demonstration program at Westinghouse Plasma's demonstration center. Westinghouse Plasma Corp created syngas from biomass and municipal solid waste. Coskata converted that syngas to ethanol.

4. Summary

Phase I of this study is to identify and evaluate commercially available technologies. The focus is to provide an evaluation of technologies which can be used to convert locally sourced biomass for installations and forward operating bases (FOBs).

There are many technologies available to convert biomass to renewable fuels and/or energy for installations and forward operating bases.

In the follow on Phase II of this study, the optimal revenue stream will be evaluated for an integrated biofuel crop production in order to facilitate cost effective fuels and biomass production.

Glossary of Terms

Biochar: Biochar is a name for charcoal when it is used for particular purposes, especially as a soil amendment. Like most charcoal, biochar is created by pyrolysis of biomass. Biochar is under investigation as an approach to carbon sequestration to produce negative carbon dioxide emissions.

Biofractination:

Biosolids: Biosolids are the nutrient-rich organic materials resulting from the treatment of sewage sludge (the name for the solid, semisolid or liquid untreated residue generated during the treatment of domestic sewage in a treatment facility). When treated and processed, sewage sludge becomes biosolids, which can be safely recycled and applied as fertilizer to sustainably improve and maintain productive soils and stimulate plant growth.

Carbon Capture: Carbon Capture and Storage (CCS) is a technology that can capture up to 90% of the carbon dioxide (CO2) emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere.

Catalytic Conversion: Catalytic processes are required for the efficient conversion of biomass hydrocarbon components into fuel. The development of such processes and the understanding of the catalytic reactions of biomass molecules have recently attracted considerable and increasing attention.

CONUS: Continental United States

DAF: Dissolved air flotation (DAF) is a water treatment process that clarifies wastewaters (or other waters) by the removal of suspended matter such as oil or solids. The removal is achieved by dissolving air in the water or wastewater under pressure and then releasing the air at atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles which adhere to the suspended matter causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device.

EEG: The German "*Erneuerbare-Energien-Geset"* (Renewable Energy Act or EEG), was first adopted in 2000. Coupled with Germany's decision in 2011 to phase out nuclear energy, the EEG was and continues to be the cornerstone of the country's "*Energiewende"* (energy transition). The *Energiewende*, one of the most ambitious overhauls of energy policy and power generation in German history, aims at increasing renewable energy generation by 80% by 2050, decreasing greenhouse gas emissions by 80% (compared to 1990 levels) in the process, and reducing energy consumption by 50% (compared to 2008). As a result of the feed-in tariff for wind, solar, hydro, geothermal, and biomass included in the original EEG, renewable energy has increased drastically in Germany, reaching up to 29% of net electricity consumption.

EPCC: EPC stands for Engineering, Procurement, Construction and is a prominent form of contracting agreement in the construction industry. The engineering and construction contractor will carry out the detailed engineering design of the project, procure all the equipment and materials necessary, and then construct to deliver a functioning facility or asset to their clients. Companies that deliver EPC Projects are commonly referred to as EPC Contractors.

Fischer-Tropsch: The Fischer–Tropsch process is a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons. It was first developed by Franz Fischer and Hans Tropsch at the "Kaiser-Wilhelm-Institut für Kohlenforschung" in Mülheim an der Ruhr, Germany in 1925. The process, a key component of gas to liquids technology, produces a synthetic lubrication oil and synthetic fuel, typically from coal, natural gas, or biomass. The Fischer–Tropsch process has received intermittent attention as a source of low-sulfur diesel fuel and to address the supply or cost of petroleum-derived hydrocarbons.

Fluidized Bed Gasifier: The Fluid-Bed Gasifier (FBG) converts solid fuels into a syngas consisting mainly of hydrogen and carbon monoxide, which can be further processed to produce a synthetic natural gas or to produce liquid fuels via the Fischer-Tropsch (FT) process. The gasifier is gravity-fed and includes gas cleaning to remove moisture and organics.

FOB: Forward Operating Base.

FOG: The fats, oil and grease (FOG) found in food ingredients such as meat, cooking oil, shortening, butter, margarine, baked goods, sauces and dairy products is a major concern for sewers. When not disposed of properly, FOG builds up in the sewer system constricting flow, which can cause sewer back-ups into homes and overflow discharges onto streets. It can also interfere with sewage treatment processes.

Genset: Generator Sets. A generator set is the combination of an engine with an electric generator (often an alternator) to generate electrical energy. A diesel genset is a specific case of an engine generator. A diesel compression-ignition engine often is designed to run on fuel oil, but some types are adapted for other liquid fuels or natural gas.

HMBCP: Hawaii Military Biofuels Crop program.

ISO 9001: ISO 9001 is one of the standards within the range of ISO 9000 standards. As an ISO 9001 certified organization, they will have implemented quality management system requirements for all areas of the business including: Facilities; People; Training; Services; and Equipment.

Mesophillic Digester: Mesophilic digester or Mesophilic biodigester is a kind of biodigester that operates in temperatures between 20°C and about 40°, typically 37°C. This is the most used kind of biodigester in the world. More than 90% of worldwide biodigesters are of this type. Thermophilic digesters are less than 10% of digesters in the world. Mesophilic digesters are used to produce biogas, biofertilizers, and sanitarization, mainly in tropical countries such as India and Brazil.

MSW: Municipal Solid Waste. MSW, more commonly known as trash or garbage, consists of everyday items we use and then throw away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses.

RDO: Renewable Diesel Fuel Oil. According to the EPA's new RFS, renewable fuels are defined as motor vehicle fuels produced from plant or animal products or wastes. Within this definition, two distinct forms of diesel fuel are specified: biodiesel and renewable diesel. Each is defined according to the process by which it is produced. The term "biodiesel" is often used very broadly to refer to any blend of conventional petroleum diesel with any renewable diesel product. In order to avoid confusion, the term biodiesel should be used in reference to pure biodiesel fuel meeting the ASTM D6571 standard. Mixtures of biodiesel with petroleum should be referred to as biodiesel blends (i.e. B20).

RFS: Renewable Fuel Standard. Under the Clean Air Act (CAA), as amended by the Energy Independence and Security Act (EISA) of 2007, the Environmental Protection Agency (EPA) is required to set the annual standards for the Renewable Fuel Standard program (RFS) for each year. This regulatory action proposes to establish the annual percentage standards for 2014 for cellulosic, biomass-based diesel, advanced biofuel, and total renewable fuels that apply to gasoline and diesel produced or imported in year 2014. EPA is also required to determine the applicable national volume of biomass-based diesel that will be required in 2015, as the statute does not specify the applicable volumes for years after 2012.

RIN: Renewable Identification Number. A Renewable Identification Number, or RIN, is a serial number assigned to a batch of biofuel for the purpose of tracking its production, use, and trading as required by the U.S. EPA's Renewable Fuel Standard (RFS) implemented according to the Energy Policy Act of 2005.

Steam Thermolysis: Steam thermolysis (pyrolysis) is the efficient use of superheated steam to process biomass to produce commercial carbon, liquid pyrolysis fuel, and accompanying fuel gas.

Syngas: Syngas, or synthesis gas, is a fuel gas mixture consisting primarily of hydrogen, carbon monoxide, and very often some carbon dioxide. The name comes from its use as intermediates in creating synthetic natural gas (SNG) and for producing ammonia or methanol.

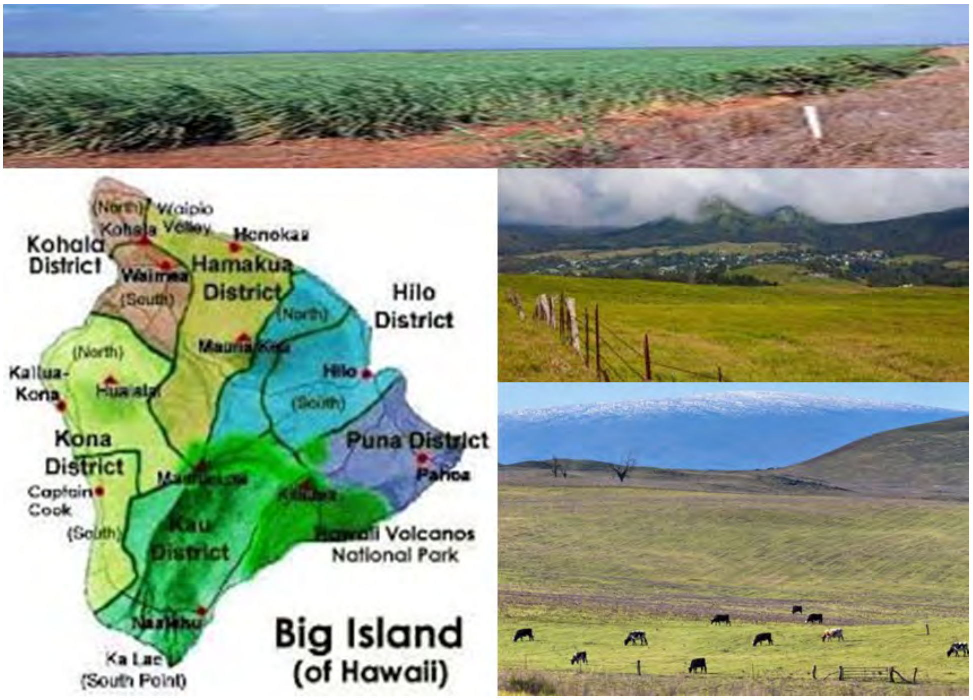
Thermal Depolymerization: Thermal depolymerization (TDP) is a deploymerization process using hydrous pyrolysis for the reduction of complex organic materials (usually waste products of various sorts, often biomass and plastic) into light crude oil. It mimics the natural geological processes thought to be involved in the production of fossil fuels. Under pressure and heat, long chain polymers of hydrogen, oxygen, and carbon decompose into short-chain petroleum hydrocarbons with a maximum length of around 18 carbons.

VOC: Volatile Organic Compounds (VOCs). VOCs are ground-water contaminants of concern because of very large environmental releases, human toxicity, and a tendency for some compounds to persist in and migrate with ground-water to drinking-water supply well. In general, VOCs have high vapor pressures, low-to-medium water solubility, and low molecular weights. Some VOCs may occur naturally in the environment, other compounds occur only as a result of manmade activities, and some compounds have both origins.

WtE: Waste to Energy. Waste-to-energy or energy-from-waste is the process of generating energy in the form of electricity and/or heat from the incineration of waste. WtE is a form of energy recovery.

Hawaii Military Biofuels Crop Program
Hawaii Island

Task 3
Hawaii Jatropha Farm Optimization Report



Prepared For:

Office of Naval Research

Under Sub Award Number MA150004 from:

Hawaii Natural Energy Institute

University of Hawaii

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Rivertop Solutions LLC

PACIFIC BIODIESEL TECHNOLOGIES

Statement of Work Task 3

TABLE OF CONTENTS

6. Introduction

This plan identifies techniques and technologies for enhancing production on the existing underproductive jatropha farm in Keaau, Hawaii.

The 200-acre *Jatropha curcas* test site was planted in 2008 with the goal of producing sustainable fuel crops for local processing and end use. Beginning in October 2012, the mature four-year-old farm received funding as a contracted research entity of Pacific Biodiesel Technologies under the Hawaii Military Biofuels Crop project (HMBC). The farm was maintained under the HMBC funding until the end date of the project, December 31, 2013.

Prior to December 2013, the following establishment, maintenance and harvesting practices were employed:

1. Initial protocol and costs for establishing a jatropha orchard
    - Land clearing

- Row spacing
- Soil Types
- Seedling planting
- Field layout for mechanical harvesting

2. Jatropha specific maintenance routine to minimize costs
    - Pruning
    - Insect control
    - Weed control

3. Jatropha harvest research data
    - Mechanical harvesting
    - Mechanical de-corticating

2. Assessment

Since January 1, 2014, eleven months of inactivity and neglect has resulted in the overgrowth of competitive weed species within the jatropha orchards. The geographic location of the farm is highly conducive to rapid plant growth due to high rainfall, high sunlight and low elevation. Grasses, broadleaf weeds, and aggressive ground covers have engulfed the understory, row breaks, and access roads. In some rows, large weed trees prevent the harvester from passing over the row. Competition for water and nutrients is assumed to have negatively impacted fruit yields. There were no harvests in 2014.

The oldest trees are six years old and within the age of their peak production. In order to conduct further research and harvests, regular weed control measures must be resumed.

To better manage the test plot, the total acreage will be reduced from 200 to 120 acres. This will consolidate the optimum level of acreage to perform commercially viable yield improvement trials while decreasing the amount of maintenance required for ongoing operations.

Current photos of farm:


3. **Action Plan for 2015**
   - Reduce total acreage from 200 to 120 acres
   - Use an additional tractor to mow in and around jatropha fields
   - Apply herbicide between the rows
   - Remove large weed trees (up to 6" diameter)
   - Initiate new experiments aiming to reduce costs and increase yields

4. **Improvement Costs**

Initial costs for the farm improvements are the lease payment for one year as well as lease of the jatropha harvester. Initial field improvement will consist of removal and control of quick growing invasive (weed) trees and overgrown weeds and grasses. The majority of work will be performed mechanically; however there is a significant amount of hand labor required for removal of the large invasive trees.

The improvement costs will consist of:

a) Lease:

b) Equipment:

c) Supplies:

d) Labor:

As maintenance is performed on a 3-acre field of jatropha the following data for labor hours and supplies bill be calculated per task as follows:

	Mowing	Herbacide	Macaranga Removal	**Total cost/acre**
Labor cost/acre	TBD	TBD	TBD	TBD
Materials cost/acre	TBD (Biodiesel)	TBD (Glyphosate)	TBD (Hand Tools)	TBD
Totals	TBD	TBD	TBD	TBD

5. Additional Trials Required

The following additional demonstration trials have been selected as a means to increase jatropha yield and/or decrease the cost of maintenance. Trials are ranked in order of economic advantage, weighing both the cost and the effect.

5.1 Fertilizer

Hypothesis: Use of conventional fertilizer on other plants is well documented, very effective and will provide for quick yield improvement and plant vigor to sustain additional yield improvement trials such as the application of plant growth regulators. From soil sampling at farm, calcium deficiency is noted as being a possible major factor inhibiting optimal jatropha field yield. See Addendum 1 for the soil nutrient data.

Objective: Establish a custom fertilizer regimen optimized for increasing jatropha yield. Baseline yield is set at roughly 1000 pounds of raw jatropha seed per acre, per year, the optimization goal for fertilization is to increase this by 50%.

Method: Test soil for nutrient content in areas known for higher yields and healthier plants and compare to the fields with the worst performing areas. Observe other factors, such as bulk compaction, soil depth, soil type, and drainage. Compare data to other studies on jatropha nutrient demands and optimum soil conditions. Fertilizer trials will occur two months prior to flowering for optimal results.

- Trial 1- Apply dolomite lime at a rate of 500 pounds per acre. This is a one-time application.
- Trial 2- Apply 16-16-16 fertilizer at a rate of 150 pounds per acre. It will consist of three monthly applications, starting two months prior to flowering and continuing one month past flowering.
- Trial 3- This trial will be performed on the same area as trial 1. 16-16-16 will be applied at a rate of 150 pounds per acre. The fertilizer will be applied four months after initial application of calcium, to allow for calcium absorption. This trial will show the effect of calcium on macro-nutrient availability in the soil.

The first trial is scheduled to commence in February. Based on the analysis of the results of these fertilizer trials, locally sourced fertilizers may be selected for improving jatropha growth conditions on underperforming rows. Field trials would confirm the projected efficacy of any selected application.

5.2 Optimal row and tree spacing determination

Hypothesis: Increased spacing between planted jatropha trees will have a positive effect on fruit yield due to increased light for photosynthesis and decreased demand for nutrients and water.

Objective: Compare yields on conventional planting densities at the jatropha farm of 1100 trees per acre (3'x12' row spacing) to yields on fields with planting densities of 75% and 50% of original.

Method:

- Trial 1- Remove trees within the row to increase spacing to a pattern of 12'x 6'.
- Trial 2- Remove an entire row, decreasing planting density by 50% and increasing spacing to 24'x3'.

5.3 Pasture/forage trials

Hypothesis: Use of pasture animals such as goats or cattle will have a twofold positive economic impact on the jatropha operation – grazing will decrease maintenance expenses, and manure generated will fertilize the fields to increase yields. For the purpose of this trial, the value of the animal will not be factored in; however, it is worth noting that a secondary revenue stream could develop with the success of this synergistic trial.

Objective: Compare the effectiveness of employing pasture animals for weed control against conventional techniques of mowing and herbicide.

Method:

- Trial 1- Graze three goats on a fenced acre containing both pasture and jatropha rows. Observe weed reduction/growth, crop damage, animal health, and grazing preferences. Compare cost data to that of conventional upkeep. Maintain animal welfare. Observe weekly and collect data for five months.
- Trial 2- (Contingent on positive results from trial 1). Fence in five acres to employ beef cattle. Perform identical observations and analyses to phase 1.
- Trial 3- (Contingent on positive results from either study). Expand fenced rows to 20 acres to observe improvement in economics and/or yields utilizing the grazing animal of choice.

5.4 Plant growth regulator research

Hypothesis: The plant growth regulator benzylaminopurine (BA), commercially known as "Configure" will have an effect on jatropha yield by increasing the ratio of female to male flowers within the flower inflorescence which will drastically increase fruit production.

Objective: Establish the efficacy of BA application to improve jatropha yield and determine if such an application is economically viable.

Method: Establish control and treated groups consisting of 10 rows each in average performing areas. Apply foliar application of BA to treated groups. BA must be applied at a specific point in the plant's natural flowering cycle. Observe plant flowering, fruiting, foliage, pests, and yield in all groups. Compare added costs of application with changes in yield for economic analysis.

Refer to Addendum 2 for the scientific study supporting this proposed trial.

5.5 Mulch research

Hypothesis: Mulch applied between the rows and at tree edges will decrease general maintenance expenses such as mowing and herbicide via weed suppression and increase soil vitality to sustain greater yields.

Objective: Establish the efficacy and cost of mulching as a means of reducing mowing time and herbicide application.

Method: Apply a 6" layer of mulch in the space between 10 adjacent rows broken into two 5-row blocks and separated by 10 control rows with normal maintenance. Monitor weed growth, jatropha appearance, flowering, and yield weekly for six months or until harvest (three month minimum).

Refer to Addendum 3, Response of *Jatropha curcas* under different spacing to jatropha de-oiled cake, for research supporting this proposed trial.

Addendum 1.

UNIVERSITY OF HAWAII AT MANOA
COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES
AGRICULTURAL DIAGNOSTIC SERVICE CENTER
1910 EAST-WEST ROAD , SHERMAN 134, HONOLULU, HAWAII, 96822
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SOIL ANALYSIS

Client Name:	Richard Ogoshi	RECEIVED:	3/15/12
C/O:	TPSS/SM-CRSP Agriculture Science III, Rm. 206	COMPLETED:	3/20/12
	Honolulu, HI 96822		
Ph:	956-2716	AGENT:	
JCNO:	12-47280		
email:	ogoshi@hawaii.edu		

			<--------------------	µg/g-----	------------------>	
SL No.	Descrip.	pH	P	K	Ca	Mg
12-632	H_2O Defficient	5.6	52	7	559	62
633	H_2O Thriving	5.8	57	18	1771	207

Keeau Twigg Smith Farm

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Addendum 2.

J Plant Growth Regul (2011) 30:166–174
DOI 10.1007/s00344-010-9179-3

Benzyladenine Treatment Significantly Increases the Seed Yield of the Biofuel Plant Jatropha curcas

Bang-Zhen Pan · Zeng-Fu Xu

Received: 18 June 2010/Accepted: 7 September 2010/Published online: 10 October 2010

Abstract Jatropha curcas, a monoecious perennial biofuel shrub belonging to the family Euphorbiaceae, has few female flowers, which is one of the most important reasons for its poor seed yield. This study was undertaken to determine the effects of the plant growth regulator 6-benzyladenine (BA) on floral development and floral sex determination of J. curcas. Exogenous application of BA significantly increased the total number of flowers per inflorescence, reaching a 3.6-fold increase (from 215 to 784) at 160 mg/l of BA. Furthermore, BA treatments induced bisexual flowers, which were not found in control inflorescences, and a substantial increase in the femaleto-male flower ratio. Consequently, a 4.5-fold increase in fruit number and a 3.3-fold increase in final seed yield were observed in inflorescences treated with 160 mg/L of BA, which resulted from the greater number of female flowers and the newly induced bisexual flowers in BA-treated inflorescences. This study indicates that the seed yield of J. curcas can be increased by manipulation of floral development and floral sex expression.

Keywords 6-Benzyladenine Bisexual Cytokinin
Female flowers Physic nut Sex determination

Introduction

Jatropha curcas (hereafter refer as Jatropha) is a perennial deciduous shrub belonging to the family Euphorbiaceae, which probably originated in Central America and is widely distributed in the tropics and subtropics (Fairless 2007; Carels 2009; Makkar and Becker 2009). Jatropha seed content is about 30–40% oil, which is an ideal feedstock for producing biodiesel (Kandpal and Madan 1995; Fairless 2007; Jongschaap and others 2007; Sunil and others 2008). At present, however, seed yield of Jatropha is poor and insufficient for the biodiesel industry (Sanderson 2009; Divakara and others 2010).

As a cross-pollinated shrub, Jatropha is monoecious and produces male and female flowers in the same inflorescence (Heller 1996; Liu and others 2008). Normally, female flowers initiate at the center of inflorescences and are surrounded by a group of male flowers (Jongschaap and others 2007). Occasionally bisexual (hermaphrodite) flowers occur (Dehgan and Webster 1979). Each Jatropha inflorescence is composed of 100–300 flowers and yields approximately 10 or more ovoid fruits (Kumar and Sharma 2008; Rao and others 2008; and this study). One of the most likely reasons for poor yield is that Jatropha has few female flowers resulting from a very low female-to-male flower ratio, which, depending on the genotype, is about 1:29–1:13 (Raju and

Ezradanam 2002; Tewari and others 2007). Thus, increasing the number of female flowers seems critical for the improvement of Jatropha seed yield.

Studies of exogenous applications of various plant growth regulators (PGRs) and analysis of endogenous phytohormones showed that PGRs play important roles in floral development (Krizek and Fletcher 2005; Irish 2009; Santner and others 2009). Exogenous cytokinin (CK) application has been shown to increase inflorescence meristem activity and promote floral initiation in several species (Wang and Li 2008; Werner and Schmulling 2009; Kiba and Sakakibara 2010). Srinivasan and Mullins (1978, 1979) reported that the tendrils of grape (Vitis vinifera) were converted into inflorescences by application of various CKs. Ohkawa (1979) found that 6-benzyladenine (BA, a synthetic compound with CK activity) treatment had a significant influence on increasing flower numbers of Lilium speciosum, particularly when combined with gibberellins A_4 and A_7 ($GA_{4\,?\,7}$). Chen (1991) showed that flower bud differentiation of lychee (Litchi chinensis) was significantly promoted by exogenous kinetin application after bud dormancy. The total number of flowers on jojoba (Simmondsia chinensis) was also significantly increased by treatment with BA (Ravetta and Palzkill 1992; Prat and others 2008). Recently, Li and others (2010) reported that the flower-specific elevation of cytokinin through transgenic expression of an Arabidopsis cytokinin biosynthesis enzyme gene (ATP/ADP isopentenyltransferase 4, AtIPT4) under the control of the APETALA1 (AP1) promoter led to a threefold increase of flowers in the transgenic plants.

PGRs are also important regulators of floral sex determination, which depends on the plant species (Khryanin 2002, 2007; Xiong and others 2009). CK has been shown to have a feminizing effect on a number of plant species (Khryanin 2002, 2007). For example, CK induced bisexual (hermaphroditic) flowers of grape (Vitis vinifera) (Negi and Olmo 1966, 1972) and also female flowers of Luffa acutangula (Bose and Nitsch 1970) and Luffa cylindrical (Takahashi and others 1980).

To find ways to increase the total number and/or the proportion of female flowers of Jatropha, which may result in increased seed yield, we investigated the effects of exogenous applications of 6-benzyladenine (BA) on the flower, fruit, and seed development of Jatropha.

Materials and Methods

Plant Materials and Growth Conditions

One-year-old plants of Jatropha curcas L. were grown in a field with normal fertilization at the Xishuangbanna Tropical Botanical Garden (XTBG, 2154^0 N, 10146^0 E, 580 m in altitude) of the Chinese Academy of Sciences located in Mengla County, Yunnan Province, southwest China. Plants were monocultured at a density of 2.5 9 2.5 m. The annual rainfall, temperature, and relative humidity records at the XTBG were 1493 mm, 21.8C and 85%, respectively. The experiments were carried out from April (when the plants were 1 year old) to November 2009.

6-Benzyladenine (BA) Application

A stock solution (25 mg/ml) of 6-benzyladenine (BA, Bio Basic Inc., Toronto, Ontario, Canada) was prepared by dissolving 1 g of BA in 5 ml of 1 N NaOH and bringing the final volume to 40 ml with distilled water. Tween-20 (Polysorbate-20, Shanghai Sangon Biological Engineering Technology & Services Co., Ltd., China) was added at the final concentration of 0.05% (v/v) as a wetting agent to all BA working solutions. Five milliliters of BA working solutions of various concentrations (80, 160, and 320 mg/l) were sprayed on each inflorescence (about 0.5 cm in diameter) and on surrounding leaves using a hand sprayer. Control inflorescences were sprayed with 5 ml of distilled water containing 0.05% (v/v) Tween-20. Spraying was consecutively conducted three times at 1-day intervals. Thirty inflorescences from 10 plants were used for each treatment.

The total number and number of each sex of flowers per inflorescence, fruits per inflorescence, and seeds per fruit were counted. A female flower was defined as a flower with pistils only, a male flower was defined as a flower with stamens only, bisexual flowers were defined as flowers with both pistils and stamens, and an asexual flower was defined as a flower with neither pistils nor stamens. The fruiting rate (%) was calculated as the number of fruits divided by the number of female and bisexual flowers.

Characterization of Seeds

After being air-dried for 2 months, weight, size, and oil content of seeds from control and BA-treated plants were measured. Seed oil contents were determined by the minispec mq-one Seed Analyzer (Bruker Optik GmbH, Germany). A calibration curve was obtained from reference samples of oil extracted from Jatropha seeds.

Statistical Analysis

Data were analyzed using the Statistical Product and Service Solution version 16.0 software (SPSS Inc, Chicago, IL). Differences among means were determined by oneway ANOVA with Tukey's or Tamhane's post hoc tests. Graphics were generated using SigmaPlot version 10.0) (Systat Software, Inc., Point Richmond, CA).

Results

Effects of BA on Jatropha Flower Development

BA treatment significantly increased the total number of flowers per inflorescence

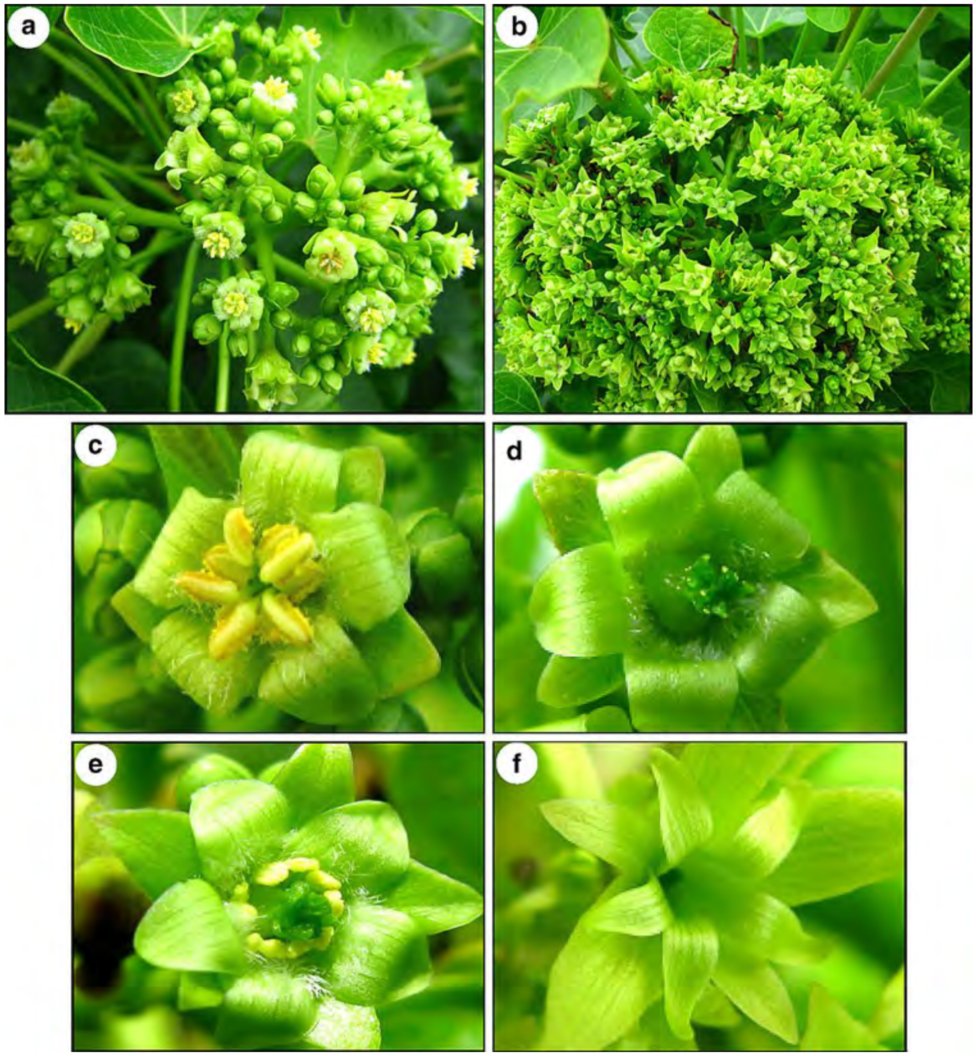


Fig. 1 Effects of BA treatments on flower development and sex expression of Jatropha. a Inflorescence from control plants. b Inflorescence from BA-treated plants. c-f Flowers of different sexual types from BA-treated plants. c Male flower. d Female flower. e Induced bisexual flower. f Induced asexual flower

compared to the control (Fig. 1a, b, 2a). BA treatment at 160 mg/l resulted in a 3.6-fold increase (from 215 to 784) in flowers per inflorescence (Fig. 2a). We found that in addition to the normal male and female flowers found in control inflorescences (Fig. 1c, d), bisexual and asexual flowers were induced in BA-treated inflorescences (Fig. 1e, f). The number and percentage of flowers of different sex types of Jatropha treated with various concentrations of BA are shown in Fig. 2. Up to 3.09% of flowers in inflorescences treated with 320 mg/l of BA were bisexual flowers (Fig. 2b), which were not found in control inflorescences.

Furthermore, interestingly, BA treatments induced a substantial increase in the total number and the proportion of female flowers (Fig. 2). The percentage of female flowers was proportional to the concentration of BA treatment. Female flowers accounted for 29.99% of total flowers in inflorescences treated with 320 mg/l of BA, but only for 6.96% in control inflorescences (Fig. 2b). The female:male ratio was increased from 1:13.4 in control inflorescence to 1:2.4 in inflorescence treated with 320 mg/l of BA (Table 1), resulting in a 4.3-fold increase in percentage of female flowers. The inflorescences treated with 160 mg/l of BA produced the greatest numbers of total flowers (784) and female flowers (156), in contrast to the control inflorescences in which only 15 female flowers were found among a total of 215 flowers (Fig. 2a). Effects of BA on Fruiting and Seed Development

As expected, many more female flowers and newly induced bisexual flowers in BA-treated inflorescences produced more fruits than the control inflorescences (Fig. 3a, b). In comparison with the control inflorescences, a 4.5-fold increase in fruit number (from 13 to 58 per inflorescence) was observed in inflorescences treated with 160 mg/l of BA (Fig. 3c, Table 2). The fruiting rates, however, were decreased in all inflorescences treated with 80–320 mg/l of BA (Fig. 3c). Linear regression analysis revealed a significantly negative correlation between fruiting rate and the number of female and bisexual flowers per inflorescence on

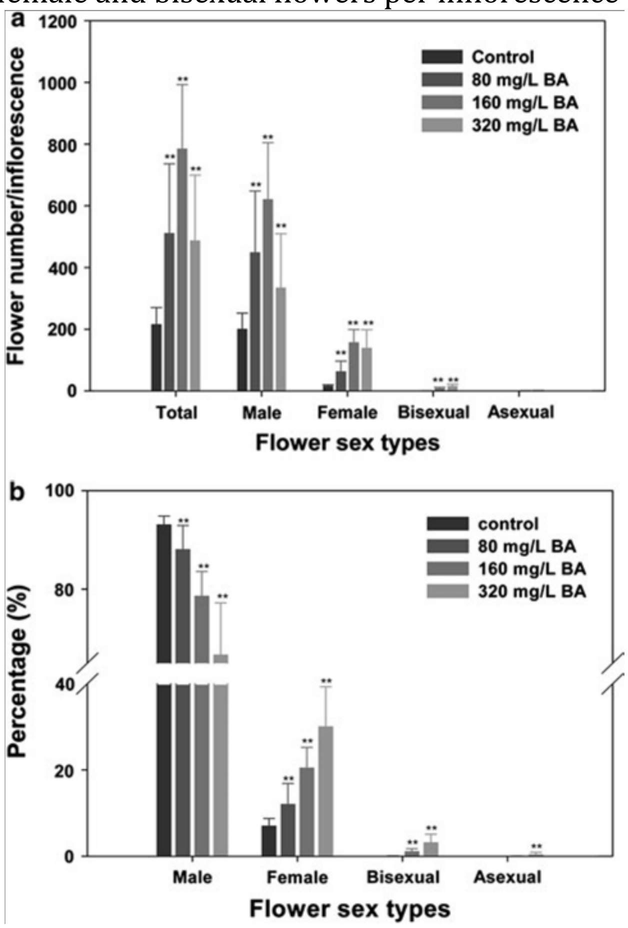


Fig. 2 a Effects of BA treatments on flower number of different sex types per inflorescence. b Effects of BA treatments on percentage of flowers of different sex types. Values are means ± standard deviations (n = 30 inflorescences). ** Statistically significant at the 1% level

Table 1 Effects of BA treatments on flower number and sex ratio in Jatropha

BA treatments	Female	Male	F:M ratio
Control	14.96 ± 4.96	200.11 ± 51.92	1:13.4
80 mg/l	62.26 ± 34.41*	448.04 ± 199.84*	1:7.2
160 mg/l	156.00 ± 43.10*	620.07 ± 184.66*	1:4.0

320 mg/l	138.16 ± 60.56*	333.24 ± 176.34*	1:2.4

Values are mean ± standard deviation (n = 30 inflorescences)

* Statistically different from the control at 1% level

plants treated with BA but not in control plants (Fig. 4), which may be a result of either the limited space in the inflorescence or the shortage of photosynthesis products (Gifford and Evans 1981; Sutherland 1986).

Although a low percentage of fruits contain one to two seeds, we found that most Jatropha fruit contains three seeds (Fig. 5a), in agreement with the fact that Jatropha female flowers usually have a three-locular ovary (Heller 1996; Divakara and others 2010). It is rare to find four-seed fruits in our experimental site under normal growth conditions, although they have been observed in some Mexican genotypes (Makkar and others 2008; Makkar and Becker 2009). The BA-treated inflorescences, however, produced four-seed fruits (Fig. 5b), and the number of four-seed fruits increased with the concentration of BA from 80 to 320 mg/l, reaching 2.0% of total fruits at 320 mg/l (data not shown). Because more one-seed and two-seed fruits were found in BA-treated inflorescences than in the controls, the average seed number per fruit in the BA-treated inflorescences was slightly, but not statistically significantly, less than that of control inflorescences (Table 2).

Although BA treatment produced many more flowers and fruits, seeds from the BA-treated fruits were slightly lighter (Table 2) and smaller (Table 3) than those from control fruits. The final seed yield per inflorescence was increased by 1.8-fold (BA at 80 mg/l) up to 3.3-fold (BA at 160 mg/l) (Table 2). Unexpectedly, the oil content of the seeds significantly increased from 31.7% (control seeds) to 34.8% (BA-treated at 160 mg/l) (Table 2).

Discussion

Floral development and floral sex determination are critical for optimizing seed yields of monoecious plants. Our data presented in this article clearly show that exogenous application of BA significantly promotes floral development and feminizing effects in Jatropha. BA treatment significantly increased seed yield per inflorescence of Jatropha by increasing the total number of flowers and the proportion of female flowers and the induction of bisexual flowers.

Accumulating evidence suggests that the BA-induced increase in the number of flowers may result from the positive role of cytokinin in the regulation of inflorescence meristem activity and size (Werner and Schmulling 2009; Kiba and Sakakibara 2010). Werner and others (2001, 2003) found that CK-deficient transgenic tobacco and Arabidopsis plants overexpressing Arabidopsis CK oxidase/dehydrogenase (AtCKX, an enzyme-degrading CK) genes developed a reduced number of flowers on each single inflorescence. Consistently, Ashikari and others (2005) found that a quantitative trait locus (QTL) controlling grain number in rice, Gn1a, is a gene for CK oxidase/dehydrogenase (OsCKX2). Reduced expression of OsCKX2 resulted from natural mutations or antisense inhibition of OsCKX2, caused CK accumulation in inflorescence meristems, and increased grain number per plant, whereas transgenic plants overexpressing OsCKX2 showed reduced grain numbers compared to control plants

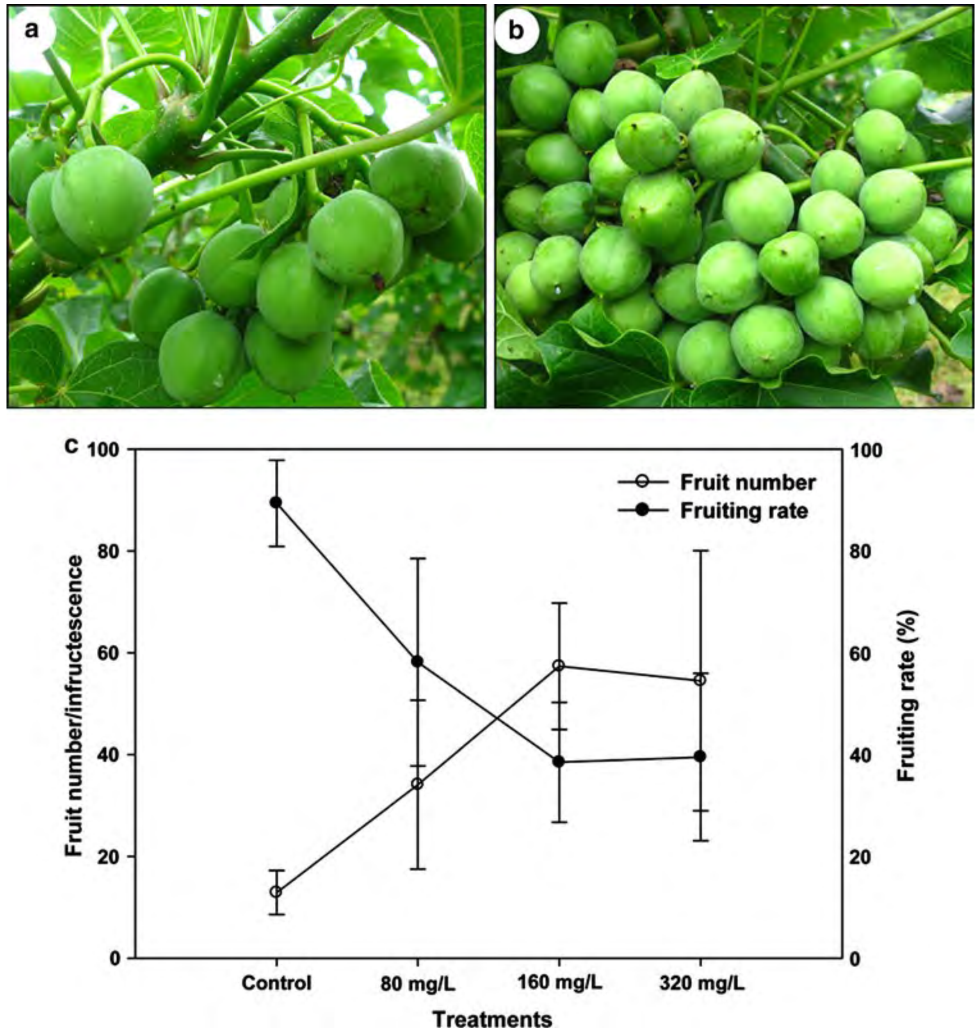


Fig. 3 a Infructescence from control plants. b Infructescence from BA-treated plants. c Effects of BA treatments on fruit number per infructescence and fruiting rate. Values are means ± standard deviations (n = 30 infructescence). Fruit number and fruiting rate of all treatments were statistically different from the control at the 1% level

Table 2 Effects of BA treatments on fruit and seed characteristics and oil content of Jatropha

BA treatments	Fruits/infructescence	Seeds/fruit	Weight/seed (g)	Seed yield/infructescence (g)	Oil content (%)
Control	12.92 ± 4.33	2.42 ± 0.38	0.77 ± 0.08	24.10 ± 10.14	31.67 ± 2.92
80 mg/l	32.88 ± 17.15**	2.25 ± 0.34	0.64 ± 0.10**	43.22 ± 23.82*	32.51 ± 3.09
160 mg/l	58.04 ± 12.09**	2.34 ± 0.99	0.64 ± 0.03**	78.58 ± 16.41**	34.76 ± 1.46**
320 mg/l	54.04 ± 25.94**	2.04 ± 0.44	0.67 ± 0.06**	68.23 ± 35.44**	32.13 ± 2.54

Values are mean ± standard deviation (n = 30 inflorescences)

* Statistically different from the control at 5% level

** Statistically different from the control at 1% level

(Ashikari and others 2005). On the other hand, a loss-offunction mutation of the rice LONELY GUY (LOG) gene encoding a CK-activating enzyme that works in the final step of bioactive cytokinin synthesis resulted in a significant decrease in floral organ numbers (Kurakawa and others 2007). Also, Li and others (2010) reported that transgenic expression of an Arabidopsis CK biosynthetic enzyme gene (AtIPT4) led to an increase in the number of flowers, which was correlated with enlarged inflorescences and flower meristems.

Another interesting observation in the present study was that the exogenous application of BA resulted in the induction of bisexual flowers and a significantly increased proportion of female flowers of Jatropha. This result is in line with the

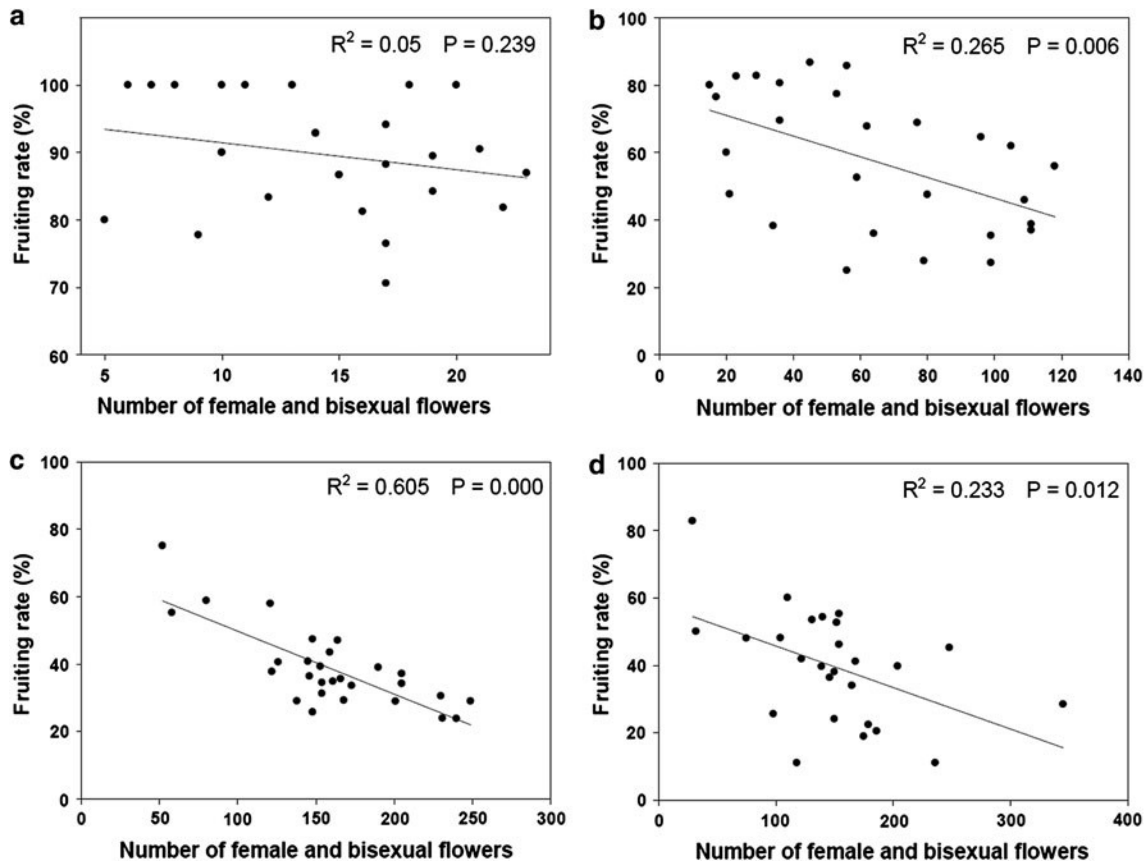


Fig. 4 Linear regression of fruiting rate versus the number of female and bisexual flowers per inflorescence of Jatropha. a Control. b BA treatment at 80 mg/l. c BA treatment at 160 mg/l. d BA treatment at 320 mg/l

previous observations in other plant species. Negi and Olmo (1966, 1972) showed that application of a synthetic cytokinin [6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine, PBA] to flower clusters of a male grapevine completely converted the flower sex from male to bisexual (hermaphrodite). Takahashi and others (1980) found that direct application of BA to the staminate inflorescence induced bisexual and pistillate flowers in Luffa cylindrica. In addition, BA was also found to promote the formation of female flowers in Momordica charantia (Ghosh and Basu 1982) and to induce the lateral female and bisexual strobili in the lower part of new shoots of Japanese red pine (Wakushima and others 1996).

Sex determination in unisexual flowers is a complicated process that is achieved by selectively arresting or aborting pistil or stamen development within a bisexual floral meristem (Lebel-Hardenack and Grant 1997; Tanurdzic and Banks 2004; Irish 2005;

Liu and others 2008). A number of studies have shown that phytohormones play a pivotal role in the process of the selective arrest or abortion of pistils or stamens in female and male flowers, respectively (Khryanin 2002; Irish 2009; Santner and others 2009). The availability of GAs plays an essential role in the expression of feminizing An1 (Anther earl) and D (Dwarf) genes in maize flowers (Dellaporta and Calderon-Urrea 1994; Irish 2005). In cucumber, ethylene is the key hormone involved in sex determination (Yamasaki and others 2003; Wang and others 2010). The expression of two genes, CS-ACS1 and CS-ACS2, encoding the ethylene biosynthetic enzymes (1-aminocyclopropane-1-carboxylic acid synthase), correlated with sexual phenotypes (Trebitsh and others 1997; Yamasaki and others 2001). Recently, Martin and others (2009) proposed an integrated model of sex determination in melon plants in which the andromonoecious gene CmACS-7, encoding an ethylene biosynthesis enzyme (Boualem and others 2008), and the gynoecious gene CmWIP1, encoding a zinc-finger transcription factor, interact to control the development of male, female, and hermaphrodite flowers. The expression of the pistil repressor CmWIP1 causes the arrest of carpel development and the repression of the expression of the stamen repressor CmACS-7, leading to the formation of male flowers. The inactivation of CmWIP1 by promoter hypermethylation, which also indirectly leads to the

Table 3 Effects of BA treatments on seed size of Jatropha

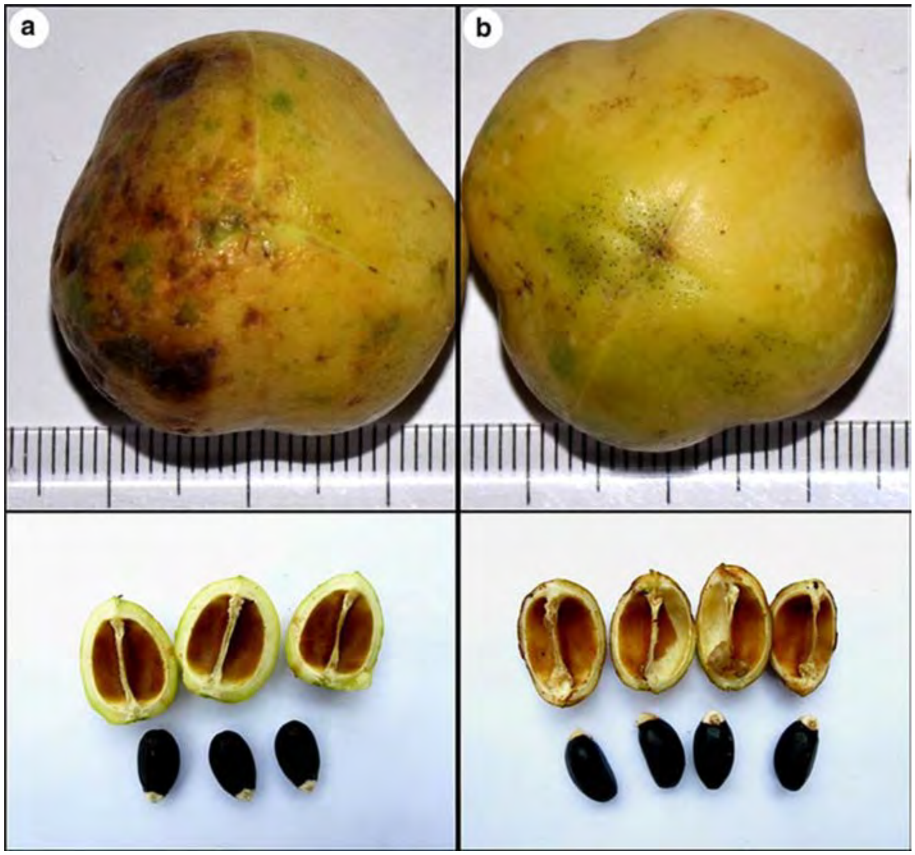
BA treatment	Width (mm)	Height (mm)	Length (mm)
Control	8.83 ± 0.18	11.19 ± 0.22	18.80 ± 0.35
80 mg/l	8.59 ± 0.46*	10.85 ± 0.34**	17.54 ± 0.78**
160 mg/l	8.43 ± 0.20**	10.80 ± 0.19**	17.07 ± 0.58**
320 mg/l	8.79 ± 0.38	10.95 ± 0.25**	17.61 ± 0.47**

Nine hundred seeds of each treatment were analyzed in the experiment. Values are mean ± standard deviation * Statistically different from the control at 5% level

** Statistically different from the control at 1% level

activation of CmACS-7, permits the development of female flowers. Hermaphrodite flowers resulted from CmWIP1 repression and the presence of a nonfunctional CmACS-7 gene (Boualem and others 2008; Martin and others 2009). These results demonstrated that genes encoding metabolic enzymes for different phytohormones and the related transcription factors play important roles in the sex determination of various plant species.

In contrast to a 3.3-fold increase in seed yield of Jatropha by BA treatment at 160 mg/l in this study (Table 2), the higher concentration of BA at 3–12 mM (equivalent to 676–2703 mg/l) was not much more effective compared to the untreated control (Abdelgadir and others 2009, 2010). These results suggest the critical importance of the concentration of BA in the improvement of seed yield of Jatropha. Because the significant effects of BA treatments on seed yield of Jatropha reported here were at the level of inflorescences, and the effects may not be significant due to the possible autoregulation of the allocation of photosynthetic products at the levels of trees and/or hectares, we are currently investigating the effectiveness of BA treatments at these levels. Preliminary data showed that there was more than a threefold increase in seed yield per Jatropha tree (data not shown). Further studies are necessary to provide direct evidence of the important roles for endogenous CKs in the floral development and sex determination of Jatropha, based on which genes encoding key enzymes in CK metabolism (Zhao 2008; Werner and Schmulling 2009; Kudo and others 2010) in Jatropha could be cloned and used for metabolic engineering of CK in Jatropha inflorescence meristem (Ma 2008; Kiba and Sakakibara 2010). Recently, Ghosh and others (2010) also found an unexpected 5- to 11-fold increase in Jatropha seed yield in the year following a soil application of paclobutrazol, a biosynthesis inhibitor of the plant hormone gibberellin. These studies indicate great potential for improvement in Jatropha seed yield by the application of plant growth regulators, and further genetic improvements through traditional breeding techniques and molecular approaches may be possible (Divakara and others 2010). In addition, other PGRs may also be explored to induce synchronous flowering and fruit maturation (Luckwill 1977; Bonnetmasimbert and Zaerr 1987; Santner and others 2009), which may facilitate mechanical harvesting of Jatropha fruits (Carels 2009; King and others 2009).



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Addendum 3.

Response of *Jatropha* curcas under different spacing to Jatropha de-oiled cake

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Abstract

This work tested the response of *Jatropha curcas* plants to jatropha cake used as organic manure. Experiments, carried out with different levels of Jatropha deoiled cake, were conducted at Mohuda located in the sub-humid part of Orissa state in India. Five levels of treatments comprising four different levels of Jatropha cake (0.75, 1.5, 2.25 and 3 tonnes ha^{-1}) and one control plot were applied to jatropha plants under two different spacings (4m x 3m and 3m x 2m). Jatropha cake significantly increased the seed yield of *Jatropha curcas* with increasing level of cake up to the maximum level of 3 t ha^{-1} under both the spacings. The treatment receiving 3 tonnes ha^{-1} recorded the highest per plant seed yield of 1.52 kg and 0.87 kg in 4m x 3m and 3m x 2m spacings, respectively. The increase in yield obtained with the highest level of cake was 120% over control in the treatment with 833 plants per hectare, while corresponding increase for 1667 plants per hectare treatment was 93%.

Applicable subject: Agronomy: Jatropha Soil Conditions/Fertilization

Full Title: Response of *Jatropha curcas* under different spacing to jatropha deoiled cake

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Purpose of the work

The past work done on nutrient management by CSMCRI, Bhavnagar revealed that using only chemical fertilizers as a nutrient source has limitations in cultivation of Jatropha in regions of high rainfall. This is due to the fact that nitrogenous and potassic fertilizers like urea and MOP are prone to leaching losses in very short span of time, especially during rainy seasons, because of high solubility of such fertilizers in water. Organic manures have the property of reducing such losses and also can give sustained supply of nutrients over a period of time. This is of great significance given the fact fruiting of *Jatropha curcas* is staggered over a long period. Jatropha cake is one such organic manure that is rich in plant essential nutrients. Our study revealed that it contains 3-4.5% N, 0.65-1.2% P_2O_5, 0.8-1.4% K_2O, 0.2-0.35% S. Micronutrients ranged 800-1000, 300-500, 30-50 and 18-25 mg kg^{-1} of Fe, Mn, Zn and Cu, respectively. Moreover, as the biodiesel programme reaches its maturity, a lot of jatropha cake will be produced as a byproduct after oil expulsion, which can find its way back into the soil as manure, rather than transporting it for some other purpose. Till date, there has been no systematic research that looks into nutrient requirement of jatropha plants from holistic angle. Thus effort was done to evaluate the effect of Jatropha cake on seed productivity of *Jatropha curcas*.

Approach

The experiments are being conducted on cultivable wasteland at Mohuda in the Orissa state of India. The climate is sub-humid receiving high rainfall during rainy months. The soil was sandy loam and non saline with pH 7.2, 05% organic carbon and the available N,
P and K were 140.2, 17.5 and 458 kg ha^{-1}, respectively. Experiments were laid out in randomized block design with five levels (0, 0.75, 1.5, 2.25 and 3 tonnes Jatropha cake ha^{-1}) and separately applied to two differently spaced jatropha population. Each treatment was replicated four times. Jatropha cake was applied as per the treatments in the month of June during the years 2005 and 2006. The plants under 4m x 3m spacing were aged 2.5 years, while they aged 2 years under 3m x 2m spacing, when first jatropha cake treatments were applied. No other chemical fertilizer was applied to the plants except Jatropha cake during 2005 and 2006. The Jatropha cake contained 3.2% N, 1.2% P_2O_5 and 1.4% K_2O. The plants received inorganic fertilizers @ 45:30:20 N: P_2O_5:K_2O ha^{-1} yr^{-1} prior to the start of cake experiment. The seeds were collected during May to December and observations were treated by analysis of variance and Duncan's Multiple Range Test using MSTAT software program.

Scientific innovation and relevance: The encouraging results of this research has fostered the use of jatropha cake as a nutrient rich manure in jatropha plantation itself by ploughing it back into the soil. This will help to increase productivity of *Jatropha curcas* on wasteland, and probably should also improve the soil fertility.

Results

Seed yield

The seed yield of jatropha was significantly influenced by different levels jatropha cake. (Table 1). The seed yield increased significantly with increasing dose of cake up to the maximum level of 3 tonnes per hectare. Maximum seed yield per plant of 1.52 kg and 0.87 kg per plant were obtained by application 3 t ha^{-1} under 4m x 3m and 3m x 2m spacing, respectively. In 4m x 3m spacing, maximum seed yield was followed by that (1.31, 1.05 and 0.78 kg plant^{-1}) obtained under 2.25, 1.5 and 0.75 t ha^{-1} treatments, respectively. Similarly under 3m x 2m spacing, 0.75, 0.63, 0.52 kg plant^{-1} were obtained by application of cake @ 2.25, 1.5 and 0.75 t ha^{-1}, respectively. Minimum seed yield (0.69 kg plant^{-1} under 4m x 3m spacing and 0.45 kg plant^{-1} under 3m x 2m spacing) was obtained under control treatment where fertilization was not done during the two years of the present study. Although the 3m x 2m spaced plants were 6 months younger than 4m x 3m spaced ones, the magnitude of yield difference between these two spacings clearly indicate that widely spaced plants tend to give more seed yield per plant. However, when calculated on per hectare basis, the maximum seed yield (1.45 t/ha) was obtained from 3m x 2m spaced population having 1667 plants per hectare by application of 3 t ha^{-1} cake which was 93% and 16% higher over control and next best yields obtained under the same spacing. The application of highest dose of cake brought about more than double increase (120%) in seed yield in plants spaced 4m x 2m.

Table 1 Effect of jatropha cake on Jatropha curcas planted under different spacing

Treatment (Jatropha cake)	Seed yield (Kg/plant)	
	4m x 3m spacing	3m x 2m spacing
Control (No cake)	0.69 d	0.45 e
0.75 t/ha	0.78 d (13)	0.52 d (16)
1.5 t/ha	1.05 c (52)	0.63 c (40)
2.25t/ha	1.31 b (90)	0.75 b (67)
3.0 t/ha	1.52 a (120)	0.87 a (93)
S.Em (±)	0.05	0.02
CV%	6.02	8.69

* S.Em- Standard error of mean; **CV- Coefficient of variation

The means of N and P levels followed by different letters differ significantly at $P<0.05$

Figures in parenthesis indicate per cent increase over control treatment.

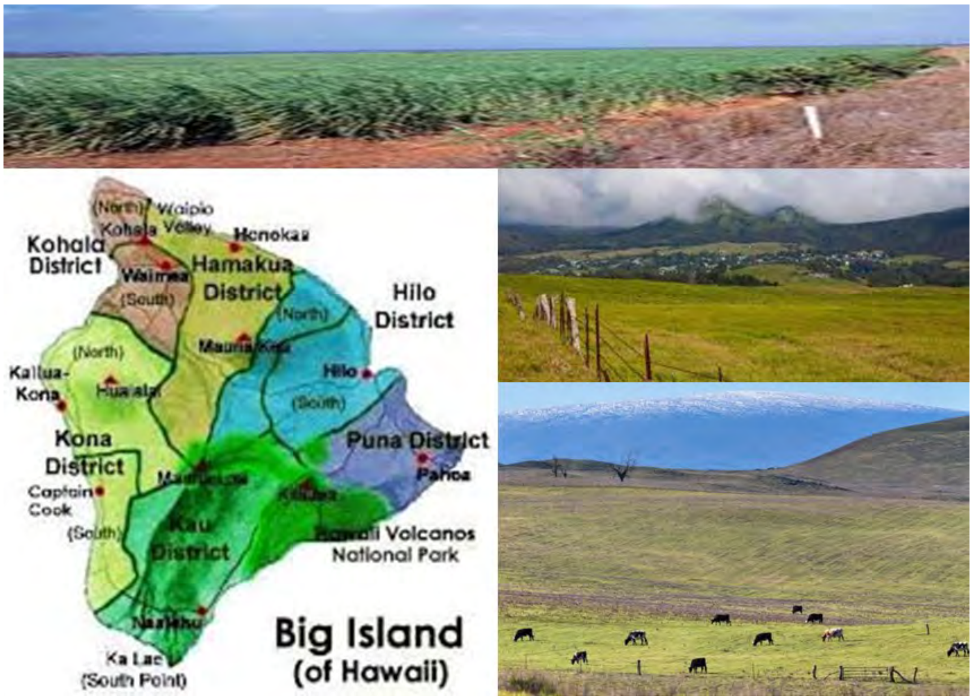
Conclusions

The results of the experiment have shown that fertilization to jatropha plantation with jatropha cake was very effective in improving yield significantly and not fertilizing it at all was detrimental. Response was obtained up to the maximum level of Jatropha cake indicating that jatropha plant responds tremendously to fertilization. 3 tonnes of Jatropha cake per hectare per year proved beneficial for maximization of seed productivity under sub-humid climate in cultivable wastelands of Orissa. It is expected that as the plant grows in future, it being a perennial species, the fertilizer requirement will change necessitating long term manurial trial study.

Acknowledgements We thank DaimlerChrysler, and DEG, Germany, CSIR, New Delhi, for financial support. We also thank Dr. P.K. Ghosh, Director, CSMCRI, Bhavnagar for continuous suggestion and support. Acknowledgement also goes to Mr. P. N. Rao and A. K. Saha for the technical support provided.

Hawaii Military Biofuels Crop Program
Hawaii Island

Task 4
Economic Analysis Outline



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PACIFIC BIODIESEL TECHNOLOGIES

TABLE OF CONTENTS

Foreword

The purpose of this techno-economic analysis is to compare a set of biofuel conversion technologies selected for their promise and near-term technical viability. Every effort has been made to make this comparison on an equivalent basis using common assumptions. The process design and parameter value choices underlying this analysis are based on public domain literature only. For these reasons, these results are not indicative of potential performance, but are meant to represent the most likely performance given the current state of public knowledge.

List of Acronyms

BTL	biomass to liquids
CFB	circulating fluidized bed
DCFROR	discounted cash flow rate of return
DME	dimethyl-ether
FCI	fixed capital investment
FT	Fischer-Tropsch
GGE	gallon of gasoline equivalent
HRSG	heat recovery steam generator
HT	high temperature
IC	indirect costs
IGCC	integrated gasification combined cycle
IRR	internal rate of return
LT	low temperature
MM	million
MTG	methanol to gasoline
MW	megawatt
Nm^3	normal cubic meter
PSA	pressure swing adsorption
PV	product value
SPR	slurry phase reactor
SMR	steam methane reforming
TCI	total capital investment
TDIC	total direct and indirect cost
TIC	total installed cost
tpd	tons per day
TPEC	total purchased equipment cost

1. Introduction

1.1 Overview

Provides an overview of the existing biofuels industry nationally, as well as the Department of the Navy's interest and current program.

1.2 Objectives and Approach

Based on Department of the Navy provided information. Includes the target economic objective of creating fuels that are competitively priced with petroleum, but which are locally produced and have stable costing.

1.3 Technology Types

This section of the analysis is a short discussion of the technologies that are currently commercially viable, and which can meet the milspecs. This section will draw on the technology study.

1.4 Projected Revenue Streams

Provides a description of each expected revenue stream to include:

- *Distilled Biodiesel*
- *Aviation Biofuel*
- *Marine Biodiesel*
- *Livestock Feed*
- *Sunflower Cooking Oil in size variety*

1.5 Estimated DoD Pre-Requisites

Navy provided description of economic pre-requisites

1.6 Fuels and Value Added

Describes the costs of the competing fuels and value added products to provide a comparison.

1.7 Assumptions

Comprehensive listing of all assumptions made in the analysis and the business plan

2. Methodology

2.1 Economic Model Types

An economic model is a simplified description of reality, designed to yield hypotheses about economic behavior that can be tested. An important feature of an economic model is that it is necessarily subjective in design because there are no objective measures of economic outcomes. Different economists will make different judgments about what is needed to explain their interpretations of reality.

There are two broad classes of economic models—theoretical and empirical. Theoretical models seek to derive verifiable implications about economic behavior under the assumption that agents maximize specific objectives subject to constraints that are well defined in the model (for example, an agent's budget). They provide qualitative answers to specific questions—such as the implications of asymmetric information (when one side to a transaction knows more than the other) or how best to handle market failures.

In contrast, empirical models aim to verify the qualitative predictions of theoretical models and convert these predictions to precise, numerical outcomes. For example, a theoretical model of an agent's consumption behavior would generally suggest a positive relationship between expenditure and income. The empirical adaptation of the theoretical model would attempt to assign a numerical value to the average amount expenditure increases when income increases.

For both the broad categories there a numerous specific models. For purposes of the analysis all the evaluated approaches will include a sensitivity analysis for a restricted set of variables.

2.2 Down-Selection Process

Provides a description of the rationale and process for arriving at the final economic model.

2.3 Preliminary Criteria

Describes the criteria for measuring the results. These will include, but not be limited to:

- *Variable effects of price*
- *Ability to compete in each market*

- *Sensitivity to petroleum pricing*
- *Production volumes*
- *Job Creation*
- *Need for imported inputs*

2.4 Scenario Development

The scenarios will be used to test the model under a variety of conditions. This will include:

- *Petroleum at $50/barrel*
- *Petroleum at $80/barrel*
- *Petroleum at $100/barrel*
- *High rain seasons*
- *Low rain seasons*
- *Hawaii isolated due to man-made or natural events*

3. Current Industry Numbers

Will provide numbers sourced from the Department of the Navy, Energy Information Administration, US Department of Agriculture, Hawaii Department of Business, Economic Development and Tourism, and industry sources. Numbers will be most up to date available at the time of publishing.

EXAMPLE Below

U.S. consumption of biofuels grows but does not approach EISA2007 applicable volumes

Consumption of biofuels grows in the AEO2014 Reference case but falls well short of the Energy Independence and Security Act of 2007 (EISA2007) RFS target [13] of 36 billion ethanol gallon equivalents in 2022 (Figure MT-56), largely because of a decline in gasoline consumption as a result of newly enacted corporate average fuel economy (CAFE) standards and updated expectations for sales of vehicles capable of using E85. Demand for motor gasoline ethanol blends (E10 and E15) falls from 8.7 MMbbl/d in 2012 to 7.9 MMbbl/d in 2022, while total biofuels consumption rises from 14 billion gallons to 16 billion ethanol gallons equivalent over the same period.

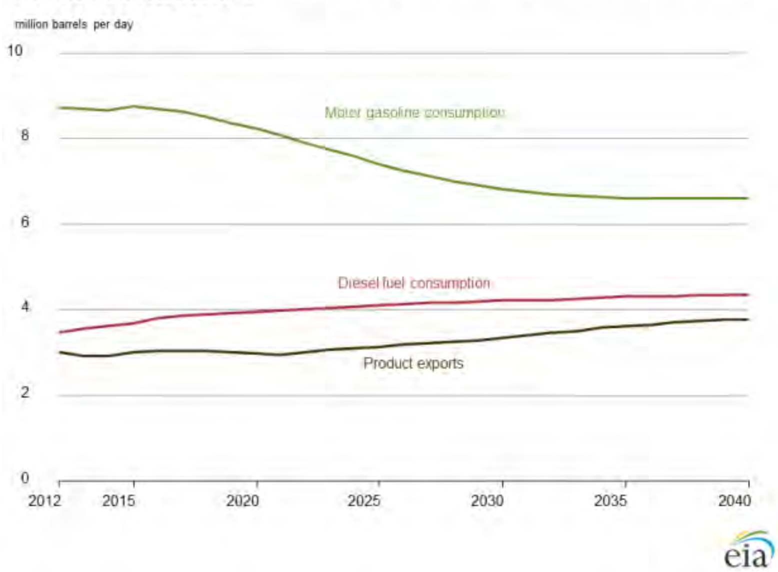


Figure MT-57. Motor gasoline consumption, diesel fuel consumption, and petroleum product exports in the Reference case, 2012-40

4. Economics Analysis

4.1 Feedstock

This section will evaluate the costs associated with the feedstock, as well as look at alternative supply sources as risk mitigation.

4.2 Fuels Markets

Description of the local and federal fuel markets across the entire range of potential refinement options. The market analysis will include direct to public sales from corporate owned and operated stations.

4.3 Livestock Feed Markets

Hawaii livestock feed markets are competing against very high cost imports, which have forced many ranchers out of business. This section will include estimates from the Hawaii Department of Agriculture regarding potential increases in the ranching industry, and consequently increases in demand for the feed, that may result from the lower cost feeds.

4.4 Cooking Oil Markets

Cooking oil is a risk mitigation, and revenue offset market for a portion of the sunflower oil production. The market is both local and export. The section will include descriptions of both bulk and branded oils in containers ranging from 5 gallons to 8 ounces. The section will also consider large scale commodities contracts.

4.5 Operating Expenses

Projected operating costs at low, moderate and full capacity.

4.6 Capital Costs

Will include an assessment of potential capital requirements for differing options for the silage based fuel production, as well as centralized vs distributed operations.

4.7 Anticipated Petroleum Prices

Will present both industry and government price projections current as of the submission of the report. Example Below:

- **Oil prices rebounded from near six-year lows touched in January as market participants took stock of declines in US rig counts and relatively positive US economic data.** At the time of writing, ICE Brent was trading at $58.25/bbl - roughly 50% below its June 2014 peak. NYMEX WTI was at $52.55/bbl.
- **Global supplies fell by 235 kb/d in January to 94.1 mb/d on lower OPEC and non-OPEC production.** Reductions in capital expenditures have cut projected 2015 non-OPEC supply growth to 800 kb/d. US 2015 production is seen 200 kb/d lower than in last month's *Report,* at an average 12.4 mb/d, with most of the cuts in 2H15.
- **OPEC crude oil output fell by 240 kb/d in January to 30.31 mb/d, led by losses from Iraq and Libya.** Output from Saudi Arabia, Kuwait, Angola and Nigeria edged up. Downward revisions to the non-OPEC supply growth forecast for 2H15 have raised the 'call' on OPEC to an average 30.2 mb/d - just above the group's official target of 30 mb/d.
- **The forecast of global oil demand growth for 2015 is unchanged from last month's *Report*, at 0.9 mb/d, bringing average demand for the year to 93.4 mb/d.**Growth is expected to gain momentum from a modest 0.6 mb/d gain in 2014, on a slightly improved macroeconomic outlook.
- **OECD industry stocks slipped by 5.3 mb in December, roughly one tenth of the five-year average draw for the month**. Consequently, inventories' surplus to average levels ballooned to 65 mb from 16 mb in November, its widest since October 2010. Preliminary data point to a seasonal 22.7 mb stock build in January.
- **Global refinery crude throughputs rose by 1.1 mb/d in December, to 79.1 mb/d,**before maintenance curbed activity in January. An unexpected dip in Saudi Arabian runs in November underpins a 140 kb/d downward revision to last month's assessment of 4Q14 runs, to 78.1 mb/d. Throughputs are projected to fall to 77.6 mb/d in 1Q15.

4.8 Anticipated Livestock Feed Prices

Information will be gathered both in regards to existing market costs as well assessments of the potential market size and demand at prices points below existing market prices. This lower price points will be evaluated with respect to impact on livestock industry.

4.9 Anticipated Cooking Oil Prices

Focus will be placed on gathering market information from big box retailers and specialty food stores in Hawaii. The export market will be based on competitive prices in California, Oregon, Washington State and Japan.

5. Sensitivity Analysis

5.1 Sensitivity Variables

The variables developed for the analysis will be designed to stress the model to identify any risks to the long term operations. To accomplish this, variables will consider the following:

- *the contribution of an factor to the overall revenue ,*
- *minimize the risk of failure*
- *identify key constraints (e.g. the maximum availability of a resource),*
- *the number of constraints*
- *likelihood of occurrence*
- *weather factors*

5.2 Sensitivity Assessment

There are two methodological approaches to sensitivity analysis: a deterministic and a stochastic approach. Deterministic sensitivity analysis assumes that the tuple of basic parameters is an element of a given subset of all possible parameter choices. It seeks to determine upper and lower bounds on the corresponding subset of economic outcomes of the model. Stochastic sensitivity analysis treats the vector of parameters as a stochastic variable with a given distribution, rendering economic equilibria of the model into stochastic variables. It aims at calculating the first moments of these variables, with the variance indicating the robustness of the results.

6. Conclusions

Section will present conclusions along with rationales

7. Initial Business Model Example

Financial Highlights by Year

Hawaii Military Biofuels Crop Program
Economic Analysis Outline

Products and Services

Hawaii Military Biofuels Crop Program
Economic Analysis Outline

Target Market

Hawaii Military Biofuels Crop Program
Economic Analysis Outline

Revenue Forecast

	FY2017	FY2018	FY2019	FY2020	FY2021
Revenue					
Bulk Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Bottled Sunflower Oil (16 oz)	$0	$0	$0	$0	$0
Bottle Sunflower Oil (8 oz)	$0	$0	$0	$0	$0
Biodiesel from Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Biofuel from Used Cooking Oil (Gal)	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0
Biofuel from Silage (Gal)	$0	$0	$0	$0	$0
Total Revenue	$0	$0	$0	$0	$0
Direct Cost					
Bulk Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Bottled Sunflower Oil (16 oz)	$0	$0	$0	$0	$0
Bottle Sunflower Oil (8 oz)	$0	$0	$0	$0	$0
Biodiesel from Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Biofuel from Used Cooking Oil (Gal)	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0
Biofuel from Silage (Gal)	$0	$0	$0	$0	$0
Total Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$0
Gross Margin %	0%	0%	0%	0%	0%

Revenue by Month

Personnel Table

	FY2017	FY2018	FY2019	FY2020	FY2021
CEO	$0	$0	$0	$0	$0
President	$0	$0	$0	$0	$0
Chief Operating Officer	$0	$0	$0	$0	$0
Chief Marketing Officer	$0	$0	$0	$0	$0
Director of Technology	$0	$0	$0	$0	$0
Chief Financial Officer	$0	$0	$0	$0	$0
Director of Sustainable Programs	$0	$0	$0	$0	$0
Director of Construction	$0	$0	$0	$0	$0
Director of Agriculture	$0	$0	$0	$0	$0
Agriculture Foreman	$0	$0	$0	$0	$0
Agriculture Worker (x26)	$0	$0	$0	$0	$0
Pellitizer Operator (x3)	$0	$0	$0	$0	$0
Heavy Equipment Operator (x2)	$0	$0	$0	$0	$0
Land Maintenance Worker (x4)	$0	$0	$0	$0	$0
Water System Manager	$0	$0	$0	$0	$0
Water System Maintenance	$0	$0	$0	$0	$0
Processing Foreman	$0	$0	$0	$0	$0
Processing Plant Operator (x4)	$0	$0	$0	$0	$0
Livestock Feed Operator	$0	$0	$0	$0	$0
Agro-Forestry Manager	$0	$0	$0	$0	$0
Forestry Specialist	$0	$0	$0	$0	$0
Biodiesel Plant Manager	$0	$0	$0	$0	$0

Biodiesel Plant Operators (x25)	$0	$0	$0	$0	$0
Chemist (x2)	$0	$0	$0	$0	$0
Silage Biofuels Plant Manager	$0	$0	$0	$0	$0
Silage Biofuels Plant Operator (x25)	$0	$0	$0	$0	$0
Sunflower Oil Bottling Plant Operator (x2)	$0	$0	$0	$0	$0
Transportation Specialist (x3)	$0	$0	$0	$0	$0
Officer Manager (x3)	$0	$0	$0	$0	$0
Administrative Staff (x3)	$0	$0	$0	$0	$0
Sales / Bookkeeping (x3)	$0	$0	$0	$0	$0
Total	$0	$0	$0	$0	$0

Hawaii Military Biofuels Crop Program
Economic Analysis Outline

Budget Table

	FY2017	FY2018	FY2019	FY2020	FY2021
Operating Expenses					
Salary	$0	$0	$0	$0	$0
Employee Related Expenses	$0	$0	$0	$0	$0
Marketing & Promotions	$0	$0	$0	$0	$0
Rent	$0	$0	$0	$0	$0
Utilities / energy	$0	$0	$0	$0	$0
Office Supplies	$0	$0	$0	$0	$0
Insurance	$0	$0	$0	$0	$0
Bottling Supplies	$0	$0	$0	$0	$0
Uniforms / Laundry	$0	$0	$0	$0	$0
Total Operating Expenses	$0	$0	$0	$0	$0
Major Purchases					
Water Systems	$0	$0	$0	$0	$0
Land Preparation Equipment	$0	$0	$0	$0	$0
Planting and Harvest Equipment	$0	$0	$0	$0	$0
Crushing Mill	$0	$0	$0	$0	$0
Pelletizing Plant	$0	$0	$0	$0	$0
Sunflower Bottling Plant	$0	$0	$0	$0	$0
Livestock Feed Plant	$0	$0	$0	$0	$0
Transportation Equipment	$0	$0	$0	$0	$0
Land Purchases	$0	$0	$0	$0	$0
Total Major Purchases	$0	$0	$0	$0	$0

Expenses by Month

Cash Flow Assumptions

Cash Inflow	
% of Sales on Credit	0%
Cash Outflow	
% of Purchases on Credit	0%

Loans and Investments Table

	FY2017	FY2018	FY2019	FY2020	FY2021
Operating Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Equipment Purchase Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Silage Biofuels Plant Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Crushing / Pelletizing Plant Capacity Addition Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Total Amount Received	$0	$0	$0	$0	$0

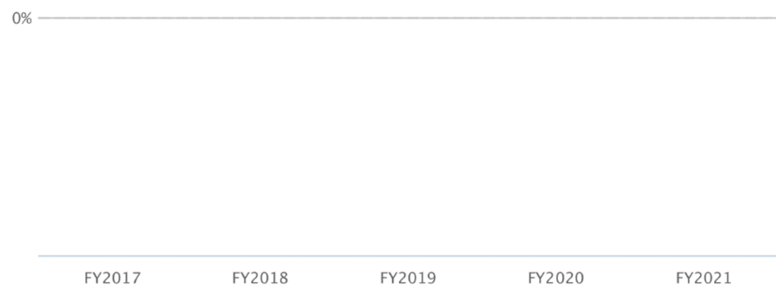
Hawaii Military Biofuels Crop Program
Economic Analysis Outline

Profit and Loss Statement

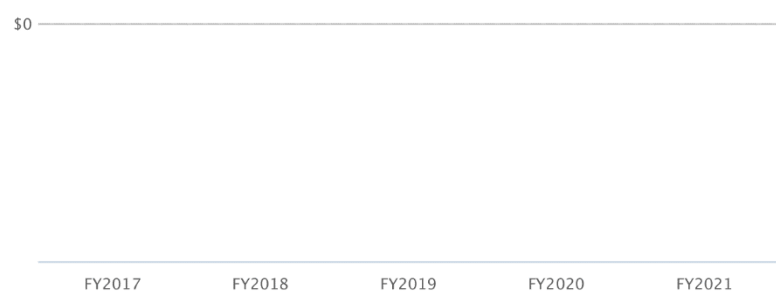
	FY2017	FY2018	FY2019	FY2020	FY2021
Revenue	$0	$0	$0	$0	$0
Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$0
Gross Margin %	0%	0%	0%	0%	0%
Operating Expenses					
Salary	$0	$0	$0	$0	$0
Employee Related Expenses	$0	$0	$0	$0	$0
Marketing & Promotions	$0	$0	$0	$0	$0
Rent	$0	$0	$0	$0	$0
Utilities / energy	$0	$0	$0	$0	$0
Office Supplies	$0	$0	$0	$0	$0
Insurance	$0	$0	$0	$0	$0
Bottling Supplies	$0	$0	$0	$0	$0
Uniforms / Laundry	$0	$0	$0	$0	$0
Total Operating Expenses	$0	$0	$0	$0	$0
Operating Income	$0	$0	$0	$0	$0
Interest Incurred	$0	$0	$0	$0	$0
Depreciation and Amortization	$0	$0	$0	$0	$0
Income Taxes	$0	$0	$0	$0	$0
Total Expenses	$0	$0	$0	$0	$0
Net Profit	$0	$0	$0	$0	$0
Net Profit / Sales	0%	0%	0%	0%	0%

Hawaii Military Biofuels Crop Program
Economic Analysis Outline

Gross Margin by Year



Net Profit (or Loss) by Year



Hawaii Military Biofuels Crop Program
Economic Analysis Outline

Balance Sheet

As of Period's End	FY2017	FY2018	FY2019	FY2020	FY2021
Cash	$0	$0	$0	$0	$0
Accounts Receivable	$0	$0	$0	$0	$0
Inventory	$0	$0	$0	$0	$0
Total Current Assets	$0	$0	$0	$0	$0
Long-Term Assets	$0	$0	$0	$0	$0
Accumulated Depreciation	$0	$0	$0	$0	$0
Total Long-Term Assets	$0	$0	$0	$0	$0
Total Assets	$0	$0	$0	$0	$0
Accounts Payable	$0	$0	$0	$0	$0
Sales Taxes Payable	$0	$0	$0	$0	$0
Short-Term Debt	$0	$0	$0	$0	$0
Total Current Liabilities	$0	$0	$0	$0	$0
Long-Term Debt	$0	$0	$0	$0	$0
Total Liabilities	$0	$0	$0	$0	$0
Paid-In Capital	$0	$0	$0	$0	$0
Retained Earnings	$0	$0	$0	$0	$0
Earnings	$0	$0	$0	$0	$0
Total Owner's Equity	$0	$0	$0	$0	$0
Total Liabilities & Equity	$0	$0	$0	$0	$0

Cash Flow Statement

	FY2017	FY2018	FY2019	FY2020	FY2021
Operations					
Net Profit	$0	$0	$0	$0	$0

Depreciation and Amortization	$0	$0	$0	$0	$0
Change in Accounts Receivable	$0	$0	$0	$0	$0
Change in Inventory	$0	$0	$0	$0	$0
Change in Accounts Payable	$0	$0	$0	$0	$0
Change in Sales Taxes Payable	$0	$0	$0	$0	$0
Net Cash Flow from Operations	$0	$0	$0	$0	$0
Investing & Financing					
Assets Purchased or Sold	$0	$0	$0	$0	$0
Investments Received	$0	$0	$0	$0	$0
Change in Short-Term Debt	$0	$0	$0	$0	$0
Change in Long-Term Debt	$0	$0	$0	$0	$0
Net Cash Flow from Investing & Financing	$0	$0	$0	$0	$0
Cash at Beginning of Period	$0	$0	$0	$0	$0
Net Change in Cash	$0	$0	$0	$0	$0
Cash at End of Period	$0	$0	$0	$0	$0

Cash Flow by Month

Cash Flow by Year

About the Cash Flow Statement

Appendix

Revenue Forecast

Revenue Forecast Table (With Monthly Detail)

FY2017	Jan '17	Feb '17	Mar '17	Apr '17	May '17	Jun '17	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17
Revenue												
Bulk Sunflower Oil (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Bottled Sunflower Oil (16 oz)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Bottle Sunflower Oil (8 oz)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biodiesel from Sunflower Oil (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biofuel from Used Cooking Oil (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biofuel from Silage (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Revenue	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Direct Cost												
Bulk Sunflower Oil (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Bottled Sunflower Oil (16 oz)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Bottle Sunflower Oil (8 oz)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biodiesel from Sunflower Oil (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biofuel from Used Cooking Oil (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biofuel from Silage (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Direct Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gross Margin %	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

	FY2017	FY2018	FY2019	FY2020	FY2021
Revenue					
Bulk Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Bottled Sunflower Oil (16 oz)	$0	$0	$0	$0	$0
Bottle Sunflower Oil (8 oz)	$0	$0	$0	$0	$0
Biodiesel from Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Biofuel from Used Cooking Oil (Gal)	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0
Biofuel from Silage (Gal)	$0	$0	$0	$0	$0
Total Revenue	$0	$0	$0	$0	$0
Direct Cost					
Bulk Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Bottled Sunflower Oil (16 oz)	$0	$0	$0	$0	$0
Bottle Sunflower Oil (8 oz)	$0	$0	$0	$0	$0
Biodiesel from Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Biofuel from Used Cooking Oil (Gal)	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0
Biofuel from Silage (Gal)	$0	$0	$0	$0	$0
Total Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$0
Gross Margin %	0%	0%	0%	0%	0%

Personnel Plan

Personnel Table (With Monthly Detail)

FY2017	Jan '17	Feb '17	Mar '17	Apr '17	May '17	Jun '17	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17
CEO	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
President	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Chief Operating Officer	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Chief Marketing Officer	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Director of Technology	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Chief Financial Officer	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Director of Sustainable Programs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Director of Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Director of Agriculture	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Agriculture Foreman	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Agriculture Worker (x26)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pellitizer Operator (x3)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Heavy Equipment Operator (x2)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Land Maintenance Worker (x4)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Water System Manager	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Water System Maintenance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Processing Foreman	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Processing Plant Operator (x4)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Livestock Feed Operator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Agro-Forestry Manager	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Forestry Specialist	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biodiesel Plant Manager	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biodiesel Plant Operators (x25)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Chemist (x2)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Silage Biofuels Plant Manager	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Silage Biofuels Plant Operator (x25)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sunflower Oil Bottling Plant Operator (x2)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Transportation Specialist (x3)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Officer Manager (x3)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Administrative Staff (x3)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sales / Bookkeeping (x3)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	FY2017	FY2018	FY2019	FY2020	FY2021
CEO	$0	$0	$0	$0	$0
President	$0	$0	$0	$0	$0
Chief Operating Officer	$0	$0	$0	$0	$0
Chief Marketing Officer	$0	$0	$0	$0	$0
Director of Technology	$0	$0	$0	$0	$0
Chief Financial Officer	$0	$0	$0	$0	$0
Director of Sustainable Programs	$0	$0	$0	$0	$0
Director of Construction	$0	$0	$0	$0	$0
Director of Agriculture	$0	$0	$0	$0	$0
Agriculture Foreman	$0	$0	$0	$0	$0
Agriculture Worker (x26)	$0	$0	$0	$0	$0
Pellitizer Operator (x3)	$0	$0	$0	$0	$0
Heavy Equipment Operator (x2)	$0	$0	$0	$0	$0
Land Maintenance Worker (x4)	$0	$0	$0	$0	$0
Water System Manager	$0	$0	$0	$0	$0
Water System Maintenance	$0	$0	$0	$0	$0
Processing Foreman	$0	$0	$0	$0	$0
Processing Plant Operator (x4)	$0	$0	$0	$0	$0
Livestock Feed Operator	$0	$0	$0	$0	$0
Agro-Forestry Manager	$0	$0	$0	$0	$0
Forestry Specialist	$0	$0	$0	$0	$0
Biodiesel Plant Manager	$0	$0	$0	$0	$0
Biodiesel Plant Operators (x25)	$0	$0	$0	$0	$0
Chemist (x2)	$0	$0	$0	$0	$0
Silage Biofuels Plant Manager	$0	$0	$0	$0	$0
Silage Biofuels Plant Operator (x25)	$0	$0	$0	$0	$0

Sunflower Oil Bottling Plant Operator (x2)	$0	$0	$0	$0	$0
Transportation Specialist (x3)	$0	$0	$0	$0	$0
Officer Manager (x3)	$0	$0	$0	$0	$0
Administrative Staff (x3)	$0	$0	$0	$0	$0
Sales / Bookkeeping (x3)	$0	$0	$0	$0	$0
Total	$0	$0	$0	$0	$0

Budget

Budget Table (With Monthly Detail)

FY2017	Jan '17	Feb '17	Mar '17	Apr '17	May '17	Jun '17	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17
Operating Expenses												
Salary	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Employee Related Expenses	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Marketing & Promotions	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Rent	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Utilities / energy	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Office Supplies	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Insurance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Bottling Supplies	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Uniforms / Laundry	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Operating Expenses	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Major Purchases												
Water Systems	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Land Preparation Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Planting and Harvest Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Crushing Mill	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pelletizing Plant	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sunflower Bottling Plant	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Livestock Feed Plant	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Transportation Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Land Purchases	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Major Purchases	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	FY2017	FY2018	FY2019	FY2020	FY2021
Operating Expenses					
Salary	$0	$0	$0	$0	$0
Employee Related Expenses	$0	$0	$0	$0	$0
Marketing & Promotions	$0	$0	$0	$0	$0
Rent	$0	$0	$0	$0	$0
Utilities / energy	$0	$0	$0	$0	$0
Office Supplies	$0	$0	$0	$0	$0
Insurance	$0	$0	$0	$0	$0
Bottling Supplies	$0	$0	$0	$0	$0
Uniforms / Laundry	$0	$0	$0	$0	$0
Total Operating Expenses	$0	$0	$0	$0	$0
Major Purchases					
Water Systems	$0	$0	$0	$0	$0
Land Preparation Equipment	$0	$0	$0	$0	$0
Planting and Harvest Equipment	$0	$0	$0	$0	$0
Crushing Mill	$0	$0	$0	$0	$0
Pelletizing Plant	$0	$0	$0	$0	$0
Sunflower Bottling Plant	$0	$0	$0	$0	$0
Livestock Feed Plant	$0	$0	$0	$0	$0
Transportation Equipment	$0	$0	$0	$0	$0
Land Purchases	$0	$0	$0	$0	$0
Total Major Purchases	$0	$0	$0	$0	$0

Loans and Investments

Loans and Investments Table (With Monthly Detail)

FY2017	Jan '17	Feb '17	Mar '17	Apr '17	May '17	Jun '17	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17
Operating Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Equipment Purchase Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Silage Biofuels Plant Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Crushing / Pelletizing Plant Capacity Addition Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Amount Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	FY2017	FY2018	FY2019	FY2020	FY2021
Operating Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Equipment Purchase Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Silage Biofuels Plant Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Crushing / Pelletizing Plant Capacity Addition Loan Loan at 0% interest for 60 mos.	$0	$0	$0	$0	$0
Total Amount Received	$0	$0	$0	$0	$0

Profit and Loss Statement

Profit and Loss Statement (With Monthly Detail)

FY2017	Jan '17	Feb '17	Mar '17	Apr '17	May '17	Jun '17	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17
Revenue	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Direct Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gross Margin %	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Operating Expenses												
Salary	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Employee Related Expenses	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Marketing & Promotions	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Rent	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Utilities / energy	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Office Supplies	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Insurance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Bottling Supplies	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Uniforms / Laundry	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Operating Expenses	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Operating Income	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Interest Incurred	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Depreciation and Amortization	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Income Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Profit	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Profit / Sales	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

	FY2017	FY2018	FY2019	FY2020	FY2021
Revenue	$0	$0	$0	$0	$0
Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$0
Gross Margin %	0%	0%	0%	0%	0%
Operating Expenses					
Salary	$0	$0	$0	$0	$0
Employee Related Expenses	$0	$0	$0	$0	$0
Marketing & Promotions	$0	$0	$0	$0	$0
Rent	$0	$0	$0	$0	$0
Utilities / energy	$0	$0	$0	$0	$0
Office Supplies	$0	$0	$0	$0	$0
Insurance	$0	$0	$0	$0	$0
Bottling Supplies	$0	$0	$0	$0	$0
Uniforms / Laundry	$0	$0	$0	$0	$0
Total Operating Expenses	$0	$0	$0	$0	$0
Operating Income	$0	$0	$0	$0	$0
Interest Incurred	$0	$0	$0	$0	$0
Depreciation and Amortization	$0	$0	$0	$0	$0
Income Taxes	$0	$0	$0	$0	$0
Total Expenses	$0	$0	$0	$0	$0
Net Profit	$0	$0	$0	$0	$0
Net Profit / Sales	0%	0%	0%	0%	0%

Balance Sheet

Balance Sheet (With Monthly Detail)

As of Period's End	Jan '17	Feb '17	Mar '17	Apr '17	May '17	Jun '17	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17
Cash	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Accounts Receivable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Inventory	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Current Assets	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Long-Term Assets	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Accumulated Depreciation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Long-Term Assets	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Assets	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Accounts Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sales Taxes Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Short-Term Debt	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Current Liabilities	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Long-Term Debt	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Liabilities	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Paid-In Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Retained Earnings	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Earnings	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Owner's Equity	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Liabilities & Equity	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

As of Period's End	FY2017	FY2018	FY2019	FY2020	FY2021
Cash	$0	$0	$0	$0	$0
Accounts Receivable	$0	$0	$0	$0	$0
Inventory	$0	$0	$0	$0	$0
Total Current Assets	$0	$0	$0	$0	$0
Long-Term Assets	$0	$0	$0	$0	$0
Accumulated Depreciation	$0	$0	$0	$0	$0
Total Long-Term Assets	$0	$0	$0	$0	$0
Total Assets	$0	$0	$0	$0	$0
Accounts Payable	$0	$0	$0	$0	$0
Sales Taxes Payable	$0	$0	$0	$0	$0
Short-Term Debt	$0	$0	$0	$0	$0
Total Current Liabilities	$0	$0	$0	$0	$0
Long-Term Debt	$0	$0	$0	$0	$0
Total Liabilities	$0	$0	$0	$0	$0
Paid-In Capital	$0	$0	$0	$0	$0
Retained Earnings	$0	$0	$0	$0	$0
Earnings	$0	$0	$0	$0	$0
Total Owner's Equity	$0	$0	$0	$0	$0
Total Liabilities & Equity	$0	$0	$0	$0	$0

Cash Flow Statement

Cash Flow Statement (With Monthly Detail)

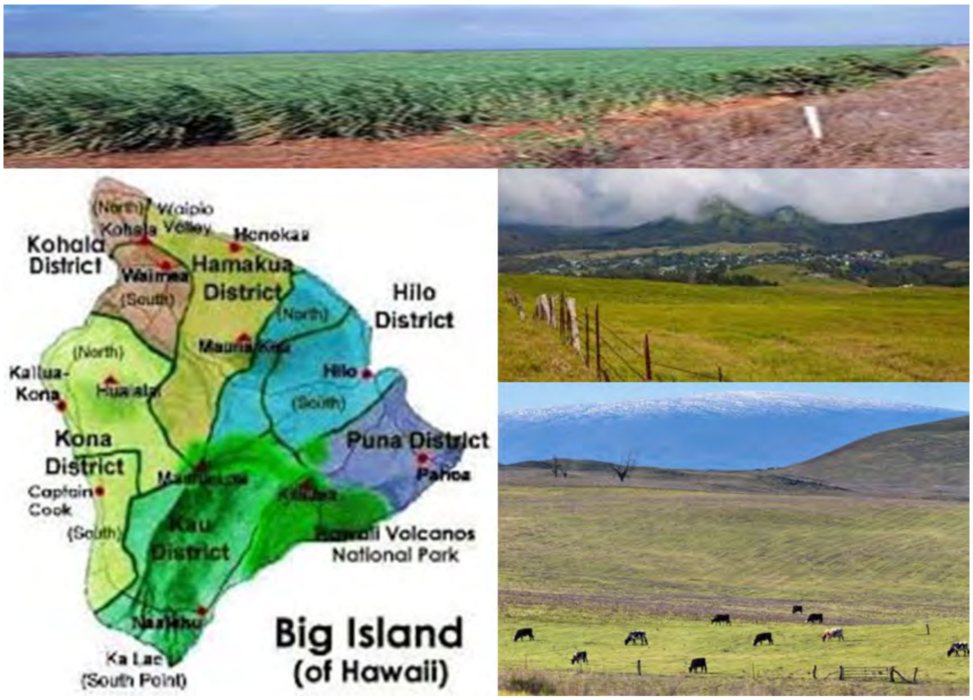
FY2017	Jan '17	Feb '17	Mar '17	Apr '17	May '17	Jun '17	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17
Operations												
Net Profit	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Depreciation and Amortization	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Accounts Receivable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Inventory	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Accounts Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Sales Taxes Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Cash Flow from Operations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Investing & Financing												
Assets Purchased or Sold	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Investments Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Short-Term Debt	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Long-Term Debt	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Net Cash Flow from Investing & Financing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cash at Beginning of Period	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Change in Cash	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cash at End of Period	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	FY2017	FY2018	FY2019	FY2020	FY2021
Operations					
Net Profit	$0	$0	$0	$0	$0
Depreciation and Amortization	$0	$0	$0	$0	$0
Change in Accounts Receivable	$0	$0	$0	$0	$0
Change in Inventory	$0	$0	$0	$0	$0
Change in Accounts Payable	$0	$0	$0	$0	$0
Change in Sales Taxes Payable	$0	$0	$0	$0	$0
Net Cash Flow from Operations	$0	$0	$0	$0	$0
Investing & Financing					
Assets Purchased or Sold	$0	$0	$0	$0	$0
Investments Received	$0	$0	$0	$0	$0
Change in Short-Term Debt	$0	$0	$0	$0	$0
Change in Long-Term Debt	$0	$0	$0	$0	$0
Net Cash Flow from Investing & Financing	$0	$0	$0	$0	$0
Cash at Beginning of Period	$0	$0	$0	$0	$0
Net Change in Cash	$0	$0	$0	$0	$0
Cash at End of Period	$0	$0	$0	$0	$0

Hawaii Military Biofuels Crop Program
Hawaii Island

Task 5
Economic Analysis



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Pacific Biodiesel Technologies

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Foreword

The purpose of this techno-economic analysis is to compare a set of biofuel conversion technologies selected for their promise and near-term technical viability. Every effort has been made to make this comparison on an equivalent basis using common assumptions. The process design and parameter value choices underlying this analysis are based on public domain literature only. For these reasons, these results are not indicative of potential performance, but are meant to represent the most likely performance given the current state of public knowledge.

List of Acronyms

BTL	biomass to liquids
CFB	circulating fluidized bed
CWT	hundred weight
DCFROR	discounted cash flow rate of return
DME	dimethyl-ether
FCI	fixed capital investment
FT	Fischer-Tropsch
GGE	gallon of gasoline equivalent
HRSG	heat recovery steam generator
HT	high temperature
IC	indirect costs
IGCC	integrated gasification combined cycle
IRR	internal rate of return
LT	low temperature
MM	million
MTG	methanol to gasoline
MW	megawatt
Nm^3	normal cubic meter
PSA	pressure swing adsorption
PV	product value
SPR	slurry phase reactor
SMR	steam methane reforming
TCI	total capital investment
TDIC	total direct and indirect cost
TIC	total installed cost
tpd	tons per day
TPEC	total purchased equipment cost

1. Introduction

1.1 Overview

The biofuels industry worldwide, including the US, has made significant increases to domestic fuel production in the last decade. Biodiesel in particular has shown double digit increases year over year until 2014, when lack of federal incentives and uncertainty of the current or future support of the Renewable Fuel Standard by the EPA caused the first negative growth year. Advanced drop-in fuels for F-76 and JP-8 were 200% of the EPA expectation for 2014, and look promising for significant growth in the next decade.

The Department of the Navy has a broad interest in biofuels ranging from installation level support for power generation and base transportation, to advanced biofuel replacements for F-76 and JP-5/8. To achieve this the Navy is exploring approaches for partnering with industry as a customer to provide the economic incentives to generate growth in the biofuels industry. The primary and most significant rationale is to improve National Security at key installations by reducing the dependence on imported fuels. In Hawaii this is particularly important as the Islands have a 2500 mile supply chain, and any in situ capacity to reduce the dependence on that supply chain through local production is of critical importance. A secondary benefit of the development of island based capacity, is that the small scale systems can provide specific data that can be used to identify opportunity for producing fuel at forward operating bases. These bases have fuel costs that are often above $100/gallon, and the logistics to get the fuel to the bases has been the cause of a significant percentage of the casualties in each theater. Identification of approaches that can be scaled to base size is a significant opportunity to improve operations in the forward bases.

1.2 Objectives and Approach

The objective of the project is to determine how best to create an agriculture based feedstock development approach that can provide advanced biofuels meeting Department of the Navy needs which include:

1) Priced at or near parity with petroleum equivalents
2) Stable pricing which can be predicted across a full year budget.
3) Pricing which is not based on commodities market value of the feedstock
4) Feedstock which has chemical composition that allows conversion to useful fuels
5) Overall economic value that incentivizes farmers to grow the crops long term

1.3 Technology Types

- Biodiesel – esterification, transesterification, distillation
- Ethanol – traditional fermentation

- Cellulosic Ethanol
- Hydroprocessed Esters and Fatty Acids – HEFA Jet
- Fisher-Tropsch diesel or jet fuel – FT Jet
- Synthetic IsoParaffinic Kerosene – SIP Jet
- Alcohol to Jet – ATJ
- Hydrotreated Depolymerized Cellulosic – HDC Jet
- Catalytic Hydrothermal Conversion – CHC Jet

1.4 Projected Revenue Streams

In order meet the expected economies for the production of fuels, while also creating profits that incentivize the farmer, the biomass that is represented by the feedstock crop must create as many products as possible. The primary initial test crop is oleic oil producing sunflower. The sunflower will have two primary harvest biomass remnants, oil bearing seed, and cellulosic silage. These will be used to produce:

1) Distilled biofuel made from the oil pressed from the seed. This will be provided to the Navy as B100 for use in diesel internal combustion engines, combustion turbine generators, and as F-76 for use in the fleet.
2) Aviation fuels derived from the cellulosic material in the silage
3) Livestock feed from the seedcake left over once the oil is pressed from the seed.
4) Sunflower cooking oil. This will be separated as a percentage from the same stock used for the fuel. The volume of cooking oil sold will be driven by the need to create revenue to ensure strong prices for the farmers, while maintaining stable pricing for the fuel.

1.5 Estimated DoD Pre-Requisites

The DoD has required pricing that, on an annual basis, is at parity with the fuels purchased from the wholesale market. In Hawaii this allows for pricing in comparison with the local refineries, which generally average \$0.30 to \$0.35 above the mainland prices. The Defense Logistics Agency (DLA) uses a standard fuel price which the DLA defines as:

"The standard price of fuel is a tool that was created by Department of Defense fiscal managers to insulate the Military Services from the normal ups and downs of the fuel marketplace. It provides the Military Services and OSD with budget stability despite the commodity market swings, with gains or losses being absorbed by a revolving fund known as the Defense Working Capital Fund (DWCF). In years that the market price of fuel is higher than the standard price, the DWCF loses money. In years that the market price is lower than the standard price, it makes money. This gain or loss can be made up by adjusting future standard prices or by providing our DoD customers with a refund. This decision is typically made by the Office of the Secretary of Defense, Comptroller. However, the DWCF must remain cash solvent. As a result, in rare instances such as fiscal year 2005, the standard price is changed during the fiscal year so the fund remains solvent.

The standard price is established well in advance of the fiscal year it is used. It is built by assembling the following blocks:

- A projection of the price of fuel 18 months in the future. (In the late fall the standard price is determined for fuel that will be sold to our customers during the Fiscal Year. As an example in the fall of 2012 the price is set that will be in effect from October 13 through September 14.)

- The budgeted cost of transporting, storing, and managing the government fuel system, including war reserve stocks and some adjustment to these costs which reflects whether the revolving fund lost or gained money during the previous years."

1.6 Fuels and Value Added

The current Standard price of fuel is:

FY 2015 Standard Prices
Effective February 1, 2015

	FY 2015	
	Per Gallon	Per Barrel
AVGAS (CONUS) - 130	$3.72	$156.24
AVGAS (OCONUS) - LL	$14.59	$612.78
Diesel Fuel:		
Distillates - F76	$3.25	$136.50
High Sulfur - DF1	$3.26	$136.92
Generic (High Sulfur) - DF2	$2.93	$123.06
Ultra Low Sulfur - DS1	$3.33	$139.86
Ultra Low Sulfur - DS2	$3.15	$132.30
Burner Grade - FS1	$3.18	$133.56
Burner Grade - FS2	$2.80	$117.60
Biodiesel - BDI	$3.14	$131.88
Jet Fuel:		
JP8 & JA1	$3.26	$136.92
JAA	$3.24	$136.08
JP5	$3.29	$138.18
JTS	$5.07	$212.94

This pricing is global and based on an annual estimate. Hawaii fuel prices are higher due to shipping, and that difference will be used to identify the parity cost. On the open markets, the retail average retail cost of diesel in Hawaii as of March of 2015 is $4.50 according to Hawaii Department of Business, Economic Development and Tourism (DBEDT) statistics. This is $1.61 above the National Average.

The current market price for sunflower livestock feed is priced based on protein content, and is generally priced slightly below soybean on a per pound basis. Recent pricing on Hawaii Island has 50 lbs bags of feed with equivalent nutritional value run from $24.60 to $28.00 per bag based on purchase volume. This provides a per pound price ranging from $0.492 and $0.56.

Finally the current wholesale price of sunflower oil is $960 per metric ton (or roughly $3.75 per gallon) if sold in bulk. However if bottled and sold as a brand the price is $39.75 retail and $22.00 wholesale. It is not anticipated that the oil would be sold as bulk, and so the $22.00 per gallon cost is the competitive figure, and we use $22/25/27 for the respective low, median and high price scenarios.

1.7 Assumptions

The evaluation of available feedstock is based on the following assumptions:

- 22-30 tons of sunflower biomass (silage) per acre during the growing season
- 1800-2000 lbs of seeds per acre
- Seeds are 40% oil, so roughly 800 lbs or 100 gallons per acre per harvest
- Potential for roughly 1000 lbs per acre of seedcake
- Cellulosic fuel conversion systems require pellets at roughly 15% moisture, which will reduce the tonnage per acre to roughly 12.5, though this is strain dependent.
- The oil requirement of the biodiesel plant will be roughly 5,500,000 gallons per year, or the equivalent of 22,000 acres production.
- Cellulosic and gasification plants will require 175-185,000 tons per year for efficient operation, which can be satisfied by the woody biomass, or by 14,500 acres of silage at 100% use, but likely 20,000 acres to account for the need to use some of the silage for restoration of nutrients in the soils.

2. Methodology

2.1 Economic Model Types

An economic model is a simplified description of reality, designed to yield hypotheses about economic behavior that can be tested. An important feature of an economic model is that it is necessarily subjective in design because there are no objective measures of economic outcomes. Different economists will make different judgments about what is needed to explain their interpretations of reality.

There are two broad classes of economic models—theoretical and empirical. Theoretical models seek to derive verifiable implications about economic behavior under the assumption that agents maximize specific objectives subject to constraints that are well defined in the model (for example, an agent's budget). They provide qualitative answers to specific questions—such as the implications of asymmetric information (when one side to a transaction knows more than the other) or how best to handle market failures.

In contrast, empirical models aim to verify the qualitative predictions of theoretical models and convert these predictions to precise, numerical outcomes. For example, a theoretical model of an agent's consumption behavior would generally suggest a positive relationship between expenditure and income. The empirical adaptation of the theoretical model would attempt to assign a numerical value to the average amount expenditure increases when income increases.

2.2 Down-Selection Process

For both the broad categories there a numerous specific models. This evaluation is based on an empirical model as its purpose is to determine whether the proposed feedstock approach can meet the pricing requirements rather than identify market behaviors.

Specifically the model needs to identify how the variance in use between allocation of the oil to the vegetable oil markets and to the fuel markets in order to maintain a steady fuel pricing, and maintaining profits for the farmers. The model has other factors which drive the per acre cost, to include labor, water and seed costs. These are considered to have fixed annual increases roughly the same as inflation, and so established in the model at 2%.

Given the outcome requirements, a simplified price variable model has been selected to assess the potential. It is based on an assessment of best case, median case and worst case prices for the output products, and holds the annual operating costs as fixed. The rationale is that, in actual operations, the balance between cooking oil and fuel uses can be adjusted to account for changes in operating conditions.

2.3 Preliminary Criteria

The criteria that drive the model outcomes include, but not be limited to:

- Variable effects of price. This was found to have the most effect in the livestock feed pricing due to the high volumes compared to other products.

- Ability to compete in each market. Competition is most difficult in the fuel markets as the capital costs for the conversion systems are far higher than those for feed and cooking oils. However, in the livestock feed market there is significant social and food security benefit to reducing the cost below market as it provides and incentive for the restoration of the cattle industry.

- Sensitivity to petroleum pricing. Recently this has become a significant issue for the alternative fuels as well as the emerging shale oil industries. However most industry estimates point towards petroleum at $70 per barrel by the end of 2015, and stabilizing in the $70-95 per barrel range going forward. The World Bank released an estimate recently indicating a steady upward trend in oil prices from an average of $53.20 in 2015 to an average of $103.40 in 2025. To account for this, the model operates on the assumption that the Standard Price will rise at roughly 3% per year, though petroleum prices in any given year can vary by 50%.

- Production volumes, which has several contributing factors. Higher production volumes are, in a vacuum, desirable. However the islands have limited agriculture lands, and devotion of too large a percentage of the lands to fuel production would limit other agriculture types. Hawaii Island has roughly 200,000 acres of useable land for agriculture. To fully support the existing biofuels plant, as well as a future cellulosic plant, slightly less than 10% of the land would be required to be used for feedstock growth. Given that more than 70% of the land is unused now this figure is achievable without great impact to the remaining agriculture sectors.

- Job Creation is important to the project, but not a factor in the economic assessment.

- Need for imported inputs is accounted for in the pricing of the fertilizer as well as seed prices. For purposes of the model the import cost factors are fixed.

2.4 Scenario Development

The scenarios will be used to test the model under a variety of conditions. This will include:

- Petroleum at $50/barrel
- Petroleum at $80/barrel
- Petroleum at $150/barrel
- Low harvest seasons
- High harvest seasons
- Some weather issues year
- Significant weather issues year

3. Current Industry Numbers

The following are current industry numbers for the fuel and sunflower markets:

FUEL:

Research & Economic Analysis Division, DBEDT

Indicator	Area	Unit	2013 1Q	2013 2Q	2013 3Q	2013 4Q	2014 1Q	2014 2Q	2014 3Q	2014 4Q	2015 1Q
Gasoline price- regular	Statewide	$/Gallon	4.24	4.36	4.33	4.03	4.07	4.35	4.30	3.91	
Gasoline price- mid grade	Statewide	$/Gallon	4.33	4.45	4.42	4.12	4.16	4.45	4.40	4.01	
Gasoline price- premium	Statewide	$/Gallon	4.42	4.54	4.51	4.21	4.25	4.54	4.49	4.10	
Diesel price	Statewide	$/Gallon	4.92	4.90	4.89	4.87	4.85	4.85	4.86	4.82	
Liquid Fuel Tax Base- Gasoline	Statewide	Gallons	109,905,088	110,506,080	114,611,336	110,556,400	111,207,344	109,389,992	115,208,128	112,918,240	
Liquid Fuel Tax Base- Diesel oil, Hwy Use	Statewide	Gallons	12,612,364	13,425,845	12,763,872	11,964,572	9,435,269	11,684,466	11,836,083	11,629,321	
Liquid Fuel Tax Base- Aviation fuel	Statewide	Gallons	58,451,720	56,410,864	57,621,000	55,773,588	71,311,328	57,644,500	56,955,480	53,565,888	

Hawaii Fuel Prices and Volumes - DBEDT Database

Hawaii Biofuels:
Ethanol imports remained steady or up slightly during the last year due to the E10 blending mandate. No ethanol production facilities were operating or under construction in Hawaii during this time. Biodiesel production in Hawaii reached 5% of on-road diesel consumption for 2014 at the Big Island Biodiesel facility in Keaau, Hawaii. Due to market pressures from reduced petroleum prices, biodiesel production in September was reduced to 50% of the previous high month. Purchases by HECO salvaged production levels in the last quarter of the year, which remained constrained on the open market. Installed biodiesel production capacity in Hawaii could produce 12% of the highway diesel use if market conditions allow.

SUNFLOWER:

The following is the latest price paid per 100 weight at the 3 main crushing mills in the Great Plains region. These prices would be higher in Hawaii.

NuSun Oilseed Average Prices				
	Date	Enderlin ND	Fargo ND	Goodland KS
	2/3/2015	$18.90	$18.75	$19.55
	2/4/2015	$18.85	$18.75	$19.50
	2/5/2015	$19.15	$19.00	$19.80
	2/6/2015	$19.00	$19.00	$19.80

	2/9/2015	$19.05	$19.10	$19.85
	2/10/2015	$18.90	$18.95	$19.70
	2/11/2015	$18.95	$19.05	$19.80
	2/12/2015	$19.05	$19.15	$19.90
	2/13/2015	$19.15	$19.25	$20.00
	2/17/2015	$19.25	$19.25	$19.80
	2/18/2015	$19.15	$19.20	$19.50
	2/19/2015	$19.15	$19.20	$19.40
	2/20/2015	$19.05	$19.10	$19.30
	2/23/2015	$18.95	$19.05	$19.20
	2/24/2015	$19.15	$19.10	$19.30
	2/25/2015	$19.25	$19.30	$19.40
	2/26/2015	$19.40	$19.40	$19.45
	2/27/2015	$19.70	$19.65	$19.75
	3/2/2015	$19.70	$19.65	$19.75
	3/3/2015	$19.75	$19.70	$19.80
	3/4/2015	$19.55	$19.55	$19.60
	3/5/2015	$19.35	$19.35	$19.40
	3/6/2015	$19.25	$19.25	$19.30
	3/9/2015	$19.15	$19.15	$19.20
	3/10/2015	$19.15	$19.15	$19.20
	3/11/2015	$19.20	$19.20	$19.25
	3/12/2015	$19.15	$19.15	$19.20
	3/13/2015	$19.05	$19.00	$19.10
	3/16/2015	$19.05	$19.00	$19.10

	3/17/2015	$18.95	$18.90	$19.10
	3/18/2015	$19.15	$19.10	$19.30
	3/19/2015	$19.15	$19.10	$19.40
	3/20/2015	$19.15	$19.15	$19.50
	3/23/2015	$19.30	$19.30	$19.70
	3/24/2015	$19.30	$19.30	$19.75
	3/25/2015	$19.30	$19.30	$19.80
	3/26/2015	$19.30	$19.30	$19.80
	3/27/2015	$19.10	$19.15	$19.60
	3/30/2015	$19.10	$19.15	$19.60
	3/31/2015	$19.10	$19.15	$19.60
	4/1/2015	$19.30	$19.30	$19.75
	4/2/2015	$19.40	$19.40	$19.85
	4/6/2015	$19.50	$19.50	$19.95
	4/7/2015	$19.45	$19.45	$19.90
	4/8/2015	$19.45	$19.45	$19.90
	Average	**$19.21**	**$19.21**	**$19.56**

National Sunflower Association Pricing Data

4. Economics Analysis

4.1 Feedstock

The current market price for oilseed is $19.21 per hundred pounds. It is expected that, given higher costs in Hawaii, the farmers will require at least $27.00 per hundred weight, though the analysis indicates that $29.11 is reasonable. In addition to the seed, the plan envisions that the enterprise will purchase roughly 10 dry tons of silage at $32 per ton. An advantage in Hawaii is the ability to harvest 2-2.5 crops per year per acre. The model assumes two 120 day growth cycles with 125 days of rest per year. This is a conservative model, but useful for determining most likely revenue case. The following is the expected outcome:

1) 1800 lbs per acre/per harvest of oilseed at 27,000 plants per acre

- Farmer nets $523.96 per acre/per harvest so $1,047.92 annual revenue per acre
- Results in 800 lbs of oil, which is 106.67 gallons
- Results in 900 lbs of livestock feed at 30% protein, 1800 lbs at 15% protein

2) 10 dry tons per acre/per harvest of dry silage at 27,000 plants per acre

- Farmer nets $320 per acre/per harvest so $640 annual revenue per acre
- 27,000 plants per acre creates 24.5-26 tons wet silage, 12.5 tons at 15% moisture

The result is roughly $843.96 gross revenue per acre per harvest, or $1,687.92 per acre per year gross revenue. Distributed across the biomass products, this results in a feedstock price of:

- $266.67 for 106.67 gallons of sunflower oil which is the equivalent of $2.50 per gallon or $84.00 per barrel. This is based on Pacific Biodiesel being able to pay $3.00 per gallon, and the crushing operation costing $0.50 per gallon to process the seed.

- $257.29 for 1800 lbs of livestock feed (900 lbs seedcake, 900 lbs silage) which is the equivalent of $0.143 per lbs or $7.15 for a 50 lbs bag.

- $320.00 for 10 tons of silage.

4.2 Fuels Markets

The fuels markets in Hawaii provide a significant price advantage over the mainland, with diesel often selling for $1.20 more per gallon retail and $0.30 per gallon wholesale in

Hawaii than on the mainland. The current average retail price of diesel in Hawaii is $4.50. Most biodiesel is sold as a blend, often B20 which is 20% biodiesel and 80% petroleum based diesel is used for the purposes of this study. The most recent US Department of Energy Clean Cities Alternative Fuels price report shows B20 at an average price of $3.18 per gallon, with petroleum based diesel at $3.06 per gallon. This is price at the pump, and does not include Federal or State subsidies. For purposes of the study we are maintaining this $0.12 spread between petroleum based diesel and B20, which creates and equivalent in transitioning to Hawaii of $4.62 per gallon if the average price of petroleum based diesel is $4.50 per gallon. Actual pricing may vary from this figure.

Clean Cities Alternative Fuel Price Report — January 2015

BIODIESEL BLENDS: B20

Table 9 shows average prices for B20, a 20% biodiesel/80% diesel fuel blend, grouped by region, as well as regular diesel prices, as provided by Clean Cities representatives. These prices were collected from across the country from Clean Cities coordinators, fuel providers, and other stakeholders on a voluntary basis.

As Table 9 illustrates, average prices for B20 are higher than conventional diesel prices in all regions of the country, ranging from $.05 per gallon higher in the Midwest and West Coast regions, to $.37 per gallon higher in the Rocky Mountain region. On average in the U.S., biodiesel in a B20 blend costs about $.12 more per gallon than conventional diesel fuel, based on current information.

Table 9. Biodiesel (B20) and Diesel Average Prices by Region from Clean Cities Sources

	Biodiesel (B20) Information Reported by Clean Cities ($ per gal)		Diesel Information Reported by Clean Cities ($ per gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	$3.64	7	$3.34	30
Central Atlantic	$3.09	29	$3.00	98
Lower Atlantic	$3.16	25	$3.06	92
Midwest	$3.04	28	$2.99	84
Gulf Coast	$3.06	5	$2.91	20
Rocky Mountain	$3.33	10	$2.96	43
West Coast	$3.23	61	$3.18	101
NATIONAL AVERAGE	$3.18	165	$3.06	468

The map to the right illustrates price differentials between B20 and diesel on a per-gallon basis, based on differentials between B20 and diesel prices for each state (as opposed to the regional averages illustrated in Table 9). In this map, negative numbers represent prices for B20 lower than diesel, and positive numbers represent B20 prices higher than diesel. States not highlighted with a color did not have any B20 data points in the current report. B20 had the most favorable pricing (per gallon) in Hawaii, Illinois and New Mexico.

Tech Note: B20 contains only about 2% less energy (BTUs) per volume than diesel. The appendix at the end of this report provides conversion factors for calculating B20 prices on a GGE and DGE basis.

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Clean Cities January 2015 B20 Price Data

The conversion technology for the silage has not yet been selected. In order to account for potential variations in production this report uses the average production statistics from the technologies evaluated as part of the Technology Evaluation. Across the expected potential fuel production technologies there was an average refining capacity of 10,000,000 gallons per year for 180,000 tons of biomass. This is roughly 55 gallons per ton. Currently the price of Jet A in Hawaii averages $4.90 across the 13 fixed base operators (FBO's) in the State. In the cracking process a range of fuels are made and the specific mix is technology dependent. For purposes of the assessment it is assumed that the plant will produce 2,500,000 aviation fuel, 2,500,000 of marine diesel and 5,000,000 of gasoline.

4.3 Livestock Feed Markets

The livestock and dairy industries in Hawaii has dropped dramatically and all of the State's feed lots have closed. The result is that the livestock feed market has dropped dramatically. A primary cause of this is the high cost of livestock feed, often more than 300% higher than mainland ranchers and dairies pay. The cattle industry alone has seen a fall from over 150,000 head processed annually as recently as 1973 to 10,450 head processed in the last data provided by USDA in 2010.

Cattle is only one market for feed, with swine, poultry, and fish also available. Given that the production of feed will be limited by acreage, the opportunity with the dairy/cattle ranch is the focus of this evaluation. On average a milking dairy cow consumes 100 lbs of feed per day. On Hawaii Island, the Big Island Dairy is currently expanding its herd from 600 to 1400 head. This alone represents a potential for 51,100,000 lbs of feed per year. Ranchers on the island have a mixture of cattle breeds that average a need for 3 lbs of feed per pound of weight gain. If the cattle are slaughter in state they are usually raised to 500 lbs by grazing, with an additional 500 lbs of feed lot weight gain, or 1500 lbs of feed per head of cattle processed. The Cattleman's Association has indicated that they would like to increase the feed lot fed cattle by 40000 head by 2020, which would require an additional 60,000,000 lbs of feed annually. These growth numbers can only be achieved if the livestock feed price is reduced to meet mainland prices which currently range from $23.50 to $29.60 per hundred lbs for high quality organic feeds.

4.4 Cooking Oil Markets

The cooking oil market is roughly divided into bulk and specialty markets. The current price for bulk sunflower oil at the port of New Orleans is $3.75 per gallon for export. This export price is roughly the same price that could be expected if export was the chosen market for Hawaii. Jedwards International, a bulk organic oils marketer is selling oil for $16.00 per gallon as price for lots of 50 gallons or more.

http://www.bulknaturaloils.com/Products/15856-bulk-high-oleic-sunflower-oil.aspx

The enterprise will target the specialty oils market to maximize returns. In this market space the oils are sold in sizes ranging from 8 oz, which can sell for $5.99 or more per unit, to one gallon, which sell for prices starting at $22.00 per gallon. The mix of unit sizes can be adjusted, and there are bottling costs that are associated with each size that affect net revenues. In order to reduce the complexity of the modeling, the business plan assumes $27.00 per gallon.

4.5 Operating Expenses

The below cost structure is based on a 40% increase in costs from those provided by the National Sunflower Association for farmers on mainland small farms (500 acres or less). These costs are on a per acre basis, and would be less on higher acre plots. Small farms have been selected for modeling the costs as these are likely to be most if not all of the farms on Hawaii Island. These costs are on a per harvest basis.

	Sunflower Low Cost	**Sunflower High Cost**	**Sunflowers Average**
A. Operating Costs			
Seed & Treatment	$47.91	$45.00	$41.40
Fertilizer	$10.60	$58.05	$64.45
Herbicide	$25.71	$71.75	$34.41
Fungicide	$0.00	$0.00	$0.00
Insecticide	$0.00	$0.00	$14.01
Fuel	$13.76	$21.47	$18.77
Machinery Operating	$10.80	$12.00	$11.00
Crop Insurance	$21.17	$31.99	$20.50
Other Costs	$7.75	$8.25	$8.25
Land Taxes	$4.35	$6.00	$4.35
Drying Costs	$0.00	$0.00	$10.00
Interest on Operating	$3.91	$7.00	$6.25
Total Operating Costs	**$145.96**	**$261.51**	**$233.39**
B. Fixed Costs			
Land Investment Costs	$108.05	$108.50	$108.50
Machinery Depreciation	$30.00	$30.00	$30.00
Site Investment	$27.50	$27.50	$27.50
Storage Costs	$3.52	$3.52	$3.52
Total Fixed Costs	**$169.07**	**$169.07**	**$169.07**
Total Operating & Fixed	**$315.03**	**$430.58**	**$402.46**
C. Labor	$26.25	$31.50	$28.25
Total Costs	**$341.28**	**$462.08**	**$430.71**

4.6 Capital Costs

The capital costs for the project are highly dependent on scale. For purposes of this model the plan focuses on a per acre model. The capital costs of the processing and conversion facilities are beyond the scope of the assessment, and not identified. The per acre model is derived from interviews with the Hawaii Department of Agriculture, Hawaii Farm Bureau and National Sunflower Association. The following represents the high average costs anticipated. The following costs are on an annual basis.

Depreciation Rate	10.0%	Storage Costs		
Investment Rate	2.50%	Non-aeration	50%	$3.70 /bu
Hours per acre	1.5	Aeration	50%	$4.30 /bu
Cost per hr.	$35.50			

Per Acre

Crop	Land Value $/acre	Land Cost $/acre	Machinery Investment $/acre	Machinery Depreciation $/acre	Site Investment $/acre	Storage $/acre	Labor $/acre
Sunflowers Confection	$6,500.00	$216.66	$300.00	$30.00	$27.50	$3.52	$35.50
Sunflowers Oil	$6,500.00	$216.66	$300.00	$30.00	$27.50	$3.52	$35.50

4.7 Anticipated Petroleum Prices

- **Oil prices rebounded from near six-year lows touched in January as market participants took stock of declines in US rig counts and relatively positive US economic data.** At the time of writing, ICE Brent was trading at $58.25/bbl - roughly 50% below its June 2014 peak. NYMEX WTI was at $52.55/bbl.

- **Global supplies fell by 235 kb/d in January to 94.1 mb/d on lower OPEC and non-OPEC production.** Reductions in capital expenditures have cut projected 2015 non-OPEC supply growth to 800 kb/d. US 2015 production is seen 200 kb/d lower than in last month's *Report,* at an average 12.4 mb/d, with most of the cuts in 2H15.

- **OPEC crude oil output fell by 240 kb/d in January to 30.31 mb/d, led by losses from Iraq and Libya.** Output from Saudi Arabia, Kuwait, Angola and Nigeria edged up. Downward revisions to the non-OPEC supply growth forecast for 2H15 have raised the 'call' on OPEC to an average 30.2 mb/d - just above the group's official target of 30 mb/d.
- **The forecast of global oil demand growth for 2015 is unchanged from last month's *Report,* at 0.9 mb/d, bringing average demand for the year to**

93.4 mb/d. Growth is expected to gain momentum from a modest 0.6 mb/d gain in 2014, on a slightly improved macroeconomic outlook.

- **OECD industry stocks slipped by 5.3 mb in December, roughly one tenth of the five-year average draw for the month**. Consequently, inventories' surplus to average levels ballooned to 65 mb from 16 mb in November, its widest since October 2010. Preliminary data point to a seasonal 22.7 mb stock build in January.

- **Global refinery crude throughputs rose by 1.1 mb/d in December, to 79.1 mb/be**fore maintenance curbed activity in January. An unexpected dip in Saudi Arabian runs in November underpins a 140 kb/d downward revision to last month's assessment of 4Q14 runs, to 78.1 mb/d. Throughputs are projected to fall to 77.6 mb/d in 1Q15.

4.8 Overall Crop Revenue

It is anticipated that the average plot size for the sunflower growers in Hawaii is modeled at 200 acres. There will be instances of larger and smaller plots, with the larger plots benefiting from scale. For purposes of the assessment, the 200 acre plot size represents a manageable plot, with many options for leasing. Larger plots are not widely available.

For 200 acre plot the annual revenues are:

Oil Seed Revenue:	$1,047.92 per acre at $29.11/hundred weight
Silage Revenue:	$640.00 per acre at $32.00 per ton
Total Revenue:	$337,584 at $1,687.92 per acre per year
Operating Costs:	$233.39 per acre per harvest
Fixed Costs:	$169.07 per acre per harvest
Total Costs:	$160,984 at $804.92 per acre per harvest
Net Revenue: for 200 acres	**$176,600**

5. Sensitivity Analysis

5.1 Sensitivity Variables

The variables developed for the analysis will be designed to stress the model to identify any risks to the long term operations. To accomplish this, variables will consider the following:

- The contribution of a factor to the overall revenue,

- minimize the risk of failure

- identify key constraints (e.g. the maximum availability of a resource),

- The number of constraints

- Likelihood of occurrence

- Weather factors

5.2 Sensitivity Assessment

There are two methodological approaches to sensitivity analysis: a deterministic and a stochastic approach. Deterministic sensitivity analysis assumes that the basic parameter is an element of a given subset of all possible parameter choices. It seeks to determine upper and lower bounds on the corresponding subset of economic outcomes of the model. Stochastic sensitivity analysis treats the vector of parameters as a stochastic variable with a given distribution, rendering economic equilibria of the model into stochastic variables. It aims at calculating the first moments of these variables, with the variance indicating the robustness of the results.

For this assessment we have focused on a deterministic analysis approach. In this approach a basic model has been built which allows a specified set of variables to be modified. The sensitivity of any variable has been tested by holding all other variables fixed. Clearly in the real world several variables could be changing at any time, however the analysis is not intended to judge overall model performance. This analysis seeks, instead, to identify the importance of each variable as a standalone.

In order to develop the model, the following sources material was used to identify the values for specific items in the model. These values are:

To determine the effect that the price per barrel has on the cost of gasoline:

> http://gascalc.appspot.com/
> http://econbrowser.com/archives/2014/06/gasoline-price-calculator

From this we used a figure that increases the cost of gasoline by $0.25 for every $10 increase in oil per barrel.

To determine the difference between the price of fuel on the mainland and the price in Hawaii the following sources were used. The price differential was also considered to hold for the Defense Logistics Agency standard pricing. While the actual standard price is somewhat lower than the Hawaii projected prices, DLA has indicated that at the volumes involved the price can be blended as long as it is within 10%.

> http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm
> http://www.eia.gov/petroleum/gasdiesel/gas_geographies.cfm#pricesbyregion
> http://www.hawaiigasprices.com/
> http://www.energy.dla.mil/DLA_finance_energy/Documents/FY%202015%20Standard%20Prices%20(Effective%20Feb.%201,%202015).pdf

$50 Per Barrel/No Weather Issues/Good Harvest

Economic Model for $50 Per Barrel Oil

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted Hawaii Diesel Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 50.00	$ 2.09	$ 2.40	$ 3.60	$ 2.35	$ 13.28
Crude Oil Price	**Predicted National Avg. Gas Price**	**Predicted National Avg. Diesel Price**	**Predicted DoD Standard B20 Price**	**Resultant Price Per Gallon Oil at Refinery**	**Revenue Contribution Per CWT Seed**
$ 50.00	$ 2.09	$ 2.40	$ 3.15	$ 1.90	$ 11.26

Operating Cost	Value
Seed& Treatment	$ 41.40
Fertilizer	$ 49.58
Herbicide	$ 34.41
Fungicide	$ -
Insecticide	$ 14.01
Fuel	$ 15.90
Machinery Ops	$ 11.00
Crop Insurance	$ 20.50
Land Taxes	$ 4.35
Drying Costs	$ 10.00
Interest	$ 6.25
Total Op. Costs	$ 207.40

Fixed Costs	Value
Land Invest. Cost	$ 108.50
Depreciation	$ 30.00
Site Investment	$ 27.50
Storage Costs	$ 3.52
Total Fixed Cost	$ 169.52
Labor Costs/HR	$ 15.00
Total Labor Cost	$ 28.25
Total Cost Per Acre	$ 405.17

Production Per Acre	Lbs
Seed	1800
Silage at 15% Moisture	20000
Oil Use Model	**%**
Oil Sold for Diesel Production	75
Oil Sold for Cooking	25
Farm Side Revenue Per Acre	**Value**
Sunflower Seed	$ 686.48
Silage	$ 320.00
Gross Revenue Per Acre	$ 1,006.48
Net Revenue Per Acre	$ 601.31

Annualized Outcome	Value
Net Revenue Per Acre	$ 601.31
Harvests Per Year	2.2
Farm Acreage	200.0
Net Annual Revenue Per Farm	$ 189,528.18

Assumptions
1. Livestock Feed is $0.143 per lbs
2. Sunflower Cooking Oil is $27.00 per gallon
3. Seed Price Contribution of Cooking Oil is $152.55 per CWT
4. Silage is sold for $32.00 per ton

This is the baseline model from which the sensitivity is assessed. This model is not intended to determine the viability of alternative fuels at any given price of oil, but rather to identify whether the farms can grow the feedstock crops profitably under a range of conditions. $50 is likely the low side average of oil going forward, though the price may dip below this on occasion, most predictions show prices staying above this level for the future.

In this baseline a 200 acre farm is generating a revenue that is above average for moderate sized farms. Specialized crop farms can see higher revenues, but they also have significantly higher costs and require flat high quality lands that are significantly more expensive.

An additional point is that the percentage of oil being sold into the cooking oil market has been set at 25%. This has two purposes. First is to enable the higher revenues to create sufficient revenues for the crushing mill operation, and so enable the sought after pricing for the farmer. The second is to ensure only the highest quality oils are segregated for sale in the specialty market, rather than the bulk market. This segregation can be changed to maintain the viability of the feedstock enterprise.

$80 Per Barrel/No Weather/Good Harvest

Economic Model for $80 Per Barrel Oil

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted Hawaii Diesel Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 80.00	$ 2.84	$ 3.15	$ 4.35	$ 3.10	$ 17.52

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted DoD Standard B20 Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 80.00	$ 2.84	$ 3.15	$ 3.90	$ 2.65	$ 15.70

Operating Cost	Value
Seed& Treatment	$ 41.40
Fertilizer	$ 79.32
Herbicide	$ 34.41
Fungicide	$ -
Insecticide	$ 14.01
Fuel	$ 19.21
Machinery Ops	$ 11.00
Crop Insurance	$ 20.50
Land Taxes	$ 4.35
Drying Costs	$ 10.00
Interest	$ 6.25
Total Op. Costs	$ 240.45

Fixed Costs	Value
Land Invest. Cost	$ 108.50
Depreciation	$ 30.00
Site Investment	$ 27.50
Storage Costs	$ 3.52
Total Fixed Cost	$ 169.52
Labor Costs/HR	$ 15.00
Total Labor Cost	$ 28.25
Total Cost Per Acre	$ 438.22

Production Per Acre	Lbs
Seed	1800
Silage at 15% Moisture	20000

Oil Use Model	%
Oil Sold for Diesel Production	75
Oil Sold for Cooking	25

Farm Side Revenue Per Acre	Value
Sunflower Seed	$ 686.48
Silage	$ 320.00
Gross Revenue Per Acre	$ 1,006.48
Net Revenue Per Acre	$ 568.25

Annualized Outcome	Value
Net Revenue Per Acre	$ 568.25
Harvests Per Year	2.2
Farm Acreage	200.0
Net Annual Revenue Per Farm	$ 161,759.03

Assumptions
1. Livestock Feed is $0.143 per lbs
2. Sunflower Cooking Oil is $27.00 per gallon
3. Seed Price Contribution of Cooking Oil is $152.55 per CWT
4. Silage is sold for $32.00 per ton

For this model the price of oil has been adjusted to $80 per barrel, and all other variables have been held at the baseline values. The oil price effects not only the price that the biofuels enterprise can pay for the sunflower seed, but also the fuel and fertilizer costs for the farm operation. Interestingly the increased revenue is more than offset by the increased costs. The result is that the net revenue for the farm drops by roughly $28,000 from the baseline. This is the opposite of what the biofuels refinery operations would see from the increased price of diesel. In operations the refinery could increase the price paid for the feedstock beyond a straight-line differential, however from the standpoint of sensitivity it is apparent that the oil price increases, and subsequent increases in fertilizer costs in particular, have a substantial impact. At this price the farms remain viable.

$150 Per Barrel/No Weather/Good Harvest

Economic Model for $150 Per Barrel Oil

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted Hawaii Diesel Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 150.00	$ 4.59	$ 4.90	$ 6.10	$ 4.85	$ 27.40

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted DoD Standard B20 Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 150.00	$ 4.59	$ 4.90	$ 5.65	$ 4.40	$ 26.07

Operating Cost	Value
Seed& Treatment	$ 41.40
Fertilizer	$ 148.73
Herbicide	$ 34.41
Fungicide	$ -
Insecticide	$ 14.01
Fuel	$ 26.94
Machinery Ops	$ 11.00
Crop Insurance	$ 20.50
Land Taxes	$ 4.35
Drying Costs	$ 10.00
Interest	$ 6.25
Total Op. Costs	$ 317.59

Fixed Costs	Value
Land Invest. Cost	$ 108.50
Depreciation	$ 30.00
Site Investment	$ 27.50
Storage Costs	$ 3.52
Total Fixed Cost	$ 169.52
Labor Costs/HR	$ 15.00
Total Labor Cost	$ 28.25
Total Cost Per Acre	$ 515.36

Production Per Acre	Lbs
Seed	1800
Silage at 15% Moisture	20000

Oil Use Model	%
Oil Sold for Diesel Production	75
Oil Sold for Cooking	25

Farm Side Revenue Per Acre	Value
Sunflower Seed	$ 686.48
Silage	$ 320.00
Gross Revenue Per Acre	$ 1,006.48
Net Revenue Per Acre	$ 491.11

Annualized Outcome	Value
Net Revenue Per Acre	$ 491.11
Harvests Per Year	2.2
Farm Acreage	200.0
Net Annual Revenue Per Farm	$ 96,964.36

Assumptions
1. Livestock Feed is $0.143 per lbs
2. Sunflower Cooking Oil is $27.00 per gallon
3. Seed Price Contribution of Cooking Oil is $152.55 per CWT
4. Silage is sold for $32.00 per ton

For this model the price of oil has been adjusted to $150 per barrel, and all other variables have been held at the baseline values. The oil price effects not only the price that the biofuels enterprise can pay for the sunflower seed, but also the fuel and fertilizer costs for the farm operation. As with the previous model the increase in costs more than offset the increase in revenue. While the farm does remain viable with a positive annual revenue, the farm has dropped below competitive with other uses for the land, and so is unlikely to incentivize the farmer to grow the feedstock crops. In order to be viable at $150 per barrel, revenue increases beyond a linear increase will have to be provided to make up for the increased costs. Some difference can be made by providing lower cost fuel to the farmers, but the most significant cost is in the fertilizer. Given that stable pricing is the most important factor, the most likely change would be to sell a higher percentage of the oil as cooking oil and pass the revenue through to the farms.

$50 Per Barrel/No Weather/Fair Harvest

Economic Model for $50 Per Barrel Oil

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted Hawaii Diesel Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 50.00	$ 2.09	$ 2.40	$ 3.60	$ 2.35	$ 13.28
Crude Oil Price	**Predicted National Avg. Gas Price**	**Predicted National Avg. Diesel Price**	**Predicted DoD Standard B20 Price**	**Resultant Price Per Gallon Oil at Refinery**	**Revenue Contribution Per CWT Seed**
$ 50.00	$ 2.09	$ 2.40	$ 3.15	$ 1.90	$ 11.26

Operating Cost	Value
Seed& Treatment	$ 41.40
Fertilizer	$ 49.58
Herbicide	$ 34.41
Fungicide	$ -
Insecticide	$ 14.01
Fuel	$ 15.90
Machinery Ops	$ 11.00
Crop Insurance	$ 20.50
Land Taxes	$ 4.35
Drying Costs	$ 10.00
Interest	$ 6.25
Total Op. Costs	$ 207.40

Fixed Costs	Value
Land Invest. Cost	$ 108.50
Depreciation	$ 30.00
Site Investment	$ 27.50
Storage Costs	$ 3.52
Total Fixed Cost	$ 169.52
Labor Costs/HR	$ 15.00
Total Labor Cost	$ 28.25
Total Cost Per Acre	$ 405.17

Production Per Acre	Lbs
Seed	1500
Silage at 15% Moisture	18000

Oil Use Model	%
Oil Sold for Diesel Production	75
Oil Sold for Cooking	25

Farm Side Revenue Per Acre	Value
Sunflower Seed	$ 572.06
Silage	$ 288.00
Gross Revenue Per Acre	$ 860.06
Net Revenue Per Acre	$ 454.90

Annualized Outcome	Value
Net Revenue Per Acre	$ 454.90
Harvests Per Year	2.2
Farm Acreage	200.0
Net Annual Revenue Per Farm	$ 125,106.68

Assumptions
1. Livestock Feed is $0.143 per lbs
2. Sunflower Cooking Oil is $27.00 per gallon
3. Seed Price Contribution of Cooking Oil is $152.55 per CWT
4. Silage is sold for $32.00 per ton

In this scenario the harvest per acre has been reduced. There are many factors that could affect this to include soil conditions, rainfall, cloud cover, average temperatures, crop damage, and pest infestation. Regardless of the cause, the effect is substantial but remains manageable even with 20% loss per acre over the baseline model. For Hawaii, a net revenue of $100,000 per acre would be roughly the minimum level of interest to the farmers given the level of investment and effort. This production level remains viable.

$50 Per Barrel/No Weather/Excellent Harvest

Economic Model for $50 Per Barrel Oil					
Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted Hawaii Diesel Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 50.00	$ 2.09	$ 2.40	$ 3.60	$ 2.35	$ 13.28
Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted DoD Standard B20 Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 50.00	$ 2.09	$ 2.40	$ 3.15	$ 1.90	$ 11.26

Operating Cost	Value
Seed& Treatment	$ 41.40
Fertilizer	$ 49.58
Herbicide	$ 34.41
Fungicide	$ -
Insecticide	$ 14.01
Fuel	$ 15.90
Machinery Ops	$ 11.00
Crop Insurance	$ 20.50
Land Taxes	$ 4.35
Drying Costs	$ 10.00
Interest	$ 6.25
Total Op. Costs	$ 207.40

Fixed Costs	Value
Land Invest. Cost	$ 108.50
Depreciation	$ 30.00
Site Investment	$ 27.50
Storage Costs	$ 3.52
Total Fixed Cost	$ 169.52
Labor Costs/HR	$ 15.00
Total Labor Cost	$ 28.25
Total Cost Per Acre	$ 405.17

Production Per Acre	Lbs
Seed	2000
Silage at 15% Moisture	22000

Oil Use Model	%
Oil Sold for Diesel Production	75
Oil Sold for Cooking	25

Farm Side Revenue Per Acre	Value
Sunflower Seed	$ 762.75
Silage	$ 352.00
Gross Revenue Per Acre	$ 1,114.75
Net Revenue Per Acre	$ 709.58

Annualized Outcome	Value
Net Revenue Per Acre	$ 709.58
Harvests Per Year	2.2
Farm Acreage	200.0
Net Annual Revenue Per Farm	$ 237,169.18

Assumptions
1. Livestock Feed is $0.143 per lbs
2. Sunflower Cooking Oil is $27.00 per gallon
3. Seed Price Contribution of Cooking Oil is $152.55 per CWT
4. Silage is sold for $32.00 per ton

In this scenario the harvest per acre has been increased to roughly the best potential outcome. At 27,000 plants per acre some farms have achieved 2000 lbs of seed per acre. If that level of production is met the farms net revenues increase significantly. The production per acre has a far greater impact based on variance than oil prices. Doubling oil price has less effect than a 20% change in production per acre. This is an expected outcome, and indicates that the priority of the research should be placed on maximizing production volumes.

$50 Per Barrel/Moderate Weather Issues/Good Harvest

Economic Model for $50 Per Barrel Oil

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted Hawaii Diesel Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 50.00	$ 2.09	$ 2.40	$ 3.60	$ 2.35	$ 13.28

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted DoD Standard B20 Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 50.00	$ 2.09	$ 2.40	$ 3.15	$ 1.90	$ 11.26

Operating Cost	Value
Seed& Treatment	$ 41.40
Fertilizer	$ 49.58
Herbicide	$ 34.41
Fungicide	$ -
Insecticide	$ 14.01
Fuel	$ 15.90
Machinery Ops	$ 11.00
Crop Insurance	$ 20.50
Land Taxes	$ 4.35
Drying Costs	$ 10.00
Interest	$ 6.25
Total Op. Costs	$ 207.40

Fixed Costs	Value
Land Invest. Cost	$ 108.50
Depreciation	$ 30.00
Site Investment	$ 27.50
Storage Costs	$ 3.52
Total Fixed Cost	$ 169.52
Labor Costs/HR	$ 15.00
Total Labor Cost	$ 28.25
Total Cost Per Acre	$ 405.17

Production Per Acre	Lbs
Seed	1800
Silage at 15% Moisture	20000

Oil Use Model	%
Oil Sold for Diesel Production	75
Oil Sold for Cooking	25

Farm Side Revenue Per Acre	Value
Sunflower Seed	$ 686.48
Silage	$ 320.00
Gross Revenue Per Acre	$ 1,006.48
Net Revenue Per Acre	$ 601.31

Annualized Outcome	Value
Net Revenue Per Acre	$ 601.31
Harvests Per Year	2.0
Farm Acreage	200.0
Net Annual Revenue Per Farm	$ 157,565.03

Assumptions
1. Livestock Feed is $0.143 per lbs
2. Sunflower Cooking Oil is $27.00 per gallon
3. Seed Price Contribution of Cooking Oil is $152.55 per CWT
4. Silage is sold for $32.00 per ton

This model resets the production and oil price data to the baseline and varies the number of harvests per year down from 2.2 to 2.0. This is to reflect moderate weather problems which increase the time for each harvest. This level of reduction has a moderate impact on the annualized revenue, but the farm operations remain well above the levels needed to incentivize the farms.

$50 Per Barrel/Significant Weather Impact /Good Harvest

Economic Model for $50 Per Barrel Oil

Crude Oil Price	Predicted National Avg. Gas Price	Predicted National Avg. Diesel Price	Predicted Hawaii Diesel Price	Resultant Price Per Gallon Oil at Refinery	Revenue Contribution Per CWT Seed
$ 50.00	$ 2.09	$ 2.40	$ 3.60	$ 2.35	$ 13.28
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$ 50.00	$ 2.09	$ 2.40	$ 3.15	$ 1.90	$ 11.26

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Seed& Treatment	$ 41.40
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Land Taxes	$ 4.35
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Interest	$ 6.25
Total Op. Costs	$ 207.40

Fixed Costs	Value
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Total Fixed Cost	$ 169.52
Labor Costs/HR	$ 15.00
Total Labor Cost	$ 28.25
Total Cost Per Acre	$ 405.17

Production Per Acre	Lbs
Seed	1800
Silage at 15% Moisture	20000

Oil Use Model	%
Oil Sold for Diesel Production	75
Oil Sold for Cooking	25

Farm Side Revenue Per Acre	Value
Sunflower Seed	$ 686.48
Silage	$ 320.00
Gross Revenue Per Acre	$ 1,006.48
Net Revenue Per Acre	$ 601.31

Annualized Outcome	Value
Net Revenue Per Acre	$ 601.31
Harvests Per Year	1.5
Farm Acreage	200.0
Net Annual Revenue Per Farm	$ 77,657.15

Assumptions
1. Livestock Feed is $0.143 per lbs
2. Sunflower Cooking Oil is $27.00 per gallon
3. Seed Price Contribution of Cooking Oil is $152.55 per CWT
4. Silage is sold for $32.00 per ton

Significant weather is an unlikely occurrence over long periods of time in Hawaii, but in the short run hurricane strength winds and heavy rains could severely damage crops. If the harvests are reduced to only 1.5 per year the revenue drop is dramatic, while the fixed costs remain. This drives the farms well below the viable level. As with the other scenarios, there are options that the biofuels enterprise could take to mitigate this loss. Also, the model does not include any receipts from crop insurance, which might be available depending on the source of the problem.

6. Conclusions

The key factor being evaluated is whether a base model can support the revenues needed to create a long term sustainable supply chain for biofuels operations in Hawaii. The analysis has shown that the operations are viable across a relatively wide range of conditions. The variable that has the most effect is the number of harvests that are achieved. Sunflower normally require about 110 days of growth in Hawaii, more in winter and less in summer. This allows for roughly 2.5 growing cycles per year. With rest and cover crop times included the most likely scenario is 2.2 harvests per year. The models show that the farms are viable as low as 1.75 harvests per year.

Other variables have less effect, and show that the farms can be maintained with oil prices ranging from $50-150 a barrel with little change to the core model. Likewise the production levels can sustain significant challenges.

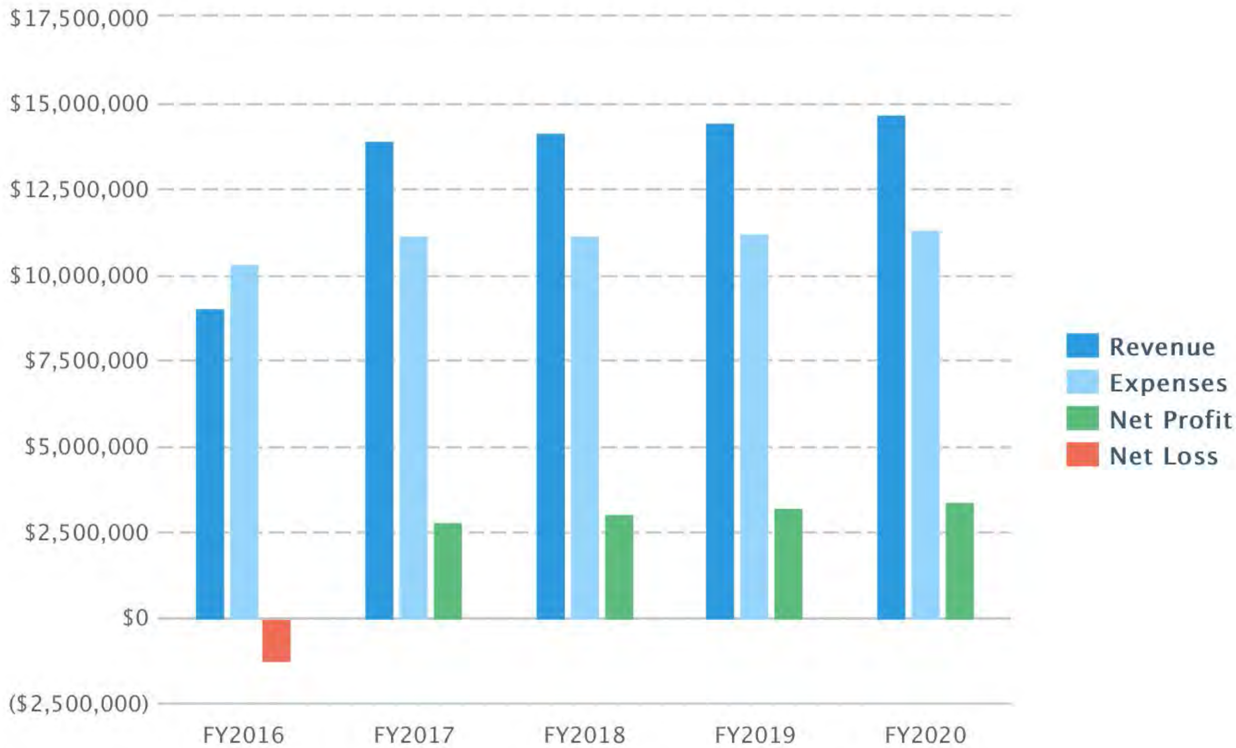
Bottom Line: A sustainable biofuels crop agriculture supply chain can be established in Hawaii.

7. Initial Business Model Example

The following is a notional business model for an enterprise that includes the agriculture and processing facilities for the seed and silage. It does not include and of the fuel production facilities or revenues from those facilities, but does draw on the economics of those facilities to establish pricing. The model anticipates a 2% rate of inflation, and assumes that the land is leased annually.

The model is built on the concept that the operation would plant and harvest 200 acres each week for 48 weeks per year. This would result in harvesting 9600 acres per year, which the model assumes requires 4800 acres of actual land. The actual farming operations will likely reach 22,000 acres to meet demand for all the products, but that is a matter of scale. The plan notionally begins in January of 2016, thought operations are not expected to reach scale for several years beyond that point.

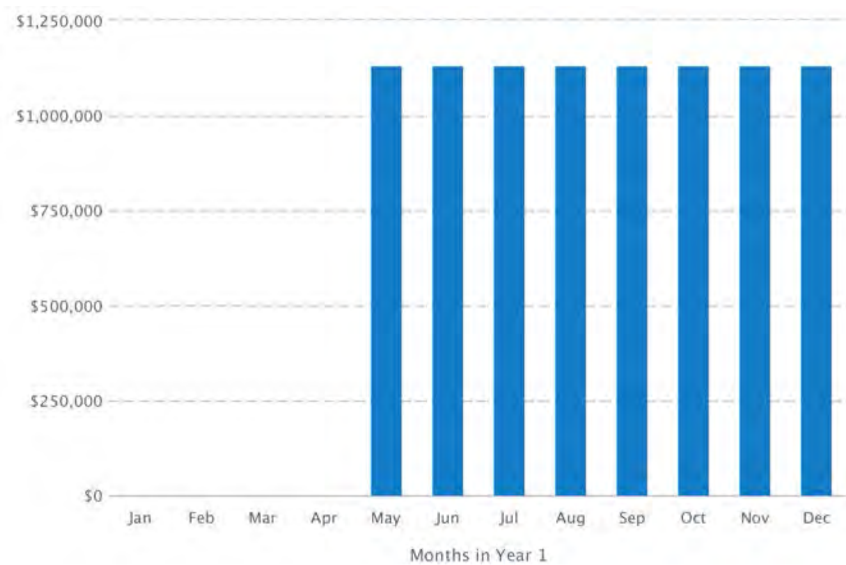
Financial Highlights by Year



Revenue Forecast	FY2016	FY2017	FY2018	FY2019	FY2020
Revenue					
Bottled Sunflower Oil (Gal)	$4,609,440	$7,052,443	$7,193,287	$7,336,692	$7,482,658
Sunflower Oil for Biodiesel (Gal)	$1,587,200	$2,426,880	$2,472,960	$2,519,040	$2,572,800
Livestock Feed (Lbs)	$806,400	$1,296,000	$1,296,000	$1,296,000	$1,296,000
Silage Sales to Outside Energy Co (Ton)	$2,048,000	$3,133,440	$3,195,840	$3,260,160	$3,325,440
Total Revenue	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Direct Cost					
Bottled Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Sunflower Oil for Biodiesel (Gal)	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0
Silage Sales to Outside Energy Co (Ton)	$0	$0	$0	$0	$0

Total Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Gross Margin %	100%	100%	100%	100%	100%

Revenue by Month



Personnel Table

	FY2016	FY2017	FY2018	FY2019	FY2020
President / COO	$90,000	$91,800	$93,636	$95,509	$97,419
Marketing Director	$60,000	$61,200	$62,424	$63,672	$64,946
Plant Engineer	$60,000	$61,200	$62,424	$63,672	$64,946
Financial Director	$60,000	$61,200	$62,424	$63,672	$64,946
Plant Director	$60,000	$61,200	$62,424	$63,672	$64,946
Director of Agriculture	$60,000	$61,200	$62,424	$63,672	$64,946
Agriculture Foreman	$36,000	$36,720	$37,454	$38,203	$38,968
Agriculture Worker (x8)	$208,000	$212,160	$216,403	$220,731	$225,146
Pelletizer Operator (x3)	$67,500	$91,800	$93,636	$95,509	$97,419
Heavy Equipment Operator	$36,000	$36,720	$37,454	$38,203	$38,968
Water Systems Engineer	$30,000	$30,600	$31,212	$31,836	$32,473
Processing Foreman	$27,000	$36,720	$37,454	$38,203	$38,968
Processing Plant Operator (x4)	$18,000	$24,480	$24,970	$25,469	$25,978
Livestock Feed Operator	$18,000	$24,480	$24,970	$25,469	$25,978

Sunflower Oil Bottling Plant Operator (x2)	$36,000	$48,960	$49,939	$50,938	$51,957
Transportation Specialist (x3)	$67,500	$91,800	$93,636	$95,509	$97,419
Officer Manager	$30,000	$30,600	$31,212	$31,836	$32,473
Administrative Staff (x2)	$36,000	$36,720	$37,454	$38,203	$38,968
Sales / Bookkeeping (x2)	$48,000	$48,960	$49,939	$50,938	$51,957
Total	$1,048,000	$1,148,520	$1,171,489	$1,194,916	$1,218,821

	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Expenses					
Salary	$1,048,000	$1,148,520	$1,171,489	$1,194,916	$1,218,821
Employee Related Expenses	$209,600	$229,704	$234,299	$238,984	$243,766
Marketing & Promotions	$120,000	$120,000	$120,000	$120,000	$120,000
Land Lease	$4,800,000	$4,800,000	$4,800,000	$4,800,000	$4,800,000
Fuel / Electricity	$280,416	$286,024	$280,416	$291,745	$297,580
Seed	$397,440	$405,388	$413,495	$421,765	$430,200
Fertilizer and Organic Supplies	$1,091,808	$1,113,644	$1,135,917	$1,158,635	$1,181,808

Insurance	$196,800	$196,800	$196,800	$196,800	$196,800
Bottling Supplies	$640,800	$653,616	$666,688	$680,021	$693,621
Equipment Operations	$105,600	$105,600	$105,600	$105,600	$105,600
Total Operating Expenses	$8,890,464	$9,059,296	$9,124,704	$9,208,466	$9,288,196
Major Purchases					
Water Systems	$600,000	$0	$0	$0	$0
Farm Equipment	$750,000	$0	$0	$0	$0
Planting and Harvest Equipment	$350,000	$0	$0	$0	$0
Crushing Mill	$1,500,000	$0	$0	$0	$0
Pelletizing Plant	$350,000	$0	$0	$0	$0
Sunflower Bottling Plant	$375,000	$0	$0	$0	$0
Livestock Feed Plant	$250,000	$0	$0	$0	$0
Transportation Equipment	$140,000	$0	$0	$0	$0
Warehouse	$650,000	$0	$0	$0	$0
Total Major Purchases	$4,965,000	$0	$0	$0	$0

Expenses by Month

Cash Flow Assumptions

Cash Inflow	
% of Sales on Credit	0%
Cash Outflow	
% of Purchases on Credit	0%

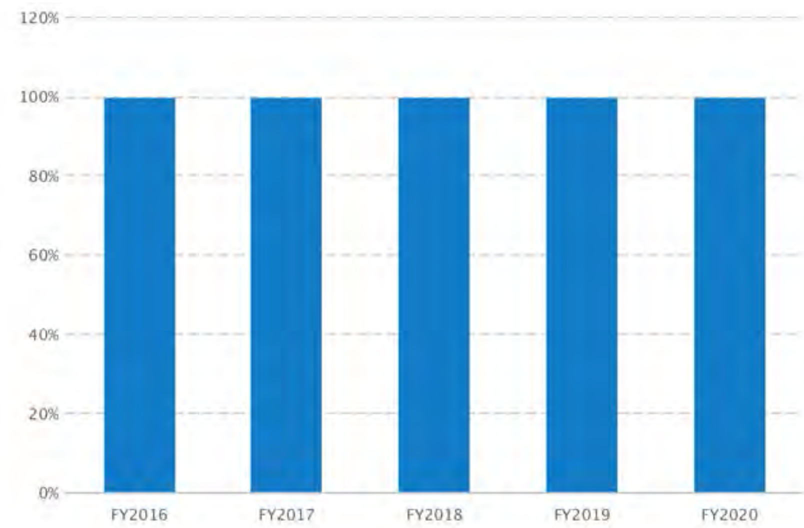
Loans and Investments Table

	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Loan Loan at 6% interest for 36 mos.	$3,500,000	$0	$0	$0	$0
Equipment Purchase Loan Loan at 6% interest for 60 mos.	$1,840,000	$0	$0	$0	$0
Facilities Loan Loan at 6% interest for 240 mos.	$3,175,000	$0	$0	$0	$0
Total Amount Received	$8,515,000	$0	$0	$0	$0

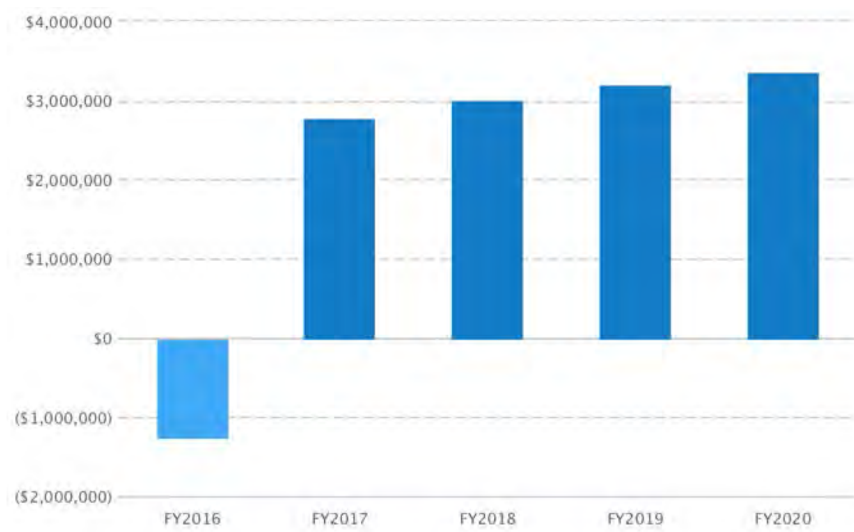
	FY2016	FY2017	FY2018	FY2019	FY2020
Revenue	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Gross Margin %	100%	100%	100%	100%	100%
Operating Expenses					
Salary	$1,048,000	$1,148,520	$1,171,489	$1,194,916	$1,218,821
Employee Related Expenses	$209,600	$229,704	$234,299	$238,984	$243,766
Marketing & Promotions	$120,000	$120,000	$120,000	$120,000	$120,000
Land Lease	$4,800,000	$4,800,000	$4,800,000	$4,800,000	$4,800,000
Fuel / Electricity	$280,416	$286,024	$280,416	$291,745	$297,580
Seed	$397,440	$405,388	$413,495	$421,765	$430,200
Fertilizer and Organic Supplies	$1,091,808	$1,113,644	$1,135,917	$1,158,635	$1,181,808
Insurance	$196,800	$196,800	$196,800	$196,800	$196,800
Bottling Supplies	$640,800	$653,616	$666,688	$680,021	$693,621
Equipment Operations	$105,600	$105,600	$105,600	$105,600	$105,600

Total Operating Expenses	$8,890,464	$9,059,296	$9,124,704	$9,208,466	$9,288,196
Operating Income	$160,576	$4,849,467	$5,033,383	$5,203,426	$5,388,702
Interest Incurred	$434,205	$384,861	$286,629	$212,058	$181,416
Depreciation and Amortization	$993,000	$993,000	$993,000	$993,000	$993,000
Income Taxes	$0	$694,321	$750,751	$799,674	$842,857
Total Expenses	$10,317,669	$11,131,478	$11,155,084	$11,213,198	$11,305,469
Net Profit	($1,266,629)	$2,777,285	$3,003,003	$3,198,694	$3,371,429
Net Profit / Sales	(14%)	20%	21%	22%	23%

Gross Margin by Year



Net Profit (or Loss) by Year



Balance Sheet

As of Period's End	FY2016	FY2017	FY2018	FY2019	FY2020
Cash	$1,897,820	$4,075,414	$6,380,494	$9,977,949	$13,823,966
Accounts Receivable	$0	$0	$0	$0	$0
Inventory	$0	$0	$0	$0	$0
Total Current Assets	$1,897,820	$4,075,414	$6,380,494	$9,977,949	$13,823,966
Long-Term Assets	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000
Accumulated Depreciation	($993,000)	($1,986,000)	($2,979,000)	($3,972,000)	($4,965,000)
Total Long-Term Assets	$3,972,000	$2,979,000	$1,986,000	$993,000	$0
Total Assets	$5,869,820	$7,054,414	$8,366,494	$10,970,949	$13,823,966
Accounts Payable	$0	$0	$0	$0	$0
Sales Taxes Payable	$0	$0	$0	$0	$0
Short-Term Debt	$0	$0	$0	$0	$0
Total Current Liabilities	$0	$0	$0	$0	$0
Long-Term Debt	$7,136,449	$5,543,758	$3,852,835	$3,258,596	$2,740,184

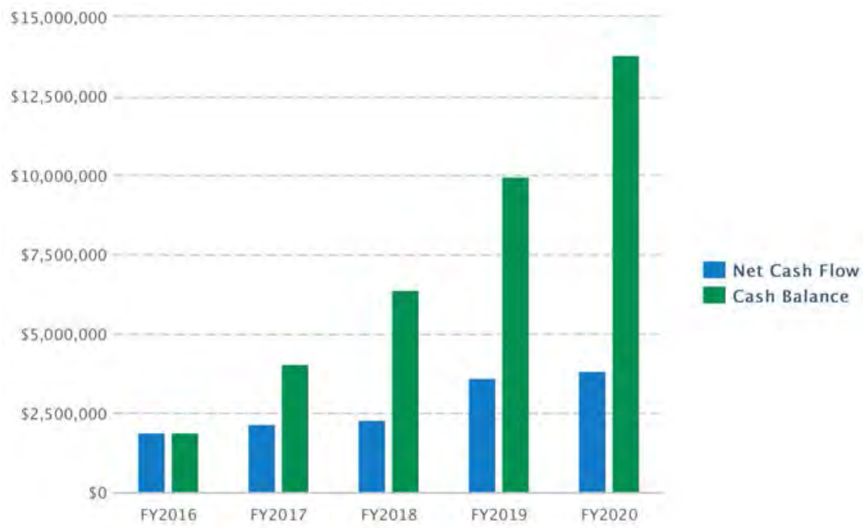
Total Liabilities	$7,136,449	$5,543,758	$3,852,835	$3,258,596	$2,740,184
Paid-In Capital	$0	$0	$0	$0	$0
Retained Earnings	$0	($1,266,629)	$1,510,656	$4,513,659	$7,712,353
Earnings	($1,266,629)	$2,777,285	$3,003,003	$3,198,694	$3,371,429
Total Owner's Equity	($1,266,629)	$1,510,656	$4,513,659	$7,712,353	$11,083,782
Total Liabilities & Equity	$5,869,820	$7,054,414	$8,366,494	$10,970,949	$13,823,966

	FY2016	FY2017	FY2018	FY2019	FY2020
Operations					
Net Profit	($1,266,629)	$2,777,285	$3,003,003	$3,198,694	$3,371,429
Depreciation and Amortization	$993,000	$993,000	$993,000	$993,000	$993,000
Change in Accounts Receivable	$0	$0	$0	$0	$0
Change in Inventory	$0	$0	$0	$0	$0
Change in Accounts Payable	$0	$0	$0	$0	$0
Change in Sales Taxes Payable	$0	$0	$0	$0	$0

Net Cash Flow from Operations	($273,629)	$3,770,285	$3,996,003	$4,191,694	$4,364,429
Investing & Financing					
Assets Purchased or Sold	($4,965,000)	$0	$0	$0	$0
Investments Received	$0	$0	$0	$0	$0
Change in Short-Term Debt	$0	$0	$0	$0	$0
Change in Long-Term Debt	$7,136,449	($1,592,691)	($1,690,923)	($594,239)	($518,412)
Net Cash Flow from Investing & Financing	$2,171,449	($1,592,691)	($1,690,923)	($594,239)	($518,412)
Cash at Beginning of Period	$0	$1,897,820	$4,075,414	$6,380,494	$9,977,949
Net Change in Cash	$1,897,820	$2,177,594	$2,305,080	$3,597,455	$3,846,017
Cash at End of Period	$1,897,820	$4,075,414	$6,380,494	$9,977,949	$13,823,966

Cash Flow by Month

Cash Flow by Year



Appendix

Revenue Forecast Table (With Monthly Detail)

FY2016	Jan '16	Feb '16	Mar '16	Apr '16	May '16	Jun '16	Jul '16	Aug '16	Sep '16	Oct '16	Nov '16	Dec '16
Revenue												
Bottled Sunflower Oil (Gal)	$0	$0	$0	$0	$576,180	$576,180	$576,180	$576,180	$576,180	$576,180	$576,180	$576,180
Sunflower Oil for Biodiesel (Gal)	$0	$0	$0	$0	$198,400	$198,400	$198,400	$198,400	$198,400	$198,400	$198,400	$198,400
Livestock Feed (Lbs)	$0	$0	$0	$0	$100,800	$100,800	$100,800	$100,800	$100,800	$100,800	$100,800	$100,800
Silage Sales to Outside Energy Co (Ton)	$0	$0	$0	$0	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000
Total Revenue	$0	$0	$0	$0	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380
Direct Cost												
Bottled Sunflower Oil (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sunflower Oil for Biodiesel (Gal)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Silage Sales to Outside Energy Co (Ton)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Direct Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380
Gross Margin %	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%

	FY2016	FY2017	FY2018	FY2019	FY2020
Revenue					
Bottled Sunflower Oil (Gal)	$4,609,440	$7,052,443	$7,193,287	$7,336,692	$7,482,658
Sunflower Oil for Biodiesel (Gal)	$1,587,200	$2,426,880	$2,472,960	$2,519,040	$2,572,800
Livestock Feed (Lbs)	$806,400	$1,296,000	$1,296,000	$1,296,000	$1,296,000
Silage Sales to Outside Energy Co (Ton)	$2,048,000	$3,133,440	$3,195,840	$3,260,160	$3,325,440
Total Revenue	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Direct Cost					
Bottled Sunflower Oil (Gal)	$0	$0	$0	$0	$0
Sunflower Oil for Biodiesel (Gal)	$0	$0	$0	$0	$0
Livestock Feed (Lbs)	$0	$0	$0	$0	$0
Silage Sales to Outside Energy Co (Ton)	$0	$0	$0	$0	$0
Total Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Gross Margin %	100%	100%	100%	100%	100%

FY2016	Jan '16	Feb '16	Mar '16	Apr '16	May '16	Jun '16	Jul '16	Aug '16	Sep '16	Oct '16	Nov '16	Dec '16
President / COO	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500
Marketing Director	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Plant Engineer	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Financial Director	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Plant Director	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Director of Agriculture	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Agriculture Foreman	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
Agriculture Worker (x8)	$17,333	$17,333	$17,333	$17,333	$17,333	$17,333	$17,333	$17,333	$17,334	$17,334	$17,334	$17,334
Pelletizer Operator (x3)	$0	$0	$0	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500
Heavy Equipment Operator	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
Water Systems Engineer	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Processing Foreman	$0	$0	$0	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
Processing Plant Operator (x4)	$0	$0	$0	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Livestock Feed Operator	$0	$0	$0	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Sunflower Oil Bottling Plant Operator (x2)	$0	$0	$0	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000
Transportation Specialist (x3)	$0	$0	$0	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500
Officer Manager	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Administrative Staff (x2)	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
Sales / Bookkeeping (x2)	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000

Total	$67,833	$67,833	$67,833	$93,833	$93,833	$93,833	$93,833	$93,833	$93,834	$93,834	$93,834	$93,834

	FY2016	FY2017	FY2018	FY2019	FY2020
President / COO	$90,000	$91,800	$93,636	$95,509	$97,419
Marketing Director	$60,000	$61,200	$62,424	$63,672	$64,946
Plant Engineer	$60,000	$61,200	$62,424	$63,672	$64,946
Financial Director	$60,000	$61,200	$62,424	$63,672	$64,946
Plant Director	$60,000	$61,200	$62,424	$63,672	$64,946
Director of Agriculture	$60,000	$61,200	$62,424	$63,672	$64,946
Agriculture Foreman	$36,000	$36,720	$37,454	$38,203	$38,968
Agriculture Worker (x8)	$208,000	$212,160	$216,403	$220,731	$225,146
Pelletizer Operator (x3)	$67,500	$91,800	$93,636	$95,509	$97,419
Heavy Equipment Operator	$36,000	$36,720	$37,454	$38,203	$38,968
Water Systems Engineer	$30,000	$30,600	$31,212	$31,836	$32,473
Processing Foreman	$27,000	$36,720	$37,454	$38,203	$38,968
Processing Plant Operator (x4)	$18,000	$24,480	$24,970	$25,469	$25,978
Livestock Feed Operator	$18,000	$24,480	$24,970	$25,469	$25,978
Sunflower Oil Bottling Plant Operator (x2)	$36,000	$48,960	$49,939	$50,938	$51,957
Transportation Specialist (x3)	$67,500	$91,800	$93,636	$95,509	$97,419
Officer Manager	$30,000	$30,600	$31,212	$31,836	$32,473
Administrative Staff (x2)	$36,000	$36,720	$37,454	$38,203	$38,968
Sales / Bookkeeping (x2)	$48,000	$48,960	$49,939	$50,938	$51,957
Total	$1,048,000	$1,148,520	$1,171,489	$1,194,916	$1,218,821

FY2016	Jan '16	Feb '16	Mar '16	Apr '16	May '16	Jun '16	Jul '16	Aug '16	Sep '16	Oct '16	Nov '16	Dec '16
Operating Expenses												
Salary	$67,833	$67,833	$67,833	$93,833	$93,833	$93,833	$93,833	$93,833	$93,834	$93,834	$93,834	$93,834
Employee Related Expenses	$13,566	$13,566	$13,566	$18,766	$18,767	$18,767	$18,767	$18,767	$18,767	$18,767	$18,767	$18,767
Marketing & Promotions	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Land Lease	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
Fuel / Electricity	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368
Seed	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120
Fertilizer and Organic Supplies	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984
Insurance	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400
Bottling Supplies	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400
Equipment Operations	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800
Total Operating Expenses	$717,471	$717,471	$717,471	$748,671	$748,672	$748,672	$748,672	$748,672	$748,673	$748,673	$748,673	$748,673
Major Purchases												
Water Systems	$600,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Farm Equipment	$750,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Planting and Harvest Equipment	$350,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Crushing Mill	$1,500,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pelletizing Plant	$350,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Sunflower Bottling Plant	$375,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Livestock Feed Plant	$250,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Transportation Equipment	$140,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Warehouse	$650,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Major Purchases	$4,965,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Expenses					
Salary	$1,048,000	$1,148,520	$1,171,489	$1,194,916	$1,218,821
Employee Related Expenses	$209,600	$229,704	$234,299	$238,984	$243,766
Marketing & Promotions	$120,000	$120,000	$120,000	$120,000	$120,000
Land Lease	$4,800,000	$4,800,000	$4,800,000	$4,800,000	$4,800,000
Fuel / Electricity	$280,416	$286,024	$280,416	$291,745	$297,580
Seed	$397,440	$405,388	$413,495	$421,765	$430,200
Fertilizer and Organic Supplies	$1,091,808	$1,113,644	$1,135,917	$1,158,635	$1,181,808
Insurance	$196,800	$196,800	$196,800	$196,800	$196,800
Bottling Supplies	$640,800	$653,616	$666,688	$680,021	$693,621
Equipment Operations	$105,600	$105,600	$105,600	$105,600	$105,600
Total Operating Expenses	$8,890,464	$9,059,296	$9,124,704	$9,208,466	$9,288,196
Major Purchases					
Water Systems	$600,000	$0	$0	$0	$0
Farm Equipment	$750,000	$0	$0	$0	$0
Planting and Harvest Equipment	$350,000	$0	$0	$0	$0
Crushing Mill	$1,500,000	$0	$0	$0	$0
Pelletizing Plant	$350,000	$0	$0	$0	$0
Sunflower Bottling Plant	$375,000	$0	$0	$0	$0
Livestock Feed Plant	$250,000	$0	$0	$0	$0
Transportation Equipment	$140,000	$0	$0	$0	$0
Warehouse	$650,000	$0	$0	$0	$0
Total Major Purchases	$4,965,000	$0	$0	$0	$0

Loans and Investments Table (With Monthly Detail)

FY2016	Jan '16	Feb '16	Mar '16	Apr '16	May '16	Jun '16	Jul '16	Aug '16	Sep '16	Oct '16	Nov '16	Dec '16
Operating Loan Loan at 6% interest for 36 mos.	$3,500,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Equipment Purchase Loan Loan at 6% interest for 60 mos.	$1,840,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Facilities Loan Loan at 6% interest for 240 mos.	$3,175,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Amount Received	$8,515,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Loan Loan at 6% interest for 36 mos.	$3,500,000	$0	$0	$0	$0
Equipment Purchase Loan Loan at 6% interest for 60 mos.	$1,840,000	$0	$0	$0	$0
Facilities Loan Loan at 6% interest for 240 mos.	$3,175,000	$0	$0	$0	$0
Total Amount Received	$8,515,000	$0	$0	$0	$0

FY2016	Jan '16	Feb '16	Mar '16	Apr '16	May '16	Jun '16	Jul '16	Aug '16	Sep '16	Oct '16	Nov '16	Dec '16
Revenue	$0	$0	$0	$0	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380
Direct Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gross Margin	$0	$0	$0	$0	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380	$1,131,380
Gross Margin %	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%
Operating Expenses												
Salary	$67,833	$67,833	$67,833	$93,833	$93,833	$93,833	$93,833	$93,833	$93,834	$93,834	$93,834	$93,834
Employee Related Expenses	$13,566	$13,566	$13,566	$18,766	$18,767	$18,767	$18,767	$18,767	$18,767	$18,767	$18,767	$18,767
Marketing & Promotions	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Land Lease	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
Fuel / Electricity	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368	$23,368
Seed	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120	$33,120
Fertilizer and Organic Supplies	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984	$90,984
Insurance	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400	$16,400
Bottling Supplies	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400	$53,400
Equipment Operations	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800	$8,800
Total Operating Expenses	$717,471	$717,471	$717,471	$748,671	$748,672	$748,672	$748,672	$748,672	$748,673	$748,673	$748,673	$748,673
Operating Income	($717,471)	($717,471)	($717,471)	($748,671)	$382,708	$382,708	$382,708	$382,708	$382,707	$382,707	$382,707	$382,707
Interest Incurred	$0	$42,575	$41,964	$41,350	$40,732	$40,113	$39,488	$38,862	$38,233	$37,599	$36,964	$36,325

Depreciation and Amortization	$82,748	$82,748	$82,748	$82,748	$82,749	$82,749	$82,749	$82,749	$82,753	$82,753	$82,753	$82,753
Income Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses	$800,219	$842,794	$842,183	$872,769	$872,153	$871,534	$870,909	$870,283	$869,659	$869,025	$868,390	$867,751
Net Profit	($800,219)	($842,794)	($842,183)	($872,769)	$259,227	$259,846	$260,471	$261,097	$261,721	$262,355	$262,990	$263,629
Net Profit / Sales	0%	0%	0%	0%	23%	23%	23%	23%	23%	23%	23%	23%

	FY2016	FY2017	FY2018	FY2019	FY2020
Revenue	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Direct Cost	$0	$0	$0	$0	$0
Gross Margin	$9,051,040	$13,908,763	$14,158,087	$14,411,892	$14,676,898
Gross Margin %	100%	100%	100%	100%	100%
Operating Expenses					
Salary	$1,048,000	$1,148,520	$1,171,489	$1,194,916	$1,218,821
Employee Related Expenses	$209,600	$229,704	$234,299	$238,984	$243,766
Marketing & Promotions	$120,000	$120,000	$120,000	$120,000	$120,000
Land Lease	$4,800,000	$4,800,000	$4,800,000	$4,800,000	$4,800,000
Fuel / Electricity	$280,416	$286,024	$280,416	$291,745	$297,580
Seed	$397,440	$405,388	$413,495	$421,765	$430,200
Fertilizer and Organic Supplies	$1,091,808	$1,113,644	$1,135,917	$1,158,635	$1,181,808
Insurance	$196,800	$196,800	$196,800	$196,800	$196,800
Bottling Supplies	$640,800	$653,616	$666,688	$680,021	$693,621
Equipment Operations	$105,600	$105,600	$105,600	$105,600	$105,600
Total Operating Expenses	$8,890,464	$9,059,296	$9,124,704	$9,208,466	$9,288,196
Operating Income	$160,576	$4,849,467	$5,033,383	$5,203,426	$5,388,702
Interest Incurred	$434,205	$384,861	$286,629	$212,058	$181,416
Depreciation and Amortization	$993,000	$993,000	$993,000	$993,000	$993,000
Income Taxes	$0	$694,321	$750,751	$799,674	$842,857
Total Expenses	$10,317,669	$11,131,478	$11,155,084	$11,213,198	$11,305,469
Net Profit	($1,266,629)	$2,777,285	$3,003,003	$3,198,694	$3,371,429
Net Profit / Sales	(14%)	20%	21%	22%	23%

As of Period's End	Jan '16	Feb '16	Mar '16	Apr '16	May '16	Jun '16	Jul '16	Aug '16	Sep '16	Oct '16	Nov '16	Dec '16
Cash	$2,832,529	$1,950,262	$1,067,995	$154,528	$372,440	$590,352	$808,264	$1,026,176	$1,244,087	$1,461,998	$1,679,909	$1,897,820
Accounts Receivable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Inventory	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Current Assets	$2,832,529	$1,950,262	$1,067,995	$154,528	$372,440	$590,352	$808,264	$1,026,176	$1,244,087	$1,461,998	$1,679,909	$1,897,820
Long-Term Assets	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000
Accumulated Depreciation	($82,748)	($165,496)	($248,244)	($330,992)	($413,741)	($496,490)	($579,239)	($661,988)	($744,741)	($827,494)	($910,247)	($993,000)
Total Long-Term Assets	$4,882,252	$4,799,504	$4,716,756	$4,634,008	$4,551,259	$4,468,510	$4,385,761	$4,303,012	$4,220,259	$4,137,506	$4,054,753	$3,972,000
Total Assets	$7,714,781	$6,749,766	$5,784,751	$4,788,536	$4,923,699	$5,058,862	$5,194,025	$5,329,188	$5,464,346	$5,599,504	$5,734,662	$5,869,820
Accounts Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sales Taxes Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Short-Term Debt	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Current Liabilities	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Long-Term Debt	$8,515,000	$8,392,779	$8,269,947	$8,146,501	$8,022,437	$7,897,754	$7,772,446	$7,646,512	$7,519,949	$7,392,752	$7,264,920	$7,136,449
Total Liabilities	$8,515,000	$8,392,779	$8,269,947	$8,146,501	$8,022,437	$7,897,754	$7,772,446	$7,646,512	$7,519,949	$7,392,752	$7,264,920	$7,136,449
Paid-In Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Retained Earnings	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Earnings	($800,219)	($1,643,013)	($2,485,196)	($3,357,965)	($3,098,738)	($2,838,892)	($2,578,421)	($2,317,324)	($2,055,603)	($1,793,248)	($1,530,258)	($1,266,629)
Total Owner's Equity	($800,219)	($1,643,013)	($2,485,196)	($3,357,965)	($3,098,738)	($2,838,892)	($2,578,421)	($2,317,324)	($2,055,603)	($1,793,248)	($1,530,258)	($1,266,629)

Total Liabilities & Equity	$7,714,781	$6,749,766	$5,784,751	$4,788,536	$4,923,699	$5,058,862	$5,194,025	$5,329,188	$5,464,346	$5,599,504	$5,734,662	$5,869,820

As of Period's End	FY2016	FY2017	FY2018	FY2019	FY2020
Cash	$1,897,820	$4,075,414	$6,380,494	$9,977,949	$13,823,966
Accounts Receivable	$0	$0	$0	$0	$0
Inventory	$0	$0	$0	$0	$0
Total Current Assets	$1,897,820	$4,075,414	$6,380,494	$9,977,949	$13,823,966
Long-Term Assets	$4,965,000	$4,965,000	$4,965,000	$4,965,000	$4,965,000
Accumulated Depreciation	($993,000)	($1,986,000)	($2,979,000)	($3,972,000)	($4,965,000)
Total Long-Term Assets	$3,972,000	$2,979,000	$1,986,000	$993,000	$0
Total Assets	$5,869,820	$7,054,414	$8,366,494	$10,970,949	$13,823,966
Accounts Payable	$0	$0	$0	$0	$0
Sales Taxes Payable	$0	$0	$0	$0	$0
Short-Term Debt	$0	$0	$0	$0	$0
Total Current Liabilities	$0	$0	$0	$0	$0
Long-Term Debt	$7,136,449	$5,543,758	$3,852,835	$3,258,596	$2,740,184
Total Liabilities	$7,136,449	$5,543,758	$3,852,835	$3,258,596	$2,740,184
Paid-In Capital	$0	$0	$0	$0	$0
Retained Earnings	$0	($1,266,629)	$1,510,656	$4,513,659	$7,712,353
Earnings	($1,266,629)	$2,777,285	$3,003,003	$3,198,694	$3,371,429
Total Owner's Equity	($1,266,629)	$1,510,656	$4,513,659	$7,712,353	$11,083,782
Total Liabilities & Equity	$5,869,820	$7,054,414	$8,366,494	$10,970,949	$13,823,966

FY2016	Jan '16	Feb '16	Mar '16	Apr '16	May '16	Jun '16	Jul '16	Aug '16	Sep '16	Oct '16	Nov '16	Dec '16
Operations												
Net Profit	($800,219)	($842,794)	($842,183)	($872,769)	$259,227	$259,846	$260,471	$261,097	$261,721	$262,355	$262,990	$263,629
Depreciation and Amortization	$82,748	$82,748	$82,748	$82,748	$82,749	$82,749	$82,749	$82,749	$82,753	$82,753	$82,753	$82,753
Change in Accounts Receivable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Inventory	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Accounts Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Sales Taxes Payable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Cash Flow from Operations	($717,471)	($760,046)	($759,435)	($790,021)	$341,976	$342,595	$343,220	$343,846	$344,474	$345,108	$345,743	$346,382
Investing & Financing												
Assets Purchased or Sold	($4,965,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Investments Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Short-Term Debt	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Change in Long-Term Debt	$8,515,000	($122,221)	($122,832)	($123,446)	($124,064)	($124,683)	($125,308)	($125,934)	($126,563)	($127,197)	($127,832)	($128,471)
Net Cash Flow from Investing & Financing	$3,550,000	($122,221)	($122,832)	($123,446)	($124,064)	($124,683)	($125,308)	($125,934)	($126,563)	($127,197)	($127,832)	($128,471)
Cash at Beginning of Period	$0	$2,832,529	$1,950,262	$1,067,995	$154,528	$372,440	$590,352	$808,264	$1,026,176	$1,244,087	$1,461,998	$1,679,909

Net Change in Cash	$2,832,529	($882,267)	($882,267)	($913,467)	$217,912	$217,912	$217,912	$217,912	$217,911	$217,911	$217,911	$217,911
Cash at End of Period	$2,832,529	$1,950,262	$1,067,995	$154,528	$372,440	$590,352	$808,264	$1,026,176	$1,244,087	$1,461,998	$1,679,909	$1,897,820

	FY2016	FY2017	FY2018	FY2019	FY2020
Operations					
Net Profit	($1,266,629)	$2,777,285	$3,003,003	$3,198,694	$3,371,429
Depreciation and Amortization	$993,000	$993,000	$993,000	$993,000	$993,000
Change in Accounts Receivable	$0	$0	$0	$0	$0
Change in Inventory	$0	$0	$0	$0	$0
Change in Accounts Payable	$0	$0	$0	$0	$0
Change in Sales Taxes Payable	$0	$0	$0	$0	$0
Net Cash Flow from Operations	($273,629)	$3,770,285	$3,996,003	$4,191,694	$4,364,429
Investing & Financing					
Assets Purchased or Sold	($4,965,000)	$0	$0	$0	$0
Investments Received	$0	$0	$0	$0	$0
Change in Short-Term Debt	$0	$0	$0	$0	$0
Change in Long-Term Debt	$7,136,449	($1,592,691)	($1,690,923)	($594,239)	($518,412)
Net Cash Flow from Investing & Financing	$2,171,449	($1,592,691)	($1,690,923)	($594,239)	($518,412)
Cash at Beginning of Period	$0	$1,897,820	$4,075,414	$6,380,494	$9,977,949
Net Change in Cash	$1,897,820	$2,177,594	$2,305,080	$3,597,455	$3,846,017
Cash at End of Period	$1,897,820	$4,075,414	$6,380,494	$9,977,949	$13,823,966

Hawaii Military Biofuels Crop Program
Hawaii Island

Task 6
Survey of Hawaii Island Biofuels Lands

Prepared For:

Office of Naval Research

Under Sub Award Number MA150004 from:

Hawaii Natural Energy Institute

University of Hawaii

Under Award N00014-11-1-0391

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Foreword

This report is a survey of lands on the Big Island of Hawaii that will identify suitable lands available for biofuels crops including irrigation potential, and an estimate of the total fuels potential from idle agricultural lands. The survey is an island-wide overview which will draw on existing information on agricultural lands from State of Hawaii and University of Hawaii sources to create a baseline that will be used to support estimates of annual crop potentials and costs.

List of Acronyms

BTL	biomass to liquids
CFB	circulating fluidized bed
CWT	hundred weight
DCFROR	discounted cash flow rate of return
DME	dimethyl-ether
FCI	fixed capital investment
FT	Fischer-Tropsch
GGE	gallon of gasoline equivalent
HRSG	heat recovery steam generator
HT	high temperature
IC	indirect costs
IGCC	integrated gasification combined cycle
IRR	internal rate of return
LT	low temperature
MM	million
MTG	methanol to gasoline
MW	megawatt
Nm^3	normal cubic meter
PSA	pressure swing adsorption
PV	product value
SPR	slurry phase reactor
SMR	steam methane reforming
TCI	total capital investment
TDIC	total direct and indirect cost
TIC	total installed cost
tpd	tons per day
TPEC	total purchased equipment cost

1. Introduction

This study will provide an inventory of available agriculture lands. The reports will further provide a description of the factors that make lands suitable for use in growing biofuels crops, and derives an estimate of the total suitable acreage along with locations. These estimates of suitable lands are based specifically on Sunflower/Safflower. The full range of biofuels crops would be able to use most, if not all, of the available lands. Finally the report provides an estimation of the resulting annual fuel production capacity using industry average conversion rates as discussed in the Task 9 Report.

1.1 Land Summary

Hawaii Island is the largest of the Hawaiian Islands, at 4,028 square miles. It is larger than all the other islands combined and roughly the same size as the State of Connecticut. The island is, however, much younger geologically and has active volcanic activity. As a result there are significant regions of the island that are uninhabited, and have little or no soil. Additionally much of the land is best suited for either pasture or crops such as coffee and macadamia nuts which do not require flat lands, and which are harvested by means that are adaptable to uneven topographies.

Districts	Agricultural	Conservation	Rural	Urban	Total
Puna	175,104	138,563	146	6,329	320,142
South Hilo	70,695	169,493	0	12,814	253,002
North Hilo	53,587	120,110	71	608	174,376
Hāmākua	162,729	235,805	13	1,041	399,588
North Kohala	64,713	13,187	16	2,434	80,350
South Kohala	**150,426**	**15,356**	**53**	**10,608**	**176,443**
North Kona	158,853	188,331	477	17,787	365,448
South Kona	110,749	35,051	31	845	146,676
Ka'u	237,743	422,239	0	1,801	661,783
Total	1,184,599	1,338,135	807	54,267	2,577,808

Source: DBEDT, Office of Planning GIS data

Figure 1: GIS Land Designation Chart

Figure 1 is drawn from the DBEDT data base and provides an overview of the acreage in each land designations for the regions on the island.

At the high points of use, the island supported roughly 140,000 acres of sugarcane and slightly more than 500,000 acres of ranching. The sugarcane lands are an indication of the lands that could be used for biofuels crops, though many of the planation regions may be too wet to be suitable for sunflower/safflower. Another key factor in availability is the land ownership. The Hawaiian Homelands agriculture lands are leased in parcels from 5 to 20 acres, and so are generally too small. The Hawaiian Homelands pasture lands are 300 acre parcels, but only 1/3 of the parcel can be used to grow crops, and only for crops which serve as livestock feed. Kamehameha lands are generally already leased, and the agriculture plots are smaller than needed for efficient crop growth.

Major Landowners on Hawaii (In Acres)

Major Owner	Planned Growth: Developed	Planned Growth: Undeveloped	ARL	Total on Hawaii
State of Hawaii	6,588.6	9,223.7	90,868.5	947,452.5
Kamehameha Schools	1,609.5	3,524.6	73,071.9	297,194.0
Parker Ranch	882.4	703.9	87,334.0	134,662.0
State DHHL	1,097.2	3,523.7	65,853.3	112,593.0
James Campbell Estate	0.0	0.0	96.5	26,700.0
Yee Hop	0.0	0.0	4,495.8	21,637.1
W.H. Shipman	1,103.6	1,548.1	6,286.5	16,839.9
Hawaii Forest Pres.	0.0	0.0	337.2	13,230.0
The Nature Conservancy	0.0	0.0	4,794.6	11,699.8
Hokukano Ranch	77.9	0.0	4,759.4	11,293.8
Queen Emma Foundation	322.5	2,086.0	2,947.1	10,261.4
Waikoloa Village Ass.	263.7	111.3	751.2	10,118.4
County of Hawaii	296.5	806.7	3,758.1	5,427.2

Note:
All acreages are based on GIS generated figures, except Total Acres, which is based on Tax Acres.
Developed parcels are based on TMK records with Bldg Value >= $10K.
Undeveloped parcels are based on TMK records with Bldg Value < $10K.

Figure 2: Island-Wide Land Ownership Table

Figure 2 provides the major landowners on the island, after the collapse of the plantation system in 1994.

The landowners fall in to 4 basic categories;

1) Government – The agriculture designated lands are available for lease, though generally are focused on ranching and food production.

2) Hawaiian Home Lands - Would require a contract with the leaseholder.

3) Private Trust Lands - There are many of these lands, and most are either available for lease or already in agriculture production. Kamehameha Schools and Parker Ranch are the largest examples of these.

4) Private Lands - Fee simple lands owned by individuals or corporations. W.H Shipman is the largest example of these lands.

Figure 3: GIS Land Designation Depiction

Figure 3 is a Geographic Information System (GIS) diagram provides pictorial overviews of the lands, with green plots being those lands being designated agricultural. The agriculture lands primarily exist in a band around the coast, with a pocket of land in the interior running around Mauna Kea at about 2500-3500 feet of altitude.

Hawaii Island has a wide range of rainfall, ranging from some of the driest points in the United States, to rainforests. The oil bearing crops being investigated are not suited for high rainfall regions, and so much of the agriculture lands are not suitable for growth of these crops. The ideal lands for these biofuels crops have flat and level topography to enable the use of combines for harvesting, moderate rainfall (between 25 and 100 inches annually), plots of at least 100 acres and appropriate soils. The assessment has identified no less than 100,000 acres on the island meeting these criteria as described below.

1.2 Infrastructure Summary

The ideal planting cycle for sunflower/safflower includes periods of high water application, and periods where the plants are starved of water in order to increase oil production. As result the productivity of the lands is greatly increased when irrigation water can be applied to match watering to the plants growth cycle. Hawaii Island has developed significant infrastructure over the last 100 years as a result of the plantation industry, but much of the infrastructure is aging and has reduced capacity. The island has three significant water systems in the North, and additional water tunnel systems in the South. The islands road and port infrastructure are more than sufficient to support all feedstock growth operations. The two primary ports, Hilo and Kawaihae, are closely positioned in proximity to the most likely growing regions, and both can handle 20' and 40' containers as well as bulk shipments.

Water distribution is the most critical need to support the large scale operations. The report will identify both existing and potential irrigation water sources, with the bottom line being that the island has more than 250 MG per day of potential irrigation capacity. Sunflower and safflower take an average of 1500 gallons per day per acre.

Key Finding: The total irrigation water capacity can, as a result, support up to 166,667 acres in production. This report will identify the potential watershed support to irrigation, though the actual irrigation system design is beyond the scope.

1.3 Hawaii Island Soils

The biofuels crops under consideration in this report require soils that are in the classification ranges between loamy and clay. These are high organic bearing soils, with some water retention capability. The soils of Hawaii Island as well as those of the entire state originate from volcanic parent materials, and have depths ranging from less than a foot up to about 8 feet. Depth is important and the oil bearing crops are drought resistant which develop deep root systems to seek out water. Hawaii Island is composed of 5 major volcanoes, listed in order of age oldest to youngest as: Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea. Soils formed on the two oldest volcanoes Mauna Kea and Kohala are formed from weathered ash and tend to be deep and less rocky depending on the location in relation to volcanic events. It is only in the oldest volcano, Kohala Mountain, that rock has weathered significantly as part of the soil forming process. The soils on the younger volcanoes, Hualalaie, Mauna Loa, and Kilauea tend to be shallow and rocky, at times just a thin layer of organic matter coating the basalt rock. As a result, the best biofuels crop soils are generally those that surround Mauna Loa, Mauna Kea, and Kohala, which are those on the northern half of the island.

Finally, the soil suitability is specifically affected by a distinct set of criteria, those being water holding capacity, soil texture, stoniness, pH, and soil charge. The significance of these properties is as follows:

Water holding capacity is the amount of water held within a soil between field capacity and permanent wilting point. Field capacity is the amount of water in a soil after it has been saturated and then let to drain 24 hours. It is a measure of the amount of water in the fine pores of a soil. This has a direct effect on the ability of the crops to find water without irrigation.

Soil Texture is the ratio of sand, silt, and clay that make up the soil. Texture varies with soil depth and landscape position. It is an important soil property because it drives soils fertility and the potential for agronomic production. Finer texture is preferred as it improves water holding and improves nutrient availability. The soils in Hilo/Puna and Waimea are relatively fine.

Stoniness or the amount of rock fragments greater than sand size particles is important as this may affect the tillage and other agronomic costs. New soils and shallow soils generally have far more rock fragments. Soils in the bands around Mauna Loa and Mauna Kea have generally the least stoniness.

pH is considered a master variable in crop production. The best soils are those with neutral or slightly base pH. pH has many variables, and will be measured at each site. Costs go up significantly for sites that require significant lime addition.

Soil charge is often a good indicator of soil fertility and correlates well with soil pH. The amount of negative charge indicates the soil's potential to hold plant essential nutrients to the soil particles and maintain them within the soil solution, making them available to plants. Soil charge is measured at each site, with the Waimea and Puna sites having good negative charges.

Key Finding: Stoniness is generally only a factor in the initial field preparation costs, which is important in land prioritization, but does not exclude regions. pH is also a correctible factor with soil amendments, and so affects costs but not biological viability. Soil charge as a measure of nutrient holding capacity is significant in that poor nutrient holding capacity is a very expensive issue to correct, and so is a driver in land selection. Soil texture is also requires significant soil amendment use to correct, and poor water holding capacity is a clear down select factor in land identification.

1.4 Land Regulations

The primary regulations that effect the land use are those related to the use of the Department of Hawaiian Home Lands. The State Constitution sets aside these lands for use by the beneficiaries of the trust. The lands that are designated pasture, which represent the vast majority of lands under consideration for inclusion in the biofuel program, restrict the use of the land for growing crops. Only crops that produce livestock feed are allowed. Sunflower is an acceptable crop, and can be grown on up to 50% of any given parcel, with the average parcel size being 300 acres.

2. Available and Suitable Lands

This section identifies available land inventories that could support biofuels crop growth. The regions from Waikoloa to Kona are not included in the land inventory specifically because there is very little rainfall, and poor access to the islands watersheds, with the result being that there is not a reliable volume of water available on the lands to make them viable for the crops of interest. Additionally the lands on the west side are in small parcels with uneven topography that is far better suited to coffee and macadamia.

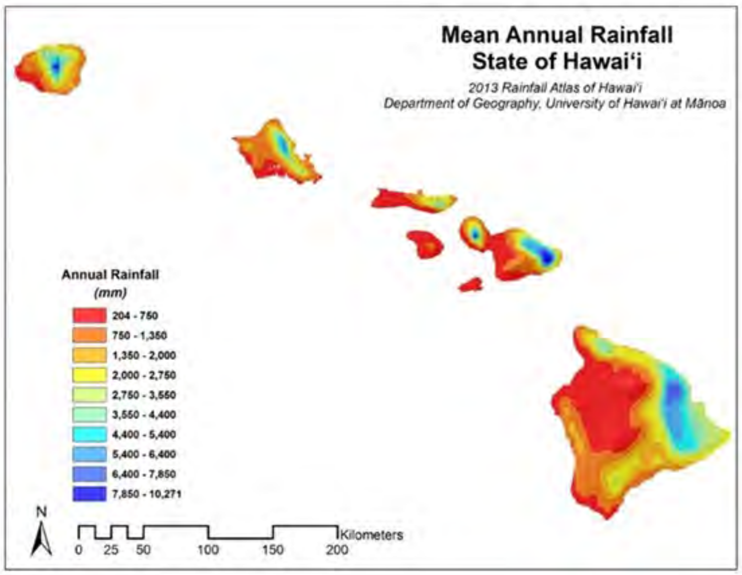

Figure 4: Hawaii Annual Rainfall

Figure 4 below provides rainfall estimates that indicate on average across the State. Sunflower, statistically, grows best in regions with between 400mm and 1000mm per growing cycle, so roughly 800mm to 2000mm in annual rainfall. Sunflower will grow in areas with higher rainfall, though with lower oil yields per pound of seed.

LUPAGMap Designation	Puna	Sout h	North Hilo	Hamakua	North Kohala	**South Kohala**	North Kona	Sout h	Ka'u	Total
High Density Urban	0	847	0	0	0	**0**	458	0	0	1,305
Medium Density Urban	478	1,481	69	292	176	**1,282**	1,456	292	421	5,947
Low Density Urban	8,013	10,073	617	2,293	2,668	**5,084**	6,287	1,070	1,148	37,253
Industrial	669	4,264	29	132	51	**1,869**	3,889	0	74	10,977
Important Agricultural Land	49,770	37,237	21,632	78,023	41,314	**51,500**	26,703	32,804	47,300	386,28[illegible]
Extensive Agriculture	88,573	26,078	31,755	82,924	21,885	**71,299**	105,074	66,368	167,426	661,38[illegible]
Rural	29,251	2,542	71	0	102	**1,908**	1,001	31	13,090	47,996
Resort / Resort Node	0	84	0	0	47	**3,212**	2,289	15	29	5,676
Open Area	2,335	1,798	434	1,266	2,119	**14,074**	6,233	2,699	4,738	35,696
Conservation	137,210	167,779	119,710	235,212	11,217	**13,957**	199,585	43,395	426,956	1,355,0[illegible]
Urban Expansion Area	3,844	122	62	0	258	**12,264**	11,995	0	597	29,142
University Use	0	664	0	0	0	**0**	461	0	0	1,125

Source: County of Hawai'i General Plan 2005

Figure 5: Hawaii County GIS Land Survey

Figure 5 above is drawn from the Hawaii County land database, and provides a list of the acres of land designated agriculture and otherwise. This information only provides a listing based on county allocation, and does not represent an actual survey of the agriculture potential of any given plot.

The acres of interest are those lands identified by the Agricultural Lands of Importance to the State of Hawai'i Study as “Prime” or “Unique,” lands identified by the Land Study Bureau’s Soil Survey Report as Class B “Good” soils and lands classified as “fair” for two or more crops, on an irrigated basis by the USDA NRCS study of suitability for various crops.

2.1 Waimea/Kohala Region

The Waimea region is dominated by lands designated as either important or extensive agriculture lands. The region provides the largest single parcels, and has roughly 126,800 acres which could be used for biofuel crops, with no less than 54,000 of these accessible within a year or less. This 54,000 includes both private and trust lands to include estimates of roughly 7000 acres out of the 21,000 acres in ranch land on the Hawaiian Homelands and 47,000 acres of other private lands. There are very few government lands available in the region.

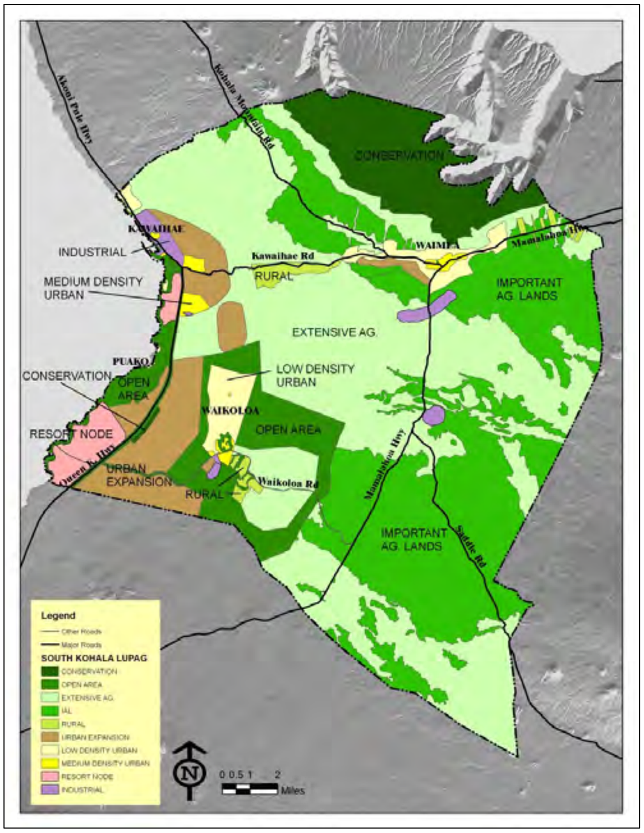

Figure 6: South Kohala (Waimea) Land Designations

Figure 6 above provides a pictorial description of the land designations, which indicate the size of the agriculture plots in the region. Additionally, the land is largely flat and level as it sits in the valley between Mauna Kea and Kohala mountains.

Key Finding: The Waimea/Kohala region has 54,000 acres of land that can be used for biofuels crops.

2.2 Hamakua/North Hilo Region

While there are 214,334 available lands in the region, the rainfall exceeds the viable levels for sunflower growth in most of the region and the lands have significant nutrient depletion which would require costly additives to be used each harvest. Additionally, the largest landowner, Kamehameha Schools, has put over 90% of their land into forestry. A comprehensive review of the remaining available lands led to the conclusion that the region does not present a good opportunity beyond 100 acres of the Hamakua Springs Farm that are currently used for corn growth.

Key Finding: This regions lands are largely already encumbered and not available for biofuels crop use.

2.3 Puna/Hilo Region

This region has 201,658 acres of agriculture lands available, with large parcels most of which are devoted to ranching, tropical crops, macadamia nut, and ornamental crops. The papaya fields, which extensive, are on lands whose soils are not suitable for biofuels crops and so there is no natural land competition in the region. The lands most of likely to support the needs are those owned by W.H. Shipman, which are planned agriculture lands with good topography, though near the high end of rainfall

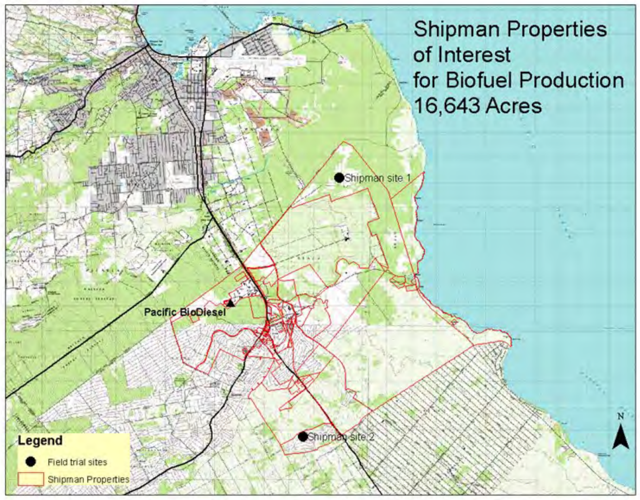

Figure 7: Available W.H. Shipman Lands

Figure 7 depicts the W.H. Shipman land holdings which are likely the best candidate lands for larger parcels.

The Puna/Hilo region is the area of the island that requires the least irrigation as the area has significant rainfall. However the soils are more variable, and many of the potential sites may require significant soil additives. The most likely lands are the 16,643 acres of flat agriculture land owned by W.H Shipman as the vast majority of the remaining lands in the region are either marginal, or already under long term lease.

Key Finding: This region has more than 20,000 acres readily available for biofuels crops.

2.4 Ka'u Region

This region has 214,726 acres of available agriculture land, but has many challenges which make it less economically viable than other regions. The land is largely sloped, with less organically rich soils. Most importantly, it is in a very remote region, with a limited agriculture workforce and long driving distances to the nearest processing facilities. The region could support significant acreage in crop growth, with recent efforts having been made to put as much as 23,000 acres into oil trees.

Key Finding: This region has more than 30,000 acres available for biofuels crops, though the logistics are significant concerns.

3 Factors Affecting Suitability

This section provides a description of the factors that are used to assess the available lands to determine the lands most suitable for biofuel crop growth. The section also details the application of the factors to each region.

3.1 Irrigation Capacity

The ability to inexpensively irrigate lands is both a production and economic driver in controlling the oil content and biomass growth of the biofuels crops. Ideally sunflower will use roughly the equivalent of 18-300 inches (roughly 450 to 750mm) of rain during its 4 month growth cycle, with the bulk of that need coming early in the cycle. This would indicate that regions with 30-80 inches (750mm to 2000mm) of annual rainfall are viable, though in fact regions with less rainfall, but access to irrigation water are more productive due to the need to starve the plant of water over its last 30 days to maximize oil production in the seed.

Of the regions in consideration, irrigation is most critical in Waimea where the annual rainfall is not generally sufficient to support 100 day growth cycles. In the South Hilo/Puna region there is sufficient rainfall to manage the crop growth with only the need for occasional use of the water system and no requirement for additional infrastructure.

The Waimea Region current irrigation system is built around water from the Upper Hamakua Ditch, which is over 100 years old. The ditch system gathers surface water, with the 3 input flumes taking in between 500,000 and 45,000,000 gallons per day depending on rainfall. The system, when first constructed, produced between 4 and 16,000,000,000 gallons per year according to US Geologic Service records. In its current state of repair the ditch has reduced the annual production to 800,000,000 gallons per year on average due to water losses. A review of USGS rainfall studies going back to 1918 show that rainfall has stayed within a 20% plus or minus band over the entire period, and 2014 had 1% more rainfall than 1918, so reduced rainfall does not factor in to water availability. The most significant needs are increased storage and increased water generation. As figure 9 below shows below, the daily sustainable ground water yields for the Waimanu and Waimea watersheds, which are the two which would be accessible for the irrigation system, are 134 million gallons per day. This would support over 89,000 acres at the 1500 gallon per day average needed for sunflower/safflower.

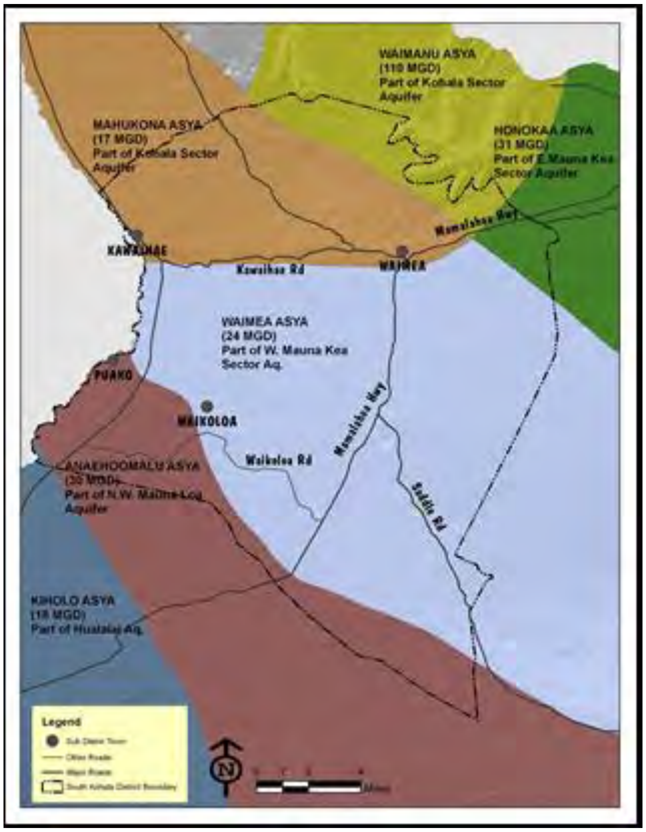

Figure 9: Waimea Region Watershed Sustainable Water Yields

Figure 9 shows the daily sustainable ground water yields for the Waimanu and Waimea watersheds, which are the two which would be accessible for the irrigation system, are 134 million gallons per day. This would support over 89,000 acres at the 1500 gallon per day average needed for sunflower/safflower.

In the Ka'u region, there is an estimated 52,000,000 gallons per day of sustainable water yield in proximity to the agriculture lands of interest. This region is very sparsely populated, and so the majority of the water is available for use. This is enough to support 34,500 acres of production.

Key Finding: Using 50% of the estimated water available, the watersheds in Waimea could support up to 45,000 acres. In the Ka’u region, the watershed has the capacity to support an additional 34,500 acres.

3.2 Soils and Topography

Soil and topography are most limiting to biofuels production from an economic standpoint. Soils which have low water handling, nutrient content of pH require significant resources to support soil additives and fertilizers. Uneven or slopped land reduce the size of the farm equipment which can be employed, and so increase the labor and equipment costs per acre farmed.

The University of Hawaii at Hilo has extensive soil maps and topography maps available for all the agriculture lands on Hawaii Island. The UH-Hilo team conducted site soil sampling at all the locations, the highlights of which will be available as an appendix to the Task 8 Mid-Crop Growth Report, and are available on request. The results of these samples, and of the review of the database indicate that the soils in Waimea, Puna, and Ka'u are best suited to support the crop growth. The soils north of Mauna Kea are loamy, and carry significant nutrients. The soils in Puna and south are composed of significant amounts of clay, and so retain a lot of water. There are roughly 120,000 acres of suitable lands in Waimea, 89,000 acres of suitable lands in Puna/South Hilo, and 105,000 acres of suitable land in Ka'u.

A second significant factor is topography. The lands in Waimea are relatively flat and can be leveled, so more than 95% of the lands with appropriate soils also have topography suitable to biofuels crops. In Puna/South Hilo over 75% of the lands with good soils also have suitable topography, Ka'u has far more lands that sloped, roughly 64,000 of the acres that have suitable soils do not have ideal topography. The Ka'u lands are still in the range of suitable, but would be the most expensive to farm due to the need for smaller, less efficient equipment.

Key Finding: In each region the acreage of land with viable soils and topography exceed the irrigation capacity, and so soils and topography are not a limiting factor.

3.3 Road and Port Infrastructure and Access

Road infrastructure is critical to biofuels crops economic viability. Generally Hawaii Island has one major belt highway that all long haul trucking must use. The Waimea and Puna/South Hilo lands have sufficient connecting road infrastructure to provide access to all the major land parcels. Ka'u has less developed road infrastructure, and will require some investment in access road construction to reach all the parcels.

Both Puna/South Hilo and Waimea have access to ports within 15 miles of the agriculture lands. Ka'u lands are fairly distant from both the ports and potential processing sites, with distances as far as 80 miles, and probable need to divert traffic to avoid lava flow blockages. The distances from Ka'u do not rule out the potential of the region, but must be factored into the economic viability calculations as they do add costs to every aspect of the operation. The Task 5 report economic analysis provides additional details on hauling distance economic impacts.

Key Finding: Infrastructure access and distance to major transportation hubs indicate that the Hilo/Puna and Waimea provide the best potential for initial commercialization.

4 Conclusion

This section provides a summary of the cumulative lands across Hawaii Island, as well as an assessment of the aggregate fuel production capacity that could be supported from those lands. The biofuel estimates are based on average industry conversion rates and not on specific technologies. This is, as a result, a conservative estimate as the most efficient technologies will have higher production rates.

4.1 Total Available and Suitable Lands

The total available lands across Hawaii Island are 757,518 ranging from Ka'u to Kohala. These lands all meet the minimum requirements for biofuels crops. **However the lands suitable and available for biofuels crops are significantly lower at roughly 82,000.** These are specifically:

1) Waimea/Kohala - The suitable inventory is 45,000 acres. The reduction is driven by the availability of agriculture water in the region.

2) Hamakua/North Hilo - The lands here are limited to roughly 400 acres. The factors reducing the availability are excessive rainfall, predominantly sloped terrain, additionally most of the lands which would provide marginal capacity to support biofuels crops have been put into forestry.

3) Puna/South Hilo - The suitable inventory is roughly 19,500 acres with soils, and excess rainfall being a predominate reason for reduction. Slope is an issue with some of the lands as well.

4) Ka'u - The suitable inventory is roughly 17,000 acres. The reduction has two predominant drivers, lack of access to water and lack of access to roads. These lands are also the most expensive to operate.

4.2 Total Fuel Production Potential

The suitable lands generate fuel potential by two means, oil and cellulosic biomass. The overall project is defining production based on 10,000 acre units, however this report is evaluating overall potential so will aggregate to a final figure. Each 10,000 acres, as documented in the Task 5 and Task 7 reports, produces roughly 950,000 gallons of oil and 100,000 tons of dry biomass per harvest. The growth cycle for the crops is 100 days plus or minus 10 days. This would conceptually allow for 3.5 harvests per year, but with cover cropping, soil rest and crop rotation the actual number is closer to 2.2. For purposes of this report the number used is 2.2 is used to match with the other assumptions.

- At 2.2 harvests per year, each 10,000 acres will produce 2,090,000 gallons of oil and 220,000 tons of dry biomass.

- With 82,000 acres available, the total is 8.2 times the 10,000 acre unit. As a result Hawaii Island has viable potential to produce 17,138,000 gallons of sunflower oil annually and 1,804,000 tons of dry biomass annually.

- The industry average is 9.0 gallons of biodiesel for each 10 gallons of sunflower oil. The result is a potential for roughly 15,250,000 gallons of biodiesel.

- The industry average is 51 gallons of fuel for each ton of biomass input. The result is a potential for roughly 92,000,000 gallons of advanced biofuels. **Note that the cellulosic systems are less commercially proven, and conversion rates are less certain**.

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Hawaii Military Biofuels Crop Program
Hawaii Island

Task 7
Supply Chain Plan

Prepared For:

Office of Naval Research

Under Sub Award Number MA150004 from:

Hawaii Natural Energy Institute

University of Hawaii

Under Award N00014-11-1-0391

Prepared By:

Rivertop Solutions LLC

PACIFIC BIODIESEL TECHNOLOGIES

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1. Introduction – Task 7

The Task 7 Statement of Work is as follows: The team will research and develop a complete supply chain logistics model covering farming to processing to end user (including consumer market for co-products). The report will provide a supply chain diagram, description of each element of the chain, and overall assessment of costs and efficiencies. The plan will identify import or local sources for inputs (seed and fertilizers), identify the best sites for processing biomass based on crop growth, identify transportation plans to include frequency for biomass pickup, and outline methods for getting products to final markets to include potential use of Defense Logistics Agency transport assets for DoD procured fuels.

1.1 Assumptions

The supply chain logistics discussion uses the following assumptions to develop the model for farming and producing fuel and other co-products from the seeds and biomass. Costs and efficiencies for logistics are discussed. Logistics discussed in this Task are narrowly defined as the transportation costs associated with moving inputs to the farming sites, farming outputs to the processing sites, and final products to market. Costs for raw materials and economic modeling for finished products are not part of this discussion.

Farming - The supply chain logistics model uses sunflower as the oilseed crop. Logistics for other similar short rotation crops may be similar. The model assumes 10,000 acres will be harvested each year. Based on experience with multiple crops trials in Hawaii, sunflower crops are known to require an average of 100 days from planting to harvest. Only 2.2 harvests per year are assumed for this study, requiring 4,545 acres under lease (10,000 acres / 2.2 rotations = 4,545 acres).

Trucking – Moving product by truck is the only viable option between points on Hawaii Island. Trucks can move biomass on flatracks, seed in bins, raw materials in containers, and fuel or raw oil in tankers. Trucking costs in Hilo today average $75.00 per hour including driver and truck. Standby time to load or unload the truck is at the same rate. This report assumes a 60-mile distance one-way from port to field and from field to biodiesel processing facility. Travel time is 1.5 hours each way, plus .8 hours loading and unloading, or $285 round trip (3.8 x 75 = $285.00)

Shipping – Moving materials from a typical West Coast location to Hilo port is assumed to be $4,500 for a 20' container, and $6,000 for a 40' container (Pasha or Matson rates). Shipping materials inter-island is typically $600 for a 20' container, and $1,000 for a 40' container.

The following discussions will use the above assumptions, as well as local knowledge, to make broad statements regarding the logistics cost.

2. Sunflower Farming Logistics

Farming 10,000 acres of sunflower will require the following material inputs based on current test plot results. (*Refer to Appendix 1 for the supply chain diagram on sunflower farming.*)

2.1 Seed. Seed will be planted at an assumed rate of 25,000 seeds per acre, or 3.65 pounds of seed per acre. This converts to a total of 36,500 pounds required per year for 10,000 acres. While heirloom seed can be saved from one harvest to be planted on the next planting, most farming in the U.S. is done with hybrid seed. It is assumed for this discussion that hybrid seed will be used, sourced from a company such as Nuseed Americas, Inc., a leading hybrid sunflower seed company, and transported via standard ocean freight containers to Hawaii Island.

Hybrid Seed. Many high yielding varieties of sunflower are hybrids. The seeds of the sunflowers grown from them will not be true to type and will require the farmer to order again for consistent results. Hybrid seeds have been optimized through breeding for specific growing environments such as low/high rainfall, wind, and other weather considerations. Additionally, hybrid varieties have the advantage of being bred for increased production, decreased time to maturity and inherent seed compositions such as high oleic fatty acid profiles. While many hybrid corn seeds are produced in Hawaii, there are currently no hybrid sunflower seeds available except from the US mainland.

Heirloom Seed. Heirloom seed varieties have the same characteristics of the plant that bore them. By using heirloom seeds, farmers can save some of their harvest for replanting rather than bringing in seed for every planting. Heirloom seed may be more difficult to grow, as it has not been optimized through a breeding program such as hybrid seed. It would be expected that yields could be significantly less for heirloom plantings. Heirloom seeds require minimal logistics. Seeds can be harvested from one field and replanted during the following planting.

Table 1 shows the anticipated cost of moving seed from the U.S. mainland to the planting sites on Hawaii Island.

Table 1

Planting Seed Logistics

Pounds per acre	3.65	
Pounds per year	36,500	
Local truckloads per year	2	$570.00
Import containers per year	2	$12,000.00
Logistics cost per year		$12,570.00

2.2 Fertilizer. Sunflower requires the addition of nutrients to the soil to produce commercially viable amounts of seed and biomass. There will be a preference to create nutrients using green manure, cover crops, rotational crops, and locally sourced nutrients. For the following discussion, we will assume the worst-case scenario of using all commercial fertilizers. For 10,000 acres, the following amount and type of fertilizer will be used. Appendix 4 explains the development of these requirements. Initial soil stabilization and nutrition is variable depending on the previous land use. The amounts discussed below are for on-going requirements after the first crop. Calcium carbonate is sourced locally from dredged coral sites. Brewer Environmental Industries (BEI) in Hilo sells crushed calcium carbonate from a stockpile in Kawaihae. BEI does not anticipated that this very large supply will be depleted in the near future. Sulfate of potash is sourced locally as a co-product of the biodiesel process. Urea and phosphate will be sourced locally from a company such as BEI Hawaii and delivered by truck, or imported by shipping container from the US West Coast. For these products we are calculating 20 tons in each 40' shipping container. One delivery truck will take the container to the site.

Table 2 shows the anticipated cost of shipping fertilizer from the US mainland (urea and phosphate) and Hawaii (potash and calcium) locations to the planting sites on Hawaii Island.

Table 2

Fertilizer Logistics

	Urea	Triple Super Phosphate	Sulfate of Potash	Calcium Carbonate
Pounds per acre	150	100	100	500
Tons per year	750	500	500	2500
Import containers per year	38	25	0	0
Shipping cost per year	$228,000	$150,000	$-	$-
Local delivery trucks per year	38	25	25	125
Trucking cost per year	$10,830	$7,125	$7,125	$35,625
Total logistics cost for fertilizer	$238,830	$157,125	$7,125	$35,625

2.3 Herbicide. Herbicide or a cover crop can be used to control weeds prior to planting each sunflower rotation. Cover crops require minimal logistics. If herbicides are used, a product such as Honcho will be sourced locally from BEI Hawaii. Logistics required for acquiring herbicide is shown in the following table. All of the herbicide for one year, procured in plastic totes, can be delivered on one truck.

Table 3 shows the cost of shipping herbicides from the source in Hilo to the planting sites on Hawaii Island.

Table 3

Herbicide Logistics

Gallons per acre	0.25
Gallons per year	2,500
275 gallons totes per year	9
Truckloads per year	1
Trucking cost per year	$285

Sunflower Farming Conclusion

Moving fertilizer to the farm is the largest logistics task for farming sunflower. An average of 2.2 truckloads of material per week will deliver all products to the farm.

3. Seed Harvesting and Processing Logistics

The sunflower farm will produce two primary products: seed and biomass. The biomass will be converted to energy at a biomass facility. The seed will be pressed into oil and meal at a crushing mill.

The logistics plan for harvested seed and biomass incorporates the use of the versatile hook-type semi-truck. This method was selected for efficiency of loading and unloading and optimizing truck turn-around time. Following is an analysis of the transportation costs.

3.1 Biomass Conversion Facility. Biomass can be processed into fuel through biomass pyrolysis, direct combustion, or gasification technology.

The best anticipated site for processing biomass into fuel would be as close as possible to the source of biomass. The site should be zoned for heavy industrial use, although agriculture zoning may be allowed depending on technology and scale. For this discussion it is assumed this site is on the same island, within 50 miles of the sunflower farming sites.

For sunflower, leaves and chaff from the combine will be left in the field for soil nutrition. The stalks will be cut, dried and baled in the field. Large square bales have been selected for efficient handling and maximum load size for on-highway trucking. Bales will be placed on hook-type flat racks, which will be picked up daily by a hook-type semi-truck and transported to the biomass facility. Truck capacity is limited by bale size; 18 tons can be transported on one truck load. We have chosen 3,000 pounds per harvested acre of biomass, based on our preliminary field data and industry data. This number is for discussion purposes only and must be verified by larger field trials at some later date.

Table 4 shows the cost of moving the biomass portion of the crop from field to processing facility. This represents one of the major logistics costs for the project and warrants further research and verification.

Table 4

Biomass Logistics

Pounds per acre	3,000
Tons per year	15,000
Truck loads per year	834
Trucking costs per year	$237,690

3.2 Crushing Mill Logistics. It is assumed that harvesting 10,000 acres of sunflower in one year will produce 18,720,000 pounds of seed per year. This number is a best estimate, and must be confirmed for the various sites using 100-acre plantings. The seed will be transported to the crushing mill for oil extraction using 40-yard capacity hook-type roll-off bins holding approximately 12.5 tons of raw seed, hauled by a hook-type semi-truck. (*Refer to Appendix 2 for the supply chain diagram on oil extraction.)*

Two products are created at the crushing mill – sunflower oil and sunflower meal. The sunflower oil will be extracted from the seed at the crush mill using mechanical screw press technology. For this discussion average yield numbers of 38% oil and 62% meal are used for the crush. A crushing mill facility would be required, sized to process the anticipated volume of sunflower seed. The best location for such a crushing mill would be adjacent to a local biodiesel production facility. Both food-grade and raw oil would be produced. Producing food-grade oil for sale at a higher margin will help to reduce the cost of the raw oil to the biodiesel refinery, which helps reduce the market price of biodiesel. It is proposed that 25% of the oil will be food-grade, all of which would be consumed in Hawaii and sold to a wholesale packaging vendor for final distribution. This packaging facility would be located on Oahu close to the largest market. Logistics are calculated for shipping food-grade oil only to Oahu by ISO-tanker with a capacity of approximately 6,500 gallons (24 tons) per unit. The raw oil will be transferred to the biodiesel refinery by pipeline (assuming the crushing mill is adjoining). No logistics cost are required for this transfer. The meal from the crush will be sold and transferred to a ranching operation for animal feed. The same roll-off bins that brought in the harvested seed are used for this transfer, at roughly 20 tons per load.

The following tables show three related logistics cost segments. Table 5 shows the cost of moving harvested seed to the crushing mill. Table 6 shows the cost of moving food-grade sunflower oil to a packaging plant. Finally, Table 7 shows the cost to move the meal to an animal feeding operation.

Table 5
Harvested Seed Logistics

Pounds per acre	1,872
Tons per year	9,360
Truck loads per week	14.4
Truck loads per year	749
Cost to ship seed to mill per year	$213,465

Table 6
Sunflower Oil Logistics

Gallons per acre (7.5 lbs. per gallon)	95
Gallons per year	950,000
Food-grade oil per year (25%)	237,500
ISO-tanker shipments per year	37
ISO-tanker shipping cost per year	$22,200

Table 7
Meal Logistics

Pounds per acre	1161
Tons per year	5803
Truck loads per week	5.6
Truck loads per year	290
Trucking cost per year	$82,650

Seed farming and processing conclusion
The largest logistics task is shipping the biomass, the least dense product, to the processing facility. The next largest task is shipping the whole seed from the field to the crushing mill. Oil logistics are optimized by transferring the oil by pipeline to the biodiesel facility. Many of the logistics tasks may be optimized by backhaul of processed materials if markets can be established in specific areas.

4. Biodiesel refining

The biodiesel refinery is the central facility that converts the raw sunflower oil to biodiesel (*Refer to Appendix 3 for the supply chain diagram on biodiesel refining*).

The refinery process uses four inputs: raw oil, methanol, potassium hydroxide and sulfuric acid.

A. Sunflower oil will be sourced locally from the crush mill and will be transported via 6,500 gallon ISO tankers or direct pipeline.
B. Methanol is imported from a West Coast source such as Vitusa Corp in Washington state and transported to the biodiesel refinery in ISO tankers.
C. Potassium Hydroxide is sourced locally from BEI Hawaii and transported in pallets of 50-pound sacks on flat bed semi-trucks.
D. Sulfuric acid is sourced locally from BEI Hawaii and transported in ISO tankers.

Note: Since the biodiesel refinery will produce fuel using mainland oil if locally sourced oil is not available, there are no additional logistics required for the chemical raw materials for the biodiesel process.

The refining equipment includes stainless steel storage and processing tanks, evaporation and distillation towers, pumps and automated controls. Sunflower oil can be processed at the same cost or less than other vegetable oils currently being refined into biodiesel in Hawaii.

The biodiesel refinery outputs are crude glycerin, potassium sulfate, distilled biodiesel and heavy boiler fuel. For this discussion, biodiesel output is set at 90% of the vegetable oil input. (reference: Big Island Biodiesel production records). Crude glycerin is sold to local feed markets. Customers typically purchase the product at the processing facility. Potassium sulfate is used locally for fertilizer at the farming operations. Logistics for this item are included in the Fertilizer section. Heavy boiler fuel is used directly at the biodiesel facility for process heat.

Biodiesel is shipped in 6,500 gallon ISO tankers to neighboring Hawaiian Islands using Young Brothers barges. In some cases, the ISO tankers are delivered directly to end users. In other cases the ISO Tankers are emptied into terminal tanks or transit trucks for delivery to end users.

For DoD consumption, we anticipate sending ISO tankers to a base fuel depot on Oahu for storage and preparation for deploying through normal DoD assets. If a dedicated fuel storage tank were established in Hilo, bulk loads could be loaded into DoD fuel ships at the port of Hilo.

Table 8 shows the cost of shipping finished biodiesel to neighbor island markets (Oahu, Maui, Kauai) from Hilo in 6,500 gallon ISO Tankers.

Table 8

Biodiesel Processing Logistics

Gallons per acre (95 gal oil x 90% yield)	85.5
Gallons per year	855,000

ISO Tankers per week	2.5
ISO Tankers per year	132
Shipping ISO to Oahu	$79,200

5. Conclusion

The discussion in this report analyzed the anticipated logistics in both scale and cost of moving materials to and from the farm, processing facility, and market. Capital costs and operational costs for the farming and processing operations were not part of this discussion.

The location of the biomass conversion facility relative to the farming operation will impact overall economics. Reduction of mainland fertilizer requirements would be vital for logistics cost reduction. While much more in-depth research and test farming is required, the logistics costs are in line with expectations.

Table 9 shows the total logistics cost from previous Tables of sunflower farming inputs and transportation of products to the processing facilities and then end users.

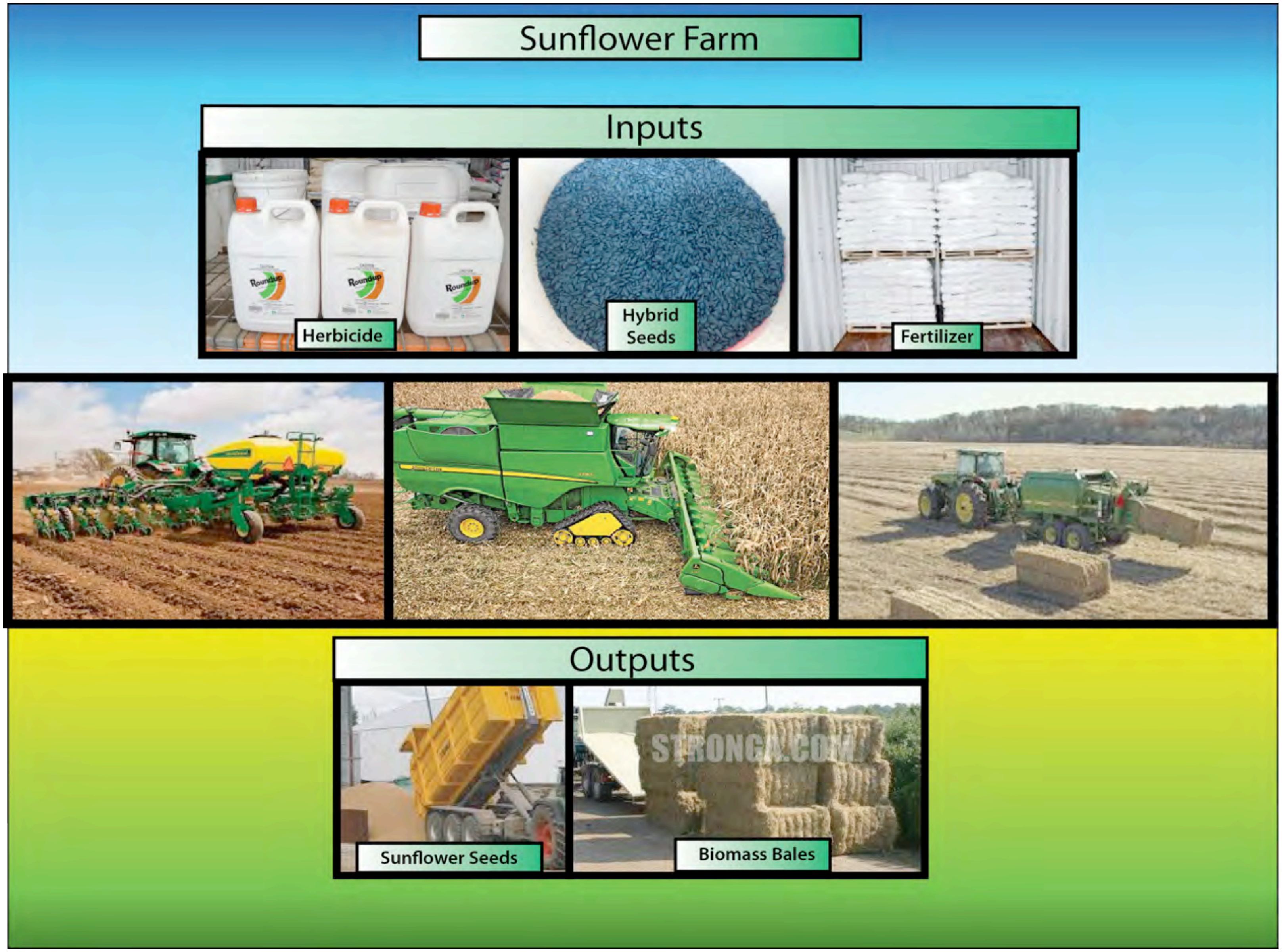
Table 9

Logistics Cost Totals

Planting Seed Logistics	$12,570
Fertilizer Logistics	$438,705
Herbicide Logistics	$285
Biomass Logistics	$237,690
Harvested Seed Logistics	$213,465
Sunflower Oil Logistics	$22,200
Meal Logistics	$82,650
Biodiesel Logistics	$79,200
Total	$1,086,765

Appendix 1

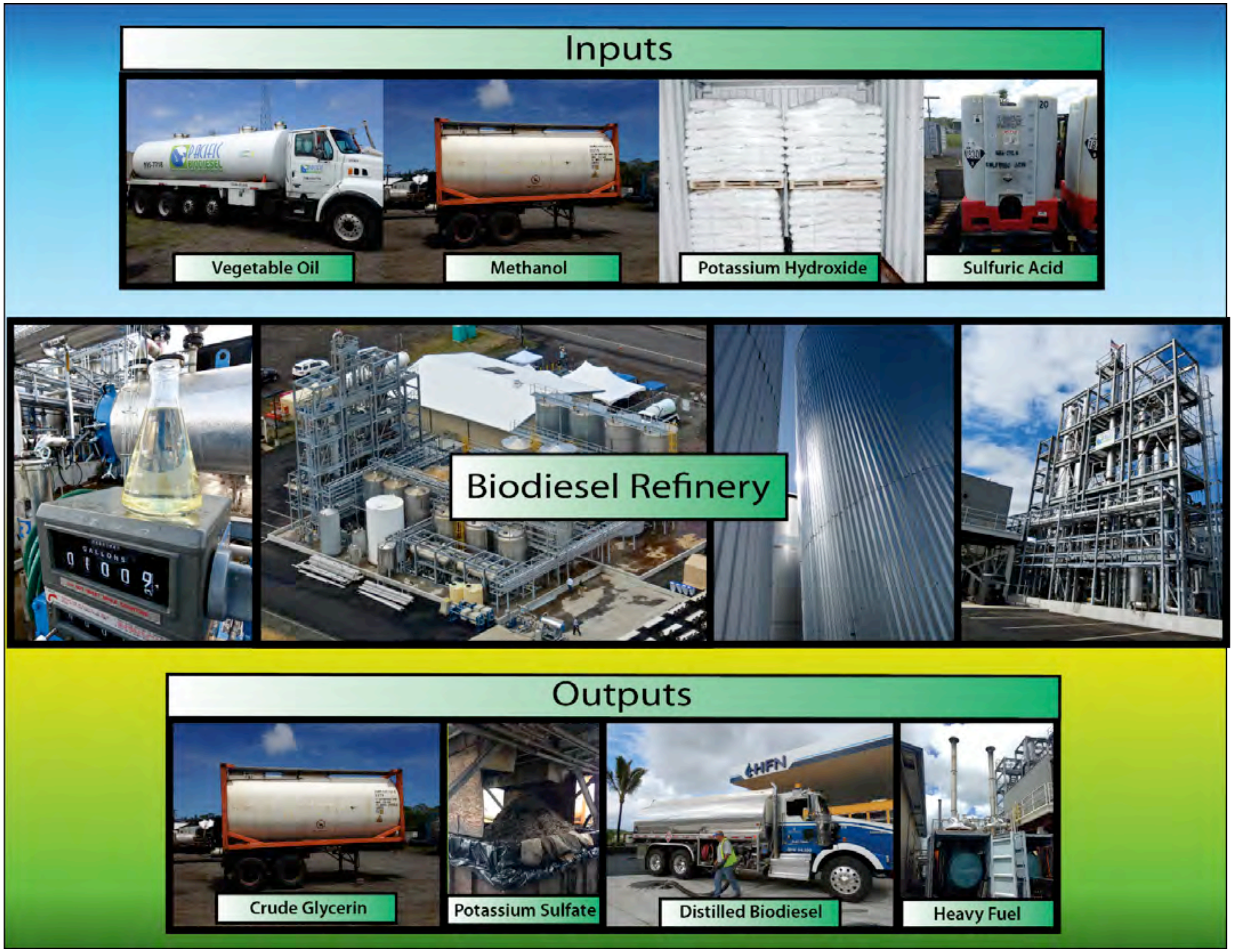
Supply chain diagram for sunflower farm.



Appendix 2

Supply chain diagram for crushing mill

Appendix 3
Supply chain diagram for biodiesel refinery



Appendix 4

The following chart from North Dakota State University shows the NPK levels required in the soil for a given sunflower seed yield goal. Sunflower does not require a large amount of fertilizer inputs, but without a consistent supply of nutrients every season, yields will not remain on a commercial scale. We have not determined that the nutrient recommendations apply to sunflowers grown in Hawaii. This data will serve as a reference point for discussion.

Nutrient recommendations for sunflower

			Soil Test Phosphorus, ppm				
	Soil N plus		VL	L	M	H	VH
Yield	fertilizer	Bray-I	0-5	6-10	11-15	16-20	21+
Goal	N required	Olsen	0-3	4-7	8-11	12-15	16+
lb/a	lb/acre-2' depth		lb P2O5/acre				
1000	50		20	15	10	0	0
1500	75		30	20	15	0	0
2000	100		40	30	20	10	0
2500	125		50	35	25	10	0

			Soil Test Potassium, ppm				
	Soil N plus		VL	L	M	H	VH
Yield	fertilizer	Bray-I	0-40	41-80	81-120	121-160	161+
Goal	N required	Olsen					
lb/a	lb/acre-2'		lb K2O/acre				
1000	50		35	25	15	0	0
1500	75		55	40	25	10	0
2000	100		70	50	30	10	0
2500	125		90	65	40	15	0

Local sources of nutrients are available, and include cover crops, compost, meat and bone meal, crushed coral and potassium sulfate.

Cover crops can be grown and incorporated into the soil to amend the nutritive and physical characteristics of the soil. Leguminous crops like soy or sunn hemp can, with the help of bacteria, "fix" nitrogen into the soil from the air. Sunn hemp as an interim crop rotation will fix up to 100 pounds equivalent of nitrogen into the soil available for the next crop. Sun hemp also has the benefit of suppressing nematode populations in the soil. A cover crop rotation of sun hemp will greatly reduce the amount of conventional nitrogen required for application.

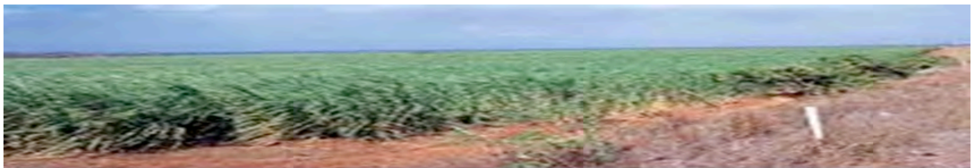
Compost is aerobically decomposed plant matter rich in humus and containing moderate amounts of N P and K. Compost will have a long term benefit on the soil, building soil structure, slowing nutrient leaching and replacing the organic matter in the soil. Compost will be a necessary component over the long term sunflower planting, as the sunflower biomass will be baled and removed from the field and not allowed to work back into the soil.

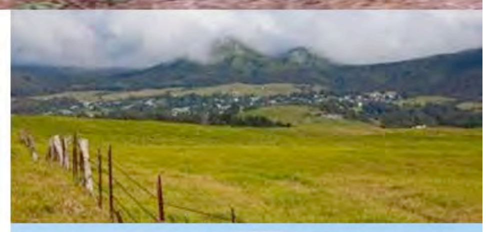
Meat and bone meal is typically found as a by-product of the rendering industry. The product contains on average 8% Nitrogen, 5% phosphorus and 10% calcium. The product could be used as a general soil amendment, acting as supplemental nitrogen, supplemental phosphorus and to boost the pH of soil through the calcium.

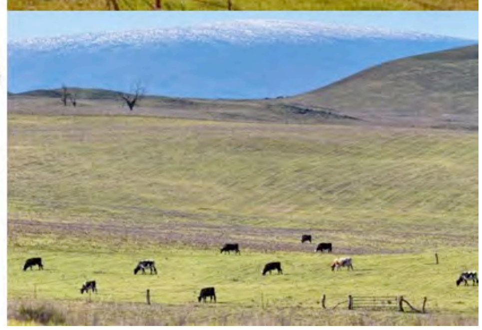
Potassium sulfate is a by-product of locally produced biodiesel. This product is able to be directly input into the field, and would provide the same results as conventional potassium.

Hawaii Military Biofuels Crop Program
Hawaii Island

Revised SOW Task 8
Bioenergy Farm Analysis







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PACIFIC BIODIESEL TECHNOLOGIES

New Task 8

Bioenergy Farm Analysis

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Forward

This Bioenergy Farm Analysis has been developed to provide a comprehensive plan for the development and operation of a farm utilizing 10,000 acres per year in a single region. The report is based on existing field test experience and data, as well as research conducted to determine equipment (e.g. vehicles, harvesters), utilities, road and building infrastructure, land preparation and processing equipment required to support the farm operations. The report identifies specific equipment, equipment costs and confirms infrastructure required for both state government provided and private surface and ground water irrigation. Included is an estimate of the potential uses for the silage in energy production using USDA supported cost estimates for conversion plants. The report also incorporates a farm plan that describes the fencing, wind break, irrigation, farm practice and rotation/cover crop plans and comprises a comprehensive review of the planning and permitting requirements including permits, environmental assessments, civil engineering and cultural/unexploded ordinance monitoring required during land preparation.

List of Acronyms

BIB	Big Island Biodiesel
BTL	biomass to liquids
CFB	circulating fluidized bed
CWT	hundred weight
DCFROR	discounted cash flow rate of return
FCI	fixed capital investment
FT	Fischer-Tropsch
GGE	gallon of gasoline equivalent
GIS	Geospatial Information System
IC	indirect costs
IGCC	integrated gasification combined cycle
LT	low temperature
MM	million
MTG	methanol to gasoline
MW	megawatt
Nm^3	normal cubic meter
PSA	pressure swing adsorption
PV	product value
SPR	slurry phase reactor
SMR	steam methane reforming
TCI	total capital investment
TDIC	total direct and indirect cost
TIC	total installed cost
tpd	tons per day
TPEC	total purchased equipment cost
WIS	Waimea Irrigation System

1. Proposed Farm

The biofuels enterprise has the markets and the existing biodiesel production capacity to process the output of 55,000 acres of harvested sunflower annually. This capacity is primarily defined by the 5MM+ gallon annual capacity of the Big Island Biodiesel (BIB) plant. Field tests to date have confirmed that sunflower can be expected to produce roughly 100 gallons of oil per acre per harvest. BIB can produce 90 gallons of biodiesel for every 100 gallons of sunflower oil, and thus can process up to 55,000 harvested acres. The field test have also shown that two harvests per year are reasonable as the time from germination to harvest has been averaging between 109 and 112 days at the test sites. With time for a cover crop, both harvests can be achieved; thus 27,500 acres planted twice annually can be converted to biodiesel with existing BIB facilities.

1.1 Size/Locations

For purposes of this plan, a farm size of 10,000 acres will be evaluated. This report will describe a plan that identifies two regions best suited to support a farm of that size, Waimea/Lalamilo and Hilo/Puna. Each of these regions has unique requirements, water being the primary difference. In neither region will the 10,000 acres be contiguous, though proximity will be less than a mile separation between any two plantings.

Figure 1: Google Earth Image of Waimea/Lalamilo Available Lands

Figure 1 shows the lands in the region that have the best immediate potential to serve as the site for the 10,000 acres of sunflower farming. This land is currently held by Parker Ranch and Hawaiian Homestead lessees.

1.2 Farm Plan Objectives

The farm plan anticipates that the 10,000 acres of usable land will produce 20,000 acres of harvested sunflower each year. With 50 working weeks each year (two weeks for vacation and contingencies), the farm will plant 400 acres each week, and harvest 400 acres each week. In a 5-day work week the operations anticipate four days of field work and one day of equipment and site maintenance. This work cycle will require the crews to plant 100 acres and harvest 100 acres each day. This plan supports a minimum individual plot size of 100 acres.

The field testing, and economics analysis (Task 5 Report) indicate that the overall supply chain costs are significantly reduced with continuous harvesting and planting which reduces the size of the equipment needed, dramatically reduces the needed storage and provides for more efficient use of infrastructure.

The specific objectives of the farm Plan are as follows:

1) Develop one hundred planting sites of 100 contiguous acres
2) Site a central operations facility from which all equipment/teams will be dispatched
3) Design farms to minimize travel distance from central site to farming sites
4) Select farming sites which minimize required infrastructure/land preparation investment

The Farm Plan (section 4 of this report), will address these objectives and identify the anticipated solution. Both regions have lands that are well suited to meeting all the objectives, though the specific infrastructure investments do vary.

1.3 Required Infrastructure

The farm sites have both common and unique infrastructure. All sites have in common the need for road and water access. Power and telecommunications are not required at the farm sites, though will be required at the central facility. Cell phone reception is preferable to enable efficient operations, but not a specific requirement. Other potential infrastructure needs include fencing, wind breaks and onsite storage, all of which may vary by site. Specific requirements are identified below.

<u>Waimea/Lalamilo</u>

The Waimea/Lalamilo region includes, according to the GIS planning data provided in Figure 2 below, roughly 150,426 acres of agriculture land. The research conducted in support of Task 6 found that roughly 54,000 acres of the land are available and could be accessed by the biofuels enterprise in the near future.

Districts	Agricultural	Conservation	Rural	Urban	Total
Puna	175,104	138,563	146	6,329	320,142
South Hilo	70,695	169,493	0	12,814	253,002
North Hilo	53,587	120,110	71	608	174,376
Hāmākua	162,729	235,805	13	1,041	399,588
North Kohala	64,713	13,187	16	2,434	80,350
South Kohala	**150,426**	**15,356**	**53**	**10,608**	**176,443**
North Kona	158,853	188,331	477	17,787	365,448
South Kona	110,749	35,051	31	845	146,676
Ka'u	237,743	422,239	0	1,801	661,783
Total	1,184,599	1,338,135	807	54,267	2,577,808

Source: DBEDT, Office of Planning GIS data

Figure 2: DBEDT GIS Data

The primary reason that the lands are currently lightly used is a lack of water infrastructure. The region, as identified in the Task 6 Report, has more than sufficient water resources, and only requires investment in infrastructure. Figure 1 outlines roughly 54,000 acres of the 150,000 identified in Figure 2. The land is accessible from county cinder roads, which are more than sufficient to handle the equipment needed to prepare, plant and harvest the lands, though additional road infrastructure will be required to specifically reach some of the lands which are currently in large pasture lots. The region has two available cinder sites which have the capacity to support all the needed road construction, reducing costs.

Hilo/Puna

The North and South Hilo districts present a large area of agricultural lands, totaling roughly 124,282 acres (Figure 2). These districts were largely divided into smaller parcels in the post sugarcane plantation era. This will limit availability of the lands for sunflower plantings by the biofuel enterprise.

Due to the fact that the bulk of land available to the biofuels enterprise was managed under the sugar plantations, roadway infrastructure and accessibility within these regions is readily available as the network of both paved and non-paved roads still in existence. These roadways are more than sufficient to handle the equipment needed to prepare, plant and harvest the lands.

Although the Puna district has 175,104 agricultural acres (Figure 2), the vast majority lies undeveloped. The largest landowner in the district, WH Shipman Limited, has roughly 2,500 acres of land suitable for sunflower.

The 2,500 acres are not a contiguous piece, but the parcels are connected to county roads via private gravel roads. Much of this land would require significant development to gain full use and access for efficient land management.

For all three districts, water infrastructure is extremely limited. Due to climatic conditions, water is not a concern as these areas receive extreme amounts of rain.

1.4 Required Farm Equipment

Based on the need to plant and harvest 100 acres each working day, the 10,000 acre farm will require moderate sized equipment capable of automating all major operating functions. The following list represents the major equipment required for each 10,000 acre farm. The daily harvest requirement is much lower than counterpart mainland farms which harvest in short periods once per year, but the equipment for the Hawaii farm is used continuously so sizing takes into account wear and operating cycles. Sunflower is a tough plant and causes significant wear on harvesting equipment, and so the larger sized equipment allows for longer equipment life. The list below also provides expected equipment life which varies from one to 20 years based on use and function.

The required equipment list has been developed based on independent research as well as interviews with the National Sunflower Association, Smude Farms, Nuseed and USDA. The required equipment includes (initial number in parenthesis indicates number required):

1. (1) Class 8 combine (Class 8 is equal to 375 hp or greater). Combine should be on tracks. Example: John Deere Combine https://www.deere.com/en_US/products/equipment/grain_harvesting/combines/s_series/s_series.page
    a. Cost: $400,000
    b. Expected Life: 10 Years
    c. Purpose: Provides platform for planting and harvesting equipment. Mid-sized combine is well suited for smaller (100 acre) plots, while still retaining the capacity for larger plots.
2. (1) Sunflower header. Example: Fantini pan style sunflower header. http://www.fantininorthamerica.com/html/girasole.html
    a. Cost: $5,000
    b. Expected Life: One Year
    c. Purpose: Removes sunflower heads from plants in order to harvest seeds. The sunflower plant is very tough and farmers indicate the header will likely need to be replaced annually.
3. (2) 345 hp rubber track tractors (tracks provide significant speed improvements on uneven ground). Example: John Deere 8345RT. Alternative is to use a D8 for disking, planting, costs are higher and slower, however D8 required for initial land clearance. http://www.tractorhouse.com/list/list.aspx?ETID=1&Manu=JOHN+DEERE&Mdltxt=8345RT&mdlx=exact
    a. Cost: $275,000
    b. Expected Life: 10 Years
    c. Tow equipment needed to prepare land for planting and move equipment to and from planting area. Have capacity to pull the disc rig.

4. (2) 200 hp rubber tire tractors. Example: 7830 model tractor. Use for transporting seed and biomass from harvester to staging area. http://www.tractorhouse.com/list/list.aspx?ETID=1&Manu=JOHN%20DEERE&Mdltxt=7830
    a. Cost: $150,000
    b. Expected Life: 10 Years
    c. Provides the towing power needed to pull the seed bins and bale trailers from the fields to collection areas. Have good speed for on-road transport.
5. (1) Disc unit. Example: Case 530C. http://www.caseih.com/northamerica/en-us/products/tillage/disk-rippers/ecolo-tiger-530c
    a. Cost: $50,000
    b. Expected Life: 3-5 Years
    c. Used to prepare land in between plantings. Will not be used for initial land preparation due to need to pull rocks. Most wear is anticipated in first two years as rocks are surfaced and cleared.
6. (1) Seed drill. Example: Sunflower Manufacturing model # 9421- 25. http://www.tractorhouse.com/list/list.aspx?ETID=1&Manu=SUNFLOWER&Mdltxt=9421-25&mdlx=exact
    a. Cost: $75,000
    b. Expected Life: Five Years
    c. Purpose: Sunflower seed drill is designed to plant at pre-set spacing and seed depths. As with other equipment, mid-size seed drill allows better maneuvering on the smaller 100-acre plots.
7. (1) Sprayer. Example: Ag Spray Equipment Model HBS1210F. http://www.tractorhouse.com/listingsdetail/detail.aspx?OHID=8272505
    a. Cost: $3,000
    b. Expected Life: 20 Years
    c. Purpose: Sunflower plots will not be irrigated as the plant does not require irrigation for the majority of its growth cycle. The spray rig will be towed by a 200 hp tractor.
8. (1) Biomass cutter/windrower. Example: https://www.deere.com/en_US/products/equipment/hay_and_forage_equipment/windrowers/windrower_traction_units/d450/d450_self_propelled_windrower.page?
    a. Cost: $100,000
    b. Expected Life: Two Years
    c. Purpose: Use to cut sunflower silage following removal of sunflower heads. The equipment is anticipated to have significant annual wear due to silage fibers being difficult to cut.
9. (1) Baler. For baling biomass. Example: https://www.deere.com/en_US/products/equipment/hay_and_forage_equipment/balers/large_square_balers/large_square_balers.page?
    a. Cost: $125,000
    b. Expected Life: 8-10 Years

    c. Purpose: Gathers cut silage and creates square bales which are simple to transport to central facilities.

10. (2) Off-road chassis for transport of seed and biomass from field to staging area. Example: Stronga HLT250 hook lift trailer. http://www.hooklifttrailers.com/25TonneHookLiftTrailer/25-Tonne-HookLift-Trailer.htm
    a. Cost: $65,000
    b. Expected Life: 20 Years
    c. Purpose: Provides trailer capacity for hauling of seed and silage bales from harvest sites to central facility

11. (4) 40-yard hook type dump bins. Universally connects to any hook chassis, off-road or on-road. Example: Stronga open hook lift bulk container. http://www.hooklift-containers.com/BulkCargoContainers/BulkCargo-Containers.htm
    a. Cost: $10,000
    b. Expected Life: 20 Years
    c. Purpose: Bins serve as actual collection unit for the sunflower seed

12. (4) Flatbed hook containers. Example: Stronga flatbed carrier. http://www.hooklift-containers.com/FlatbedContainers/Flatbed-Plant-Containers.htm
    a. Cost: $5,000
    b. Expected Life: 20 Years
    c. Purpose: Flat carrier serves as the hauling unit for the silage bales

13. (1) On-road hook type semi-truck. Kenworth T-800. 350 to 450 hp. Example: http://www.truckpaper.com/list/list.aspx?catid=801&Manu=KENWORTH&bcatid=27
    a. Cost: $150,000
    b. Expected Life: 10 Years
    c. Purpose: Truck to haul (10)/(11)/(12) from farm sites to central processing facility

14. (1) Low-boy equipment trailer for hauling tractors, attachments, etc. Example: http://www.truckpaper.com/listingsdetail/detail.aspx?OHID=4816583
    a. Cost: $75,000
    b. Expected Life: 10 Years
    c. Purpose: Trailer for moving larger equipment such as combine between sites.

15. (2) 4000 Gallon Water Tank Truck: Example: Kenworth T800 http://www.dogfaceequipment.com/equipment/t800-4000-gallon-water-truck/
    a. Cost: $30,000
    b. Expected Life: 15 Years
    c. Purpose: Haul agriculture water to farm sites for irrigation.

Figure 3: Images for Farm Equipment 1-6

Figure 4: Images for Farm Equipment 7-15

Figures 3 and 4 above provide examples of the type and size of equipment needed to support the Farm Plan, but are not intended to identify or select the manufacturer.

1.5 Supporting State/County Infrastructure

The primary County infrastructure involved in the project are the fire and access roads maintained on the Homestead, and the belt highway which will be used to move the sunflower seed and biomass from the fields and the processing site to the Big Island Biodiesel facility. Hawaii County Safe Drinking water will also be used at the processing facility, particularly for the virgin cooking oil which must meet FDA food safety requirements. In the Waimea/Lalimilo region there is an existing 8-inch main stubbed off at the site which would serve as the processing facility. This main has more than 500% of the required capacity to support the processing facility. BIB already has access to county safe drinking water. The biofuels enterprise will use the county waste system, but this will not require any additional infrastructure as the existing system of waste transfer stations is sufficient. Lastly, the biofuels enterprise will be reliant on the county emergency services. Both sites are in close proximity to ambulance, fire and police.

The State would primarily support the farm through the provision of agriculture water, in the event that the enterprise and State agree that expansion of the State system is the best approach. The Waimea Irrigation System (WIS) has the water resources to support the entire project requirements, but currently lacks storage and the ditch collection system needs significant repair. In full repair the system produced an average of 8MM gallons per day from 1919-1960 with equivalent rainfall conditions as seen on the Kohala Mountain today. The system was originally designed with over 300MG of storage, but this was reduced following the State assumption of the previously privately run system to the current 60MG. The Waimea region has 24MG per day of sustainable ground water yield that is basically untapped, and provides the opportunity to evaluate alternative irrigation water system design. The WIS is built on a 24-inch main core, and has more than sufficient distribution capacity.

The North and South Hilo and Puna districts have no formal irrigation systems due to high rainfall conditions resulting in a minimum of 130 inches of rainfall near the coast and a maximum of over 300 inches at 2,000-3,000 feet elevations. (NOAA 2015) http://www.prh.noaa.gov/hnl/climate/phto_clim.php.

2. Capital Costs

2.1 Expected Land Costs

The current agriculture land lease prices in the Waimea region run between $100 and $300 per acre per year for irrigated land, and $40 per acre per year for pasture lands. More than 95% of the land under consideration for the biofuels enterprise are currently in pasture. Initial discussion with the landowners in the region indicate that long term leases would likely be achievable at $100 per acre. Many of the ranches currently lease 100 acre plots for $4000 per year. Some examples of recent leases include:

1. 40 Acres of Hawaii Department of Agriculture land in Hawaii North Kohala for $5130 (Item V) http://hdoa.hawaii.gov/arm/files/2012/12/Notice-of-Lease-by-Negotiation-11-11-13.pdf
2. Hawaii county Hamakua Agriculture lands at $11.63 per acre http://www.hawaiilife.com/articles/2011/08/hawaii-county-offering-leasehold/

On fee simple lands, the lands that currently lack access to water have sold in the range of $500 per acre, though that price has been significantly affected by the US Army purchase of 24,000 acres of Parker Ranch land for $11MM. For purposes of planning, it is likely that $750/acre would be an average across the various plots.

These costs would result in Waimea/Lalimilo land costs of either $1MM per year for leased land, or an investment of $7.5MM as a single investment.

Land on the east side of Hawaii Island varies significantly in price between the North/South Hilo districts and the Puna district. Unlike the Waimea region, prices in these three districts are driven by soil quality. For instance, North/South Hilo have deep, workable soil that ideally suits high value cash crops such as ginger and sweet potato. Alternatively, Puna has soil that is generally made up of a younger, rocky mix of decomposed organics that averages only a few inches of topsoil. Only a select few crops can be grown in this media, resulting in prices that are much lower than North/South Hilo.

Landowners in both regions indicate lease prices per acre in Puna average roughly $350 per acre per year. In North/South Hilo, market prices per acre per year for leased land are close to $1000.

The majority of the land lying in the North/South Hilo and Puna districts has been divided into smaller farms of less than 100 acres. It is recognized that outright purchase of a large area of land there would likely not be feasible.

The above mentioned lease information would result in total lease costs of $10MM per year in North/South Hilo and $3.5MM in the Puna district.

2.2 Farm Equipment Costs

The farm equipment listed in section 1.4 above covers all of the major equipment for each 10,000 acre farm. There are many minor items that are consumable and used in routine farm operations such as shovels, wheel barrows, and so on. These items are covered in the business plan as operating expenses and thus not included here. The costs for each piece of equipment are covered in 1.4.

The cumulative cost for the equipment is **$2,083,000**.

The annual depreciation, based on expected life cycles is **$246,500**.

2.3 Infrastructure Costs

The total infrastructure cost varies significantly based on the determination of whether to use private or State-owned agriculture water system. A decision to build a private water system has the positive impact of insulating existing farmers from any impacts of the increased water usage in the region. Additionally, the private water system can provide backup to the aging State WIS, and so would likely garner the support of the existing farming community, which might otherwise express concerns about the plan. For purposes of this assessment, it is assumed that the water system will be private. The biofuels enterprise will also need to construct private roads to provide internal access to many of the sites, as well as storage for roughly 1000 acres of harvest to ensure no loss of harvest during maintenance periods for the processing equipment.

The three basic components of the water system are a ground well, a reservoir system and a distribution system. The Task 6 report cited the sustainable yield studies, while the latest test drill information from the University of Hawaii at Hilo Geology Department provides evidence that the water resource would be reached at roughly 1,500-foot depths. The lands will not need to be permanently irrigated as field tests have demonstrated that sunflower only requires irrigation for roughly three weeks during the growth cycle, and only 1-2 days per week (two days in the first two weeks, and one day in the third week. This will mean that on any given day only 400 acres will be irrigated at 3,500 gallons per day, or 1.4MM gallons per day. A system with the capacity of 2MM per day allows for loss and maintenance periods. Storage is generally 20-30 times one day's usage for systems dependent on pumped water using ground water sources. To support this, a 60MM gallon reservoir will be used for planning. The reservoir will be placed no less than 100 feet higher than the highest farm plot to allow gravity feed distribution. Most sites will be developed with feed from a Driscoll line distribution infrastructure, though some sites may depend on trucked water. The costs for these systems are:

1) 2MM gallon per day well, drilling and pump installation at a 1,500 foot depth, with pump building and foundation - $5,500,000
2) 60MM gallon reservoir - $4,750,000
3) Distribution system for 2MM gallon per day (24-inch) - $1,650,000

These estimates are based on current water system design costs developed to support the Hawaii Department of Agriculture and Mauna Kea Soil and Water Conservation District. Reservoir costs are developed using the information gathered by NRCS to support the Waimea – Paauilo Watershed Environment Impact Statement.

Road infrastructure costs are based on the use of local cinder from the Waimea region, which will enable a material cost of roughly $300,000 per mile. It is likely that 4-5 miles of internal roads will be required, with resulting material costs of $1,500,000 and labor/construction costs of an additional $200,000 per mile for a total of $2,500,000.

Sunflower storage in purpose built silos runs roughly $250,000 for 2000 tons of storage. This is sufficient for the Farm Plan. With pad and construction, the total cost is $350,000.

3. Projected Operating Costs (Field Test Specific)

The Task 5 economic analysis report developed a set of assumptions on farm operating costs based on existing mainland data. Task 7 further refined the information to incorporate expected Hawaii shipping and cost differentials into all the imported supplies. Following the initial field tests, several key findings emerged that will affect operating costs. First, the field tests have shown a lower need for fertilizer than is found on the mainland, though the long range sustainability of the soils will likely require increased fertilizer use over time. A second key finding saw improved germination rates with early irrigation, either as a result of rainfall or irrigation. This second finding will add some cost per acre to account for the water usage, with the expectation that at roughly $21 per acre foot, and a need for 1.5 acre foot of water per acre over the 110-120 day growth cycle, adding up to $31.50 per acre for water costs.

Projected Full Farm Annual Operating Costs				
Cost Category	**Per Acre / Per Harvest**	**Harvest Multiple**	**Annual Full Farm**	**Notes**
Land Preparation	$30.00	2	$600,000.00	Assumes land to be cleared by disc vice till
Seed and Treatment	$47.91	2	$958,200.00	Importing seed at Nuseed pricing
Cover Crop	$65.00	2	$1,300,000.00	Based on winter wheat costs in South Dakota
Fertilizer	$12.12	2	$242,400.00	Original Estimate of 150 lbs acre revised to 37 lbs per acre
Herbicide	$12.50	2	$250,000.00	Not currently used, estimate is for future use
Fungicide	$9.75	2	$195,000.00	Not currently used, estimate is for future use
Insecticide	$11.25	2	$225,000.00	Not currently used, based on future use of Neem oil
Import Logistics	$12.25	2	$245,000.00	Roll up from Task 7 Report at 25% usage rate
Fuel	$13.25	2	$265,000.00	Reflects use of biodiesel
Labor (hourly)			$1,831,992.00	Roughly 4 times Task 5 costs due to 10,000 acre farm size
Labor (Benefits)			$366,398.40	Estimated at 20% of labor
Crop Insurance	$21.17	2	$423,400.00	USDA signficantly revising crop insurance program
Land Cost (Lease)	$25.00	2	$500,000.00	Annual Lease at $50 per acre averaging pasture and ag
Equipment Depreciation			$246,500.00	
Water/Irrigation	$31.50	2	$630,000.00	Either payment to State or to repay infrastructure loan
Transport to Processing	$23.77	2	$475,400.00	Based on Task 7 Report
Accounting/Legal			$45,000.00	
Total Annual Operating Cost			**$8,799,290.40**	
Operating Cost Per Acre			**$439.96**	

Figure 5: Annual Operating Costs

Figure 5 above provides the breakdown of the annual operating costs. The per acre cost of $439.96 is below most of the mainland costs, due largely to the higher usage rate of the land. The Hawaii acreage would be in production 320-340 days of the year, while mainland farms are in production roughly 190 days.

There are several less significant cost revisions that the crop tests have shown to date. The stronger per acre harvest size increases the number of trips required to haul the seed to the crushing mill. Although the original plan postulated that the land be tilled between crops cycles, subsequent tests have shown that till-free is better suited to the Waimea lands, with a far less expensive disc approach being sufficient to maintain the land in plant ready states.

4. Farm Plan

4.1 Fencing

All the proposed sites currently have fencing in place to support cattle operations. To support the specific plots and road development, additional fencing will be constructed along any new road. Several of the sites border small pre-existing streams, where the water attracts goat and pig populations. For these sites, added chain link fencing will be put in place. To date no field test sites have been disturbed by either pig or goat activity, though two of the Waimea sites have had goat traffic in the vicinity of the planting.

4.2 Windbreaks

Sunflower is a plant that thrives on the stress presented by wind, with the plant reacting by drawing additional nutrients from the ground to create more fibrous stalks. This wind stress preference has been confirmed by the success of the plant in the very windy plains surrounding the Black Sea and in the plains of the Dakotas. As such, wind breaks are planned at larger than the normal intervals. On the larger parcels, wind breaks will be built surrounding 400 acre parcels. Each smaller scale parcel will also have wind breaks down to a minimum size of 100 acres. The specific tree varieties will be developed in consultation with the parcel owners to match their overarching farm plans.

4.3 Land Preparation

The initial land preparation will be the most labor and cost intensive phase of the operation. Much of the initial effort will be to identify the lands which will present the least effort to develop, with the constraint of creating 100 acre contiguous parcels at a minimum. The basic process will employ bulldozers in the D8 to D10 size range to create initial disc passes. This has been previously completed in the Waimea region in the early 1950’s, and interviews with local farmers indicate that 3-5 passes were required. When the disc operations uncover rocks, these will be removed by excavators and rock trucks, and crushed to provide a base for the roads. Once the majority of the rocks have been removed, additional passes with the disc will be made to cut the root system of the grass, and to prepare the soils for the planting. It will likely take 4-5 years to completely prepare all the land.

4.4 Irrigation

Irrigation will be done with large, mobile sprayers which will be moved from site to site. Each region will be provided with corrugated steel tanks which will hold sufficient water to support the pumps, likely 100,000 gallons, and will be filled by a Driscoll line from the reservoir during irrigation operations. The irrigation system will use 3000 gallons per minute from the tank. Each acre requires 3,500 per day according to USDA and HDOA, with a total of 400 acres being irrigated on any given day for a total of 1.4MM gallons. To achieve this, the irrigation will be operated roughly eight hours per day in order to provide 1,440,000 gallons to cover the daily water requirements. Plots will be irrigated twice per week during the first and second week after planting, and once per week in the third week. After that no irrigation is needed unless a significant drought of more than 20 days is experienced.

4.5 Soil Management

Given the field test results, the current soil management plan will be to front-load the soil with roughly 32 lbs. per acre of nitrogen in the form of urea, and with calcium to promote phosphorous uptake. After the first 2-3 harvests, it is anticipated the all the nutrients required by the plant will be front-loaded prior to planting to allow the soils to remain healthy. The root systems from the sunflower will be cut and retained in the soil by the disc operations to provide nitrogen and micro-organism replenishment. The enterprise will use organic pest management approaches, and avoid the use of herbicides to the greatest degree possible. The creeping nature of the kikuyu grass may require the use of Roundup on the areas surrounding the parcels to prevent the spread during the fallow on crop rotation periods, though field tests to date have shown that the sunflower is dominant enough to choke out the grasses during its growth cycle.

4.6 Crop Rotation

Each crop will be followed by a 50-60 day cover crop, with the specific rotation to be determined by ongoing field tests. Typical rotation crops include legumes, grain sorghum, grasses, winter wheat (not a candidate in Hawaii), corn and alfalfa. Standard rotation cycles from the mainland provide some useful information regarding good crop choices, but the winter cold season has effects on the soils and pests that are not seen in Hawaii. As a result the crop rotations will be developed during the first several years of larger scale operation.

4.7 Planting

Planting will be automated with the use of a seed header towed by a tractor, likely with 27,000 plant per acre rates and 3-inch seed depths. The field tests to date have shown an average root ball size of eight inches, which support the suggested spacing. Following land preparation the sites will be planted in 100 acre parcels. The rows will be spaced to allow irrigation rigs to cover all the planting areas. Sites will be irrigated at 3,500 gallons per acre immediately following planting. The nitrogen and phosphorous will be applied to the land at the time of planting, but separated from the seed to prevent burning the plants.

4.8 Harvesting

Harvesting will be automated by use of a combine, seed header, biomass cutter and baler. The first pass will cut the heads from the sunflower and collect them in bins which will transport the heads to the processing facility. Following the completion of the harvesting of the heads, the biomass cutter will take the silage from roughly two inches above the ground, and leave collectible piles in lines through the fields. The final stage is the baler. The baler will take the silage and create large rectangular bales, which will be picked up by trucks and transported to the processing facility are well.

4.9 Jatropha Farm Specifics

Jatropha is a long-term orchard crop, therefore the jatropha farm will be developed in a manner which maximizes maintenance and harvesting efficiency.

The farm will be planted in a grid formation with access roads and borderlands built in according to the demands of the mechanical harvester. Vertical access roads will be placed every 800 feet and horizontal access roads every 400 feet. Maintenance and harvesting support personnel will use these access roads to perform duties.

The ground will be cleared by bulldozer, and smoothed for maximum long-term farm maintenance and harvester efficiency. Plants will be planted in a manner that maximizes efficiency; rows will be oriented East-West, and will be spaced on 12 foot centers. Plants will be planted 3.5 feet apart.

Wind is not a concern at the geographical location in which the farm lies. Therefore, no windbreaks will be planted.

Fencing is not necessary for the farm. There are no animals which pose a threat to crop performance at the location of the jatropha farm.

5. List of Required Documents

5.1 Environmental

The determination to develop an environmental impact statement will be guided by Hawaii Revised Statutes Chapter 343. The statutes do not require an Environmental Assessment for private lands, as long as no State of County funds are used. However, the Homesteads Lands are Trust lands for which the State of Hawaii has fiduciary responsibility. As such, according to HRS 343-5 (a) (1), an Environmental Assessment will be required for the agriculture and agriculture processing components if they alter the existing uses for the land. This would only affect the actual processing facility. The most likely location for the processing facility is co-located with the Waimea Nui Community Development Initiative Agriculture Complex, which has already completed a Final Environmental Assessment as of May 2015. As such, it is not expected that any HRS 343 requirements will be imposed.

5.2 Civil Engineering

Civil engineering for the project will be required to support the road construction, as well as the irrigation system easement. If a new building is constructed to support the processing facility, a civil engineering plan will be required for the foundation as well as the electrical, water and wastewater infrastructure.

5.3 Permits

In 2012 the Hawaii legislature passed Act 203, which is designed to encourage the expansion of local agriculture in the State. Each County has adopted Act 203 into the respective County Code. The Act has been adopted in HRS as well in section 46-88. This section states that "The aggregate floor area of the exempted agricultural buildings shall not exceed….eight thousand square feet plus two per cent of the acreage per zoning lot for lots greater than five acres.." in HRS 46-88 (2) (c) (1) (C). The act further provides the definition of the exempt structures, which cover all the facilities expected to be used by the enterprise. The following excerpt from HRS 46-88 (8) provides:

> "(8) Permit-exempt structures shall be exempt from any certificate of occupancy requirements.
>
> (d) As used in this section:
>
> "Agricultural building" means a nonresidential building or structure, built for agricultural or aquacultural purposes, located on a commercial farm or ranch constructed or installed to house farm or ranch implements, agricultural or aquacultural feeds or supplies, livestock, poultry, or other agricultural or aquacultural products, used in or

necessary for the operation of the farm or ranch, or for the processing and selling of farm or ranch products.

"Agricultural operation" means the planting, cultivating, harvesting, processing, or storage of crops, including those planted, cultivated, harvested, and processed for food, ornamental, grazing, feed, or forestry purposes, as well as the feeding, breeding, management, and sale of animals including livestock, poultry, honeybees, and their products."

There are several permits that will apply to the operation. These are:

County Permits:

- Sign Permit (Public Works Building Division)
- Grading & Grubbing Permit (Public Works Engineering Division)

State Permits:

- Department of Planning and Permitting Construction Plan Review and Approval (State)
- Department of Health Construction Plan Review and Approval
- Dealer License (DOA Commodities Branch)
- Underground Storage Tank Permit (DOH Solid and Hazardous Waste)
- Solid Waste Management Permit: Remediation (DOH Solid and Hazardous Waste)
- Water Quality Certification (DOH Clean Water Branch)
- NPDES Permit (DOH Clean Water Branch)
- Food Establishment Permit (DOH Food and Drug)
- Food Safety Certification
- Community Noise Permit (DOH Indoor and Radiological Health)

5.4 Unexploded Ordinance Mitigation

As of December 2014 the Army Corps of Engineers (ACE) has determined that the former Waikoloa Maneuver Area, which constituted the training areas for troops during World War II, may have included the farm and pastoral regions that represent the lands identified for the biofuels enterprise. The ACE has determined that the lands have been in continuous agriculture use, and that agriculture operations do not present an unusual hazard. As such, the lands designated for sunflower growth do not require clearance, and will follow the existing procedures requiring all work to stop if ammunition is discovered, that the police be notified, and that the DoD be brought in to detonate or destroy the munitions.

The facilities and roads, however, will require an initial scan of the land intended for use, and will require an on-site monitor for any "earth altering activities" such as excavation.

5.5 Archaeological/Cultural

Continuing agriculture operations do not require State Historic Planning Department (SHPD) approval. All road and facility construction will require clearance. The region has been in agriculture production or forestry for most of the last 500 years. There are also several historic sites whose locations are held confidential by the State Burial Council. The lands do have several of these sites, and the development plan will require planning to avoid any of these areas. The site of the processing facility already has a SHPD clearance as part of the Waimea Nui Final Environmental Assessment as well as a Federal National Environmental Policy Act (NEPA) finding of No Significant Impact (FONSI).

6. Opportunities for Silage Conversion

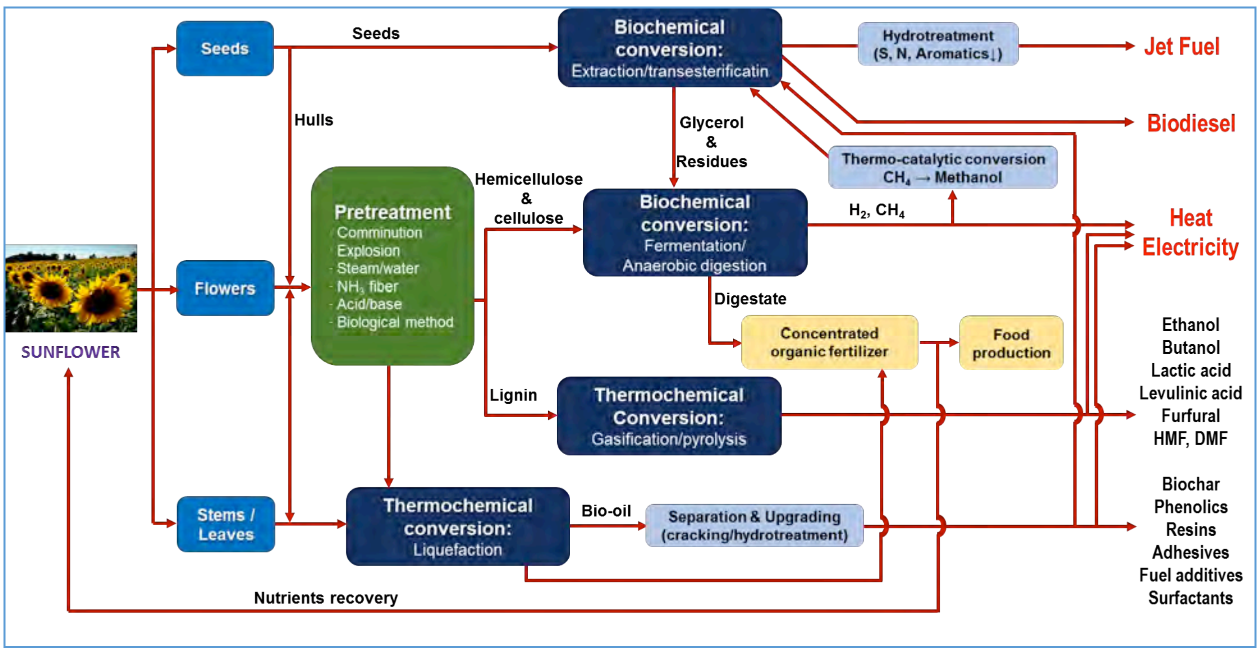

Figure 6: UH-Hilo Developed Conversion Technology Overview

Figure 6 above has been developed by Dr. Shiwu Sung at the University of Hawaii-Hilo to provide a comprehensive overview of conversion pathways for the sunflower plant. The two primary paths are biological and thermochemical. The island currently has one of the most advanced biodiesel plant in the nation which employs transesterification to convert oils to biodiesel. The remaining biomass, referred to as silage, can be processed either by biochemical or thermochemical means. An overview of these paths is provided below.

6.1 Biological Conversion

Biochemical conversion employs biological and chemical breakdown of organic materials to produce gas, alcohols, or other chemical products. The major types of biochemical conversion technologies:

- Anaerobic Digestion
- Aerobic Digestion
- Transesterification
- Catalytic Cracking of Plastic (Not covered as plastic is not a feedstock)
- Syngas to Ethanol (Not covered as ethanol is not a target fuel)

The largest fuel contributing component is the conversion of silage to fuels. The average across the technologies is roughly 40 gallons per ton of silage, with some of the higher interest technologies approaching 55 gallons per ton of silage. There is a basic concept for conversion in place now, from which the enterprise will conduct a technology selection process.

Pretreatment

The main objective of pretreatment is to prepare the sunflower biomass silage for efficient downstream biofuel conversion processes. The pretreatment will be applied with a multitude of approaches that is classified into three categories: 1) physical, 2) chemical and 3) biological pretreatment. Physical pretreatments, which include comminution (milling and chipping) and steam explosion, aim at decreasing particle size and increasing surface area, whereas chemical pretreatments make use of acid/base to promote hydrolysis and improve the yield of glucose recovery from cellulose by removing hemicellulose or lignin. Biological pretreatments will enhance the hydrolysis and digestibility by using enzyme or microorganism.

Biomass Conversion Potential Approaches

Anaerobic digestion is a multistage biological conversion route, consisting of hydrolysis, acidogenesis, and methanogenesis, which finally converts feedstock to methane (CH_4). In addition, during the acidogenesis step, hydrogen (H_2) can be obtained, unless the methanogenesis step is active. Cellulose, hemicellulose, and protein, accounting for 40% of silage on total solid (TS) basis, can be converted to 37,600-51,300 ft^3 CH_4/acre using the following theoretical CH_4 conversion: 1 lb. COD=5.62 ft^3 CH_4. In addition, during transesterification, approximately 0.76 lb. of glycerol for each gallon of biodiesel is produced. It would be fed into anaerobic digester together with silage for synergistic CH_4 production. CH_4 is then pretreated to remove trace amounts of hydrogen sulfide and converted into methanol (375-515 gal/acre) through a thermo-catalytic reaction. Finally, methanol, together with the bio-oil, is used to produce biodiesel through transesterification. Any excess biogas not required for methanol production will be used for electricity and heat recovery.

Anaerobic digestion (AD) can be considered both a biological conversion technology and a composting technology because the digestate is a compostable residue. As a composting technology processing a source-separated municipal solid waste, the AD facility would qualify for diversion credit. Anaerobic digestion and ethanol production are included in this study because technically they convert MSW to a useful fuel. Also, there are a number of vendors offering these technologies, and many commercial scale anaerobic digestion facilities are in operation outside the U.S.

6.2 Thermochemical Conversion

Thermochemical technologies are used for converting biomass into fuel gases and chemicals. The thermochemical process involves multiple stages. The first stage involves converting solid biomass into gases. In the second stage the gases are condensed into oils. In the third and final stage the oils are conditioned and synthesized to produce syngas. Syngas contains carbon and hydrogen and can be used to produce ammonia, lubricants, and through the Fischer-Tropsch process can be used to produce biodiesel. The major types of thermochemical processes include:

- Pyrolysis
- Pyrolysis/gasification
- Pyrolysis/steam reforming
- Conventional gasification (fixed bed and fluid bed)
- Plasma gasification
- Thermal depolymerization

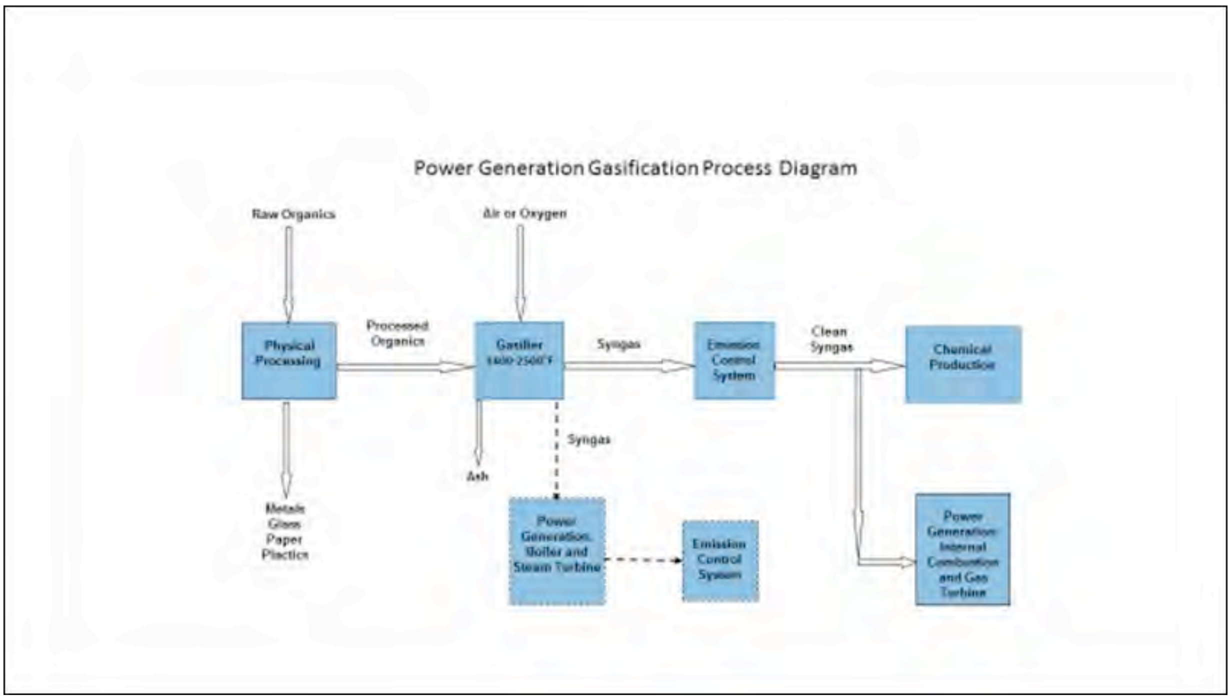

Figure 7: Example of Gasification Process

Figure 7 above is an example of the use of gasification process for converting the silage to syngas. Typical conversion rates are 95-96%, with 4% remaining as an ash that can be used for soil amendments if the process is only used for conversion of agriculture waste. Detailed discussion of thermochemical processes are provided in Appendix B.

6.3 USDA Conversion Plant Recent Funding/Cost Estimates

Following extensive research and discussion with USDA in Washington DC, the following plant types were identified. Each of these systems have been awarded loan guarantees from USDA as a result of a year or more of technical and economic review. These plants are all possibilities to use the silage resource to convert to fuels ranging from gasoline to JP5/8. The technologies are beyond research, though the gasification processes are newly commercialized and do not have long track records. Each requires roughly 200,000 tons of input per year to create roughly 10MM gallons of output. The moisture content required by each varies, but runs roughly from 15% to 17%. Field test yield reports indicate that the sunflower crops will produce at least 5 and as much as 10 tons per acre at 15% moisture. As a result, when the full 10,000 acres is in production, there is likely to be sufficient silage and cover crop residue to operate no less than a 5MM gallon per year plant, and potentially a 10MM gallon per year module.

The technologies selected are those that currently show the most promise, though the actual technology selection process is likely several years away, and so there is sufficient time to evaluate evolving options. In the near term both the AESI gasification system and the DVO anaerobic digester are candidates for installation in Waimea as shared assets with the existing Waimea Nui Community Development Initiative, which would use the energy for electrical generation. The electricity may be used to create hydrogen, ammonia, or power water distribution systems.

Cool Planet Energy Systems

Cool Planet has developed and is currently in construction on a 10MM gallon per year pyrolysis based plant. According to USDA, Cool Planet's gasoline, diesel and jet fuel stocks can be blended into the current fuel supply to reduce CO_2 from the air without sacrificing performance or increasing prices at the pump. This has been demonstrated at a 100,000 gallon per year scale for 6 years, and as part of a 10 MG per year plant that employs identical components.

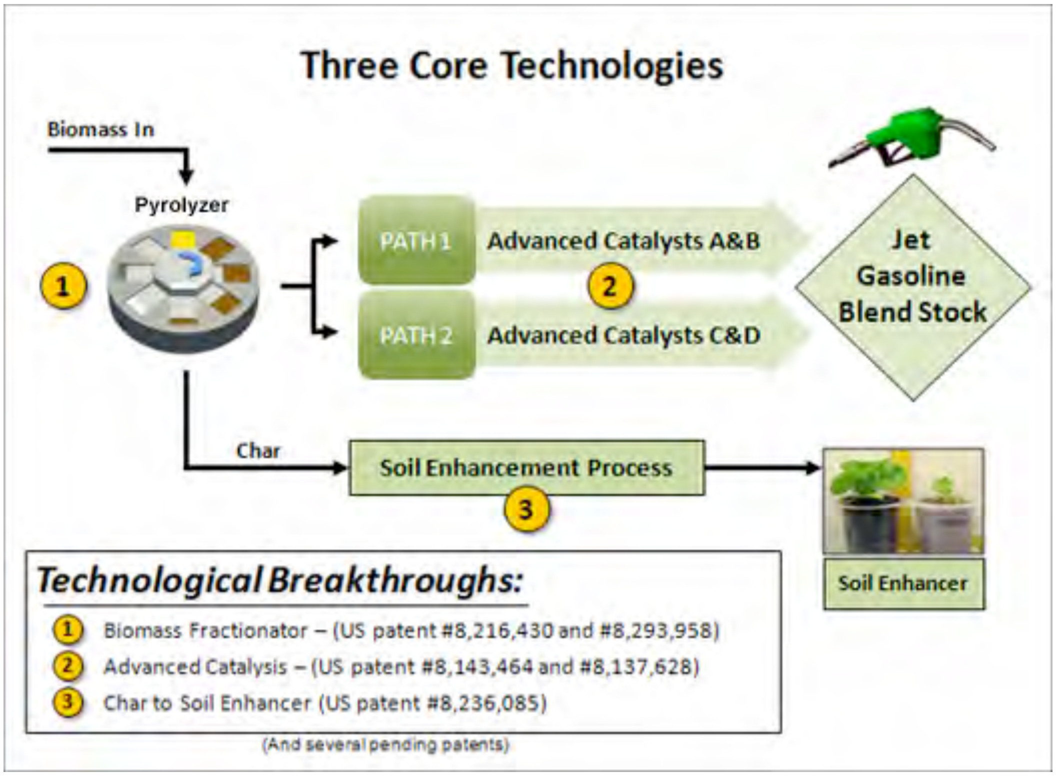

Figure 8: Cool Planet Conversion Process Overview

Figure 8 above provides on overview of Cool Planet's patented conversion technology approach. Catalytic conversion is a well proven technology, and has been used for fuel production for decades. USDA testing indicated that Cool Planet's technology was a commercially viable adaptation which enables efficient fuel production from the hydrocarbons released in the pyrolysis. The remainder of the organic material is collected as biochar, which UH-Hilo's agriculture department has determined is a great value in improving water and micro-organism retention in most Hawaii Island soils.

Due to the company's patented technology and bio-char products, its green fuels have the capability to be carbon negative.

> **Potential:** Cool Planet is a carbon negative technology specifically designed to process biomass. The outputs are bio-char, which is valuable to the farm side of the biofuels enterprise, and fuels which can meet milspec requirements. The system produces 55 gallons per ton. The company is US based, and has been approved for USDA loan guarantees. The system is designed in 10MM gallon per year increments and can be built in parallel to create larger capacity.
>
> **Concerns:** The Company has only one plant in operation, so there is no long-term track record of success.
>
> **Mobility:** The system is fixed and is neither mobile nor moveable.

Conclusion: This system, whose overall cycle is shown in figure 9 below, is only a consideration as a conversion system for large scale biomass operations. It does not have operating history, but is purpose built to provide fuels, and has recently passed a 12-month USDA/DOE technical review. This system is a strong contender to be the eventual conversion technology for the advanced biofuels, particularly if the carbon negative claims, shown in figure 9 below, are validated in production.

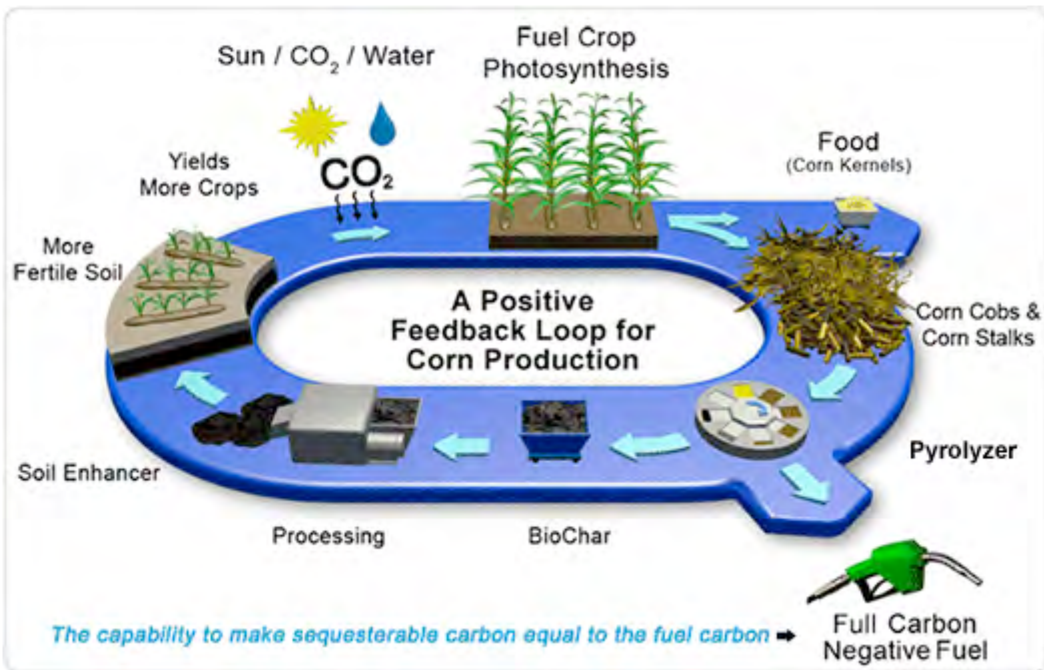

Figure 9: Carbon Negative Process Description

Alternative Energy Solutions Intl Inc. (AESI)

AESI's units operate from a differentiated process whereby solid fuels are first gasified and then combusted in the same device; referred to as Vertically Integrated Gasification and Combustion. Simply burning biomass is less complete than burning produced syngas which is why gasification followed by combustion is a better approach and it reduces issues related to emissions. The system can be used to either create steam for electrical generation, or directly use the syngas to run turbine generators. There are over 4,000 AESI units in operation around the world, and they average 500 KW generation capacity at 10 tons per day of bio-feedstock input. These systems can provide all the power needed by the processing facility through the use of roughly 2 acres per day of silage.

Biomass fuels are carbon neutral, and can be obtained at costs that are increasingly lower than oil, propane and natural gas. Through gasification, biomass fuels can be derived from many different sources, including waste streams, enabling low to negative cost fuel use.

Solid fuel biomass gasifiers can be integrated into mechanical system configurations no matter the industry or market segment, either replacing or appending existing system operations.

Based on a technology developed over 50 years ago by Uniconfort, an ISO 9001 company, and now exclusively fabricated by AESI in the United States as the GLOBAL Series (as represented by Figure 10 below), AESI GLOBAL Series accommodates biomass fuel diversity, composition, and moisture content from 12-17%. The Global Series includes automated feeder systems and fully automated base power electrical generation.

Figure 10: AESI GLOBAL Series Standalone Gasifier

Potential: AESI has a wide range of modular systems that have long in-service track records. The company has more than 3000 units currently operating in the field, and a strong operational up-time record with operating times of more than 98% over the first five years. The conventional gasification process used produces syngas at 96% conversion efficiency. The syngas is compatible with Fischer-Tropsch systems that produce milspec fuels. The systems conversion efficiency is roughly 52 gallons per ton. AESI has the lowest cost per ton of processing of any of the reviewed systems.

Concerns: This is also a smaller scale technology, though the modularity is designed to create larger scale facilities in units. The system has also not been tested with Fischer-Tropsch conversion technologies that currently produce fuels meeting military specifications. Some integration risk exists.

Mobility: The system is modular and could be designed to be mobile on a trailer-based design. The mobile system would require a second trailer to store feedstock.

Conclusion: This system has good potential for forward operating base, and individual facility use given the modularity and low maintenance design. It will also have strong potential for micro-grid energy production in proximity to the biofuels enterprise farming systems. The system is not designed for syngas off-take as the boilers are integrated, which eliminates the system as a fuel production design. This is offset, however, by the automation, which has potential for bases where the generation has to be autonomous and where the system must operate on less than one hour of maintenance/operation input daily. This design has the best potential in the 250KW - 1MW electrical generation range h module, which makes it the strongest candidate for electrical generation for the crushing mills as well as the biodiesel and advanced biofuel refineries.

DVO Inc.

DVO has a patented two-stage digester and converts manure and other organic wastes into three byproducts: a biogas, which can be burned in a generator set or turbine to create electricity or scrubbed to make natural gas (i.e. CNG for transportation fuels); a bio-solid, used as a bedding for cows or as a soil amendment; and a liquid stream that is non-odorous and can be applied as a fertilizer to growing crops.

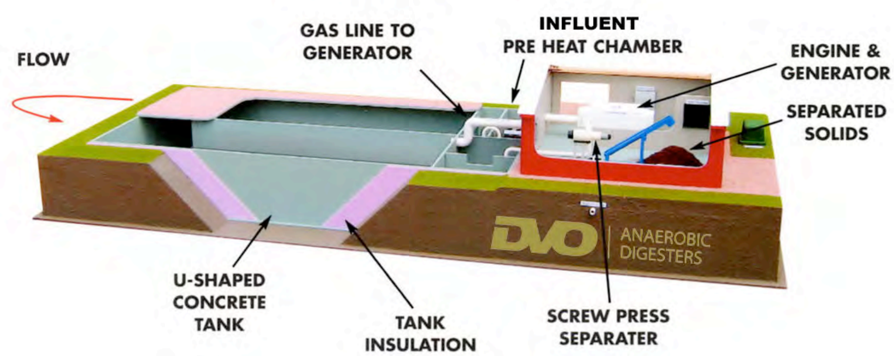

Figure 11: Mixed Plug Flow Digester Design

Figure 11 above shows a mixed plug flow in ground design that is used by DVO. The design has few moving parts, none in the digester itself, and is consequently very low maintenance. The process can mix sunflower biomass with other clean organic waste streams such as municipal separated organics, wasted food and food processing waste, slaughterhouse waste, and animal manures from dairy, swine, and poultry operations. Many other types of organic wastes can be digested in DVO's digester, such as fats, oils, sugars, starches, etc.

The system can be implemented at agri-businesses with organic wastes such as meat packing plants, dairy plants, and vegetable processors, as well as municipal sewage treatment plants and other waste treatment facilities.

DVO digesters are designed to be operated by the owner/farmer, are simple to maintain and are optimized for reliability.

Potential: The technology has over 100 units in service around the US, with as long as 15 years of service life. The plants are all operating, and are all economically viable. The system is designed to process energy bearing agriculture waste. The output is methane, which can be converted to methanol, a viable fuel for internal combustion engines. The largest plant can process 500 tons per day.

Concerns: Digestion will not produce either aviation or maritime fuels.

Mobility: The system is fixed and is neither mobile nor moveable.

Conclusions: This system has by far the best economic performance of all. It is a good fit for wastewater treatment at any base with a fixed plant. The digestion technology is not the most efficient energy system for the biofuels, however it does produce a far greater volume of fertilizer in liquid and to a lesser degree in the solids. The effluents are all non-organic due to the absence of oxygen for 28 days, which is the cycle for the mixed plug flow digesters. The system will be considered for electrical generation if the fertilizer component proves to be an economic driver on the feedstock growth.

6.4 Oil Bearing Seed Infrastructure

The oil bearing seed is the precursor for three of the co-products that are envisioned for production in the biofuels enterprise: sunflower cooking oil, sunflower oil for fuel and livestock feed. The core facility that supports all of these outputs is a crushing mill, which is the industrial facility that processes the sunflower seed from the fields. These facilities are fairly standard, and can be developed from as small as one ton per day, to as much as 1200 tons per day.

Pacific Biodiesel has designed a 120-ton per day mill for the enterprise. The mill consists of receiving silos; seed pre-processing which include seed washing, seed drying, husk removal and pre-milling; processed seed storage; crushing and extruding, and seed and feed storage. These mills are built from industrial equipment readily available on the market. Typical crushing mills are enclosed facilities with silos adjacent to the exterior of the building.

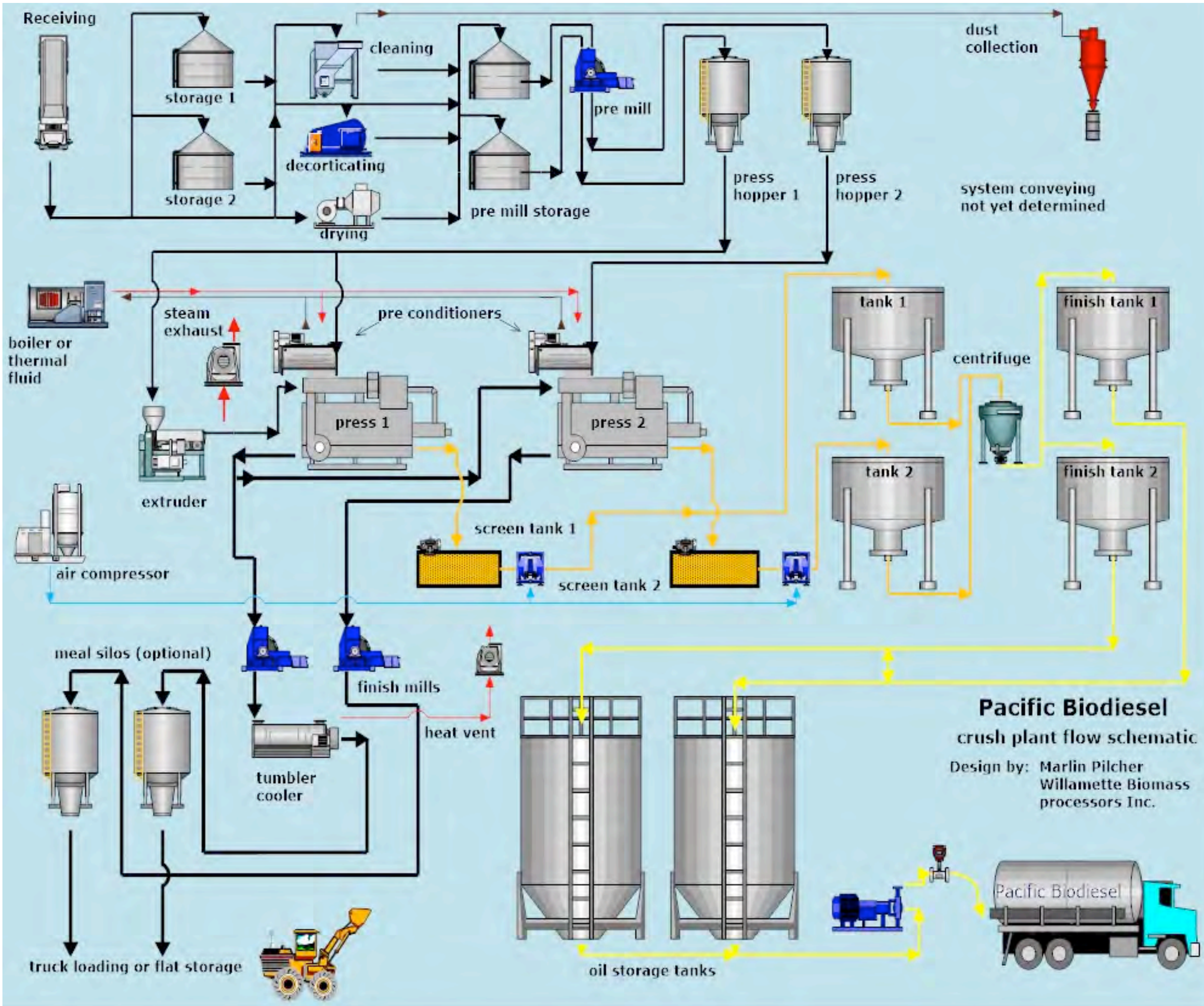

Figure 12: Pacific Biodiesel Crushing Mill Design

Figure 12 above identifies the complete process flow from the acceptance of sunflower or jatropha seed from the farm site processing facility to the creation of biodiesel. A similar process will be used for the creation of the food grade cooking oils, though the entire facility will be designed to the meet the emerging FDA mandated food safety requirements.

7. Conclusions

Hawaii Island has the land, water and energy resources needed to support a 10,000 acre biofuel farming operations in both the Waimea and Hilo/Puna regions. The farm operations will almost certainly not be contiguous acreage given the topography and the size of most of the available plots. There are two tracts of land in the Waimea region that exceed 10,000 acres, but the topography across areas of each of the tracts would make farming difficult. However, with the weekly planting/harvesting farming approach having a single plot is both unnecessary, and would likely require significant road and irrigation infrastructure to cover all of the currently undeveloped acreage. There are more than sufficient available plots with existing road access to reach the 10,000 acre goal while maintaining a 400 acre per week production cycle.

The existing biofuels operations, livestock feed markets, along with current and projected bio-markets have been shown to both produce the revenue and create the demand needed to support the farms as detailed in the reports for Task 5 and 7.

Hawaii Island has sufficient natural resources to support at least two 10,000 acre farm operations. Between rainfall, surface water and ground water, the Island has resources vastly exceeding the 1.2MM gallons per day that the farm would need when irrigating the 400 acre plots with the standard agriculture use of 3,500 gallons per day.

There are several existing commercially available biomass conversion systems currently operating that have the ability to convert the silage to either fuels (preferred) or electricity. These systems can enable the full use of the total sunflower/jatropha biomass envisioned, maximizing the revenue opportunity for the farm.

BOTTOM LINE: By operating a biofuels farm with weekly plantings and harvests, creating a 10,000 acre biofuels crop farming operation is economically viable and realistic.

Hawaii Military Biofuels Crop Program

Task 9
Field Report Summary

Prepared For:

Hawaii Natural Energy Institute

Under Award N00014-11-1-0391 from:

Office of Naval Research

Under Sub Award Number MA150004 from:

Hawaii Natural Energy Institute

University of Hawaii

Prepared By:

PACIFIC BIODIESEL TECHNOLOGIES

Task 9

Field Report Summary

TABLE OF CONTENTS

Forward

This report is a summary of field reports from Pacific Biodiesel and Rivertop Solutions that includes analyses from the University of Hawaii at Hilo for 10 sunflower test plots on Hawaii Island planted in 2015. This report also organizes data and draws basic conclusions regarding the growth of sunflowers on Hawaii Island with the specific goal of increasing yield and economic viability of locally grown and processed biofuels.

I. Test Site Methods and Field Observations

A. Test Site 1: Shipman 1 – 19° 40'44.23" N 155° 00'44.79"W

1. Initial Preparation

The ground was first sprayed with glyphosate to kill existing weeds.

Several passes with a disc plow were then made to break up the soil and roots. Larger rocks were removed using a backhoe.

The site was marked with 3-foot surveyors' stakes identifying the three variables – irrigation, fertilizer and variety.

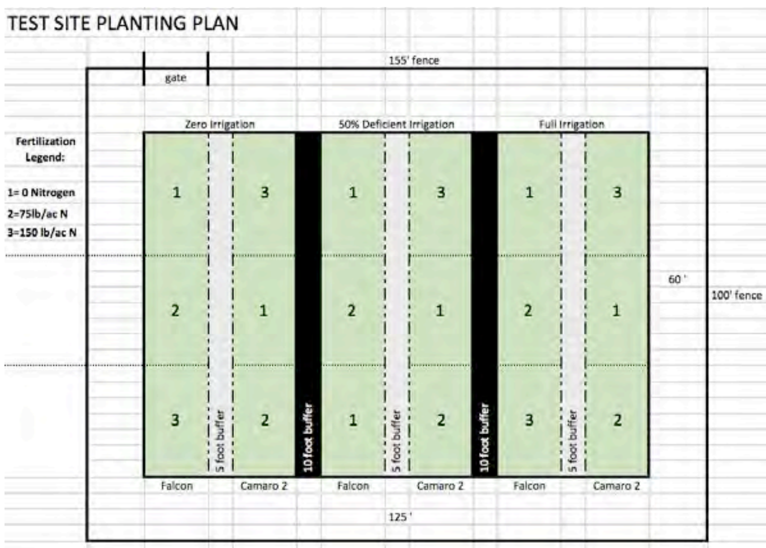

Figure 1: Site layout for Shipman 1 test site

A main water line from a nearby well was extended to the field. A drip-irrigation system was constructed for 2/3 of the field. Half of the system was programed to deliver the recommended amount of moisture to the sunflowers. The other half delivered 50% of the recommended moisture. The system was not placed until after planting.

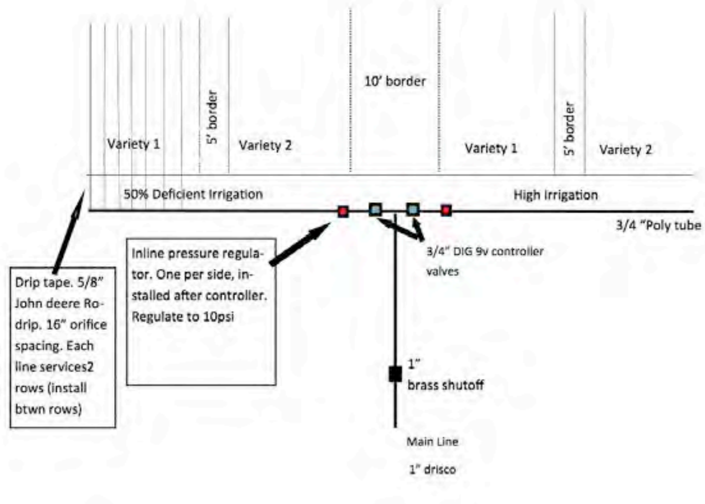

Figure 2: Irrigation system plan for the Shipman 1 site

Fertilizer was applied to the planting area.

A preliminary soil analysis was performed in order to amend the soil properly prior to planting.

UNIVERSITY OF HAWAII AT MANOA
COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES
AGRICULTURAL DIAGNOSTIC SERVICE CENTER
1910 EAST-WEST ROAD , SHERMAN 134, HONOLULU, HAWAII, 96822
Phone: (808)956-6706 Fax: (808)956-2592

SOIL ANALYSIS

Client Name: Bruce W. Mathews
C/O: UH Hilo CAFNRM
200 W. Kawili St.
Hilo, HI 96720
Ph: (808) 932-7036
JCNO: 15-51483
email: bmathews@hawaii.edu

RECEIVED: 3/11/15
COMPLETED: 3/27/15
AGENT:

					<----------------		µg/g	---------------->	
SL No.	Descrip.	pH	% N	%C	P	K	Ca	Mg	Na
15-393	Shipman Site 2	5.7	0.36	6.70	30	62	1237	705	27

mod. Truog extractable P.

Figure 3: Preliminary soil analysis for Shipman 1 site

Based on the preliminary soil analysis and input from UHH, the fertilizer application rates used on this site were:

(1) Calcium: Dolopril: 2000 lbs/acre

(2) Nitrogen Full:Urea: 150 lbs/acre

(3) Nitrogen Half:Urea: 75 lbs/acre

(4) Phosphorus:Triple Phosphate: 50 lbs/acre

(5) Potassium:Potassium Sulfate: 50 lbs/acre

Figure 4: Shipman 1 site being prepared for planting

2. Planting

A Monosem 4-row seeder was configured for oil sunflower seeds and set to plant 20” X 8.5” rows with a plant density of 36,000 per acre.

Two varieties of sunflower were planted at this site: Falcon and Camarro II.

Shallow soil and rocks underneath prevented seed penetration in a few areas inconsistently throughout the field.

Spot herbicide treatments were applied to kill weeds that had regrown on the East side of the field.

Figure 5: Tractor with borrowed seeder used for this experiment

3. Growth

Around 90% germination was observed in both varieties.

Weed regrowth was very quick. Manual methods were used to control initial weed regrowth. Morning glory vines were especially quick to recover after control methods were employed and took to climbing the sunflower stalks.

Several plants were pulled up to observe root growth during the mid-growth analysis. The roots appeared relatively shallow, possibly due to the lack of deep soil at the site.

Un-irrigated and under-irrigated sections were observed to grow faster and larger than the full irrigation section. Little difference was observed between 50% and no irrigation.

Fully fertilized and half fertilized sections were observed to grow larger than the unfertilized sections.

Figure 6: Young sunflower plants after germination (top) and 2 weeks after germination (bottom left, right)

Figure 7: Sunflowers in full bloom

4. Drying and Harvesting

   The site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel and meal samples were produced and tested.

Figure 8: Sunflower heads being harvested at Shipman 1 site

B. Test Site 2: Honomu: 19° 51'13.84" N 155° 07'25.31"W

1. Initial Preparation

   The weeds on the site were plowed under using a disk plow.

   Glyphosate herbicide was applied to kill weeds at the site.

   The site was then marked with 3-foot surveyor stakes marking the three variables – irrigation, fertilizer and variety.

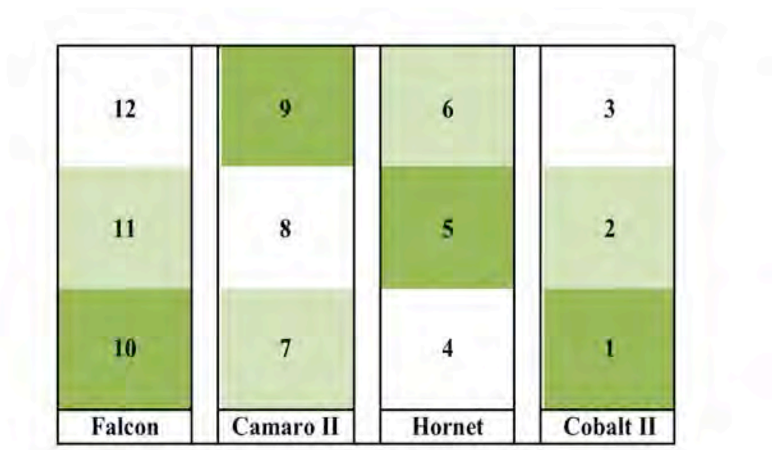

Figure 9: Site layout for Honomu test site. Three fertilizer levels were applied – 0 (white), 50 (light grey) and 100 % (dark grey)

   A preliminary soil analysis was performed in order to amend the soil properly prior to planting.

	SOIL ANALYSIS									
	Client Name:	Bruce W. Mathews			RECEIVED:	4/1/15				
	C/O:	UH Hilo CAFNRM			COMPLETED:	4/10/15				
		200 W. Kawili St.								
		Hilo, HI 96720								
	Ph:	(808) 933-0853			AGENT:					
	JCNO:	15-51501								
	email:	bmathews@hawaii.edu								
					<--------------------		µg/g	------------------>		
SL No.	Descrip.	pH	% N	%C	P	K	Ca	Mg	Na	
15-472	Honomu	5.4	0.60	10.0	22	67	105	64	25	
473	Maulua Schrop 2	5.5	0.40	7.5	14	75	66	38	16	
474	Shipman 2	5.6	0.62	8.1	19	107	256	122	22	
mod. Truog extractable P.										

Figure 10: Initial soil analysis from Honomu test site

Based on the preliminary soil analysis and input from UHH, the fertilizer application rates used on this site were:

(1) Calcium: Dolopril – 1500 lbs/acre

(2) Nitrogen Full: Urea – 150 lbs/acre

(3) Nitrogen Half: Urea – 75 lbs/acre

(4) Phosphorus: Triple Phosphate – 50 lbs/acre

(5) Potassium: Potassium Sulfate – 50 lbs/acre

No irrigation was used at this site.

Figure 11: Honomu site prior to staking and planting

2. Planting

A Monosem 4-row seeder was configured for oil sunflower seeds and set to a planting density of 36,000 plants per acre in 8.5” X 20”.

Four varieties of sunflower were planted: Falcon, Camarro II, Hornet and Cobalt.

3. Growth

Germination was around 90%.

Weed pressure became an issue. Plowing the weed growth prior to spraying herbicide was not effective for controlling a grass that spreads underground via stolon. The growth of the grass outpaced the sunflowers.

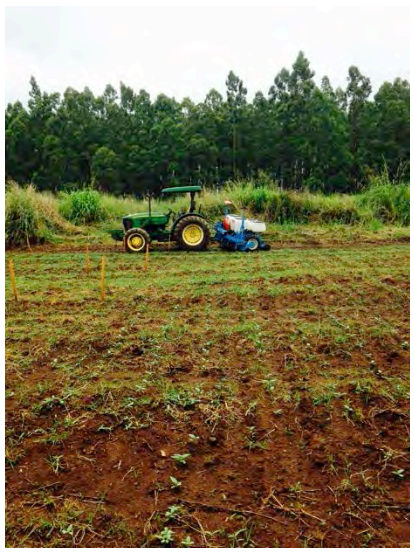

Figure 12: Honomu site one week after germination

4. Drying and Harvesting

Site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel and meal samples were produced and tested.

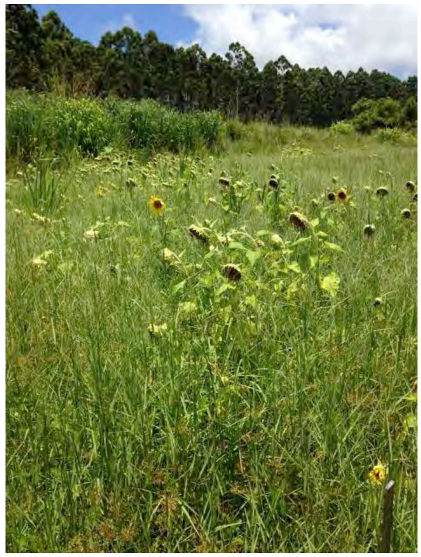

Figure 13: Honomu site on harvest day (note thick weed growth)

C. Test Site 3: Maulua: 19° 56'32.24" N 155° 13'03.14"W

1. Initial Preparation

   Heavy rains and loose soil combined to form an impassable quagmire for two weeks, trapping one of the tractors and delaying initial disking.

   The site was disked multiple times; glyphosate was sprayed to kill existing weeds.

   An initial soil analysis was performed in order to amend the soil properly prior to planting analysis.

SOIL ANALYSIS

Client Name:	Bruce W. Mathews	RECEIVED:	4/1/15
C/O:	UH Hilo CAFNRM	COMPLETED:	4/10/15
	200 W. Kawili St.		
	Hilo, HI 96720		
Ph:	(808) 933-0853	AGENT:	
JCNO:	15-51501		
email:	bmathews@hawaii.edu		

					<-------------------		µg/g	----------------->	
SL No.	Descrip.	pH	% N	%C	P	K	Ca	Mg	Na
15-472	Honomu	5.4	0.60	10.0	22	67	105	64	25
473	Maulua Schrop 2	5.5	0.40	7.5	14	75	66	38	16
474	Shipman 2	5.6	0.62	8.1	19	107	256	122	22

mod. Truog extractable P.

Figure 14: Initial soil analysis for Maulua test site

Based on the initial soil analysis the fertilizer application rates used on this site were:

(1) Calcium: Dolopril – 4000 lbs/acre

(2) Nitrogen Full: Urea – 75 lbs/acre

(3) Nitrogen Half: Urea – 35 lbs/acre

(4) Phosphorus: Triple Phosphate – 400 lbs/acre

(5) Potassium: Potassium Sulfate – 400 lbs/acre

No irrigation was used at this site.

Figure 15: Site layout for Maulua test site. Three fertilizer levels were applied: 0 (white), 50 (light grey) and 100% (dark grey).

2. Planting

A Monosem 4-row seeder was configured for oil sunflower seeds and set to a planting density of 36,000 plants per acre and rows 8.5” X 20”.

Four varieties of sunflower were planted: Falcon, Camarro II, Hornet and Cobalt.

3. Growth

The site seemed to grow well with moderate weed regrowth.

Figure 16: Maulua test site mid-growth (left) and in full bloom (right)

4. Drying and Harvesting

   The site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel and meal samples were produced and tested.

   Adequate drying in the field was not possible due to wet conditions.

   The seed heads of Cobalt began to rot and Falcon started to release seeds.

   Insect pests including numerous rose beetles were observed in and on the sunflower heads.

   Cattle damage was observed in the test field.

Figure 17: Maulua test site on harvest day

D. Test Site 4: Shipman 2

1. Initial Preparation

The site was treated with glyphosate herbicide to kill weeds.

A disk plow was used to break up the soil prior to planting.

Heavy rains created very muddy conditions, which delayed initial planting.

Weed regrowth at the site was quick and prolific. Reapplying herbicide and plowing under weeds would have been necessary to plant successfully.

e) A preliminary soil analysis was performed in order to amend the soil properly prior to planting.

SOIL ANALYSIS

	Client Name:	Bruce W. Mathews				RECEIVED:	4/1/15			
	C/O:	UH Hilo CAFNRM				COMPLETED:	4/10/15			
		200 W. Kawili St.								
		Hilo, HI 96720								
	Ph:	(808) 933-0853				AGENT:				
	JCNO:	15-51501								
	email:	bmathews@hawaii.edu								
						<-------------------		µg/g	------------------->	
SL No.	Descrip.	pH	% N	%C		P	K	Ca	Mg	Na
15-472	Honomu	5.4	0.60	10.0		22	67	105	64	25
473	Maulua Schrop 2	5.5	0.40	7.5		14	75	66	38	16
474	Shipman 2	5.6	0.62	8.1		19	107	256	122	22

mod. Truog extractable P.

Figure 18: Preliminary soil analysis for Shipman 2 site

Based on the initial soil analysis the fertilizer application rates used on this site were:

(a) Calcium: Dolopril – 4000 lbs/acre

(b) Nitrogen Full: Urea – 75 lbs/acre

(c) Nitrogen Half: Urea – 35 lbs/acre

(d) Phosphorus: Triple Phosphate – 400 lbs/acre

(e) Potassium: Postassium Sulfate – 400 lbs/acre

No irrigation was used at this site.

2. Planting

A Monosem 4-row seeder was configured for oil sunflower seeds and set to a planting density of 36,000 plants per acre in 8.5” X 20”.

Four varieties of sunflower were planted: Falcon, Camarro II, Hornet and Cobalt.

3. Growth

15% germination was attributed to heavy rain and clay soil.

Plants were overtaken by weeds.

The site was not replanted due to lapse in funding.

E. Test Site 5: Waimea 1

1. Initial Preparation

The site was mowed and then grubbed to remove grass roots using a bulldozer.

No herbicide or fertilizer was applied to the site.

2. Planting

Initial site germination was less than 25%. Plants pulled on 8/3 to determine root size, small taproots noted.

The site was re-planted 8/8 by hand with equivalent of 26,000 per acre of Cobalt, 27,000 per acre each for Hornet and Falcon.

3. Growth

The site had 30.1 inches of rainfall, including more than six inches in a single day. Rainfall appeared to drown plants. Plants were seen to have significant mold development.

Plants were removed for possible replanting.

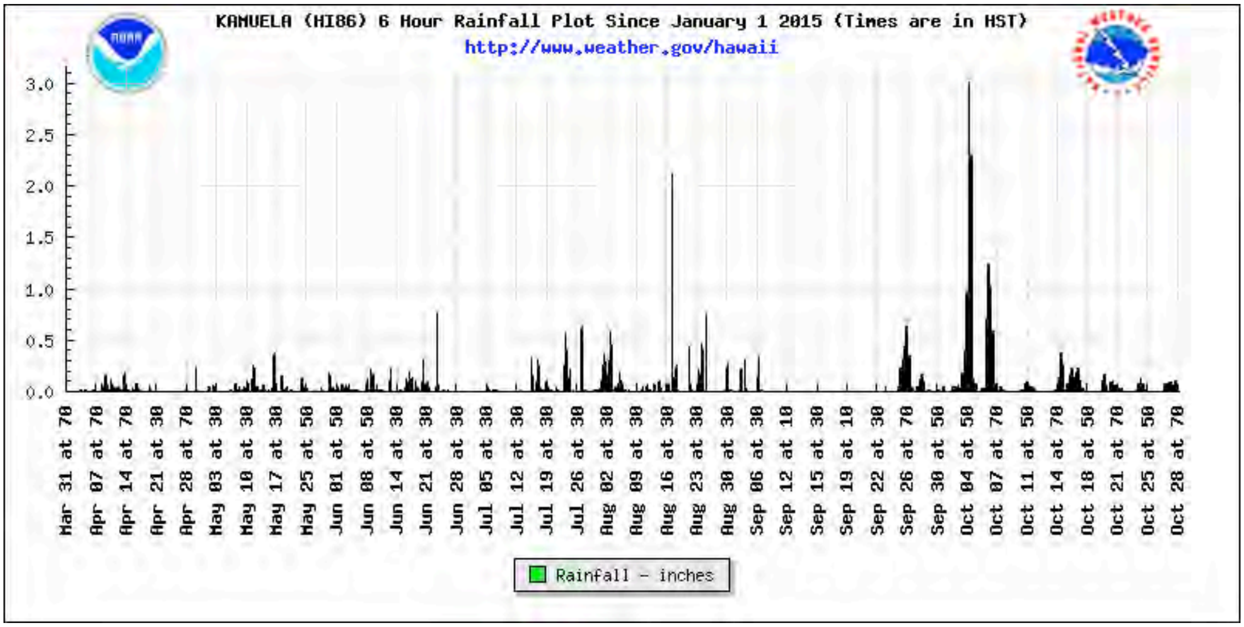

Figure 19: Recorded rainfall near the Waimea 1 site

F. Test Site 6: Waimea 2

1. Initial Preparation

   The site was mowed and then grubbed to remove grass roots using a bulldozer.

   No herbicide or fertilizer was applied to the site.

   A drip irrigation system was designed for the site.

2. Planting

   A Monosem 4-row seeder was configured for oil sunflower seeds and set to a planting density of 36,000 plants per acre and rows 8.5” X 20”.

   Three varieties of sunflower were planted: Falcon, Camarro II and Hornet.

Figure 20: Waimea 2 site a few days after germination

3. Growth

Figure 21: Waimea 2 site mid-growth

4. Drying and Harvesting

   Site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel and meal samples were produced and tested.

Figure 22: Waimea 2 site on harvest day

G. Test Site 7: Waimea 3 (20°0'52.6" N, 155°38'21.4"W, elevation 2837 ft.)

1. Initial Preparation

Site was mowed and then grubbed to remove grass roots.

The soil was then rolled to a powdery consistency.

No herbicide or fertilizer was applied to the site.

No rain gauge was installed at the site because the rainfall and other pertinent weather data is constantly being recorded.

An irrigation plan with 2 variations was designed. The high irrigation zone received 1000 gallons/acre/day while the low irrigation zone received 2000 gallons/acre/week.

2 **Cobalt II**	**1** **Cobalt II**
4 **Falcon**	**3** **Falcon**
50% Irrigation	**100% Irrigation**

Figure 23: Site layout for Waimea 3 test site

Figure 24: Waimea 3 site prior to planting

2. Planting

   A Monosem 4-row seeder was configured for oil sunflower seeds and set to a planting density of 36,000 plants per acre and rows 8.5” X 20”.

   Two varieties of sunflower were planted: Falcon and Hornet.

3. Growth

   The site showed strong growth, particularly in the moderate irrigation strip. High irrigation strip has mixed results with lower germination rates.

   The site showed little to no weed growth in sunflower planted area.

4. Drying and Harvesting

   Site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel and meal samples were produced and tested.

   The best yields were observed from the moderate irrigation zone, in the middle third of the planted area.

   There was very little rainfall in the test area during the last two weeks prior to harvest.

Figure 25: Stalk and head from Waimea 3 site

H. Test Site 8: Waimea 4

1. Initial Preparation

   Site was mowed and then grubbed to remove grass roots using a bulldozer.

   No herbicide or fertilizer was applied to the site.

2. Planting

   A Monosem 4-row seeder was configured for oil sunflower seeds and set to a planting density of 36,000 plants per acre and rows 8.5” X 20”.

   Two varieties of sunflower were planted: Falcon and Hornet.

3. Growth

   The site shows no significant pest, weed or grass incursions on to the test planting area. Neem oil was applied during the month as a pesticide due to significant ant activity in the area surrounding the test site. No herbicides were applied.

   The site experienced near daily cloud cover, fog and misting.

4. Drying and Harvesting

   Head sizes measured a minimum of 1.75 inches and maximum of 2.5 inches. The heads were too small to harvest effectively and plants were all less than three feet.

   Rainfall over the growth period was 42.5 inches, far exceeding the recommended rainfall for growing period.

Due to a late start on the first round of plantings, there was not enough time remaining in the project to complete a second round of plantings. A substitute task was created to plant cover crops on several of the sites. This initial foray into cover crops gave the farming team some insight into challenges and opportunities for this important aspect of sustainable agriculture. It was agreed that these crops are worth investigating further including analysis of overall costs and gains to the sites.

II. Material Analysis

Sunflower seed, meal and residue were analyzed to determine their value to local feed and energy markets.

A. Seed Analysis

Nutrient, mineral and energy composition of sunflower oilseed expressed on dry matter basis.

Component[a]	Unit	Average ± SD[b]	Reported Composition Range[c]
Main Analysis			
CP	%	14.4 ± 1.5	15.7 - 20.8
NDF	%	29.8 ± 4.0	24.0 - 30.3
ADF	%	21.5 ± 2.9	16.5 - 24.0
Lignin	%	6.8 ± 1.1	6.0 - 6.3
Hemicellulose	%	8.3 ± 1.3	8.0
Cellulose	%	14.7 ± 1.9	-
NFC	%	6.0 ± 2.1	2.5
Ether Extract	%	45.9 ± 5.5	41.0 - 52.4
Ash	%	3.9 ± 0.4	2.6 - 5.1
Minerals			
P	%	0.63 ± 0.06	0.51 - 0.67
K	%	0.97 ± 0.14	0.91 - 1.06
Ca	%	0.19 ± 0.04	0.18 - 0.71
Mg	%	0.34 ± 0.04	0.30 - 0.34
S	%	0.21 ± 0.02	0.21
Na	%	0.00 ± 0.00	0.01
Fe	ppm	50 ± 27	144
Mn	ppm	31 ± 12	35
Zn	ppm	49 ± 6	53
Cu	ppm	17 ± 2	20
Mo	ppm	0.2 ± 0.2	1.8
Energy			
TDN	%	125 ± 9	93 - 122
NEl	Mcal/lb	1.59 ± 0.14	1.38
NEm	Mcal/lb	1.74 ± 0.16	1.42
NEg	Mcal/lb	1.28 ± 0.12	1.03

[a]CP = Crude Protein, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, NFC = Non-Fiber Carbohydrates, TDN = Total Digestible Nutrients, NEl = Net Energy for Lactation, NEm = Net Energy for Maintanance, NEg = Net Energy for Gain. Hemicellulose = NDF - ADF. Cellulose = ADF - lignin. NFC = 100 - CP - NDF - ether extract - ash.

[b]Average ± standard deviation of 26 whole seed samples.

[c]Reported composition ranges adapted from Huezé et al. (2015a), NRC (2001), Martínez Force et al (2015), Petit (2003), Beauchemin et al (2009), Walker (2006), Ítavo (2015), Lardy and Anderson (2009), Alcalde et al (2011), Schingoethe (1992).

B. Meal Analysis

Nutrient, mineral and energy composition of sunflower meal expressed on dry matter basis.

Component[a]	Unit	Average ± SD[b]	Reported Composition Range[c]
Main Analysis			
CP	%	21.4 ± 3.0	27.9 - 44.6
NDF	%	39.9 ± 6.4	42.9
ADF	%	27.4 ± 5.1	17.0 - 30.2
Lignin	%	8.8 ± 1.5	10.0
Hemicellulose[3]	%	12.5 ± 1.8	-
Cellulose[4]	%	18.6 ± 3.6	-
NFC[5]	%	10.2 ± 2.4	-
Ether Extract	%	22.5 ± 9.1	7.6 - 13.8
Ash	%	6.0 ± 0.9	5.7 - 7.1
Minerals			
P	%	0.92 ± 0.17	0.84 - 1.14
K	%	1.49 ± 0.26	1.00 - 1.56
Ca	%	0.27 ± 0.04	0.34 - 0.56
Mg	%	0.52 ± 0.11	0.36 - 0.78
S	%	0.31 ± 0.04	0.37 - 0.38
Na	%	0.01 ± 0.00	0.01 - 0.02
Fe	ppm	189 ± 169	110 - 422
Mn	ppm	53 ± 20	23 - 37
Zn	ppm	77 ± 12	77 - 100
Cu	ppm	27 ± 4	26 - 35
Mo	ppm	0.2 ± 0.2	-
Energy			
TDN	%	87 ± 16	61 - 74
NEl	ppm	1.04 ± 0.23	0.77
NEm	ppm	1.10 ± 0.27	0.80 - 0.92
NEg	ppm	0.77 ± 0.21	0.61

[a]CP = Crude Protein, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, NFC = Non-Fiber Carbohydrates, TDN = Total Digestible Nutrients, NEl = Net Energy for Lactation, NEm = Net Energy for Maintanance, NEg = Net Energy for Gain. Hemicellulose = NDF - ADF. Cellulose = ADF - lignin. NFC = 100 - CP - NDF - ether extract - ash.

[b]Average ± standard deviation of 21 sunflower meal samples, mechanically-extracted.

[c]Reported composition ranges adapted from Batal & Dale (2010); Huezé et al. (2015b), NRC (2001), Waller (2010).

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C. Residue Analysis

Nutrient, mineral and energy composition of sunflower crop residue on dry matter basis.

Component[a]	Unit	Average ± SD[b]	Reported Composition Range[c]
Main Analysis			
CP	%	4.8 ± 1.0	5.7 - 13.0
NDF	%	47.8 ± 7.6	39.6 - 66.9
ADF	%	41.0 ± 6.6	33.0 - 56.6
Lignin	%	10.0 ± 2.2	9.7 - 15.7
Hemicellulose[3]	%	6.8 ± 3.6	10.3
Cellulose[4]	%	31.1 ± 5.1	33
NFC[5]	%	30.8 ± 8.2	-
Ether Extract	%	4.6 ± 3.0	1.5 - 10.7
Ash	%	12.0 ± 2.9	8.4 - 13.2
Minerals			
P	%	0.15 ± 0.06	0.08 - 0.38
K	%	3.31 ± 0.80	1.51 - 3.74
Ca	%	1.68 ± 0.45	1.10 - 1.75
Mg	%	0.49 ± 0.21	0.09 - 0.86
S	%	0.28 ± 0.08	0.01 - 0.20
Na	%	0.06 ± 0.02	0.02 - 0.10
Fe	ppm	1129 ± 1961[d]	150 - 415
Mn	ppm	139 ± 85	27 - 34
Zn	ppm	59 ± 22	34 - 43
Cu	ppm	12 ± 3	4 - 18
Mo	ppm	0.2 ± 0.2	15
Energy			
TDN	%	53 ± 4	55 - 66
NEl	ppm	0.54 ± 0.06	-
NEm	ppm	0.47 ± 0.08	0.56
NEg	ppm	0.22 ± 0.07	0.26

[a]CP = Crude Protein, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, NFC = Non-Fiber Carbohydrates, TDN = Total Digestible Nutrients, NEl = Net Energy for Lactation, NEm = Net Energy for Maintanance, NEg = Net Energy for Gain. Hemicellulose = NDF - ADF. Cellulose = ADF - lignin. NFC = 100 - CP - NDF - ether extract - ash.

[b]Average ± standard deviation of 26 dried and ground sunflower crop residue samples.

[c]Reported range adapted from Blamey et al (1997), Drackley et al (1985), Huezé et al (2015c), Lardy & Anderson (2009), Martínez Force et al (2015), McGuffey & Schingoethe (1980), NRC (2001), Stock et al (1991).

[d]Iron (Fe) concentrations showed a large variation between sites. Average Fe concentrations were 37, 411, 2090, and 4375 ppm in Shipman 1, Maulua, Waimea 2, and Waimea 3, respectively.

Figure 26: The left photo shows harvested sunflower heads air drying in the lab. The right photo shows sunflower meal pressed from the seeds.

D. Calorific Values

This testing deviated from the Statement of Work in that no mid-growth calorific measurements were completed. The ending calorific values were used to assess mid-growth progress. It was concluded that these values were representative of the information being sought.

1. Methods

Mature plants, between 105 and 109 days old, were clipped at ground level. Seeds were separated from seed heads and processed separately. The remaining biomass, consisting of empty seed heads, stems and leaves, was oven dried at 60°C for at least 72 hours and subsequently ground in a Wiley mill (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific. Swedesboro, NJ) to pass a 1 mm stainless steel screen. The ground biomass samples were analyzed for calorific value by Hazen Research, Inc., Golden, CO. Higher Heating Values (HHV) shown in this report are not sulfur corrected.

2. Results

Average HHV for all samples was 7,058 BTU per pound or 16.4 MJ/kg. To compare, corn stover and sugar cane bagasse have an average HHV of 7,487 and 7,031 BTU per pound, respectively (Boundy *et al.,* 2011). Table 1 shows calorific values for all samples. At the Maulua and Waimea 3 sites, Cobalt II had the greatest HHV. At Maulua (35 pounds per acre N), Cobalt II had the overall greatest calorific value of 8,271 BTU per pound.

3. Note

A separate sample from Waimea 2 was analyzed to determine potential heating value. One of the largest Falcon sunflower stems (without seed head) was clipped and processed as described above. The HHV of this sample was 6,632 BTU per pound, which is similar to the sample of an average sized Falcon plant at Waimea 2.

Site	Hybrid	N Fertilizer lbs./ac	Irrigation %	Calorific Value HHV (Btu/lb.)	Calorific Value HHV (MJ/kg)
Shipman 1	Falcon	0	0	6,957	16.2
		75	0	7,516	17.5
		150	0	6,632	15.4
	Camaro II	0	0	6,738	15.7
		75	0	7,024	16.3
		150	0	7,147	16.6
Honomu	Composite[a]	0	0	7,014	16.3
Waimea 2	Falcon	0	0	6,763	15.7
	Camaro II	0	0	6,860	16.0
	Hornet	0	0	6,876	16.0
Maulua	Falcon	0	0	7,450	17.3
		17.5	0	7,568	17.6
		35	0	7,735	18.0
	Camaro II	0	0	6,994	16.3
		17.5	0	6,714	15.6
		35	0	7,225	16.8
	Cobalt II	0	0	7,323	17.0
		17.5	0	7,274	16.9
		35	0	**8,271**	**19.2**
	Hornet	0	0	7,039	16.4
		17.5	0	7,201	16.7
		35	0	7,006	16.3
Waimea 3	Falcon	-[b]	50	6,640	15.4
		-	100	6,396	14.9
	Cobalt II	-	50	6,579	15.3
		-	100	6,561	15.3
	Average			**7,058**	**16.4**

[a] Honomu sample was a composite of Falcon, Camaro II, Cobalt II and Hornet Hybrids.

[b] Fertilizer rate applied at Waimea 3 site is unknown.

Boundy, B., Diegel, S. W., Wright, L., & Davis, S. C. (2011). Biomass Energy Data Book: Edition 4. Retrieved from http://cta.ornl.gov/bedb.

Figure 27: This figure shows the calorific value of sunflower biomass per site, hybrid, fertilization, and irrigation.

E. Average Yields

1. Seed, Foliage, and Density

Yields of seed and foliage were estimated after harvesting test plots, determining the average yields among varieties and treatments, and extrapolating results to 1-acre scale. These figures do not necessarily reflect an unbiased comparison of growing sites due to inconsistency in treatments, varieties, and cultural practices.

Shipman 1 had the highest seed yield and lowest seed moisture at harvest.

Waimea 3 had the highest foliage yield and highest 100 seed dry weight.

Site	Seed Yield (lbs. /acre)	Foliage Yield (lbs. /acre)	Plant density (plants/acre)	Dry Weight per 100 seeds (g)	Seed Moisture % at harvest
Shipman 1	2,567	4,333	42,567	3.3	38
Honomu	123	443	27,878	1.2	51
Waimea 2	953	3,397	53,958	1.7	70
Waimea 3	2,306	6,468	32,375	4.5	61
Maulua	2,062	4,428	31,476	4.2	35

Figure 28: Seed, foliage and plant density averages between test sites

2. Variety

Four varieties of sunflower were used in the project. Two of the varieties were “high oleic” varieties: Cobalt II and Hornet. The other two varieties, Falcon and Camarro II, are considered “mid oleic.”

Camaro II showed the highest seed and foliage yield.

Seed weight was highest for Cobalt II.

Hybrid	Oleic Acid Type	Herbicide Technology	Mildew Resistance	Seed Yield (lbs/acre)	Foliage Yield (lbs/acre)	Dry Weight per 100 seeds (g)	Seed Moisture % at Harvest
Camaro II	Mid-oleic	Clearfield	Downy Mildew Resistant	2,169	3,703	3.1	40
Falcon	Mid-oleic	ExpressSun	-	1,749	3,275	2.9	45
Cobalt II	High oleic	Clearfield	Downy Mildew Resistant	1,357	3,602	3.9	37
Hornet	High oleic	Clearfield	Downy Mildew Resistant	1,065	3,643	2.1	58
			Average	**1,585**	**3,556**	**3.0**	**45**

Figure 29: Average yield per variety across all harvested test sites

III. Conclusions and Recommendations

After growing sunflowers on several sites on the East and North parts of the Big Island, below are summaries that include some of the recommendations we can offer.

A. Moisture

1. Initial

The seeds do require wet soil to germinate. In some of the drier regions of Waimea the first couple of inches dry very quickly when exposed to the constant winds present there. This resulted in a lack of germination.

The soil must be well drained for the germinated plants to survive. Clay soils and moderate to heavy rains during the first few weeks tended to “drown” the new plants. The Shipman 2 site was inundated with rain soon after planting resulting in a very low survival rate.

2. Growth

After the first two weeks, the sunflowers do not require much water.

Un-irrigated sections tended to do better than the irrigated ones in areas with some rainfall.

Irrigation %	Seed Yield (lbs. /acre)	Foliage Yield (lbs. /acre)	Plant density (plants/acre)	Number of seeds per plant
0	3,693	6,142	37,771	1,084
50	2,118	3,424	46,764	712
100	1,890	3,433	43,167	752
Average	**2,567**	**4,333**	**42,567**	**849**

Figure 30: Average yield per irrigation level at Shipman 1

3. Drydown

Dry conditions are necessary for the drydown phase. In Maulua the excessive rain and/or humidity resulted in rotting seed heads and mold growth.

4. More investigation is needed to determine optimum water management at each individual site.

B. Weed Management

1. Herbicide

Single glyphosate treatments worked well initially for several sites but weeds still regrew quickly and in some cases outpaced sunflowers.

Glyphosate was not effective at controlling Wainaku grass at the Honomu site. This may have been due to an initial disking prior to application.

2. Disking

Initial disking was effective at incorporating dead weeds and turning under small plants, however this did not result in positive weed control after a few weeks.

Wainaku grass in Honomu and morning glory at Shipman 1 grew quickly in the disked areas.

3. Grubbing

The Waimea sites were grubbed using a bulldozer rather than being sprayed with herbicide or disked. Due to the deep soil in that area and equipment readily available, it was a viable option for small plantings.

By scraping off several inches of topsoil, all grass roots and seeds near the surface were removed. This was highly effective at discouraging weed growth.

C. Fertilizer

1. Nitrogen

Sunflowers tended to grow larger with higher seed yields when some Nitrogen fertilizer was provided. Excess Nitrogen did not result in higher yields.

In the Shipman site, the area with moderate amounts of added urea had the highest seed yield and highest foliage yield. This treatment was 75 lbs/acre of urea where the 100% treatment was 150 lbs/acre.

More investigation would be useful to determine optimum fertilizer for each site.

Fertilizer %	Seed Yield (lbs. /acre)	Foliage Yield (lbs. /acre)	Plant density (plants/acre)	Number of seeds per plant
0	2,459	4,045	46,764	715
50	2,634	4,757	43,167	797
100	2,608	4,198	37,771	1,035
Average	**2,567**	**4,333**	**42,567**	**849**

Figure 31: Average yields per fertilizer treatment on at the Shipman 1 site.

D. Planting Density

1. Notes on Planting Density

The seeder used for this project was set to plant at 36,000 plants/acre. The average extrapolated planting density came out much higher at most sites. Generally the highest planting density also resulted in the highest seed yield. The data suggests that a higher than recommended seed density could be beneficial, but due to small sample size and extrapolation margin for error, larger plantings should be done to evaluate high plant density as a yield boosting strategy.

Hawaii Military Biofuels Crop Program

Task 10
Land Selection and Site Identification

Prepared For:

Hawaii Natural Energy Institute

Under Award N00014-11-1-0391 from:

Office of Naval Research

Under Sub Award Number MA150004 from:

Hawaii Natural Energy Institute

University of Hawaii

Prepared By:

Rivertop Solutions LLC

PACIFIC BIODIESEL TECHNOLOGIES

New Task 10

Land Selection & Site Identification

TABLE OF CONTENTS

Forward

Based on the farm plans from the Bioenergy Farm Analysis, the team provided site selection for two 10,000-acre farming operations. The selection draws upon data gathered regarding rainfall, soil composition and wind and irrigation surveys, paired with field test results and site preparation cost estimates, to provide a rationale for the selection. The Land Selection and Site Identification includes requirements for preliminary engineering plans, draft environmental statements, and draft permit and lease documents required to prepare the sites for commercial operation. The report will include the site specific information as well as estimates of capital costs and expenses to develop the permits and designs for commercial scale farming using the economic and logistics analysis previously conducted. Data is also provided regarding crop growth potential and operating costs for each farming operation.

Glossary of Acronyms

DBEDT	Department of Business, Economic Development, and Tourism
DHHL	Department of Hawaiian Homelands
DoD	Department of Defense
DOH	Department of Health
FONSI	Finding of No Significant Impact
GIS	Geospatial Information System
HDOA	Hawaii Department of Agriculture
HRS	Hawaii Revised Statute
MM	Million
NEPA	National Environmental Policy Act
NRCS	USDA Natural Resources Conservation Service
SHPD	State (of Hawaii) Historic Planning Department
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
WIS	Waimea Irrigation System

1. Factors Affecting Suitability

This section provides a description of the factors that are used to assess the available lands to determine which ones are most suitable for biofuel crop growth. The section also details the application of the factors to each region.

1.1 Rainfall

The ability to inexpensively irrigate lands is both a production and economic driver in controlling the oil content and biomass growth of the biofuel crops. Ideally sunflower will use roughly the equivalent of 18-300 inches (roughly 450 to 750mm) of rain during its 4-month growth cycle, with the bulk of the requirement coming early in the cycle. This would indicate that regions with 30-80 inches (750mm to 2000mm) of annual rainfall are viable, though in fact regions with less rainfall, but access to irrigation water are more productive due to the need to starve the plant of water during its last 30 days to maximize oil production in the seed.

Of the regions in consideration, irrigation is most critical in Waimea where the annual rainfall is not generally sufficient to support 100-day growth cycles. In the South Hilo/Puna region there is sufficient rainfall to manage the crop growth with only the need for occasional use of the water system and no requirement for additional infrastructure; however, restricting the rainfall during the last 30 days prior to harvest will be problematic in South Hilo/Puna.

The Waimea Region current irrigation system is built around water supplied from the Upper Hamakua Ditch which is over 100 years old. The ditch system gathers surface water, with the three input flumes taking in between 500,000 and 45,000,000 gallons per day, depending on rainfall. The system, when first constructed, produced between 4 and 16,000,000,000 gallons per year according to US Geologic Service records. In its current state of repair, the ditch has a reduced annual production, supplying 800,000,000 gallons per year on average due to water losses. A review of USGS rainfall studies going back to 1918 show that rainfall has stayed within a 20% plus or minus band over the entire period, and 2014 had 1% more rainfall than 1918, so reduced rainfall does not factor in to water availability. The most significant needs are increased storage and increased water generation. As shown in figure 1 below, the daily sustainable ground water yields for the Waimanu and Waimea watersheds, which are the two that would be accessible for the irrigation system, are 134 million gallons per day. This would support over 89,000 acres at the 1500-gallon per day average needed for sunflower/safflower.

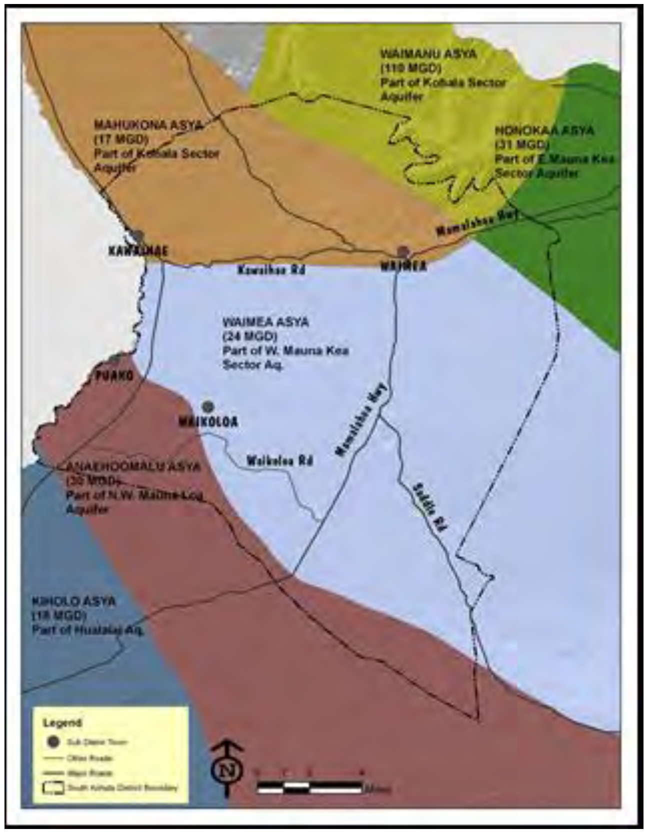

Figure 1: Waimea Region Watershed Sustainable Water Yields

In the Ka'u region, there is an estimated 52,000,000 gallons per day of sustainable water yield in proximity to the agriculture lands of interest. This region is very sparsely populated, making the majority of the water available for use. There is enough water in this region to support 34,500 acres of production.

Key Finding: Using 50% of the estimated water available, the watersheds in Waimea could support up to 45,000 acres. In the Ka’u region, the watershed has the capacity to support an additional 34,500 acres.

1.2 Soils and Topography

Soil and topography can be limiting to biofuels production from an economic standpoint. Uneven or sloped lands reduce the size of the farm equipment which can be employed, and so increase the labor and equipment costs per acre farmed.

The University of Hawaii at Hilo has extensive soil and topography maps available for all the agriculture lands on Hawaii Island. The UH-Hilo team conducted site soil sampling at all the locations, the highlights of which will be available as an appendix to the Task 8 Mid-Crop Growth Report, and are available on request. The results of these samples and of the review of the database indicate that the soils in Waimea, Puna, and Ka'u are best suited to support the crop growth. The soils north of Mauna Kea are loamy, and carry significant nutrients. The soils in Puna and South Hilo are composed of significant amounts of clay.

There are roughly 120,000 acres of suitable lands in Waimea, 89,000 acres of suitable lands in Puna/South Hilo, and 105,000 acres of suitable land in Ka'u.

A second significant factor is topography. The lands in Waimea are relatively flat and can be leveled, so that more than 95% of the lands with appropriate soils are suitable to biofuels crops. In Puna/South Hilo, over 75% of the lands with good soils also have suitable topography. Ka'u has far more lands that slope; roughly 64,000 of the acres that have suitable soils do not have ideal topography. The Ka'u lands are still in the range of suitable, but would be the most expensive to farm due to the need for smaller, less efficient equipment.

Key Finding: In each region the acreage of land with viable soils and topography exceed the irrigation capacity, and so soils and topography are not a limiting factor.

1.3 Wind and Irrigation Surveys

Sunflower thrives on the stress presented by wind, with the plant reacting by drawing additional nutrients from the ground to create more fibrous stalks. This wind stress preference has been confirmed by the success of the plant in the very windy plains surrounding the Black Sea and in the plains of the Dakotas. As such, windbreaks are planned at larger than the normal intervals. On the larger parcels, windbreaks will be built surrounding 400 acre parcels. Each smaller scale parcel will also have windbreaks down to a minimum size of 100 acres. The specific tree varieties will be developed in consultation with the parcel owners to match their overarching farm plans.

Irrigation will be done with large, mobile sprayers which will be moved from site to site. Each region will be provided corrugated steel tanks which will hold sufficient water to support the pumps, likely 100,000 gallons, and will be filled by a Driscoll line from the reservoir during irrigation operations. The irrigation system will use 3,000 gallons per minute from the tank. Each acre requires 3,500 per day according to USDA and HDOA, with a total of 400 acres being irrigated on any given day, for a total requirement of 1.4MM gallons. To achieve this, the irrigation will be operated roughly eight hours per day in order to provide 1,440,000 gallons to cover the daily water requirements. Plots will be irrigated twice per week during the first and second week after planting, and once per week in the third week. After that no irrigation is needed unless a significant drought of more than 20 days is experienced.

1.4 Field Test Results

After growing sunflowers on several sites on the East and North parts of the Big Island, the following recommendations are offered:

1.4.1 Moisture

A. Initial

   a. The seeds require wet soil to germinate. In some of the drier regions of Waimea the first couple of inches dried very quickly when exposed to the constant winds present there. This resulted in a lack of germination.
   b. The soil must be well drained for the germinated plants to survive. Clay soils and moderate to heavy rains during the first few weeks tended to “drown” the new plants. The Shipman 2 site

was inundated with rain soon after planting which resulted in a very low survival rate.

B. Growth
   a. After the first two weeks, sunflowers do not require much water.
   b. Unirrigated sections tended to do better than the irrigated ones in areas with some rainfall.

Irrigation %	Seed Yield (lbs. /acre)	Foliage Yield (lbs. /acre)	Plant density (plants/acre)	Number of seeds per plant
0	3,693	6,142	37,771	1,084
50	2,118	3,424	46,764	712
100	1,890	3,433	43,167	752
Average	**2,567**	**4,333**	**42,567**	**849**

Figure 2: Average yield per irrigation level at Shipman 1

C. Dry conditions are necessary for the drydown phase. In Maulua, the excessive rain and/or humidity resulted in rotting seed heads and mold.

D. More investigation is needed to determine optimum water management at each individual site.

1.4.2 Weed Management

A. Herbicide
   a. Single glyphosate treatments worked initially for several sites but weeds still regrew quickly and in some cases outpaced sunflowers.
   b. Glyphosate was not effective at controlling Wainaku grass at the Honomu site. This may have been due to an initial disking prior to application.

B. Disking
   a. Initial disking was effective at incorporating dead weeds and turning under small plants, however this did not result in positive weed control after a few weeks.
   b. Wainaku grass in Honomu and morning glory at Shipman 1 grew quickly in the disked areas.

C. Grubbing
   a. The Waimea sites were grubbed using a bulldozer rather than being sprayed with herbicide or disked. Due to the deep soil in that area and equipment readily available, it was a viable option for small plantings.
   b. By scraping off several inches of topsoil, all grass roots and seeds near the surface were removed. This was highly effective for discouraging weed growth.

1.4.3 Fertilizer

A. Sunflowers tended to grow larger with higher seed yields when some Nitrogen fertilizer was provided. Excess Nitrogen did not result in higher yields.

B. In the Shipman site, the area with moderate amounts of added urea had the highest seed yield and highest foliage yield. This treatment was 75 lbs/acre of urea where the 100% treatment was 150 lbs/acre.

C. More investigation would be useful to determine optimum fertilizer for each site.

Fertilizer %	Seed Yield (lbs. /acre)	Foliage Yield (lbs. /acre)	Plant density (plants/acre)	Number of seeds per plant
0	2,459	4,045	46,764	715
50	2,634	4,757	43,167	797
100	2,608	4,198	37,771	1,035
Average	**2,567**	**4,333**	**42,567**	**849**

Figure 3: Average yields per fertilizer treatment at the Shipman 1 site

1.4.4 Planting Density

A. Notes on Planting Density The seeder used for this project was set to plant at 36,000 plants/acre.

B. The average extrapolated planting density came out much higher at most sites.

C. Generally the highest planting density also resulted in the highest seed yield.

D. The data suggests that a higher than recommended seed density could be beneficial. Due to small sample size and extrapolation margin for error, larger plantings should be done to evaluate high plant density as a yield boosting strategy.

1.5 Site Preparation Cost Estimates

The total infrastructure cost varies significantly based on the determination of whether to use a private or State-owned agriculture water system. A private water system would have the positive impact of insulating existing farmers from any impacts of the increased water usage in the region. Additionally, the private water system can provide backup to the aging State WIS, and so would likely garner the support of the existing farming community, which might otherwise express concerns about the plan. For purposes of this assessment, it is assumed that the water system will be private. The biofuels enterprise will also need to construct private roads to provide internal access to many of the sites, as well as storage for roughly

1,000 acres of harvest to ensure no loss of harvest during maintenance periods for the processing equipment.

The three basic components of the water system are a ground well, a reservoir system and a distribution system. The Task 6 report cited the sustainable yield studies, while the latest test drill information from the University of Hawaii at Hilo Geology Department provides evidence that the water resource would be reached at roughly 1,500-foot depths. The lands will not need to be permanently irrigated as field tests have demonstrated that sunflower only requires irrigation for roughly three weeks during the growth cycle, and only 1-2 days per week (two days in the first two weeks, and one day in the third week. This means that on any given day only 400 acres will be irrigated at 3,500 gallons per day, or 1.4MM gallons per day. A system with the capacity of 2MM per day allows for loss and maintenance periods. Storage is generally 20-30 times one day's usage for systems dependent on pumped water using ground water sources. To support this, a 60MM gallon reservoir will be used for planning. The reservoir would be placed no less than 100 feet higher than the highest farm plot to allow gravity feed distribution. Most sites will be developed with feed from a Driscoll line distribution infrastructure, though some sites may depend on trucked water. The costs for these systems are:

1) 2MM gallon per day well, drilling and pump installation at a 1,500 foot depth, with pump building and foundation - $5,500,000
2) 60MM gallon reservoir - $4,750,000
3) Distribution system for 2MM gallon per day (24-inch) - $1,650,000

The above estimates are based on current water system design costs developed to support the Hawaii Department of Agriculture and Mauna Kea Soil and Water Conservation District. Reservoir costs are developed using the information gathered by NRCS to support the Waimea-Paauilo Watershed Environment Impact Statement.

Road infrastructure costs are based on the use of local cinder from the Waimea region, which will enable a material cost of roughly $300,000 per mile. It is likely that 4-5 miles of internal roads will be required, with resulting material costs of $1,500,000 and labor/construction costs of an additional $200,000 per mile for a total of $2,500,000.

Sunflower storage in purpose built silos runs roughly $250,000 for 2,000 tons of storage. This is sufficient for the Farm Plan. With pad and construction, the total cost is $350,000.

Key Finding: A key factor in sunflower growth is the amount of water that is required during the sunflower growth cycle; specifically, more in the initial stages and less when nearing harvest. The regions with 30-80 inches (750mm to 2000mm) of annual rainfall are viable, though in fact regions with less rainfall, but access to irrigation water are more productive due to the need to starve the plant of water over its last 30 days to maximize oil production in the seed. It is readily apparent that the Waimea region is the only viable area to grow the sunflowers, as it is easier to provide irrigation water during the initial growth cycle rather than attempting to prevent rainfall from the sunflowers as it gets closer to harvest. For this reason, the Waimea region has a critical advantage over the other regions and thus the rest of this task report will focus on that region.

2. Site Selection Data

2.1 Soil Data to Crop Cost Estimates

Given the field test results, the current soil management plan was to front-load the soil with roughly 32 lbs. per acre of nitrogen in the form of urea, and with calcium to promote phosphorous uptake. After the first 2-3 harvests, it is anticipated that all the nutrients required by the plant will be front-loaded prior to planting to allow the soils to remain healthy. The root systems from the sunflower will be cut and retained in the soil by the disc operations to provide nitrogen and micro-organism replenishment. The enterprise will use organic pest management approaches, and avoid the use of herbicides to the greatest degree possible. The creeping nature of the kikuyu grass may require use of Roundup on the areas surrounding the parcels to prevent the spread during the fallow on crop rotation periods, though field tests to date have shown that the sunflower is dominant enough to choke out the grasses during its growth cycle.

To summarize Task 9, there were four Waimea test sites studied: Waimea 1, 2, 3 and 4.

A. Waimea 1 site had 30.1 inches of rainfall, to include greater than 6 inches on a single day. Rainfall appeared to drown plants. Plants were seen to have significant mold development.

B. Waimea 2 site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel, and meal samples were produced and tested.

C. Waimea 2 site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel, and meal samples were produced and tested.

Waimea 3 site showed strong growth, particularly in the moderate irrigation strip. The high irrigation strip had mixed results, with lower germination rates. The site showed little to no weed growth in sunflower planted area. The site was harvested, heads were dried, seeds were separated and processed. Oil, biodiesel and meal samples were produced and tested. The best yields were observed from the moderate irrigation zone, in the middle third of the planted area. There was very little rainfall in the test area during the last two weeks prior to harvest.

Waimea 4 site showed no significant pest, weed or grass incursions on the test planting area. Neem oil was applied during the month as a pesticide due to significant ant activity in the area surrounding the test site. No herbicides were applied. The site experienced near daily cloud cover, fog and misting. Sunflower head sizes measured at a minimum of 1.75 inches and maximum of 2.5 inches. The heads were too small to harvest effectively and plants were all less than three feet. Rainfall over growth period was 42.5 inches, which far exceeds recommended rainfall for growing period.

2.2 Site Infrastructure Cost Data

A. The three basic components of the water system are a ground well, a reservoir system and a distribution system. The costs for these systems are:

1) 2MM gallon per day well, drilling and pump installation at a 1,500 foot depth, with pump building and foundation - $5,500,000
2) 60MM gallon reservoir - $4,750,000
3) Distribution system for 2MM gallon per day (24-inch) - $1,650,000

B. Road infrastructure costs (based on the use of local cinder from the Waimea region) total $2,500,000:

1) Material cost of roughly $300,000 per mile. It is likely that 4-5 miles of internal roads will be required, with resulting material costs of $1,500,000
2) Labor/construction costs of an additional $200,000 per mile

C. Sunflower storage costs:

1) In purpose built silos runs roughly $250,000 for 2,000 tons of storage.
2) With pad and construction, the total cost is $350,000.

2.3 Site Lease/Purchase Cost Estimates

The current agriculture land lease prices in the Waimea region run between $100 and $300 per acre per year for irrigated land, and $40 per acre per year for pasture lands. More than 95% of the land under consideration for the biofuels enterprise are currently in pasture. Initial discussion with the landowners in the region indicate that long term leases would likely be achievable at $100 per acre. Many of the ranches currently lease 100-acre plots for $4000 per year. Some examples of recent leases include:

1) 40 Acres of Hawaii Department of Agriculture land in Hawaii North Kohala for $5130 (Item V) http://hdoa.hawaii.gov/arm/files/2012/12/Notice-of-Lease-by-Negotiation-11-11-13.pdf

2) Hawaii county Hamakua Agriculture lands at $11.63 per acre http://www.hawaiilife.com/articles/2011/08/hawaii-county-offering-leasehold/

On fee simple lands, the lands that currently lack access to water have sold in the range of $500 per acre, though that price has been significantly affected by the U.S. Army purchase of 24,000 acres of Parker Ranch land for $11MM. For purposes of planning, it is likely that $750/acre would be an average across the various plots.

These costs would result in Waimea/Lalimilo land costs of either $1MM per year for leased land, or an investment of $7.5MM as a single investment.

3. Required Documents for Commercial Operation

3.1 Preliminary Engineering Plans

Civil engineering for the project will be required to support the road construction, as well as the irrigation system easement. If a new building is constructed to support the processing facility, a civil engineering plan will be required for the foundation as well as the electrical, water and wastewater infrastructure.

3.2 Draft Environmental Statements

The determination to develop an environmental impact statement will be guided by Hawaii Revised Statutes Chapter 343. The statutes do not require an Environmental Assessment for private lands, as long as no State or County funds are used. However, the Homesteads Lands are Trust lands for which the State of Hawaii has fiduciary responsibility. As such, according to HRS 343-5 (a) (1), an Environmental Assessment will be required for the agriculture and agriculture processing components if they alter the existing uses for the land. This would only affect the actual processing facility. The most likely location for the processing facility is co-located with the Waimea Nui Community Development Initiative Agriculture Complex, which has already completed a Final Environmental Assessment as of May 2015. As such, it is not expected that any HRS 343 requirements will be imposed.

Continuing agriculture operations do not require State Historic Planning Department (SHPD) approval. All road and facility construction will require clearance. The region has been in agriculture production or forestry for most of the last 500 years. There are also several historic sites whose locations are held confidential by the State Burial Council. The lands do have several of these sites, and the development plan will require planning to avoid any of these areas. The site of the processing facility already has a SHPD clearance as part of the Waimea Nui Final Environmental Assessment as well as a Federal National Environmental Policy Act (NEPA) Finding of No Significant Impact (FONSI).

3.3 Draft Permits & Leases

In 2012, the Hawaii legislature passed Act 203, which is designed to encourage the expansion of local agriculture in the State. Each County has adopted Act 203 into their respective County Code. The Act has been adopted in HRS as well in section 46-88. This section states that "The aggregate floor area of the exempted agricultural buildings shall not exceed….eight thousand square feet plus two per cent of the acreage per zoning lot for lots greater than five acres..." in HRS 46-88 (2) (c) (1) (C). The act further provides the definition of the exempt structures, which cover all the facilities expected to be used by the enterprise. The following excerpt from HRS 46-88 (8) provides:

"(8) Permit-exempt structures shall be exempt from any certificate of occupancy requirements.

(d) As used in this section:

"Agricultural building" means a nonresidential building or structure, built for agricultural or aquacultural purposes, located on a commercial farm or ranch constructed or installed to house farm or ranch implements, agricultural or aquacultural feeds or supplies, livestock, poultry, or other agricultural or aquacultural products, used in or necessary for the operation of the farm or ranch, or for the processing and selling of farm or ranch products.

"Agricultural operation" means the planting, cultivating, harvesting, processing, or storage of crops, including those planted, cultivated, harvested, and processed for food, ornamental, grazing, feed, or forestry purposes, as well as the feeding, breeding, management, and sale of animals including livestock, poultry, honeybees, and their products."

There are several permits that will apply to the farm operation. These are:

County Permits:

- Sign Permit (Public Works Building Division)
- Grading & Grubbing Permit (Public Works Engineering Division)

State Permits:

- Department of Health Construction Plan Review and Approval
- Dealer License (HDOA Commodities Branch)
- Underground Storage Tank Permit (DOH Solid and Hazardous Waste)
- Solid Waste Management Permit: Remediation (DOH Solid and Hazardous Waste)
- Water Quality Certification (DOH Clean Water Branch)
- NPDES Permit (DOH Clean Water Branch)
- Food Establishment Permit (DOH Food and Drug)
- Food Safety Certification
- Community Noise Permit (DOH Indoor and Radiological Health)

Unexploded Ordinance Mitigation:

As of December 2014, the U.S. Army Corps of Engineers (USACE) has determined that the former Waikoloa Maneuver Area, which constituted the training areas for troops during World War II, may have included the farm and pastoral regions that represent the lands identified for the biofuels enterprise. The USACE has determined that the lands have been in continuous agriculture use, and that agriculture operations do not present an unusual hazard. As such, the lands designated for sunflower growth do not require clearance, and will follow the existing procedures requiring all work to stop if ammunition is discovered, that the police be notified, and that the DoD be brought in to detonate or destroy the munitions.

The facilities and roads, however, will require an initial scan of the land intended for use, and will require an on-site monitor for any "earth altering activities" such as excavation.

4. Site Specific Information

4.1 Estimate of Capital Costs

Estimate of Capital Costs			
Description	**Acres**	**Per Acre**	**Total**
Land Costs (Waimea Pasture)	10,000	$100	**$1,000,000**
Farm Equipment Costs			**$2,083,000**
Infrastructure Costs			
Private Water System			
2MM Gal/Day Well; 1,500 ft. Depth			$5,500,000
60 MM Gal Reservoir			$4,750,000
Distribution system for 2MM gallon per day (24-inch)			$1,650,000
Road Infrastructure	**Miles**	**Per Mile**	
Material Costs (Local Cinder)	5	$300,000	$1,500,000
Labor Construction Costs	13	$200,000	$2,500,000
	Tons	**Per Ton**	
Sunflower Storage Silos(with pad & construction)	2,800	$125	$350,000
Total			**$16,250,000**

Figure 4: Estimate of capital costs

4.2 Permit Costs

Permit Costs	
State Permits	**Cost**
Department of Health Construction Plan Review and Approval (Sanitation Branch, Kona Plan Review)	$300
Dealer License (DOA Commodities Branch)	$40
Underground Storage Tank Permit (DOH Solid and Hazardous Waste) (Installation & Operation)	$150
Solid Waste Management Permit: Remediation (DOH Solid and Hazardous Waste) (Solid Waste Management Permit By Rule)	$25
Water Quality Certification (DOH Clean Water Branch) (Filing Fee)	$1,000
NPDES Permit (DOH Clean Water Branch)	$1,000
Food Establishment Permit (DOH Food and Drug) (annual and renewal)	$400
Food Safety Certification (Food Safety Management Principles Course with Exam)	$125
Community Noise Permit (DOH Indoor and Radiological Health)	$50
Subtotal	***$3,090***
County Permits	
Department of Planning and Permitting Construction Plan Review and Approval (State)	$500
Sign Permit (Public Works Building Division)	$500
Grading & Grubbing Permit (Public Works Engineering Division)	$90
Subtotal	***$1,090***
Grand Total	**$4,180**

Figure 5: Estimate of permit costs

4.3 Commercial Scale Farming Design Costs

Commercial Scale Farm Design Costs			
Farm Design, Planning Consulting Rate: $135/hr			
Description	No. of Hours	Unit Cost	Total
Boundary Map	30	$135.00	$4,050.00
Predesign Consulting	20	$135.00	$2,700.00
Aerial Topo Map Production	30	$135.00	$4,050.00
Design Platform	50	$135.00	$6,750.00
Site Visit	50	$135.00	$6,750.00
Concept Planning	40	$135.00	$5,400.00
GIS/CAD Based Concept Plan	150	$135.00	$20,250.00
Design Development Estimates	150	$135.00	$20,250.00
Concept/Detail Plan	20	$135.00	$2,700.00
Concept/Detail Feedback	20	$135.00	$2,700.00
Concept/Detail Revisions	10	$135.00	$1,350.00
Follow Up	40	$135.00	$5,400.00
Total			**$82,350.00**

Figure 6: Estimate of commercial scale farm design costs

4.4 Crop Growth Potential

The suitable lands generate fuel potential by two means, oil and cellulosic biomass. The overall project is defining production based on 10,000 acre units; however, this report is evaluating overall potential so will aggregate to a final figure. Each 10,000 acres, as documented in the Task 5 and Task 7 reports, produces roughly 950,000 gallons of oil and 100,000 tons of dry biomass per harvest. The growth cycle for the crops is 100 days plus or minus 10 days. This would conceptually allow for 3.5 harvests per year, but with cover cropping, soil rest and crop rotation the actual number is closer to 2.2. For purposes of this report, the number used is 2.2 and it is used to match with the other assumptions.

- At 2.2 harvests per year, each 10,000 acres will produce 2,090,000 gallons of oil and 220,000 tons of dry biomass.

- With 82,000 acres available, the total is 8.2 times the 10,000 acre unit. As a result Hawaii Island has viable potential to produce 17,138,000 gallons of sunflower oil annually and 1,804,000 tons of dry biomass annually.

- The industry average is 9.0 gallons of biodiesel for each 10 gallons of sunflower oil. The result is a potential for roughly 15,250,000 gallons of biodiesel.

- The industry average is 51 gallons of fuel for each ton of biomass input. The result is a potential for roughly 92,000,000 gallons of advanced biofuels. **Note that the cellulosic systems are less commercially proven and conversion rates are less certain**.

4.5 Operating Costs

The Task 5 economic analysis report developed a set of assumptions on farm operating costs based on existing mainland data. Task 7 further refined the information to incorporate expected Hawaii shipping and cost differentials into all the imported supplies. Following the initial field tests, several key findings emerged that will affect operating costs. First, the field tests have shown a lower need for fertilizer than is found on the mainland, though the long range sustainability of the soils will likely require increased fertilizer use over time. A second key finding saw improved germination rates with early irrigation, either as a result of rainfall or irrigation. This second finding will add some cost per acre to account for the water usage, with the expectation that at roughly $21 per acre foot, and a need for 1.5 acre foot of water per acre over the 110-120 day growth cycle, adding up to $31.50 per acre for water costs.

Projected Full Farm Annual Operating Costs				
Cost Category	**Per Acre / Per Harvest**	**Harvest Multiple**	**Annual Full Farm**	**Notes**
Land Preparation	$30.00	2	$600,000.00	Assumes land to be cleared by disc vice till
Seed and Treatment	$47.91	2	$958,200.00	Importing seed at Nuseed pricing
Cover Crop	$65.00	2	$1,300,000.00	Based on winter wheat costs in South Dakota
Fertilizer	$12.12	2	$242,400.00	Original Estimate of 150 lbs acre revised to 37 lbs per acre
Herbicide	$12.50	2	$250,000.00	Not currently used, estimate is for future use
Fungicide	$9.75	2	$195,000.00	Not currently used, estimate is for future use
Insecticide	$11.25	2	$225,000.00	Not currently used, based on future use of Neem oil
Import Logistics	$12.25	2	$245,000.00	Roll up from Task 7 Report at 25% usage rate
Fuel	$13.25	2	$265,000.00	Reflects use of biodiesel
Labor (hourly)			$1,831,992.00	Roughly 4 times Task 5 costs due to 10,000 acre farm size
Labor (Benefits)			$366,398.40	Estimated at 20% of labor
Crop Insurance	$21.17	2	$423,400.00	USDA signficantly revising crop insurance program
Land Cost (Lease)	$25.00	2	$500,000.00	Annual Lease at $50 per acre averaging pasture and ag
Equipment Depreciation			$246,500.00	
Water/Irrigation	$31.50	2	$630,000.00	Either payment to State or to repay infrastructure loan
Transport to Processing	$23.77	2	$475,400.00	Based on Task 7 Report
Accounting/Legal			$45,000.00	
Total Annual Operating Cost			**$8,799,290.40**	
Operating Cost Per Acre			**$439.96**	

Figure 7: Annual Operating Costs

Figure 7 above provides the breakdown of the annual operating costs. The per acre cost of $439.96 is below most of the mainland costs, due largely to the higher usage rate of the land. The Hawaii acreage would be in production 320-340 days of the year, while mainland farms are in production roughly 190 days.

There are several less significant cost revisions that the crop tests have shown to date. The stronger per acre harvest size increases the number of trips required to haul the seed to the crushing mill. Although the original plan postulated that the land be tilled between crops cycles, subsequent tests have shown that till-free is better suited to the Waimea lands, with a far less expensive disc approach being sufficient to maintain the land in plant ready states.

5. Conclusions

Only two tests sites in Waimea – Waimea 2 and 3 – produced sufficient sunflower heads to harvest and test.

The Waimea/Kohala region is dominated by lands designated as either important or extensive agriculture lands. The region provides the largest single parcels, and has roughly 126,800 acres which could be used for biofuel crops, with no less than 54,000 of these accessible within a year or less. This 54,000 acres includes both private and trust lands to include estimates of roughly 7,000 acres out of the 21,000 acres in ranch land on the Hawaiian Homelands and 47,000 acres of other private lands. There are very few government lands available in the region. The suitable inventory is 45,000 acres. The reduction is driven by the availability of agriculture water in the region.

The primary reason that the lands are currently lightly used is a lack of water infrastructure. The region, as identified in the Task 6 Report, has more than sufficient water resources, and only requires investment in infrastructure. Figure 9 outlines roughly 54,000 acres of the 150,000 identified in Figure 8. The land is accessible from county cinder roads, which are more than sufficient to handle the equipment needed to prepare, plant and harvest the lands, though additional road infrastructure will be required to specifically reach some of the lands which are currently in large pasture lots. The region has two available cinder sites which have the capacity to support all the needed road construction, reducing costs.

Districts	Agricultural	Conservation	Rural	Urban	Total
Puna	175,104	138,563	146	6,329	320,142
South Hilo	70,695	169,493	0	12,814	253,002
North Hilo	53,587	120,110	71	608	174,376
Hämäkua	162,729	235,805	13	1,041	399,588
North Kohala	64,713	13,187	16	2,434	80,350
South Kohala	**150,426**	**15,356**	**53**	**10,608**	**176,443**
North Kona	158,853	188,331	477	17,787	365,448
South Kona	110,749	35,051	31	845	146,676
Ka'u	237,743	422,239	0	1,801	661,783
Total	1,184,599	1,338,135	807	54,267	2,577,808

Source: DBEDT, Office of Planning GIS data

Figure 8: GIS Land Designation Chart

Figure 8 is drawn from the DBEDT database and provides an overview of the acreage in each land designations for the regions on the island.

Major Landowners on Hawaii
(In Acres)

Major Owner	Planned Growth: Developed	Planned Growth: Undeveloped	ARL	Total on Hawaii
State of Hawaii	6,588.6	9,223.7	90,868.5	947,452.5
Kamehameha Schools	1,609.5	3,524.6	73,071.9	297,194.0
Parker Ranch	882.4	703.9	87,334.0	134,662.0
State DHHL	1,097.2	3,523.7	65,853.3	112,593.0
James Campbell Estate	0.0	0.0	96.5	26,700.0
Yee Hop	0.0	0.0	4,495.8	21,637.1
W.H. Shipman	1,103.6	1,548.1	6,286.5	16,839.9
Hawaii Forest Pres.	0.0	0.0	337.2	13,230.0
The Nature Conservancy	0.0	0.0	4,794.6	11,699.8
Hokukano Ranch	77.9	0.0	4,759.4	11,293.8
Queen Emma Foundation	322.5	2,086.0	2,947.1	10,261.4
Waikoloa Village Ass.	263.7	111.3	751.2	10,118.4
County of Hawaii	296.5	806.7	3,758.1	5,427.2

Note:
All acreages are based on GIS generated figures, except Total Acres, which is based on Tax Acres.
Developed parcels are based on TMK records with Bldg Value >= $10K
Undeveloped parcels are based on TMK records with Bldg Value < $10K

Figure 9: Island-Wide Land Ownership Table

Figure 9 provides the major landowners on the island, after the collapse of the plantation system in 1994.

In particular, the dry Puukapu area shown in figure 10 below, has potential for pastureland suitable for sunflower growth, sufficient irrigation and conversely minimal rainfall during the last 30 days prior to harvest, and topography suitable for efficient use of farming equipment for planting and harvesting. Landowners in this area include Parker Ranch and the Department of Hawaiian Homelands (DHHL).

Figure 10: Puukapu Area

Summary Table Per 10,00 Acre Farm Lots			
Costs	Acres	Cost Per Acre	
Land Costs:			$1,000,000
Farm Equipment Costs:			$2,083,000
Infrastructure Costs:			$16,250,000
Permit Costs:			$4,180
Commercial Scale Farming Design Cost:			$82,350
Annual Operating Cost:	10,000	$439.96	$4,399,600
Production			
209,000	gallons of oil annually		
220,000	tons of dry biomass annually		
188,100	gallons of biodiesel annually		
11,220,000	gallons of advanced biofuels annually		

Figure 11: Summary Table of Costs and Production per 10,000 Acre Farm Lot

Hawaii Island has the land, water and energy resources needed to support a 10,000 acre biofuel farming operations in the Waimea/Kohala region. The farm operations will almost certainly not be contiguous acreage given the topography and the size of most of the available plots. There are two tracts of land in the Waimea region that exceed 10,000 acres, but the topography across areas of each of the tracts would make farming difficult. However, with the weekly planting/harvesting farming approach having a single plot is both unnecessary, and would likely require significant road and irrigation infrastructure to cover all of the currently undeveloped acreage. There are more than sufficient available plots with existing road access to reach the 10,000 acre goal while maintaining a 400 acre per week production cycle.

The existing biofuels operations, livestock feed markets, along with current and projected bio-markets have been shown to both produce the revenue and create the demand needed to support the farms as detailed in the reports for Task 5 and 7.

Hawaii Island has sufficient natural resources to support at least two 10,000 acre farm operations. Between rainfall, surface water and ground water, the Island has resources vastly exceeding the 1.2MM gallons per day that the farm would need when irrigating the 400 acre plots with the standard agriculture use of 3,500 gallons per day.

There are several existing commercially available biomass conversion systems currently operating that have the ability to convert the silage to either fuels (preferred) or electricity. These systems can enable the full use of the total sunflower/jatropha biomass envisioned, maximizing the revenue opportunity for the farm.

BOTTOM LINE: By operating a biofuels farm with weekly plantings and harvests, creating a 10,000 acre biofuels crop farming operation is economically viable and realistic.

Hawaii Military Biofuels Crop Program

Task 11
Jatropha Farm Optimization

Prepared For:

Hawaii Natural Energy Institute

Under Award N00014-11-1-0391 from:

Office of Naval Research

Under Sub Award Number MA150004 from:

Hawaii Natural Energy Institute

University of Hawaii

Prepared By:

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Table of Contents

Forward

This document details the work performed to maintain and develop an existing mature *Jatropha curcas* farm. Improvements to the farm's key baseline metrics and progress toward optimization goals are documented in this report. Based on key findings, the report will assess and summarize the suitability of jatropha to meet DOD operational goals of local fuel production for increased energy security.

I. Introduction

The 200-acre *Jatropha curcas* test site was planted in 2008 with the goal of producing sustainable fuel crops for local processing and end use. Beginning in October 2012, the mature four-year-old farm received funding as a contracted research entity of Pacific Biodiesel Technologies under the Hawaii Military Biofuels Crop project (HMBC). The farm was maintained under the HMBC funding until the end date of the first phase of the project, December 31, 2013. The current phase of the HMBC project began in February 2015.

Farming tasks pertaining to the maintenance and harvesting regimen were historically centralized around mechanization of all tasks. This general practice of complete mechanization provided emphasis on cost reduction as a means to ensure operational success. Due to the prior common understanding that jatropha did not require fertilizer to produce marketable yields, emphasis was not placed on increasing yields by employing proactive farming techniques.

For this phase of the jatropha cultivation, however, the use of fertilizers and mulch, row spacing adjustment, forage animals for understory maintenance and plant growth regulators were proposed to increase yield.

Under this current round of HMBC funding, the the farm was reduced from 200 non-contiguous acres to 120 contiguous acres. This reduction was deemed necessary in order to properly and more efficiently maintain the fields within the established budget.

The following report is a documentation of employment of various techniques aimed at increasing jatropha fruit yield and decreasing maintenance costs.

II. Detail of preliminary maintenance

Prior to implementation of the Farm Optimization Plan (FOP) set forth in Task 3, preliminary pruning and maintenance of the jatropha farm was required. Due to a gap in funding, farm maintenance was deferred for a period of 14 months. During this time, fast growing soft wood trees already present in the fields outpaced jatropha growth. Notably, macaranga (*Macaranga tanarius*) and gunpowder trees (*Trema orientalis*) began to form a canopy over the jatropha fields. Under a normal maintenance regime these undesirable trees are controlled and not allowed to negatively impact jatropha production. During the course of the 14-month funding gap, the extremely fast growing weed trees grew to an average height of 14 feet. Shade from these trees initiated a dormancy response from the jatropha underneath. While the jatropha did not perish, all fruit production came to a halt. In order to restart jatropha production, removal of the macaranga and gunpowder trees was required. Due to tight intergrowth of undesirable trees and jatropha trees, the simplest and most cost effective plan for removal centered on the use of a Caterpillar 345 B excavator outfitted with a Fecon “bullhog” mowing attachment.

Fig. 1 Pruned jatropha in foreground, after weed tree removal

Fig. 2 Close-up view of Cat 345B with mower

Removal of the macaranga and gunpowder trees coincided with jatropha tree pruning. During regular production, *Jatropha curcas* must be pruned yearly in order to maintain harvestable height and plant vigor. After removing the undesirable trees, jatropha was subsequently pruned with the excavator to a height of 24-30 inches, as detailed in Figure 1. The excavator cleared and pruned approximately two acres per 8-hour work day. Additional maintenance in the form of mowing and herbicide spraying followed immediately to ensure understory control.

III. Historically established jatropha baseline metrics

Prior to implementing the jatropha optimization plan, the following baseline metrics were observed.

A. No-fertilizer regimen

As mentioned in the introduction, jatropha was originally touted for its ability to thrive and produce marketable yields without requiring fertilizer. For this reason, and to avoid unnecessary expense, fertilizer was not used within the fields. Ultimately, yield results determined that this no-fertilizer program garnered relatively low jatropha yield, and that fertilizer is indeed necessary for *Jatropha curcas*. Across the farm, yield under the no fertilizer regimen averaged 900 pounds per acre, per harvest of dried jatropha seed. This seed contains approximately 35% oil weight, which equates to 42 gallons of crude jatropha oil per acre, per harvest.

B. Mowing row interiors

Field maintenance is absolutely necessary in order to produce maximum yields. Mowing the interior spaces between the rows required .5 labor hours per acre mowing weeds and grasses. In order to control weed growth, mowing was required every six weeks. Based on 120 acres of jatropha, this amounted to 40 labor hours per month spent on mowing.

C. Herbicide on tree understory

Herbicide was applied at the bases of trees to combat weeds, vines and grasses not cut by mowing. Herbicide applied by tractor, via 100-gallon tractor-mounted spray tank, was used on a bi-monthly basis. Based on 120 acres, application time and materials took roughly 30 minutes per acre and cost $18 per acre.

IV. Results of farm optimization plan

A. Fertilizer regimen

The farm optimization plan (FOP) called for the following fertilization regimens to be applied:

Test soil for nutrient content in areas known for higher yields and healthier plants and compare to the fields with the worst performing areas. Observe other factors, such as bulk compaction, soil depth, soil type, and drainage. Compare data to other studies on jatropha nutrient demands and optimum soil conditions. Fertilizer trials should occur two months prior to flowering for optimal results.

- ***Trial 1 - Apply** dolomite lime at a rate of 500 pounds per acre. This is a one-time application.*
- ***Trial 2** - Apply 16-16-16 fertilizer at a rate of 150 pounds per acre. It will consist of three monthly applications, starting two months prior to flowering and continuing one month past flowering.*
- ***Trial 3** - This trial will be performed on the same area as trial 1. 16-16-16 will be applied at a rate of 150 pounds per acre. The fertilizer will be applied four months after initial application of calcium, to allow for calcium absorption. This trial will show the effect of calcium on macro-nutrient availability in the soil.*

Soil tests were taken on May 19, 2015 in five different areas of a selected jatropha field displaying variability in fruit production. After reviewing the results, these soil samples presented data suggesting the field was very low in all macro-nutrients, and that the variability in yields was due to variability in nutrient levels inherent in the soil. Across the tested area, soil contained relatively low levels of calcium. These results were as expected for the area. Refer to addendum 1 for analysis results.

In accordance with the FOP and in congruence with the soil results, a fertilizer regimen was administered in July and August of 2015.

1. Observation of calcium carbonate application

Trial 1 focused on increasing soil pH via application of calcium carbonate. Due to a relatively low level of calcium in the soil per the soil sample results, prilled calcium carbonate was broadcast at a rate of 1,500 pounds per acre to all jatropha within the sub-plot area. The results of this test were recorded in terms of yield increase. Results of this application of calcium alone were inconclusive, producing negligible increases in fruit production. There was no noticeable increase to fruit production in the November harvest due to this amendment, and for this reason, no fruit from this test was harvested.

2. Observations of macro-nutrient application

Trial 2 of the fertilizer regimen on the FOP was administered in August of 2015. Triple sixteen (16-16-16) fertilizer was selected due to a balanced macro nutrient profile and ready availability. Three monthly applications at a rate of 150 pounds per acre were administered directly to the soil at the tree drip-line. Three sub-plots of 12 trees each were randomly selected for this fertilizer application. Fruit data was collected on these sub-plots and is presented below in figures 3 and 4.

Seed was collected from three sub-plots which contained 12 plants each. A random sample of 20 fruit was selected for husking (figure 4), and total number of seeds from those fruit were quantified and dried to 10% moisture. Dried seed weight of that random sample was calculated and recorded in figure 4.

		Fruit count*	Total seed**	Seed weight per subplot (g)		Seed weight per subplot (lb.)	**Seed pounds per acre****
Rep 1		2234	5138.2	3949.7		8.7	**1044.9**
Rep 2		2467	6167.5	4920.4		10.8	**1301.7**
Rep 3		2410	5784	4848.4		10.7	**1282.7**

Figure 3: Jatropha fruit count data from increased fertilizer application

****Collected and counted 11-5-15***
*****Based on subplot seed weight and 1440 plants per acre, calculated from numbers in figure 4***

	Seed count*	Average number of seed per fruit	Weight of seed (g)**	Average single seed weight
Rep 1	46	2.3	35.36	0.77
Rep 2	50	2.5	39.89	0.79
Rep 3	51	2.4	42.75	0.84

Figure 4: Jatropha seed count data derived from 20 fruit

****Seed count data based on 20 fruit randomly selected for husking***
***** Total weight of seed sample gathered from 20 fruit, after drying to 10% moisture***

Figure 5. Green jatropha fruit

Figure 6. Ripe jatropha fruit

3. Macro nutrient plus calcium application

Trial 3 of the fertilizer regimen of the FOP was not performed due to budgetary constraints.

B. Optimal row and tree spacing experiment

According to the Farm Optimization Plan (FOP), tree population density and row spacing experimentation were to be performed in order to increase fruit yield. The FOP specifically called for the following treatment:

Hypothesis: Increased spacing between planted jatropha trees will have a positive effect on fruit yield due to increased light for photosynthesis and decreased demand for nutrients and water.

Objective: Compare yields on conventional planting densities at the jatropha farm of 1100 trees per acre (3'x12' row spacing) to yields on fields with planting densities of 75% and 50% of original.

Method:

- ***Trial 1 - Remove trees within the row to increase spacing to a pattern of 12' x 6'.***

- ***Trial 2 - Remove an entire row, decreasing planting density by 50% and increasing spacing to 24' x 3'.***

The concept of increasing fruit yield by widening space between trees for increased light penetration and decreased nutrient demand on the soil would be realized at the cost of directly reducing tree population which could potentially negatively impact future yields. In recognizing this conundrum, the team decided to move forward prudently and administer a trial which would likely produce positive results while striving to reduce chances of automatically reducing overall per acre yield due to over-culling trees. As originally planted, tree population density was equal to 1,100 trees per acre. A 25% tree population reduction was determined for the test so that tree population would be reduced from 1,100 to 825 trees.

Additionally, a second population reduction trial was administered. Under this sub-trial, and in a different field, every third row was completely removed from a square acre. This was replicated three times. Overall population reduction remained the same, only the method of tree reduction differed. The results and effects of differing methods of tree population reduction will require additional time to quantify. Surrounding trees have yet to show any positive response to the additional light and decreased nutrient demand. Further, the trial was administered in an area which remained under a no-fertilizer regimen of jatropha production. For this reason, effects to baseline metrics in terms of yield are not yet determinable. One unforeseen negative impact directly attributable to the removal of trees is a prominent increase in growth of weeds and grasses due to higher levels of solar radiation reaching the understory. This initial spike in weed pressure may decrease over time as tree canopies close in; however, the additional growth required extra herbicide to be applied.

C. Pasture and forage trial

The FOP called for the following actions pertaining to the use of animals to control weed growth within jatropha orchards:

Hypothesis: Use of pasture animals such as goats or cattle will have a two-fold positive economic impact on the jatropha operation, with grazing to decrease maintenance expenses, and manure generation to fertilize the fields to increase yields. For the purpose of this trial, the value of the animal will not be factored in; however, it is worth noting that a secondary revenue stream could develop with the success of this synergistic trial.

Objective: Compare the effectiveness of employing pasture animals for weed control against conventional techniques of mowing and herbicide.

Method:

- ***Test 1 - Graze three goats on a fenced acre containing both pasture and jatropha rows. Observe weed reduction/growth, crop damage, animal health, and grazing preferences. Compare cost data to that of conventional upkeep. Maintain animal welfare. Observe weekly and collect data for five months.***

- ***Test 2 - (Contingent on positive results from Test 1.) Fence in five acres to deploy beef cattle. Perform identical observations and analyses to Test 1.***
- ***Test 3 - (Contingent on positive results from either previous test.) Expand fenced rows to 20 acres to observe improvement in economics and/or yields utilizing the grazing animal of choice.***

For the purposes of practicality and availability, the actual trial deviated from the FOP in that cattle were used in Test 1 of the pasture and forage portion of the FOP instead of goats. Due to budget constraints, a one-acre fenced paddock was constructed. Results of the trial are detailed below.

At the 70-foot elevation in the Puna district, regular nightly rainfall and abundant daytime solar radiation cause rapid vegetative growth of all plants. Within existing jatropha fields, the following grass and weed species are present:

- Sourgrass- *Digitaria insularis*
- Guineagrass- *Panicum maximum*
- Wainakugrass- *Panicum repens*
- Crimson fountaingrass- *Pennisetum setaceum*
- Molassesgrass- *Melinis minutiflora*
- Sleeping grass- *Mimosa Pudica*
- Maile pilau- *Paederia scandens*
- Gunpowder tree- *Trema orientalis*
- Macaranga tree- *Macaranga tanarius*
- Glorybush- *Tibouchina urvilleana*
- Seashore vervain- *Verbena literalis*
- Candle bush- *Senna alata*
- Bushy beardgrass- *Schizachyrium condensatum*
- Castor bean- *Ricinus Communis*
- Melochia- *Melochia umbellata*
- Melastoma- *Melastoma candidum*
- Largeleaf lantana- *Lantana camara*
- Spreading dayflower- *Commelina difusa*
- Koster's curse- *Clidemia hirta*
- Spiny amaranth- *Amaranthus spinosus*

A low-pressure grazing regimen was chosen as a safeguard to the animals, as they would not consume the inedible jatropha leaves. The grazing trial began in March of 2015. Two young (~2 years old) heifers were released in the one-acre paddock for a three week period of time. Results were immediately visible.

1. Week one results of grazing

   Cattle began consuming the most desirable grasses first, eating young shoots of the more palatable molasses grass (*Melinis minutiflora*), guinea grass (*Panicum maximum)* and wainaku grass (*Panicum repens)*. Grazing was mostly limited to open areas surrounding the field; cattle did not begin to graze the row interiors in week one.

2. Week 2 results of grazing

Grazing continued on the perimeter of the jatropha fields. Grasses and weeds were completely consumed in this area at the end of week 2. Minimal grazing was observed on row interiors; nearly all grazing efforts remained in open areas where more desirable forage existed. The perimeter area was nearly exhausted of edible forage.

3. Week 3 results of grazing

Due to limited supply of edible forage in the perimeter areas, cattle began to enter rows and grazed on edible grasses and weeds. Foraging in this area was thorough, with at least 80% of available grasses and weeds being consumed.

Inter-grazing cattle with jatropha curcas was highly beneficial for weed maintenance. With continued use of cattle as weed control vectors, mowing would likely not be required for routine maintenance.

Cattle were very effective at controlling vines and grasses; however, certain weeds were not controlled such as gunpowder trees (Trema orientalis) and macaranga trees (Macaranga tanarius). With initial manual removal of these trees, cattle would likely eat any new tree shoots that regrow.

In addition to decreasing maintenance cost, cattle manure will likely have a positive effect on seed yield. Additional testing would be required to determine the amount of nutrients returned to the soil.

The pasture and forage trial decreased the amount of time required to control weed pressure. Mowing required an estimated 60 labor hours per month. With expanded use of cattle, the amount of time required will be reduced by roughly 50% to 30 labor hours per month. The saved labor hours would be spent managing cattle instead of mowing.

Figure 7. Undesirable overgrowth at beginning of cattle grazing trial

Figure 8. Fence line view, grazed area on right

Figure 9. View of grazed paddock detailing uneaten jatropha

D. Plant growth regulator trial

The FOP called for plant growth regulator (PGR) hormones to be trialed to produce higher yields; however, the plant growth regulator trial portion of the FOP was not performed due to budget constraints.

E. Mulching trial

The FOP planned for the application of mulch along the base of the trees for the purpose of increased soil vitality and weed pressure reduction. The mulch trial was not performed under the FOP due to budget constraints.

V. Final analysis of improvements to baseline metrics and conclusions

The most significant improvement to successful cultivation of jatropha appears to be proper selection of the trees, including hybrid varieties. While initial results are quite encouraging, the evaluation of different varieties will take time, continuing well beyond this project timeline.

The greatest improvement to baseline metrics of existing trees were noted within the fertilizer trial. Yield increases of over 70% are indicated with optimized fertilizer application. These yield increases will only result in positive economic returns for a farm when applied to well selected hybrid trees. Rainfall, temperature, relative humidity and solar radiation all play a major role in determining yield. Selecting planting sites carefully is therefore a significant contributor to overall economics.

Based on our current work, it appears that jatropha could be advantageous to the fulfillment of DOD fuel production goals when correct varieties are planted in suitable locations and managed well in regards to fertilizers, weed controls and plant growth regulators.

VI. Addendum 1

Soil sample results 5-19-15

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SOIL ANALYSIS

Pacific Biodiesel Technologies
ATTN: James Twigg-Smith
16-240 Mikahala Street
Keaau, HI 96749

RECEIVED: 05-19-15
COMPLETED:

AGENT:
PHONE:

Phone No.: 854-6568
JCNO: 15-051910
COMMENT

			mmhos/cm		ppm,ug/g				%	%		mg/dm3
LABNO	EXTRT	DESCRIPTION	pH	EC	P	K	Ca	Mg	N	TC	Mn	Fe
15-878		1	6.0		30	186	866	138	0.47		5.2	109
15-879		2	5.8		40	31	537	41	0.24		3.0	80
15-880		3	6.0		26	42	2306	258	0.58		5.4	174
15-881		4	6.2		17	1244	3168	240	0.56		6.7	147
15-882		5	5.7		17	123	869	81	0.59		5.0	119

*Extractants: P/MT=Mod. Truog, P/OL=Olsen, AA=Ammon. Acetate bases.