CALIFORNIA ENERGY COMMISSION

Biomass-Based Diesel Storyline

AB118 Update

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Energy Commission Staff with support from the Biomass-based Diesel Working Group analyzed the cost and circumstances necessary for a 20% Biomass Based Diesel blend used in California.

Executive Summary

This paper presents California Energy Commission (Energy Commission) staff's *Implementation storyline*, of Biomass-based diesel fuel blends as replacements for and supplements to conventional petroleum-based diesel for California's transportation fuels market to the year 2050. Biomass-based diesel fuel penetration displacing 20 percent of expected diesel demand has been evaluated.

The Energy Independence and Security Act of 2007 (EISA07) collectively refers to Biomass-based diesel fuels. These fuels include both mono alkyl esters traditionally known as biodiesel and renewable hydrocarbons known as renewable diesel. The biodiesel is made by reacting both new and used animal fats and vegetable oils (including algae-produced oils) with an alcohol (typically methanol) to form esters that are better diesel fuels than their biomass precursors. Renewable diesel is made from the same biomass feedstock as biodiesel by heating the feedstock in the presence of a catalyst and hydrogen to form hydrocarbons that are better diesel fuels than typical (petroleum-based) ultra low sulfur diesel fuel. Research and development is also well underway on two other pathways to produce renewable diesel: gasification of various sources (farm waste, forest waste, trash, etc.) of cellulosic biomass followed by synthesis of diesel fuel molecules and biotechnological conversion of sugars, starches and cellulose to diesel fuel using micro-organisms.

This analysis was developed with support and oversight from the Energy Commission's *Biomass-Based Diesel Working Group* formerly known as the *Renewable Diesel Working Group* to ensure plausibility. This paper employs the AB 1007 Full Fuel Cycle Analysis to estimate the potential greenhouse gas emission reductions from a 20 percent Biomass-based diesel blend.

Staff analyzed the effects of monetary and non-monetary incentives and mandates, their cost-effectiveness in obtaining petroleum and emissions reductions, and the sufficiency of consumer demand. Based on numerous findings, staff concluded that Biomass-based diesel fuels can significantly displace petroleum demand, reduce emissions and are worth implementing.

Based on detailed analyses on Biomass-based diesels, staff concluded that:

- Additional government incentives and/or mandates would be necessary to encourage Biomass-based diesel fuels use above 4 percent diesel displacement.
- To achieve a greater than 5 percent diesel displacement within the next 5-7 years, incentives of $0.25 to $0.60 will be necessary, depending on wholesale diesel pricing relative to renewable diesel feedstock costs. Absent such incentives, a Biomass-based diesel mandate would be an alternative path to achieve a 15-20 percent displacement.
- Reducing diesel fuels' carbon intensity 10 percent exclusively by Biomass-based diesels can be met with 15 percent Biomass-based diesel blends.[1]

[1] Assumes 65% Full Fuel Cycle GHG benefit.

- By 2022 and 2050 if Biomass-based diesels displace 20 percent of diesel demand this would lead to a reduction of 1.5 – 2.4 billion diesel gallons and 12 – 25 million tons of greenhouse gas. This penetration level seems feasible at a competitive incentive or mandated cost, with emissions reductions and using the existing infrastructure, while retaining performance standards for diesel vehicles and equipment.[2]

Recommended State Actions

Based on staffs research and analyses, staff perceives Biomass-based diesels to be an alternative fuel option with significant promise. Biomass-based diesels' potential to displace petroleum-diesel, to improve emissions, to blend with all grades of diesel, and to displace either petroleum or upgrade crude, as well as its consequent economic benefits to refineries in terms of production flexibility, its eventual availability in volume, and its transparency to consumers, present strong arguments for its expanded use. Consequently, staff offers the following recommendations to address the issues impeding Biomass-based diesels use:

1. **Near-Term (within three years): Lack of (i) segregated storage and rack integration at existing diesel terminals and (ii) bulk storage facilities sufficient to receive Biomass-based diesels from abroad and keep bulk Biomass-based diesel segregated.**
   1.1. The State Legislature should enhance government oversight of improvements to the state's transportation fuel supply infrastructure. The Legislature should empower the Energy Commission to oversee and facilitate the permitting process of transportation fuel supply infrastructure improvements. The Legislature must ensure that construction at ports and inland bulk distribution diesel terminals is done in a timely manner and that it is responsive to environmental and other state concerns. Staff envisions that this step will support all XTL diesels[3], Biomass-based diesels, and imported petroleum supplies.
   1.2. The Commission should provide $500,000 per bulk receiving terminal capable of distributing over 250 million gallons of Biomass-based diesel fuel annually by 2010. The awards are necessary to obtain permits, which could secure a new terminal. With competition for costal shoreline access there is a critical need to begin the permitting process for constructing (a) new terminal(s) with deepwater port access to receive Biomass-based diesel feedstocks and finished fuels. While final permitting of a facility will require permits from a number of city, state and federal agencies, obtaining a conditional use permit that includes presenting an environmental impact report (EIR) is the biggest bottleneck in the permitting process. For example one potential site is in Richmond City, the Richmond City Council will be changing January 1, 2009. The current City Council is favorably predisposed to building a terminal. It is not clear this same predisposition will exist after the first of the year.

[2] For the Reference Fuel Price Scenario. The Low or High Fuel Price Scenarios have lower and higher values respectively.
[3] XTLs represent Gas-to-Liquid, Coal-to-Liquids, and Petroleum Coal-to-Liquids that produce diesel fuel.

1.3. Absent a GHG reduction mandate that may inspire Biomass-based diesel use, the State Legislature should consider a tax credit for infrastructure improvement at refineries and bulk distribution terminals to support the storage and blending of Biomass-based diesel.

1.4. The California State Water Resources Control Board (SWRB) issued a letter indicating that biodiesel cannot be used in underground storage tanks (USTs) because Underwriters Laboratory (UL) has not certified the USTs for use with biodiesel. The UST equipment manufacturers have tested biodiesel with their equipment and approved them for use with biodiesel, but UL has not had sufficient time to complete its certification processes. The Commission staff will investigate this issue and develop recommendations and actions to assist SWRB concerns if appropriate.

2. Near-Term limited In-State Production Capacity

2.1. Assist in co-funding preliminary site selection and permit applications for new in-state Biomass-based diesel plants. There is great risk in setting up new plants in California –State partnering with new plant developers is envisioned to help reduce expense and accelerate site selection and permitting. Given the uncertainty that has been created by the indirect land use issue and California's reputation for being a hard place to build a processing plant, this might trim as much as a year off of the implementation schedule.

3. **Near-Term: Limited Market Demand for Biomass-based Diesels**

3.1. In-State Fuel Production Support – is proposed to bridge the gap until the Low Carbon Fuel Standard is implemented. A subsidy of 18 cents per gallon is proposed for in-state produced Biomass-based diesel fuels; fuels receiving support must be sold in California.

3.2. Low Carbon Fuel Standard – implementing the standard broad enough to allow all Biomass-based diesels.

3.3. The Energy Commission, Air Resources Board, and key California Air Quality Management Districts need to develop an accord on Renewable diesel and Biodiesel merits. This accord should proclaim Renewable diesels and Biodiesel virtues, and encourage their use to the maximum extent practical within their existing and future programs.

3.4. Sustainability of producing Biomass-based diesel feedstock's and further quantification of the life cycle greenhouse gas benefits from Biomass-based diesel requires more assessment.

4. Mid-Term: Limited In-State Biomass-based diesel Production.

4.1. The State should establish "Floor" price protection that provides up to 60 cents per gallon tax exemption for Biomass-based diesel fuels indexed to California Diesel Rack prices relative to a composite reflective of Biomass-based diesel feedstock costs (i.e. the composite would be comprised of prices for soy, palm and canola oils, yellow grease, and inedible animals fats on a weighted average basis that accounts for the estimated market share of the feedstocks in the overall Biomass-based diesel market). As new feedstocks emerge such as

algae, these can be added to the feedstock composite. Subsidy cost would be funded via a 0.1 cent (one tenth of a cent) per gallon tax increase per diesel gallon sold. Legislation should require that the fuels receiving support must be sold in California.

4.2. The Commission should continue to examine clean diesel cars and light trucks as a greenhouse gas emission reduction strategy, and their potential to create more demand for Biomass-based diesel fuels.

5. Long-term unconventional Renewable diesel plants (Algae, BTL and Thermal Conversion) should be encouraged and need additional support to be established.

5.1. The Legislature should establish an accelerated depreciation tax rate, and loan guarantees for Renewable Diesel plants built in California that use agricultural waste, timber waste, and or feedstocks not compatible with Biodiesel and Hydro-processes. Staff envisions this action to assist the first BTL and Thermal Conversion plants in acquiring favorable financing.

5.2. The Legislature should enact a “Floor Protection” for unconventional Renewable Diesel plants to protect the first ten-years of plant operation. The Floor would protect unconventional plants when diesel rack prices drop below competitive levels. Up to 25 cents per gallon production subsidy would be provided in equal proportion to diesel rack price declines from a set point.

5.3. Research and demonstration funding and assistance to prospective new technologies and plants that use unconventional feedstocks should be developed.

Introduction and Overview

This paper presents California Energy Commission (Energy Commission) staff’s implementation analysis of Biomass-based diesel fuel blends as replacements for and supplements to conventional petroleum-based diesel for California’s transportation fuels market to the year 2050. Collectively referred to as Biomass-based diesels, the blends include Algae Diesel, Biodiesel, Biomass-to-Liquid (BTL), Hydrogen Process Diesel (HPD) and Thermal Conversion (AKA Depolymerization) Diesel (TCD). Background, details on Biomass-based diesel fuels is contained in the *Renewable Diesel Option Paper*, this paper documents the reasoning and values used to evaluate plausible future scenario of Biomass-based diesels. This paper incorporates the Energy Commissions’ 2007 Full Fuel Cycle Analysis to quantify greenhouse gas emission reductions from Biomass-based diesels.

Staff analyzed the effects of monetary and non-monetary incentives and mandates, their cost-effectiveness in obtaining petroleum and emissions reductions, and the sufficiency of consumer demand. Based on numerous findings, staff concluded that Biomass-based diesel fuels have the potential to significantly displace petroleum

demand and to improve emissions and are worth implementing.

Overarching Assumptions

In this document Biomass-based diesels were defined and evaluated as either; 1) esterified diesel (***Biodiesel***) or 2) non-esterified renewable diesel (Renewable Diesel). References to Biodiesel shall refer only to transesterified methyl-esters compatible with ASTM D-6751. References to Renewable diesel includes the following; Algae, BTL, Green diesel, Hydrogen-conversion and thermal-conversion diesels and biotechnology derived diesels (similar to those being developed by Amyris, Synthetic Genomics and LS9) compatible with ASTM D-975.

Using as a foundation the findings from initial research, consultation with stakeholders, and analysis, staff employed the following global assumptions to analyze a potential scenario:

- Biomass-based diesels cost the refineries or blenders $1.00 – $2.00 more per gallon of petroleum diesel.
- California incentive scenarios (or higher cost) of 25, 50 cents, $1.00, $1.50 and $2.00 per gallon exist, in addition to the current federal $1.00 per gallon incentive.
- To achieve any meaningful level of diesel displacement such as 5% or greater, Biomass-based diesel must at least be priced competitively with conventional diesel.
- Renewable diesel fuels are compatible with existing retailing infrastructure and diesel powered vehicles and equipment up to 50 percent.
- Biodiesel (transesterified) is predominantly used as B5 but is compatible up to 20 percent diesel blends –due to the expected ASTM B20 specification adoption.
- Algae diesel is produced in commercial quantities in California post 2015 and sold as biodiesel or renewable diesel fuels.
- Biomass-based fuels require 20-years to reach their maximum scenario displacement potential of 20 percent. To attain the full displacement potential in 20 years, it is necessary to achieve a meaningful baseline level of displacement of 5% or greater within 10 years.
- Abundant, and economic, renewable oils or other feedstocks are available internationally and domestically to meet the assumed California demand schedule.
- Foreign supplies of bio-feedstocks will represent the majority of California's immediate to near-term supply growth needs.
- This scenario was evaluated assuming high crude oil price scenarios from the Energy Information Agency's (EIA) 2007 Annual Energy Outlook, adjusted to reflect California's refining and market margins.

- Biomass-based diesel is in limited supply currently, existing federal incentives may not be adequate to spur new production facilities or ensure significantly greater quantities beyond 5 percent.
- Renewable diesel fuels allow refineries to produce more diesel fuel. Due to their lower specific gravity, higher cetane, higher heating value, and greater GHG reductions relative to; diesel, Light Cycle oils, and Biodiesel.
- Most Renewable diesels require capital expenditures at bulk receiving and storage facilities or refineries, and biodiesel requires bulk receiving and bulk terminal distribution capital expenditures.
- Renewable diesel blends have similar fuel economy and power to petroleum-based diesel fuels; their energy content is similar to diesel.

Staff believe that biodiesel up to B20 is an accepted industry practice for California diesel fuel. Staff envisioned renewable diesel fuels are used to make up the balance of the displacement target. However, biodiesel blends greater than B5 are assumed to be discretionarily used where available and cost-effective. Fleets complying with the Energy Policy Act of 1992 – currently using B20– are envisioned to use any biomass-based fuel blend of 20 percent.

For the expected crude oil price case (See the Retail Price Discussion - High case) staff assumed that biodiesel use increases through 2010 reaching 5 percent (220 million gallons) statewide displacement. In the earlier years, International supply is expected to provide a significant portion of Biomass-based diesel used in California. With sufficient incentives or mandates international supplies combined with in-state and other domestic sources are envisioned to displace 10% diesel demand by 2017.

All Biomass-based diesel fuels discussed herein are assumed to be compatible with existing diesel engines without modification. There is no incremental cost related to vehicle purchase or retrofitting. Consumer acceptance and use of Biomass-based diesels was not considered an obstacle. Regarding Biomass-based diesels, sufficient incentive was assumed to form its supply while enabling the same retail price as diesel. Or a mandate is in place compelling Biomass-based diesel blends and diesel retail price increases consistent in magnitude with the incentive cost case. The existing diesel retail infrastructure is assumed to store and dispense renewable diesel fuel blends without modification. However, the terminals and racks may incur storage and dispenser improvement cost of $750k - $2 million[4] [5] per terminal facility (biodiesel only). Renewable diesel fuels may have additional storage and equipment cost (i.e. a standalone biofeed hydrotreater unit) at the refinery, or for bulk storage, but no additional infrastructure changes were assumed after the refinery.

Analytic Goal of the Implementation Analysis

[4] Crimson Renewable comments on current pricing for a heated biodiesel tank fully integrated into a diesel rack with sequential blending. 5/25/07 e-mail.

[5] Tellurian Proposal to the Air Resources Board, $25 million Alternative Fuel Grant Solicitation.

One scenario was evaluated for each alternative fuel in the AB 118 analysis update, not to find the only “true” path, but to gather information to establish a foundation upon which to develop the combined alternative fuel plan.

A fundamental analysis outcome from the Storyline Analysis is to determine the price supply curves for each alternative fuel option from 2005 through 2050. Collectively, all alternative fuel options will yield individual price supply curves per milestone year. Subsequently, all price supply curves will be combined to determine the supply timing as well as petroleum reduction, alternative fuel demand, emission reductions, consumers and governmental cost. These are all important informational needs for consideration when developing an alternative fuel use plan.

Bio-Oil Supply

Biomass-based diesel fuels can be produced from a variety of fats and oils. Potential feedstocks include; palm oil, soybeans, rapeseed, cottonseeds, ground nuts, sunflower, copra, canola, jatropha, algae, animal fats, animal renderings, yellow grease (used cooking oils) and grease trappings. Globally 145 million metric tons of oils and fats from vegetable and animal origin are produced annually[6]. For context, 145 million metric tons could produce 45.6 billion gallons of diesel. However, today’s fats and oils are used for food, industrial and cosmetic purposes and only a small portion is converted into fuel.

European, and domestic biodiesel production increased sharply due to; European Directives requiring renewable blend levels, supported with financial compliance incentives. In the USA unprecedented crude oil prices, higher retail diesel prices, and 2004 and 2005 federal legislation providing up to a $1.00 per biodiesel gallon have spurred recent domestic biodiesel supply increases. Figure 1. shows the rapid increase in production and an illustration of how a California 20 percent Biomass-based diesel supply would compare relative to other countries and the nation.[7] Note: the 20 percent case is not a baseline case but a scenario that will be discussed later. California’s port access to the Pacific Rim countries is a major influence to significant near term supply. California is already experiencing a major upsurge in biodiesel use. In 2006, 33 million gallons of biodiesel fuel was collectively use in on & off-road vehicles and marine vessels.[8] Today, seventy percent of California’s biodiesel volume comes from imported sources. For 2008 Biodiesel use in California is expected to reach (100 million gallons) just over 2 percent of California’s aggregate on-and off-road diesel demand.

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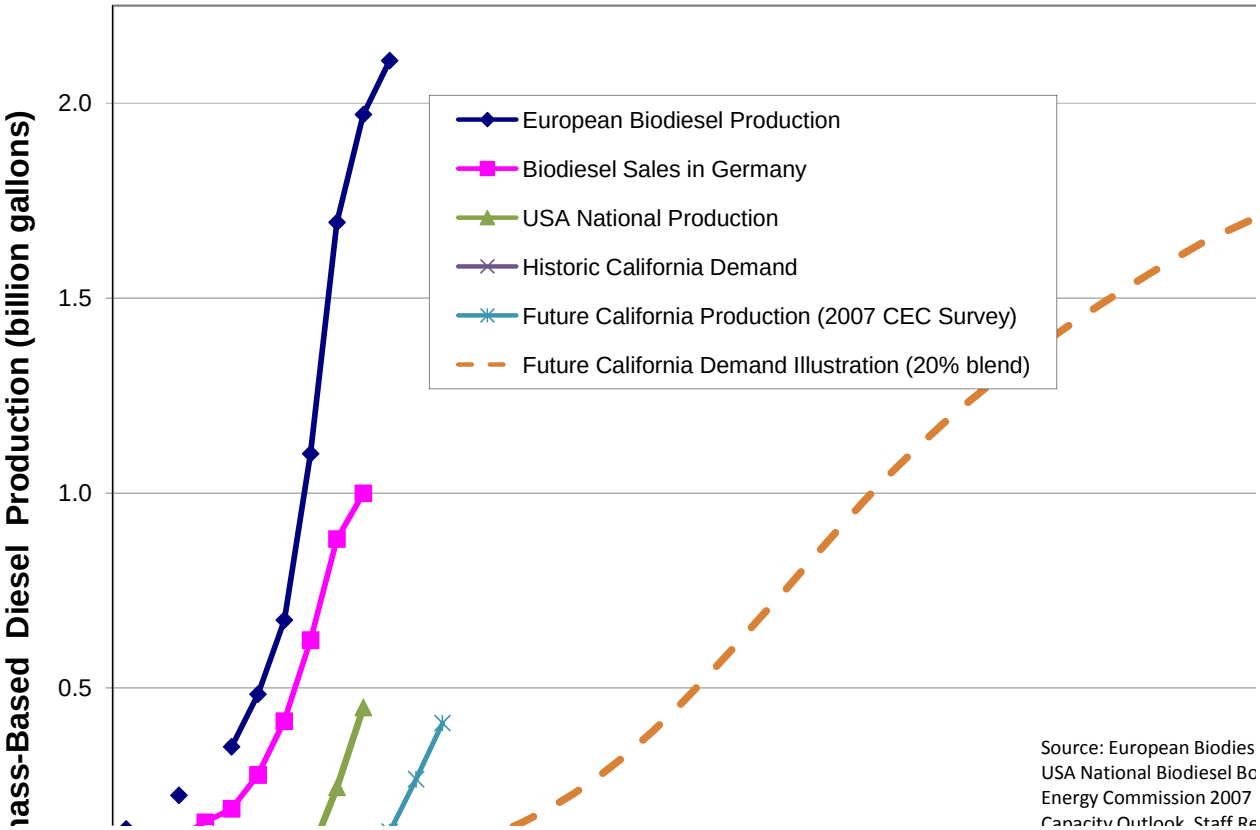
[6] FAO Corporate Document Repository, Food Outlook Global Market Analysis, No1. June 2006. http://www.fao.org/docrep/009/J7927e/j7927e06.htm

[7] European Biodiesel Production - European Biodiesel Board www.ebb-eu.org
Germany Biodiesel Sales - Biodiesel and other Biofuels Abridged version of the UFOP Report 2005/2006.
USA Biodiesel Produciton - National Biodiesel Board
Ca Biodiesel Sales - Staff phone survey, and Board of Equalization data Taxable and non Taxable Sales. Note: Staff assumed it takes 24 years, from 2008, to reach 20% maximum blends. In 2007 Biodiesel volumes represented 1% of California diesel sales.

[8] California Board of Equalization 2006 value.

There are insufficient price history supply relationships, and too many confounding factors to analytically determine a price-to-supply incentive response for Biodiesel or Renewable diesels. Bio-oil crop choice, crop-yield variances as great as 100% from year to year, evolving greenhouse gas policies, and market prices are all in frenzied state and have not settled sufficiently to enable a reliable analytical price-supply analysis. Thus judgment from a body of industry stakeholders, and studying the European experience were used to estimate the price-to-supply response for this analysis.

Fig. 1 Europe, USA and California Biodiesel Trends and potential Biomass-based Diesel Trends 1998-2050



The upper limits of domestic and worldwide feedstock production was not determined but it was assumed that over 20-30 years it could grow by 6 percent to meet the additional 3 billion gallons Biomass-based diesel demand evaluated for California. Over the last three years world oilseed production has grown 10 percent, and industry experts indicate there is ample room for additional growth.

Great uncertainty exists in projecting California production due to California's limited and infant industry today. With aggressive incentives and sustained high diesel prices,

staff roughly estimate by 2030 in-State Production of Biomass-based diesel, could reach 800 -1,000 million gallons, based on Germany's and France's biodiesel production trends from 1998 to 2006. Suggested Biomass-based diesel production volumes within 25-years for California were inferred by the 2006 biodiesel production from Germany and France; 740 and 160 million gallons respectively.

Uncertainties and Competition for fats and oils - Since 2000 there has been a strong and growing interest in using Biomass-based diesels worldwide. In part, this is due to the crude oil price escalations and the European Directive to use less carbon-intensive fuels. This strong global interest in Biomass-based diesel feed sources will compete with the scenarios envisioned for California. The consequence imposes greater uncertainty in the timing and quantity of supply and a more inelastic supply to incentive response. Thus a greater range of supply-to-incentives response was modeled to account for this uncertainty. Below is an abridged list of the key issues likely to impact Biofuel supplies. Staff will continue to investigate these issues and more, well beyond the AB 1007 analysis.

List of key issues complicating and bolstering uncertainties of future Bio-feed supplies.

- Bio-feed supply – Can sufficient and cost effective in-state, and foreign supplies be accessed.
- Competition for bio-feed supplies from other States, Nations and Countries seeking GHG, energy security, and petroleum depletion policy goals.
- Market supply and market price behavior of crude oil and fatty oil commodities.
- China and India's market demands for crude oil and bio-feeds.
- Regulatory market certainty impacting industries' ability to make investment risk decisions necessary to secure bio-oil supplies, and produce Renewable Diesel.
- Bio-feeds supply response to incentives
- Perception of indirect land use change impacts

Retail Price Scenarios

This update analysis was done using one fuel price scenario Table 1 shows the projected crude oil scenario based on the Energy Information Association's (EIAs) 2007 Annual Energy Outlook Price Forecast adjusted to reflect the typical California grade and priced crude.

Table 1. Fuel Price Scenario Crude Oil Prices

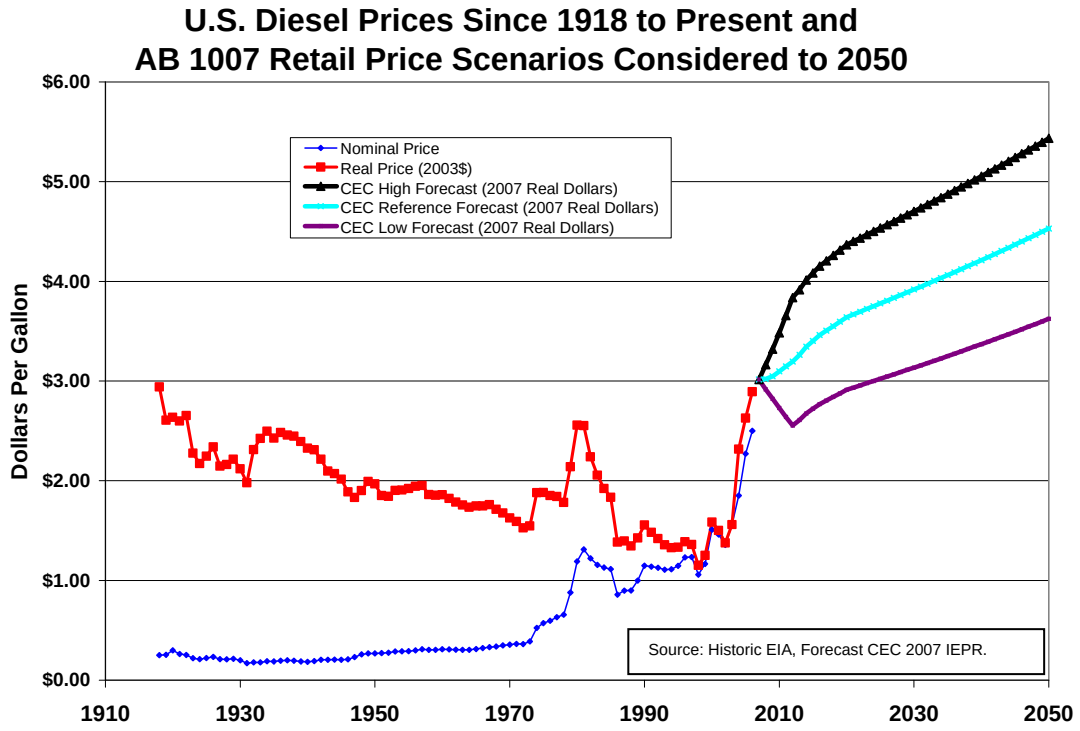
Crude Oil Price Scenario	2007	2012	2017	2022	2030	2050
High Case	76	84	99	108	119	145

Prices are in dollars/barrel, in constant 2007 dollars

Staff has developed California-specific highway transportation fuel price forecasts for regular-grade gasoline and diesel based on the U.S. Energy Information

Administration's (EIA) *2007 Annual Energy Outlook* crude oil price forecast cases for use in the Energy Commission's AB 1007 alternative fuel penetration analyses. The High, Reference and Low fuel price cases correspond in name and in underlying crude oil price assumptions shown in Table 1. These cases use differing assumptions for crude oil prices, crude oil to rack fuel price margins, and rack price to retail price margins. Figure 2 shows the context of historic U.S. diesel retail prices relative to the three future fuel price scenarios.

Figure 2 Diesel Retail Price Forecasts for AB 1007 Analysis



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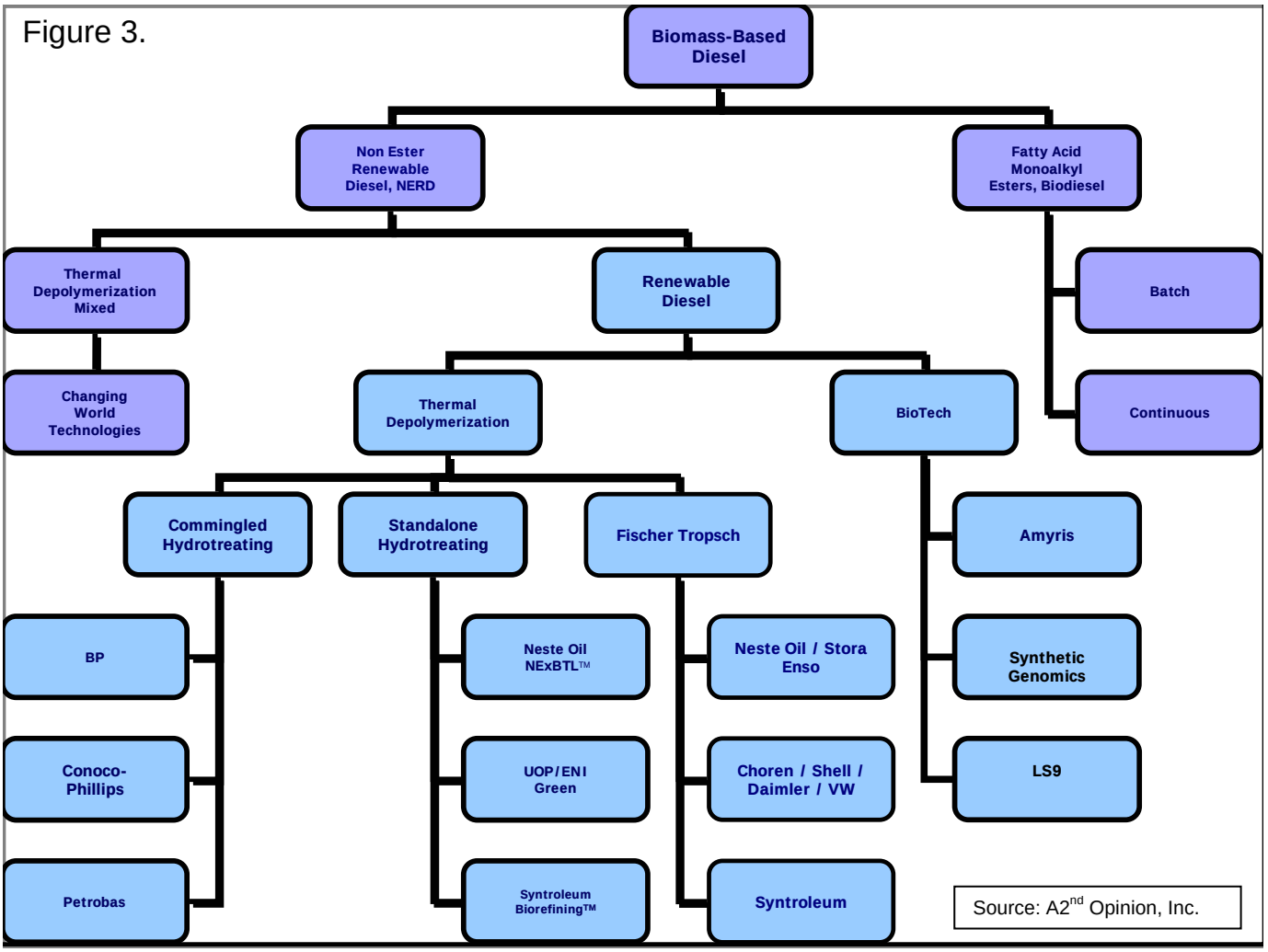
Barriers and Hurdles

The key barriers to biodiesel use has been, higher fuel cost, limited supply, occasional poor fuel quality, and the lack of an adequate American Society of Testing Material (ASTM) fuel standard. Recently ASTM indicated it will be issuing an updated D-975 standard in which any diesel fuel containing less than 5.49 vol% biodiesel that meets D-975 standards is approved. Diesel fuels containing between 5.50 vol% and 20.49 vol% biodiesel fall under the new B6-B20 standard. That B6-B20 standard contains requirements from both the biodiesel standard D-6751 and D-975. The D-975 ninety percent distillation point is relaxed to allow for the heavier biodiesel and some of the D-6751 stability and contamination standards are added to control those properties. While the standards have been voted out of committee, there are some negative vote issues that have to be resolved before the new standards are final.

The remaining renewable diesel fuels are less mature but quickly evolving. Because they are made up of hydrocarbons, there should be no ASTM fuel standard barrier to entry as long as the finished diesel fuel meets the applicable existing ASTM standard. Figure 3 summarizes how these fuels are developing and the entities that are creating these alternative fuels.

Figure 3 Biomass-based Diesel Technology Pathways



Changing World Technology has a small thermal depolymerization plant in Cartridge Missouri operating since 2002. The Changing World Technologies' product is essentially a boiler fuel containing a mixture of hydrocarbons.

BP, ConocoPhillips and Petrobas have focused on commingled processing in which the biomass fat or oil is co-processed in a typical distillate hydrotreater with petroleum distillate. BP has proven the process with rapeseed oil in Europe and tallow in

Australia. ConocoPhillips has proven the process in Ireland and is believed to be processing high quality animal fat from Tyson in the US. Petrobas reports that they have completed extensive pilot plant work on a variety of feedstocks and was expected to begin using the process in their refineries by late 2007 or early 2008.

Neste Oil started up the World's first commercial scale standalone hydrotreating process during the summer of 2007. The Neste plant is operating on a mixture of rapeseed oil, palm oil and animal fat and is producing product that meets ASTM D975 standards and has a cloud point as low as minus 27 degrees Centigrade and a cetane rating as high as 91. Neste has a second identical plant under construction at Porvoo, Finland that should start up in 2009 and is actively seeking other renewable diesel ventures. Neste has also announced that it is building an 800,000 t/a plant in Singapore that should start up in 2010 and an 800,000 t/a plant that should start up in Rotterdam in 2011. Neste has a goal to be using only non-food feedstocks by 2020. UOP/Eni has a commercial startup scheduled in 2009 for their separate train process. Syntroleum plans to start up a plant in Louisiana in mid 2010 using some very low quality fats from Tyson.

In the future renewable diesel will be made by gasifying waste or cellulosic materials and then building diesel fuel molecules out of the gas molecules or some other yet to be discovered technology. The known players in the gasification / Fischer Tropsch efforts are mentioned in Figure 3. Their common problem is cleaning synthesis gas. BTL plants are under construction in China and in Germany today.

Amyris Biotechnologies is developing a large-scale fermentation process to produce biofuels. Amyris is developing a diesel substitute that they believe can achieve lower costs and much greater scale than vegetable oil based biodiesels. Their renewable diesel, like most renewable diesels, is inherently stable, usable in cold temperatures and does not break down during storage and transport like conventional biodiesel. Their renewable diesel will be made from the same feedstocks and production plants that are used to make ethanol. They have a joint venture underway in Brazil that is expected to have an operational pilot plant in 2009 and a commercial plant in 2010. Other participants in biotechnological renewable diesel production include Synthetic Genomics and LS9.

One major impediment to California using large quantities of Biomass-based diesel today is California's limited deep water port access to foreign sources of oils. There is also limited marine to bulk off-take storage and terminals equipped to store and blend Biomass-based diesels. Yellow grease collection infrastructure is also limited and is slowly transitioning into a biodiesel feed for some plants and may continue if prevailing high diesel prices remain.

Biomass-Based Diesels Energy Content

On average, Biomass-based fuels are assumed to have the same energy content and thus the same fuel economy as petroleum diesel, see the below Table 2 findings. The one percent higher energy content average found with Biomass-based diesels is assumed to be within the uncertainty and inherent energy content variability found in producing conventional diesel fuels today.

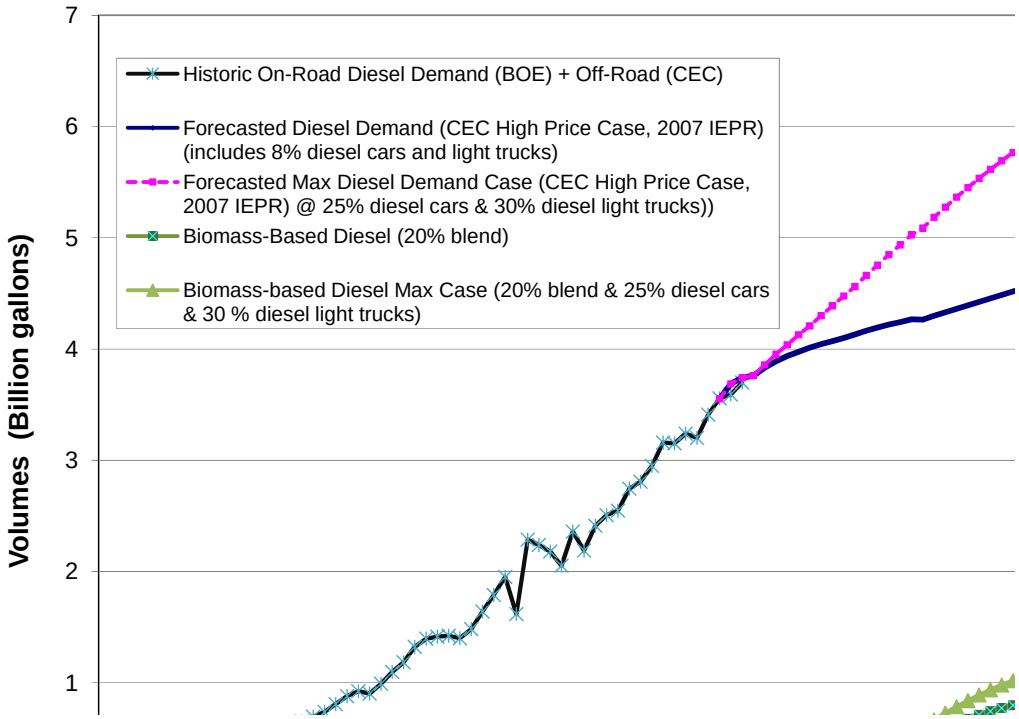
Table 2. Energy Content

Fuel	Energy Content (LHV BTUs)	Sources
Petroleum Diesel	127,460	CEC, Life Cycle Analysis (LCA)
Biodiesel	117,900	CEC, LCA
Neste Renewable Diesel	146,270	Neste
BTL Renewable Diesel	123,140	Choren
Average Biomass-based Diesel	128,833	

Forecasted California Diesel Demand

In California on- and off-road diesel fuels meet the same fuel specifications and are commingled in community terminal facilities and pipeline distributions. Therefore, a unique off-road diesel fuel does not exist until at the terminal rack where a red fuel dye is added for tax exclusion proposes. The staff assumed that most Renewable diesel volumes would leave the refinery property via common carrier pipelines and biodiesel and some other Renewable diesels may be blended later at a terminal. Staff further assumed that if a State tax incentive, or mandate were developed it would apply equally to off and on-road diesel demand. Consequently, aggregated volumes of off and on-road diesel fuel was used for the Biomass-based diesel analysis. Figure 4 Illustrates the aggregate on- and off-road future diesel fuel demand assumed for AB 118. This forecasted demand is based on the 2007 Integrated Energy Policy Report analysis, Pavley highest-fuel demand scenario. As a sensitivity study a High Diesel Demand Case was also evaluated. The High Diesel demand case was modeled to capture the possibility that California's may follow the European diesel car market penetrations for cars and light truck. For the High Diesel demand case staff assumed diesel car and truck penetrate 25, and 30 percent respectively. The Commission's base case assumed (12 percent) for cars and trucks. The Biomass-based diesel market penetrations are assumed to take on the classical "S" shape curve to reach its maximum value, after 20 years.

Figure 4 Historic & Forecast Diesel Demand and Biomass-based Diesel Supply 1950-2050



Scenario Assumptions

Biomass-based diesel scenario was evaluated to illustrate the supply and cost-effectiveness of State-funded fuel incentives at 50-cents through $2.00 per gallon, and Research and Development funding of $50 to $500 million. A low Carbon Fuel Standard Baseline scenario was also evaluated; where a 10 percent reduced carbon intensity goal was assumed. This scenario was limited to 20 percent diesel displacement

Low Carbon Fuel Standard

The Low Carbon Fuel Standard (LCFS) is envisioned to require a 10 percent reduction in carbon intensity for diesel. The AB 1007, Full Fuel Cycle Analysis finds that Renewable diesels typically have a 70 percent reduced Greenhouse Gases (GHGs) on a pure gallon basis relative to petroleum diesel. Consequently, a 15 percent blend was determined as a compliance blend, (20 percent blends would be required for Biodiesel). Biodiesel's different GHG benefit is attributed to Biodiesel's lower energy content per pure gallon relative to other Renewable diesels.

Moderate Scenario

Biomass-based diesel penetration was evaluated for a 20 percent blend for on-and off road diesel demand. Ensuring that foreign feedstock supply is eligible for state and

federal incentives was considered key for this volume. The 20 percent blend is viewed to be consistent with, a Low Carbon Fuel Standard goal of 10 percent reduced carbon intensity.

The staff assumed that existing Federal Biomass-based diesel tax credits are extended to 2050, and that the foreign feed source eligibility is maintained. Additional State incentives (50 cents to $2.00/gallon) are added to reach the higher supply volumes. Capital intensive projects like BTL and HTU plants, receive special attention to help cover their longer-term debit cost. Tax credits are developed that consider the long permitting process and ensures that they provide a true 10-year opportunity for plant owners to recover plant capital investments. Thermal Depolymerization plants using unconventional feeds are built and distribute significant Renewable diesel volumes within existing pipelines commingled with petroleum diesel. Minimal diesel infrastructure changes are made downstream of the refinery. The fuel tax incentive is applied on a percent basis per Biomass-based content - with a maximum cap of 30 percent. Biomass-based diesel market evolves into mainstream applications, blends vary in the retail dispensers between 5-30 percent throughout the state, and on average 20 percent Biomass-based content is achieved.

Staff assume that instate and foreign supply expand Biomass-based diesel production and foreign suppliers offer product to California, and meet market needs for the Pacific Rim, Europe and China. By 2050, 1-1.3 billion gallons per year of Biomass-based diesel would be demanded for the 20 percent displacement case. This demand is augmented with domestic supply when economic.

In 2005 Germany produced nearly 1 billion gallons of biodiesel from their agriculture industry. Given California's more favorable growing climate staff believe that California could match Germanys production rate if sufficient incentives were applied and after 20-years. However, in 2007 an average California farmer revenues was $2,000 per acre and current oil crop yields are 100 gallons per acre this would translate into $20/gallon for the feed stock alone.[9] This is too high a price and would require too great an incentive to be cost justified. Marginal California crop land yielding revenue at $500 per acre and using a higher yielding crop i.e., Jatropha would be considered economically competitive at $2.00 per gallon, feedstock only considered. Marginal land availability is very limited and even more limited with adequate water supply. California has a significant cattle raising industry offering a potential tallow supply for producing Biodiesel and Renewable diesel which may provide an economically attractive option in addition to the plant based oils.

Table 3 show the assumed mature, after 20 years, Biomass-based diesel supply, shown as a percent of projected California diesel demand. The three different supply responses to varying incentives for three different fuel/crude oil scenarios are shown. Judgment vetted with industry stakeholders was used to estimate supply response to

[9] Energy Commission - Mini Analysis – *Agriculture -What would a California grown fuel crop cost per gallon?* 2007.

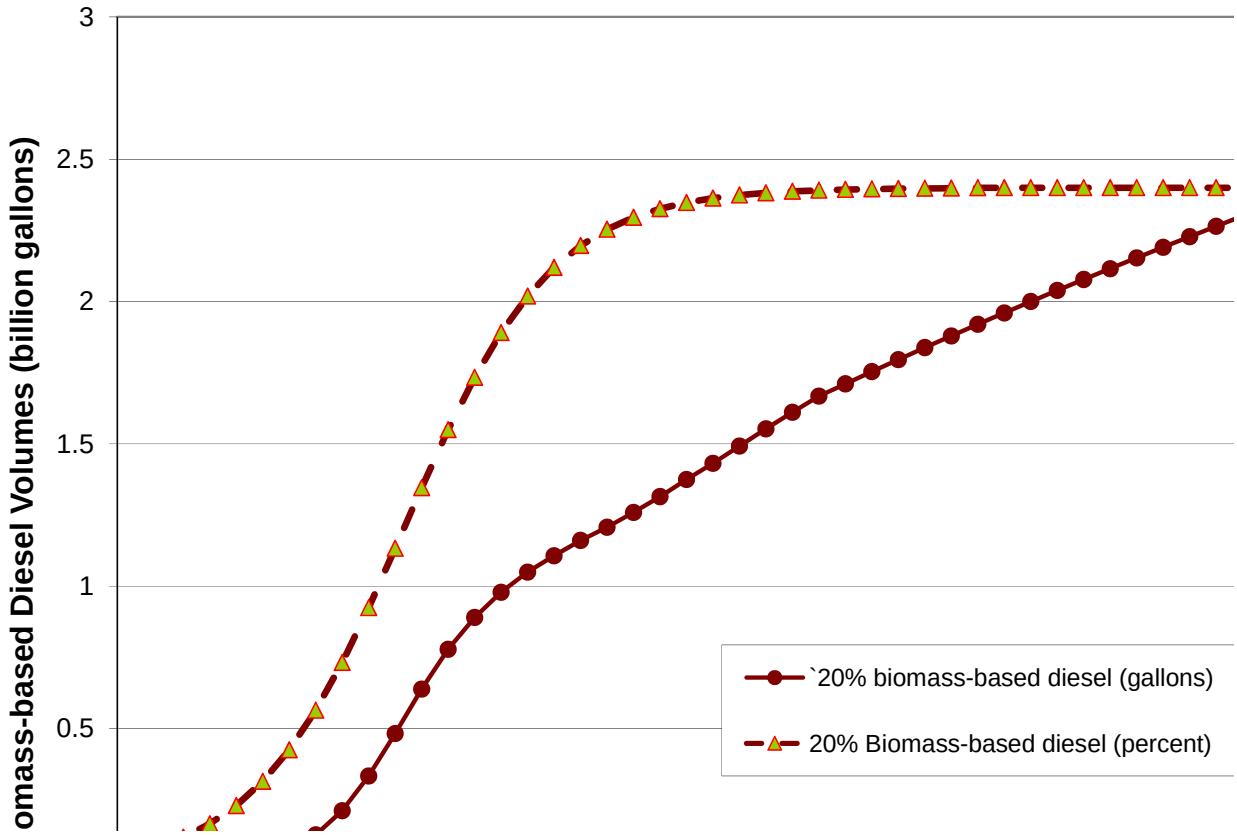
the assumed additional incentives. The response was scaled to the range in fuel price scenario. Figure 5 provides a close up view of the volumes requirements for Biomass-based diesel fuels to meet various levels of penetration over time as petroleum fuel demand continues to climb. These values are imbedded in the spread sheet model used to evaluate Biomass-based diesel fuels.

Table 3. Maximum Biomass-based Diesel Penetrations after 20-years in Response to Varying Incentives

Existing Federal Incentive	Additional State Incentive ($/gallon)	Total Incentive ($/gallon)	Estimated Biomass-Based blend potentials*
$1.00	$0.00	$1.00	6%
$1.00	$0.50	$1.50	14%
$1.00	$1.00	$2.00	24%
$1.00	$1.50	$2.50	38%
$1.00	$2.00	$3.00	52%

*Source: Biomass-based Diesel Workging Groups & Staff's - educated opinion

Figure 5 Biomass-based Diesel Penetration Assumptions



Cost Assumptions

For the incentive case staff assumed that all Biomass-based diesel fuels retailed at the same price as conventional diesel due to sufficient incentives offsetting the higher cost of the Biomass-based fuels. A Low Carbon Fuel Standard case was also evaluated where all diesel prices rise uniformly in response to an assumed industry response using 15 percent Biomass-based diesel blends. This 15 percent level was deemed sufficient to reduce the carbon intensity of diesel fuels 10 percent, based on an assumed 65 percent Full Fuel Cycle GHG reduction benefit determined for Biomass-based diesels by the Commissions Full Fuel Cycle Analyses. State funded Biomass-based diesel incentives of 50 cents; $1.00, $1.50, and $2.00 per gallon are evaluated in addition to existing federal incentives. If the State mandated Biomass-based diesel content i.e. Low Carbon Fuel Standard, or more, then all diesel fuel prices were assumed to raise commiserate with the Biomass-based diesel's incremental cost.

Table 4 shows a parametric chart of the incremental Biomass-based diesel fuels blended cost impact on price. For example, if the Biomass-based diesel fuels require a 50 cent incentive per gallon to reach 15 percent blends, (or had mandated cost of compliance of 50 cents per gallon more) then blending at 15 percent would raise the finished fuel price 7.5 cents per gallon. This higher price was used to determine Biomass-based diesels petroleum and emissions reductions cost effectiveness.

Table 4 Incremental Blended Cost of the Biomass-based Fuels

	Incremental Biomass-Based Diesel cost (¢/gallon) relative to diesel							
	10	**20**	**30**	**40**	**50**	**60**	**80**	**100**
% Blend	**Elevated Retail Fuel Prices (cents/gallon)**							
5%	0.5	1	1.5	2	2.5	3	4	5
10%	1	2	3	4	5	6	8	10
15%	1.5	3	4.5	6	7.5	9	12	15
20%	2	4	6	8	10	12	16	20
25%	2.5	5	7.5	10	12.5	15	20	25
30%	3	6	9	12	15	18	24	30

Source: Energy Commission, Emerging Fuels Office, Staff Analysis

Evaluation Metrics

Biomass-based diesel was evaluated directly from the Energy Commission's projected diesel demand assuming some percentage relationship to Biomass-based diesel volumes. A Scenario Model was constructed that allow quantifying petroleum reduction consumer and governmental cost and quantified criteria and GHG emissions. An Environmental Benefits spreadsheet was used to quantify emissions changes and to later enable cost-effectiveness analysis associated with proposed policy strategies. The

Scenario model incorporates the full fuel-cycle (GREET-derived), emission factors, cost effective, and emission calculations. The model compares the Energy Commission's diesel demand forecasts for California, with alternative fuels projected scenarios.

The current version of the model quantifies reduced transportation fuel demand, costs, and emissions; many of the input emission values were vetted through the AB 1007 Full Fuel Cycle Analysis process, with stakeholders including the California Air Resources Board staff. As such, the current version of the model represents a snapshot of technologies today and may evolve as updates and facts change over time.

Results

Figure 7 shows the Price Supply curves for Biomass-based diesel fuels which also represents Petroleum Reduction. Note the range in supply response portrayed for the varied incentive levels per milestone year. Results represent incentives starting from the Federal $1.00 incentive and additional state incentives up to a $2.00 maximum. Figure 8 shows the Greenhouse Gas Price Supply Curve for the same periods and same incentive values. Greenhouse Gas reduction attributed to biomass-based Diesels was assumed at 65 percent based on the Full Fuel Cycle Analysis final results. Incentives are reported in gasoline-gallon-equivalents for Figure 8 only. Using gasoline-gallon-equivalent values allows one to directly compare Biomass-based diesel results with gasoline reducing options.

Figure 7 2030 Biomass-based Diesel Price Supply Curve - Petroleum Reduction **(With additional State incentives @; 0, 50¢, $1.0, $1.5, $2.0, respectively)**

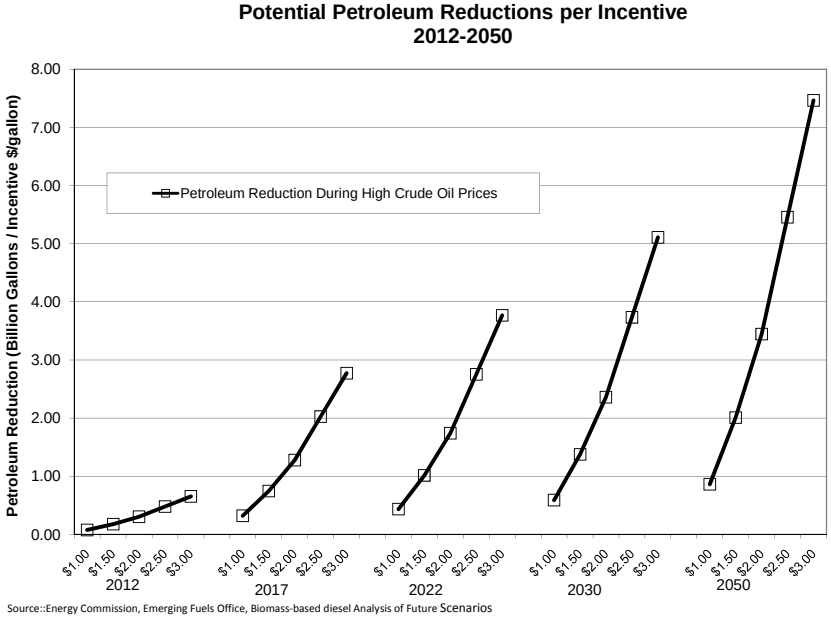


Figure 8. Biomass-based Diesel Greenhouse Gas Reduction Price Supply Curve (With additional incentives @; 0, 50¢, $1.0, $1.5, $2.0, respectively)

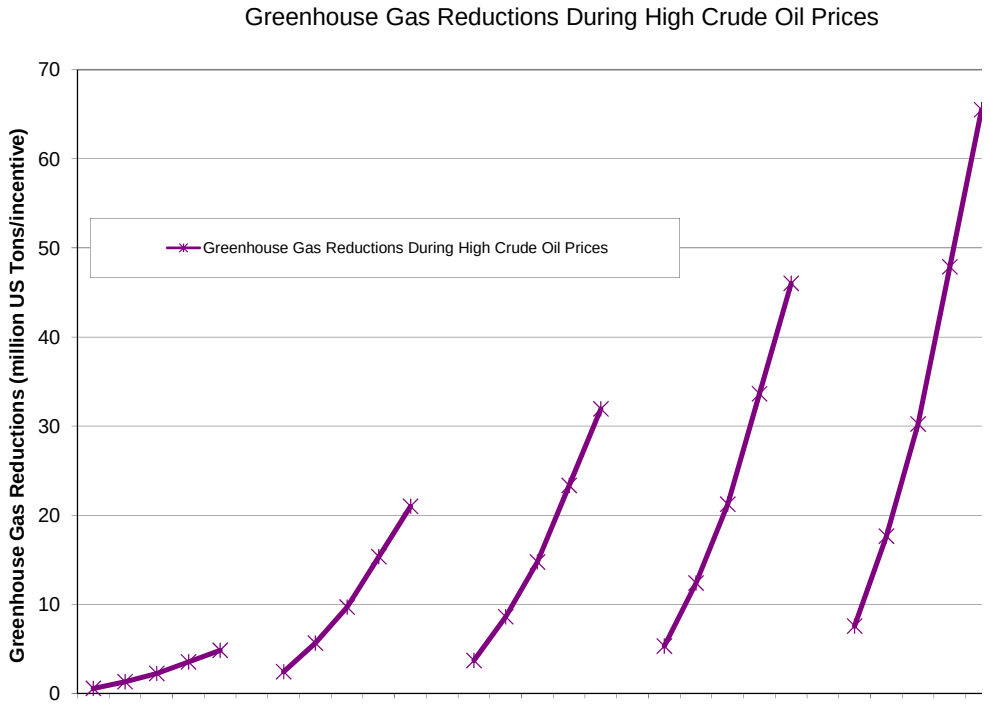


Table 5 shows the criteria emissions, toxics, greenhouse gas and petroleum reductions determined in for the volumes assumed for each milestone year. Emission values were derived from the TIAX Full Fuel Cycle Analysis applied to the volumes determined by the stated volume assumptions. GHG reductions of 65% were assumed.

Table 5 Emission and Petroleum Reductions for 20% Biomass-based Diesel Penetration

(Tons /year)

Single Year	NOx	CO	NMOG	Toxics (Weighted)	Particulate Matter	GHGs	Petroleum Reduction (billion gallons)
2012	-352	259	124	0.0	20	929,064	0.121
2017	-915	673	321	-0.1	51	2,172,124	0.283
2022	-1898	1396	666	-0.2	107	4,072,669	0.530
2030	-3530	2597	1238	-0.4	199	6,758,221	0.880
2050	-5369	3949	1883	-0.6	302	8,709,303	1.134

Source: Emerging Fuels Office, Biomass-based Diesel Analysis of Future Scenarios

Discussion of Results:

Consumer response or motivations to use Biomass-based diesel was not considered to be a limiting factor, provided that the fuel was available and at the same price as diesel/or else mandated and all diesel prices rise uniformly. An analogue is gasoline and ethanol blends used today. The scenario evaluated considered that over time most all retail diesel stations and off road fuel would contain some blend of Biomass-based diesel.

Generally, Biomass-based diesel fuels are envisioned to have greater market price volatility than crude oil due to their relative; smaller volume, longer lead time to acquire more feedstock, market competition, and localized weather conditions that affect harvest yields and thus impact price. For Biomass-based diesels to work economically, flexibility in using the fuel and incentives is envisioned. It is believed that during any year a wide range of Biomass-based diesel blends could be used based on supply and market conditions. However, on average the scenario maximum would be reached. Biomass-based diesel content variances would be dictated by the competition between; commodity prices, incentive levels, crude oil prices, and diesel retail prices.

By far the greatest uncertainty was found in the feedstock supply. Near term imported oils, augmented with in-state supply of fuel-crops, agriculture waste, and tallow are anticipated supplies. Long term algae and biomass to diesel sources are anticipated to bolster supply and enable reaching significantly higher volumes.