Scenario Analysis
For Renewable Diesel Fuels

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Abstract

This paper presents California Energy Commission (Energy Commission) staff's scenario analysis, of Renewable diesels fuel blends as replacements for and supplements to conventional petroleum-based diesel for California's transportation fuels market to the year 2050. Renewable diesel fuel penetration scenarios displacing 5 to 40 percent of expected diesel demand was evaluated. Collectively referred to as Renewable diesels, the blends include Algae Diesel, Biomass-to-liquid (BTL), Biodiesel, Hydrogen-processed vegetable oils, and thermal conversion diesel (TCD). This work was done with support and oversight from the Energy Commission's *Renewable Diesel Working Group* to ensure scenarios plausibility. This paper employs the AB 1007 Full-Fuel Cycle Analysis results and quantifies the emissions implications with the various XTL scenarios evaluated.

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 Renewable diesel fuels can significantly displace petroleum demand and to reduce emissions and are worth implementing. Staff generated price supply curves for scenarios where Renewable diesel fuels were mandated or incentivized to displace 10 to 30 percent of diesel demand by 2030 - 2050.

Key Words

Algae Diesel, Biomass-to-liquid (BTL), B5, B20, Hydrogen Thermal Depolymerized Diesel, Hydrogen Processed Vegetable oils, Gas-to-Liquid, Biomass-to-Liquid, diesel fuel blends, biodiesel, synthetic diesel fuels, synthetic diesel blends

Introduction and Overview

This paper presents California Energy Commission (Energy Commission) staff's Scenario Analysis of Renewable 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 Renewable diesels, the blends include Algae Diesel, Biodiesel, Bio-Mass-to-Liquid (BTL), Hydrogen Process Diesel (HPD) and Thermal Conversion (AKA Depolymerization) Diesel (TCD). Background, details on Renewable diesel fuels is contained in the ***Renewable Diesel Option Paper***, this paper documents the reasoning and values used to evaluate plausible future scenarios of Renewable diesels with the AB 1007 criteria. This paper incorporates the Energy Commissions' 2007 Full Fuel Cycle Analysis into the scenarios and quantifies emission and economic impacts.

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 Renewable diesel fuels have the potential to significantly displace petroleum demand and to improve emissions and are worth implementing.

Based on detailed analyses of the scenarios, staff concluded that:

- Additional government incentives and/or mandates would be necessary to encourage Renewable diesel Fuels use above 4 percent diesel displacement.
- To achieve a 5% level of diesel displacement within the next 5-7 years, incentives of $0.25 to $0.50 will be necessary, depending on wholesale diesel pricing relative to renewable diesel feedstock costs. Absent such incentives, a renewable diesel mandate would be an alternative path to achieve a 5% displacement level, which will also provide a meaningful baseline to achieve higher displacement levels in subsequent years via an incentive-based plan.
- Reducing diesel fuels' carbon intensity 10 percent exclusively by Renewable diesels can be met with 15 percent Renewable diesel blends.[1]
- By 2022 and 2050 if Renewable diesels displace 20 percent of diesel demand this would reduce 1.5 – 2.4 billion diesel gallons and 15 – 27 million tons of greenhouse gas respectively. This penetration level seems feasible at competitive incentive or mandated cost, with emissions reductions and using the existing infrastructure, while retaining performance standards for diesel vehicles and equipment.[2].
- If Renewable diesels displaced 30 percent of diesel demand in 2022 and 2050 this, would displace 2.2 – 4.3 billion petroleum gallons annually and reduce GHGs 24-47 tons.
- By 2030 and 2050 Renewable diesels (and *XTL diesels*) <u>each</u> can displace 26-33 (+/-2%) percent of diesel demand; before reducing petroleum diesel demand

[1] Assumes 70% Full Fuel Cycle GHG benefit.
[2] For the Reference Fuel Price Scenario. The Low or High Fuel Price Scenarios have lower and higher values respectively.

below 2007 levels. This represents 2.5 – 4 billion gallons per year respectively, for each fuel type. Reaching these levels may require additional incentives up to $2.00 per Renewable diesel gallon.

Recommended State Actions

Based on staffs research and analyses, staff perceives Renewable diesels to be an alternative fuel option with significant promise. Renewable 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 argument for further exploration. Consequently, staff offers the following recommendations to address the issues impeding Renewable diesels use:

1. **Near-Term (within three years): Lack of (i) bulk storage facilities sufficient to receive Renewable diesels from abroad and keep bulk Renewable diesel segregated and (ii) segregated storage and rack integration at existing diesel terminals.**
   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 XTLs Diesels[3], Renewable diesels, and petroleum supplies imported to California.
   1.2. Absent a renewable diesel blending mandate, the State Legislature should consider a tax credit for infrastructure improvement at bulk distribution terminals to support the storage and blending of renewable diesel.

2. **Near-Term: Limited Market Demand for Renewable Diesels**
   2.1. Low Carbon Fuel Standard – implementing the standard in a way that pulls Renewable diesels into market.
   2.2. 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 its use to the maximum extent practical within their existing and future programs.
   2.3. "

3. **Mid-Term: Limited In-State Renewable diesel Production.**

[3] XTLs represent Gas-to-Liquid, Coal-to-Liquids, and Petroleum Coke-to-Liquids that produce diesel fuel.

3.1. The State Legislature should establish “Floor” price protection that provides up to 25 cents per gallon excise tax exemption for Renewable diesel fuels indexed to California Diesel Rack prices relative to a composite reflective of renewable 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 renewable 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 per gallon tax increase per diesel gallon sold. Legislation must require that the fuels receiving support must be sold in California.

3.2. The state should support/endorse clean diesel cars and light trucks as a greenhouse gas emission reduction strategy, which also builds demand for Renewable diesel fuels.

4. Long-term Unconventional Renewable diesel Plants (Algae, BTL, Thermal Conversion) should be encouraged and need additional support to get established.

4.1. 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 feeds not compatible with Biodiesel and Hydro processed diesels. Staff envisions this action to assist the first BTL and Thermal Conversion plants acquire favorable financing.

4.2. The Legislature should enact a “Floor Protection” to Unconventional Renewable diesel plants to protect the first 15-years of a plant operation. The Floor would protect unconventional plants when diesel rack prices drop below $1.75 per gallon. Up to 25 cents per gallon produced would be provided in equal proportion to diesel rack prices declines below $1.75 per gallon.

4.3. Research and Demonstration funding and assistance to prospective new plants that use unconventional feeds should be developed.

Overarching Assumptions

In this document Renewable diesels fuels shall refer to any of the following; Algae, Biodiesel, BTL, Hydrogen-conversion and Thermal-conversion diesels. Reference to Biodiesel shall refer only to transesterified methyl-esters compatible with ASTM D-6751.

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

- Renewable diesels cost the refineries or blenders $1.00 – 2.00 more per gallon.
- Governmental incentives of25, 50 cents, $1.00, $1.50 and $2.00 per gallon are available, in addition to the existing federal $1.00 per gallon incentive.
- To achieve any meaningful level of diesel displacement such as 5% or greater, renewable diesel must at least be price competitive with conventional diesel

- Algae, BTL, Hydrogen process Diesel, and Thermal Conversion Diesel fuels are compatible with 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 may be produce in California post 2015 and sold as biodiesel or HPD fuels.
- Renewable fuels require 20-years to reach their maximum scenario displacement potential of 10-20 percent and 30-years to reach 30 percent displacement. To attain the full displacement potential in 20 and 30 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.
- All scenarios were evaluated assuming the three crude oil price scenarios from the Energy Information Agency (EIA) 2007 Annual Energy Outlook, adjusted to reflect California's refining and market margins.
- Renewable diesel is in limited supply currently, existing federal incentives may not be adequate to spur new production facilities or ensure significantly greater quantities beyond 10 percent levels.
- Renewable diesel allows refineries to produce more diesel fuel.
- Most Renewable diesels require capital expenditures either at bulk storage facilities or refineries, and at terminal distribution systems.
- Blends of Renewable diesel have similar fuel economy and power to that of petroleum-based diesel fuels; their energy content is similar to diesel.

Staff assumed that biodiesel up to B20 is an accepted industry standard for California diesel fuel. Staff envisioned the Algae-Diesel, TCP, hydro-processed vegetable oils and BTL sources 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 renewable fuel blend of 20 percent.

For the expected crude oil price case (See the Retail Price Discussion - Reference case) staff assumed that biodiesel use increases through 2010 reaching 5 percent (220 million gallons) statewide displacement. In the earlier years, abundant International supply is expected to provide a significant portion of renewable diesel used in California. These international supplies combined with in-state and other domestic sources should be able to meet up to 10% diesel displacement by 2017.

All Renewable diesel fuels discussed herein are assumed to be compatible with existing diesel engines without modification. There is no incremental cost related to vehicle purchase. Consumer acceptance and use of Renewable diesels was not considered an

obstacle. With Renewable diesels sufficient incentive was assumed to form its supply while enabling the same retail price as diesel or a mandate compelled its volumetric use and all prices increases uniformly. 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 $750k - $2 million [4]per terminal facility (biodiesel only). Algae-Diesel, TCP, Hydrogen Processed Vegetable oils, and BTL fuels may have additional storage cost at the refinery, or for bulk storage, but no additional infrastructure changes were assumed after the refinery.

Analytic Goal of Scenario Analysis

Various scenarios are evaluated for each alternative fuel, not to find the only "true" path, but to gather information for each path and to establish a foundation upon which to develop the combined alternative fuel plan as defined in AB 1007. Scenarios analysis also allows testing upper limits of conventional diesel displacement, i.e., 30-40 percent levels.

A fundamental analysis outcome from the Scenario Analysis is to determine the price supply curves for each alternative fuel option from 2007 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 and of; 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

Renewable 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, jatrophia, 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[5]. 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 proposes 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

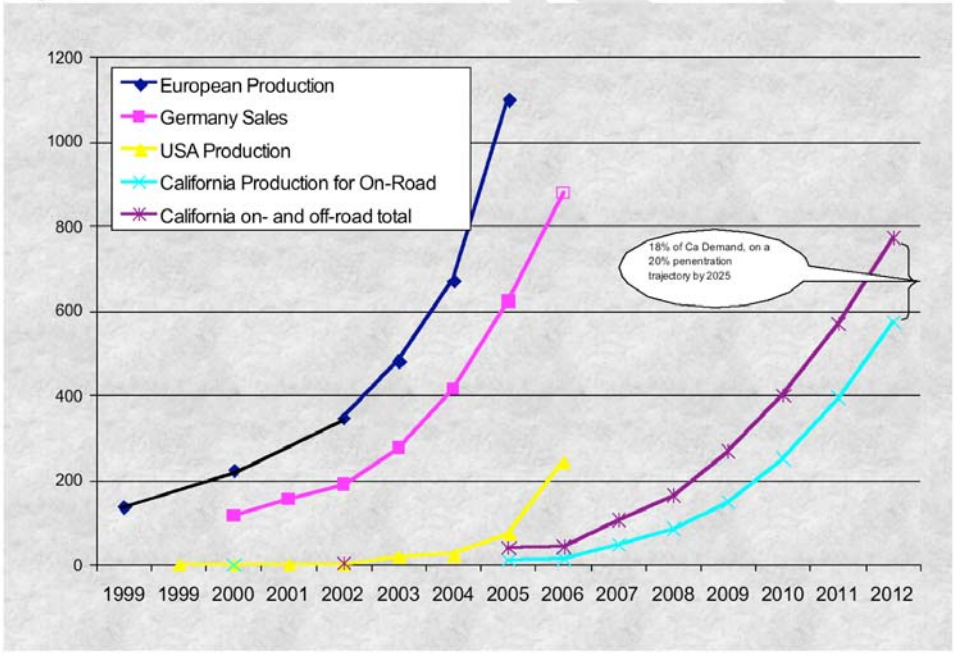
[4] Crimson Renewable comments on current pricing for a heated biodiesel tank fully integrated into a diesel rack with sequential blending. 5/25/07 e-mail.

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

in production and an illustration of how a California 20 percent Renewable diesel supply would compare relative to other countries and the nation.[6] Note: the 20 percent case is not a baseline case but a scenario that will be discussed later. California's port access to Pacific Rim countries is a major influence to significant near term supply. California is already experiencing a major upsurge in biodiesel use. In 2006 45 million gallons of biodiesel fuel was collectively use in On & Off-Road vehicles and marine vessels.[7] 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.

There is 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 a 100% from year to year, evolving greenhouse gas policies, and market prices are all in frenzied state and have not settled sufficient to enable a reliable analytical price supply analysis. Thus judgment from a body of industry stakeholders, and studying the European experience was used to estimate the price to supply response for this analysis.

Fig. 1 Europe, USA and California Biodiesel Trends



[6] 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.

[7] California Board of Equalization 2006 values.

The upper limits of domestic and world wide feedstock production was not determined but it was assumed that over 20-30 years it could grow 6 percent to meet the additional 3 billion gallons Renewable 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 Renewable diesel, could reach 800 -1,000 million gallons, based on Germany and France's biodiesel production trends from 1998 to 2005. Suggested Renewable diesel production volumes within 25-years for California were inferred by the 2006 biodiesel production from Germany and France;740 to 160 million gallons respectively.

Uncertainties and Competition for fats and oils - since 2000 there has been a strong and growing interest in using Renewable diesels world wide. 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 Renewable 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 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

Retail Price Scenarios

All AB 1007 analyses were done using three fuel price scenarios Table 1 shows the projected crude oil prices scenarios 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

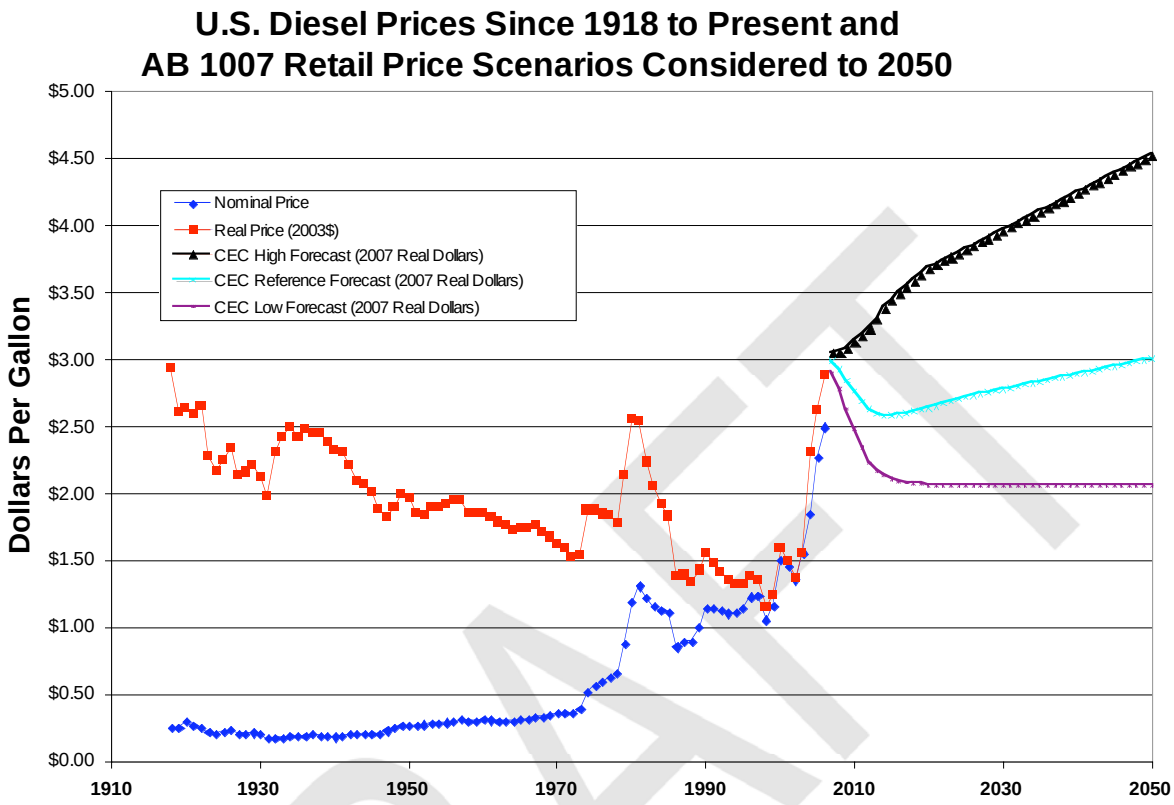
Crude Oil Price Scenario	2007	2012	2017	2022	2030	2050
High	63	70	83	90	99	121
Reference	63	49	48	51	55	64
Low	63	37	31	31	31	31

Prices are dollars per 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 to the EIA's 2007 High, Reference and Low crude oil price cases using the U.S. refiner acquisition cost of imported crude oil index. These cases use differing assumptions for crude oil prices, crude oil to rack fuel price margins, and rack price to retail price margins.

The High Diesel Retail Price Case starts at $3.05 in 2007 and increases to $4.53, by 2050. The Reference Case starts at $2.99 in 2007, dips to $2.60, in 2015 and ends at $3.01 in 2050. The Low Case starts at $2.90 in 2007 and drops to $2.07 by 2030-2050. All prices used in this work are in 2007 dollars, using the 5/30/06 Energy Commission deflator series, unless otherwise specified. 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



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. The ASTM is expected to adopt a B5 biodiesel fuel specification for use in regular diesel fuel (ASTM D-975) before 2010. The remaining Renewable diesel fuels are less mature but quickly evolving. A BTL plant is under construction in China and in Germany today, one hydrogen treated vegetable oil plant is scheduled for completion this year by Neste, and Changing World Technology has a small plant in Cartridge Missouri operating since 2002. ConocoPhillips and Tyson Foods made a public announcement to produce 175 million gallons of fuel in the USA starting in 2007 - 2008. Algae plants are not anticipate for another 10-year. Generally the Renewable diesels; lagged biodiesel supply, due to their greater cost barriers, and higher risk. The ConocoPhillips announcement and another soon to be made announcement indicate that larger-scaled commercial Renewable diesel plants are being seriously considered.

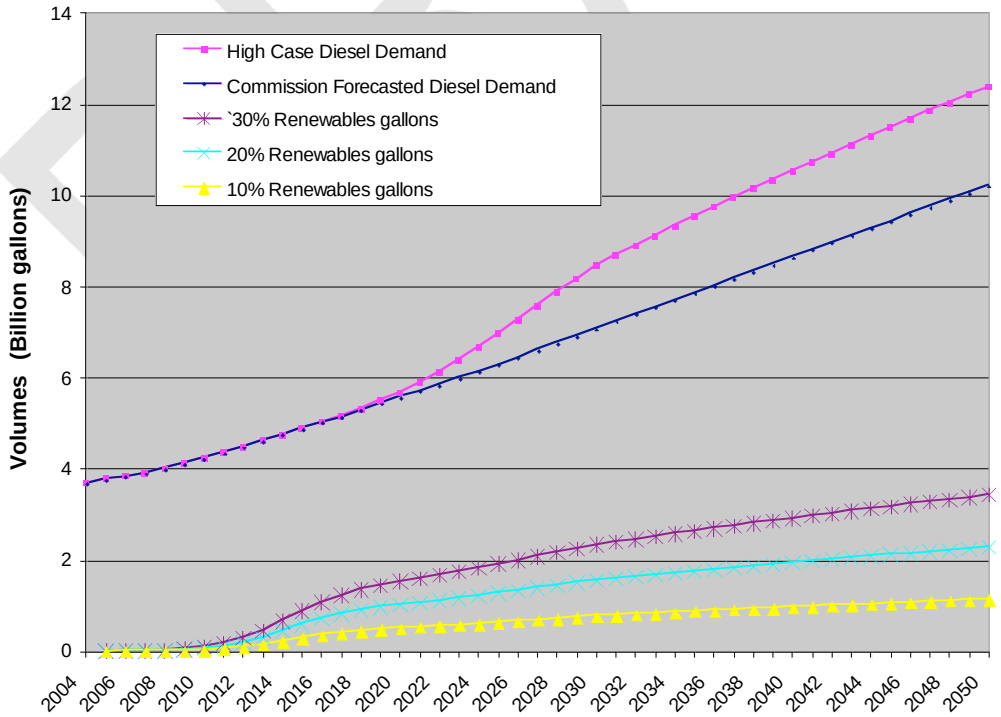
One major impediment to California using large quantities of Renewable diesel today is California's limited deep water port access to foreign sources of oils. There is also limited marine to bulk off-take storage and terminals equipped to store and blend Renewable diesels. Yellow grease collection infrastructure is also limited and is slowly

transitioning into a biodiesel feed for some plants and may continue if prevailing high diesel prices remain.

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 Renewable diesel analysis. Figure 3 Illustrates the aggregate on- and off-road future diesel fuel demand assumed. This forecasted demand is based on the 2005 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 after European diesel car market penetrations for cars and light truck assumed to penetrate 45, and 57 percent respectively. The Renewable diesel market penetrations are assumed to take on the classical “S” shape curve to reach its maximum value, after 20-30 years.

Figure 3 Diesel Demand Forecast and Renewable Diesel Supply Scenarios



Scenario Assumptions

Renewable diesel scenarios were 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. The scenarios were limited to 40 percent diesel displacement in part due to the concurrent likelihood that other non-petroleum fuels i.e., XTL fuels[8], will also be competing in the diesel market thus limiting both fuel options penetrations. It is noteworthy that a hypothetical 26-33 percent Renewable diesel and XTL diesel (Gas-to-Liquids & Coal-to-Liquids) concurrently used in 2030- 2050 respectively would still require today's diesel production levels.

Baseline Scenario

A Baseline scenario was evaluated with minimal extensions to existing laws and policies that promote Renewable diesels. The Baseline scenario assumes Renewable diesel peaks at the demand displacements is shown in Table 2. This scenario is based on the current $1.00/gallon federal biodiesel tax credit and assumes that today's expanding market continues to a 4-6 percent maximum diesel penetration. Staff assumes that the federal incentive is extended to 2020 regardless of foreign or domestic origin. No State financial incentives on fuel production basis are provided. The federal fuel tax incentive is applied on a percent basis per renewable content. No state research and development funds are provided to accelerate advanced Renewable diesel fuels. Biodiesel continues its niche-market like today nominally retailed as a B5, B20, and B99, limited terminal blending investments are made.

Low Carbon Fuel Standard

A modified Baseline Scenario was also evaluated where 15 percent blends were used to comply to the Governors Executive Order S-1-07 the Low Carbon Fuel Standard (LCFS). This LCFS is envisioned to require a 10 percent reduction in carbon intensity for transportation fuels. The 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 to Aggressive Scenarios

Various Renewable diesel penetration scenarios were evaluated assuming; 10, 20, 30, and 40 percent penetrations occur for on-and off road diesel demand. Minimal to aggressive governmental incentives were evaluated to illustrate potential cost effectiveness of using Renewable fuels at higher levels. Ensuring that foreign feedstock supply is eligible for state and federal incentives was considered key for the large volumes. Conversely, a Low Carbon Fuel Standard goal of 10 percent reduced carbon

[8] XTL Fuels is defined as Gas-to-Liquid, Coal-to-Liquids, and Petroleum-Coke-to-Liquids fuels.

intensity, a “Mandate” was also evaluated. Incentive cost assumed necessary to reach 15 percent blends were assumed to translate to higher retail prices.

The staff assumed that existing Federal Renewable 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 Delolymerization plants using unconventional feeds are built and distribute significant Renewable diesel volumes within existing pipelines commingled with petroleum diesel. No diesel infrastructure changes are made downstream of the refinery. The fuel tax incentive is applied on a percent basis per renewable content - with a maximum cap of 30 percent. Renewable diesel market evolves into a more mainstream application blends vary unnoticed between 5-30 percent throughout the state, on typically 15-20 percent renewable content is achieved. With incentives totaling above $2.00, 20-30 percent Renewable diesel content is believed possible in the High and Reference fuel price scenarios.

Staff assume that instate and foreign supply expand Renewable diesel production and foreign suppliers offer product to California, and meet market needs for the Pacific Rim, Europe and China. By 2050, 3.6-4.2 billion gallons per year of Renewable diesel would be demanded for the 30 percent displacement case, and volumes would flow to California markets with up to $2.00/gallon added incentive available. This demand is augmented with domestic supply when economic. In 2005 Germany produced nearly 1 billion gallons of biodiesel from their own 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. California has the additional advantage of a significant cattle raising industry offering a significant tallow supply potential for use biodiesel and Renewable diesel. State Research and development funds for advanced renewable fuels i.e., Algae, are evaluated at $50 and $500 million for 2010 to 2020 which further assure the penetration rates listed below in Table 2 are met.

Table 2 show the assumed mature, after 20-30 years, Renewable 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 the assumed additional incentives. The response was scaled to the range in fuel price scenario. Figure 4 illustrates the assumed Renewable diesel supply response to incentives during three different crude oil price scenarios. Figure 5 provides a close up view of the volumes requirements for Renewable 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 Renewable diesel fuels.

Table 2. Maximum Renewable Diesel Penetrations after 20-years in Response to Varying Incentives

Existing Federal Incentive	**Additional Incentive ($ / gallon)**	**Total Incentive ($ / gallon)**	**Low**	**Reference**	**High**
$1.00	**0**	**$1.00**	4%	5%	6%
$1.00	**50¢**	**$1.50**	8%	11%	14%
$1.00	**$1.00**	**$2.00**	14%	20%	24%
$1.00	**$1.50**	**$2.50**	22%	31%	38%
$1.00	**$2.00**	**$3.00**	30%	44%	52%

Figure 4 Incentives vs Diesel Fuel Displacement for the Three Fuel Price Scenarios

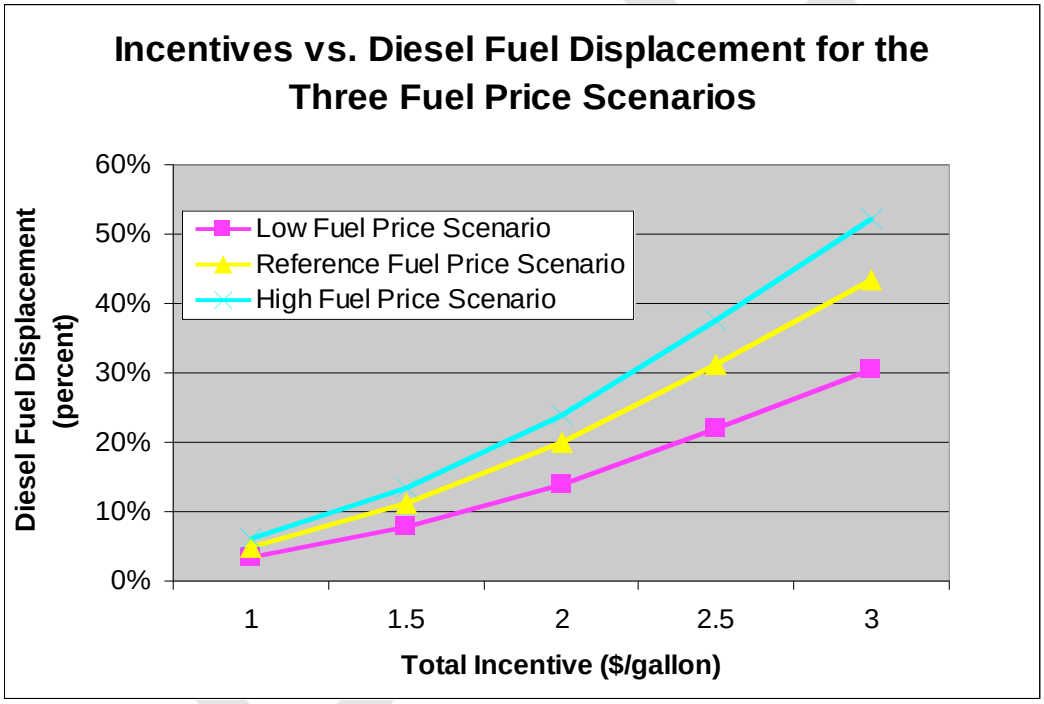
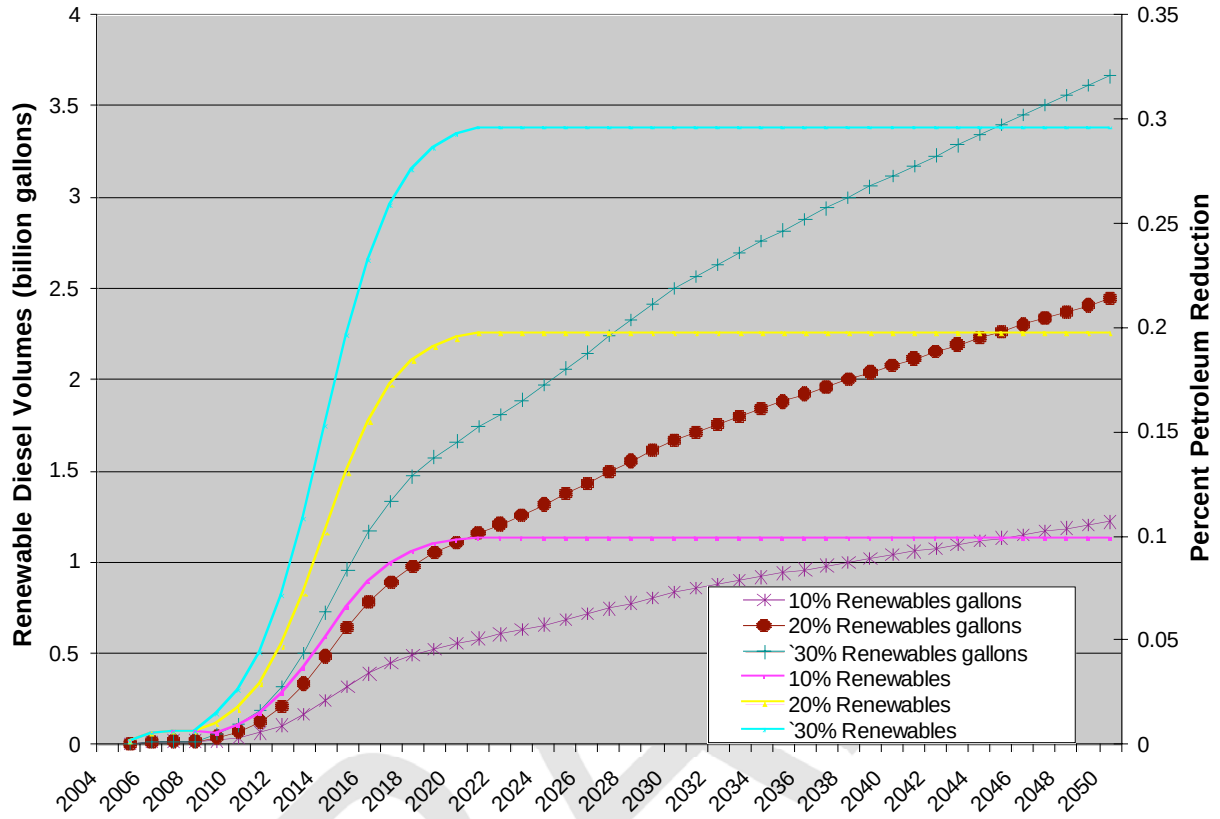


Figure 5 Renewable Diesel Penetration Assumptions



Cost Assumptions

For the incentive case staff assumed that all Renewable diesel fuels retailed at the same price as conventional diesel due to sufficient incentives offsetting the higher cost of the renewable 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 Renewable diesel blends. This 15 percent level was deemed sufficient to reduce the carbon intensity of diesel fuels 10 percent, based on an assumed 70 percent Full Fuel Cycle GHG reduction benefit determined for Renewable diesels by the Commissions Full Fuel Cycle Analyses. State funded Renewable 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 Renewable diesel content ie., Low Carbon Fuel Standard, or more , then all diesel fuel prices were assumed to raise commiserate with the Renewable diesel's incremental cost.

Table 3 shows a parametric chart of incremental Renewable diesel fuels cost blended cost impact on price. For example, if the Renewable 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 cost, and taxes were used to determine Renewable diesels petroleum and emissions reductions cost effectiveness.

Table 3. Incremental Blended Cost of the Renewable Fuels

Incremental Renewable Diesel cost (¢/gallon) relative to diesel							
10	**20**	**30**	**40**	**50**	**60**	**80**	**100**

% Blend	Elevated 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
35%	3.5	7	10.5	14	17.5	21	28	35
40%	4	8	12	16	20	24	32	40
45%	4.5	9	13.5	18	22.5	27	36	45
50%	5	10	15	20	25	30	40	50

Evaluation Metrics

Renewable diesel and XTL diesel analysis were both done directly from the Energy Commission's projected diesel demand assuming some percentage relationship to Renewable 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 Renewable diesel fuels which also represents Petroleum Reduction. Note the range in supply response portrayed for the three fuel price scenarios. 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.

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

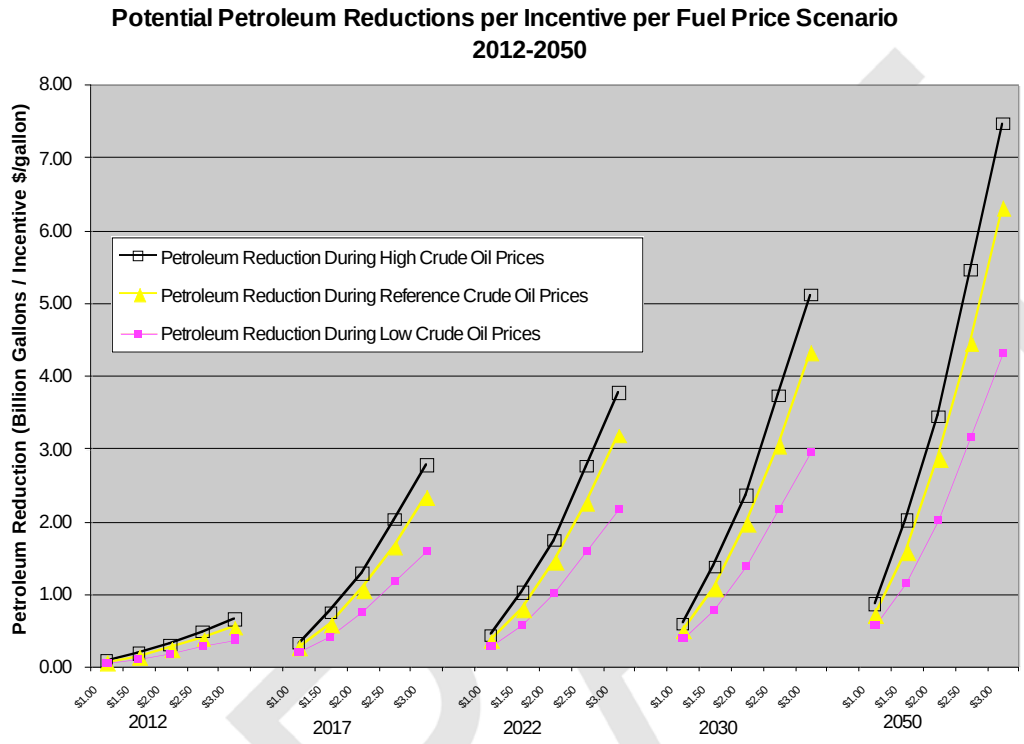


Figure 8. Renewable Diesel Greenhouse Gas Reduction Price Supply Curve (With additional incentives @; 0, 50¢, $1.0, $1.5, $2.0, respectively)

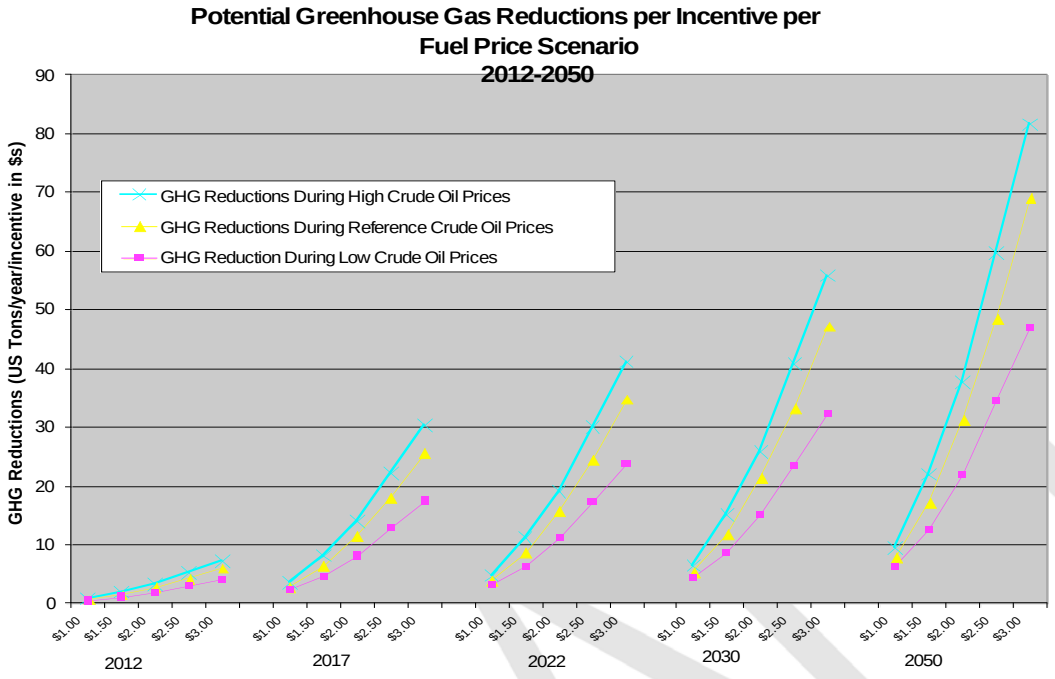


Table 4 shows the criteria emissions, toxics, greenhouse gas and petroleum reductions determined in for the volumes assumed for each milestone year. Emission values were derived from the TIAX Full Fuel Cycle Analysis applied to the volumes determined by the stated volume assumptions.

Table 4 Emission and Petroleum Reductions for 30% Renewable Diesel Penetration

(Tons/year)

Single Year	NOx	CO	NMOG	Toxics	Particulate Matter	GHGs	Petroleum Reduction (billion gallons)
2012	23	-3	-1	0	2	4,121,523	0.377
2017	99	-11	-4	-2	7	17,463,581	1.599
2022	134	-15	-6	-2	10	23,734,445	2.173
2030	182	-21	-8	-3	13	32,191,403	2.947
2050	265	-30	-12	-5	19	47,033,384	4.306

Discussion of Results:

Consumer response or motivations to use Biodiesel 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 scenarios evaluated considered that over time most all retail diesel stations and off road fuel would contain some blend of Renewable diesel.

Generally, Renewable 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 Renewable diesels to work economically, flexibility in using the fuel and incentives is envisioned. It is believed that during any year a wide range of Renewable diesel blends could be used based on supply and market conditions. However, on average the scenario maximum would be reached. Renewable 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 sources are anticipated to bolster supply and enable reaching significantly higher volumes.