OPTION 2J
RENEWABLE DIESEL FUELS
(BIODIESEL AND OTHER BIOGAS-TO-LIQUID FUELS)

Description

This option examines the status of renewable diesel fuels and possible state actions that may lead to their expanded use. Renewable diesel fuels are 1) biodiesel, 2) biomass-to-liquid (BTL), and 3) thermal conversion process (TCP) fuels.[1] The staff performed a cost benefit analysis for these fuel options assuming 20 cents per gallon premium cost over conventional diesel for up to a 20 percent renewable content. This analysis considers broadening the definition of what qualifies for additional tax credits, and extending the term, under the American Jobs Creation Act of 2004 (Pub. L. 108-357).

Background

Renewable diesel fuels are produced from a variety of resources, and are used either as a blend or as a pure (neat) fuel. However, for this analysis, renewable diesel fuels are considered as blends up to 20 percent. All three renewable fuels offer greenhouse gas (GHG) reduction potential. However, according to a recent European study, the advanced biomass conversion fuels (BTL & TCP) were found to have greater GHG reduction potential for similar energy use than biodiesel.[2] These renewable fuels share three advantages:

- They do not require any unique distribution infrastructure except what is necessary to transport them to refineries or fuel depots;
- They require little or no modifications to existing infrastructure and new vehicles; and
- Being mixable with conventional fuels, they can be used in various proportions depending on their local and seasonal availability.

Future use of renewable fuels is particularly important with the significant growth in demand anticipated worldwide and statewide for transportation fuels. The Energy Information Administration (EIA) projects that the nation's dependence on foreign oil will grow from today's 53 percent share to 70 percent by 2025.[3] This frames the context of using domestic fuel sources to increase supply and reduce future risk resulting from increased reliance on foreign oil.

Discussion on Renewable Diesel Fuels Options

Biodiesel

In the U.S., biodiesel is typically made from soybean oil, recycled cooking oils, and animal fats. However, palm or rapeseed oils, are used in other countries. Biodiesel is made by reacting these materials with alcohol (usually methanol). Biodiesel generally has characteristics that make it superior to common diesel fuel. It has relatively low aromatics and sulfur content. This improves its emission performance when used in engines. Biodiesel also has a relatively high cetane rating of 52, making it a good fuel in compression ignition engines (also called diesel engines). Two percent by volume biodiesel blended into conventional, petroleum-derived diesel provides an alternative fuel with improved lubricity.[4]

Biodiesel can be used in most applications in the same manner as conventional petroleum diesel. In cold weather, diesel fuel and biodiesel can cloud or even gel. Low blends of biodiesel generally react to cold weather very similar to diesel. Solutions for winter operability with biodiesel and blends are much the same as conventional diesel fuel. Also, there may be some materials compatibility issues with seals and gaskets in engines manufactured before 1994 when blends higher than B20 are used. The current practice is to limit the percentage of biodiesel to no more than 20 percent (B20) to avoid these problems.

Today, most major engine companies have stated that the use of blends up to B20 will not void their parts and workmanship warranties. This includes blends below 20 percent biodiesel, such as the 2 percent (B2) or 5 percent (B5) biodiesel blends that are becoming more common. Biodiesel is presently produced, marketed, and used in California, but less than five million gallons of biodiesel were used in California in 2004. Biodiesel's maximum diesel displacement is frequently characterized, by the biodiesel industry, as a 5 to 10 percent diesel displacement option on a nationwide basis.

Biodiesel contains 7 percent less energy per gallon than California Air Resources Board (CARB) diesel. For this analysis, staff assumed an energy content (lower heating value) of 118,200 British Thermal Units (BTUs) per biodiesel gallon,[5,6] and for conventional CARB diesel 127,500 BTUs per gallon.

The U.S. Department of Energy (DOE) Office of Transportation Technologies has estimated the net energy balance for biodiesel production as one gallon of petroleum fuel is required to produce 3.37 gallons of biodiesel.[7] Additionally, the DOE and the U.S. Department of Agriculture completed a Lifecycle Inventory Study for Biodiesel and concluded the overall lifecycle emissions of carbon dioxide (a major greenhouse gas) from biodiesel are 78 percent lower than the overall carbon dioxide emissions from petroleum diesel. Biodiesel has successfully completed the U.S. Environmental Protection Agency's (EPA's) Tier 1 and Tier 2 Health Effects Studies. It also has an established American Society for Testing and Materials (ASTM) fuel specification, ASTM D6751.

Biomass-to-Liquid (BTL) Diesel

BTL Diesel is produced from a broad range of feedstocks, including animal waste, wood wastes, crop residuals, plastics, tires, treated sewage sludge, and other hydrocarbons. The BTL fuel is produced through a biomass gasification process. For example, wood or other dense biomass waste is gasified and converted into a liquid using a Fischer-Tropsch reaction. The liquid can then be refined into a high quality diesel blendstock with a cetane rating of 75 or higher and zero aromatics and sulfur content. To date, BTL has been produced in Europe (6,500 barrels per day), but none is produced in the U.S. Based on a small BTL pilot plant built in Germany, BTL fuel is anticipated to have 0-30 percent higher costs than diesel[8]. BTL has the potential to be the most productive per acre of the renewable diesel fuel options and produces a higher quality fuel. However, BTL production has significant capital cost, plant complexity, and risk compared to conventional crude production and refining. A recent European Wells-to-Wheels study determined that BTL has significant greenhouse gas emissions reduction potential.[9]

Thermal Conversion Process (TCP) Fuel, Also Referred as Hydrous Thermal Upgrading (HTU)

TCP is produced from a broad range of feedstocks, including animal waste, animal carcasses, wood wastes, agricultural waste, plastics, tires, sewage sludge, and other waste containing hydrocarbons, fats, carbohydrates, or protein. The liquid produced is light renewable oil. The TCP process uses pressure and temperature to break down and then further process the feed in a refinery coker unit. The TCP produces a diesel-like crude oil that may be used directly or refined into conventional diesel fuel. Several TCP demonstration plants operating in the U.S. and Europe show promise and the economics appear competitive with forecasted gasoline and diesel prices.[10] The staff opinion is that the TCP process fuel has the potential to provide the lowest cost biofuel option.

Note: Although not fully evaluated, the Jatrophia tree is another potential biomass source that may be applicable to California. D1 Oil's Ltd. is promoting this additional biofuel diesel source. Although not as productive as palm oil, the most productive oil bearing plant per hectare, this potential biofuel can be grown on more arid, poor soil conditioned areas which significantly increases its petroleum displacement potential. The D1 Oil Company is claiming rights to 37,000 hectare of land in Africa, India, and Southeast Asia for Jatropha production. D1 Oil has announced that it will assist the Indian state of Tamil Nadul to promote the cultivation of Jatropha on 33 million hectares of degraded land which is available for reclamation. Each hectare can produce 3,000 liters of oil (800 gallons). The D1 Oil Company also has options for plantation rights for an additional 6 million hectares. In aggregate, 40 million hectares of land could produce 32 billion gallons/year of diesel fuel.[11]

Status

Biodiesel

In 2004 in the U.S., 27 commercial biodiesel plants produced over 33 million gallons.[12] Neat biodiesel has a retail price of $2.75 per gallon depending on purchase volume and delivery costs.[13] Presently, B20 retails for 13 to 22 cents per gallon more than petroleum diesel.[14,15] However, in 2004, federal legislation was enacted providing a one cent per gallon reduction in fuel excise tax for each percentage point of biodiesel used in diesel fuel, limited to 20 percent.[16] This legislation effectively reduces the cost of biodiesel for blenders by up to $1.00 per gallon for two years.

The U.S. DOE is conducting research to reduce the cost of producing biodiesel and to expand supplies using novel feedstocks and new production technologies. A portion of the work is directed at reducing oxides of nitrogen (NO_x) exhaust emissions.

Biomass-to-Liquid (BTL)

No commercial scale production of BTL fuel exists in the U.S. today. Worldwide, a few small demonstration facilities have produced small quantities of BTL. New large scale plants are under development in China and the European Union (EU) using timber as a feed source. At a recent conference, BTL was characterized at a slightly higher (7 percent) price than conventional diesel, yet significantly lower than biodiesel prices.[17] Recent federal excise tax credits are limited to biodiesel and do not apply to other renewable fuels like BTL. Remedies include expanding and extending the blender's credit for all renewable fuels to bring parity.

Thermal Conversion Process (TCP)

One commercial plant exists in Carthage, Missouri (Changing World Technology and Con Agri Foods) producing 4-7 million gallons/year of #4 crude oil made from the turkey processing plant waste. In 2005 the plant sold this crude oil [with 300 parts per million (ppm) sulfur crude oil] to a local refinery at an introductory market price of $28 per barrel – in a $35/barrel petroleum market. This refinery may further process the crude with other petroleum into conventional diesel fuel. At a recent European conference, the TCP process, referenced as HTU, was characterized with a slightly higher price (7 percent) than conventional diesel, but 30 percent lower price than conventional diesel by 2015-2025.[18] However, TCP fuel cost is highly dependent on other value-added streams, which leads to great uncertainty on its final fuel cost in America. In America, unlike in Europe, there is no ban on feeding animal waste to animals, consequently the TCP plant secures animal waste at a cost instead of revenue to the plant. Compounding this is the federal excise tax credits that are limited to biodiesel and do not apply to the TCP processed fuels.

The TCP allows the food processing industry to address several of its environmental, health, and economic issues. Changing World Technology claims that if the TCP process were applied to U.S. agriculture waste residues, estimated by the U.S. EPA to be in excess of six billion tons, up to four billion gallons of fuel could be produced. Applying the TCP process to California's 35 million tons of paper, plastics, organics, and tires, Changing World Technology claims they could produce 2.2 billion gallons of diesel fuel. The existing TCP plant's design simplicity and product upgrading through refineries are viewed as positive attributes.

The potential supply of renewable diesel fuels is shown in Table 1. The volumes in this table are technically feasible, but uncertain.

Table 1. Potential Volumes of Renewable Diesel (million gallons/year) [19]

Year	Biodiesel[1]	BTL	TCP	Total Renewable	20% CA Diesel
2005	30	0	7.5[1]	37.5	640
2015	65	Unknown	1,000[2]	2,065	800
2025	700	Unknown	2,200[2]	2,900	1,000
[1] National Supply [2] California Supply [20]					

Assumptions

The staff assumed a 20 percent renewable diesel content goal is achieved with the expansion (and extension) of biodiesel tax credits similar to what is offered in the 2004 American Jobs Creation Act and that all renewable-based fuels receive the credit. However, for very large, capital intensive projects like BTL and HTU plants, a two-year support window is insufficient. Consequently the staff assumed that the tax credits were extended for up to 10 years to help cover the debt costs. The incentive is worth one-cent per gallon per percent renewable content - with a 20 percent cap. This effectively provides a dollar subsidy per neat renewable gallon.

The staff assumed that biodiesel ranging from B2 to B5 is an accepted industry standard for California diesel fuel. Staff envisioned the TCP and BTL sources are used to make up the balance of the 20 percent displacement goal. However, B20 and higher blends use is assumed to be discretionary where available and cost-effective. Fleets complying with the Energy Policy Act of 1992 – currently using B20 – are envisioned to use any renewable fuel blend of 20 percent. Examples of combinations include blends from either biodiesel, TCP, BTL, or any combination of the three.

The staff assumed that biodiesel use increases from 2005 through 2010 reaching a maximum of 5 percent (150 million gallons) statewide displacement. In the earlier years, the national supply of biodiesel may limit the volume that could be used as a blending agent, although supplies should be sufficient for the full 5 percent blending rate by 2010. In the mature biodiesel market, blends up to 5 percent are assumed to use less than 10 percent of the projected national supply of B100.

All renewable diesel fuels discussed herein are assumed to be compatible with existing diesel engines without modification up to 20 percent. There is no incremental cost related to vehicle purchase. The existing diesel fuel retail infrastructure is also assumed to store and dispense renewable diesel fuel blends without modification. However, the terminals and racks may incur an additional storage and dispenser cost that staff estimates at $50,000[21] - $500,000 per terminal facility (biodiesel only). It is unclear if the TCP and BTL fuels will have additional storage cost at the refinery; staff assumed there were none for the analysis.

Table 2 shows the estimated exhaust emission reductions from renewable diesel fuels used in this analysis. Negative numbers indicate increased emissions. Preliminary test results indicate that these reductions are possible. Biodiesel generally has exhaust emission reduction in proportion to its concentration.[22] NOx emissions from biodiesel blends are comparable to CARB diesel[2] or slightly higher.[23,24] The range in emission levels vary, depending on the feedstock used to produce the biodiesel and the quality of the petroleum diesel used in the mixture.

CARB's Diesel Toxicity Reduction Program has established a goal to reduce the diesel fleet's exhaust particulate matter 75 percent by 2010. This reduction is envisioned by requiring retrofitted aftertreatment devices, which reduce particulate matter (PM), hydrocarbon (HC), carbon monoxide (CO) emissions greater than 85 percent. From 2007-2010 cleaner renewable diesel fuel emission reductions may occur. However, post 2010, the staff assumed that CARB meets its goal without the use of renewable diesel fuels by 2010.

Table 2. Assumed Exhaust Emission Reduction with Renewable Diesel Fuels on Non-Aftertreatment Equipped Diesel Engines

Fuels	HC	CO	NOx	PM	CO_2	Toxics
Biodiesel Neat[1]	67%	48%	-10%	47%	0%	50%
Biodiesel B20[1]	20%	10%	-2%	24%	0%	10%
Biodiesel B5[2]	5%	2.5%	-0.5%	6%	0%	2.5%
Biodiesel B2[2]	2%	1%	-0.2	2.4%	0%	1%
Thermal Conversion Process[3]	0%	0%	0%	0%	0%	0%
Biomass-to-Liquid (100%)[4]	25%	40%	10%	30%	0%	50%
Biomass-to-Liquid (15%)[4]	3.75%	6%	1.5%	4.5%	0%	7.5%

1. CARB's Staff Report: *Initial Statement of Reasons Proposed Amendments to the California Diesel Fuel Regulations*, June 6, 2003, pg. 92. Adopted May 10, 2004. CARB referenced to U.S. EPA: December 2000. Regulatory Impact Analysis: Heavy Duty Engine Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements. Chapter III pg. 2. EPA420-R-00-026.
2. Energy Commission linear extrapolation from B20 values.
3. TCP fuels have not been emission tested; however, the fuel is processed and sold as conventional diesel fuel. Staff assumes the fuel has the same exhaust emissions as ultra-low sulfur diesel fuel.
4. Energy Commission averaged four neat-GTL test program results and linearly extrapolated to a 15 percent blend.

Cost Assumptions

In this analysis, the staff assumed that all renewable diesel fuels are the same retail cost as conventional diesel. This is made possible by sufficient governmental incentives enabling competitive pricing and governmental policy that seek some minimum renewable fuel content.

Table 3 shows the staff-assigned percent displacement and resulting volumes of fuel used for this analysis.

Table 3. Assumed Diesel Reduction From Renewable Diesel Fuels

	Year		
	2015	2020	2025
Annual Reduction (million gallons)	300	880	1,000
Reduction From Base Case Demand (percent)	5	20	20

Results

Tables 4 and 5 display the results for diesel reduction from all renewable diesel fuels. Table 4 shows the results assuming a five percent discount rate, in 2005 dollars. Table 5 assumes a 12 percent discount rate. In both tables, three fuel costs, (referred to as low, high, very high) were determined by the Energy Commission's Fuels Office and contained in *Forecasts of California Transportation Energy Demand 2005-2025*.

Table 4. Petroleum Reduction and Benefits for a 20 Percent Renewable Diesel Use (5 Percent Discount)

Petroleum Reduction and Benefits for Selected Alternative Fuel Scenarios							
Alternative Fuel Option or Scenario	Displacement in 2025, billion gallon gasoline equivalent	Reduction from Base Case Demand, percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% discount rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88 / gal diesel)	1.0	20	0	(0.8)	0.7	0.6	0.5
High Fuel Price ($2.20 / gal diesel)	1.0	20	0	(0.8)	0.7	0.6	0.5
Highest Fuel Price ($2.43 / gal diesel)	1.0	20	0	(0.8)	0.7	0.6	0.5
* Petroleum reduction was valued at 13 cents/gallon gasoline equivalent.							

Table 5. Petroleum Reduction and Benefits For a 20 Percent Renewable Diesel (12 Percent Discount)

Petroleum Reduction and Benefits for Selected Alternative Fuel Scenarios							
Alternative Fuel Option or Scenario	Displacement in 2025, billion gallon gasoline equivalent	Reduction from Base Case Demand, percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% discount rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88 / gal diesel)	1.0	20	0	(0.3)	0.3	0.3	0.3
High Fuel Price ($2.20 / gal diesel)	1.0	20	0	(0.3)	0.3	0.3	0.3
Highest Fuel Price ($2.43 / gal diesel)	1.0	20	0	(0.3)	0.3	0.3	0.5
* Petroleum reduction was valued at 13 cents/gallon gasoline equivalent.							

Key Drivers and Uncertainties

The key uncertainties in this analysis involve the following:

- Staff needs to assess the economic feasibility of feedstocks for attaining a 20 percent diesel displacement goal. Other impediments to expanding renewable diesel production and use need to be accurately quantified.

- The investment needed to establish a production capacity to meet a 20 percent diesel displacement goal is unknown.

- It is likely that any reduction in fuel excise tax used to support the higher cost of renewable diesel fuels would have to be offset by higher revenues from another source.

- The long-term production cost of renewable diesel is unclear as production technology improves, higher cost feedstock are likely to evolve perhaps matching process improvements developed over time.

Endnotes

[1] Not considered for this analysis but recognized as an additional potential fuel source is a very similar process that recycles mixed plastics wastes into crude oil, several plants are built in other countries (i.e. Poland) and producing over one million barrels of crude oil annually. See H.SMARTTech. http://www.ciwmb.ca.gov/part2000/Events/02Conf/ConvTech/Plastic.htm.

[2] *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*, European Commission, Joint Research Centre, Version 1b, January 2004, pg. 19.

[3] DOD - presentation to Congress 2005.

[4] U. S. DOE, Office of Transportation Technologies, [http://www.ott.doe.gov/biofuels/renewable_diesel.html].

[5] *2004 Biodiesel Handling and Use Guidelines*, U.S. Dept. of Energy, Energy Efficiency and Renewable Energy, DOE/GO-102004-1999 September 2004, p. 5.

[6] U.S. DOE, Alternative Fuels Data Center, [http://www.afdc.doe.gov/altfuel/bio_papers.html], May 2002; The stated range from about 117,000 to 124,000 Btu per gallon comes from different rounded values published in papers found at this website.

[7] U.S. DOE, Office of Transportation Technologies website, "Biodiesel Benefits."

[8] Comparison was made relative to California Diesel whole sale prices experienced in 2004 ($1.00 - $1.75 per gallon), assuming BTL cost of $1.75-$1.92 /gallon based on a 300-6,000 bbl/day BTL plant in Alaska.

[9] *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*, European Commission, Joint Research Centre, Version 1b, January 2004, pg. 19.

[10] Peter Jansen, NTO, Netherlands, Innovative Biofuel Production Process: *Fischer-Tropsch Process and Hydro Thermal Upgrading, EU China Workshop on BioFuels*, November 4-5, 2004, http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf.

[11] Peter Mullins, *Increasing Demand fore Biofuel Engines*, Diesel & Gas Turbine Worldwide, January-February 2005, pg. 42-45.

[12] National Biodiesel Board.

[13]Biodiesel (neat) prices Los Angeles CA, $2.75, San Francisco, $2.77, and U.S. Average $2.64 (pre taxed, and pre tax incentive) Alternative Fuels Index reported 4/14/05. Diesel rack price $1.95/ gallon, Spot was $1.88, and Retail was $2.71, $2.63, $2.68 Northern, Central, and Southern California Source: Energy.ca.gov gasoline and diesel prices.

[14] Ibid.

[15] Peter Jansen NTO, Netherlands, EU China Workshop on BioFuels, European Commission Presentation, shows the Cost of Transportation Fuels, RME Biodiesel at 25 €/GJ ($5.64/gallon) compared to 6-7 €/GJ ($1.35-$1.58/gallon) for Gasoline and Diesel. http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf

[16] American Jobs Creation Act of 2004, (Pub. L. 1.8-357) (Act).

[17] Peter Jansen, NTO, Netherlands, Innovative Biofuel Production Process: *Fischer-Tropsch Process and Hydro Thermal Upgrading, EU China Workshop on BioFuels*, November 4-5, 2004, http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf.

[18] Peter Jansen, NTO, Netherlands, Innovative Biofuel Production Process: *Fischer-Tropsch Process and Hydro Thermal Upgrading, EU China Workshop on BioFuels*, November 4-5, 2004, http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf.

[19] Supply projections based upon staff communication between Gary Yowell and Dr. K. Shaine Tyson, National Renewable Energy Laboratory, August 2001.

[20] Assumes that 100 percent of California's 35 million tons from Paper, Plastics, Organics, and tires is used to produce oil. Cited 1999 Statewide Waste Composition Study. Changing World Technologies, Inc. Presentation to Los Angeles City, on Municipal Solid Waste to Oil Presentation, April 21, 2005.

[21] Per Scott Hughes, Hughes Consulting, cost estimate for a 20,000 gallon tank likely for a small terminal.

[22] Thomas D. Durbin, et. al., Final Report, *Evaluation of the Effects of Biodiesel and Biodiesel Blends on Exhaust Emission Rates and Reactivity-2*, Center for Environmental Research and Technology, College of Engineering, University of California, Riverside, CA, August 2001.

[23] Clark, N.N., et al., *Transient Emissions Comparisons of Alternative Compression Ignition Fuels*, West Virginia University, submitted to 1999 SAE Congress.

[24] Starr, M.E., *Influence on Transient Emissions at Various Injection Timings, using Cetane Improvers, Biodiesel, and Low Aromatic Fuels*, 1997, SAE Technical Paper No. 972904.