Biomass-Derived Energy Products and Co-Products Market and Off-take Study

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Revised Subtask 4.1 Deliverable on: Analysis/Assessment of Co-Product Market Options for Bio-Energy Systems
AND
Assessing Bio-Energy Product Markets Options
(Report covers both product and co-product markets)

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And submitted to

Hawai‘i Natural Energy Institute
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Hawaii, USA

Prepared for

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Puunene, Hawaii, USA

By

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Irvine, California, USA

September 7, 2012

Stillwater Associates

Disclaimer

Stillwater Associates LLC prepared this report for the sole benefit of Hawaiian Commercial & Sugar Company.

Stillwater Associates LLC conducted the analysis and prepared this report using reasonable care and skill in applying methods of analysis consistent with normal industry practice. All results are based on information available at the time of presentation. Changes in factors upon which the report is based could affect the results. Forecasts are inherently uncertain because of events that cannot be foreseen, including the actions of governments, individuals, third parties and competitors. NO IMPLIED WARRANTY OF MERCHANTABILITY SHALL APPLY.

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Executive Summary

Hawaiian Commercial and Sugar retained Stillwater Associates LLC to create a Biomass Derived Energy Products and Co-Products Market and Off-take Study in September 2011. HC&S is evaluating a number of technologies that convert sugar cane products into "drop-in" biofuels and co-products.

The first step in the Stillwater study was to develop a list of the biofuels and co-products that can be produced by the technology processes being studied by HC&S. The biofuels chosen for further evaluation include jet fuel and diesel produced via a Fischer Tropsch (FT) process, as well as algal oil, biobutanol, and pyrolysis oil.

The second step in the study was to develop a market analysis for the products. This study assumes FT fuels will meet ASTM specifications for jet fuel or diesel, qualifying them as "drop-in fuels". These fuels could be marketed on Maui. The other potential fuels, in basestock form, include algal oil, biobutanol and pyrolysis oil, and require further processing in an oil refinery to be converted to liquid fuels. Stillwater estimated the cost to transport these to an Oahu refinery and process them into renewable "drop in" fuels that can be blended with petroleum fuels. Stillwater also estimated the value of Renewable Fuel Standard credits created by the production of these biofuels. The value of the products at the farm gate, in 2015, is shown below. The base case prices for fuels were derived from projections made from the EIA Annual Energy Outlook 2011 Forecasts.

Table 1. Netback Value for Possible Biofuel Products & Co-Products

$/gallon	Netback Value Calculation (2015 Base Case Pricing)						
	FT Products		Algal Oil Products				
	Jet	ULSD	Jet	ULSD	F76	Butanol	Pyrolysis Oil
Base Case Price - Kahului	2.844	3.093	-	-	-	-	-
Base Case Price - Oahu	-	-	2.745	3.025	2.758	2.745	1.790
Refining Cost (Small Volume)	-	-	(0.350)	(0.350)	(0.350)	(12.070)	(2.480) [3]
Logistics Cost	(0.065)	(0.043)	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)
RINs (2011)	1.305	1.305	1.305	1.305	1.305	1.305	1.305
Taxes[1]	-	-	-	-	-	-	-
Netback Value at the farm	4.084	4.355	3.616 [2]	3.896	3.629	(8.104)	0.531
NBV relative to FT ULSD at the farm	(0.270)	Base	(0.738)	(0.458)	(0.726)	(12.458)	(3.823)

Memo:

1 This analysis assumes that any tax applies equally to each product. Taxes in Hawaii need to be quantified further.

2 Somewhat overstated because the yield of jet will be less than the yield of diesel

3 Pyrolysis oil price reflects the 68% yield of naphtha and diesel from pyrolysis oil

The analysis concludes that the best value for a fuel or fuel basestock at the sugar farm gate would be ultra-low sulfur diesel (ULSD) produced from the FT process. This is due to the relatively high price of diesel in Hawaii in general and specifically on Maui. Jet fuel produced from the FT process and sold on Maui would be the second best option from the perspective of its value at the sugar farm gate. The modest amounts of FT fuels produced could be consumed on Maui.

For the basestocks, the analysis concluded that, with a small amount of capital, there is some capacity to process algal oil into diesel at the Tesoro Kapolei refinery. This refining capacity appears to be sufficient to treat the projected algal oil volumes. Conversion of biobutanol into jet fuel is technically feasible, but the small volume of biobutanol does not support the capital investment required to build the conversion technology. Pyrolysis oil can be converted into renewable fuel oil at a refinery for power generation or converted to drop-in fuels. A demonstration project is under construction at the Tesoro Refinery in Kapolei, Oahu that is backed by a $25 million U.S. Department of Energy award. The project is based on RTP technology by Ensyn for pyrolysis oil production. The pyrolysis oil will then be upgraded to transport fuels using technology developed by Honeywell's UOP, working with DOE, the DOE's National Renewable Energy Lab and Pacific Northwest National Laboratory (PNNL). Honeywell has completed construction of the Phase I demonstration plant. The demonstration plant's design capacity is one ton per day of biomass into five barrels per day of renewable fuel. Phase II of the project will be focused on upgrading the demonstration plant to produce drop-in fuels by 2014. The final phase is a commercial plant with a planned capacity of 23-50 million gallons per year. This phase is currently unfunded and the completion date is to be determined.

The Renewable Fuel Standard created a credit-trading program based on Renewable Identification Numbers (RINs). The value of RINs is subject to market and regulatory forces and is difficult to forecast confidently.

We note the sugar farm's production costs for these fuel products are outside the scope of the Stillwater study. In order to determine the most profitable sugar cane product, the cost to produce each fuel product must be determined. HC&S staff will determine the cost-to-produce fuel products and compare these with the netback values shown above. They will also compare that analysis with their outlook for the value of the farm's current sugar production. These comparisons will then provide the economic data necessary to determine a course of action.

In addition, this study does not consider efficiency improvements in the farm's current steam and power operation. Such improvements may be the lowest cost way to increase the creation of renewable energy.

Detailed explanations of fuels, refining processes, pricing tables, and regulations are contained in the Appendix. The first appendix, "The Carbon Story", will be useful for the reader who is interested in the understanding on how fuels are constructed.

1 Project Overview

Stillwater Associates LLC has been engaged by Hawaiian Commercial and Sugar (HC&S) to investigate the cost and marketability of the transportation products and co-products that HC&S could produce from sugar cane via four renewable fuel conversion processes. These processes, which include Fischer Tropsch, Lipid Production, Butanol, and Pyrolysis, provide finished fuels and/or fuel basestocks that need further processing in an oil refinery on Oahu to convert these into finished fuels, as shown in the table below. These projections were made based on annual net cane production of 1.4 million tons with 200,000 short tons raw value (STRV) sugar with all associated co-products such as additional fermentable sugars in cane juice, bagasse, and leafy trash. The volumetric projections for biofuels were made using proprietary conversion yield information based on available feedstocks to provide some perspective of the scale of operations being proposed so that capital requirements could be estimated.

Table 2. Fuel Refining Processes Under Consideration

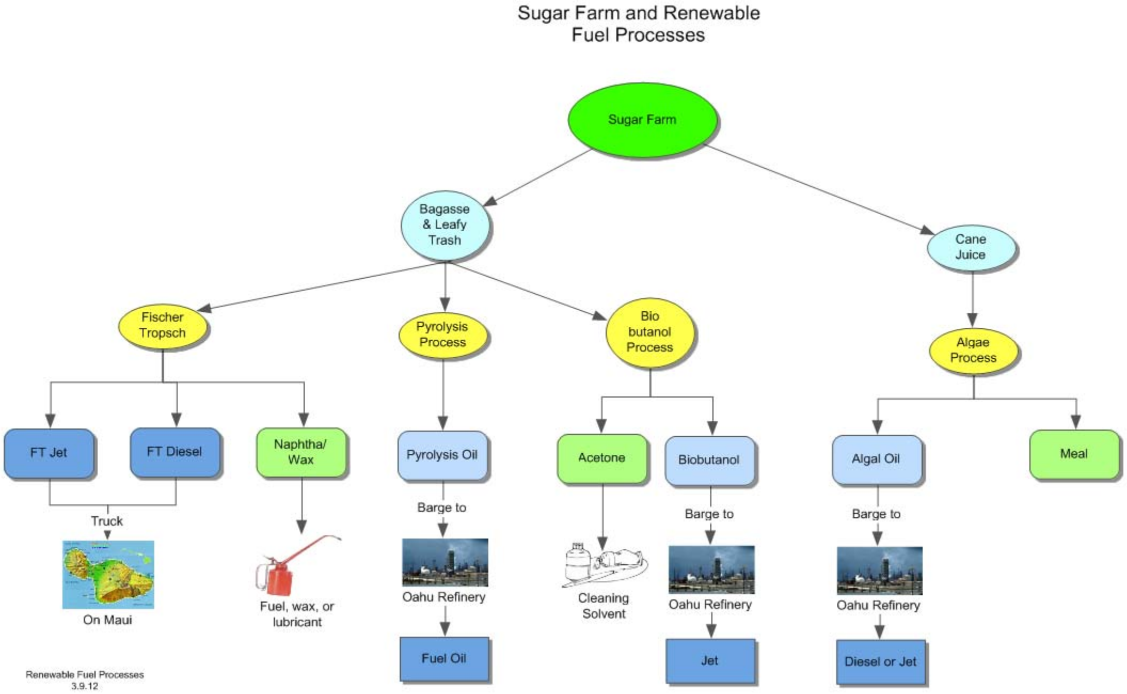
Process	Primary Product	Biomass Feedstock	Primary Product Volume (MGY)[1]	Primary Product Volume (KBD)	Drop-In Fuel or Base-stock	Co-Products for Sale	Co-Product Volume
Fischer Tropsch	Jet Fuel or Diesel	Bagasse and cane trash	21.3	1.4	Drop-In Fuel	Naphtha and wax	20-25% of products.
Lipid Production	Algal Oil	Fermentable sugars from cane juice	19.4	1.3	Basestock	Meal for animal feed	39 K TPY
Butanol	Biobutanol	Bagasse and cane trash plant sugars	7.1	0.5	Basestock	Acetone	Minor Volume
Pyrolysis	Pyrolysis Oil	Bagasse and cane trash	16.8	1.1	Basestock	None	None at HC&S

[1] MGY – Million Gallons per Year, KBD – Thousand Barrels per Day

HC&S is examining a case where they would produce FT fuels from biomass and algal oil from cane juice. The FT technology could produce a finished jet fuel that would be blended with conventionally produced jet fuel for the Kahului Airport. The technology could also produce a renewable diesel for commercial and industrial demand on Maui. The estimated volume of FT production could be consumed on Maui. The algal oil, biobutanol and pyrolysis oil would be barged to Oahu.

A view of the process options is contained in the following diagram:

Figure 1. Sugar Farm and Renewable Fuel Processes



1.1.1 *Drop-In Fuels or Basestock?*

Drop-in fuels are defined as fuels manufactured from renewable sources that "…require no change in systems configuration, engine architecture, fuel infrastructure, or fuel handling."[1] This is in contrast with first generation renewable fuels that required special consideration for use because of problems in the distribution system or difficulties with engine performance. For example, ethanol-blended gasoline can be rendered unusable if it comes into contact with water. Similarly, biodiesel blends have performance problems in cold weather.

The market for drop-in fuels is emerging and is generally thought of as distillates like jet fuel or diesel, rather than gasoline. Drop-in fuels are typically made from vegetable oils or animal fats (triglycerides) and are normally produced at a petroleum refinery because refineries already have the required technology and are a source of hydrogen which is essential for producing drop-in fuels. In a two-step process, a refinery hydrotreater strips the oxygen from the triglyceride molecules making up the vegetable oil or animal fat. A second hydrotreater isomerizes the first stage product using a precious metal catalyst to improve cold flow properties.

Renewable diesel can be blended with petroleum diesel at any ratio where the final blend meets the appropriate ASTM specification, although the blend could be subject to additional certification by the user or engine manufacturer. Renewable jet fuel is restricted to blends of 50% with petroleum jet because renewable jet fuel does not have the aromatic compounds needed for jet engine lubrication.

The military, especially the Navy, is putting significant resources into renewable distillates like jet fuel and diesel. The Secretary of the Navy recently announced a program in which the Navy and

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[1] RFI-11-27-PKM, Defense Production Act Title III, Advanced Drop-in Biofuels Production Market Research, Department of the Air Force, Air Force Research Laboratory, August 2011

the departments of Agriculture and Energy will invest $510 million over three years to promote drop-in aviation and marine biofuels.[2]

Navy jet fuel is referred to as JP5 and is specially formulated for ship-borne safety. Air Force JP8 is closer to civilian Jet-A in formulation. Aircraft engines run successfully on all three types. JP5 that is made from renewable fuel basestocks is called Hydrotreated Renewable JP5 (HRJ-5) and renewable fuel based JP8 is HRJ-8. The Air Force is testing HRJ-8. Navy diesel fuel is known as F76.

Renewable diesel can also be used as Ultra Low Sulfur Diesel (ULSD), the standard civilian diesel fuel, because its properties match that of ULSD.

1.1.2 Fuel Basestocks

The three other processes HC&S is evaluating will produce Fuel Basestocks. The label “basestock” is used to define intermediate products that do not meet finished fuel specifications and will have to be transported to one of the oil refineries on Oahu for further refining. Each basestock would require a different processing technology at the refinery.

1.1.3 Blendstocks

Blendstocks are renewable fuels that can be blended with petroleum fuels but the resulting product does not meet all the necessary quality specifications. Ethanol and biodiesel are examples of blendstocks under this definition. These have been excluded from the scope of this exercise because the focus is drop-in fuels.

1.2 Co-Products

The process will produce co-products, materials that are not the main focus of the process. The study touches on co-product disposition.

1.3 Refining Capacity in Hawaii

Hawaii’s two refineries are located in the Campbell Industrial estate at Barbers Point, at the southwestern tip of Oahu, and are owned and operated by Chevron and Tesoro respectively.

The Chevron refinery is the older of the two and was started up in 1962 with a capacity of 33,000 bpd. It has since been expanded to its current capacity of 55,000 bpd. The Chevron refinery occupies 248 acres of land and employs 186 full-time employees and 64 contractors.[3]

When it started up in 1970, the refinery currently owned by Tesoro was built with assistance from the State of Hawaii with the objective to introduce an element of competition in the local market, as well as for strategic reasons related to energy security for the State. The refinery, then owned by Pacific Refining, Inc. (PRI) and operating under the name Hawaii Independent Refining, Inc. (HIRI), was built under the Small Refiners Exceptions Regulations of that period, which limited its capacity to just under 30,000 bpd. Its current capacity is 95,000 bpd. It occupies 203 acres in the Campbell Industrial Park and employs 205 full time employees plus a further 400 contractors [4].

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[2] New Biofuels Market to Reduce Foreign Oil Dependence, *American Forces Press Service,* by Lisa Daniel, August 16, 2011

[3] Foreign Trade Zone Board, *FTZ No. 9 Annual Report 2001*, January 22, 2002.

[4] Foreign Trade Zone Board, *FTZ No. 9 Annual Report 2001*, January 22, 2002.

2 Market & Off-Take Assessment

2.1 Market Demand

The distillate category is generally divided between jet fuel and diesel fuel. Civilian distillate demand in Hawaii is estimated at 12-15 KBD of jet fuel and 20 KBD of diesel. Most of the product demand is concentrated on Oahu because of its population and military facilities. Demand on Maui is estimated at 3-4 KBD[5] of jet fuel and 1.5 KBD of diesel. Civilian jet fuel demand is directly related to the visitor industry. Diesel demand is largely driven by surface transportation, including trucks and marine vessels. Hawaii also uses diesel for power generation. About 7 KBD of diesel is burned to generate electricity statewide, including about 3.6 KBD by MECO.[6] Distillate demand for transportation is likely to grow with the population. Distillate demand for electricity generation will vary with the supply of other power sources and reduction of petroleum use for electricity generation is being promoted under the Hawaii Clean Energy Initiative (HCEI).

Table 3. Civilian Distillate Demand[7]

	Civilian Demand (KBD)					
State of Hawaii	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Diesel (taxable, non-taxable)	11.6	12.5*	13.6	14.5	11.5	11.9
Diesel for Electricity Generation	7.7	7.4	7.0	7.2	7.2	7.1
Aviation**	14.9	15.0	12.7	12.7	11.5	14.4
Oahu						
Diesel (taxable, non-taxable)	6.9	7.8	9.3	10.2	7.8	7.4
Diesel for Electricity Generation	0.2	0.3	0.2	0.4	0.2	0.1
Aviation	7.8	7.5	6.6	6.8	5.7	7.3
Maui						
Diesel (taxable, non-taxable)	1.5	1.4	1.5	1.5	1.3	2.0
Diesel for Electricity Generation	4.0	3.7	3.6	3.5	3.6	3.5
Aviation	4.3	4.3	3.3	3.2	3.3	4.1

* Monthly diesel volumes for June and September 2007 were outside of normal range and adjusted to reflect the average.
**The Aviation category includes aviation gasoline, but the bulk of the category is jet fuel.

2.1.1 Demand Seasonality of Diesel and Jet Fuel

Stillwater examined consumption data provided by DBEDT to determine average demand seasonality for diesel and jet fuel. While the consumption for on-highway diesel remains relatively unchanged throughout the year, between 2,900 and 3,900 bpd, consumption seems to be higher in the late spring and summer.

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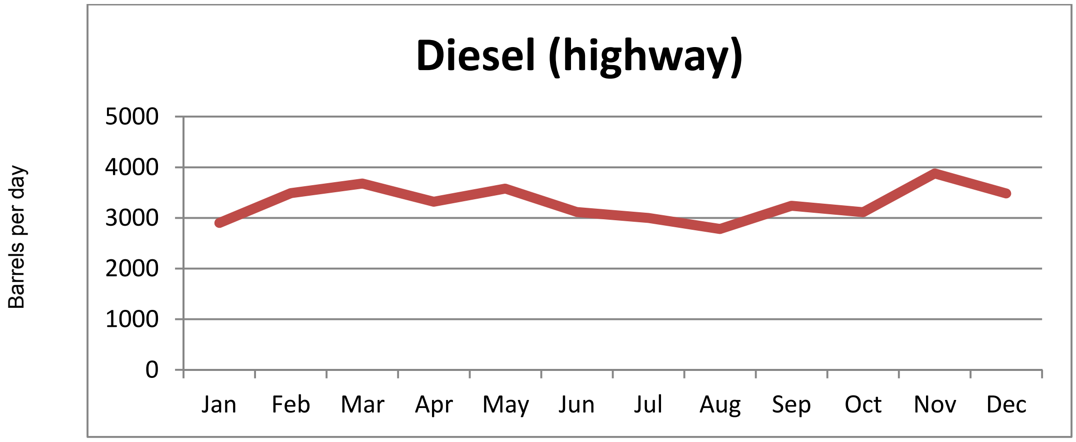
[5] Stillwater conversations with market participants
[6] Department of Economics, Business Development and Tourism "Monthly Energy Data.xls"
[7] Ibid, DBEDT

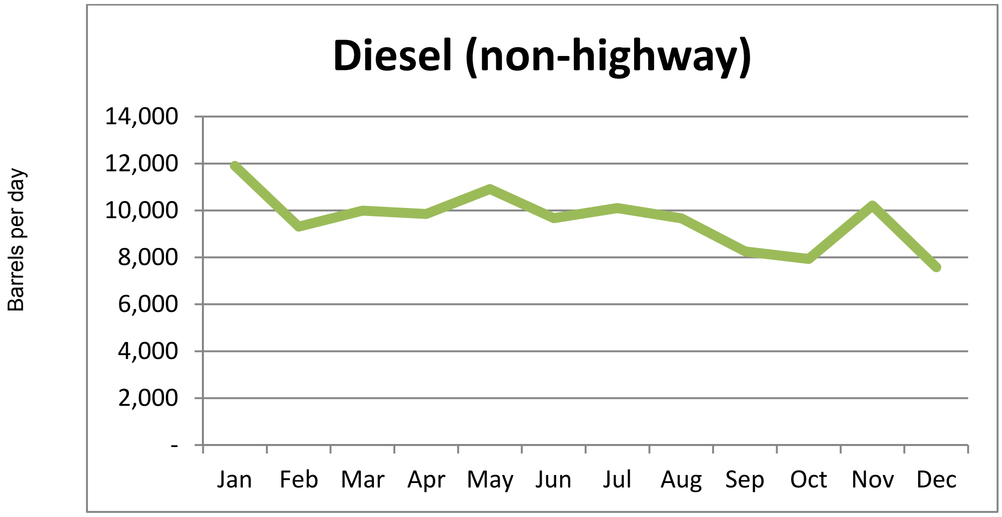
Figure 2. Average Diesel Consumption (Highway) between 2006 – 2012 To Date



Source: DBEDT

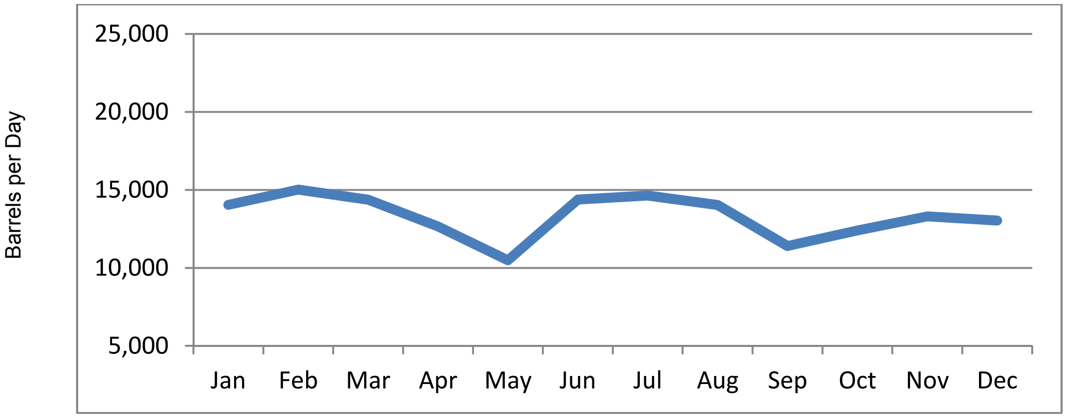
Non-highway diesel consumption is much higher than highway diesel consumption, with a high of almost 12 KBD and a low of about 7.5 KBD. Non-highway diesel consumption peaks in January and then again in November.

Figure 3. Average Diesel Consumption (Non-Highway) between 2006 – 2012 To Date



Average jet fuel consumption ranges from 16.7 KBD high in July to a 10 KBD low in April and May. Jet fuel consumption drops off before and after the peak summer travel season.

Figure 4. Average Jet Fuel Consumption between 2006 – 2012 To Date



Source: DBEDT

2.1.2 Military Renewable Fuels Initiatives

Military initiatives are also driving renewable fuels requirements. According to the Green Initiative for Fuels Transition Pacific (GIFTPAC), the Government seeks to identify responsible potential sources and obtain information regarding possible suppliers of bio-derived alternative fuel for aviation purposes, and potentially for marine diesel, for delivery to various locations in the state of Hawaii. [8] The Defense Logistics Agency estimate of military distillate requirements in Hawaii is shown below:

Table 4. Estimated Military Distillate Requirements

Military Requirements	Gallons per Year	KBD
JP8	78,550,000	5.1
JP5	7,180,000	0.5
F76	42,250,000	2.8
Commercial Diesel	750,000	0.0
Total	128,730,000	8.4

Source: Green Initiative for Fuels Transition Pacific (8.2.10)

According to the DLA Request for Information, “DoD is interested in long-term prospects for the manufacture and supply of aviation biofuels and marine diesel biofuels in increasing quantities, potentially from multiple suppliers and feedstock sources, to foster an assured domestic supply of these fuels through a healthy industry with sustainable, ongoing competition. DoD intends to purchase bio-derived jet and marine diesel fuels which meet approved specifications, meet the provisions of the Energy Independence and Security Act (EISA) Section 526, are a “drop in fuel” that can utilize existing infrastructure, are delivered to DoD fully blended (50:50 blend ratio with conventional petroleum product counterpart (JP8, JP5 or F76) and ready for use. Cost competitiveness with conventional petroleum derived fuels is a key objective. To comply with EISA 526, the bio-derived fuels must have lifecycle greenhouse gas emissions that are less than or equal to those of conventional petroleum derived fuels. All potential providers of bio-derived fuels must comply with all applicable federal, state, local environmental laws and regulations.”[9]

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[8] Green Initiative for Fuels Transition Pacific (GIFTPAC), Solicitation Number: DESCBCRFI001, Defense Logistics Agency**,** June 25, 2010

[9] Ibid DBEDT

2.1.3 Drop-In Fuels Demand

HC&S is considering a Fischer Tropsch process for converting agricultural fiber into jet fuel or diesel that could be blended directly with petroleum fuels. These renewable fuels would not require further processing in an oil refinery. As noted earlier, FT jet or diesel production could be about 21.9 MGY or about 1.4 KBD.

2.1.3.1 Jet on Maui

Jet fuel demand at Kahului Airport is estimated at about 3.5 KBD so all the jet fuel could be consumed locally. We note that drop-in jet fuel must be blended 50/50 with petroleum jet fuel because renewable fuels do not contain aromatic compounds that jet engines need. This blending requirement may create a need for additional storage capacity to accommodate the blending or the blending could be done on a truck by truck basis. In this latter case, a truck would load 50% petroleum diesel and then drive to the sugar plant to load the renewable jet. ASTM specifications require that the resulting blend be laboratory tested and certified prior to release.[10] Laboratory facilities would be needed to run the tests which include distillation, flash point, density, freezing point, existent gum fatty acid methyl ester, thermal stability, and antioxidants.

There is no military fuel demand on Maui.

2.1.3.2 Diesel on Maui

According to DBEDT statistics[11], the demand for diesel on Maui falls into three categories: taxable, non-taxable, and utility. Taxable diesel is used on-highway and non-taxable diesel is used off-highway for construction, marine, or by government agencies.

The forecast 1.4 KBD of FT diesel would nearly meet Maui’s surface transportation diesel demand of about 1.5 KBD, as long as the FT diesel meets the ASTM specification (D975) for diesel. The FT diesel should have qualities that refiners will find attractive, including high cetane number and low sulfur and low aromatic content. The Oahu refiners are likely to evaluate use of the FT diesel as a diesel blendstock, because of the attractive properties and could consider barging the FT diesel to Oahu to extend their diesel production. In this scenario, they would continue to supply Maui’s traditional diesel demand by barge from Oahu. Mainland refiners have blended FT diesel produced from natural gas to improve their refinery-produced diesel.

Potentially some of this diesel would be used to meet MECO’s demand for electricity. It should be noted, however, that the FT diesel would be created from bagasse that is currently being burned to create process steam and heat for the sugar cane operation, with excess power sold into the grid. Efficiency improvements in the farm’s current steam and power operation may be the lowest cost way to increase the creation of renewable power.

ASTM specifications do not mandate 50/50 blending for diesel. Therefore, the renewable diesel could be truck blended whether the delivery truck loads a portion of its load at the petroleum terminal and then loads the balance from the renewable diesel tank at the sugar farm.

2.1.3.3 Fuel Basestocks

It is likely that the basestocks will be purchased by a refiner at the sugar plant gate. The refiners have the logistics capability to barge the basestocks; algal oil, biobutanol, or pyrolysis oil to Oahu for further processing in one of the oil refineries. For example, the Tesoro refinery has the infrastructure to support conversion to a drop-in fuel and represents a source of hydrogen needed to convert the basestocks to drop in fuels.

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[10] ASTM D7566-11a “Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons”, July 15, 2011

[11] Ibid DBEDT

2.1.4 Renewable Blending Components

The scope of this project does not include blending components like ethanol and biodiesel because they are not considered to be ‘drop-in’ products. They are not considered ‘drop-in’ because the supply chain has to accommodate their different properties like ethanol’s tolerance for water contamination or cold flow performance for biodiesel. Gasoline in Hawaii contains up to 10% ethanol

Biobutanol can be used to replace ethanol as the renewable component in gasoline. As well, algal oil can be processed into biodiesel via the fatty acid methyl ester (FAME) process that Pacific Biodiesel uses at Kahului.

2.1.5 Co-Products

The information on co-products that could be produced is somewhat limited. At this stage in the project, we were unable to obtain co-product specifications from the technology providers so the analysis is at only a very general level.

The FT process will produce naphtha and waxes. Naphtha could be blended with gasoline, probably generating RINs credits, see Section 2.7.1. However, FT naphtha is paraffinic, with low octane, and is a poor gasoline blendstock. Otherwise, the naphtha could be burned to provide process heat for the FT process or sold to MECO for power generation. FT also produces high-carbon-number waxes and lubricating oils. These could be valuable; however the quantities will probably be quite small.

The algal oil process will create 39 thousand tons per year of meal. Algae meal could refer either to the algal biomass without extracting the oil, or to the de-oiled oil cake. When oil is removed from the algal biomass, the resulting cake does not have lipid content, and is primarily rich in protein and carbohydrates.

Algae cake is a source of nutrients for humans and animals, because the cake of many algal species has high protein content, sometimes as high as 50 to 60% of dry matter. Except for sulfur-containing amino acids (methionine and cystine), the essential amino acid content in many algal species is favorable for the nutrition of farm animals. Algae are also a rich source of carotene, vitamin C and K, and B-vitamins.

Overall, the algal biomass comprises three main components – carbohydrates, proteins and lipids. Once the lipids have been extracted the left-over cake is primarily composed of carbohydrates and proteins. Depending on the growth medium and the nutrients, algae meal could contain some substances such as lead, arsenic, mercury, and heavy metals.[12]

The exact composition of the algae meal depends on the algae species as well as the growth conditions. In addition, it also depends on the amount of oil that has been extracted.

AgriLife Research scientists have identified algae co-products or algae cake as a potential high-protein ingredient in animal feeds, such as cattle and fish food. .[13] However the study is not complete and does not provide specific benefits or cost analysis.

Algae (microalgae and ogo seaweed) continues to be Hawaii's most valuable aquaculture crop encompassing both local and export sales. *Spirulina* and *Hematococcus* microalgae for aquaculture feed additives and human nutritional supplements and health foods were the leading species in total value, with more than $11M in farm-gate sales.[14]

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[12] http://www.oilgae.com/algae/left_over/left_over.html

[13] http://hawaii.gov/hdoa/adp/outlook/?searchterm=algae

[14] http://hawaii.gov/hdoa/adp/outlook/?searchterm=algae

Studies have shown that adding microalgae species *Hypneacervicornis* and *Cryptonemia crenulata* to shrimp feed resulted in significant increase in shrimp growth rates.[15]

There are several studies showing the benefits of using algae cake to replace fish feed for fish and farm animals and data would suggest that algae cake can be used in fertilizers. There are several early stage companies with business plans dependent on the creation of fuel from algae and use of the cake by-product; however we were unable to locate companies that are currently making a profit from this model. Another option could be to use the algae cake for biomass boiler fuel to supplement the biomass fuel currently used for cogeneration.

Acetone will be a co-product of the butanol process. Acetone is a colorless, flammable liquid that is miscible with water. Acetone is a solvent and is used for cleaning purposes. Worldwide production capacity in 2010 was estimated at 6.7 million tons per year. Acetone is produced from propylene, a hydrocarbon. The price of acetone varied from $75 and $110 per ton in 2010. [16]

2.2 Biomass Based Renewable Fuel Companies Operating in Hawaii

Pacific Biodiesel produces biodiesel from waste cooking oil at plants in Kahului and Honolulu. There are many other companies on Hawaii with plans to produce energy from vegetable-based biomass feedstocks. However, to date, none of these other companies are producing fuel. Three companies, Aina Koa Pono, Honeywell UOP, and Big Island Biodiesel (Pacific Biodiesel on the Big Island), have a proposed transportation biofuel production capacity of nearly 80 million gallons per year based on information presented in Table 5. The recently completed Honeywell UOP demonstration plant is located next to Tesoro's Kapolei refinery. The demonstration plant's design capacity is one ton per day of biomass into five barrels per day of renewable fuel. Phase II of the project to be completed in 2014 will be focused on performance testing and upgrading the demonstration plant to produce drop-in fuels. About 300 metric tons each of different feedstocks will be fed into the facility and refiners will test the quality of biofuel produced. The final phase is a commercial plant with a planned capacity of 23-50 million gallons per year. This phase is currently unfunded and the completion date is to be determined.

There are seven companies with plans to produce power from biomass-based feedstocks with combined proposed 60-megawatt production capacity. The most promising prospect is Hu Honua Bioenergy (HHB). HHB is developing a 24-megawatt renewable energy facility located in Pepe'ekeo, Hawaii, is projected to produce up to ten percent of the islands electricity needs. The company plans to use wood scrap, including eucalyptus, for feedstock. Recently, HELCO signed a 20-year contract to buy biomass electricity at a price not tied to oil from HHB. The plant will be housed in the old Pepe'ekeo power plant and is anticipated to be completed approximately 18 months after refurbishment of the former plant begins.

The following table lists renewable energy companies operating in Hawaii with biomass based fuel production facilities in varying stages of development. Capacities listed in this table are design capacities reported by each company.

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[15] Da Silva R.L. Barbosa J.M. 2008. Seaweed meal as a protein source for the white shrimp Lipopenaeus vannamei. Journal of Applied Phycology 21:193-197. Article

[16] EO Camara Greiner and C Funada (June 2010). "CEH Marketing Research Report: ACETONE". *Chemical Economics Handbook*. SRI consulting.

Table 5. Biomass Based Renewable Fuel Companies Operating in Hawaii

Project Developer	Island	Fuel Purpose	Feedstock	Project Description	Proposed Production Capacity
AES (Cogeneration)	Oahu	Power	Eucalyptus- Coal Cogeneration	AES plans to add an additional 5MW of renewable energy per year, with the potential to increase up to 20MWs per year by burning eucalyptus if final testing is successful. This would augment the existing 180-megawatt operation that produces 18 percent of Oahu's electricity.	5 MW
Aina Koa Pono	Hawaii	Power and Transportation	Sorghum, other locally grown crops	Aina Koa Pono would produce between 3,000 and 5,000 gallons of liquid fuel per acre per year suitable as a substitute for petroleum fuels in power plants or transportation.	2.7 MW; 24 MGY
Big Island Carbon	Hawaii	Power, Resource purification	Macadamia nut shell	Macadamia nut shells discarded by Big Island growers will be transformed into granulated activated carbon used for air, water, and chemical purification. The shells can also be converted into biofuels that can be mixed with diesel to power the company's facility.	1,000 tons granular activated carbon
Green Energy Hawaii	Kauai	Power	Albizia	Biomass fired generation anticipated to provide power to 8,500 homes on Kauai.	7 MW
Honeywell UOP	Oahu	Transportation	Various Biomass	Pilot project to convert various biomass resources for green gasoline for transportation. The Integrated Biorefinery, funded by a $25 million US Department of Energy grant, is a project by UOP.	Phase I 2012 – 5 BPD Phase II 2014– TBD Phase III TBD – 23-50 MGY
Hu Honua Bioenergy	Hawaii	Power	Eucalyptus	The Hilo Coast Processing Company power plant in Pepe'ekeo will be upgraded to run on 100% locally grown eucalyptus trees and other biomass that would normally be thrown into landfills. What was once an old sugar plantation power plant will be transformed into a modern biofuel facility that will provide enough power for 18,000 homes, about 7 to 10% of the Big Island's total electricity needs.	25 MW
Pacific Biodiesel	Hawaii	Transportation	Waste grease, local crops	Hawaii's newest and most advanced biodiesel processing facility by the state's first commercial biofuel producer, will process used cooking oil, trap grease, and locally grown crops into fuel for vehicles and equipment with diesel engines.	2.6 MGY
Pacific West Energy	Kauai	Power	Various Biomass	The Company will convert existing and former sugar cane lands and woody biomass lands on the island of Kauai into an energy plantation by first constructing an approximately 20 megawatt (MW) capacity biomass power plant (Phase 1). In a subsequent phase, the Company intends to integrate biofuel (including ethanol) production (Phase 2).	20 MW
Phycal Pilot Facility	Oahu	Power	Algae	Phycal will supply up to 150,000 gallons of algae-base biofuel to HECO's Kahe Generating Station by April 2014. This is part of a pilot project based in a 34-acre facility near Wahiawa, to be followed with demonstration project that aims to produce up to 3 million gallons of algae biofuel	150,000 – 3 MGY

Source: DBEDT

2.3 Estimate of Off-Take Prices

The price of transportation fuel is governed by the supply and demand of the fuels, the supply and demand of the crude oil from which they are manufactured, processing and transportation costs, and government regulations. Typically, the price of fuel is based on an agreed reference price(s) which floats with the changes in the market. For example, a purchase/sale contract for jet fuel in Los Angeles could be based on the Los Angeles spot market price, which is generally referenced to the price of distillate (heating oil) on the New York Mercantile Exchange.

Hawaii fuel market participants have historically struggled to find a consistent benchmark for trade in the state because of the distance from spot market references like Los Angeles, Portland, Singapore, or New York.

Long term, fixed price deals are very difficult to do because of volatility of the fuel market. Short term hedges are workable, but the futures market is not liquid enough to effectively hedge five or ten years into the future.

The Defense Logistics Agency uses the average of Los Angeles, San Francisco, and Seattle spot pipeline prices for jet fuel and diesel as the basis for its purchases.[17]

2.3.1 Hawaiian Petroleum Product Prices

Stillwater Associates has had experience working in the Hawaiian energy markets for over eight years. There are a number of points that contribute to the Hawaii petroleum product pricing versus other markets:

- Spot markets represent large bulk transactions in cargo or pipeline batch quantities. Spot assessments provide transparency by measuring the “market clearing” price between refiners, traders, and large consumers. There is no spot market in Hawaii. The West Coast spot markets of Los Angeles, San Francisco, the Pacific Northwest, and Singapore are the closest spot markets.

- Hawaii has relatively small market import product needs as the local refineries supply the majority of the State’s petroleum product requirements. In 2011 10.8 KBD of jet fuel was imported to the state. There are no imports of diesel from abroad. .

- Hawaii is geographically isolated from the closest product and refining centers, the US West Coast and Singapore.

- The size and import facilities on the Neighbor Islands cannot accommodate large efficient tankers, resulting in higher thresholds to take advantage of arbitrage opportunities from refineries in Asia or the Mainland.

- As a result of the above, the geographical isolation from the US West Coast and Asia, product markets, coupled with small product import requirements, requires shipment from these refining centers in either small lots with higher transport costs, or large lots with higher storage costs, carrying costs, and exposure to changes in inventory value.

- It is Stillwater’s experience that Hawaii market participants generally correlate pricing with the US West Coast, although we have observed contracts tied to the Singapore spot markets.

- Because Hawaii is comprised of islands, land transport is not an option. As a result, integration of the energy markets is only via barge unlike the mainland where electrical

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[17] DLA Solicitation; SP0600-10-R-0161, Period Oct 1, 2010 through Sep 30, 2011, page A33

interconnects, petroleum pipelines, rail and tank trucks connect markets. In effect, Hawaii is broken into smaller markets with higher inter market costs.

2.3.2 Relative pricing of products in Hawaii.

We have several observations about product pricing in Hawaii:

- Of the three major products using Oahu as the comparison point, diesel at about 17 cpg over US West Coast (USWC) has held the highest premium when compared to USWC markets, followed by gasoline at 10 cpg. Jet has held a slight 1 to 2 cpg premium.
- The high diesel premium reflects that Hawaii needs to import small quantities (estimated at 1-2 KBD) from the mainland.[18] This small quantity and limited availability in other markets like Asia forms a high price to supply the market.
- Jet premiums to the USWC are much more moderate reflecting the large percentage of jet that is supplied from Asian supply points. Jet has a much higher sulfur content specification at 0.2% or 2000 ppm, while the sulfur content in ULSD is 15 ppm max. ULSD requires more processing than jet to reduce the sulfur content.
- Gasoline (naphtha) is in excess in Hawaii with refinery supply exceeding local demand. Excess naphtha is burned by utilities to generate electricity on Kauai and the Big Island.
- Military JP8 price, the grade similar to commercial jet, carries a premium to the commercial jet prices on Oahu. This fuel is supplied from one of the state's refineries.
- Military Distillate (F76) prices are significantly lower than ULSD diesel used in Hawaii since the sulfur specification is 0.5% maximum (5000 ppm) instead of 15 ppm max for ULSD. This fuel is supplied from one of the local refineries.
- The cost of barge transport and storage to Maui is about 8 cpg.
- Residual fuel oil prices, ex tax, track world residual prices and are close to the US average residual fuel prices for power generation.
- The premium value of diesel fuel versus jet fuel at face value is a disincentive for producing renewable jet out of diesel based feedstock. A process that makes jet from diesel is producing a lower valued product from a higher valued product. In order for such to be economic, there will need to be a significant incremental incentive such as subsidies or credits to make this viable.

Detailed price forecasts are in the Appendix 3.

2.3.3 Military Contracting

Military fuels are contracted through an annual bidding process conducted by the Defense Logistics Agency (DLA). Quantities for each product for each region are estimated as part of the bid package along with the bid criteria. Normally refiners in the region are the bidders to supply the product. Bids are submitted with offered product quantity, the location of supply, and price expressed as a cents-per-gallon differential to established reference prices for similar products in the region. The DLA models the offered quantities and prices with logistics costs to derive the overall low cost fuel supply solution for that region. The results of the modeling are used to select the successful bid volumes. For military fuel supplied in Hawaii, the specified reference price is the average of Platt's monthly spot pipeline in Seattle, San Francisco, and LA markets. The

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[18] Stillwater conversations with market participants

prices forecasted in Appendix 3 use the differentials to the reference prices from the last contract awards. Tesoro captured all the military supply in Hawaii in the last bidding cycle.

2.4 Logistics

Any products that meet ASTM fuel specifications can be sold on Maui. The FT jet and diesel products would be in this category although the FT jet must be blended with petroleum jet. Basestocks will have to be transported to Oahu for further refining.

HC&S will need tankage on site for any of the products it produces. The most efficient way to transport basestocks to Oahu is via barge. Tankage at Kahului harbor will have to be secured for the basestock. It is likely that the algal oil or biobutanol will be transported to Oahu via a backhaul movement on a fuels barge to the Kalaeloa Barbers Point Harbor and then pipelined or trucked to a refinery. Depending on the composition of the pyrolysis oil, corrosion resistant containers might be required because the steel in the trucks, barges and pipelines might not be able to handle the acidity.

Logistics costs are estimated as follows:

Table 6. Logistics Costs

$/barrel	FT Jet	FT Diesel	Lipids	Butanol	Pyrolysis Oil
Trucking to Kahului	1.79 [1]	0.89 [2]	0.89	0.89	0.89
Storage in Kahului	0.93	0.93 [2]	0.93	0.93	0.93
Wharfage in Kahului	-	-	0.18	0.18	0.18
Barging to Oahu	-	-	1.51	1.51	1.51
Total ($/bbl)	2.72	1.82	3.51	3.51	3.51
Total ($/gallon)	0.06	0.04	0.08	0.08	0.08

Memo:
1 Assumes jet is trucked to the Harbor, blended, and then trucked to the airport
2 Costs per "MECO Energy Cost Adjustment Factors" 10-01-11

2.5 Refining Outlook

HC&S is evaluating the cost to produce three different types of renewable fuel basestocks: algal oil from algae, biobutanol and pyrolysis oil. These basestocks will have to be processed in an oil refinery to convert them into renewable fuel. Table 7 details the processing volumes and costs for these basestocks. A detailed explanation of the processes and costs is contained in Appendix 1.

Table 7. Refining Volumes & Costs on Oahu

	Agal Oil				Butanol	Pyrolysis Oil	
	Incremental Renewable Distillate	De-Bottleneck for Additional Distillate	New Build within an Existing Refinery	New Build Capacity for Distillate	New Build Capacity for Jet	Renewable Fuel Oil	Renewable Distillate New Build Capacity
Input Volume (KBD)	~1	2 - 4	1	1	0.5	~1	1.1
Capital Costs ($MM)	5	15	75	114	167	5	101
Capital Recovery ($/gal)	0.10	0.08	1.5	2.36	6.32	0.1	1.88
Operating Costs ($/gal)	0.25	0.57	0.57	0.60	1.50	0.25	0.60
Refining Costs ($/gal)	0.35	0.65	2.00	2.96	7.82	0.35	2.48

In the case of algal oil, which could also include vegetable oil or animal fats, a properly equipped refinery can process relatively small quantities with relatively limited capital expenditures and operating costs, especially if the refinery has spare processing capacity. In Hawaii, the Tesoro Kapolei refinery has the proper hydrotreating and hydrocracking equipment to process some algal oil into renewable diesel. This Incremental Renewable Distillate case has a cost estimate of $0.35 per gallon.

Stillwater estimates Tesoro could debottleneck Kapolei to process additional algal oil, if it were available, but would likely need new hydrogen plant to provide hydrogen for the hydroprocessing units. Since the refinery will use naphtha for hydrogen plant feed, the treating costs will be significant relative to mainland refining costs that use cheap natural gas for hydrogen plant feed. The refining costs for this second increment would increase to $0.65 per gallon.

The third case, “New Build with an Existing Refinery”, represents new capacity built at a refinery. Capital cost would be minimized as the facility could be optimized to use existing pumps, pipelines, tanks, personnel, and other infrastructure. The refining cost for this case is estimated at $2.00 per gallon.

“New Build Capacity” reflects the cost for constructing and operating an entirely new renewable fuel facility unrelated to an oil refinery. We note that Chevron Barber’s Point has no hydrotreating capacity so any renewable projects at that facility would be more costly than at Tesoro Kapolei. Capital and operating costs are Stillwater estimates and must be confirmed with the refiners if the project continues. This case estimates the refining cost to be $2.96 per gallon.

As to butanol, because it is a C4, the refinery has to essentially connect three butanol molecules together in order to make a C12 jet fuel. While the processes to accomplish this are well known, and described in the Appendix 2, these processes are not practiced in fuels refineries. New capacity would have to be built at a significant cost. This oligomerization process does result in significant volume loss.

Small volumes of pyrolysis oil probably could be processed at the Kapolei refinery and converted to fuel oil for use in boilers. Pyrolysis oil is a challenging material since its water content and acidity from organic acids are high. These properties differentiate pyrolysis oil from traditional hydrocarbons in terms of use and upgrading. Pyrolysis oil can be used as boiler fuel directly for industrial uses and power generation with modifications to the burners and storage/delivery systems. Alternatively, small volumes of pyrolysis oil probably could be processed at the Kapolei refinery and converted to conventional fuel oil that would mitigate these issues provided that suitable technology is commercialized. Because of its properties, we expect that conversion of pyrolysis oil to renewable distillate would require the same significant capital investment to build additional hydroprocessing capacity that processing algal oil would require.

The capital outlay is assumed over three years. Capital return starts in year 4 and is flat for 15 years. Working capital in year 3 is 15% of the investment. Cash flows are taken at the end of the period. This method is before income tax and assumes a 20% rate-of-return.

In summary, the volumes of algal oil proposed by HC&S probably could be further processed at the Tesoro Kapolei refinery for the production of renewable distillate with relatively low investment. Processing biobutanol into jet fuel would be significantly more expensive because of the very small feedstock volume and high capital cost. Processing of pyrolysis oil in the refinery will be more challenging because of the properties and contaminants in the material. The operation of the demonstration units could address the feasibility of this option.

2.6 Sales Contract Length and Issues

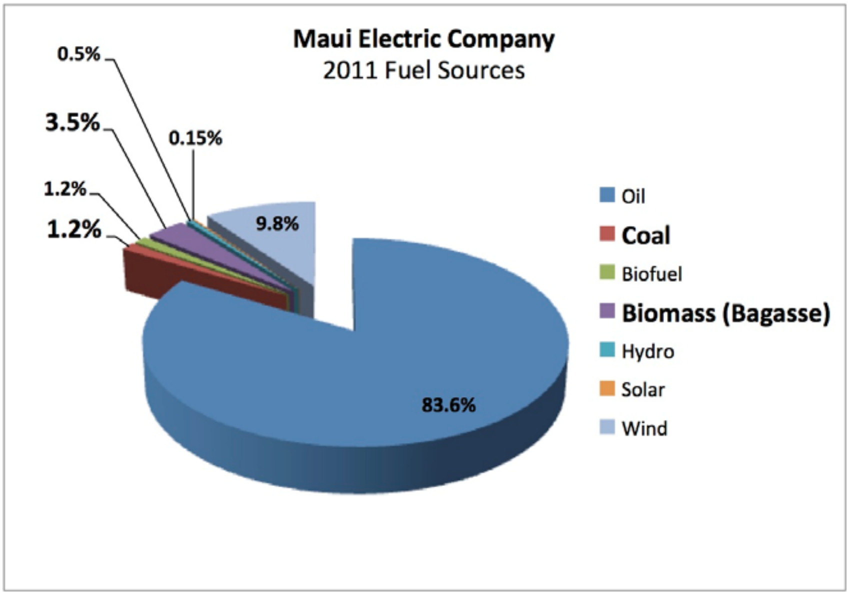
Prior to investing in a new technology, a refiner looks for assurances around feedstock availability, quality, and market pricing to manage and minimize the risk associated with the investment. Any refinery would need assurances that feedstock supply would continue to be available prior to investing in the processing of a new material. In the case of feedstock based on sugar cane, the refiner or other customers would want to understand the impact of the 270 day campaign season on feedstock or finished product availability.

Contracts for the sale of petroleum products are usually short term, up to a year, for example. Military fuel purchase contracts are typically one-year length and are rebid on an annual basis. We understand the Navy is in the development stages of a program to encourage production of renewable fuels. This program may include provisions for multi-year contracting.

2.7 Electricity

The sugar cane production process creates process steam and heat that is used by the farm and electricity that is sold into the grid by burning bagasse, crushed sugar cane stalks. HC&S provides between 5-6% of Maui's electricity from the burning of bagasse, hydropower, and supplemental fossil fuels from coal and oil. Maui Electric (MECO) supplies power from a mix of resources as depicted in Figure 5, with oil (diesel and fuel oil) comprising about 85% of the mix.

Figure 5. Maui Electric Company 2011 Fuel Sources



Source: Hawaii Electric "About Our Fuel Mix"

As can be seen from Figure 5, diesel or fuel oil generates the majority of electricity on Maui. Any bagasse diverted from power generation to transportation fuel will result in increased petroleum use by MECO if not replaced by alternative energy sources.

2.7.1 Naphtha Use for Power Generation

Naphtha is a by-product of the refining process. It is a light straight run cut at the low end of the gasoline boiling range with poor octane properties. In Hawaii naphtha makes up 11% of the total refined products, but is not a very valuable commodity to refineries. Some naphtha gets exported, Japan being the primary export market. There the product is sold as a feedstock for steam crackers in petrochemical plants. Historically, up until about 2005, the Petroleum Administration for Defense Districts V (PADD 5) exported about two cargoes a month of naphtha. In recent years, those shipments have dropped off dramatically. According to EIA export data, there have been almost no exports of naphtha in 2012 from PADD 5.

Naphtha is also sold locally. When produced during block runs of low sulfur crudes, the product is very low in sulfur and is used in two gas turbine power plants, one on Hawaii and one on Kauai. The 63-megawatt Hawaii facility owned by Hamakua Energy Partners (HEP) is the largest electrical generating plant on the Big Island of Hawaii and provides power to Hawaii Electric Light Company (HELCO). Stillwater estimates that the HEP plant burns 2900 bpd of naphtha. Originally supplied by Tesoro, HEP started buying naphtha from the Chevron refinery on January 1, 2012. The Kaua'i Island Utility Cooperative (KIUC) owns the 26-megawatt Kapaia Power station on Kauai. This facility runs on 978 bpd of naphtha annually and is supplied by Chevron.

2.8 Government Support Programs

Federal and state governments have a host of support programs in the renewable energy space. This study will only focus on the federal Renewable Fuel Standard and tax policies that impact transportation fuels.

2.8.1 The Renewable Fuel Standard (RFS)

Corn-based fuel ethanol is expected to meet the vast majority of the RFS fuel mandate over the next eight years. By 2012, RFS2 requires 15.2 BGY of renewable fuel be used, of which 13.2 BGY (87%) likely will be corn-based fuel ethanol. The mandated volumes for conventional biodiesel and corn-based ethanol increase every year through 2015 when they are capped at 15 BGY for the remainder of the program. More detail on the RFS can be found in Appendix 4.

Refiners and importers have to meet their Renewable Volume Obligation by blending renewable fuels or by obtaining credits from others. Each gallon of renewable fuel is assigned a Renewable Identification Number (RIN). RINs are categorized by fuel type – cellulosic, biomass based diesel, advanced biofuel or ethanol. As discussed in the Appendix, RINs are actively traded.

There is significant uncertainty as to which RINs categories and values will apply to the products HC&S is considering. We cannot determine at this time if the products will qualify as cellulosic, biomass based diesel or advanced biofuels. For the purpose of our economic analysis, we have assumed the RINs values would be the highest available, which in 2011 have been biomass based diesel at an average price of $1.30 per gallon.

2.8.2 Other

The products will generally have handling characteristics similar to petroleum fuels. Industry handling practices are controlled by the information contained in the Material Safety Data Sheet (MSDS). This is a federally-mandated legal document containing information on potentially hazardous safety, health, environmental, and Department of Transportation issues. Any company manufacturing a substance deemed potentially hazardous under federal guidelines must issue an MSDS to each purchaser.

An MSDS has nine sections dealing with toxicity, safety, storage, handling, fire, and explosion. The emergency procedures must provide information on what to do when accidents occur, symptoms related to exposure, first aid and long term medical treatment.

The products being contemplated should fit within existing MSDS. For this not to be the case, API standard practice is that there would need to be a product significantly different than any existing products.

Examples of MSDS can be found in Appendix 6.

2.9 Netback Values

The objective of this study is to create an estimate of the value of the renewable fuels or basestocks that HC&S could produce. We have used the netback value convention (NBV) where we estimate the sales price of the product at the point of sale using forecast 2015 prices and then account for all of the costs incurred to get the product to that point of sale. The table below summarizes the netback value of the products studied and is the same as Table 1 presented in the Executive Summary.

Table 8: Netback Value Calculation

$/gallon	Netback Value Calculation (2015 Base Case Pricing)						
	FT Products		Algal Oil Products				
	Jet	ULSD	Jet	ULSD	F76	Butanol	Pyrolysis Oil
Base Case Price - Kahului	2.844	3.093	-	-	-	-	-
Base Case Price - Oahu	-	-	2.745	3.025	2.758	2.745	1.790
Refining Cost (Small Volume)	-	-	(0.350)	(0.350)	(0.350)	(12.070)	(2.480) [3]
Logistics Cost	(0.065)	(0.043)	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)
RINs (2011)	1.305	1.305	1.305	1.305	1.305	1.305	1.305
Taxes[1]	-	-	-	-	-	-	-
Netback Value at the farm	4.084	4.355	3.616 [2]	3.896	3.629	(8.104)	0.531
NBV relative to FT ULSD at the farm	(0.270)	Base	(0.738)	(0.458)	(0.726)	(12.458)	(3.823)

Memo:

1 This analysis assumes that any tax applies equally to each product. Taxes in Hawaii need to be quantified further.

2 Somewhat overstated because the yield of jet will be less than the yield of diesel

3 Pyrolysis oil price reflects the 68% yield of naphtha and diesel from pyrolysis oil

The netback value of FT-ULSD at the sugar mill is the highest because of the premium price of ULSD in that market, as well as the low logistics cost, relative to product delivered to Oahu. This price assumes all the FT ULSD is consumed by surface transportation, rather than for generating power. Similarly, ULSD is the product of choice for any volumes processed on Oahu. Biobutanol is singularly disadvantaged because of its very high refining cost. The netback value for pyrolysis oil is disadvantaged by the yield loss in converting raw pyrolysis oil to drop in fuels. In addition, pyrolysis oil may carry a higher capital cost if integration with the refinery is minimal.

This analysis does not provide the cost-to-produce fuels products or their value relative to the netback of today's conventional sugar cane products. The final analysis will also have to include applicable tax.

2.10 Conclusions

Based on the information reported in the last table, the best value for a fuel or fuel basestock at the sugar farm gate would be ULSD produced from the FT process. This is due to the high price of diesel in Hawaii in general and specifically on Maui. Jet fuel produced from the FT process and sold on Maui would be the second best option from the perspective of its value at the sugar farm gate. The modest amounts of FT fuel produced could be consumed on Maui.

For the basestocks, with a small amount of capital, there is some capacity to process algal oil into diesel at the Tesoro Kapolei refinery. This refining capacity appears to be sufficient to treat the projected algal oil volumes. Larger volumes of feedstock would require significant capital outlays for new processing equipment, raising the costs from about $0.35 per gallon to $2.00 per gallon or more.

Conversion of biobutanol into jet fuel is technically feasible, but the small volume of biobutanol does not support the capital investment required. Pyrolysis oil can be converted into renewable fuel oil at a refinery for boilers in power generation, but this has not been demonstrated commercially. Pyrolysis oil can also be converted to a drop in fuel, but this has not been demonstrated commercially and the capital cost is anticipated to be high.

UOP LLC is building a demonstration plant at the Tesoro Kapolei refinery to convert pyrolysis oil to renewable gasoline, jet and diesel fuels. Backed by a $25 million U.S. Department of Energy award, the plant seeks to demonstrate viability of the technology, test the fuels produced and evaluate the environmental footprint of the fuels and the process technology. The plant scheduled for initial production in 2012 and full production in 2014, will define the cost and requirements for converting pyrolysis oil commercially.

The value of Renewable Identification Numbers (RINs) is subject to market and regulatory forces and is difficult to forecast confidently. The RIN category of each product could have a significant impact on its value.

This study does not include the cost-to-produce of the fuel products nor does it compare the value of the fuels with the value of the traditional sugar cane production process output. HC&S staff will determine the cost-to-produce fuel products and compare these with the netback values shown above. They will also compare that analysis with their outlook for the value of the farm's current sugar production.

We note efficiency improvements in the farm's current steam and power operation may be the lowest cost way to increase the creation of renewable power.

APPENDIX 1

The Carbon Story

It is useful to review the makeup of hydrocarbon molecules in order to understand how fuels are constructed and to appreciate the processing issues.

Hydrocarbon molecules are formed from carbohydrates that are found in all living organisms. Many items such as plastics and most (or even all) of our legacy liquid fuels are derived from Hydrocarbons. The primary hydrocarbon molecules are carbon chains or carbon rings with hydrogen. The molecules for what were once living organisms were combined with other atoms such as oxygen, sulfur, and nitrogen. Over time, the carbohydrate material from dead organisms was deoxygenated to produce hydrocarbons. The raw material from these hydrocarbons are in the form of crude oil, natural gas, coal, wood, peat, etc., and were all originally derived from living organisms.

Hydrocarbon molecules have properties that are a function of the number of carbon atoms in the molecule and structure of the molecule. Oxygen, sulfur, nitrogen or other atoms, if part of the molecule, usually will greatly change the properties of the base hydrocarbon.

Hydrocarbons fuels produced from crude oil in a refinery will have very few molecules that contain oxygen, sulfur or nitrogen. These various hydrocarbon chains have different end uses depending on the number of carbon atoms in the molecule. The molecules and their uses are described here in ascending order of size:

1. C1 is methane – the primary component of natural gas that is used on the Mainland for industrial, power generation and home heating uses. It is generally co-produced with crude oil or as the primary component in a mixture of light hydrocarbon gases (natural gas).
2. C2 is ethane – most often converted to ethylene and used to make plastics. It may be blended in to natural gas depending on recovery economics.
3. C3 is propane – Primary component of liquefied petroleum gas (LPG) used for home and restaurant fuel and in your grill bottle. On the mainland propane is also converted to propylene and used to make plastics.
4. C4 is butane – Also a component of LPG but it has a lower vapor pressure than C3. Depending on gasoline vapor pressure requirements, butane is blended into gasoline. This usually occurs during the winter when it is cold.
5. C5 to C10 mixture is gasoline. C5 is pentane, C6 is hexane, C7 is heptanes, C8 is octane, etc. A pure specific form (isomer) of octane in a test engine is the definition of a 100 octane rating. A pure specific isomer form of heptanes is the definition of a zero octane rating. The performance of a gasoline blend against these references gives the octane rating of the blend. The regular unleaded gasoline consumers buy has an octane rating of 87. Premium gasoline will have a rating of 91 to 93 depending on the area of the country and marketer.
6. C10 to C14 mixture is Jet Fuel. The lightest components are restricted to minimize flammability and the heaviest components are limited to control the potential for freezing at the low (minus 40 or more) temperatures that an airplane experiences at altitude.
7. C14 to C22 mixture is Diesel, centered on C18s. If the need for jet fuel is low, the jet fuel molecules may be added to the diesel. The heaviest components of diesel are limited by the cold flow properties of the diesel blend. Vegetable oil & animal fats are generally three C18s, connected by a glycerin molecule, and the glycerin is separated in refining.
8. C22+ mixture is Industrial Fuel Oil and marine bunker fuel. All the molecules in this mixture have more than 22 carbon atoms.

9. Asphalt is a specialized product that has hydrocarbon molecules that have many, many carbon atoms and are of very complex structure.

Bio-derived liquid fuels generally have oxygen in the hydrocarbon chain structure (chemically referred to as alcohols, fatty acids, triglycerides, algal oil). An exception can be FT products from bio-derived sources since the feedstock is first converted to primary building blocks of hydrocarbons which are then recombined to form carbon chains. There are two primary bio-derived liquid fuel types in commercial use. First, there are alcohols, such as fuel ethanol, derived from corn or sugar. Second, there are is biodiesel derived from vegetable oils and animal fats. Though liquids, these materials cannot necessarily be used as direct substitutes for legacy hydrocarbon fuels. A summary of alternative and biomass feedstock derived liquid fuels that are either commercial or under development is provided in Table 2 with further explanation provided below.

1. Fuel ethanol can be blended with gasoline and used in the current vehicle fleet. Currently, this is limited to 10% by regulation. A move to 15% is currently being considered. In flexible fuel vehicles ("FFVs"), E85 which is a blend of 85% fuel ethanol and 15% gasoline, can be used. Alcohol burns with a colorless flame, which precludes its use on a neat basis for safety reasons.
2. Higher carbon number alcohols, such as butanol, have potential for displacing fuel ethanol because the higher alcohols have more desirable properties (vapor pressure, energy content, water affinity) than fuel ethanol when blended with gasoline.
3. Vegetable oil & animal fats are generally C18s, which makes them an ideal material for diesel. Bio-based oils have a very narrow carbon number range and in this regard differ from oil-based diesel, which has the full range of carbon numbers for the fuel. Biodiesel contains oxygen in the carbon chain.
4. Bio-jet production would require C12 molecules and the removal of the oxygen atoms that are part of the bio-oils.
5. There are no significant plant/animal C12 molecules in vegetable oils or animal fats. Creating C12 jet fuel requires cracking a C18 to a C12 (and a C6 or two C3s) and at the same time hydrogenation and removal of the oxygen atom. The ideal site for this process is in an oil refinery where the equipment may already exist and the infrastructure is in place to handle byproducts.
6. One can create a C12 for jet fuel by putting together smaller molecules. Examples are combining: six C2 bio-ethanol molecules or three C4 biobutanol molecules to make a C12. To accomplish this, energy is required and there is a substantial volume loss.
7. The FT process can take syngas from bio-resources and produce carbon molecules from methane to very heavy waxes. By its nature, the FT process makes a distribution of carbon numbers and to make the process most efficient, the yield of wax, which is C22 and heavier is maximized. This wax must be cracked, hydrotreated and separated to make material in the jet fuel and/or diesel range.

Table 2. Alternative and Renewable Liquid Fuels

Fuel	Feedstock	Average Carbon Number	Proven Commercial Process?	RFS2 Classification	Remarks
Ethanol	Corn	C2	Yes	Renewable Fuel	Current blended-in fuel
	Sugar Cane	C2	Yes	Other Advanced	
	Cellulose	C2	No	Cellulosic	
	Other Biomass	C2	No	Probably Other Advanced	
Bio butanol	Same feedstocks as ethanol	C4	No	Probably Other Advanced	Alternative to ethanol
Biodiesel (alkyl ester)	Veg oil / Fats	C18	yes	Biomass based diesel	Current blended-in fuel
	Algae oil	C18	No		
Renewable Diesel (hydrocarbon)	Veg oil / Fats/Algae Oil	C18	Several processes are now online		Biodiesel that is hydrogenated to be drop in fuel.
Renewable Jet (hydrocarbon)	Vegetable oil / Fats / Algae Oil	C12	No large scale production	Not defined	Processing in an oil refinery to produce drop-in fuel. Note these fuels need to be certified for use.
	Ethanol/bio butanol	C12	Uses three processes used in refining to combine and treat smaller molecules.	Not defined	
FT Distillates	Syngas from Natural Gas	Process produces C1 through C100+ that must be cracked to diesel and jet range hydrocarbons	Large scale is commercial, small scale is not	Not defined but will depend on feedstock	FT product requires cracking and hydrotreating to produce drop in fuels. Even at large scale, requires very low raw material costs
	Syngas from Biomass or other carbonaceous material		No	Not defined but will depend on feedstock	

APPENDIX 2: REFINING BASESTOCKS

1 Refining Algal Oil

Algal oils from algae have the same basic molecular structure as vegetable oils, tallows, lards, fats and greases. This triglyceride molecule is made of three (mostly) C18 straight chain fatty acid molecules connected together by a glycerol molecule.

Processing algal oils into renewable jet and diesel is simple and uses existing refining technologies. Processing consists of two steps:

1. Hydrotreating of the feed to remove oxygen. This is done in a hydrotreater at conditions similar to naphtha or jet hydrotreating. Removing the oxygen from the triglyceride produces three (mostly) C18 straight chain paraffin molecules. The process requires about the same amount of hydrogen as that for hydrocracking. For a 1,000 BPD unit, hydrogen requirements will be on the order of 2 million SCFD for this first step. The product is a “green diesel”, much better than bio-diesel, which still has a good bit of oxygen left in the product, but with rather poor cold flow properties (cloud and pour point) because of its paraffinic configuration. In this form, the green diesel could be blended at somewhere between 10% and 30% with conventional diesel, depending on the point of use (local temperature).

2. In order to improve the cold flow properties, the green diesel is fed to a second hydrotreating stage where it is reacted with hydrogen over an isomerization catalyst which rearranges the molecules. Operating conditions are similar to those for the first stage hydrotreater. Isomerization of the straight chain paraffins into isoparaffins reduces diesel cloud and pour point to that of conventional diesel and the diesel is thus considered a “drop in” replacement for conventional diesel. Renewable diesel has no sulfur, no aromatics and has a cetane number as high as 100 (versus 40-50 for conventional diesel). It is a very high quality product and can be used to upgrade low-cetane diesel blendstocks from refineries. As long as the FT diesel meets ASTM 975 specifications, it can be used neat. Some refiners on the Mainland have blended this product with petroleum diesel to take advantage of its superior properties.

   If the temperature of the isomerization catalyst is increased, the long chain molecules begin to break into C12’s (jet fuel) and C6’s (naphtha). Some of the C6’s break into C3’s (propane). The jet product is renewable jet, usable by either the military or commercial airlines. It is typically blended 50/50 with conventional jet. The naphtha is of relatively low quality and is useful mostly as a gasoline blendstock or hydrogen plant feed. Hydrogen consumption will be on the same order of magnitude as that for conventional hydrocracking, or 2 MMSCFD for diesel operations and 2.5 MMSCFD for jet operation.

Separation of diesel, jet, naphtha and LPG is done by simple distillation.

It is important to note that algal oil is corrosive to carbon steels, especially at higher temperatures. Feed tanks must be coated and feed lines to the first hydrotreating stage must be of special carbon steel to prevent corrosion. For a new unit, stainless steels will be used selectively in the first stage hydrotreater. Reusing an existing hydrotreater may necessitate upgrading some parts of the unit to stainless steels. Some of the oxygen in the feed is converted in the first stage hydrotreater to CO2, which must be removed from the recycle hydrogen stream. This is typically done with an amine compound, which requires an amine unit be available in an existing plant, or built new as part of a grassroots facility. Capture and disposal of CO2 and a small amount of sulfur compounds from the feed are part of the infrastructure for the plant, and can be a significant capital cost for a small facility.

1.1 Integration with an Existing Refinery

If an existing refinery is available to process the algal oils, the capital cost will go down dramatically, from $5 to $15 million to provide dedicated, corrosion resistant feed tankage, along with metallurgical upgrades in the first stage hydrotreater and possibly a new isomerization reactor. The refinery must have extra hydrogen for the process, and the ability to handle the various gas and liquid products. Even a relatively small refinery with a hydrocracker or distillate hydrotreating should be able to make green diesel and blend the product with refinery diesel. If the refinery makes jet fuel, converting the green diesel to jet fuel should be relatively easy with addition of the isomerization reactor; however, it may not be possible to separate renewable jet and diesel from conventional products depending on the process configuration. The refiner will probably ask the technology provider to assist in determining how much algal oils or other biofeeds can be processed in his units.

1.2 Capital Cost for a Greenfield Unit

The capital cost of a new 1 KBD unit built on a green field site, including infrastructure will be on the order of $114 million. The capital cost includes the cost of a hydrogen plant to make hydrogen for the two hydrotreating units. Infrastructure includes feed and product handling, tankage, utilities, buildings, and gas and water treating.

1.3 Typical Operating Costs

Typical operating costs for the hydrotreating stage would be as follows:

Power, kwh/bbl feed:	1.7
Fuel, MMBTU/bbl feed:	0.238
MP Steam, lb/bbl feed:	7.0
Cooling Water, gal/bbl feed:	300

1.3.1 Operating Costs for Hydrogen Plant

Following are typical utilities for a hydrogen plant.

Kwh/lb H2	0.15
Fuel, MBTU/lb H2	45.0
Cooling Water, gal. lb H2	65.0
Boiler Feed Water, gal. lb H2	1.0
Catalysts and chemicals, cents/lb H2	0.5
Feed gas, mol/mol H2	0.26

The most likely feedstock for the hydrogen plant is LPG or naphtha.

Manpower to operate and maintain the two hydrotreating units is approximately 16-20. Total manpower for a full greenfield facility would be on the order of 40-50. Plant management, engineering, and other support groups would add another 5-10 people.

Using an existing facility to process algal oils would add at most a few operating and maintenance positions, possibly none depending on how the facility is configured and staffed. Costs would be limited to incremental variable costs (mostly utilities), catalysts and fees to the facility owner.

Since a refiner would be making jet and diesel products in most cases, it is likely he would purchase the renewable fuels and blend them with his own stocks. The refiner would also take the gas and liquid byproducts to use internally or sell into local markets.

1.4 Infrastructure Costs

Infrastructure for this complex will include:

1. Feedstock and product offloading and loading (truck, barge)
2. Feed and product tankage and transfer pumps
3. Pipelines to and from process units
4. Electric power facilities
5. Fuel facilities (gas or liquid)
6. Steam generation
7. Cooling water
8. Catalyst and chemicals storage
9. Office buildings and control room
10. Processing of sour water and effluent water
11. Processing of acid gases
12. Manpower to operate and maintain infrastructure: approximately 20

To the extent that biofuel processing can be done in existing refinery or chemical plant facilities that have these infrastructure facilities, the need for new infrastructure can be reduced or eliminated. For a new facility this can reduce overall capital costs by 35% or more. In the example above, the total capital cost could be as low as $75MM for new process units integrated into an existing refinery.

2 Converting Biobutanols to Renewable Jet and Diesel

Converting biobutanols to renewable jet and diesel is a straightforward process, using existing refining and chemical plant technologies. Biobutanols are four carbon alcohols, and consist of n-butanol, isobutanol, secondary butanol and tertiary butanol.

The conversion process consists of the following steps:

1. Dehydration of the alcohol to the corresponding butylene olefin, i.e., isobutanol converts to isobutylene
2. Reaction of two or more olefins to a larger olefin. This is called oligomerization. For example, three isobutylenes react to form a C12 olefin and four isobutylenes react to form a C16 olefin.
3. Addition of hydrogen to saturate the isoolefins to isoparaffins, the desired form of the finished product. The C12 isoolefin reacts with hydrogen to form the C12 isoparaffin, or renewable jet fuel. The C16 isoolefins produces a C16 isoparaffin or renewable diesel fuel.
4. Separation of the products by distillation. Jet and diesel are separated as finished products. Unreacted materials are recycled back to their reactors for further conversion to jet and diesel.

Yields of butanols to finished jet and diesel are very high, on the order to 90-95 wt% (65-70 vol%) of the starting feedstocks, but butanol yield from starting feedstock is low.

Renewable jet and diesel produced by this route are considered "drop in" fuels following certification, and are essentially identical to conventional jet and diesel.

Both the renewable jet and diesel have zero aromatics, which provide some lubricity, and are typically blended 50/50 with conventional jet and diesel at the present time.

For discussion purposes we will assume that the alcohol preparation steps produce iso-butyl alcohol, isobutanol.

2.1 Dehydration

Dehydration is an intermediate feed preparation step in the production of renewable jet and diesel fuel. The primary product is isobutylene. The desired reaction involves the removal of one molecule of water from each molecule of isobutanol to produce isobutylene. The reaction is quick and easy, using an acid catalyst at low pressures and low to moderate temperatures. Conversions and yields can be as high as 90% of fresh feed.

The technology for alcohol dehydration is similar to catalytic reforming on naphtha used in refining, and was used in the production of MTBE, a gasoline blend component. Reaction products are separated by distillation.

2.1.1 Dehydrogenation Capital Cost Estimate - 1,000 BPD Plant

The capital cost is similar to that of a semi-regeneration catalytic reforming unit. A 1,000 BPD unit in Hawaii would be about $22 million. This includes a 1.4 multiplier to account for the difference in Gulf Coast versus Hawaii construction costs.

Table 1. Dehydrogenation Plant Utilities Summary

Power, Kwh/bbl	6
Fuel, KBtu/bbl	1728
Cooling Water, gal/bbl	60
Steam, lb/bbl	(36) *
Manpower to operate and maintain unit	3

*Parentheses indicate steam product.

2.2 Catalytic Polymerization

Butylenes can be reacted with each other to form C8 olefins (dimerization), C12 olefins (trimerization) or C16 olefins (tetramerization). Two isobutylene molecules react to form a diisobutylene molecule, the typical refinery product in catalytic polymerization. This dimer product can be recycled back to the reactor where it will react with more isobutylene to form the C12 trimer or C16 tetramer.

Conversion to polymers is essentially complete and yields are about 0.7 gallons of product per gallon of olefin feed.

The reaction occurs over an acid catalyst at around 400F and 500 psig. The feed must be very pure to prevent side reactions with the catalyst and loss of catalyst activity. Feed contaminants are caustic materials or other basic materials such as sulfur and oxygen. Older reactor designs can be either tubes filled with catalyst surrounded by a water bath to control temperatures, or vertical vessels with multiple beds of catalyst with butane used as bed quench. Newer reactors use a homogeneous catalyst system containing aluminum and nickel materials, which are miscible in the hydrocarbon feed. The catalyst is injected continuously in very low concentrations into the reactor, then removed from the reactor products.

After leaving the reactor, the products are distilled to separate the butanes and lighter materials from the product. Unreacted isobutylene is recycled back to feed, while heavier polymerized products (dimers, trimers, tetramers) are separated by distillation and either removed as finished products or recycled for further polymerization to jet or diesel.

2.2.1 Catalytic Polymerization Capital Cost Estimate - 1,000 BPD Plant

Capital cost is approximately $65 million. This includes a location factor of 1.4 relative to costs on the US Gulf Coast.

Table 2. Catalytic Polymerization Plant Utilities Summary

Power, Kwh/bbl	8
Fuel, Kbtu/bbl	350
Steam, lb/bbl	350
Cooling Water, gal/bbl	3585*
Manpower to operate and maintain unit	3

* Cooling water usage for a poly unit producing distillates. Poly units producing gasoline use about one half this amount of water per barrel.

2.3 Saturation

Following production of the polymers, the products go to a hydrotreater where hydrogen is added to the olefins to make C12 and C16 paraffins, the desired final products. Hydrogen reacts with the olefins at relatively low pressures (<500 psig) and moderate temperatures (500-600F) over a saturation catalyst. Product yields are almost 100%. The reaction to make cetane from cetene requires about 450-500 SCFB (standard cubic feet of hydrogen per barrel of feed), and a source of hydrogen must be available. If a refinery is nearby and has excess hydrogen, this may be sufficient for the process needs. Small quantities of hydrogen can be provided by liquid truck if there is an industrial gas company nearby that can produce liquid hydrogen. Otherwise, a small steam methane or naphtha reforming unit (SMR/SNR) must be built to supply the hydrogen.

For example, 1,000 BPD of olefin feed to the hydrotreater will require about 500,000 SCF of hydrogen for saturation to renewable jet or diesel. The capital cost for such a small plant will be very high; thus, every effort should be made to enter into a processing agreement with a local refiner.

2.4 Hydrogen Plant Capital Costs

The capital cost for a 0.5 MMSCFD naphtha hydrogen plant is approximately $8 million. This includes a 1.4 location factor. The capital cost for a 0.5 MMSCFD hydrogen purification unit is approximately $1.0 million. Total hydrogen plant cost is approximately $9 million, including a 1.4 location factor.

Table 3. Hydrogen Plant Utilities Summary

Kwh/lb H2	0.15
Fuel, MBTU/lb H2	45.0
Cooling Water, gal. lb H2	65.0
BFW, gal. lb H2	1.0
Catalysts and chemicals, cents/lb H2	0.5
Feed gas, mol/mol H2	0.26
Manpower to operate and maintain unit	4

If hydrogen is available from an existing refinery or chemical plant, the cost of hydrogen will likely be the incremental operating cost times the pounds of hydrogen used or a total of $1.07/lb. The owner of the hydrogen plant will charge for the feedstock cost, plus a small amount for catalyst and chemicals usage, and will want a fixed fee in addition to operating costs.

2.4.1 Saturation Unit Capital Costs

The capital cost for a 1,000 BPD hydrotreater is approximately $15 million. This includes a location factor of 1.4.

Table 4. Saturation Unit Utilities Summary

Power, Kwh/bbl	1.1
Fuel, Kbtu/bbl	35.0
Steam, lb/bbl	0.0
CW, gal/bbl	210.0
Catalyst replacement, $/BBL	0.05
Manpower to operate and maintain unit	3

Table 5. Total Estimated Capital Costs for a 1,000 BPD Greenfield Biobutanol Feed to Renewable Fuels Facility

Plant	$ Million
Dehydration	22
Polymerization	65
Saturation	15
H2 Plant	9
Process Unit Total	111
Infrastructure @ 50%	56
Total Greenfield Cost	**167**

3 Pyrolysis Oil Processing

Pyrolysis oil is the product of thermal decomposition of organic material. The properties of the pyrolysis oil vary with the process conditions under which decomposition occurs and the material that undergoes thermal decomposition. Because there is a range of feedstocks and technologies that can produce pyrolysis oils, it needs to be noted that the specific quality of the pyrolysis oil from the proposed HC&S facility was not provided and this analysis is based on available public information. The processing technology to upgrade pyrolysis oil to drop in fuels is under development as part of the UOP demonstration unit. The processing scheme and estimates presented here represent Stillwater's judgment of what will ultimately be required in a commercial scale facility.

The key characteristic differentiating thermal processes are the reactions that occur are non-selective with many side reactions resulting in a product that is a complex soup of molecules. As a result, pyrolysis oil is a more complex mixture than even crude oil. Besides having the hydrocarbon molecules that crude oil has, pyrolysis oils have molecules with oxygen, nitrogen and sulfur in significant percentages. The following table gives a gross comparison of properties.

Table 6. Gross Comparison of Properties

	Pyrolysis Oil[1]	Crude Oils
Water content (wt.%)	15 - 30	<0.5%
pH	2.8 – 4.0	~ 6 - 7
Density (kg/L)	1.1 - 1.25	0.8 – 1.0
Elemental analysis (wt.% dry)		
Carbon	55 - 60	~85 - 90
Hydrogen	5 - 8	~10 - 15
Nitrogen	< 0.1	0.01 – 0.5
Sulfur	0 - 0.05	0.1 - 5
Oxygen	35 - 40	nil
Insoluble Solids	0.5 - 0.8	~0
Higher Heating Value (MJ/kg)	17	~40
Viscosity (315 K, cP)	25-1000	5 - 100

1. *Compiled from various sources*

Comparatively, vegetable oil, tallow, lards, fats and greases are a simple mixture that is mostly simple organic compounds over a small range of carbon numbers. Other impurities in these materials are minor.

The Stillwater assessment is based on research of public data, public information and discussions with UOP, a provider of both pyrolysis technology and an active developer of pyrolysis oil processing technology. The assessment is that pyrolysis oil to drop in fuels has significant challenges before the technology is commercialized.

Pyrolysis oil characteristics that make successful upgrading to drop in fuels or even using in combustion challenging are:

1. Pyrolysis oil is corrosive due to the very low pH from organic acids and the dissolved water. This property makes processing pyrolysis oil to a drop-in fuel much more complex, difficult and costly than processing vegetable oils since higher grades of metallurgy and additional processing steps will be needed to mitigate the acids.
2. Many compounds formed by thermal processes are unstable compounds that will continue to react, often by polymerizing or combining with other compounds to form heavier materials. An analogy to this is the brown film that forms in a fry pan when oil is overheated (thermally decomposed). This property makes processing or burning of the material difficult since it rapidly fouls equipment.
3. Pyrolysis oils have a significant amount of very finely divided solids as a result of the thermal process. These solids will add to equipment fouling, forming stable emulsions and plugging catalyst beds. A means to separate the solids to a very low level will be required in the process.
4. Pyrolysis oil has a density heavier than water. Petroleum products and biofuels have densities lighter than water. When lighter than water, a material can easily be separated from an aqueous phase (unless it is soluble in that phase), and is easier to deal with in case of a spill.
5. It is not expected that pyrolysis oil will have a very high boiling point since the predominate carbon numbers should largely reflect the carbon numbers in the material that is thermally decomposed. Heavier materials will be present as a result of polymerization and combination. It is anticipated that when the material is hydrotreated to remove oxygen, a fairly significant amount of gasoline and light material will result. In addition, the high oxygen content will require very high hydrogen consumption to convert the oxygen to water and carbon dioxide.
6. Pyrolysis oil has a low heating value at less than half that of petroleum. The laws of thermodynamics would dictate that the yield of petroleum-like drop in fuels would at best be less than half of the input volume unless a significant amount of external energy is added.
7. A significant weight loss occurs in the conversion of raw pyrolysis oil to drop in fuels. An analysis by UOP in 2008 estimated the weight percent yield of 21 wt% naphtha (gasoline range) and 21 wt% diesel from pyrolysis oil. The conceptual process used the aqueous phase organics to generate hydrogen for hydrogenation. The 42% hydrocarbon yield can be increased if the aqueous phase organics can also be processed to hydrocarbons.

The National Renewable Energy Laboratory issue a report in November 2010, “Techno-Economic Analysis of Biomass Fast Pyrolysis to Transportation Fuels” Wright, Daugaard and Hsu that developed technical and economic modeling for investment in pyrolysis oil plants. In the paper, a process flow and costs are provided.

Stillwater anticipates the processing for pyrolysis oil will have the following characteristics:

1. Several processing steps that will progressively treat the pyrolysis oil, such that at the end, the material will be a mixture of hydrocarbon molecules without the impurities or undesirable properties.

2. An initial stage beyond phase separation will be required that would serve to reduce the water, to eliminate the solids, to reduce the acidity and to reduce the reactivity of the pyrolysis oil. Low investment options may exist to achieve all of these goals; however these would probably involve use of chemicals with potentially large amounts of hazardous byproducts. Two phases would be produced. An aqueous phase which has been proposed to be used to generate hydrogen in the NREL paper and an organic phase that would be further processed as below. This aqueous phase will require significant treatment if it is to be discharged to the environment.
3. A first hydrotreating stage to remove oxygen, stabilize the material, remove some sulfur and nitrogen similar to the first step in algae oil processing above.
4. A second hydrotreating stage to remove the remaining sulfur and nitrogen, and improve the properties. This could be similar to the second stage of algae oil processing. However, if the pyrolysis oil contained high percentages of aromatic compounds, much more severe processing conditions will be required.
5. A separation step to distill the product into LPG, naphtha, jet, diesel and fuel oil fractions.
6. An aqueous treatment step to render the water contaminated with organic acids, esters, phenols, etc. environmentally safe for discharge.

A better concept of the upgrading process could be developed if the specific properties of the pyrolysis oil were provided.

3.1 Estimated Production Volume of Drop In Fuels

Based on the above processing scheme, the estimated yield of drop in fuels from 16.8 million gallons per year (1,096 barrels per day) is 5.3 million gallons per year of diesel (346 BPD) with an additional 6.0 million gallons per year of naphtha (390 BPD) plus LPG. This yield is somewhat higher than UOP estimated in 2008 because of the use of hydrogen from an external source.

The value of the yield could be quantified as shown in the following:

		Yield			
Product	**BPD**	**Volume %**	**Weight %**	**Price ($/gal)**	**Pyrolysis Oil Value ($/gal)**
Naphtha	390	35.6	23	2.318	0.8252
Diesel	350	31.9	23	3.025	0.9650
Pyrolysis Oil	1096	100	100		1.7902

Note: The naphtha price is calculated by equating naphtha to diesel price on a BTU basis on Maui and then netting that price back to Oahu. In 2014, the Maui naphtha price was forecast at $2.401. This price, less $0.084 in transportation costs results in a price on Oahu of $2.318.

3.2 Capital Cost for a Greenfield Unit

The capital cost of a new pyrolysis oil upgrading facility built on a greenfield site, including infrastructure will be on the order of $101 million; $55 million for the process units and $45 million for the remainder of the facility including water treating. The capital cost includes the cost of a small hydrogen plant to make hydrogen for the two hydrotreating units. Infrastructure includes feed and product handling, tankage, utilities, buildings, and gas treating

Table 7. Pyrolysis Oil Upgrading Capital Estimate

	New Capacity	**Estimated Capital ($MM)**
Pretreat Stage	1,100 bpd	$15.88
First Stage Hydrotreating	880 bpd	$13.89
Second Stage Hydrocracking	690 bpd	$12.01
Hydrogen Plant	4,300 mscf	$12.46
Process Plant Subtotal		$54.24
Infrastructure at 50%		$27.12
Byproduct Water Handling	Allowance for water with high impurities	$20.00
Total Greenfield		**$101.36**
Note: The level of development of this technology is low or proprietary. The estimates are order of magnitude in accuracy at best. Better estimates may be prepared through discussions with the technologiy providers who are developing this technology.		

3.3 Integration with an Existing Refinery

It may be possible to integrate a portion of the facility into an existing refinery where capacity to produce additional hydrogen and hydrocracking/hydrotreating capacity exists. By this integration, the cost of the hydrogen plant, hydrocracker and majority of infrastructure will be saved. The pretreat stage, first stage hydrotreating and byproduct water handling have such unique requirements because of the feedstock that those process steps will have to be built new. The anticipated capital for integration into a refinery would be $35 to 50 million.

3.4 Utilities Summary

The major two utility requirements for the greenfield facility would be:

Power	260 kW
Fuel	25 MM BTU/hour

Other operating cost would be similar to those for processing Algal Oil.

APPENDIX 3

1 Forecasting Hawaiian Petroleum Product Prices

1.1 Summary

Primary petroleum product prices in Hawaii were forecasted based upon the Energy Information Agency's *2011 Annual Energy Outlook* (AEO) with differentials based on the historic difference in prices between Hawaii and the US West Coast (Petroleum Administration for Defense Districts PADD V) for several price series. The starting point for prices was the PADD V wholesale product prices for the reference case for gasoline, jet, and transportation diesel. Several methodologies were used for forecasting prices in Hawaii. A history of Hawaii-to-PADD V prices was derived from the EIA historical price database that was used to establish differentials for forecasting gasoline and diesel prices. .Hawaii and Industry sources were used to determine commercial jet differentials to the West Coast. MECO rate adjustment filings were correlated with the West Coast and Mainland pricing for utility fuels. The most recent Defense Logistics Agency (DLA) awards for Hawaii supply were used for military fuels pricing. The resulting Hawaii constant dollar prices for gasoline, jet fuel, and diesel were inflated to current or nominal dollars using the inflation factors imbedded in the AEO.

We expect period-to-period volatility to continue, but over the longer period required for a capital project, a forecast of this type would apply.

1.2 Basis

The forecast is primarily based on the Energy Information Administration's Annual Energy Outlook. The EIA is the statistical arm of the US Department of Energy (DOE). The AEO is the most complete forecast of energy demand, use, supply, and prices that is publically available and is commonly used as a reference for energy forecasting.[19] As the name implies, an AEO is issued each year.

The Reference Case in the 2011 AEO published in April 2011 forms the basis for our forecast. The Reference Case reflects the EIA's judgment for the most likely supply and demand for petroleum, with associated economic growth, changes in crude oil production due to oil prices, the growth in unconventional and alternative liquids resources, and changes in energy consumption due to elasticity. To provide sensitivity, alternative forecasts were developed for two additional AEO scenarios the High Oil Price scenario and Low Oil Price scenario.

The EIA also publishes a monthly Short Term Energy Outlook (STEO) that forecast prices for the balance of the current year and the following year. The STEO was not used to forecast prices since it would only modify the forecast for 2012 which probably is not a relevant time period for the types of investment being considered.

Several highlights of the 2011 AEO are:

- Real GDP is expected to grow at an average 2.7% per year 2009 through 2035 in the Reference Case.
- The real price of oil in the Reference Case (2009 dollars) is forecast to be $125 per barrel in 2035.
- Energy, particularly oil demand is impacted by alternatives such as increasing biofuels production, the new fleet economy standards, decreases in consumption due to higher prices, and the increase of natural gas production.

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[19] http://www.eia.gov/forecasts/aeo/l

- In 2035, US petroleum product demand is expected to be 21.9 million barrels per day, 2.9 million barrels more than 2009. Alternatives to petroleum are expected to contribute the equivalent of 2.5 million barrels per day.

- A total of 57 sensitivity cases are presented in the 2011 AEO.

- California's Low Carbon Fuel Standard (LCFS), which reduces the carbon intensity of gasoline and diesel fuels in that State by 10 percent from 2012 through 2020, is incorporated.

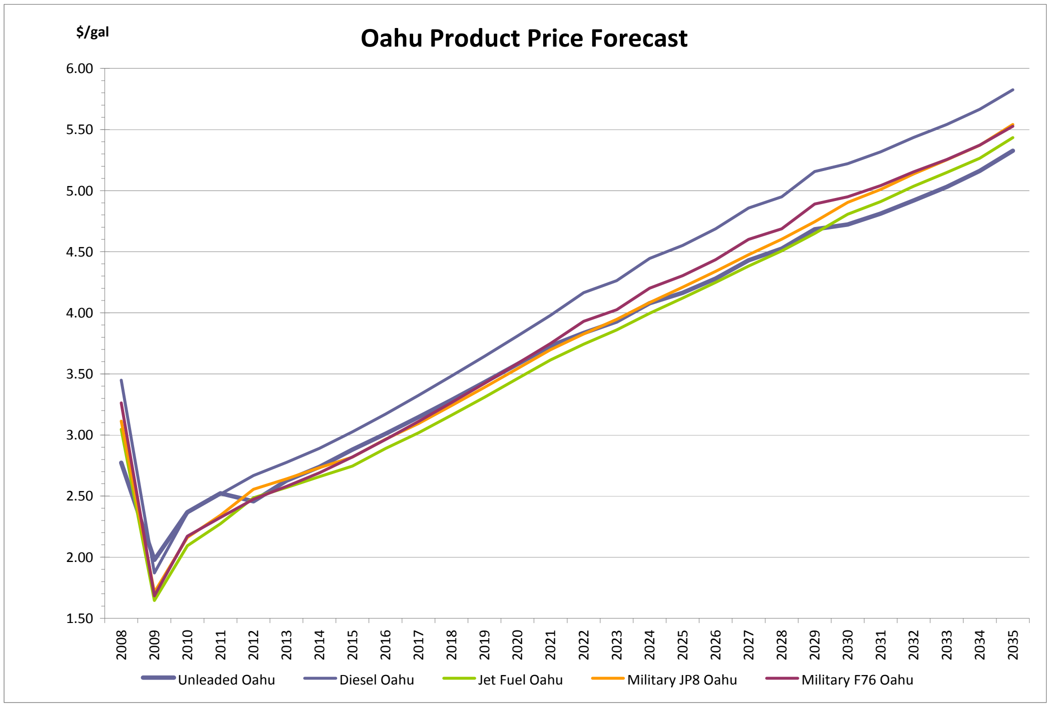
- The AEO forecasts a "hitch" in the diesel, and to a lesser extent gasoline, prices in the 2015 to 2021 time period. Conversations with the EIA indicate this is due to implementation of the California LCFS. EIA advised this period should be smoothed over for Hawaii price forecasts.

1.3 Forecasted Prices

The prices forecasted in this report are in "nominal" or "current" dollars that represent the price that is experienced in the forecast year. This differs from prices that are expressed as "real" or "constant" dollars which are the prices expressed corrected for the effects of inflation and are expressed in dollars valued at a point in time such as 2009$.

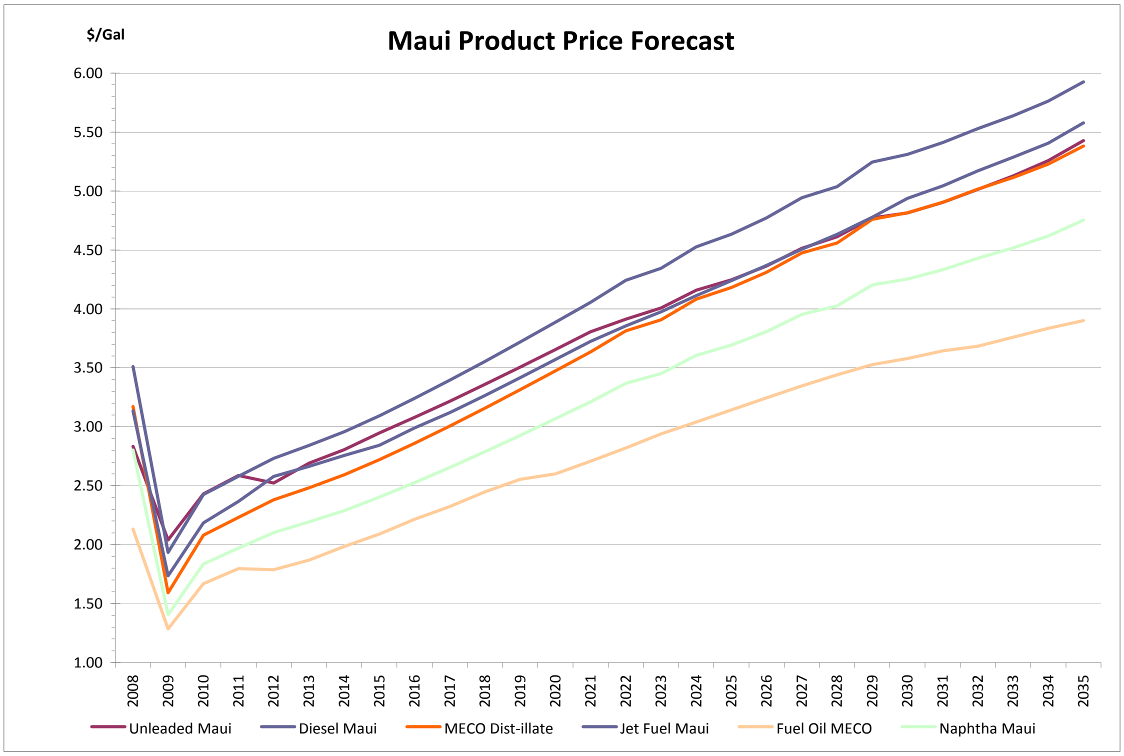
To forecast Jet and Diesel prices in Hawaii from the AEO price forecast for the Pacific region, or PADD V, forecasted wholesale prices for each of the products was used as the basis. The AEO prices were adjusted using various historic relationships to correlate between PADD V wholesale prices and Hawaii prices. Military Fuel prices were forecast by a similar method using the latest Defense Logistics Agency awards. Fuel Oil prices were developed from the costs in the MECO PUC filings compared to the AEO and forecast with the AEO fuel oil prices. The following Base Case forecast for Oahu is in Figure 1 that illustrates the pricing trend for selected products:

Figure 1: Oahu Product Price Forecast (current dollars)



The following Base Case forecast for the products on Maui of interest to HC&S is shown in Figure 2.

Figure 2: Maui Product Price Forecast (current dollars)

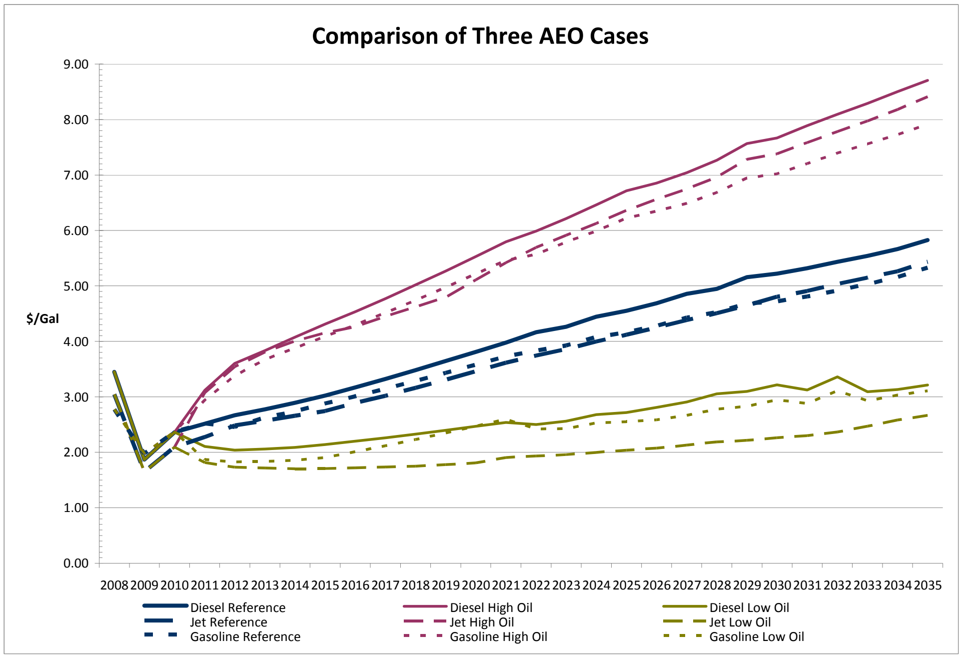


A table of values for all the products is included later along with a description of derivation for each price series.

Two additional price forecast cases were similarly developed as sensitivities to the Base Case and are included in this document. These are based on the AEO High Oil Price case and Low Oil Price case. The High Oil Price case is based on a scenario where oil prices in real terms increase by 4.6% through 2035 and the Low Oil Price case are based on a scenario where oil prices in real terms decrease slightly.

The following figure illustrates the difference in prices under the Reference, High Oil, and Low Oil Cases:

Figure 3: Comparison of Three Annual Energy Outlook Cases (current dollars)



1.5 Relative pricing of products in Hawaii.

We have several observations about product pricing in Hawaii:

- Of the three major products using Oahu as the comparison point, diesel at about 17 cpg over US West Coast (USWC) has held the highest premium when compared to USWC markets, followed by gasoline at 10 cpg. Jet has held a slight 1 to 2 cpg premium.

- The high diesel premium reflects that Hawaii needs to import small quantities from the mainland.[20] This small quantity and limited availability in other markets like Asia forms a high price to supply the market.

- Jet premiums to the USWC are much more moderate reflecting the large percentage of Jet that is supplied from Asian supply points. Jet has a much higher sulfur content specification at 0.2% or 2000 ppm, while the sulfur content in ULSD is 15 ppm max. ULSD requires more processing than jet to reduce the sulfur content.

- Gasoline (naphtha) is in excess in Hawaii with refinery supply exceeding local demand. Excess naphtha is burned by utilities to generate electricity on Kauai and the Big Island.

- Military JP8 price, the grade similar to commercial jet, is very close to the commercial jet prices on Oahu. This fuel is supplied from one of the state's refineries.

- Military Distillate (F76) prices are significantly lower than ULSD diesel used in Hawaii since the sulfur specification is 0.5% maximum (5000 ppm) instead of 15 ppm max for ULSD. This fuel is supplied from one of the local refineries.

- The cost of barge transport and storage to Maui is about 8 cpg.

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[20] Stillwater conversations with market participants

- Residual fuel oil in Hawaii is supplied from local refineries or various imported sources. Although not supplied from the US mainland, imported residual fuel oil and US utility residual oil will both track global prices. Using the AEO forecast for residual fuel preserves a consistent reference case for all the fuels.

- The premium value of diesel fuel versus jet fuel at face value is a disincentive for producing renewable jet out of diesel based feedstock. A process that makes jet from diesel is producing a lower valued product from a higher valued product. In order for such to be economic, there will need to be a significant incremental incentive such as subsidies or credits to make this viable.

1.5.1 Factors Impacting the Forecasted Prices

The forecasted prices for gasoline, naphtha, jet fuel, diesel, and fuel oil are primarily driven by the AEO forecast from the EIA. These are updated annually and can be used to update the forecast. A smaller, but significant driver for the forecasted prices are the historical relationships used to adjust the US forecasts to forecasted prices. We see two factors that will probably affect the price relationships:

- **US Crude Oil Market** – Recent news items have highlighted the growing importance of the shale resource in the US and Canada. The growing production from shale is centered on the Dakotas coupled with the already growing tar sands resource in Canada has produced an energy glut in an area roughly described by an oval surrounding Edmonton, Alberta; Detroit; Salt Lake City and Cushing, Oklahoma. The wide discounts for WTI crude oil to import crude oils reflect this glut. This situation has reversed a long standing cost advantage that the coastal PADD V refineries have had over PADD IV refiners. It is expected that PADD IV refiners will penetrate some of the interface markets between the PADDs. This along with reduced demand because of California's Low Carbon Fuel Standard will make product surplus on the US West Coast, requiring offshore movements or shutdown of capacity.

- **Diesel Market Changes** - During the past several years and continuing into the future, changes in US diesel specifications and requirements have impacted the markets. Starting in 2006, the sulfur level for on-road diesel was reduced from 500 ppm (LSD) to 15 ppm (ULSD). The requirement for ULSD use is spreading to other uses. As a result, there is little trade in LSD and any spot price is not reliable. In addition, regulatory requirements such as California's Low Carbon Fuel Standard and the US Renewable Fuels Standard will impact the market prices and thus indices of petroleum based fuels. In the future, care will have to be taken to ensure that any pricing basis contain credits or debits for these regulations

Table 1. Base Case Pricing Table

Hawaii Forecasted Prices - 2012 to 2035
Projections based on EIA 2011 Annual Energy Outlook, Reference Case
Current Dollars per gallon

	GASOLINES		DISTILLATES				JET FUELS				OTHER	
	Unleaded Oahu	Unleaded Maui	Diesel Oahu	Diesel Maui	MECO Dist-illate	Military F76 Oahu	Jet Fuel Oahu	Jet Fuel Maui	Military JP5 Oahu	Military JP8 Oahu	Fuel Oil MECO	Naphtha Maui
2008	2.772	2.834	3.448	3.510	3.172	3.263	3.046	3.135	3.176	3.113	2.131	2.802
2009	1.978	2.041	1.871	1.934	1.592	1.684	1.645	1.735	1.776	1.713	1.285	1.406
2010	2.368	2.432	2.361	2.425	2.080	2.173	2.093	2.184	2.225	2.161	1.668	1.837
2011	2.523	2.587	2.515	2.579	2.230	2.324	2.274	2.366	2.408	2.343	1.797	1.970
2012	2.458	2.523	2.668	2.732	2.379	2.474	2.486	2.579	2.621	2.556	1.787	2.101
2013	2.625	2.691	2.776	2.841	2.482	2.579	2.570	2.664	2.707	2.641	1.868	2.193
2014	2.737	2.804	2.890	2.957	2.592	2.690	2.659	2.756	2.799	2.732	1.984	2.289
2015	2.880	2.948	3.025	3.093	2.720	2.820	2.745	2.844	2.888	2.819	2.089	2.402
2016	3.010	3.079	3.171	3.240	2.860	2.962	2.889	2.989	3.035	2.965	2.213	2.526
2017	3.145	3.216	3.323	3.394	3.006	3.110	3.017	3.119	3.165	3.094	2.324	2.655
2018	3.287	3.360	3.482	3.555	3.158	3.265	3.162	3.266	3.313	3.240	2.448	2.789
2019	3.431	3.505	3.644	3.718	3.313	3.422	3.309	3.416	3.464	3.389	2.554	2.926
2020	3.580	3.655	3.811	3.887	3.474	3.585	3.461	3.570	3.619	3.543	2.600	3.068
2021	3.729	3.806	3.979	4.056	3.635	3.748	3.614	3.725	3.775	3.697	2.708	3.210
2022	3.834	3.913	4.164	4.242	3.814	3.929	3.743	3.856	3.906	3.827	2.820	3.369
2023	3.928	4.008	4.263	4.343	3.907	4.024	3.860	3.975	4.027	3.946	2.939	3.451
2024	4.078	4.159	4.445	4.527	4.083	4.202	3.996	4.113	4.165	4.084	3.041	3.606
2025	4.164	4.246	4.551	4.634	4.182	4.304	4.120	4.239	4.293	4.209	3.143	3.694
2026	4.279	4.363	4.687	4.771	4.311	4.435	4.248	4.369	4.424	4.339	3.244	3.808
2027	4.428	4.514	4.858	4.943	4.475	4.601	4.383	4.506	4.562	4.476	3.347	3.952
2028	4.525	4.613	4.948	5.036	4.559	4.687	4.507	4.633	4.689	4.601	3.439	4.026
2029	4.682	4.771	5.156	5.246	4.759	4.890	4.649	4.778	4.835	4.746	3.527	4.203
2030	4.723	4.814	5.221	5.311	4.816	4.949	4.806	4.936	4.995	4.904	3.578	4.254
2031	4.811	4.903	5.318	5.410	4.906	5.041	4.910	5.043	5.103	5.010	3.643	4.333
2032	4.919	5.013	5.435	5.530	5.015	5.154	5.035	5.170	5.231	5.137	3.683	4.430
2033	5.030	5.126	5.541	5.637	5.113	5.254	5.148	5.287	5.349	5.252	3.760	4.516
2034	5.160	5.258	5.666	5.764	5.229	5.373	5.265	5.406	5.469	5.371	3.835	4.618
2035	5.327	5.426	5.826	5.926	5.381	5.527	5.433	5.577	5.642	5.541	3.900	4.752

Forecasting Methodology by Product and Location

Prices are based on the EIA AEO 2011 Forecasts for the Reference Case, High Oil Price Case or Low Oil Price Case. Gasoline, Jet and Diesel Prices are based on the Wholesale/reseller forecast for the Pacific (PADDV) region in each AEO 2011 Case. The years 2015 to 2021 are smoothed from the AEO 2011 forecast based on advice of the EIA. Those years have an influence from California's LCFS program that effectively accelerates pricing and creates a discontinuity. Residual fuel oil price (Fuel Oil MECO), used for electricity generation, is based on the US Utility Resid forecast in each of the AEO 2011 Cases. Historical data, analysis and industry sources are used to correlate the particular product and location prices. The prices were forecast in constant 2009$ and inflated to current dollars using the inflation imbedded in the AEO 2011 Cases.

The correlation basis for each price series is below:

1. Unleaded Oahu – Gasoline is forecast using the last 5 year average difference between Hawaii and PADD V. This value is 10.8 cents per gallon.
2. Unleaded Maui – Gasoline is forecast be adding 6.26 cents per gallon to the Oahu price which reflects the cost of transporting, landing and storing product at Kahului.
3. Diesel Oahu - Diesel is forecast using the last 5 year average difference between Hawaii and PADD V. This value is 17.1 cents per gallon.
4. Diesel Maui - Diesel is forecast by adding 6.26 cents per gallon to the Oahu price which reflects the cost of transporting, landing and storing product at Kahului.
5. MECO Distillate – Distillate (diesel) to MECO is forecast using the average differential to PADD V resale based on 2010-2011 PUC filings. This value is 10.8 cents per gallon reflecting the higher sulfur content to MECO.

6. Military F76 Oahu – The basis for the military fuel contract is the average of the Seattle, San Francisco and Los Angeles markets. These markets were correlated to the PADD V reseller prices then the premium in the latest contract award was applied.
7. Jet Fuel Oahu – Industry sources were used to estimate the differential to LA spot for HNL. This was 1 – 2 cents per gallon. A five year history was used to correlate the LA spot to PADD V reseller prices.
8. Jet Fuel Maui - Industry sources were used to estimate the differential to HNL spot for OGG. This was 8 – 10 cents per gallon.
9. Military JP5 Oahu - The basis for the military fuel contract is the average of the Seattle, San Francisco and Los Angeles markets. These markets were correlated to the PADD V reseller prices then the premium in the latest contract award was applied.
10. Military JP8 Oahu - The basis for the military fuel contract is the average of the Seattle, San Francisco and Los Angeles markets. These markets were correlated to the PADD V reseller prices then the premium in the latest contract award was applied.
11. Fuel Oil MECO – Fuel Oil to MECO is forecast using the average differential to US resid, electricity generation based on 2010-2011 PUC filings. This value is minus 5.7 cents per gallon. [see 1.5 above]
12. Naphtha Maui – Naphtha is forecast at 88.32 % of MECO Distillate to adjust for BTU content (121 mbtu/gal vs 137 mbtu/gal).

Table 2. High Price Case Pricing Table

Hawaii Forecasted Prices - 2012 to 2035
Projections based on EIA 2011 Annual Energy Outlook, High Oil Price Case
Current Dollars per gallon

	GASOLINES		DISTILLATES				JET FUELS				OTHER	
	Unleaded Oahu	Unleaded Maui	Diesel Oahu	Diesel Maui	MECO Dist-illate	Military F76 Oahu	Jet Fuel Oahu	Jet Fuel Maui	Military JP5 Oahu	Military JP8 Oahu	Fuel Oil MECO	Naphtha Maui
2008	2.772	2.834	3.448	3.510	3.172	3.263	3.046	3.135	3.176	3.113	2.131	2.802
2009	1.978	2.041	1.871	1.934	1.592	1.684	1.645	1.735	1.776	1.713	1.285	1.406
2010	2.368	2.432	2.361	2.425	2.080	2.173	2.093	2.184	2.225	2.161	1.668	1.837
2011	2.942	3.006	3.119	3.183	2.834	2.927	3.072	3.164	3.205	3.141	2.306	2.503
2012	3.382	3.446	3.602	3.667	3.313	3.408	3.544	3.637	3.679	3.614	2.813	2.926
2013	3.672	3.738	3.833	3.899	3.540	3.636	3.806	3.901	3.943	3.877	3.094	3.126
2014	3.880	3.947	4.076	4.143	3.777	3.876	4.006	4.102	4.145	4.078	3.315	3.336
2015	4.089	4.158	4.311	4.380	4.006	4.107	4.152	4.250	4.294	4.226	3.519	3.538
2016	4.295	4.365	4.534	4.604	4.223	4.325	4.262	4.362	4.407	4.337	3.680	3.730
2017	4.514	4.585	4.771	4.842	4.454	4.558	4.450	4.552	4.598	4.527	3.775	3.934
2018	4.741	4.814	5.017	5.090	4.694	4.800	4.622	4.726	4.773	4.700	3.972	4.146
2019	4.973	5.047	5.268	5.342	4.938	5.047	4.796	4.902	4.950	4.876	4.164	4.361
2020	5.214	5.289	5.529	5.604	5.192	5.303	5.109	5.218	5.267	5.191	4.338	4.586
2021	5.459	5.536	5.795	5.872	5.452	5.565	5.418	5.529	5.579	5.502	4.525	4.815
2022	5.571	5.649	5.988	6.066	5.638	5.753	5.692	5.805	5.856	5.777	4.623	4.980
2023	5.789	5.869	6.214	6.293	5.858	5.975	5.913	6.027	6.079	5.999	4.800	5.173
2024	5.988	6.069	6.459	6.541	6.097	6.216	6.127	6.244	6.296	6.215	4.927	5.385
2025	6.221	6.303	6.714	6.797	6.345	6.467	6.362	6.481	6.535	6.452	5.100	5.604
2026	6.351	6.435	6.854	6.938	6.477	6.601	6.562	6.684	6.738	6.654	5.276	5.721
2027	6.487	6.573	7.041	7.127	6.657	6.784	6.744	6.868	6.923	6.837	5.491	5.880
2028	6.684	6.772	7.263	7.351	6.872	7.001	6.961	7.087	7.144	7.055	5.661	6.070
2029	6.944	7.034	7.563	7.653	7.165	7.296	7.283	7.412	7.470	7.380	5.827	6.328
2030	7.020	7.111	7.665	7.757	7.259	7.393	7.380	7.511	7.570	7.478	5.917	6.411
2031	7.202	7.295	7.890	7.983	7.476	7.612	7.584	7.718	7.778	7.685	6.078	6.603
2032	7.393	7.488	8.095	8.190	7.672	7.811	7.783	7.919	7.980	7.885	6.209	6.776
2033	7.559	7.656	8.291	8.388	7.859	8.001	7.972	8.111	8.174	8.077	6.283	6.941
2034	7.727	7.826	8.505	8.604	8.065	8.210	8.180	8.322	8.386	8.287	6.421	7.123
2035	7.914	8.015	8.707	8.808	8.258	8.406	8.408	8.553	8.618	8.517	6.532	7.294

Table 3. Low Price Case Pricing Table

Hawaii Forecasted Prices - 2012 to 2035
Projections based on EIA 2011 Annual Energy Outlook, Low Oil Price Case
Current Dollars per gallon

	GASOLINES		**DISTILLATES**				**JET FUELS**				**OTHER**	
	Unleaded Oahu	**Unleaded Maui**	**Diesel Oahu**	**Diesel Maui**	**MECO Dist-illate**	**Military F76 Oahu**	**Jet Fuel Oahu**	**Jet Fuel Maui**	**Military JP5 Oahu**	**Military JP8 Oahu**	**Fuel Oil MECO**	**Naphtha Maui**
2008	2.772	2.834	3.448	3.510	3.172	3.263	3.046	3.135	3.176	3.113	2.131	2.802
2009	1.978	2.041	1.871	1.934	1.592	1.684	1.645	1.735	1.776	1.713	1.285	1.406
2010	2.368	2.432	2.361	2.425	2.080	2.173	2.093	2.184	2.225	2.161	1.668	1.837
2011	1.869	1.933	2.107	2.171	1.822	1.915	1.814	1.906	1.948	1.884	1.006	1.609
2012	1.828	1.893	2.038	2.103	1.750	1.845	1.732	1.825	1.867	1.802	0.911	1.545
2013	1.837	1.902	2.060	2.126	1.767	1.864	1.718	1.812	1.855	1.789	0.877	1.561
2014	1.858	1.925	2.086	2.153	1.788	1.886	1.705	1.802	1.845	1.778	0.876	1.579
2015	1.907	1.975	2.139	2.207	1.835	1.935	1.707	1.805	1.849	1.781	0.871	1.620
2016	2.010	2.080	2.199	2.269	1.888	1.990	1.721	1.821	1.866	1.796	0.878	1.668
2017	2.117	2.189	2.261	2.332	1.944	2.048	1.735	1.837	1.883	1.812	0.892	1.717
2018	2.232	2.304	2.328	2.401	2.003	2.110	1.751	1.856	1.903	1.830	0.897	1.769
2019	2.349	2.423	2.396	2.470	2.064	2.173	1.778	1.885	1.933	1.859	0.910	1.823
2020	2.474	2.550	2.470	2.546	2.130	2.242	1.809	1.918	1.968	1.891	0.922	1.881
2021	2.595	2.673	2.536	2.614	2.190	2.304	1.908	2.019	2.070	1.992	0.928	1.934
2022	2.419	2.499	2.499	2.579	2.145	2.262	1.934	2.048	2.099	2.019	0.921	1.895
2023	2.428	2.509	2.561	2.642	2.201	2.319	1.959	2.075	2.127	2.046	0.905	1.944
2024	2.531	2.614	2.680	2.763	2.312	2.433	1.999	2.118	2.172	2.089	0.905	2.042
2025	2.552	2.636	2.717	2.801	2.342	2.465	2.037	2.158	2.212	2.128	0.911	2.068
2026	2.587	2.673	2.810	2.896	2.428	2.554	2.076	2.199	2.255	2.169	0.943	2.144
2027	2.666	2.753	2.908	2.995	2.518	2.646	2.131	2.256	2.313	2.225	0.968	2.224
2028	2.778	2.867	3.053	3.142	2.655	2.786	2.189	2.317	2.375	2.285	0.990	2.345
2029	2.832	2.923	3.098	3.189	2.692	2.826	2.217	2.348	2.407	2.315	0.980	2.378
2030	2.946	3.039	3.217	3.310	2.804	2.940	2.260	2.393	2.453	2.360	0.935	2.476
2031	2.880	2.974	3.126	3.220	2.705	2.843	2.302	2.438	2.499	2.404	0.955	2.389
2032	3.109	3.205	3.360	3.456	2.930	3.072	2.365	2.503	2.566	2.469	0.895	2.588
2033	2.929	3.027	3.091	3.189	2.653	2.797	2.470	2.611	2.674	2.576	0.883	2.343
2034	3.034	3.134	3.135	3.235	2.689	2.835	2.581	2.725	2.790	2.690	0.890	2.375
2035	3.109	3.211	3.212	3.314	2.757	2.907	2.664	2.811	2.877	2.774	0.914	2.435

APPENDIX 4

1 Renewable Fuel Standard Details

1.1 RFS1

The Energy Policy Act of 2005 (EPACT05), Public Law 109-58 passed by the 109th Congress of the United States, was signed on August 8, 2005 to establish the Renewable Fuel Standard (RFS1) with the expressed purpose "To ensure jobs for our future with secure, affordable and reliable energy." It mandated, among numerous other things, that 7.5 billion gallons per year (BGY) of fuel ethanol be blended into gasoline by 2012. Further, during 2006 as a result of liability concerns stemming from EPACT05, the industry completed the elimination of MTBE from domestic markets, which resulted in a more rapid shift to fuel ethanol than the mandate would have required.

The mandated conventional biodiesel and corn-based ethanol volume was 4.0 BGY for the 2006 RFS1 and 4.7 BGY for the 2007 RFS1. But, the first compliance year was not until 2007 after the US EPA issued its May 1, 2007 Final Rule to introduce the mechanism to track compliance, the Renewable Identification Number (RIN), starting September 1, 2007. The first quarterly reporting deadline was in February, 2008.

1.2 RFS2

The Energy Independence and Security Act of 2007 (EISA07), Public Law 110-140 passed by the 110th Congress of the United States, was signed on December 19, 2007 to establish the Renewable Fuel Standard – 2 (RFS2). Its purpose is "To move the United States toward greater energy independence and security, to increase the production of clean renewable fuels […] to promote research on and deploy greenhouse gas capture and storage options….".

RFS2 increased the 2008 standard to 7.76% from the RFS1 standard of 4.63%, thus mandating a larger volume of renewable fuel than required under EPACT 2005. Further, the total mandated renewable fuel volume increases every year until 2022 when it reaches 36 BGY.

RFS2 renewable fuel mandates expanded beyond conventional biodiesel and corn-based fuel ethanol to include an advanced biofuel category of fuels that can demonstrate full lifecycle GHG emission reductions versus those of the fossil fuel displaced. The required GHG reductions for advanced biofuels are as follows: cellulosic biofuels (60% GHG reduction), biomass-based diesel (50%), and other undifferentiated advanced biofuels (50%).

1.2.1 Renewable Identification Numbers RINS

Each gallon of renewable fuel is assigned a Renewable Identifications Number by its manufacturer. A RIN is a 38 character sequence as shown below.

K YYYY CCCC FFFFF BBBBB *RR D* SSSSSSSS EEEEEEEE

Where:

K = Code distinguishing assigned RINs from separated RINs
YYYY = Calendar year of production or import
CCCC = Company ID
FFFFF = Facility ID
BBBBB = Batch number
RR **= Code identifying the Equivalence Value**
D **= Code identifying the renewable fuel category**
SSSSSSSS = Start of RIN block
EEEEEEEE = End of RIN block

Because RINs have a two-year shelf life, there will be both current and previous year RINs for each of the four biofuel categories, a total of eight separate RINs trading at any given time. Further, due to the mid-year implementation of the RFS2 Final Rule, RFS1 RINs issued through June, 2010 will coexist with RFS2 RINs issued starting in July, 2010 with the full transition from RFS1 to RFS2 RINs not occurring until 2013.

Equivalence Values

Equivalence values are used to determine the number of gallon-RINs that can be generated for a batch of renewable fuel. The intent is to reflect the specific energy content of each fuel relative to ethanol, which is defined to have an EV of 1.0. The use of equivalence values in RFS2 will continue effectively unchanged from RFS1 with the minor exception that non-ester renewable diesel will be required to have a minimum lower energy value of at least 123,500 Btu/gal in order to qualify for an EV of 1.7. Equivalence values are assigned for certain renewable fuels as follows.

Table 1. Equivalence Value

Renewable Fuel	Equivalence Value	RR Code
Ethanol	1.0	10
Biodiesel (mono-alky ester)	1.5	15
Butanol	1.3	13
Non-ester Renewable Diesel	1.7	17

For example, if company produces a 1,000 gallon batch of biodiesel, 1,000 biomass diesel RINs or 1,500 Renewable RINs could be generated.

1.2.2 D Codes

Under RFS1 there were only two types of D codes (1 and 2) while now there are five; codes 3, 4, 5, 6, & 7, representing the four separate categories of renewable fuel: cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel (D code 7 is a subset of D code 6). D code 1 from RFS1 has been replaced with D code 3, and D2 has been replaced with D6, as specified in Table 1 § 80.1426 of RFS2 (not shown). Below is a table from the RFS2 Regulations showing the D Code definitions.

Table 2. Final D Code Definitions

D value	Meaning under RFS1	Meaning under RFS2
1	Cellulosic biomass ethanol	Not applicable.
2	Renewable fuel not cellulosic biomass ethanol	Not applicable.
3	Not applicable	Cellulosic biofuel.
4	Not applicable	Biomass-based diesel.
5	Not applicable	Advanced biofuel.
6	Not applicable	Renewable fuel.
7	Not applicable	Cellulosic diesel.

The following tables summarize the volume requirements for each main category of renewable fuel by year.

Table 3. Renewable Fuel Volume Requirements for RFS2 (billion gallons)

	Renewable Fuels						
		Advanced Biofuels, 50%					
Year	Conventional Biodiesel & Corn-based Ethanol (arrow indicates change RFS1 to RFS2)	Cellulosic Biofuel	Biomass-Based Diesel	Advanced Biofuel to Balance	Total Advanced Biofuel	Total Conventional & Advanced Renewable Fuel	RFS %
ΔGHG	-20%>12/19/07	-60%	-50%	-50%			
2006	4.00					4.00	
2007	4.70					4.70	
2008	5.40 → 9.00					9.00	4.63 → 7.76
2009	6.10 → 10.50		0.50	0.10	0.60	11.10	10.21
2010	6.80 → 12.00	0.10	0.65	0.20	0.95	12.95	
2010a	6.80 → 12.00	0.0065	1.15		1.1565	12.95	8.25
2011	7.40 → 12.60	0.25	0.80	0.30	1.35	13.95	
2012	7.50 → 13.20	0.50	1.00	0.50	2.00	15.20	
2013	13.80	1.00	≥1.00	0.75	2.75	16.55	
2014	14.40	1.75	≥1.00	1.00	3.75	18.15	
2015	15.00	3.00	≥1.00	1.50	5.50	20.50	
2016	15.00	4.25	≥1.00	2.00	7.25	22.25	
2017	15.00	5.50	≥1.00	2.50	9.00	24.00	
2018	15.00	7.00	≥1.00	3.00	11.00	26.00	
2019	15.00	8.50	≥1.00	3.50	13.00	28.00	
2020	15.00	10.50	≥1.00	3.50	15.00	30.00	
2021	15.00	13.50	≥1.00	3.50	18.00	33.00	
2022	15.00	16.00	≥1.00	4.00	21.00	36.00	

In practice, the categories have evolved.

Table 4. January - September 2011 Actual Renewable Fuels Volume (Gal) and RINs[21]

Fuel Category		Non-cellulosic Ethanol (EV 1.0)	Biogas	Heating Oil (EV 1.1)	Heating Oil (EV 1.2)	Biodiesel (EV 1.5)	Non-ester Renewable Diesel (EV 1.5)	Heating Oil (EV 1.6)	Non-ester Renewable Diesel (EV 1.6)	Non-ester Renewable Diesel (EV 1.7)	Total
Cellulosic Biofuel (D3)	RINs	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	Volume	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Biomass-Based Dsl (D4)	RINs	NA	NA	NA	NA	1,028,859,376	165,266	NA	14,613,828	35,823,254	1,079,461,724
	Volume	NA	NA	NA	NA	685,897,513	110,177	NA	9,133,613	21,072,499	716,213,802
Advanced Biofuel (D5)	RINs	90,628,355	605,946	0	0	0	0	5,605,635	15,544,253	5,603,279	117,987,468
	Volume	90,628,355	605,946	0	0	0	0	3,503,529	9,715,186	3,296,043	107,749,059
Renew- able Fuel (D6)	RINs	10,169,926,767	0	0	0	2,668,951	0	0	0	0	10,172,595,718
	Volume	10,169,926,767	0	0	0	1,779,300	0	0	0	0	10,171,706,067
Cellulosic Diesel (D7)	RINs	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	Volume	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Table 10 illustrates that volumes of fuel are being categorized by Equivalence Value by the EPA. These categories are somewhat different than the categories defined in the regulation, creating some confusion on how EPA will keep score and which products fit into the categories.

1.2.3 *Renewable Volume Obligation and RINs Prices*

Refiners and importers are Obligated Parties under the RFS and have a Renewable Volume Obligation (RVO) that is determined annually by the EPA. Obligated Parties have to blend or buy RINs a percentage of their obligated volume to demonstrate they are in compliance. For 2011 the RVO is:

Product	% of Obligation
Cellulosic Biofuel	0.003 %
Biomass-based Diesel	0.690 %
Advanced Biofuel	0.780 %
Renewable Fuel	8.010 %

Obligated parties obtain RINs when they blend renewable fuels with petroleum fuels. If they do not blend enough, then they have to enter the RINs market to buy RINs from firms that blend but are not obligated parties. RINs are actively traded over-the-counter. RINs value averages for 2011, through November 22, data are summarized in Table 5.[22]:

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[21] http://www.epa.gov/otaq/fuels/rfsdata/2011emts.htm

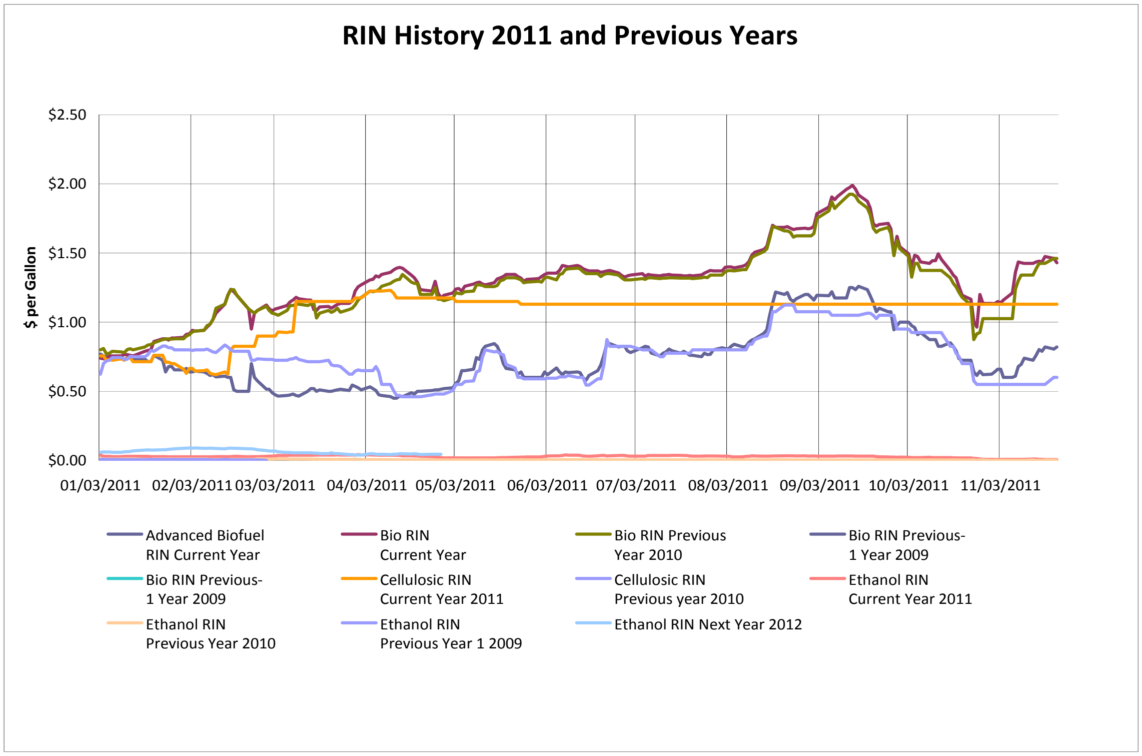
[22] Oil Price Information Service Data

Table 5. Average 2011 RINs Prices

Product Name	Period	Vintage	Average YTD ($/gal)
Advanced Biofuel RIN	Current Year	2011	0.742
Bio RIN	Current Year	2011	1.305
Bio RIN	Previous Year	2010	1.267
Bio RIN	Previous-1 Year	2009	0.008
Cellulosic RIN	Current Year	2011	1.062
Cellulosic RIN	Previous Year	2010	0.752
Ethanol RIN	Current Year	2011	0.028
Ethanol RIN	Next Year	2012	0.063
Ethanol RIN	Previous Year	2010	0.005
Ethanol RIN	Previous-1 Year	2009	0.006

The value of “Bio RIN”, representing Biomass Based Diesel has been very volatile, reflecting the uncertainty of the ramp up of biodiesel production relative to the RVO during the year.

Figure 1. Daily RINs Prices, January – November 2011 ($/gallon)



APPENDIX 5

1 Military Jet and Diesel Differences to Commercial Jet and Diesel

Most military jet fuels are almost identical to their commercial counterparts and differ only by the amount of additive and by a few military-unique additives that are necessary in military weapon systems, engines, and missions. However, there are some low-volume military fuels for very specific applications and they differ greatly from commercial jet fuels. Both commercial and military jet fuels can be divided into two broad categories: kerojet fuels and naphtha-jet fuels. The primary difference between the two categories is their distillation range.

A kerojet molecule has mostly 10-14 carbon atoms; whereas, a naphtha-jet molecule has mostly 5-14 carbon atoms due to its wider distillation range, which is why it is sometimes referred to as a "wide-cut" jet fuel. The distillation range is determined by performance requirements such as freezing point, flash point and smoke point. Flash point is the lowest temperature at which a liquid can sustain a flame in the presence of an ignition source. While a low flash point improves ignition performance, it also makes a fuel more flammable during shipment and handling. These specifications have often been relaxed to balance performance requirements with cost and availability.

Kerojet includes the most commonly used commercial fuels, Jet A and Jet A-1, and the military fuels, JP-5 and JP-8. All of their distillations are similar, with the 10% distillation point at 400°F and the final boiling point at 570°F. Jet A is used in the United States, while Jet A-1 is used in the rest of the world. Both Jet A and Jet A-1 have a flash point of 100°F, but Jet A has a freezing point of −40°F, while Jet A-1 has a freezing point of −53°F. Jet A-1 has a mandated anti-static additive and a lower level of acidity. Their specifications allow certain additives to be added such as antistatic agents, corrosion and icing inhibitors, antioxidants, biocides and metal deactivators.

Jet A-1 is similar to JP-8 with a flash point of 100°F; however, JP-8 has the Jet A-1 freezing point of -53°F. It was developed by the U.S. Air Force, the military's biggest user of jet fuel, as a replacement for JP-4 because the JP-4 flash point is only 0°F. JP-8 is formulated with icing inhibitor, corrosion inhibitors, lubricants, and antistatic additives. The U.S. Navy uses a similar formula, JP-5, with a higher flash point of 140°F and a higher cost, thus limiting its use to reducing the risk of fire on aircraft carriers and other situations where the danger of fire is greatest. The JP-5 flash point is substantially higher than the Jet A flash point because it is stored in large quantities on aircraft carriers and support vessels. Its freezing point is −50°F and does not contain antistatic agents.

Naphtha-jet is primarily for low temperature applications and includes commercial Jet B and military JP-4, which are similar, but JP-4 has a lighter distillation. Also, JP-4 contains anti-icing, antioxidant, corrosion inhibitor and antistatic additives. JP-4 has a low flash point of 0°F, freezes at −76°F and is a nonconductive liquid that tends to build up static electricity when being moved through pipes and tanks.

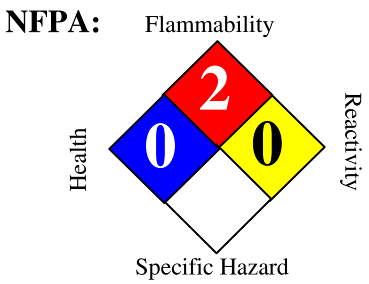
Jet fuel is very similar to diesel fuel, and may be burned in diesel engines. Jet fuel is often used in ground support vehicles at airports, instead of diesel, and by the military's tactical vehicles. However, jet fuel is a poor lubricant compared to diesel, thereby increasing engine wear unless an additive is used to improve lubrication.

Navy diesel is called “F76”, often referred to as “Naval Distillate”, and is similar to commercial diesel fuel. The major difference between F76 and ULSD is the sulfur level. The quality specification for F76 allows up 5,000 PPM of sulfur versus only 15 PPM for ULSD. F76 has a trace metal maximum and ULSD does not. F76 also has a slightly heavier distillation, resulting in a higher 90% point (675°F versus 640°F), flash point (140°F versus 126°F), viscosity (4.3cSt versus 4.1cSt) and cetane index (43 versus 41).

APPENDIX 6: Material Safety Data Sheets

Material Safety Data Sheet
Diesel Low Sulfur (LSD) and Ultra Low Sulfur Diesel (ULSD)

NFPA:



HMIS III:

HEALTH	1
FLAMMABILITY	2
PHYSICAL	0

0 = Insignificant, 1 = Slight, 2 = Moderate, 3 = High, 4 = Extreme

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product name : Diesel Low Sulfur (LSD) and Ultra Low Sulfur Diesel (ULSD)

Synonyms : CARB Diesel, 888100004478

MSDS Number : 888100004478 **Version** : 2.17

Product Use Description : Fuel

Company : For: Tesoro Refining & Marketing Co.
19100 Ridgewood Parkway, San Antonio, TX 78259

Tesoro Call Center : (877) 783-7676 **Chemtrec (Emergency Contact)** : (800) 424-9300

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Regulatory status : This material is considered hazardous by the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200).

Signal Word : WARNING

Hazard Summary : Toxic. Combustible Liquid

Potential Health Effects

Eyes : Eye irritation may result from contact with liquid, mists, and/or vapors.

Inhalation : Vapors or mists from this material can irritate the nose, throat, and lungs, and can cause signs and symptoms of central nervous system depression, depending on the concentration and duration of exposure.

Skin : Skin irritation leading to dermatitis may occur upon prolonged or repeated contact. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are repeatedly exposed. Long-term, repeated skin contact may cause skin cancer

Ingestion : Harmful or fatal if swallowed. Do NOT induce vomiting. This material can irritate the mouth, throat, stomach, and cause nausea, vomiting, diarrhea and restlessness Aspiration hazard if liquid is inhaled into lungs, particularly from vomiting after ingestion. Aspiration may result in chemical pneumonia, severe

	lung damage, respiratory failure and even death.
Target Organs	: Central nervous system, Eyes, Skin, Kidney, Liver

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No.	Weight %
Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6	100%
Nonane	111-84-2	0 - 5%
Naphthalene	91-20-3	0 - 1%
1,2,4-Trimethylbenzene	95-63-6	0 - 2%
Xylene	1330-20-7	0 - 2%
Sulfur	7704-34-9	15 ppm maximum

SECTION 4. FIRST AID MEASURES

Inhalation	: Move to fresh air. Give oxygen. If breathing is irregular or stopped, administer artificial respiration. Seek medical attention immediately.
Skin contact	: Take off all contaminated clothing immediately. Wash off immediately with soap and plenty of water. Wash contaminated clothing before re-use. If skin irritation persists, seek medical attention immediately.
Eye contact	: Remove contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes. If symptoms persist, seek medical attention.
Ingestion	: Do not induce vomiting without medical advice. If a person vomits when lying on his back, place him in the recovery position. Seek medical attention immediately.
Notes to physician	: Symptoms: Dizziness, Discomfort, Headache, Nausea, Disorder, Vomiting, Lung edema, Aspiration may cause pulmonary edema and pneumonitis, Liver disorders, Kidney disorders.

SECTION 5. FIRE-FIGHTING MEASURES

Form	: Liquid
Flash point	: 38℃ Minimum for #1 Diesel, 52℃ Minimum for #2 Diesel
Auto Ignition temperature	: 257 ℃ (495 ℉)
Lower explosive limit	: 0.6 %(V)
Upper explosive limit	: 4.7 %(V)
Suitable extinguishing media	: Carbon dioxide (CO2), Water spray, Dry chemical, Foam, Keep containers and surroundings cool with water spray.
Specific hazards during fire	: Fire Hazard Do not use a solid water stream as it may scatter and spread fire. Cool

fighting		closed containers exposed to fire with water spray.
Special protective equipment for fire-fighters	:	Wear self-contained breathing apparatus and protective suit. Use personal protective equipment.
Further information	:	Exposure to decomposition products may be a hazard to health. Isolate area around container involved in fire. Cool tanks, shells, and containers exposed to fire and excessive heat with water. For massive fires the use of unmanned hose holders or monitor nozzles may be advantageous to further minimize personnel exposure. Major fires may require withdrawal, allowing the tank to burn. Large storage tank fires typically require specially trained personnel and equipment to extinguish the fire, often including the need for properly applied fire fighting foam.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions	:	Evacuate nonessential personnel and remove or secure all ignition sources. Consider wind direction; stay upwind and uphill, if possible. Evaluate the direction of product travel, diking, sewers, etc. to contain spill areas. Spills may infiltrate subsurface soil and groundwater; professional assistance may be necessary to determine the extent of subsurface impact. Ensure adequate ventilation. Use personal protective equipment.
Environmental precautions	:	Carefully contain and stop the source of the spill, if safe to do so. Protect bodies of water by diking, absorbents, or absorbent boom, if possible. Do not flush down sewer or drainage systems, unless system is designed and permitted to handle such material. The use of fire fighting foam may be useful in certain situations to reduce vapors. The proper use of water spray may effectively disperse product vapors or the liquid itself, preventing contact with ignition sources or areas/equipment that require protection. Discharge into the environment must be avoided. If the product contaminates rivers and lakes or drains inform respective authorities.
Methods for cleaning up	:	Take up with sand or oil absorbing materials. Carefully shovel, scoop or sweep up into a waste container for reclamation or disposal - caution, flammable vapors may accumulate in closed containers. Response and clean-up crews must be properly trained and must utilize proper protective equipment (see Section 8).

SECTION 7. HANDLING AND STORAGE

Handling	:	Keep away from fire, sparks and heated surfaces. No smoking near areas where material is stored or handled. The product should only be stored and handled in areas with intrinsically safe electrical classification.
Advice on protection against fire and explosion	:	Hydrocarbon liquids including this product can act as a non-conductive flammable liquid (or static accumulators), and may form ignitable vapor-air mixtures in storage tanks or other containers. Precautions to prevent static-initated fire or explosion during transfer, storage or handling, include but are not limited to these examples: (1) Ground and bond containers during product transfers. Grounding and bonding may not be adequate protection to prevent ignition or explosion of hydrocarbon liquids and vapors that are static accumulators. (2) Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when higher flash point material (such as fuel oil or diesel) is loaded into tanks previously containing low flash point products (such gasoline or naphtha). (3) Storage tank level floats must be effectively bonded.

For more information on precautions to prevent static-initated fire or explosion, see NFPA 77, Recommended Practice on Static Electricity (2007), and API Recommended Practice 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents (2008).

Dust explosion class : Not applicable

Requirements for storage areas and containers : Keep away from flame, sparks, excessive temperatures and open flame. Use approved containers. Keep containers closed and clearly labeled. Empty or partially full product containers or vessels may contain explosive vapors. Do not pressurize, cut, heat, weld or expose containers to sources of ignition. Store in a well-ventilated area. The storage area should comply with NFPA 30 "Flammable and Combustible Liquid Code". The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 "Cleaning Mobile Tanks In Flammable and Combustible Liquid Service" and API RP 2015 "Cleaning Petroleum Storage Tanks".

Other data : Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure.

Advice on common storage Keep away from food, drink and animal feed. Incompatible with oxidizing agents. Incompatible with acids.

SECTION 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Guidelines

List	Components	CAS-No.	Type:	Value
OSHA Z1	Xylene	1330-20-7	PEL	100 ppm 435 mg/m3
	Naphthalene	91-20-3	PEL	10 ppm 50 mg/m3
ACGIH	Diesel Fuel	68476-30-2	TWA	100 mg/m3
	Xylene	1330-20-7	TWA	100 ppm
		1330-20-7	STEL	150 ppm
	Naphthalene	91-20-3	TWA	10 ppm
		91-20-3	STEL	15 ppm
	Nonane	111-84-2	TWA	200 ppm

Engineering measures : Use adequate ventilation to keep gas and vapor concentrations of this product below occupational exposure and flammability limits, particularly in confined spaces. Use only intrinsically safe electrical equipment approved for use in classified areas.

Eye protection : Safety glasses or goggles are recommended where there is a possibility of splashing or spraying.

Hand protection : Gloves constructed of nitrile, neoprene, or PVC are recommended. Consult manufacturer specifications for further information.

Skin and body protection : If needed to prevent skin contact, chemical protective clothing such as of DuPont

		TyChem®, Saranex or equivalent recommended based on degree of exposure. The resistance of specific material may vary from product to product as well as with degree of exposure.
Respiratory protection	:	A NIOSH/ MSHA-approved air-purifying respirator with organic vapor cartridges or canister may be permissible under certain circumstances where airborne concentrations are or may be expected to exceed exposure limits or for odor or irritation. Protection provided by air-purifying respirators is limited. Refer to OSHA 29 CFR 1910.134, ANSI Z88.2-1992, NIOSH Respirator Decision Logic, and the manufacturer for additional guidance on respiratory protection selection. Use a NIOSH/ MSHA-approved positive-pressure supplied-air respirator if there is a potential for uncontrolled release, exposure levels are not known, in oxygen-deficient atmospheres, or any other circumstance where an air-purifying respirator may not provide adequate protection.
Work / Hygiene practices	:	Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure. Use good personal hygiene practices. Avoid repeated and/or prolonged skin exposure. Wash hands before eating, drinking, smoking, or using toilet facilities. Do not use as a cleaning solvent on the skin. Do not use solvents or harsh abrasive skin cleaners for washing this product from exposed skin areas. Waterless hand cleaners are effective. Promptly remove contaminated clothing and launder before reuse. Use care when laundering to prevent the formation of flammable vapors which could ignite via washer or dryer. Consider the need to discard contaminated leather shoes and gloves.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Form	:	Liquid
Appearance	:	Clear, straw colored
Odor	:	Characteristic petroleum (kerosene) odor
Flash point - typical	:	38°C Minimum for #1 Diesel, 52°C Minimum for #2 Diesel
Auto Ignition temperature	:	257 °C (495 °F)
Thermal decomposition	:	No decomposition if stored and applied as directed.
Lower explosive limit	:	0.6 %(V)
Upper explosive limit	:	4.7 %(V)
pH	:	Not applicable
Freezing point	:	No data available
Boiling point	:	148 - 372 °C(298 - 702 °F)
Vapor Pressure	:	< 2 mm Hg at 20 °C
Density	:	**0.86** g/cm3
Water solubility	:	Negligible
Viscosity, dynamic	:	1.7 - 40 mPa.s at 37.8 °C (100.0 °F)

Percent Volatiles : 100 %

Conductivity (conductivity can be reduced by environmental factors such as a decrease in temperature

Diesel Fuel Oils at terminal load rack:	At least 25 pS/m
Ultra Low Sulfur Diesel (ULSD) without conductivity additive:	0 pS/m to 5 pS/m
ULSD at terminal load rack with conductivity additive:	At least 50 pS/m but conductivity may decrease from environmental factors such as temperature drop.
JP-8 at terminal load rack:	150 pS/m to 600 pS/m

SECTION 10. STABILITY AND REACTIVITY

Conditions to avoid : Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources. Keep away from strong oxidizers. Viton ® ; Fluorel ®

Materials to avoid : Strong oxidizing agents. Peroxides

Hazardous decomposition products : Carbon monoxide, carbon dioxide and noncombusted hydrocarbons (smoke). Diesel exhaust particulates may be a lung hazard - see Section 11.

Thermal decomposition : No decomposition if stored and applied as directed.

Hazardous reactions : Keep away from oxidizing agents, and acidic or alkaline products.

SECTION 11. TOXICOLOGICAL INFORMATION

Carcinogenicity

NTP : Naphthalene (CAS-No.: 91-20-3)

IARC : Naphthalene (CAS-No.: 91-20-3)

OSHA : No component of this product which is present at levels greater than or equal to 0.1 % is identified as a carcinogen or potential carcinogen by OSHA.

CA Prop 65 : WARNING! This product contains a chemical known to the State of California to cause cancer.
naphthalene (CAS-No.: 91-20-3)

Skin irritation : Irritating to skin.

Eye irritation : Irritating to eyes.

Further information : Studies have shown that similar products produce skin cancer or skin tumors in laboratory animals following repeated applications without washing or removal. The significance of this finding to human exposure has not been determined. Other studies with active skin carcinogens have shown that washing the animal's skin with soap and water between applications reduced tumor formation.
Positive mutagenicity results have been reported.
Repeated over-exposure may cause liver and kidney injury
IARC classifies whole diesel fuel exhaust particulates as probably carcinogenic to humans (Group 2A). NIOSH regards whole diesel fuel exhaust particulates as a potential cause of occupational lung cancer based on animal studies and limited evidence in humans.

Component:

Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6	Acute oral toxicity: LD50 rat Dose: 5,001 mg/kg Acute dermal toxicity: LD50 rabbit

		Dose: 2,001 mg/kg Acute inhalation toxicity: LC50 rat Dose: 7.64 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Severe skin irritation Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Nonane	111-84-2	Acute oral toxicity: LD50 mouse Dose: 218 mg/kg Acute inhalation toxicity: LC50 rat Exposure time: 4 h
Naphthalene	91-20-3	Acute oral toxicity: LD50 rat Dose: 2,001 mg/kg Acute dermal toxicity: LD50 rat Dose: 2,501 mg/kg Acute inhalation toxicity: LC50 rat Dose: 101 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation Carcinogenicity: N11.00422130
1,2,4-Trimethylbenzene	95-63-6	Acute inhalation toxicity: LC50 rat Dose: 18 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Skin irritation Eye irritation: Classification: Irritating to eyes. Result: Eye irritation
Xylene	1330-20-7	Acute oral toxicity: LD50 rat Dose: 2,840 mg/kg Acute dermal toxicity: LD50 rabbit Dose: ca. 4,500 mg/kg Acute inhalation toxicity: LC50 rat Dose: 6,350 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Repeated or prolonged exposure may cause skin irritation and dermatitis, due to degreasing properties of the product. Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation

SECTION 12. ECOLOGICAL INFORMATION

Additional ecological : Keep out of sewers, drainage areas, and waterways. Report spills and releases, as

information applicable, under Federal and State regulations.

Component:

Naphthalene	91-20-3	Toxicity to algae: EC50 Species: Dose: 33 mg/l Exposure time: 24 h
1,2,4-Trimethylbenzene	95-63-6	Toxicity to fish: LC50 Species: Pimephales promelas (fathead minnow) Dose: 7.72 mg/l Exposure time: 96 h Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia Dose: 3.6 mg/l Exposure time: 48 h

SECTION 13. DISPOSAL CONSIDERATIONS

Disposal : In accordance with local and national regulations.

SECTION 14. TRANSPORT INFORMATION

CFR

Proper shipping name : DIESEL FUEL
UN-No. : UN1202 (NA 1993)
Class : 3
Packing group : III

TDG

Proper shipping name : DIESEL FUEL
UN-No. : UN1202 (NA 1993)
Class : 3
Packing group : III

IATA Cargo Transport

UN UN-No. : UN1202 (NA 1993)
Description of the goods : DIESEL FUEL
Class : 3
Packaging group : III
ICAO-Labels : 3
Packing instruction (cargo aircraft) : 366
Packing instruction (cargo aircraft) : Y344

IATA Passenger Transport

UN UN-No. : UN1202 (NA 1993)
Description of the goods : DIESEL FUEL
Class : 3
Packaging group : III

ICAO-Labels : 3
Packing instruction (passenger aircraft) : 355
Packing instruction (passenger aircraft) : Y344

IMDG-Code

UN-No. : UN 1202 (NA 1993)
Description of the goods : DIESEL FUEL
Class : 3
Packaging group : III
IMDG-Labels : 3
EmS Number : F-E S-E
Marine pollutant : No

SECTION 15. REGULATORY INFORMATION

OSHA Hazards : Combustible Liquid
Moderate skin irritant
Moderate eye irritant
Toxic by ingestion
POSSIBLE CANCER HAZARD

CERCLA SECTION 103 and SARA SECTION 304 (RELEASE TO THE ENVIROMENT)
The CERCLA definition of hazardous substances contains a "petroleum exclusion" clause which exempts crude oil. Fractions of crude oil, and products (both finished and intermediate) from the crude oil refining process and any indigenous components of such from the CERCLA Section 103 reporting requirements. However, other federal reporting requirements, including SARA Section 304, as well as the Clean Water Act may still apply.

TSCA Status : On TSCA Inventory

DSL Status : All components of this product are on the Canadian DSL list.

SARA 311/312 Hazards : Fire Hazard
Acute Health Hazard
Chronic Health Hazard

SARA III US. EPA Emergency Planning and Community Right-To-Know Act (EPCRA) SARA Title III Section 313 Toxic Chemicals (40 CFR 372.65) - Supplier Notification Required

Components	CAS-No.
Xylene	1330-20-7
1,2,4-Trimethylbenzene	95-63-6
Naphthalene	91-20-3

PENN RTK US. Pennsylvania Worker and Community Right-to-Know Law (34 Pa. Code Chap. 301-323)

Components	CAS-No.
Nonane	111-84-2

Naphthalene	91-20-3
1,2,4-Trimethylbenzene	95-63-6
xylene	1330-20-7
Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6

MASS RTK US. Massachusetts Commonwealth's Right-to-Know Law (Appendix A to 105 Code of Massachusetts Regulations Section 670.000)

Components	CAS-No.
Xylene	1330-20-7
1,2,4-Trimethylbenzene	95-63-6
Naphthalene	91-20-3
Nonane	111-84-2

NJ RTK US. New Jersey Worker and Community Right-to-Know Act (New Jersey Statute Annotated Section 34:5A-5)

Components	CAS-No.
Nonane	111-84-2
Naphthalene	91-20-3
1,2,4-Trimethylbenzene	95-63-6
Xylene	1330-20-7
Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6

California Prop. 65 : WARNING! This product contains a chemical known to the State of California to cause cancer.

Naphthalene 91-20-3

SECTION 16. OTHER INFORMATION

Further information

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

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01/27/2011

65, 66, 295

Material Safety Data Sheet
Jet Fuel

NFPA:

TESORO

HMIS III:

HEALTH	1
FLAMMABILITY	2
PHYSICAL	0

0 = Insignificant, 1 = Slight, 2 = Moderate,
3 = High, 4 = Extreme

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product name : Jet Fuel

Synonyms : Jet Fuel - A, B, A-I, A-50, High Sulfur, Military, Jet A & B Aviation Turbine Fuel, Jet A-I, Jet A; Avjet For Blending; Jet Q Turbine Fuel, Aviation Fuel; Turbine Fuel; JP-4; JP-5; JP-8, Av-Jet, 888100004452

MSDS Number : 888100004452 **Version** : 2.12

Product Use Description : Fuel

Company : For: Tesoro Refining & Marketing Co.
19100 Ridgewood Parkway, San Antonio, TX 78259

Tesoro Call Center : (877) 783-7676 **Chemtrec (Emergency Contact)** : (800) 424-9300

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Regulatory status : This material is considered hazardous by the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200).

Signal Word : WARNING

Hazard Summary : Harmful or fatal if swallowed. Harmful by inhalation. Irritating to eyes, respiratory system and skin. Affects central nervous system. Flammable.

Potential Health Effects

Eyes : Severe eye irritant. Contact may cause stinging, watering, redness, swelling, and eye damage.

Skin : Prolonged or repeated skin contact with liquid may cause defatting resulting in drying, redness and possible blistering. Practically non-toxic if absorbed following acute (single) exposure. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are repeatedly exposed.

Ingestion : Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest and death may occur.

Inhalation : Inhalation of fumes or mist may result in respiratory tract irritation and central nervous system (brain) effects may include headache, dizziness, loss of balance and coordination, unconsciousness, coma, respiratory failure, and death. WARNING: the burning of any hydrocarbon as a fuel in an area without adequate ventilation may result in hazardous levels of combustion products, including carbon monoxide, and inadequate oxygen levels, which may cause unconsciousness, suffocation, and death.

Chronic Exposure : Similar products produced skin cancer and systemic toxicity in laboratory animals following repeated applications. The significance of these results to human exposures has not been determined - see Section 11 Toxicological Information.

Target Organs : Eyes, Skin, Respiratory system, Irritation from skin exposure may aggravate existing open wounds, skin disorders, and dermatitis (rash)

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No.	Weight %
Kerosene (petroleum)	8008-20-6	100%
Naphthalene	91-20-3	0 to 3%
Ethyl Benzene	100-41-4	0 to 1%
Trimethy Benzene	95-63-6	0 to 1%
Ethyl Benzene	100-41-4	0 to 1%
Diethylene Glycol Monomethyl Ether	111-77-3	0 to 0.15%
Alkyl Dithiothiadiazole	N/A	0 to 15%

SECTION 4. FIRST AID MEASURES

Inhalation : If inhaled, remove to fresh air. If not breathing, give artificial respiration. If necessary, provide additional oxygen once breathing is restored if trained to do so. Seek medical attention immediately.

Skin contact : Take off all contaminated clothing immediately. Wash off immediately with soap and plenty of water. Wash contaminated clothing before re-use. If skin irritation persists, seek medical attention.

Eye contact : In case of eye contact, remove contact lens and rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Seek medical attention immediately.

Ingestion : Do NOT induce vomiting. Do not give liquids. Seek medical attention immediately. If vomiting does occur naturally, keep head below the hips to reduce the risks of aspiration. Monitor for breathing difficulties. Small amounts of material which enter the mouth should be rinsed out until the taste is dissipated.

Notes to physician : Symptoms: Aspiration may cause pulmonary edema and pneumonitis. Treatment: Do not induce vomiting, use gastric lavage only. Remove from further exposure and treat symptomatically.

SECTION 5. FIRE-FIGHTING MEASURES

Form	:	Liquid
Flash point	:	38 °C (100 °F) minimum
Auto Ignition temperature	:	210 °C (410 °F)
Lower explosive limit	:	0.7 %(V)
Upper explosive limit	:	5.0 %(V)
Suitable extinguishing media	:	Carbon dioxide (CO2), Water spray, Dry chemical, Foam, Keep containers and surroundings cool with water spray., Do not use a solid water stream as it may scatter and spread fire., Water may be ineffective for fighting the fire, but may be used to cool fire-exposed containers.
Specific hazards during fire fighting	:	Fire Hazard. Do not use a solid water stream as it may scatter and spread fire. Cool closed containers exposed to fire with water spray. Sealed containers may rupture when heated. Above the flash point, explosive vapor-air mixtures may be formed. Vapors can flow along surfaces to distant ignition source and flash back.
Special protective equipment for fire-fighters	:	Firefighting activities that may result in potential exposure to high heat, smoke or toxic by-products of combustion should require NIOSH/MSHA- approved pressure-demand self-contained breathing apparatus with full facepiece and full protective clothing.
Further information	:	Exposure to decomposition products may be a hazard to health. Standard procedure for chemical fires.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions	:	ACTIVATE FACILITY'S SPILL CONTINGENCY OR EMERGENCY RESPONSE PLAN if applicable. Evacuate nonessential personnel and remove or secure all ignition sources. Consider wind direction; stay upwind and uphill, if possible. Evaluate the direction of product travel, diking, sewers, etc. to contain spill areas. Spills may infiltrate subsurface soil and groundwater; professional assistance may be necessary to determine the extent of subsurface impact.
Environmental precautions	:	Carefully contain and stop the source of the spill, if safe to do so. Protect bodies of water by diking, absorbents, or absorbent boom, if possible. Do not flush down sewer or drainage systems, unless system is designed and permitted to handle such material. The use of fire fighting foam may be useful in certain situations to reduce vapors. The proper use of water spray may effectively disperse product vapors or the liquid itself, preventing contact with ignition sources or areas/equipment that require protection.
Methods for cleaning up	:	Take up with sand or oil absorbing materials. Carefully shovel, scoop or sweep up into a waste container for reclamation or disposal - caution, flammable vapors may accumulate in closed containers. Response and clean-up crews must be properly trained and must utilize proper protective equipment (see Section 8).

SECTION 7. HANDLING AND STORAGE

Handling	:	Keep away from fire, sparks and heated surfaces. No smoking near areas where material is stored or handled. The product should only be stored and handled in areas with intrinsically safe electrical classification.

Advice on protection against fire and explosion : Hydrocarbon liquids including this product can act as a non-conductive flammable liquid (or static accumulators), and may form ignitable vapor-air mixtures in storage tanks or other containers. Precautions to prevent static-initated fire or explosion during transfer, storage or handling, include but are not limited to these examples:

(1) Ground and bond containers during product transfers. Grounding and bonding may not be adequate protection to prevent ignition or explosion of hydrocarbon liquids and vapors that are static accumulators.
(2) Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when higher flash point material (such as fuel oil or diesel) is loaded into tanks previously containing low flash point products (such gasoline or naphtha).
(3) Storage tank level floats must be effectively bonded.

For more information on precautions to prevent static-initated fire or explosion, see NFPA 77, Recommended Practice on Static Electricity (2007), and API Recommended Practice 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents (2008).

Dust explosion class : Not applicable

Requirements for storage areas and containers : Keep away from flame, sparks, excessive temperatures and open flame. Use approved containers. Keep containers closed and clearly labeled. Empty or partially full product containers or vessels may contain explosive vapors. Do not pressurize, cut, heat, weld or expose containers to sources of ignition. Store in a well-ventilated area. The storage area should comply with NFPA 30 "Flammable and Combustible Liquid Code". The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 "Cleaning Mobile Tanks In Flammable and Combustible Liquid Service" and API RP 2015 "Cleaning Petroleum Storage Tanks".

Advice on common storage : Keep away from food, drink and animal feed. Incompatible with oxidizing agents. Incompatible with acids.

Other data : Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure.

SECTION 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Guidelines

List	Components	CAS-No.	Type:	Value
OSHA Z1	Naphthalene	91-20-3	PEL	10 ppm 50 mg/m3
	Ethyl Benzene	100-41-4	PEL	100 ppm 435 mg/m3
ACGIH	Naphthalene	91-20-3	TWA	10 ppm
		91-20-3	STEL	15 ppm
	Kerosene (petroleum)	8008-20-6	TWA	200 mg/m3
	Ethyl Benzene	100-41-4	TWA	100 ppm 434 mg/m3
			STEL	125 ppm 543 mg/m3

Protective measures : Keep out of reach of children.

Engineering measures : Use only intrinsically safe electrical equipment approved for use in classified areas. Emergency eye wash capability should be available in the vicinity of any potential splash exposure.

Eye protection : Goggles and face shield as needed to prevent eye and face contact.

Hand protection : Gloves constructed of nitrile, neoprene, or PVC are recommended.

Skin and body protection : Chemical protective clothing such as DuPont TyChem ®, Barricade or equivalent, recommended based on degree of exposure. Consult manufacturer specifications for further information.

Respiratory protection : NIOSH/MSHA approved positive-pressure self-contained breathing apparatus (SCBA) or Type C positive-pressure supplied air with escape bottle must be used for gas concentrations above occupational exposure limits, for potential of uncontrolled release, if exposure levels are not known, or in an oxygen-deficient atmosphere.

Work / Hygiene practices : Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure. Use good personal hygiene practices. Avoid repeated and/or prolonged skin exposure. Wash hands before eating, drinking, smoking, or using toilet facilities. Do not use as a cleaning solvent on the skin. Do not use solvents or harsh abrasive skin cleaners for washing this product from exposed skin areas. Waterless hand cleaners are effective. Promptly remove contaminated clothing and launder before reuse. Use care when laundering to prevent the formation of flammable vapors which could ignite via washer or dryer. Consider the need to discard contaminated leather shoes and gloves.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Form : Liquid

Appearance : Light yellow to white

Odor : Characteristic Petroleum distillate

Flash point : 38 °C (100 °F) minimum

Auto Ignition temperature : 210 °C (410 °F)

Thermal decomposition : No decomposition if stored and applied as directed.

Lower explosive limit : 0.7 %(V)

Upper explosive limit : 5.0 %(V)

pH : Not applicable

Specific gravity : 0.8 (H20=1)

Freezing point : -45°C to -62°C (-50°F to -80°F)

Boiling Range : 160 - 300 °C(320 - 572 °F)

Vapor Pressure : 6.9 hPa
at 20 °C (68 °F)

Relative Vapor Density : 4.5

Density : 0.8 g/cm3

Water solubility : Insoluble

Viscosity, kinematic : 1.6 mm2/s
at 40 °C (104 °F)

Percent Volatiles	: 100 %
Conductivity (conductivity can be reduced by environmental factors such as a decrease in temperature)	Diesel Fuel Oils at terminal load rack: At least 25 pS/m Ultra Low Sulfur Diesel (ULSD) without conductivity additive: 0 pS/m to 5 pS/m ULSD at terminal load rack with conductivity additive: At least 50 pS/m but conductivity may decrease from environmental factors such as temperature drop. JP-8 at terminal load rack: 150 pS/m to 600 pS/m

SECTION 10. STABILITY AND REACTIVITY

Conditions to avoid	: Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources. Keep away from strong oxidizers.
Materials to avoid	: Keep away from strong oxidizers such as nitric and sulfuric acids.
Hazardous decomposition products	: Risk of explosion. In case of fire hazardous decomposition products may be produced such as: Smoke. Hydrocarbons. Carbon Monoxide and Carbon Dioxide.
Thermal decomposition	: No decomposition if stored and applied as directed.
Hazardous reactions	: Stable under normal conditions of use; however, incompatible with strong acids and strong oxidizers.

SECTION 11. TOXICOLOGICAL INFORMATION

Carcinogenicity

NTP	: Naphthalene (CAS-No.: 91-20-3)
IARC	: Kerosene is not listed as carcinogenic by NTP, OSHA, and ACGIH. IARC has listed kerosene as a probable human carcinogen. naphthalene (CAS-No.: 91-20-3) Kerosene (petroleum) (CAS-No.: 8008-20-6)
CA Prop 65	: WARNING! This product contains a chemical known to the State of California to cause cancer. Naphthalene (CAS-No.: 91-20-3)
Skin irritation	: Irritating to skin.
Eye irritation	: Irritating to eyes.
Further information	: Kerosene does not have a measurable effect on human reproduction or development. Kerosene is not listed as carcinogenic by NTP, OSHA, and ACGIH. IARC has listed kerosene as a probable human carcinogen. Some petroleum distillates have been found to cause adverse reproductive effects in laboratory animals. Acute and chronic exposure to kerosene may result in CNS effects including irritability, restlessness, ataxia, drowsiness, convulsions, coma and death. The most common health effect associated with chronic kerosene exposure is dermatitis.

Component:

Kerosene (petroleum)	8008-20-6	Acute oral toxicity: LD50 rat Dose: 5 mg/kg Acute dermal toxicity: LD50 rabbit Dose: 2,001 mg/kg

		Acute inhalation toxicity: LC50 rat Dose: 5.28 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Skin irritation
Naphthalene	91-20-3	Acute oral toxicity: LD50 rat Dose: 2,001 mg/kg Acute dermal toxicity: LD50 rat Dose: 2,501 mg/kg Acute inhalation toxicity: LC50 rat Dose: 101 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation Carcinogenicity: N11.00422130

SECTION 12. ECOLOGICAL INFORMATION

Additional ecological information : Release of this product should be prevented from contaminating soil and water and from entering drainage and sewer systems. U.S.A. regulations require reporting spills of this material that could reach any surface waters. The toll free number for the U.S. Coast Guard National Response Center is (800) 424-8802. Naphthalene (91-20-3) one of the ingredients in this mixture is classified as a Marine Pollutant.

Component:

Naphthalene	91-20-3	Toxicity to algae: EC50 Species: Dose: 33 mg/l Exposure time: 24 h

SECTION 13. DISPOSAL CONSIDERATIONS

Disposal : Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved waste facility.
Processing, use or contamination of this product may change the waste management options.
State and local disposal regulations may differ from federal disposal regulations.
Dispose of container and unused contents in accordance with federal, state and local requirements.

SECTION 14. TRANSPORT INFORMATION

CFR

Proper shipping name : Fuel, aviation, turbine engine
UN-No. : 1863
Class : 3
Packing group : III

TDG

Proper shipping name	Fuel, aviation, turbine engine
UN-No.	UN1863
Class	3
Packing group	III

IATA Cargo Transport

UN UN-No.	UN1863
Description of the goods	Fuel, aviation, turbine engine
Class	3
Packaging group	III
ICAO-Labels	3
Packing instruction (cargo aircraft)	366
Packing instruction (cargo aircraft)	Y344

IATA Passenger Transport

UN UN-No.	UN1863
Description of the goods	Fuel, aviation, turbine engine
Class	3
Packaging group	III
ICAO-Labels	3
Packing instruction (passenger aircraft)	355
Packing instruction (passenger aircraft)	Y344

IMDG-Code

UN-No.	UN 1863
Description of the goods	Fuel, aviation, turbine engine
Class	3
Packaging group	III
IMDG-Labels	3
EmS Number	F-E S-E
Marine pollutant	Yes

SECTION 15. REGULATORY INFORMATION

OSHA Hazards	Toxic by inhalation. Highly toxic by ingestion Moderate skin irritant Severe eye irritant Combustible
TSCA Status	On TSCA Inventory
DSL Status	All components of this product are on the Canadian DSL list.
SARA 311/312 Hazards	Acute Health Hazard Chronic Health Hazard Fire Hazard

CERCLA SECTION 103 and SARA SECTION 304 (RELEASE TO THE ENVIROMENT)

The CERCLA definition of hazardous substances contains a "petroleum exclusion" clause which exempts crude oil. Fractions of crude oil, and products (both finished and intermediate) from the crude oil refining process and any indigenous components of such from the CERCLA Section 103 reporting requirements. However, other federal reporting requirements, including SARA Section 304, as well as the Clean Water Act may still apply**.**

California Prop. 65 : WARNING! This product contains a chemical known to the State of California to cause cancer.

Naphthalene	91-20-3

SECTION 16. OTHER INFORMATION

Further information

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

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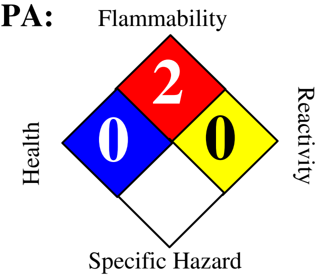
Revision Date : 01/27/2011

40, 41, 42, 43, 44, 45, 60, 113, 137, 138, 139, 140, 141, 142, 263, 285, 1048, 1117, 1137, 1138, 1546

Material Safety Data Sheet
Diesel Fuel - High Sulfur

NFPA:



TESORO

HMIS III:

HEALTH	1
FLAMMABILITY	2
PHYSICAL	0

0 = Insignificant, 1 = Slight, 2 = Moderate,
3 = High, 4 = Extreme

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product name	:	Diesel Fuel - High Sulfur		
Synonyms	:	Heating Oil, Gas Oil Light Straight Run, High Sulfur Diesel Fuel #1, High Sulfur Diesel Fuel #2, Marine Diesel Fuel, F76, 888100004572		
MSDS Number	:	888100004572	**Version**	: 2.8
Product Use Description	:	Fuel		
Company	:	For: Tesoro Refining & Marketing Co. 19100 Ridgewood Parkway, San Antonio, TX 78259		
Tesoro Call Center	:	(877) 783-7676	**Chemtrec (Emergency Contact)**	: (800) 424-9300

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Regulatory status : This material is considered hazardous by the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200).

Signal Word : WARNING

Hazard Summary : Combustible Liquid

Toxic

Potential Health Effects

Inhalation : Vapors or mists from this material can irritate the nose, throat, and lungs, and can cause signs and symptoms of central nervous system depression, depending on the concentration and duration of exposure.

Eyes : Eye irritation may result from contact with liquid, mists, and/or vapors.

Skin : Skin irritation leading to dermatitis may occur upon prolonged or repeated contact. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are repeatedly exposed. Long-term, repeated skin contact may cause skin cancer.

Ingestion : Harmful or fatal if swallowed. Do NOT induce vomiting. This material can irritate the mouth, throat, stomach, and cause nausea, vomiting, diarrhea and restlessness. Aspiration hazard if liquid is inhaled into lungs, particularly from vomiting after ingestion. Aspiration may result in chemical pneumonia, severe lung damage, respiratory failure and even death.

Target Organs : Kidney, Liver, Central nervous system, Eyes, Skin

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No.	Weight %
Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6	100%
Naphthalene	91-20-3	1 - 5%
Xylene	1330-20-7	1 - 5%
Nonane	111-84-2	0.75 - 1%
1,2,4-Trimethylbenzene	95-63-6	0.75 - 1%
Sulfur	7704-34-9	0.5% Maximum

SECTION 4. FIRST AID MEASURES

Inhalation : Move to fresh air. Give oxygen. If breathing is irregular or stopped, administer artificial respiration. Seek medical attention immediately.

Skin contact : Take off all contaminated clothing immediately. Wash off immediately with soap and plenty of water. Wash contaminated clothing before re-use. If skin irritation persists, seek medical attention.

Eye contact : Remove contact lenses. Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. If eye irritation persists, seek medical attention.

Ingestion : Do NOT induce vomiting. Ingestion may result in nausea, vomiting, diarrhea and restlessness. Aspiration may cause pulmonary edema and pneumonitis. Seek medical attention immediately.

Notes to physician : Symptoms: Dizziness, Discomfort, Headache, Nausea, Disorder, Vomiting, Lung edema, Aspiration may cause pulmonary edema and pneumonitis. Liver disorders, Kidney disorders.

SECTION 5. FIRE-FIGHTING MEASURES

Form : Liquid

Flash point : 38 °C (100 °F) Minimum for #1 Diesel ; 52°C Minimum for #2 Diesel

Lower explosive limit : 0.7 %(V)

Upper explosive limit : 5 %(V)

Suitable extinguishing media : Carbon dioxide (CO2), Water spray, Dry chemical, Foam, Keep containers and surroundings cool with water spray.

Specific hazards during fire fighting : Fire Hazard Do not use a solid water stream as it may scatter and spread fire. Cool closed containers exposed to fire with water spray.

Special protective equipment for fire-fighters	: Wear self-contained breathing apparatus and protective suit. Use personal protective equipment.
Further information	: Exposure to decomposition products may be a hazard to health. Isolate area around container involved in fire. Cool tanks, shells, and containers exposed to fire and excessive heat with water. For massive fires the use of unmanned hose holders or monitor nozzles may be advantageous to further minimize personnel exposure. Major fires may require withdrawal, allowing the tank to burn. Large storage tank fires typically require specially trained personnel and equipment to extinguish the fire, often including the need for properly applied fire fighting foam.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions	: Consider wind direction; stay upwind and uphill, if possible. Evacuate nonessential personnel and remove or secure all ignition sources. Evaluate the direction of product travel, diking, sewers, etc. to contain spill areas. Spills may infiltrate subsurface soil and groundwater; professional assistance may be necessary to determine the extent of subsurface impact. Ensure adequate ventilation. Use personal protective equipment.
Environmental precautions	: Carefully contain and stop the source of the spill, if safe to do so. Do not flush down sewer or drainage systems, unless system is designed and permitted to handle such material. The use of fire fighting foam may be useful in certain situations to reduce vapors. The proper use of water spray may effectively disperse product vapors or the liquid itself, preventing contact with ignition sources or areas/equipment that require protection. Discharge into the environment must be avoided. If the product contaminates rivers and lakes or drains inform respective authorities.
Methods for cleaning up	: Take up with sand or oil absorbing materials. Carefully shovel, scoop or sweep up into a waste container for reclamation or disposal - caution, flammable vapors may accumulate in closed containers. Response and clean-up crews must be properly trained and must utilize proper protective equipment (see Section 8).

SECTION 7. HANDLING AND STORAGE

Handling	: Keep away from fire, sparks and heated surfaces. No smoking near areas where material is stored or handled. The product should only be stored and handled in areas with intrinsically safe electrical classification.
Advice on protection against fire and explosion	: Hydrocarbon liquids including this product can act as a non-conductive flammable liquid (or static accumulators), and may form ignitable vapor-air mixtures in storage tanks or other containers. Precautions to prevent static-initated fire or explosion during transfer, storage or handling, include but are not limited to these examples: (1) Ground and bond containers during product transfers. Grounding and bonding may not be adequate protection to prevent ignition or explosion of hydrocarbon liquids and vapors that are static accumulators. (2) Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when higher flash point material (such as fuel oil or diesel) is loaded into tanks previously containing low flash point products (such gasoline or naphtha). (3) Storage tank level floats must be effectively bonded. For more information on precautions to prevent static-initated fire or explosion, see NFPA 77, Recommended Practice on Static Electricity (2007), and API

Recommended Practice 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents (2008).

Dust explosion class : Not applicable

Requirements for storage areas and containers : Keep away from flame, sparks, excessive temperatures and open flame. Use approved containers. Keep containers closed and clearly labeled. Empty or partially full product containers or vessels may contain explosive vapors. Do not pressurize, cut, heat, weld or expose containers to sources of ignition. Store in a well-ventilated area. The storage area should comply with NFPA 30 "Flammable and Combustible Liquid Code". The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 "Cleaning Mobile Tanks In Flammable and Combustible Liquid Service" and API RP 2015 "Cleaning Petroleum Storage Tanks".

Advice on common storage : Keep away from food, drink and animal feed. Incompatible with oxidizing agents. Incompatible with acids.

Other data : No decomposition if stored and applied as directed.

SECTION 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Guidelines

List	Components	CAS-No.	Type:	Value
OSHA Z1	Naphthalene	91-20-3	PEL	10 ppm 50 mg/m3
	Xylene	1330-20-7	PEL	100 ppm 435 mg/m3
ACGIH	Diesel Fuel	68476-30-2	TWA	100 mg/m3
ACGIH	Naphthalene	91-20-3	TWA	10 ppm
		91-20-3	STEL	15 ppm
	Xylene	1330-20-7	TWA	100 ppm
		1330-20-7	STEL	150 ppm
	Nonane	111-84-2	TWA	200 ppm

Engineering measures : Use only intrinsically safe electrical equipment approved for use in classified areas.

Eye protection : Safety glasses with side-shields reference to 29 CFR 1910.133

Hand protection : Gloves constructed of nitrile, neoprene, or PVC are recommended. Consult manufacturer specifications for further information.

Skin and body protection : If needed to prevent skin contact, chemical protective clothing such as of DuPont TyChem®, Saranex or equivalent recommended based on degree of exposure. The resistance of specific material may vary from product to product as well as with degree of exposure.

Respiratory protection : A NIOSH/ MSHA-approved air-purifying respirator with organic vapor cartridges or canister may be permissible under certain circumstances where airborne concentrations are or may be expected to exceed exposure limits or for odor or irritation. Protection provided by air-purifying respirators is limited. Refer to OSHA 29 CFR 1910.134, ANSI Z88.2-1992, NIOSH Respirator Decision Logic, and the manufacturer for additional guidance on respiratory protection selection. NIOSH/MSHA approved positive-pressure self-contained breathing apparatus (SCBA) or Type C positive-pressure supplied air with escape bottle must be used for gas concentrations above occupational exposure limits, for potential of uncontrolled release, if exposure levels are not known, or in an oxygen-deficient atmosphere.

Work / Hygiene practices : Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure. Use good personal hygiene practices. Avoid repeated and/or prolonged skin exposure. Wash hands before eating, drinking, smoking, or using toilet facilities. Do not use as a cleaning solvent on the skin. Do not use solvents or harsh abrasive skin cleaners for washing this product from exposed skin areas. Waterless hand cleaners are effective. Promptly remove contaminated clothing and launder before reuse. Use care when laundering to prevent the formation of flammable vapors which could ignite via washer or dryer. Consider the need to discard contaminated leather shoes and gloves.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Form : Liquid

Appearance : Clear, straw colored

Odor : Characteristic petroleum (kerosene) odor

Flash point : 38 °C (100 °F) Minimum for #1 Diesel ; 52°C Minimum for #2 Diesel

Thermal decomposition : No decomposition if stored and applied as directed.

Lower explosive limit : 0.7 %(V)

Upper explosive limit : 5 %(V)

Freezing point : Not applicable

Boiling point : 160 °C(320 °F)

Vapor Pressure : <2mm Hg at 20°C
at 20 °C (68 °F)

Relative Vapor Density : 5.7 (Air = 1.0)

Water solubility : Negligible

Percent Volatiles : 100 %

Conductivity (conductivity can be reduced by environmental factors such as a decrease in temperature)

Diesel Fuel Oils at terminal load rack:	At least 25 pS/m
Ultra Low Sulfur Diesel (ULSD) without conductivity additive:	0 pS/m to 5 pS/m
ULSD at terminal load rack with conductivity additive:	At least 50 pS/m but conductivity may decrease from environmental factors such as temperature drop.
JP-8 at terminal load rack:	150 pS/m to 600 pS/m

SECTION 10. STABILITY AND REACTIVITY

Conditions to avoid : Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources. Keep away from strong oxidizers. Viton ® ; Fluorel ®

Materials to avoid : Strong oxidizing agents Peroxides

Hazardous decomposition products : Carbon monoxide, carbon dioxide and noncombusted hydrocarbons (smoke). Diesel exhaust particulates may be a lung hazard - see Section 11.

Thermal decomposition : No decomposition if stored and applied as directed. No decomposition if used as directed.

Hazardous reactions : Keep away from oxidizing agents, and acidic or alkaline products.

SECTION 11. TOXICOLOGICAL INFORMATION

Carcinogenicity

NTP : Naphthalene (CAS-No.: 91-20-3)

IARC : Naphthalene (CAS-No.: 91-20-3)

OSHA : No component of this product which is present at levels greater than or equal to 0.1 % is identified as a carcinogen or potential carcinogen by OSHA.

CA Prop 65 : WARNING! This product contains a chemical known to the State of California to cause cancer.
Naphthalene (CAS-No.: 91-20-3)

Skin irritation : Irritating to skin.

Eye irritation : Irritating to eyes.

Further information : Studies have shown that similar products produce skin cancer or skin tumors in laboratory animals following repeated applications without washing or removal. The significance of this finding to human exposure has not been determined. Other studies with active skin carcinogens have shown that washing the animal's skin with soap and water between applications reduced tumor formation.
Positive mutagenicity results have been reported.
Repeated over-exposure may cause liver and kidney injury
IARC classifies whole diesel fuel exhaust particulates as probably carcinogenic to humans (Group 2A). NIOSH regards whole diesel fuel exhaust particulates as a potential cause of occupational lung cancer based on animal studies and limited evidence in humans.

Component:

Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6	Acute oral toxicity: LD50 rat Dose: 5,001 mg/kg Acute dermal toxicity: LD50 rabbit Dose: 2,001 mg/kg Acute inhalation toxicity: LC50 rat Dose: 7.64 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Severe skin irritation Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Naphthalene	91-20-3	Acute oral toxicity: LD50 rat

		Dose: 2,001 mg/kg Acute dermal toxicity: LD50 rat Dose: 2,501 mg/kg Acute inhalation toxicity: LC50 rat Dose: 101 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation Carcinogenicity: N11.00422130
Xylene	1330-20-7	Acute oral toxicity: LD50 rat Dose: 2,840 mg/kg Acute dermal toxicity: LD50 rabbit Dose: ca. 4,500 mg/kg Acute inhalation toxicity: LC50 rat Dose: 6,350 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Repeated or prolonged exposure may cause skin irritation and dermatitis, due to degreasing properties of the product. Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Nonane	111-84-2	Acute oral toxicity: LD50 mouse Dose: 218 mg/kg Acute inhalation toxicity: LC50 rat Exposure time: 4 h
1,2,4-Trimethylbenzene	95-63-6	Acute inhalation toxicity: LC50 rat Dose: 18 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Skin irritation Eye irritation: Classification: Irritating to eyes. Result: Eye irritation
Sulfur	7704-34-9	Acute oral toxicity: LD50 rat Dose: 5,001 mg/kg Acute dermal toxicity: LD50 rabbit Dose: 2,001 mg/kg Acute inhalation toxicity: LC50 rat Dose: 9.24 mg/l Exposure time: 4 h Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation

SECTION 12. ECOLOGICAL INFORMATION

Biochemical Oxygen Demand (BOD) : No data available

Chemical Oxygen Demand (COD)	: No data available
Adsorbed organic bound halogens (AOX)	: Not included
Additional ecological information	: Keep out of sewers, drainage areas, and waterways. Report spills and releases, as applicable, under Federal and State regulations.

Component:

Naphthalene	91-20-3	Toxicity to algae: EC50 Species: Dose: 33 mg/l Exposure time: 24 h
1,2,4-Trimethylbenzene	95-63-6	Toxicity to fish: LC50 Species: Pimephales promelas (fathead minnow) Dose: 7.72 mg/l Exposure time: 96 h Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia Dose: 3.6 mg/l Exposure time: 48 h
Sulfur	7704-34-9	Acute and prolonged toxicity for aquatic invertebrates: EC0 Species: Daphnia magna (Water flea) Dose: > 10,000 mg/l Exposure time: 24 h

SECTION 13. DISPOSAL CONSIDERATIONS

Disposal : Consult federal, state and local waste regulations to determine appropriate waste characterization of material and allowable disposal methods.

SECTION 14. TRANSPORT INFORMATION

CFR

Proper shipping name	: DIESEL FUEL
UN-No.	: 1202 (NA 1993)
Class	: 3
Packing group	: III

TDG

Proper shipping name	: DIESEL FUEL
UN-No.	: UN1202 (NA 1993)
Class	: 3
Packing group	: III

IATA Cargo Transport

UN UN-No.	: UN1202 (NA 1993)
Description of the goods	: DIESEL FUEL
Class	: 3
Packaging group	: III

ICAO-Labels : 3
Packing instruction (cargo aircraft) : 366
Packing instruction (cargo aircraft) : Y344

IATA Passenger Transport

UN UN-No. : UN1202 (NA 1993)
Description of the goods : DIESEL FUEL
Class : 3
Packaging group : III
ICAO-Labels : 3
Packing instruction (passenger aircraft) : 355
Packing instruction (passenger aircraft) : Y344

IMDG-Code

UN-No. : UN 1202 (NA 1993)
Description of the goods : DIESEL FUEL
Class : 3
Packaging group : III
IMDG-Labels : 3
EmS Number : F-E S-E
Marine pollutant : No

SECTION 15. REGULATORY INFORMATION

OSHA Hazards : Combustible Liquid
Toxic by ingestion
Severe skin irritant
Moderate eye irritant
Possible Cancer Hazard

CERCLA SECTION 103 and SARA SECTION 304 (RELEASE TO THE ENVIROMENT)
The CERCLA definition of hazardous substances contains a "petroleum exclusion" clause which exempts crude oil. Fractions of crude oil, and products (both finished and intermediate) from the crude oil refining process and any indigenous components of such from the CERCLA Section 103 reporting requirements. However, other federal reporting requirements, including SARA Section 304, as well as the Clean Water Act may still apply.

TSCA Status : On TSCA Inventory

DSL Status : All components of this product are on the Canadian DSL list.

SARA 311/312 Hazards : Fire Hazard
Acute Health Hazard
Chronic Health Hazard

SARA III US. EPA Emergency Planning and Community Right-To-Know Act (EPCRA) SARA Title III Section 313 Toxic Chemicals (40 CFR 372.65) - Supplier Notification Required

Components	CAS-No.

Naphthalene	91-20-3
Xylene	1330-20-7
1,2,4-trimethylbenzene	95-63-6

PENN RTK US. Pennsylvania Worker and Community Right-to-Know Law (34 Pa. Code Chap. 301-323)

Components	CAS-No.
Sulfur	7704-34-9
1,2,4-trimethylbenzene	95-63-6
Nonane	111-84-2
Xylene	1330-20-7
Naphthalene	91-20-3
Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6

MASS RTK US. Massachusetts Commonwealth's Right-to-Know Law (Appendix A to 105 Code of Massachusetts Regulations Section 670.000)

Components	CAS-No.
Sulfur	7704-34-9
1,2,4-Trimethylbenzene	95-63-6
Nonane	111-84-2
Xylene	1330-20-7
Naphthalene	91-20-3

NJ RTK US. New Jersey Worker and Community Right-to-Know Act (New Jersey Statute Annotated Section 34:5A-5)

Components	CAS-No.
Sulfur	7704-34-9
1,2,4-Trimethylbenzene	95-63-6
Nonane	111-84-2
Xylene	1330-20-7
Naphthalene	91-20-3
Fuels, diesel, No 2; Gasoil - unspecified	68476-34-6

California Prop. 65 : WARNING! This product contains a chemical known to the State of California to cause cancer.

Naphthalene	91-20-3

SECTION 16. OTHER INFORMATION

Further information

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

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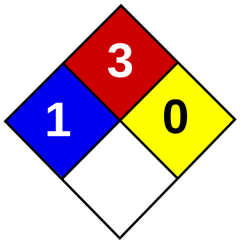

Health	1
Fire	3
Reactivity	0
Personal Protection	H

Material Safety Data Sheet
1-Butanol MSDS

Section 1: Chemical Product and Company Identification

Product Name: 1-Butanol

Catalog Codes: SLB3157, SLB1489

CAS#: 71-36-3

RTECS: EO1400000

TSCA: TSCA 8(b) inventory: 1-Butanol

CI#: Not applicable.

Synonym: Propylcarbinol

Chemical Name: N-Butyl alcohol

Chemical Formula: CH3(CH2)2CH2OH

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
{1-}Butanol	71-36-3	100

Toxicological Data on Ingredients: 1-Butanol: ORAL (LD50): Acute: 790 mg/kg [Rat.]. DERMAL (LD50): Acute: 3400 mg/kg [Rabbit.].

Section 3: Hazards Identification

Potential Acute Health Effects:
Very hazardous in case of skin contact (irritant, permeator), of eye contact (irritant), of ingestion, of inhalation. Slightly hazardous in case of skin contact (sensitizer). Inflammation of the eye is characterized by redness, watering, and itching. Skin inflammation is characterized by itching, scaling, reddening, or, occasionally, blistering.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. Repeated or prolonged exposure is not known to aggravate medical condition.

Section 4: First Aid Measures

Eye Contact:

Check for and remove any contact lenses. Immediately flush eyes with running water for at least 15 minutes, keeping eyelids open. Cold water may be used. Get medical attention immediately.

Skin Contact:
In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Cover the irritated skin with an emollient. Cold water may be used.Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

Serious Skin Contact:
Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention if symptoms appear.

Serious Inhalation:
Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Flammable.

Auto-Ignition Temperature: 343°C (649.4°F)

Flash Points: CLOSED CUP: 28.9°C (84°F). OPEN CUP: 36.1°C (97°F) (Cleveland).

Flammable Limits: LOWER: 1.4% UPPER: 11.2%

Products of Combustion: These products are carbon oxides (CO, CO2).

Fire Hazards in Presence of Various Substances:
Highly flammable in presence of open flames and sparks. Flammable in presence of heat, of oxidizing materials, of reducing materials, of combustible materials.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
Flammable liquid, soluble or dispersed in water. SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use alcohol foam, water spray or fog. Cool containing vessels with water jet in order to prevent pressure build-up, autoignition or explosion.

Special Remarks on Fire Hazards: May form explosive mixtures with air. CAUTION: MAY BURN WITH NEAR INVISIBLE FLAME

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:
Dilute with water and mop up, or absorb with an inert dry material and place in an appropriate waste disposal container.

Large Spill:

Flammable liquid. Keep away from heat. Keep away from sources of ignition. Stop leak if without risk. Absorb with DRY earth, sand or other non-combustible material. Do not touch spilled material. Prevent entry into sewers, basements or confined areas; dike if needed. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:
Keep away from heat. Keep away from sources of ignition. Ground all equipment containing material. Do not ingest. Do not breathe gas/fumes/ vapor/spray. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Avoid contact with skin and eyes. Keep away from incompatibles such as oxidizing agents, reducing agents.

Storage:
Store in a segregated and approved area. Keep container in a cool, well-ventilated area. Keep container tightly closed and sealed until ready for use. Avoid all possible sources of ignition (spark or flame).

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors below their respective threshold limit value. Ensure that eyewash stations and safety showers are proximal to the work-station location.

Personal Protection:
Splash goggles. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Vapor respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
CEIL: 152 (mg/m3) Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Liquid. (Z)

Odor: Vinous. (Slight.)

Taste: Not available.

Molecular Weight: 74.12g/mole

Color: Colorless.

pH (1% soln/water): Not available.

Boiling Point: 117.7°C (243.9°F)

Melting Point: -89.5°C (-129.1°F)

Critical Temperature: Not available.

Specific Gravity: 0.81(Water = 1)

Vapor Pressure: 0.6 kPa (@ 20°C)

Vapor Density: 2.55 (Air = 1)

Volatility: Not available.

Odor Threshold: 1.2 ppm

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: See solubility in water, methanol, diethyl ether, n-octanol.

Solubility:
Easily soluble in methanol, diethyl ether. Partially soluble in cold water, hot water, n-octanol.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances:
Highly reactive with oxidizing agents, reducing agents. Slightly reactive to reactive with organic materials, acids, alkalis.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Dermal contact. Eye contact. Inhalation. Ingestion.

Toxicity to Animals:
WARNING: THE LC50 VALUES HEREUNDER ARE ESTIMATED ON THE BASIS OF A 4-HOUR EXPOSURE. Acute oral toxicity (LD50): 790 mg/kg [Rat.]. Acute dermal toxicity (LD50): 3400 mg/kg [Rabbit.]. Acute toxicity of the vapor (LC50): 8000 4 hours [Rat.].

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans:
Very hazardous in case of skin contact (irritant, permeator), of ingestion, of inhalation. Slightly hazardous in case of skin contact (sensitizer).

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Can cause gastrointestinal disturbances.

Special Remarks on other Toxic Effects on Humans: Exposure can cause nausea, headache and vomiting.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: CLASS 3: Flammable liquid.

Identification: : Butanol UNNA: UN1120 PG: III

Special Provisions for Transport: Not available.

Section 15: Other Regulatory Information

Federal and State Regulations:
Pennsylvania RTK: 1-Butanol Massachusetts RTK: 1-Butanol TSCA 8(b) inventory: 1-Butanol

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).

Other Classifications:

WHMIS (Canada):
CLASS B-2: Flammable liquid with a flash point lower than 37.8°C (100°F). CLASS D-2B: Material causing other toxic effects (TOXIC).

DSCL (EEC):
R10- Flammable. R22- Harmful if swallowed. R38- Irritating to skin. R41- Risk of serious damage to eyes.

HMIS (U.S.A.):

Health Hazard: 1

Fire Hazard: 3

Reactivity: 0

Personal Protection: h

National Fire Protection Association (U.S.A.):

Health: 1

Flammability: 3

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Splash goggles.

Section 16: Other Information

References: -Manufacturer's Material Safety Data Sheet.

Other Special Considerations: Not available.

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