CALIFORNIA
ENERGY COMMISSION

California Energy Commission
Clean Transportation Program

FINAL PROJECT REPORT

Scale Up of Biodiesel Production Facility with Reduced Carbon Intensity

Prepared for: California Energy Commission
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Gavin Newsom, Governor
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California Energy Commission

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-11-601 to provide funding opportunities for the development of new, California-based biofuel production facilities that can sustainably produce low carbon transportation fuels, or for projects that lower the carbon intensity. In response to PON-11-601, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards March 23, 2012 and the agreement was executed as ARV-11-015 on June 6, 2012.

ABSTRACT

The Scale up of Biodiesel Production Facility with Reduced Carbon Intensity Project expanded nameplate production capacity at the New Leaf Biofuel, LLC facility from 1.5 million to 5.0 million gallons per year; reduced the carbon intensity of the biodiesel from 11.76 to 10.44 grams carbon dioxide equivalent/megajoule; and increased the refining capacity of co-products.

The Project was executed in two phases. Phase 1 included purchase and installation of three processing tanks, centrifuges, pumps, heating and cooling elements, and other plant support equipment to increase production capacity. Phase 1 also included replacement of one 1991 and one 1985 Class 7 truck, with new 2013 and 2014 vehicles, for additional feedstock collection. Phase 2 included purchase and installation of equipment needed to reduce the carbon intensity of the fuel produced at the biodiesel facility. Equipment purchased and installed included upgrades to a distillation column at a partner industrial facility, to enable distillation of wet methanol from the facility. Phase 2 also included installation of various plant efficiency improvement measures including variable frequency drives, upgraded control software, piping insulation, a new energy efficient boiler, and centrifuge upgrades. Finally, Phase 2 also included upgrades to the facility's existing fuel transport, and delivery systems, and to existing feedstock collection and management practices.

New Leaf Biofuel, LLC increased the production of biodiesel at its San Diego plant and reduced the carbon intensity of the fuel by cogeneration and distillation of methanol.

Keywords: California Energy Commission, biodiesel, fuel, alternative fuels

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EXECUTIVE SUMMARY

The objective of this Project entitled "Scale up of Existing Biodiesel Plant with Reduced Carbon Intensity" (Project) was to expand the biodiesel production capacity at New Leaf Biofuel, LLC in San Diego while reducing the carbon intensity of the fuel and increasing the production of co-products. In this way, the Project supported implementation of the Renewable Fuel Standard and the Low Carbon Fuel Standard in California, in a region where the availability of biodiesel was severely limited.

New Leaf proposed to achieve the Project objectives by first increasing fuel production capacity, and then by improving carbon intensity values of the produced fuel. To achieve increased fuel production, the company proposed installation of 3 new, larger biodiesel reaction tanks, capable of increasing batch size from 1,750 gallons to 4,000 gallons, along with relevant appurtenances. To achieve improved carbon intensity values, New Leaf proposed installation of a molecular sieve to remove water from the existing facility's glycerin-derived methanol stream, thereby improving the quality of co-product methanol; by installing a new combined heat and power system that included two Capstone micro-turbines outfitted with combined heat and power capability; and through other feedstock acquisition and fuel distribution efficiencies.

The Project faced several economic and technical hurdles during its implementation. These included a substantial and unexpected change in economic conditions resulting primarily from changes in the federal Renewable Fuel Standard. Additionally, during the Project design phase, New Leaf's engineers concluded that constraints at the Project site prohibited deployment of the proposed molecular sieve, and that the proposed Capstone micro-turbines were not anticipated to provide the long-term carbon intensity reduction benefit that was originally anticipated. Therefore, in lieu of these pieces of equipment, New Leaf implemented a series of small to moderate scale upgrades at the plant that carefully targeted improving carbon intensity scores through improvements in feedstock collection and management, select efficiency related plant upgrades, and modifications to the facility's fuel transport and delivery processes. In place of the molecular sieve, New Leaf partnered with an industrial facility, located approximately 100 miles from the Project site, to make improvements to an existing distillation column, which has since been used for the removal of water from one of the facility's methane streams.

Despite these hurdles, New Leaf was able to achieve its primary objectives by (1) successfully expanding nameplate production capacity at the biofuels facility, from 1.5 million gallons per year to 5.0 million gallons per year; (2) reducing the carbon intensity value of biodiesel produced by the facility from 11.76 to 10.44 grams carbon dioxide equivalent/megajoule; and (3) increasing production of saleable co-products glycerin and dewatered methanol. Project implementation has allowed a 39 percent reduction in electricity use and a 39 percent reduction in water use by the Project, while simultaneously supporting an increase in employment of approximately 15 percent at the facility and a significant increase in economic activity in the Disadvantaged Area Community in which the facility is located.

New Leaf is pleased with the results of the Project, which successfully achieved the goals and objectives identified in the initial proposal to the CEC. The Project's success could not have been achieved without a highly committed Project team and CEC support and cooperation. The Project's ability to remain on schedule for actual anticipated biodiesel production rates was primarily hindered by unexpected requirements and economic conditions, resulting from regulatory changes in policies that support alternative fuels.[1] However, other aspects of the Project were completed within the allotted project timeframe.

Drawing on the Project's successful carbon intensity reduction strategy, New Leaf will pursue a new California Air Resources Board Low Carbon Fuel Standard pathway based on these improvements. Plans are being drawn for a scale-up to 8 million gallons per year in 2017. New Leaf recommends that future upgrade projects include flexibility to substitute equipment or processes within the grant framework, to the extent that it can be substantiated that such a substitution would achieve the same goals and objectives originally included in the Project, and also provide additional process, economic, or environmental benefit.

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[1] Production has not yet reached 5 million gallons per year; however, all physical equipment needed meet that production rate is installed and functioning and the facility is ramping up production on a regular basis consistent with market conditions.

CHAPTER 1: Introduction

1.1 The Recipient

New Leaf Biofuel, LLC (New Leaf), established in 2006, operates a small biodiesel production facility in San Diego that operates 24 hours per day, 365 days per year. The Company is a California Disadvantaged Business Enterprise that is 70 percent owned by women. New Leaf is an active and respected member of the San Diego business community, with the plant located within an Enterprise Zone. New Leaf has been recognized by the California Center for Sustainable Energy with a SANDEE Award for Excellence in Transportation, and by the Air Pollution Control District with its Blue-Sky Award.

The fuel feedstock is a combination of waste vegetable oil collected along New Leaf's own collection route including approximately 1500 restaurants, and waste vegetable oil purchased from third parties doing business in the Southern California region. The company also operates a successful grease trap cleaning business. This endeavor provides added value to New Leaf's restaurant customers, secures longevity of feedstock contracts, and grants New Leaf access to trap grease (brown grease). Brown grease is a small portion of the biodiesel feedstock.

The Company has earned a reputation for producing a high-quality biodiesel fuel that consistently exceeds American Society of Testing and Measurement standards. New Leaf sells its produced biodiesel to fleets and diesel fuel blenders in the greater San Diego area. It had a maximum production capacity of about 1.5 million gallons in 2012 when this project began. Figure 1 shows the headquarters production building entrance in San Diego, CA.

Figure 1: New Leaf Biofuel, LLC Headquarters, San Diego, CA.

Source: New Leaf Biofuel, LLC

1.2 Project Purpose, Goals, and Objectives

New Leaf implemented the "Scale Up of Biodiesel Production Facility with Reduced Carbon Intensity Project" (Project), with funding support from the CEC, to support California's Low Carbon Fuel Standard. The Project specifically targeted a region where, historically, the availability of biodiesel has been severely limited, San Diego County.

The overarching intent of the Project was to expand the capacity of New Leaf's then-existing biodiesel facility while reducing the carbon intensity (CI) of New Leaf's fuel. New Leaf's plan was to achieve this goal by installing additional processing tanks and supportive equipment, cogeneration, and methanol recovery.

The Project sought to accomplish the following objectives:

1. Increase the production capacity of biodiesel from waste oils, at a facility that had already demonstrated commercial viability, from 1.5 to 5 million gallons per year (Phase 1)
2. Reduce the CI of the biodiesel fuel, from 11.76[2] to 10.44
    a. Cogeneration
    b. Molecular sieve technology to dewater methanol from co-product
3. Increase refining capacity of co-products.

1.3 Project Overview

The Project included upgrades to increase production capacity and reduce CI.

1.3.1 Increased Production Capacity

The plant upgrade involved engineering, permitting and installation of biodiesel processing equipment tied into New Leaf's previously existing facility, to increase production capacity. New equipment that was installed included three larger, yet functionally identical, skid-mounted processing tanks, and support equipment such as piping, pumps, valves, controls, centrifuge, heating/cooling elements, etc. The new processing tanks are capable of producing 4000-gallon batches (previous tanks were limited to 1750-gallon batches). Additional software coding was required to integrate new processing vessels into existing control system.

These upgrades were sufficient to increase nameplate production capacity of the plant from 1.5 million gallons per year to 5.0 million gallons per year, while also increasing co-product generation rates to 1.0 million gallons per year, based on a feedstock of primarily waste vegetable oil, along with some brown grease.

1.3.2 Reduced Carbon Intensity

To reduce the CI of the biodiesel fuel produced at the plant, New Leaf initially proposed to incorporate two improved processing methods: 1) a combined heat and power system and 2) improved methanol recovery.

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[2] Table 4. Energy Densities of LCFS Fuels and Blendstocks. BIOD003 from LCFS http://www.arb.ca.gov/fuels/lcfs/CleanFinalRegOrder112612.pdf

The original plan was for New Leaf to install two 65-kilowatt (kW) Capstone brand, cogeneration-enabled micro-turbines that would have provided 100 percent of the power and 50 percent of the heat for the production plant. New Leaf also initially proposed to install an improved methanol recovery system (a molecular sieve) on site, to dewater methanol from produced glycerin (6 percent water). However, based on engineering design guidance provided to New Leaf during the project design phase, these proposed upgrades were found to be non-optimal for the facility. Instead, a series of other facility upgrades were completed which, based on California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET) modeling, were sufficient to reduce CI from 11.76 to 10.44 grams of carbon dioxide equivalent (CO_2e)/ megajoule (MJ). Details of the upgrades that were completed are provided in Section 2.0.

1.3.3 Estimated Timeline

In its proposal, New Leaf estimated that the Project would be complete within 8 months of Project funding, by June 2013. In actuality, the Project was commissioned for its capacity production of 5.0 million gallons per year in May 2013. However, due to unanticipated economic constraints, the facility did not produce at full capacity during the project timeframe. The facility is expected to produce at full capacity in 2016.

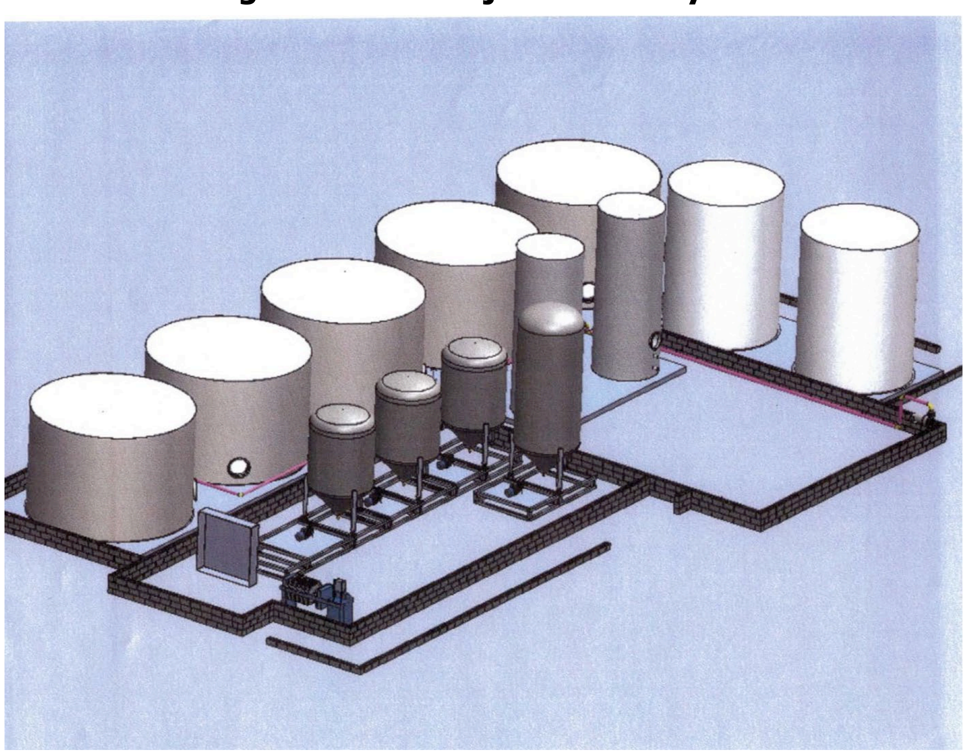
CHAPTER 2: Project Implementation

2.1 Background on Existing Production Plant

The existing biodiesel processing technology was a series of skid-mounted American Society of Mechanical Engineers certified pressure vessels and supporting equipment, originally supplied by a European manufacturer of biodiesel processing equipment, Ageratec Biodiesel Solutions, now owned by Alfa Laval. However, these had been significantly re-engineered by New Leaf over five years (Figure 2). The American Society of Mechanical Engineers pressure vessels were designed to optimize biodiesel production in a batch process. The process uses acid esterification as a pretreatment to allow flexibility of feedstocks and a standard two-step transesterification, followed by a proprietary washing technique that minimizes water usage. All co-product removed during the reactionary phases is sent through a refining process to separate glycerin, methanol, material organic non-glycerol and water. The methanol was unfit for reuse in the biodiesel process due to the high moisture content. As a result, this useful co-product, 97,000 gallons per year of wet methanol, was sold at a heavily discounted rate and transported out of state.

New Leaf's entire plant was and continues to be automated using an advanced Mitsubishi programmable logic controller (PLC) system. All process parameters are controlled and monitored remotely including all valve positions, pump frequencies, temperatures, pressures and chemical dosing by mass by Mitsubishi's supervisory control and data acquisition software. This sophisticated automation system contributes to repetitive quality control and improves plant safety due to its remote capabilities.

Figure 2: Pre-Project Plant Layout



Source: New Leaf Biofuel, LLC

Prior to Project implementation, New Leaf generated two to three batches of biodiesel per day, depending on the quality of the incoming feedstock. With the tank sizes existing at that time (ranging between 800 and 4300 gallons), the finished product batch size was approximately 1750 gallons. In 2011, the plant produced about 1.5 million gallons of biodiesel. For a discussion of pre-versus post-Project fuel production rates, please refer to Section 3.1.3.

2.2 Phase 1

Phase 1 of the Project involved the engineering, permitting and installation of equipment into New Leaf's current facility infrastructure to increase biodiesel and coproduct production capacity.

2.2.1 Phase 1 Technology Upgrades

The plant upgrade involved the engineering, permitting and installation of equipment into New Leaf's existing facility infrastructure. The new equipment, including three 5600-gallon, skid-mounted processing tanks and support equipment such as piping, pumps, valves, controls, centrifuge and heating/cooling elements, immediately increased production capacity. The added volume both increased the batch size and increased the number of batches possible per day because it eliminated a previous bottleneck that existed in the washing step. Two of the smaller processing tanks were modified to improve plant efficiency and co-product refining. Plant engineers wrote additional code to integrate the new processing vessels into the existing PLC control system.

2.2.2 Implementation of Phase I

New Leaf Biofuel acquired an updated air quality permit from the San Diego Air Pollution Control District (acquired April 17, 2013), a fire permit for biodiesel plant operation (acquired October 2, 2014), and a structural permit for the natural gas boiler (acquired December 18, 2013).

Construction for Phase 1 was limited; New Leaf served as the owner/contractor, with help from some minor subcontractors. The first construction step in Phase 1, fabricating the frames for 3 biodiesel reactors, was performed offsite by NorthStar Propeller. NorthStar delivered the three new vessels by truck in late summer and fall of 2012 (see Figure 3 below).

Figure 3: Tanks Arrive Via Truck

Source: New Leaf Biofuel, LLC

Then New Leaf and NorthStar removed existing roof beams and used a crane to hoist the new reactors off of the truck and into the facility (see Figure 4 below).

Figure 4: Tanks Hoisted into Processing Room Through Roof

Source: New Leaf Biofuel, LLC

After re-installation of the roof beams and roof, the team installed the new reactors, anchoring them to the existing concrete slab (see Figure 5 below).

Figure 5: Tanks K7 and K8 in Place

Source: New Leaf Biofuel, LLC

Supporting equipment, including pumps, agitators, variable frequency devices, valves, and gauges were installed, as was pipe connecting reactors to raw material and product tanks. Each vessel was connected into the existing PLC (see Figure 6 below).

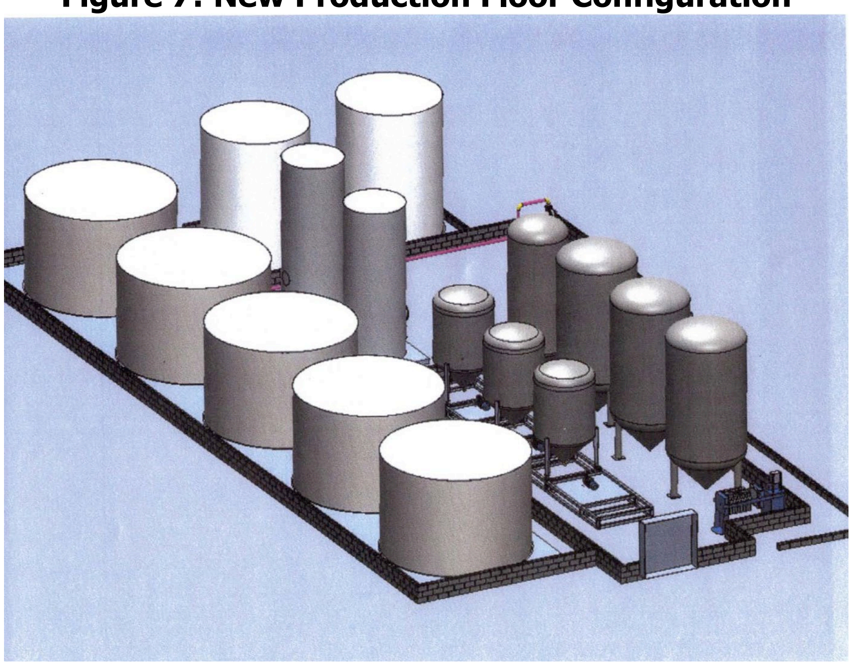
The team fabricated an exhaust manifold and fit and installed associated centrifuges and exhaust ducting. Hot water and fuel piping were installed, along with shutoff valves and fittings. The team installed a filter press and a methylate mix tank. The PLC and cooling system were relocated to the warehouse, and the cooling system plumbing was upgraded. A new vacuum pump was installed, along with instrumentation and electrical connections to the entire new system, as warranted. A soft starter was also installed on the air compressor. Pipes were insulated. Underwriters Laboratories certification was ordered to prepare for certification under International Organization for Standardization 9001, which will confirm adherence to international industry performance standards.

Commissioning began for each tank as the piping was complete. All three reactors were in commercial operation by May 2013. Software integration was slower than expected due to an unexpected leave of absence by New Leaf's chief engineer. During the second half of 2013, the reactors operated in only a semi-automated state. This resulted in less than optimal biodiesel production. However, the reactors continued running nonetheless, and New Leaf submitted a written Notice of Commercial Operation for Phase 1 in August 2013. In December of 2013, the software integration was finally completed, and the reactors were running optimally. At that time, New Leaf submitted a Summary Report of Software Update Completion to the CEC. Figure 7 shows the new floor configuration.

Figure 6: All Three Reactors in Place and Piped in

Source: New Leaf Biofuel, LLC

Figure 7: New Production Floor Configuration



Source: New Leaf Biofuel, LLC

2.3 Phase 2

Phase 2 of the Project involved installation, implementation, and operation of CI score improvements to the plant. The methanol dewatering process, replacement of existing boilers, plus grid electricity supply with combined heat and power, were proposed as targets for CI improvement under the Project.

2.3.1 Pre-Existing Plant

The existing plant, prior to implementation of the Project, did not include combined heat and power (cogeneration). Heat was provided by a boiler, which was originally proposed to be upgraded to cogeneration under the Project. Electric power came from the utility company.

The existing plant design included recovery of methanol during the acid esterification and transesterification steps of the biodiesel production process. It also recovered any remaining methanol from co-product glycerin. However, the methanol recovered from the glycerin, then and now, includes 6 percent water. The methanol's high-water content had rendered it unfit for re-use in the biodiesel process, and therefore the wet methanol was being transported offsite for other uses.

2.3.2 Adjustments to Proposed Carbon Intensity Improvements

New Leaf had originally proposed to reduce the CI of the biodiesel produced at its existing facility by installing a cogeneration system and by improving the facility's methanol recovery process. The proposed cogeneration system would have included two Capstone Turbine Corporation (a California manufacturer), 65 kW micro-turbine cogeneration units, to be powered by natural gas. The cogeneration system was to generate power for virtually all onsite electrical equipment including biodiesel processors, support equipment, laboratory and the office, while also capturing exhaust heat from the turbines to provide 50 percent of the facility's heat load. The balance of heat demand was to come from existing boilers powered by biodiesel byproducts. However, during the engineering and design phase of the Project, New Leaf's team of engineers determined that the Capstone technology would not provide significant CI benefits in the long term (See Engineering – Phase 2 Report submitted May 2015, attached as Appendix A).

The Project's proposed methanol recovery improvements targeted the methanol that is scrubbed from the facility's glycerin coproduct. In order for the glycerin to be saleable, it must contain less than 1 percent methanol. Therefore, as part of its glycerin refining process, New Leaf removes methanol and other impurities from the glycerin. The recovered methanol has a high-water content (approximately 6 percent) and therefore is unfit for reuse in the biodiesel process. Biodiesel producers traditionally remove moisture from methanol by distillation. However, this option was thought to be cost prohibitive for a small producer like New Leaf. As a result, New Leaf had historically sold its wet methanol at a heavily discounted rate for use in other industries. At an anticipated production capacity of 5 million gallons of biodiesel production per year, New Leaf could recover approximately 223,000 gallons per year of wet methanol from the glycerin. As a lower cost alternative to distillation, New Leaf's engineer had planned to build and install a molecular sieve to dry the recovered methanol to make it fit for biodiesel processing. This equipment was proposed to accomplish the dual goals of reducing New Leaf's costs to produce biodiesel by increasing the volume of recovered methanol, while also reducing the carbon intensity of the biodiesel. This part of the Project called for a 300-

gallon capacity packed bed vessel, controls such as valves, temperature and pressure controllers, and pumps.

However, upon further research, New Leaf engineers determined that the plant footprint near downtown San Diego would not support the original design for the molecular sieve equipment. As a result, New Leaf changed course and began searching for an alternative to dehydrate the methanol. New Leaf ultimately formed a relationship with a manufacturing plant, located approximately 100 miles from the Project site that had an existing distillation column that would be capable of distilling methanol with some equipment and software modifications. The two companies entered into a contract whereby New Leaf was to invest capital to upgrade the equipment and would be repaid over time through discounts for services provided in processing New Leaf's co-products.

2.3.3 Actual Carbon Intensity Improvements

New Leaf implemented many process and operations changes in order to reduce CI to 10.44 g CO_2e/MJ without installation of the originally proposed cogeneration turbine units.

Coproduct Processing

- Methanol processing.

Feedstock Collection and Management

- **Truck Replacement:** Replaced two Class-7 trucks (model years 1985 and 1991) with new, higher efficiency 2013 and 2014 vehicles, both of which include a post 2010 emission control system; both new vehicles have been operating on road since January, 2015, using solely biodiesel, with an estimated fuel efficiency of 7 miles per gallon.
- **Tank Installation:** Installed 10,000-gallon tanks to store raw cooking oil on-site, reducing transport effort/emissions.
- **Feedstock Procurement Upgrades:** New equipment installed under the Project allowed Baker Commodities Inc. (a feedstock partner) to divert 40,000 of used cooking oil per month to the New Leaf Facility, rather than transporting it from San Diego County to Los Angeles. This reduced round trip transportation of feedstock from 600 miles to 30 miles per month (95 percent reduction).

Plant Upgrades

- **New Reactors:** Installed new jacketed reactors in the processing room. This eliminated the need for external heat exchangers, and substantially reduced the amount of heat needed to bring the reactors to the required processing temperature (completed under Phase 1).
- **Variable Frequency Drives:** Installed load leveling variable frequency devices and associated control software.
- **Upgraded Control Software:** Completed software/control upgrades that optimized facility production using integrated control software.
- **Piping Insulation:** Installed high insulation piping for all process heating and cooling lines, thereby reducing heat loss and energy consumption.
- **New Energy Efficient Boiler:** Installed a new 2.2 one million British thermal unit (BTU)/hour natural gas boiler, which replaced two old, low efficiency boilers.
- **Centrifuge Upgrade:** New Leaf installed a larger centrifuge in the oil receiving area, allowing more efficient processing of raw cooking oil.

Fuel Transport and Delivery

- **Reduced Transport Distance:** Expansion of the New Leaf facility allowed Pilot Truck to source its biodiesel locally, displacing transport of up to 100,000 gallons per month of biodiesel from Los Angeles and reducing round trip travel from 200 miles to 32 miles per trip (84 percent reduction).

2.3.4 Implementation

New Leaf began Phase 2 in the summer of 2013. The first step in Phase 2 was to permit and install piping to connect to an existing natural gas line near the property, including demolition of existing concrete, trenching, installation of a 3-inch natural gas line, and backfilling.

Construction for Phase 2 was minor. New Leaf served as the owner/contractor, with help from some minor subcontractors. Other Phase 2 elements included removal of the old and installation of a new boiler and heat exchanger on the existing concrete pad, additional natural gas and hot water piping, electricity supply, and feed oil installation tank, and insulation of piping.

New Leaf engaged electrical contractor Gammill Electric to perform the initial pipeline installation work. Trenching and connections were completed in June of 2013. In August of 2013, New Leaf began searching for a new contractor to complete the remainder of Phase 2, and ultimately decided to engage San Diego based Solana Energy to manage the Project. Solana Energy takes a holistic approach to its projects, ensuring that a property owner is taking advantage of every opportunity to improve efficiency and reduce energy use. New Leaf and Solana signed a contract for Phase 2 in March of 2014 and began working on engaging contractors for the Project. Solana's scope of work included engineering, construction, public relations, and energy incentives.

New Leaf later initiated work with contractors including Accuchem and Western States Controls to upgrade the existing methanol dehydration equipment. Permitting for the methanol facility is managed separately by the contracted partner where methane distillation now occurs. Upgrades involved installation of a mass flow meter, installation of a new automation system, and the purchase of several decommissioned railcars for storage of coproducts.

Since completing Phase 2, New Leaf submitted a Notice of Commercial Operation Phase 2 to the CEC on June 10, 2015.

CHAPTER 3: Project Evaluation

This chapter includes an assessment of the success of the Project as measured by the degree to which goals and objectives were achieved. The baseline period ran from December 2012 through February 2013. Six months of operational data were collected January through June 2015 in support of the Project. All data analysis requested in Task 7 of the Project's Scope of Work is presented here, too.

3.1 Time Operating

The biorefinery could run 24 hours a day and 7 days a week, with some time closed for holidays. Time operating includes up and down time over the six-month data collection period. Results indicate that monthly operating hours ranged from 58 percent in January 2015 to 81 percent in March 2015, for an overall total of 72 percent up time. Please see Table 1 for additional detail.

Table 1: Facility Operating Time, January through June 2015

Month	Monthly Operating Hours	Monthly Down Hours	Percent Operational
January	390	279	58%
February	401	203	66%
March	545	125	81%
April	548	100	85%
May	432	237	65%
June	483	165	74%
Total	2799	1109	72%

Source: New Leaf Biofuel, LLC

3.2 Feedstock Conversion Efficiency 92.2 Percent

The feedstock was primarily waste vegetable oil; this estimate ignores the brown grease blended in. Feedstock conversion efficiency considers the energy content of product fuel in comparison to the energy content of incoming feedstock. Energy density of 130.6 MJ/gallon for waste vegetable oil feedstock, 68.2 MJ/gallon for methanol, 134.47 MJ/gallon for diesel, and 126.1 MJ/gallon for pure biodiesel are facts from the Low Carbon Fuel Standard (LCFS) Final Regulation Order 112612, p. 49. During the facility's demonstration period 1,208,131 gallons of waste vegetable oil and 245,248 gallons of methanol, supported by the energy of 7,370 gallons of diesel produced 1,283,774 gallons of biodiesel. The total conversion efficiency of New Leaf's process was 92.2 percent.

3.3 National Market Downturn

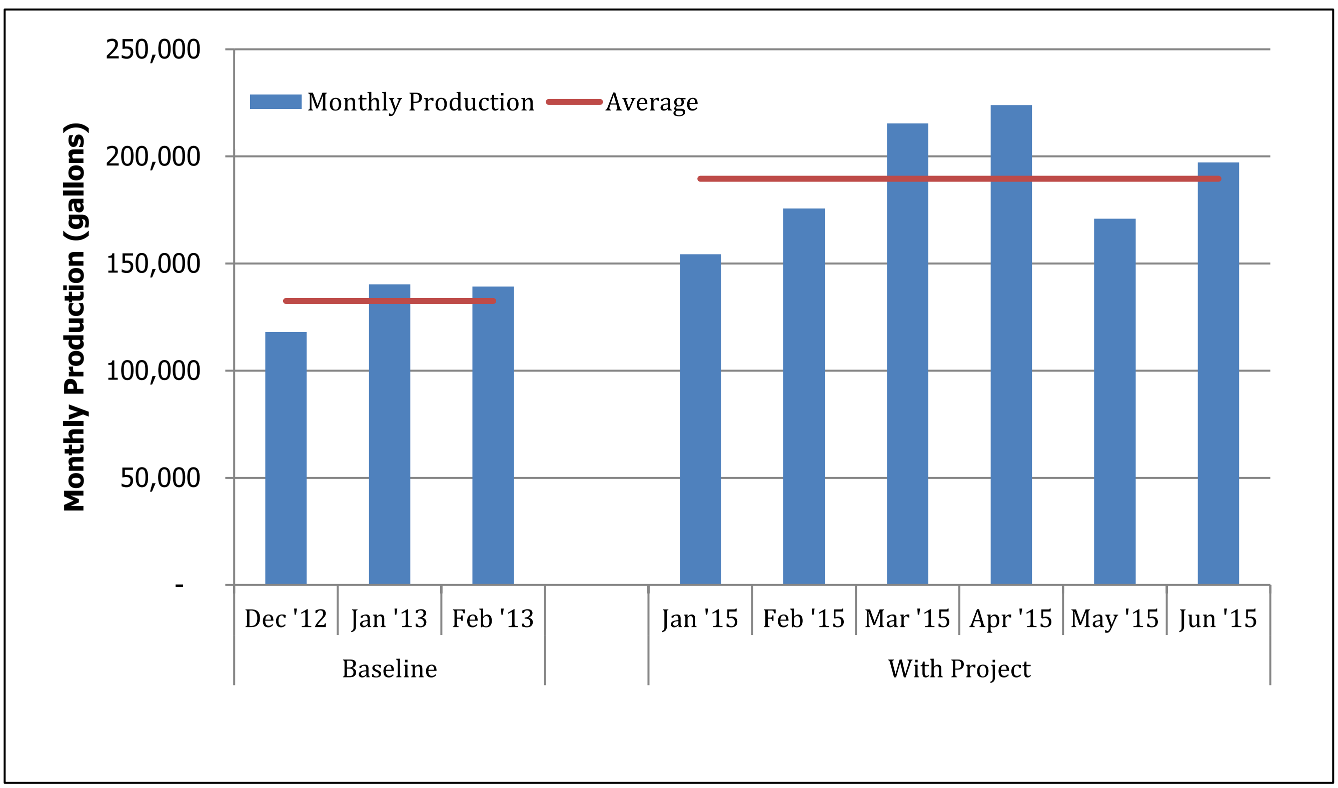
The Project achieved its objective of increasing production capacity to five million gallons per year in May 2013. Actual facility production has lagged behind that figure due to poor market conditions. Briefly, the Federal Biodiesel Personal Income Tax Incentive expired at the end of 2013, discouraging our investors. More importantly, the US Environmental Protection Agency released a reduced biodiesel Volume Obligation in late 2013, severely increasing price competition. The reduced possibility of selling for renewable identification numbers continued with the draft proposal that held the federal Biomass-Based Diesel portion of the Renewable Fuel Standard at 1.28 billion gallons for 2014 and 2015, the same volume as 2013. The biodiesel industry produced nearly 2 billion gallons of biodiesel in 2013, much of which would be carried over to 2014 by Obligated Parties. When the market for biodiesel dropped off, New Leaf's newly upgraded plant was producing each gallon of fuel at a financial loss. New Leaf had to raise prices in order to cover costs, which caused many customers to discontinue use of biodiesel in favor of cheaper petroleum diesel. In order to ensure that the Company could ride out the poor market conditions, New Leaf reduced expenses by conducting a layoff, and scaled back production of biodiesel to preserve cash in spring 2014.

During late 2014 and into 2015, what appear to be steadily improving market conditions are allowing New Leaf to again increase production. In this way, the company has achieved an approximately 250,000 gallons per year annualized increase in production capacity so far in 2015, in comparison to 2014. New Leaf anticipates continued improvement in economic and fuel production performance.

3.4 Biodiesel Production

Figure 8 shows monthly and average monthly biodiesel production during January through June 2015. Production rates ranged from a minimum of 154,000 gallons in January 2015, to a peak of nearly 224,000 gallons in April 2015, for an average monthly production rate of nearly 190,000 gallons (equivalent to 2.27 million gallons per year). In comparison the facility produced an average of 133,000 gallons per month during the baseline period (equivalent to 1.59 million gallons per year).

Figure 8: Monthly and Average Biodiesel Production: January to June 2015 Versus Baseline



Source: New Leaf Biofuel, LLC

3.5 Petroleum Fuel Displaced Annually

At the end of the demonstration period, the Project had achieved an incremental increase in biodiesel production of 685,000 gallons per year, which is equivalent to a petroleum energy displacement of approximately 630,000 gallons per year of ultra-low sulfur diesel.

3.6 Biodiesel Quality

All biodiesel produced by New Leaf undergoes stringent quality control process conducted at an on-site laboratory. All fuel is produced in accordance with American Society for Testing and Materials standards, and also of sufficient quality to meet strict specifications maintained by Chevron and Petro-Diamond for certified suppliers. New Leaf continues to maintain its solid reputation as a producer of consistently high-quality biodiesel.

3.7 Estimate of Carbon Intensity

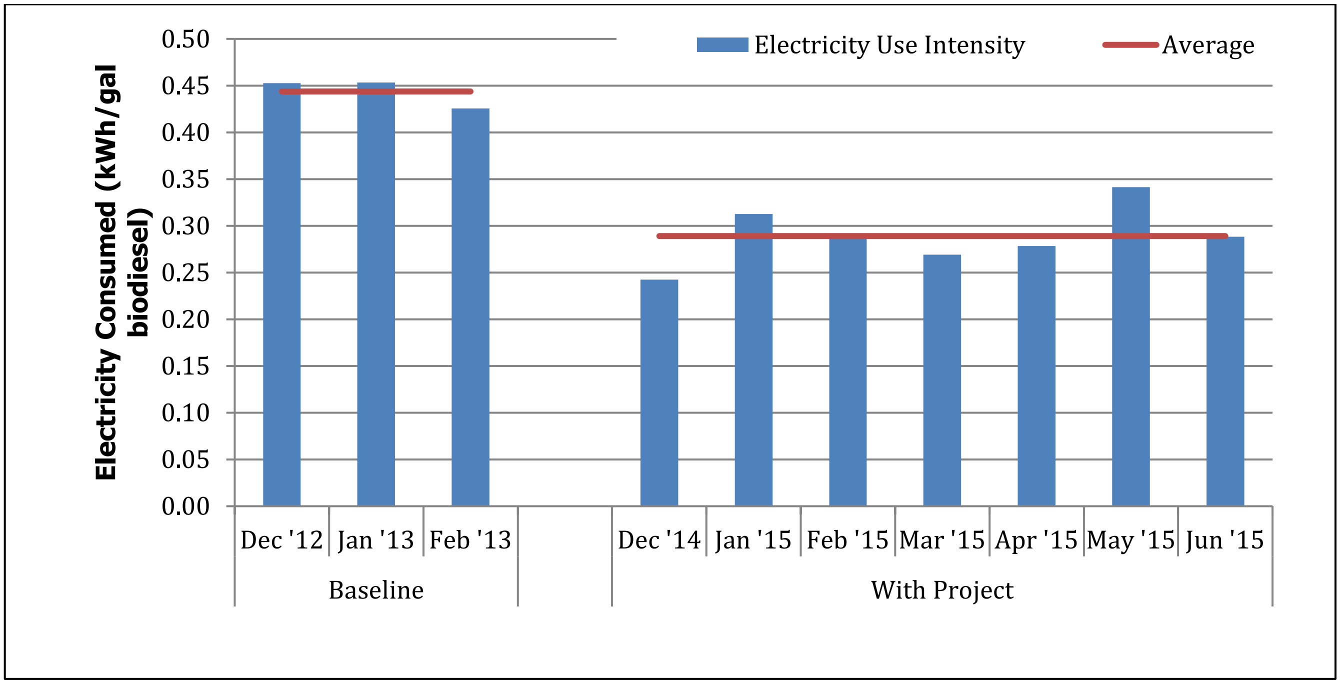
Reducing CI scores of New Leaf's biodiesel is a critical component of the Project. New Leaf's proposal estimated that the Project would result in a CI reduction for produced biodiesel from 11.76 g $CO2e$/MJ to 10.44 g $CO2e$/MJ. As discussed in Section 2, New Leaf completed several alternative CI reduction measures, in lieu of implementing cogeneration and the proposed methanol cleaning processes. Based on initial calculations New Leaf estimates that the CI reduction activities completed to date are sufficient to reduce the company's produced biodiesel to the target 10.44 g $CO2e$/MJ. New Leaf is currently in the process of seeking approval for a new LCFS pathway, which would document and codify these findings.

3.8 Electricity, Natural Gas, and Water Consumption

Electricity, natural gas, and water consumption data are shown per gallon of biodiesel produced. The project resulted in significant reductions in electricity, fuel, and water consumption, in comparison to baseline.

The electricity consumption rate decreased from 0.79 Kilowatt-hour (kWh)/gallon on average during the baseline period, to 0.48 kWh/gallon average during the Project reporting period, a 39 percent reduction in electricity use intensity. Reductions in electricity consumption resulted from implementation of the CI intensity reduction measures listed in Section 2.2, especially installation of variable frequency devices, the centrifuge upgrade, and updated control software (Figure 9).

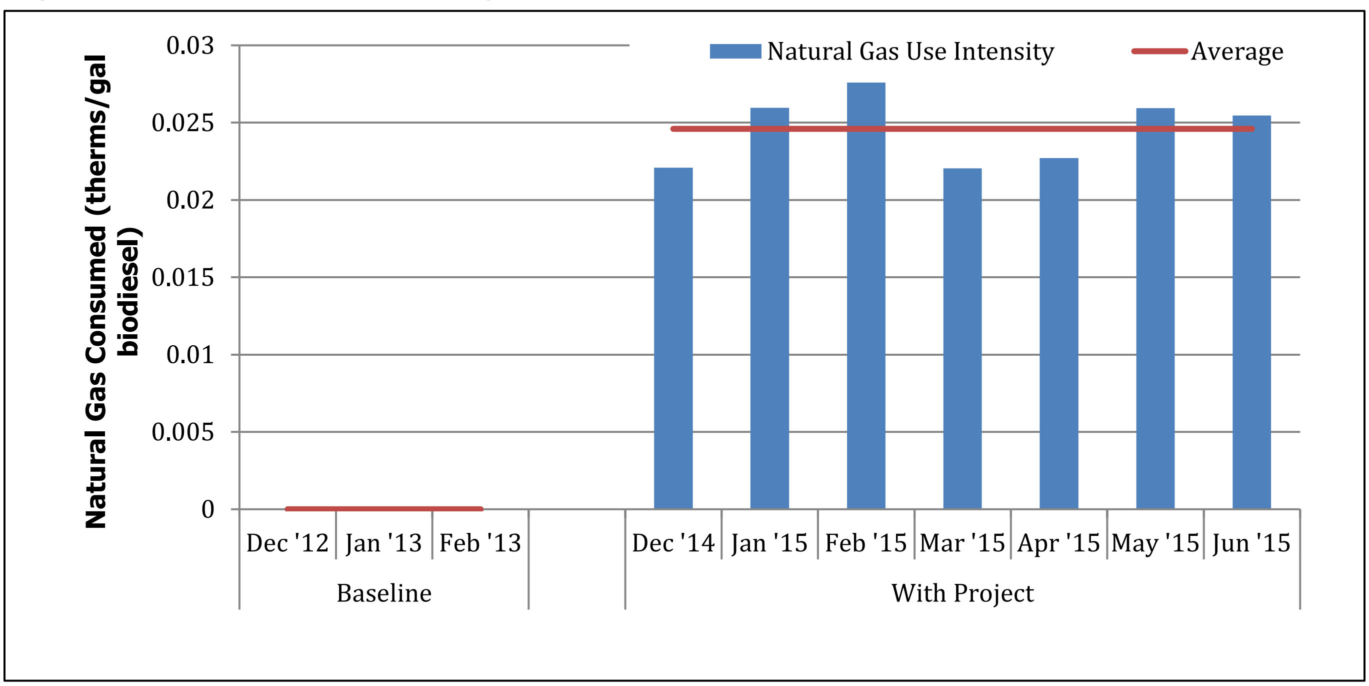
Figure 9: Monthly and Average Electricity Use: January to June 2015 versus Baseline



Source: New Leaf Biofuel, LLC

Natural gas consumption increased from zero therms/gallon to 0.025 therms/gallon, on average (Figure 10). Prior to initiation of the Project, the existing facility relied on a combination of biodiesel and fossil diesel combusted in two small, inefficient boilers. Unfortunately, fuel consumption records for these boilers are not available. However, it is expected that transition to the new energy efficient boiler resulted in a net increase in fuel use efficiency, and a concurrent reduction in airborne emissions associated with diesel combustion.

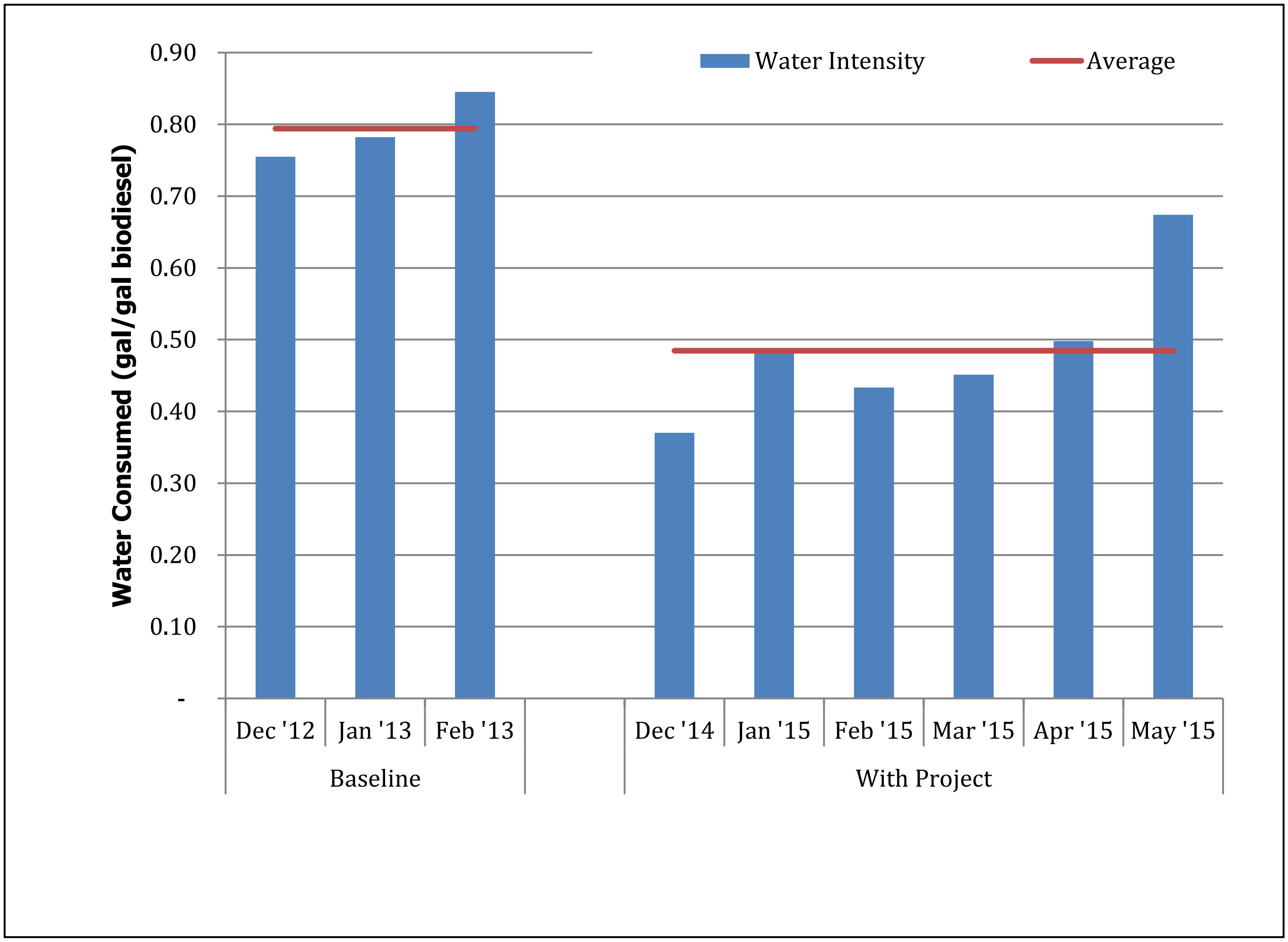
Figure 10: Monthly and Average Natural Gas: January to June 2015 Versus Baseline



Source: New Leaf Biofuel, LLC

The Project reduced water consumption from an average of 0.79 to 0.48-gallon water/gallon biodiesel produced, a 39 percent reduction in water use intensity (Figure 11). Water savings were achieved through facility process improvements that targeted water use reduction, including a more efficient boiler system, where hot water is continuously reused.

Figure 11: Monthly and Average Water Use Intensity: January to June 2015 Versus Baseline



Source: New Leaf Biofuel, LLC

3.9 Project Performance Compared to the Proposal

The Project proposal specified target expectations for the production of biodiesel in batches of 4,000 gallons, as compared to the 1,750-gallon capacity of the previous tanks. This batch size was achieved upon completion of installation of the reactors. The Project proposal also forwarded performance expectations regarding the timing of biodiesel production targets. These were as follows: 3 million gallons per year at 8 months after Project funding; 4 million gallons per year at 10 months after Project funding; and 5 million gallons per year 12 months after Project funding. Due to economic constraints discussed previously (see Section 3.3), these expectations were not realized.

Other expectations from the proposal included:

- A 90 percent reduction in greenhouse gas (GHG) emissions based on a reduction of 84.3 g CO2e/MJ fuel in comparison to the ultra-low sulfur diesel baseline of 94.71 g CO2e/MJ[3]. This was achieved with completion of Phase 2.
- A total GHG emissions savings associated with 3.5 million gallons per year of additional petroleum-based diesel offset. To date, the Project has achieved additional fossil diesel offsets of approximately 685,000 gallons per year.
- Operation within the permitting standards/requirements of the Air Pollution Control District. The Project operates within these requirements; thus, this expectation has been realized.

3.10 Environmental Impact

The Project has resulted in several categories of environmental benefits. These include the following:

- **Reduced Carbon Intensity:** The Project has successfully reduced CI of its product fuel from 11.76 g CO_2e/MJ (baseline) to an estimated 10.44 g CO2e/MJ, 11.2 percent.
- **Petroleum Diesel Fuel Displacement:** As of the end of the demonstration period, the Project was producing an annualized volume of 2.27 million gallons of biodiesel per year. In comparison to baseline (1.59 million gallons per year), this represents an incremental increase in biodiesel production of approximately 685,000 gallons per year and 342,500 gallon in half a year. The energy equivalent of a gallon of biodiesel is 0.92 gallons of ultra-low sulfur diesel. For the half year data collection period petroleum displacement increased to approximately 312,000 gallons of ultra-low sulfur diesel.
- **Reduced Water Use Intensity:** The 39 percent reduction in water use intensity saved about 350,000 gallons of water during the half year, a significant savings over baseline conditions.
- **Reduced Air Pollutants:** The Project also indirectly reduces criteria air pollutants and toxic air contaminants due to offset of customer consumed fossil diesel combustion. Emissions associated with the combustion of approximately 770,000 gallons of fossil diesel per year are currently being offset by the Project. Prior to Project implementation, the facility burned diesel fuel in two small, inefficient boilers, which provided process heat for the facility. Fuel consumption data were not available for the boilers. However, boiler replacement with new natural gas fired equipment curtailed diesel particulate matter emissions and toxic air contaminants associated with diesel combustion. It also reduced criteria air pollutant emissions, consistent with a transition from diesel fuel to natural gas.

3.11 Technology Advancement

Existing technologies were applied. The Project successfully upgraded the biodiesel production system which reduced carbon intensity through a series of process, equipment, and feedstock management optimization steps (Chapter 2). New Leaf is currently in the process of documenting and seeking approval for a new LCFS pathway, which would verify the CI reduction actions implemented under the Project. The Project is a model for other biodiesel

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[3] Table B1. Carbon Intensity lookup table using Method 1 on page 24 "ULSD ave. crude to CA refineries" is 94.71 gCO2e/MJ http://www.arb.ca.gov/fuels/lcfs/013009lcfs_drf_reg.pdf

producers seeking to reduce CI. Through successful demonstration of CI reduction, it promotes deployment of minor to moderate-scale process and operations-level upgrades. When taken together, these incremental steps produce a significant reduction down to 10.44 CI.

3.12 Greenhouse Gas Emissions Reduction

The Project has successfully increased biodiesel production at New Leaf's facility, from a baseline value of 1.59 million gallons per year to 2.27 million gallons per year, for a net increase of approximately 685,000 gallons per year. Figure 12 shows the equation using a CI of 10.44 g CO_2e/MJ for New Leaf biodiesel and assuming a CI of 94.71 g CO_2e/MJ for ultra-low sulfur diesel and assuming a fuel lower heating value of 117,100 Btu/gal (LCFS/ Final Regulation Order 112612, p. 49) for New Leaf Biodiesel, the Project's realized net increase in biodiesel production generates over 7,000 metric tons of annualized additional GHG emissions savings.

Figure 12: Calculations for metric tons CO2e offset per year by facility

$$684{,}533\ GPY\ biodiesel * 117{,}100\frac{Btu}{gal} * \ 0.001055\frac{\mathrm{MJ}}{\mathrm{Btu}} * \left(94.71\ \frac{g\ CO2e}{MJ} - 10.44\ \frac{g\ CO2e}{MJ}\right) * 0.000001\frac{MT}{g} = \mathbf{7{,}121\ \mathit{MT\ CO2e\ offset\ per\ year}}$$

Source: California Air Resources Board http://www.arb.ca.gov/fuels/lcfs/CleanFinalRegOrder112612.pdf and New Leaf Biofuel

During the six months demonstration period, 3560 metric ton (MT) CO2e GHG emissions were reduced.

3.13 Cost to Benefit Ratio $144/MT

The production increase of 342,000 gallons reduced GHG emissions 3560 MT CO2e. At a total CEC funding amount of $511,934, the ratio of grant cost to demo period benefit is $143.78 per metric ton CO2e reduced. In the inverse, demo pd 6,954 MT GHG emissions reduced per million dollars of grant.[4]

3.14 Job Creation and Retention

The Project resulted in the creation of a total of 2 new jobs to date and will result in the creation of 5 additional jobs when plant production reaches capacity. Jobs creation and retention was unexpectedly hindered by changing biodiesel market conditions, which caused a slower ramp up in actual plant production (but not production capacity) than was originally anticipated.

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[4] California Energy Commission, 2013 Intergraded Energy Policy Report, page 59-60. https://ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-100-2013-001-CMF

3.15 Benefits to California Firms

Benefits to California firms other than New Leaf include income on Project construction and equipment procurement, which supports job retention. These California based contractors also benefitted from biodiesel production system retrofit experience.

3.16 Other Project Benefits

State sales tax paid on equipment benefited the state's general fund.

About a third of the petroleum used in California is harvested in California. Reducing the consumption of imported petroleum-based transportation fuel enhanced California's energy independence and energy security.

3.17 Other Environmental Benefits and Sustainability Goals

The grant recipient is helping to establish the California's biodiesel industry, in which waste material is transformed into fuel and useful chemicals, increasing overall sustainability.

In comparison to use of fossil petroleum diesel, the use of waste cooking oils to produce biodiesel avoids water quality degradation associated with management of produced water from petroleum wells; reduces transportation distances and resulting air emissions for raw feedstock (i.e., globally sourced crude oil versus locally sourced waste vegetable oil); reduces combustion of diesel for heating in comparison to the baseline facility; reduces the need for storage of petroleum diesel in tanks, which can leak and cause environmental hazards; and reduces airborne emissions of diesel particulates, GHG emissions, and other diesel-related air quality pollutants.

3.18 Transition to Renewable Fuels

The Project successfully achieved an incremental increase in annual biodiesel production of approximately 685,000 gallons per year in comparison to the baseline period. This volume of fuel was sold into California's transportation markets, increasing availability of renewable transportation fuel and thereby directly supporting conversion of California's transportation fleet from fossil to renewable energy sources. Additionally, the Project's successful demonstration of reduced CI values through implementation of incremental project upgrades provides a potential pathway for other biodiesel producers to similarly reduce their CI value, through similar incremental upgrades. Reduced CI values further support GHG emissions reductions, but, importantly, help ensure that CI values meet or exceed fuel blender demand, which supports salability of the produced fuel.

CHAPTER 4: Conclusions

New Leaf was able to successfully expand nameplate production capacity at their biofuels facility. Unforeseen engineering and design issues presented critical challenges to implementing the proposed molecular sieve and cogeneration equipment. However, in spite of these technical challenges, New Leaf was able to identify other feedstock management, plant, and fuel transport and delivery upgrades that reduced CI values equivalent to the cogeneration and methanol dewatering equipment originally proposed. These successes underscore the benefits of adaptive management strategies to the viability of biodiesel businesses in California, and also highlight incremental small to moderate sized upgrades that can meaningfully reduce CI values.

4.1 Goals and Objectives

The Project successfully completed the objectives written for the three goals specified in the Scope of Work.

Goal 1: Increase production of biodiesel from waste oils from 1.5 to 5 million gallons per year

Objective: Expand the production capacity of the Recipient's existing biodiesel facility

Objective: Purchase and install three new 5,600-gallon processing vessels with full connections and controls.

The proposed tanks were successfully installed by May 2013, increasing rated production capacity to 5.0 million gallons per year and achieving the objectives of Goal 1. Actual production was approximately 2.27 million gallons per year by Project completion. The slower than expected ramp up was due to poor biodiesel market conditions.

Goal 2: Reduce CI of biodiesel from 11.76 to 10.44 g CO_2e/MJ

Objective: Decrease the CI of the resulting fuel from 11.76 to 10.44

- Equipment Phase II as proposed:
  - Two new 56 kW natural gas micro-turbines for cogeneration.
  - Provide 100 percent of facility electricity
  - Capture exhaust heat for 50 percent of the heat load
  - Supporting equipment including pumps, valves, and other appurtenances
- Phase II as Accomplished
  - Truck replacement
  - Truck replacement
  - Methanol distillation
  - Feedstock transportation distance severely reduced

As discussed in Section 1.2.2, the proposed micro-turbines were not optimal for the facility. In lieu of these improvements, the Project team implemented incremental process and management improvements sufficient to meet the target CI reduction of 11.76 to 10.44, based on CA-GREET modeling. Therefore, whereas the Project did not deploy cogeneration or the proposed molecular sieve, implementation of alternate and more cost/process effective solutions were still successful in reaching the initially proposed CI reduction target.

Goal 3: Increase Refining Capacity of Co-Products

Objective: Molecular sieve equipment for methanol recovery will be purchased and installed

- As proposed:
  - Purchase and install molecular sieve equipment
- As accomplished:
  - Methanol distillation

The molecular sieve equipment was too big to fit into the facility. As discussed in Section 1.2.2, the wet methanol is trucked to a distillation facility. Saleable dewatered methanol from the glycerin stream increased from zero to 7,075 gallons per month on average. Additionally, this Project increased its production of co-products by increasing biodiesel production. Glycerin production increased from an average of 31,500 gallons per month during the baseline period to 41,600 gallons per month during the demonstration period.[5] Goal 3 was 100 percent achieved.

4.2 Project Conclusions

Project benefits include reducing electricity consumption from 0.36 to 0.29 kWh per gallon biodiesel, reducing natural gas consumption from 0.026 to 0.024 therms per gallon biodiesel, and reducing water consumption from 0.79 to 0.48 gallons per gallon biodiesel, with an estimated CI reduction of 11 percent.

The ability to remain on schedule for anticipated biodiesel production rates was primarily hindered by unexpected economic conditions, resulting from regulatory changes in policies that support alternative fuels. However, other aspects of the Project were completed within the allotted Project timeframe.

New Leaf is pleased with the results of the Project, which successfully achieved the goals and objectives identified in the initial proposal to the CEC. The Project's success could not have been achieved without our committed project team and CEC support and cooperation.

4.3 Project Recommendations

New Leaf recommends that future upgrade projects continue to include flexibility to substitute equipment or processes within the grant framework, to the extent that it can be substantiated that such a substitution would achieve the same goals and objectives originally included in the Project, while providing additional process, economic, or environmental benefit.

[5] Note that the baseline period volume also includes non-separated methanol.

GLOSSARY

BRITISH THERMAL UNIT (Btu)—The standard measure of heat energy. It takes one Btu to raise the temperature of one pound of water by one-degree Fahrenheit at sea level. MMBtu stands for one million Btu.

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The CEC's five major areas of responsibilities are:

1. Forecasting future statewide energy needs.
2. Licensing power plants sufficient to meet those needs.
3. Promoting energy conservation and efficiency measures.
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels.
5. Planning for and directing state response to energy emergencies.

Funding for the CEC's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account, and other sources.

CALIFORNIA GREENHOUSE GASES, REGULATED EMISSIONS, AND ENERGY USE IN TRANSPORTATION (CA-GREET)— The CA-GREET model is a California-specific version of Argonne National Laboratory's GREET life cycle model which is used to calculate GHG emissions under the California Low Carbon Fuel Standard (LCFS).[6]

CARBON DIOXIDE EQUIVALENT (CO2e)—A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.

CARBON INTENSITY (CI)—The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels.

GREENHOUSE GAS (GHG)—Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (NOx), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

KILOWATT (kW)—One thousand watts. A unit of measure of the amount of electricity needed to operate given equipment. On a hot summer afternoon, a typical home—with central air conditioning and other equipment in use—might have a demand of 4 kW each hour.

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[6] Life Cycle Associates, CA-GREET Website. http://www.lifecycleassociates.com/lca-tools/ca_greet/

KILOWATT-HOUR (kWh)—The most commonly used unit of measure telling the amount of electricity consumed over time, means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumed 534 kWh in an average month.

LOW CARBON FUEL STANDARD (LCFS)—A set of standards designed to encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and therefore reduce greenhouse gas emissions. The LCFS standards are expressed in terms of the carbon intensity of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California that aim cut greenhouse gas emissions and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options.

MEGAJOULE (MJ)—A joule is a unit of work or energy equal to the amount of work done when the point of application of force of one newton is displaced one meter in the direction of the force. It takes 1,055 joules to equal a British thermal unit. It takes about one million joules to make a pot of coffee. A megajoule itself totals one million joules.

METRIC TON (MT)—A unit of mass equal to 1,000 kilograms.

PROGRAMABLE LOGIC COMPUTER (PLC)—An industrial digital computer which has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high reliability control and ease of programming and process fault diagnosis.

APPENDIX A: Engineering-Phase 2 Report Evaluation of Congregation Units

A key objective of the New Leaf Biofuels Facility project is to reduce the carbon intensity of biodiesel produced by New Leaf Biofuels with improvements in feedstock collection, fuel plant and fuel transport and delivery. New Leaf has estimated carbon intensity of biodiesel produced at its facility would be reduced from 11.76 gCO2e/MJ to 10.44 gCO2e/MJ, a 12.6 percent reduction from the established Biodiesel CA-GREET 1.8 pathway and an 89.0 percent reduction from baseline. As part of this project, New Leaf has completed process improvements and equipment acquisition and installation to reduce CI related to 1) Feedstock Collection (including acquisition of new low-carbon transportation vehicles, installation of feedstock collection tanks, and reducing transportation miles related to feedstock collection); 2) Fuel Plant (including installation of Jacketed Reactors, new Control Software, installation of new insulated piping, installation of a new 2.2 million BTU boiler, installation of a new centrifuge and improved methanol recovery); and 3) Fuel Transportation and Delivery (including expansion of local distribution network reducing transportation of biodiesel).

The New Leaf proposal also originally included the consideration of installation of two 65 kW Capstone micro turbines to provide 100 percent of the power and 50 percent of the heat for the production plant, which New Leaf believed would further reduce CI related to the facility. The installations of these micro turbines were included as match equipment funding. New Leaf did not seek CEC funding for this equipment. As originally envisioned, this equipment would be connected to the existing natural gas line behind the property and installed as a turnkey system on an existing reinforced slab.

New Leaf engaged Superior Process Technologies to evaluate the proposal and conduct a mass and energy balance utilizing the turbines in conjunction with New Leaf’s production projections over the next few years. Superior Process Technologies evaluated the C65-ICHP model turbine. This turbine, utilizing natural gas, will generate 65 kW at 29 percent thermal to electric efficiency; it will exhaust 1.08 lbs./second of flue gas (=3,888 pounds per hour); at 588-degree Fahrenheit, and use 11,800 BTU's of thermal energy per kWh of electricity produced. (See Data Sheet, attached).

For New Leaf, Superior Process Technologies estimated that the 65 kW Capstone turbine will consume (65 kW x 11,800 BTU/kWh = 767,000 BTU/hour), and generate (1.08 lbs./sec =) 3,888 pounds per hour of stack gas, also highlighted; in order to generate this amount of stack gas, I had to increase the "Percent Excess Air" to 515 percent; this resulting stack gas, when cooled from 588 degree Fahrenheit down to 250 degree Fahrenheit, will recover an estimated 336,316 BTU's per hour.

For financial modeling, Superior Processing Technologies Capstone Turbines assumed that turbines would generate 90 percent of the plant electrical load while running at 67.85 percent of their maximum capacity. The turbines are estimated to consume 89,922 Therms per year at a cost of $75,534.20 per year. The recovered thermal energy from the flue gas will amount to 445,798 BTU’s/hour, or 3,209.7 Therms per month. The balance of the electricity and natural gas needed to run the plant would be purchased from SDGE at $0.84/Therms and $0.25/kWh. The final total utility costs for electricity and natural gas are estimated to be $126,844 per year. Projected savings of $147,332 per year are estimated, resulting in a payback period of 2.58 years, on a $380,000 installed capital cost for the turbines. (See Financial Model, attached).

While the project provided a reasonable payback period, Superior Process Technologies was concerned that as facility increases production to 8.0 MPGY and makes additional process improvements, the thermal energy provided by the capstones turbines would be significantly underutilized. Although the capstones are ideal for heating water to 220 degrees Fahrenheit, there is sufficient amount of waste heat that can be recovered, which works well for a small batch biodiesel plant. However, larger biodiesel plants (for instance, 8.0 MPGY) require hot oil and/or steam in order to generate the amount of heat necessary to run efficiently. Waste heat from the exhaust gas to heat a thermal oil system at 500-degree Fahrenheit would not allow substantial waste heat recovery, and would provide minimal, if any, CI improvement.

Finally, the New Leaf facility sits on a highly constrained industrial property with little room for additional equipment. New Leaf was advised that the installation of additional turbines, with limited, if any added value appropriate for the larger proposed 8.0 MPGY facility, was inconsistent with the facility's constrained space. As a result, New Leaf determined that the capstones were not a good fit for the plant.

Figure A-1 shows the engineering report for the turbines.

Figure A-1: Engineering Report

Model	Fuels	Power Output[1]	Electrical Efficiency	Exhaust Gas Flow		Exhaust Temperature		Net Heat Rate		Dimensions[2] (W x D x H)	
		kW	%	kg/s	lbm/s	C°	F°	MJ/kWh	btu/kWh	m	in
GASEOUS FUELS[3]											
C30 LP	NG	28	25	0.31	0.68	275	530	13.8	13,100	0.76 x 1.5 x 1.8	30 x 60 x 70
C30 HP	NG, P, LG, DG	30	26	0.31	0.68	275	530	13.8	13,100	0.76 x 1.5 x 1.8	30 x 60 x 70
C30 HZLC[4]	NG	30	26	0.32	0.70	275	530	13.8	13,100	0.87 x 2.9 x 2.2	34 x 112 x 85
C65	NG, P	65	29	0.49	1.08	309	588	12.4	11,800	0.76 x 1.9 x 1.8	30 x 77 x 76
C65 ICHP	NG, P, LG, DG	65	29	0.49	1.08	309	588	12.4	11,800	0.76 x 2.2 x 2.4	30 x 87 x 93
C65 CARB	NG	65	28	0.51	1.13	311	592	12.9	12,200	0.76 x 2.2 x 2.6	30 x 87 x 103
C65 CARB	LG, DG	65	29	0.49	1.08	309	588	12.4	11,800	0.76 x 2.2 x 2.6	30 x 77 x 85
C65 HZLC[4]	NG	65	29	0.50	1.09	325	617	12.9	12,200	0.87 x 3.2 x 2.3	35 x 128 x 90
C200 LP	NG	190	31	1.3	2.9	280	535	11.6	11,000	1.7 x 3.8 x 2.5	67 x 150 x 98
C200 HP	NG, P, LG, DG	200	33	1.3	2.9	280	535	10.9	10,300	1.7 x 3.8 x 2.5	67 x 150 x 98
C200 HZLC[4]	NG	200	33	1.3	2.9	280	535	10.9	10,300	1.9 x 3.2 x 3.1	74 x 126 x 122
C600 LP	NG	570	31	4.0	8.8	280	535	11.6	11,000	2.4 x 9.1 x 2.9	96 x 360 x 114
C600 HP	NG, P, LG, DG	600	33	4.0	8.8	280	535	10.9	10,300	2.4 x 9.1 x 2.9	96 x 360 x 114
C800 LP	NG	760	31	5.3	11.7	280	535	11.6	11,000	2.4 x 9.1 x 2.9	96 x 360 x 114
C800 HP	NG, P, LG, DG	800	33	5.3	11.7	280	535	10.9	10,300	2.4 x 9.1 x 2.9	96 x 360 x 114
C1000 LP	NG	950	31	6.7	14.7	280	535	11.6	11,000	2.4 x 9.1 x 2.9	96 x 360 x 114
C1000 HP	NG, P, LG, DG	1000	33	6.7	14.7	280	535	10.9	10,300	2.4 x 9.1 x 2.9	96 x 360 x 114
LIQUID FUELS[5]											
C30	D, A, K	29	25	0.31	0.69	275	530	14.4	13,700	0.76 x 1.5 x 1.9	30 x 60 x 70
C65	D, A, K	65	29	0.49	1.08	309	588	12.4	11,800	0.76 x 1.9 x 1.8	30 x 77 x 76
C65 ICHP	D, A, K	65	29	0.49	1.08	309	588	12.4	11,800	0.76 x 2.2 x 2.4	30 x 87 x 93
C200	D	190	30	1.3	2.9	280	535	10.9	10,300	1.7 x 3.8 x 2.5	67 x 150 x 98

[1] Nominal full power performance at ISO conditions: 59° F, 14.696 psia, 60% RH
[2] Height dimensions are to the roofline. Exhaust outlet can extend up to 7 inches above the roofline.
[3] Models available to operate on these different fuels: NG – Natural Gas; P – Propane; LG – Landfill Gas; DG – Digester Gas
[4] Hazardous Location units suitable for use in potentially explosive atmospheres (UL Class I, Division 2 or Atex Class I, Zone 2)
[5] Models available to operate on these different fuels: D – Diesel; A – Aviation; K – Kerosene

Specifications are not warrantied and are subject to change without notice.

C200

C1000

"COMBUSTION HEAT"

(CMBHEAT.XLS)

Originally written in Fortran Dec/8/1981
converted to GWbasic in early 1990's
put on Excel spreadsheet on Aug/9/1996
by Kirk Cobb

This program can be used to estimate the effectiveness of any combustion process used to generate heat for any purpose, such as direct process heat, steam generation, or heating a building. Any combustible fuel can be evaluated, hydrocarbons, carbohydrates, methane, wet wood, etc. This program can handle a fuel containing Carbon, Hydrogen, Oxygen, Sulfur, and non-combustible ash and water in the fuel. The program will estimate the amount of process heat available, based on the estimated heat of combustion of the 'composite' fuel, the amount of excess air available for combustion, and the exit stack gas temperature.

										my Home Furnace	Estimate for a "Solar Turbine" generating 4.6 MW of Electricity 320% excess air	Estimate for a "Capstone Turbine" generating 65 KW of Electricity 515% excess air	Estimate for a "Capstone Turbine" generating 65 KW of Electricity 515% excess air
	Data Column #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Row #	FUEL NAME	Methane	Methane	Methane	Methane	Ethane	Ethane	Ethane	84% Methane 16% Ethane	84% Methane 16% Ethane	CH4:C2H6 CO2 Mix	CH4:C2H6 CO2 Mix	CH4:C2H6 CO2 Mix
1	# of Carbon Atoms	1	1	1	1	2	2	2	1.16	1.16	1.075	1.075	1
2	# of Hydrogen Atoms	4	4	4	4	6	6	6	4.32	4.32	4.11	4.11	4
3	# of Oxygen Atoms	0	0	0	0	0	0	0	0	0	0.015	0.015	0
4	# of Sulfur Atoms	0	0	0	0	0	0	0	0	0	0	0	0
5													
6	**Fuel Weight Percents:**												
7	Wt% Ash	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8	Wt% Water	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9	Wt% Combustible	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
10	Wt% Carbon	75.00%	75.00%	75.00%	75.00%	80.00%	80.00%	80.00%	76.32%	76.32%	74.78%	74.78%	75.00%
11	Wt% Hydrogen	25.00%	25.00%	25.00%	25.00%	20.00%	20.00%	20.00%	23.68%	23.68%	23.83%	23.83%	25.00%
12	Wt% Oxygen	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.39%	1.39%	0.00%
13	Wt% Sulfur	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
14													
15	Molec.Wt. of Combustible	16	16	16	16	30	30	30	18.24	18.24	17.25	17.25	16
16													
17	Gas Density, if Fuel is a Gas:	0.04215	0.0421496	0.0421496	0.04215	0.0790306	0.0790306	0.0790306	0.04805058	0.04805058	0.045442571	0.045442571	0.042149631
18	Heat of Combustion BTU's/Lb	23,475.50	23,475.50	23,475.50	23,475.50	21,599.00	21,599.00	21,599.00	22,981.68	22,981.68	22,757.20	22,757.20	23,475.50
19	of Flammable Portion of Fuel												
20	Heat of Combustion Kcal/Gram	13.04	13.04	13.04	13.04	12.00	12.00	12.00	12.77	12.77	12.64	12.64	13.04
21	High Heat of Combustion (BTU's/Lb)	23,475.50	23,475.50	23,475.50	23,475.50	21,599.00	21,599.00	21,599.00	22,981.68	22,981.68	22,757.20	22,757.20	23,475.50
22													
23	"High" BTU's/Cubic Foot :	989.48	989.48	989.48	989.48	1,706.98	1,706.98	1,706.98	1,104.28	1,104.28	1,034.15	1,034.15	989.48
24	LBs of Oxygen/Lb Fuel	4.00	4.00	4.00	4.00	3.73	3.73	3.73	3.93	3.93	3.8864	3.8864	4.0000
25	LBs of Nitrogen/Lb Fuel	13.33	13.33	13.33	13.33	12.44	12.44	12.44	13.09	13.09	12.9484	12.9484	13.3269
26	LBs of AIR/Lb of Fuel	17.33	17.33	17.33	17.33	16.17	16.17	16.17	17.02	17.02	16.8347	16.8347	17.3269
27	Stoichiometric Stack Gas:												
28	CO2; lbs/lb of Fuel:	2.75	2.75	2.75	2.75	2.93	2.93	2.93	2.80	2.80	2.74	2.74	2.75
29	H2O; lbs/lb of Fuel:	2.25	2.25	2.25	2.25	1.80	1.80	1.80	2.13	2.13	2.14	2.14	2.25
30	SO2; lbs/lb of Fuel:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	Nitrogen; lbs/lb of Fuel:	13.33	13.33	13.33	13.33	12.44	12.44	12.44	13.09	13.09	12.95	12.95	13.33
32	ash: lbs/lb of Fuel:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33													
34	LOW Heat of Combustion (BTU/lb)	21,225.50	21,225.50	21,225.50	21,225.50	19,799.00	19,799.00	19,799.00	20,850.11	20,850.11	20,612.85	20,612.85	21,225.50
35	"Low" BTU/Cubic Foot	894.647	894.647	894.647	894.647	1564.726	1564.726	1564.726	1001.860	1001.860	936.701	936.701	894.647
36	**Stack Gas with Excess Air**												
37	Percent Excess Air:	0%	15%	50%	100%	0%	40%	70%	**15%**	**40%**	**320%**	**515%**	**515%**
38	Total Air for Combustion, lb/lb fuel:	17.33	19.93	25.99	34.65	16.17	22.64	27.49	19.58	23.83	70.7059	103.5336	106.5606
39	CO2; lbs/lb of Fuel:	2.75	2.75	2.75	2.75	2.93	2.93	2.93	2.80	2.80	2.7420	2.7420	2.7500
40	H2O; lbs/lb of Fuel:	2.25	2.25	2.25	2.25	1.80	1.80	1.80	2.13	2.13	2.1443	2.1443	2.2500
41	SO2; lbs/lb of Fuel:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000
42	Nitrogen; lbs/lb of Fuel:	13.33	15.33	19.99	26.65	12.44	17.41	21.15	15.06	18.33	54.3831	79.6324	81.9606
43	Oxygen; lbs/lb of Fuel:	0.00	0.60	2.00	4.00	0.00	1.49	2.61	0.59	1.57	12.4364	20.0148	20.6000
44	ash; lbs/lb of Fuel:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000
45													
46	Total Heat Duty, BTU's/Hour :	6,250,000	6,250,000	6,250,000	6,250,000	6,250,000	6,250,000	6,250,000	6,250,000	82,000	40,770,536	767,000	767,000
47													
48	Total Fuel needed, Lbs/Hour :	294.46	294.46	294.46	294.46	315.67	315.67	315.67	299.76	3.93	1,977.92	37.21	36.14
49	Total Combustion Air, lbs/hr:	5,102.04	5,867.34	7,653.05	10,204.07	5,104.99	7,146.99	8,678.48	5,868.19	93.73	139,850.49	3,852.47	3,850.65
50	Total Combustion Air, SCFM:	1,133.79	1,303.85	1,700.68	2,267.57	1,134.44	1,588.22	1,928.55	1,304.04	20.83	31,077.89	856.10	855.70
51	Total CO2 in Stack Gas, lbs/hr:	809.76	809.76	809.76	809.76	925.97	925.97	925.97	838.80	11.01	5,423.51	102.03	99.37
52	Total H2O in Stack Gas, lbs/hr:	662.53	662.53	662.53	662.53	568.21	568.21	568.21	638.96	8.38	4,241.34	79.79	81.31
53	Total SO2 in Stack Gas, lbs/hr:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	Total Nitrogen in Stack Gas, lbs/hr:	3,924.21	4,512.84	5,886.31	7,848.42	3,926.48	5,497.07	6,675.02	4,513.49	72.09	107,565.36	2,963.11	2,961.71
55	Total Oxyten in Stack Gas, lbs/hr:	0.00	176.67	588.91	1,177.83	0.00	471.40	824.96	176.70	6.18	24,598.19	744.75	744.40
56	Total Stack Gas, pph	5,396.49	6,161.80	7,947.51	10,498.53	5,420.66	7,462.66	8,994.16	6,167.95	97.66	141,828.41	3,889.68	3,886.79
57	initial stack temp, deg F, if Cp = 0.3	3,860.53	3,381.05	2,621.37	1,984.40	3,843.32	2,791.68	2,316.32	3,377.68	2,798.81	958.21	657.30	588.00
58	CO2 lb-moles/hour	18.40	18.40	18.40	18.40	21.04	21.04	21.04	19.06	0.25	123.26	2.32	2.26
59	H2O lb-moles/hour	36.81	36.81	36.81	36.81	31.57	31.57	31.57	35.50	0.47	235.63	4.43	4.52
60	SO2 lb-moles/hour	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	N2 lb-moles/hour	140.15	161.17	210.23	280.30	140.23	196.32	238.39	161.20	2.57	3,841.62	105.83	105.78
62	O2 lb-moles/hour	0.00	5.52	18.40	36.81	0.00	14.73	25.78	5.52	0.19	768.69	23.27	23.26
63	Total Stack Gas, lb-moles/hour	195.36	221.90	283.84	372.32	192.84	263.67	316.79	221.28	3.48	4,969.21	135.85	135.81
64													
65	Average Stack Gas MW	27.62	27.77	28.00	28.20	28.11	28.30	28.39	27.87	28.03	28.54	28.63	28.62
66	Estimated Stack Gas Temp, deg F	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00
67	Stack Gas Density, lbs/CF	0.0357	0.0359	0.0362	0.0364	0.0363	0.0366	0.0367	0.0360	0.0362	0.0369	0.0370	0.0370
68	Estimated Stack Gas Flow, ACFM	2,519.5	2,861.8	3,660.6	4,801.7	2,487.0	3,400.4	4,085.5	2,853.8	44.9	64,086.2	1,752.0	1,751.5
69													
70	Total Pounds of Stack Gas/ Lb Fuel	18.33	20.93	26.99	35.65	17.17	23.64	28.49	20.58	24.83	71.71	104.53	107.56
71													
72	Stack Gas Wt% CO2	15.01%	13.14%	10.19%	7.71%	17.08%	12.41%	10.30%	13.60%	11.27%	3.82%	2.62%	2.56%
73	Stack Gas Wt% H2O	12.28%	10.75%	8.34%	6.31%	10.48%	7.61%	6.32%	10.36%	8.58%	2.99%	2.05%	2.09%
74	Stack Gas Wt% SO2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
75	Stack Gas Wt% Nitrogen	72.72%	73.24%	74.06%	74.76%	72.44%	73.66%	74.22%	73.18%	73.82%	75.84%	76.18%	76.20%
76	Stack Gas Wt% Oxygen	0.00%	2.87%	7.41%	11.22%	0.00%	6.32%	9.17%	2.86%	6.33%	17.34%	19.15%	19.15%
77													
78	lb-moles of Stack Gas on DRY basis:												
79	Percent Excess Air:	0%	15%	50%	100%	0%	40%	70%	15%	40%	320%	515%	515%
80	CO2 lb-moles/hour	18.40	18.40	18.40	18.40	21.04	21.04	21.04	19.06	0.25	123.26	2.32	2.26
81	H2O lb-moles/hour	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	SO2 lb-moles/hour	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	N2 lb-moles/hour	140.15	161.17	210.23	280.30	140.23	196.32	238.39	161.20	2.57	3,841.62	105.83	105.78
84	O2 lb-moles/hour	0.00	5.52	18.40	36.81	0.00	14.73	25.78	5.52	0.19	768.69	23.27	23.26
85	Total DRY Stack Gas, lb-moles/hour	158.55	185.10	247.03	335.51	161.28	232.10	285.22	185.78	3.02	4,733.58	131.42	131.30
86													
87	Volume % Stack Gas on DRY Basis:												
88	volume % CO2	11.61%	9.94%	7.45%	5.49%	13.05%	9.07%	7.38%	10.26%	8.29%	2.60%	1.76%	1.72%
89	volume % N2	88.39%	87.07%	85.10%	83.54%	86.95%	84.59%	83.58%	86.77%	85.31%	81.16%	80.53%	80.56%
90	volume % O2	0.00%	2.98%	7.45%	10.97%	0.00%	6.35%	9.04%	2.97%	6.40%	16.24%	17.71%	17.72%
91		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
92													
93	Estimated Available Heat from Stack BTU/Hr =									63,723	25,713,839	405,567	336,316
94	if cooled to 250 F												
95													
96													
97		% Thermal	% Thermal	% Thermal	% Thermal	% Thermal	% Thermal	% Thermal	% Thermal	% Thermal	% Thermal	% Thermal	% Thermal
98	Stack Temp	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency
99													
100	200	94.82%	94.08%	92.37%	89.92%	94.80%	92.84%	91.37%	94.08%	92.85%	79.13%	69.57%	58.99%
101	300	92.23%	91.13%	88.56%	84.88%	92.19%	89.25%	87.05%	91.12%	89.28%	68.69%	54.36%	43.78%
102	400	89.64%	88.17%	84.74%	79.84%	89.59%	85.67%	82.73%	88.16%	85.71%	58.26%	39.14%	28.58%
103	500	87.05%	85.21%	80.93%	74.80%	86.99%	82.09%	78.41%	85.20%	82.14%	47.82%	23.93%	13.38%
104	600	84.46%	82.25%	77.11%	69.76%	84.39%	78.51%	74.10%	82.24%	78.56%	37.38%		
105	800	79.28%	76.34%	69.48%	59.69%	79.18%	71.34%	65.46%	76.32%	71.42%	16.51%		
106	1000	74.10%	70.42%	61.85%	49.61%	73.98%	64.18%	56.83%	70.39%	64.27%	-4.36%		
107	1200	68.92%	64.51%	54.22%	39.53%	68.78%	57.02%	48.19%	64.47%	57.12%	-25.23%		

Source: New Lead Biofuel

APPENDIX B: Carbon Intensity Estimate

Figure B-1 shows the carbon intensity estimate report for this project.

Figure B-1: Carbon Intensity Estimate

1. GHG Emissions

New Leaf Biofuel's (NLB) proposed used cooking oil (UCO) to biodiesel fuel plant results in a substantial (90%) reduction in carbon intensity (g CO_2e/MJ) relative to the petroleum diesel baseline under the California Low Carbon Fuel Standard (LCFS). Figure 1 below summarizes the greenhouse gas emission results compared to the Ultra-Low Sulfur Diesel (ULSD) baseline and the default LCFS result for UCO-to-biodiesel. NLB intends to install a natural gas microturbine to generate process steam and electricity and expand fuel production to 5 million gallons per year (MGY). In addition to achieving a low carbon intensity score, the proposed project will displace a significant quantity of petroleum energy and associated greenhouse gas emissions.

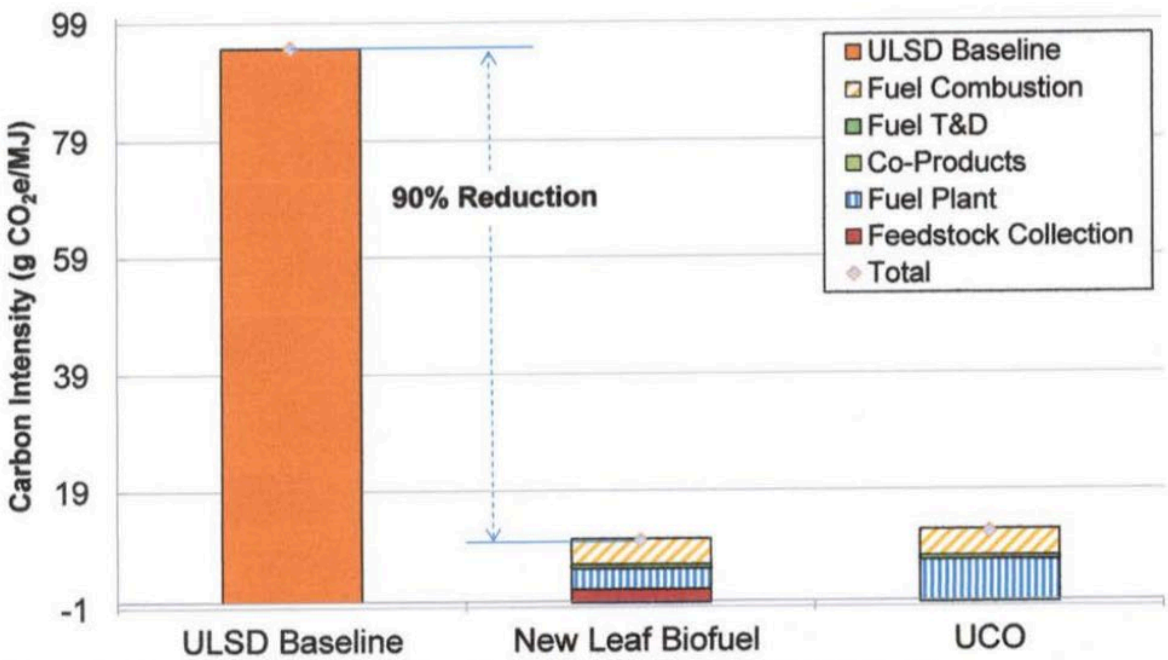

Figure 1. Greenhouse Gas Emissions from Used Cooking Oil-to-Biodiesel

The fuel pathway includes UCO collection and transport, biodiesel and glycerin production, fuel transport and distribution and fuel combustion. Greenhouse gas emissions were estimated using the CA-GREET model using input parameters developed from NLB's process data. Table 1 below presents the input parameters used for the analysis. Following the LCFS convention, the analysis utilizes the energy allocation method to allocate energy use and greenhouse gas emission results between the biodiesel and glycerin produced (on a refined glycerin basis).

Feedstock collection and transport was modeled by averaging the 2011 feedstock data for the collected and purchased oil separately and calculating results for the oil collected within a 50 mile radius and oil purchased within a 100 mile radius (87% of feedstock) and a 326 mile radius (3% of feedstock). NLB will collect approximately 10% of the UCO from existing contracts and purchase the remaining 90% of the feedstock. The feedstock transport calculations account for

Table 1. Life Cycle Input Parameters for UCO-to-Biodiesel

Used Cooking Oil to Biodiesel

Used Cooking Oil Collection and Transport

Oil Transport Segment	Mode	Capacity (tons)	Distance (mi)	Share
Restaurant to BD Plant	Heavy Duty Truck	25	50	100.0%
Restaurant to BD Plant	Rail		0	0.0%

Fuel Plant

Fuel Plant Configuration Turbine cogen

Feedstock Factors	Parameter
Feedstock factor (lb Wet Oil/lb Purified Oil)	1.07
Oil use (lb Oil/lb BD)	1.11

Energy and Chemical Inputs (Btu/lb)		Btu/lb BD
Natural gas	Boiler	0
Natural gas	Micro-Turbine	553
Coal	Boiler	0
LPG	Boiler	0

Chemical Inputs (Btu/lb BD)	Btu/lb BD
Methanol	865
Sodium hydroxide	42
Sodium methoxide	209
Sulfuric Acid	63
Total	1,734

Electricity	kWh/lb BD	Btu/lb BD	MJ/kg
Grid electricity	0.000	0	0.0

Product Allocation

Product Allocation	lb/lb BD	Energy Share
Biodiesel	1.00	95.1%
Glycerin (kg/kg BD)	0.105	4.9%

Biodiesel Transport and Distribution

Fuel Transport	Mode	Capacity (tons)	Distance (mi)	Share
Fuel to Blending Facility	Heavy Duty Truck	25	50	80.0%
	Rail		0	100.0%

Fuel Distribution				
Heavy duty truck	Heavy Duty Truck	25	90	100.0%

the material contained in the UCO that cannot be converted to fuel (MIU). Collection and transport is responsible for 1.9 g CO_2e/MJ fuel (19% of emissions).

NLB provided fuel plant process data including the material and energy balance, which were converted to input parameters expressed per lb biodiesel produced. The natural gas input accounts for the steam and electricity requirements based on the microturbine's OEM performance data. The material flows of methanol and glycerin in NLB's fuel plant are complicated because NLB recycles methanol and unreacted oil material and crude glycerin is sold and in varying forms. However, the quantity of methanol required for biodiesel production and the resulting glycerin yield is well understood and represented by the default inputs in the CA-GREET model. Therefore, the CA-GREET default input parameters for methanol input and glycerin yield were used in this analysis. The CA-GREET analysis does not consider emission impacts of chemical catalysts consumed in the reaction so the fuel plant chemicals were not included in this analysis. The fuel plant greenhouse gas emissions (3.5 g CO_2e/MJ) account for approximately 34% of the total fuel carbon intensity. The glycerin produced represents 4.9% of the energy produced by the fuel plant and receives a credit of -0.3 CO_2e/MJ (-3% of fuel carbon intensity).

Fuel transport and distribution and fuel combustion results are the same as for the LCFS UCO-to-biodiesel fuel pathway. Fuel transport results are based on 80% of the biodiesel transported from the fuel plant to the blending facility by heavy duty truck (HDT) followed by 90 miles of distribution by HDT to a refueling station; the remaining 20% of the biodiesel is transported directly to the refueling station by heavy duty truck. Fuel transport and distribution emissions (0.8 g CO_2e/MJ fuel) account for 7% of the total fuel carbon intensity. Fuel combustion is calculated based on the methane and nitrous oxide emissions from a heavy duty truck, plus carbon dioxide from oxidation of the methyl carbon in the biodiesel derived from methanol. Carbon dioxide resulting from combustion of carbon in the hydrocarbon part of the ester fuel is considered climate neutral. The resulting fuel combustion emissions are 4.5 g CO_2e/MJ fuel, equivalent to 43% of the carbon intensity.

2. Petroleum Energy and Greenhouse Gas Reduction

New Leaf Biofuel plans to produce an additional 3.5 MGY beyond their current production capacity. Every gallon of biodiesel produces displaces an equivalent quantity of petroleum diesel energy directly, plus the difference between the life cycle petroleum energy for ULSD and biodiesel. Table 2 below summarizes the results. NLB's 3.5 MGY biodiesel contains an equivalent amount of energy to 3.3 MGY ULSD. For the UCO-to-biodiesel fuel pathway, 42,773 Btu of petroleum are consumed for every mmBtu of biodiesel produced; petroleum consumption (including energy in the fuel) for ULSD is 1,096,069 Btu per mmBtu of ULSD produced. The lower heating value of biodiesel relative to ULSD and the higher petroleum use for producing ULSD relative to biodiesel cancel each other out approximately, indicating that 3.5 MGY biodiesel displaces 3.5 MGY ULSD, or 440,725 mmBtu/year petroleum.

The effect of the 3.5 MGY biodiesel displacing ULSD displaces greenhouse gas emissions in addition to petroleum energy. Table 3 below summarizes the greenhouse gas emission savings based on the carbon intensity for NLB biodiesel and ULSD. The table shows annual fuel energy produced in mmBtu and MJ. As the table indicates, production of 3.5 MGY biodiesel results in greenhouse gas savings of 37.2 billion g CO_2e/year by displacing 3.5 MGY ULSD and its associated emissions.

Table 2. Petroleum Energy Savings

	New Leaf Biofuel	Equivalent CA ULSD
Annual Fuel Production (MGY)	3.5	3.3
Fuel Heating Value (Btu/gal, LHV)	119,500	127,464
Annual Energy Production (mmBtu/yr)	418,425	418,425
Life Cycle Petroleum Energy (Btu/mmBtu)	42,773	1,096,069
Total Annual Petroleum Energy (mmBtu/yr)	17,897	458,662
Annual Petroleum Energy Savings (mmBtu/yr)	440,725	
ULSD Gallon-Equivalent Saved	3,457,658	

Table 3. Greenhouse Gas Emission Savings Associated with Displaced Petroleum

	New Leaf Biofuel	Equivalent CA ULSD
Annual Energy Production (mmBtu/yr)	418,425	
Annual Energy Production (MJ/yr)	441,461,744	
Carbon Intensity (g CO_2e/MJ)	10.44	94.71
Total Annual Emissions (Billion g CO_2e/year)	4.6	41.8
Annual Emission Savings (Billion g CO_2e/year)	37.2	

Life Cycle Associates, LLC

Life Cycle Analysis of used cooking oil to biodiesel based on CA-GREET1.8b Model

21-Feb-12

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Description

This Excel workbook contains the inputs and results of a life cycle assessment of fatty acid methyl ester (FAME) biodiesel fuel produced in California. The analysis was performed using the CA-GREET model and the analysis is consistent with the California Low Carbon Fuel Standard.

Notes

- Input parameters are in blue text and may be changed by the user
- Calculations are black text and should not be changed

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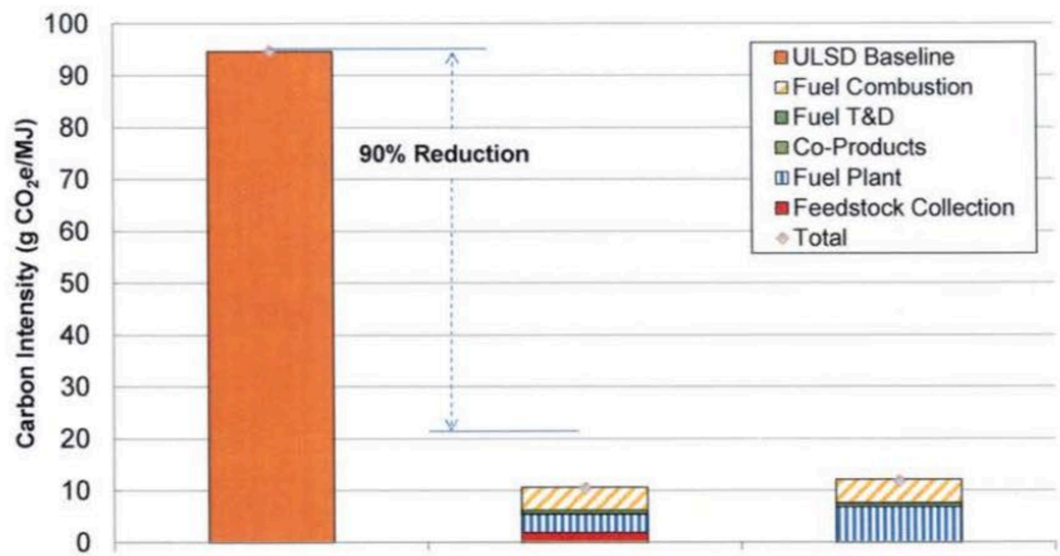
Used Cooking Oil-to-Biodiesel Results (g CO_2e/MJ)

Pathway Component	New Leaf Biofuel
Feedstock Collection	1.94
Fuel Plant	3.53
Co-Products	-0.27
Fuel T&D	0.76
Fuel Combustion	4.48
Total	**10.44**
Reduction from Baseline	**89.0%**

For Graphing

	ULSD Baseline	New Leaf Biofuel	UCO
Feedstock Collection		1.94	0.00
Fuel Plant		3.53	6.86
Co-Products		-0.27	-0.34
Fuel T&D		0.76	0.76
Fuel Combustion		4.48	4.48
ULSD Baseline	94.71		
Total	94.71	10.44	11.76



Petroleum Displacement Calculation

	New Leaf Biofuel	CA ULSD	Units
Fuel heating value	119,550	127,464	Btu/gal (LHV)
Annual Volume Production	3,500,000	3,282,704	Gallons/year
Annual Energy Production	418,425	418,425	mmBtu/year
Life Cycle Petroleum Energy Use	42,773	1,096,069	Btu/mmBtu
Total Petroleum Energy Use	17,897	458,622	mmBtu/year
Petroleum Energy Savings	440,725		mmBtu/year
Petroleum Energy Savings	125,921		Petroleum Btu saved/gal Biodiesel
Gallons of ULSD-Equivalent Saved	**3,457,658**		Gallons CA ULSD/year

For each gallon of biodiesel, displacing 119,550 Btu ULSD directly + 7,433 Btu embedded petroleum energy

Greenhouse gas emission reduction

	New Leaf Biofuel	CA ULSD	Units
Annual Fuel Production	441,461,744	441,461,744	MJ/year
Carbon Intensity	10.44	94.71	g CO2e/MJ
Carbon Intensity	4,607,197,962	41,810,841,778	g CO2e/year
Emission Savings	37,203,643,816		g CO2e/year

Used Cooking Oil to Biodiesel

Used Cooking Oil Collection and Transport

Oil Transport Segment	Mode	Capacity (tons)	Distance (mi)	Share
Restaurant to BD Plant	Heavy Duty Truck	25	50	100.0%
Restaurant to BD Plant	Rail		0	0.0%

Fuel Plant

Fuel Plant Configuration Turbine cogen

Feedstock Factors	Parameter
Feedstock factor (lb Wet Oil/lb Purified Oil)	1.07
Oil use (lb Oil/lb BD)	1.11

Energy and Chemical Inputs (Btu/lb)		Btu/lb BD
Natural gas	Boiler	0
Natural gas	Micro-Turbine	553
Coal	Boiler	0
LPG	Boiler	0

Chemical Inputs (Btu/lb BD)	Btu/lb BD
Methanol	865
Sodium hydroxide	42
Sodium methoxide	209
Sulfuric Acid	63
Total	1,734

Electricity	kWh/lb BD	Btu/lb BD	MJ/kg
Grid electricity	0.000	0	0.0

Product Allocation

Product Allocation	lb/lb BD	Energy Share
Biodiesel	1.00	95.1%
Glycerin (kg/kg BD)	0.105	4.9%

Biodiesel Transport and Distribution

Fuel Transport	Mode	Capacity (tons)	Distance (mi)	Share
Fuel to Blending Facility	Heavy Duty Truck	25	50	80.0%
	Rail		0	100.0%
Fuel Distribution				
Heavy duty truck	Heavy Duty Truck	25	90	100.0%

Fuel Combustion

Vehicle Energy Use	HD Vehicle (MJ/mi)
Vehicle total energy use	19.4
Methanol Energy Share	0.054

HD Vehicle Exhaust Emissions	EF (g/mi)	g/MJ
CH_4	0.035	0.002
N_2O	0.048	0.002
Fossil Derived CO_2		3.67
TTW Emissions (g CO_2e/MJ)		4.48

Biodiesel Plant
UCO to Biodiesel

	UCO Collection & Transport	Fuel Plant	Co-Product Credit	Fuel Transport and Distribution	WTT
Total energy	25,748	140,066	-8,178	10,055	167,691
Fossil fuels	25,723	140,035	-8,175	10,046	167,630
Coal	341	28	-18	133	484
Natural gas	2,651	128,137	-6,451	1,035	125,373
Petroleum	22,732	11,870	-1,707	8,878	41,773
VOC	0.836	1.710	-0.126	0.327	2.747
CO	3.783	3.015	-0.335	1.478	7.940
NOx	11.090	6.070	-0.846	4.331	20.644
PM10	0.312	0.952	-0.062	0.122	1.324
PM2.5	0.230	0.908	-0.056	0.090	1.173
SOx	0.389	1.768	-0.106	0.152	2.203
CH4	2.425	14.847	-0.852	0.947	17.367
N2O	0.049	0.064	-0.006	0.019	0.126
CO2	1,971	3,333	-262	770	5,812
GHG (g CO_2e/mmBtu)	2,046	3,724	-285	799	6,284
GHG (g CO_2e/MJ)	1.94	3.53	-0.27	0.76	5.96

Source: New Leaf Biofuels