CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Increased Efficiency for Processing Low Carbon Intensity Biodiesel Feedstocks at an Existing Biorefinery

Prepared for: California Energy Commission

Prepared by: American Biodiesel, Inc. dba Community Fuels

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation 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.
- 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-13-609 to cost share the development of pilot-scale and commercial-scale advanced biofuel production facilities in California. In response to PON-13-069, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards dated July 18, 2014 and the agreement was executed as ARV-14-024 on October 10, 2014.

ABSTRACT

The objective of the Increased Efficiency for Processing Low Carbon Intensity Biodiesel Feedstocks at an Existing Biorefinery project was to increase the efficiency of processing low carbon intensity feedstocks into biodiesel at the existing refinery operated by American Biodiesel, Inc. dba Community Fuels at the Port of Stockton in Stockton, California. The project, which leveraged a substantial amount of existing infrastructure at the biorefinery, included the design, construction, and commissioning of new storage tanks, an additional reactor, and related upgrades of equipment for separation and purification of the biodiesel product and glycerin co-product. The new equipment and operational modifications implemented during this project have improved product yields and extended the upper limit of free fatty acid content and other feedstock impurities in the feedstocks that can be effectively processed at the biorefinery. This has made efficient processing feasible for a wider range and greater volume of waste greases, agricultural byproducts, and other lower-grade feedstocks with low carbon intensity values. The project includes upgrades to the existing on-site quality control laboratory, which will allow it to accommodate the larger number of samples requiring analysis as a result of the project. All biodiesel produced at the biorefinery will be analyzed to ensure that it meets fuel quality specifications, which will contribute to maintaining the viability of the biofuel supply in California. During operations at the biorefinery from June 2019 to May 2020, the average carbon intensity of the biodiesel produced was about 45 grams of carbon dioxide equivalent per mega joule (which represents nearly a 40 percent reduction from the start of the project agreement and about 60 percent reduction relative to the ultra-low sulfur diesel baseline) and low carbon intensity feedstocks accounted for about 40 percent of the total feedstock processed. Over some periods during the project, feedstock achieved blends containing more than 55 percent low carbon intensity feedstocks, far exceeding the 25 percent objective established as the project goal. Over the projected 20-year lifetime of the project equipment, the project is expected to result in the displacement of more than eight million petroleum diesel gallon equivalents per year and reductions in greenhouse gas emissions of more than 1.25 million metric tons of carbon dioxide equivalents.

Keywords: California Energy Commission, Community Fuels, biodiesel, renewable fuels, fuel quality, greenhouse gas emissions, low carbon fuel standard, petroleum displacement, carbon intensity, feedstock

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EXECUTIVE SUMMARY

The objective of the Increased Efficiency for Processing Low Carbon Intensity Biodiesel Feedstocks at an Existing Biorefinery project was to increase the efficiency of processing low carbon intensity feedstocks into biodiesel at the refinery operated by American Biodiesel, Inc. dba Community Fuels at the Port of Stockton in Stockton, California. The project leveraged a substantial amount of existing infrastructure at the biorefinery, included the design, construction, and commissioning of new storage tanks, an additional reactor, a new chiller, heat exchanger, and recirculation pump for the methanol recovery and recycling system, additional heat exchangers for the fuel winterization[1] process, and several other upgrades of equipment used for separation and purification of the biodiesel product and glycerin co-product. Process modifications made to increase efficiency included improved monitoring and operation of the existing steam boiler to prevent shutdowns, changing the position of inlets on the distillation column, recovery of residual biodiesel from spent filtration media, and separation and recovery of free fatty acids from the glycerin. Community Fuels facilitated the process modifications by upgrading the instrumentation and controls system at the biorefinery.

The new equipment and operational modifications implemented during this project have improved product yields and extended the upper limit of free fatty acids and other feedstock impurities that can be effectively processed at the biorefinery. This has made efficient processing feasible for a wider range and greater volume of waste greases, agricultural byproducts, and other lower-grade feedstocks with low carbon intensity values. Over the course of the project, Community Fuels received around 105 samples of fats and oils for evaluation as feedstock. Community Fuels performed laboratory analyses on the samples to determine their content of free fatty acids, moisture, insoluble and unsaponifiable[2], and other properties useful for predicting how successfully they could be converted to biodiesel in the full-scale process at Community Fuels' biorefinery. Community Fuels frequently performed laboratory production simulations, and close monitoring of production and fuel quality occurred with all new feedstocks introduced for production trials.

Since the implementation of the current project, the primary low carbon intensity feedstocks selected for processing at Community Fuels' biorefinery include corn oil from wet distillers grains with solubles, tallows (derived from animal fats), and used cooking oil, which have carbon intensity values of about 29 grams of equivalent carbon dioxide (CO2) per megajoule, 29 grams of equivalent CO2 per megajoule to 32 grams of equivalent CO2 per megajoule, and 16 grams of equivalent CO2 per megajoule, respectively. From calendar year 2010 to 2013, the average carbon intensity of biodiesel produced at the Community Fuels biorefinery was about 70 grams of equivalent CO2 per megajoule and low- carbon intensity feedstocks

1 A process ensuring that finished biodiesel fuel will have favorable cold weather flow properties to meet fuel specifications.

2 Components of a fatty substance (oil, fat, wax) that fail to form soaps when treated with alkali, and remain insoluble in water but soluble in organic solvents.

accounted for nearly two percent of the total feedstock volume processed at the biorefinery. Over the duration of the agreement (December 2014 through May 2020), the average carbon intensity of the biodiesel was reduced to an average of 52 grams of equivalent CO2 per megajoule, with a range of about 16 grams of equivalent CO2 per megajoule to 83 grams of equivalent CO2 per megajoule, depending on which feedstocks Community Fuels used for processing. Low- carbon intensity feedstocks accounted for about 12 percent of the total feedstock during this period. Over the period of June 2019 to May 2020, the average carbon intensity of the biodiesel was reduced further to 44 grams of equivalent CO2 per megajoule (representing a 37 percent reduction from the start of the project agreement and a 56 percent reduction relative to the ultra-low sulfur diesel baseline) and low-carbon intensity feedstocks accounted for about 36 percent of the total feedstock. The drop in the average biodiesel carbon intensity value was not as low as predicted by the original calculations in the project proposal, which Community Fuels based on the very low carbon intensity value for biodiesel produced from corn oil from wet distillers' grain with soluble (4 grams of equivalent CO2 per megajoule) that was valid at the time. This was partially balanced, however, by exceeding the original target of 25 percent for the portion of the total feedstock accounted for by low-carbon intensity feedstocks. Over some recent time periods, the project team achieved feedstock blends containing over 55 percent low-carbon intensity feedstocks during production operations, far exceeding the original objectives of the project.

When running at full capacity using a feedstock blend containing almost 36 percent low carbon intensity feedstocks, the biorefinery will produce 8.75 million gallons of biodiesel per year derived from low carbon intensity feedstocks. This volume of biodiesel will result in the displacement of 8.21 million gallons of petroleum diesel gallon equivalents per year. The associated reduction in greenhouse gas emissions (assuming a carbon intensity value of 44 grams of equivalent CO2 per megajoule for the biodiesel) was projected to be about 62,575 metric tons of CO2 equivalent per year, with a total reduction of more than 1.25 million metric tons metric tons of CO2 equivalent over the projected 20-year lifetime of the project equipment.

Ensuring fuel quality is critical to the growth of the biodiesel industry in California and the smooth implementation of California's Low Carbon Fuel Standard. The project included upgrades to the existing on-site quality control laboratory, which will be used to evaluate prospective new feedstocks, analyze and evaluate process changes, troubleshoot production issues during in-process trials, and certify that the finished biodiesel fuel meets the current American Society for Testing and Materials and even more stringent customer specifications.

The results of the project will contribute directly towards achieving the key policy objectives set forth in the California Energy Commission's *2014-2015 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program*, achieving near-term and long-term reductions in GHG emissions, reducing California's use and dependence on petroleum transportation fuels, increasing the use of alternative and renewable fuels, and producing alternative and renewable low-carbon fuels in California.

CHAPTER 1: Introduction

Background

Biodiesel is a type of fuel consisting of fatty acid esters produced from vegetable oils and animal fats. It is a clean-burning, renewable fuel that can be blended at any level with petroleum diesel and used by most diesel engines with few or no modifications. Results from life cycle assessments demonstrate that displacing petroleum diesel with biodiesel can reduce greenhouse gas (GHG) emissions by 65 percent to 95 percent.[3] Using biodiesel blended with petroleum diesel offers California consumers of transportation fuels an immediate means of meeting GHG emission reduction targets that have been mandated by the state's climate change policies and legislation.

American Biodiesel, Inc., which does business as Community Fuels constructed and operates a biodiesel production facility (biorefinery), laboratory, and bulk fuel terminal at the Port of Stockton in Stockton, California. The biorefinery occupies a total area of nearly seven acres and has produced biodiesel every month since it began operations in 2008, making it one of the longest operating biorefineries in the western United States. The site is strategically located in close proximity to existing fuel distribution facilities, major trucking corridors (including Interstates 5, 80, 580 and State Highway 99), rail lines (served by two transcontinental railroads—Union Pacific and Burlington Northern Santa Fe), and marine shipping via the deep water shipping channel connecting Stockton to San Francisco Bay through the California Delta.

The proprietary production process at the biorefinery has demonstrated flow rates that would support production of over 20 million gallons of biodiesel per year under continuous operation. The process includes robust product separation and purification processes that result in exceptional fuel quality. The process equipment currently installed includes multiple reactors, evaporators, a distillation column, dryers, filtration system, vacuum pump, separation tanks, centrifuges, heat exchangers, chillers, condensers, pumps, and mixers. Additional biorefinery infrastructure includes storage tanks, loading and unloading equipment for raw materials (feedstock, methanol, catalyst) and products (biodiesel and glycerin), a natural gas fired boiler, an emergency electricity generator, nitrogen generators, air compressors, extensive controls, instrumentation, and piping (Figure 1).

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3 Wang, Michael, Hong Huo, and Salil Arora. 2011. *Methods of Dealing with Co-products of Biofuels in Life-cycle Analysis and Consequent Results within the U.S. Context*. *Energy Policy*. 39(10), 5726–5736. Available at https://doi.org/10.1016/j.enpol.2010.03.052.; Pradhan, A., D.S. Shrestha, J. Van Gerpen, A. McAloon, W. Yee, M. Haas, and J.A. Duffield. 2012. *Reassessment of Life Cycle Greenhouse Gas Emissions for Soybean Biodiesel*. *Transactions of the ASABE*. 55(6), 2257-2264. Available at https://elibrary.asabe.org/abstract.asp?aid=42483.

Figure 1: Community Fuels Existing Biorefinery at Port of Stockton, California

Source: Community Fuels.

Converting Fats, Oils, and Grease to Biodiesel

Triglycerides contained in fats and oils are converted to fatty acid methyl ester (FAME) biodiesel by way of a transesterification[4] reaction. The triglycerides are reacted with an excess of methanol in the presence of an alkaline catalyst to produce FAME and glycerin. The FAME and glycerin phases that are present in the post-reaction mixture are separated and excess methanol is recovered and purified by distillation for re-use in the production process. Impurities in the raw FAME are removed by a sequence of purification steps that include water washing, filtration, and drying.

Problem Statement

Being able to process a greater number of alternative feedstocks would result in biodiesel with a lower carbon intensity (CI), which will help to achieve California's targets for greenhouse gas (GHG) emission reduction. Some of these alternative feedstocks, however, contain impurities that pose a variety of production challenges with existing processes. Under the CEC Clean Transportation Program solicitation PON-13-609 *(Pilot-Scale and Commercial-Scale Advanced Biofuels: Production Facilities)*, Community Fuels successfully proposed for grant funding the project titled "Increased Efficiency for Processing Low Carbon Intensity Biodiesel Feedstocks at an Existing Biorefinery" (project). Successful implementation of the project will make it feasible to process a wider range and greater volumes of waste greases, agricultural byproducts, and other lower-grade feedstocks with low CI values. The project aligned closely with the following

4 The chemical reaction between triglycerides and an alcohol, in the presence of a catalyst, that results in fatty acid methyl esters and glycerol as the products.

key policy objectives set forth in the CEC's *2014-2015 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program*[5]:

- Achieving near-term and long-term reductions in GHG emissions
- Reducing California's use and dependence on petroleum transportation fuels
- Increasing the use of alternative and renewable fuels
- Producing alternative and renewable low-carbon fuels in California

[5] California Energy Commission staff. *2014-2015 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program*. April 2014. Publication Number: CEC-600-2013-003-CMF. Available at http://web.archive.org/web/20170829173909/http://www.energy.ca.gov/2013publications/CEC-600-2013-003/CEC-600-2013-003-CMF.pdf.

CHAPTER 2: Project Objectives

Community Fuels proposed to increase the efficiency for processing low carbon intensity feedstocks containing high levels of free fatty acids (FFA) into biodiesel at its biorefinery. Community Fuels designed the operational objectives described in the original proposal to maximize product yields, reduce the amount of chemicals and energy required for product purification, and extend the upper limit of FFA and other impurities that can be effectively processed at the biorefinery. This would make it feasible to process a wider range and greater volume of waste greases, agricultural byproducts, and other lower-grade feedstocks with low CI values.

The project approach emphasized feedstock flexibility and the ability to process a range of fats and oils with low CI values. Community Fuels anticipated that 25 percent of the biorefinery's total output capacity will be produced from feedstocks with low CI values upon successful implementation of the proposed project. Operation of the biorefinery at full capacity using a feedstock blend containing 25 percent low-CI feedstocks would result in the production of 6.25 million gallons of biodiesel per year derived from low-CI feedstocks. Delivering 6.25 million gallons of biodiesel per year into California's diesel fuel supply would result in the displacement of 5.85 million gallons of petroleum diesel gallon equivalents per year. The associated reduction in GHG emissions (assuming a CI value of 4.00 grams of equivalent CO2 per megajoule for the biodiesel produced from alternative feedstocks) was projected to be 74,125 metric tons of carbon dioxide equivalents per year, with a total reduction of 1.48 million metric tons of CO2 equivalents over the projected 20-year lifetime of the system.

The project proposal recognized that ensuring fuel quality is critical to the growth of the biodiesel industry in California and the smooth implementation of California's Low Carbon Fuel Standard (LCFS). When processing a wide range of low-CI feedstocks, it will be critical to verify that the biodiesel produced from these feedstocks meets the current American Society for Testing and Materials standards and the even more stringent customer specifications for fuel quality. The project included upgrades to the existing on-site quality control laboratory, which will be used to evaluate prospective new feedstocks, to analyze and evaluate process changes, to troubleshoot production issues during in-process trials, and to certify all finished batches of biodiesel produced at the biorefinery.

CHAPTER 3: Design, Procurement and Construction

Design Engineering and Process Modifications

Community Fuels worked with multiple engineering subcontractors throughout the project to incrementally implement efficiency improvements and to make modifications and enhancements to increase the efficiency of biodiesel production from low-CI feedstocks. To reduce the risk of damage to the biorefinery and refining processes, Community Fuels commissioned modifications incrementally through in-process production trials in several separate stages, with data collection to help inform the next steps of improvements.

Acid Esterification Process

Lower-grade fats and oils used as alternative, low-CI feedstocks, can contain elevated levels of FFA. An established option for pretreating feedstocks that may have higher FFA is to convert the FFA to FAME by means of an acid-catalyzed esterification reaction[6]. Community Fuels worked with engineering contractor Springhouse Consulting to create a customized design for the installation of an additional reactor for the acid esterification reaction that would fully integrate into operations at the biorefinery.

Separation of Glycerin and Free Fatty Acids

Following separation from the FAME product, the glycerin co-product is then made slightly acidic to neutralize the excess methoxide catalyst from the transesterification reaction. Upon addition of the acid, soaps that accumulated in the glycerin are converted to FFA. Under previous operations, the FFA remained with the glycerin and the mixture was sold as a single bulk product. It is desirable to separate the FFA from the glycerin, however, because FFA can be sold for a higher price as a distinct product.

By modifying the valves and instrumentation on the existing glycerin storage tank and developing new operating procedures, it has become possible to separate FFA from the glycerin. This has resulted in a new product and revenue source, thereby making more efficient use of feedstock resources. This will be especially important when processing low-CI feedstocks, which may generate higher levels of soaps during the transesterification process. The FFA recovered from the glycerin will be stored in the repurposed tank that had been intended initially for use as the feedstock dryer.

Methanol Handling, Recovery and Purification

Due to the excess of methanol required by the acid-catalyzed esterification reaction, greater volumes of methanol will be delivered to the biorefinery. The project team evaluated the possibility of taking delivery of methanol by rail, which would be more efficient than the

[6] A process where an alcohol and an acid catalyst are added to a feedstock to reduce free fatty acids in order to produce biodiesel.

current method of truck delivery. After performing initial design studies, however, Community Fuels concluded that the cost of equipment and site modifications required for offloading methanol from rail cars would be prohibitively high.

The increase in methanol use associated with processing higher volumes of alternative feedstocks will place an additional load on the existing distillation system used to recover and purify excess methanol. The project design included several upgrades to the existing system to enhance its performance. These included increasing the chilling capacity, adding a recirculation pump at the bottom of the distillation column, adding reflux plates to the distillation column, and changing the position of several inlets to the distillation column.

Equipment Installation and Construction

Storage Tanks

Community Fuels installed two new 25,000-gallon cone-bottom storage tanks (Figure 2), which are used for receiving and storing alternative feedstocks with high cloud points and other impurities that may require special handling, such as heating and blending. Community Fuels performed additional work in support of receiving alternative feedstock deliveries included pouring new concrete in the truck staging area adjacent to the tank farm to create a containment area and installing a new steam header for heating rail cars containing alternative feedstocks with high cloud points.

Figure 2: New Storage Tanks for Alternative Feedstocks

Source: Community Fuels

Community Fuels also installed an additional 25,000-gallon stainless steel sloped bottom tank in the existing containment area (Figure 3). The material of the new tank is compatible to process both water and pre-treated feedstock with a high acid content. Initially, the tank will receive used water from the wash column used to purify the raw FAME product following the esterification and transesterification reactions and removal of excess methanol. Ultimately, if the wash column is eliminated as has been investigated, the new tank could then be used as a holding tank for pre-treated feedstock. The tank is equipped with valves at various heights from which settled contaminants and other material can be removed. One example of an efficiency improvement made possible by this equipment is that unreacted fats and oils that could be carried over to the tank can be recovered easily through the outlets for subsequent reintroduction into production.

Figure 3: Sloped Bottom Tank with Outlets at Multiple Levels

Source: Community Fuels

Acid Esterification Reactor

Community Fuels installed a stainless steel reactor into the existing process room for use with the esterification process (Figure 4). The reactor is equipped with a mixer, instrumentation, and controls; piping, pumps, and valves have been installed to connect the reactor with the downstream process steps. After the esterification reaction has been completed, the contents of the reactor will be allowed to stand until they separate into an aqueous phase (consisting primarily of water, salts, and methanol) and a phase containing the FAME converted from FFAs and the unreacted fats/oils from the original feedstock. The aqueous phase will be sent to the existing glycerin neutralization tank, where it will be combined with the glycerin recovered from the transesterification process. The FAME/oil phase will be sent to the transesterification reactors, where the unreacted fats and oils will be converted completely to FAME.

Figure 4: New Stainless Steel Reactor

Two views of the new stainless steel reactor: a) the reactor vessel and base from the process room floor; b) the top of the reactor, with mixer motor and instrumentation installed, from the elevated platform in the process room.

Source: Community Fuels

Methanol Recovery and Recycling System Modifications

Community Fuels' biorefinery includes a system for separating excess methanol from the FAME and glycerin products and purifying the recovered methanol in a distillation column. This represents a major advantage in terms of cost and sustainability relative to biodiesel production facilities that do not recover excess methanol from the FAME production process. Not recovering the excess methanol results in inefficient utilization of a primary raw material and generation of a hazardous waste stream. To improve the efficiency of chemical consumption, recycling and recovery, Community Fuels installed a new 170-ton air-cooled chiller (Figure 5) and a new heat exchanger and recirculation pump in the methanol distillation system. In addition, Community Fuels changed the positions of several inlets to the distillation column to improve performance.

Figure 5: New Chiller for Methanol Recovery and Recycling System

Source: Community Fuels

Piping and Pumps

Community Fuels made several significant modifications to the existing pumps and piping associated with the FAME dryer, winterization[7] system, and filter press. These changes were necessary in order to alleviate problems with clogging and coating of surfaces with a waxy, gelatinous material encountered when processing certain types of alternative feedstocks. These modifications are described in further detail in Chapter 7.

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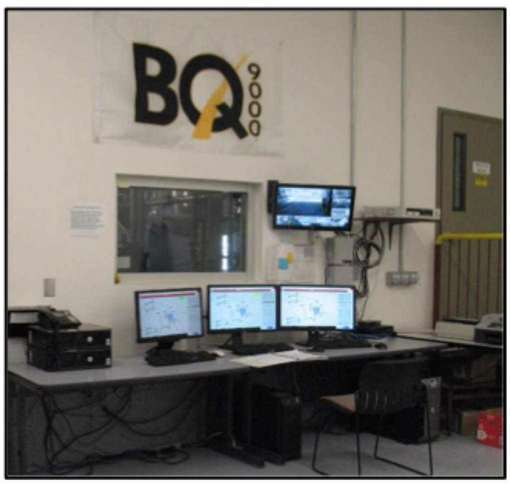
7 A process ensuring that finished biodiesel fuel will have favorable cold weather flow properties to meet fuel specifications.

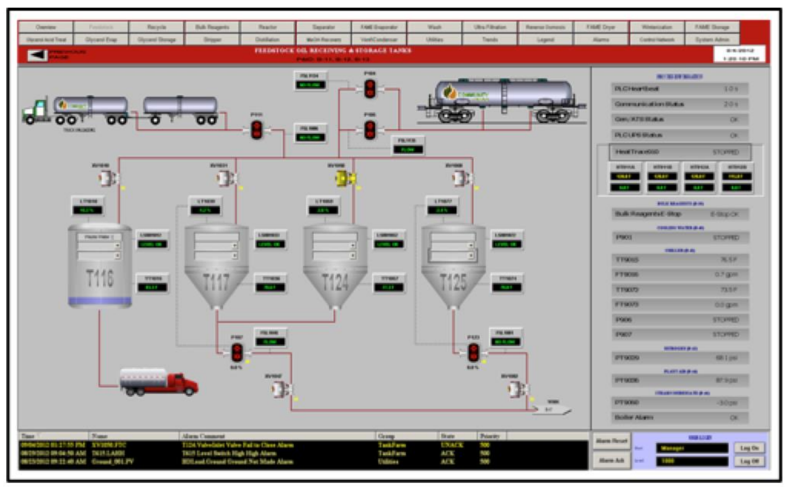
The new process equipment added under this project required the installation of associated piping and pumps to integrate the equipment into the biorefinery. All of the new piping and pumps have been sized to accommodate the target biodiesel production volume of 25 million gallons per year. The system components have also been designed to support operations that utilize high-FFA feedstocks to account for up to 25 percent of the total feedstock mix at the biorefinery. Several types of pumps are used at the biorefinery, including slide vane, gear, centrifugal, and diaphragm pumps. Efforts are underway to standardize these pumps so that a reasonably sized inventory of replacements can be stored onsite.

Instrumentation and Controls

The Community Fuels biorefinery features an integrated process control system designed specifically for Community Fuels that automates key aspects of production (Figure 6). A network of sensors is used to monitor a wide range of operating parameters, including flow rates, tank levels, pump and valve status, temperatures, pressures, and other physical and chemical properties of the materials being processed. The sensor data allow for real-time system analysis and adjustments.

Figure 6: Biorefinery Control Room and Example of Operator Display Screen





Source: Community Fuels

Community Fuels replaced the existing human-machine interface (HMI) servers with two new virtual host servers and one drive array (Figure 7). The new servers are configured to host virtual machines in a redundant pair. The drive array hosts the virtual servers which will run the HMI application in a high-availability cluster. In a high-availability cluster configuration, if any of the primary virtual servers fail, the backup server for the assigned role takes over with no production down time. The new servers have been installed and connected to the existing controls system network. Community Fuels hired a contractor to migrate the existing HMI application to a new version of the software along with databases, reporting services, and historical data.

Figure 7: New HMI Servers and Drive Array

Source: Community Fuels

Community Fuels creates and maintains its own proprietary code for the process control system, which was designed to accommodate upgrades and future expansions of the biorefinery. Community Fuels made several changes to the process control system programming in order to integrate the new equipment and instrumentation installed for this project. Community Fuels made these changes incrementally for each individual modification to the production process to mitigate the risk associated with making major changes to the existing process control system all at once.

Upgrading controls and instrumentation was particularly critical for the steam boiler. Prior to the project, the boiler was frequently unable to maintain sufficiently high operating temperatures. This caused the boiler to shut down, which severely disrupted production operations. Community Fuels evaluated a hot oil boiler as an option for improving efficiency and capacity of the process heating system. Relative to steam boilers, hot oil boilers are advantageous because they can produce a higher temperature working fluid, require no chemical treatment of the working fluid, and are easier to operate. While transitioning from a steam boiler to a hot oil boiler was identified as a long-term goal for the biorefinery, Community Fuels determined that the cost would be too high to include in this project.

As an alternative solution, Community Fuels installed additional instrumentation to the boiler and integrated the instrumentation and controls through the HMI. This allowed the biorefinery operators to monitor the boiler in near real time and gain a better understanding of the conditions that led to boiler shutdowns. The operators are now able to be more proactive and make adjustments as necessary to keep the boiler operating properly and problems with maintaining the boiler temperature are no longer experienced.

Fuel Quality Testing and Certification

Community Fuels' biorefinery includes a state-of-the-art on-site quality control laboratory equipped with instrumentation for analyzing incoming feedstocks and other raw materials and outgoing biodiesel and glycerin (Figure 8). These in-house laboratory resources, which far surpass industry norms, contribute fundamentally to the exceptional quality assurance and quality control practices that have earned Community Fuels a reputation within the marketplace for supplying fuel of impeccable quality. Community Fuels was the first biodiesel producer in the nation to secure both BQ9000 Laboratory and Producer certifications.

Figure 8: Onsite Analytical Laboratory at the Community Fuels Biorefinery

Source: Community Fuels

Samples are collected and analyzed regularly to verify that all finished biodiesel meets the current fuel quality specifications under American Society for Testing and Materials as well as far more stringent internal specifications and customer specifications. In addition to analyzing samples of feedstocks and finished biodiesel, the on-site laboratory is used to test other raw materials and intermediate products sampled from various points in the process to assess system performance. As part of the process evaluations performed during this project, Community Fuels considered alternatives for the transesterification catalyst and the filtration media used with the filter press. Community Fuels obtained samples of the alternative catalyst and filtration media from suppliers and tested in the laboratory. While the results suggested that they could provide some efficiency improvements, Community Fuels had concerns about the higher costs of these materials and the potential to complicate or delay the project by introducing them into the existing process. The project team determined that it was preferable to stay with the existing catalyst and filtration media to maintain consistency in those aspects of the process and limit the number of variables that needed to be considered during commissioning of the new equipment and process efficiency modifications.

Specific upgrades to the laboratory performed during the project included the addition of an "ElemeNtS"[8] model analytical system from PAC Analytical (Figure 9). This instrument is dedicated to analyzing components containing sulfur by introducing samples into a high temperature combustion tube, where sulfur is oxidized to sulfur dioxide in an oxygen rich atmosphere and detected with a photomultiplier tube using UV light. The analyzer helps to monitor sulfur concentrations in the finished biodiesel product, which is especially important when processing a wide range of feedstocks that can contain sulfated amino acids capable of elevating the sulfur content of the biodiesel above American Society for Testing and Materials specifications. In addition, Community Fuels enhanced the existing Fourier Transform Near Infrared spectrometer to include calibrations for methyl ester content, free and total glycerin, and acid number to provide real-time analytical data during production to enhance the project teams' efforts at maximizing the percentage of low-CI feedstocks processed.

Figure 9: New Sulfur Analyzer for the Onsite Analytical Laboratory

Source: Community Fuels

8 PAC-Lab Instruments-Antek https://www.paclp.com/lab-instruments/brand/antek

CHAPTER 4: Personnel Training

Community Fuels identified many areas of its biodiesel production process that could be optimized or modified to improve performance and reduce operating costs. System tests are ongoing as each process modification requires commissioning, optimization, and operator training. Specific changes to the system are implemented individually so that the project team can assess its impacts prior to making additional changes.

This work has included the development of standard operating procedures and other training materials related to new equipment and process modifications associated with this project. Community Fuels currently has 87 active standard operating procedures in use that are related to operations at the biorefinery and 54 standard operating procedures for the onsite laboratory. In addition, the biorefinery managers have produced written checklists of procedural steps for operators to follow when starting up or shutting down critical system components. Operators are also provided with a written list of standard ranges for select operating parameters (i.e., temperatures, flow rates, and other diagnostic information monitored at points throughout the production process). If the biorefinery is operated with one or more of the parameters outside of its standard range during production, the operator must document it in writing and notify the biorefinery managers. The standard operating procedures, checklists, and operating parameters are important resources for training new biorefinery operators and maintaining high levels of efficiency and safety during production.

Over the course of the project, Community Fuels experienced high turnover in personnel and a shortfall of qualified applicants for new hires. Community Fuels hired more than 25 new employees during the period from November 2014 to the December 2020; of those, only 14 are still actively employed. The lack of sufficient operators contributed to project delays and an inability to operate the plant 24 hours per day, seven days per week (24/7) to achieve its full production capacity. Community Fuels has switched from using an outside specialized staffing agency for filling operator positions to recruiting and hiring candidates on their own. In addition, Community Fuels created and filled a new Production Manager position in February 2019. The duties of that position include specific items related to more comprehensively training operators and material handlers at the biorefinery. These measures have led to an improvement in recruiting and retaining qualified personnel.

While the Community Fuels biorefinery is designed to run continuously and achieves highest efficiency under a 24/7 operations, production schedules are influenced by market conditions and the level of demand for biodiesel. The biorefinery is currently operating at reduced levels, as the COVID-19 pandemic has impacted supply chains and demand for all transportation fuels. When market conditions improve and there is sufficient, steady demand for the biodiesel product, it will be possible to transition quickly to continuous operations. There are currently enough trained managers and operators to support 24/7 shift scheduling; however, additional material handlers would need to be added, but those positions do not require lengthy training periods.

CHAPTER 5:
Data Collection and Analysis

Selection of Alternative Feedstocks for Production Trials

Over the course of the project, Community Fuels received 106 samples of fats, oils, and grease for evaluation as feedstock (Table 1). Corn oil, tallows, and used cooking oils comprised the majority of these samples. Community Fuels performed laboratory analyses on the samples to determine their content of FFA, the amount of moisture, insolubles and unsaponifiables, and other properties useful for predicting how successfully they could be converted to biodiesel. Community Fuels frequently performed laboratory production simulations, and close monitoring of production and fuel quality occurred with all new feedstocks introduced for production trials.

Table 1: Feedstock Samples Received for Laboratory Analysis

Feedstock	Number of Samples
Vegetable Oils	
Corn	32
Canola	9
Soybean	7
Camelina	2
Safflower	2
Meadowfoam	1
Other	4
Animal Fats and Rendering Products	
Tallows	19
Used Cooking Oils	14
Poultry Fat	6
White Grease	2
Lard	2
Yellow Grease	1
Other	5

Source: Community Fuels

Operations

Maximum Biodiesel Production Capacity

Community Fuels increased the biodiesel production capacity of the biorefinery from 10 million gallons per year to 25 million gallons per year under a separate CEC-funded project (ARV-13-008). The current production equipment has been operating at throughput rates as high as 50 gallons per minute, which is adequate to support a production level of 25 million gallons per year under continuous 24/7 operations. In the proposal for the current project, Community Fuels set a goal for 25 percent of the total output capacity of the biorefinery to be produced from low-CI feedstocks. Based on a total production capacity of 25 million gallons per year, that equates to an objective of 6.25 million gallons per year of biodiesel produced from low-CI feedstocks.

After Community Fuels installed and commissioned all of the project-related equipment, and implemented the process modifications, biodiesel production flow demonstrated flow rates of up to nearly 40 gallons per minute. Annualized, assuming 24/7 operation with five percent downtime for repairs and maintenance, this would support production of more than 19 million gallons of biodiesel per year. The COVID-19 pandemic has resulted in inconsistent diesel and biodiesel demand, however. As demand improves and stabilizes, the project team will work to quickly increase utilization of the biorefinery's full production capacity.

Carbon Intensity

The relevant fossil fuels reference baseline is ultra-low sulfur diesel[9], which is diesel fuel that has a sulfur content of 15 parts per million and a CI value of 100.45 gCO_2e/MJ that is based on the average crude oil supplied to California refineries and average California refinery efficiencies.[10] Community Fuels' biorefinery is registered under the Biofuel Producer Registration program (Company ID 4935, Facility ID 82728) of the California Air Resources Board (CARB) with a CARB-approved physical pathway (PHY01). While the project equipment was designed to emphasize feedstock flexibility and the ability to process a range of fats and oils, the original intent of the project was to focus on corn oil derived from the distillers grains with solubles (DGS) by-product of ethanol production. At the time of the project proposal submission, the LCFS lookup tables for FAME biodiesel produced at Community Fuels' biorefinery using corn oil from wet DGS as the feedstock specified a CI value of 4.00 gCO_2e/MJ. Since that time, however, CARB has updated the CI values for biodiesel produced from this feedstock by all producers to be in the range of 27-33 gCO_2e/MJ.

Since the implementation of the current project, the primary low-CI feedstocks selected for processing at Community Fuels' biorefinery include corn oil from DGS, tallows (animal fats),

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9 A cleaner-burning diesel fuel that was developed for the use of improved pollution control devices that reduce harmful diesel emissions more effectively.

10 California Air Resources Board staff. *California Air Resources Board CA-GREET 3.0 Lookup Table Pathways Technical Support Documentation*. August 2018. Available at https://www.arb.ca.gov/fuels/lcfs/ca-greet/lut-doc.pdf.

and used cooking oil. The CI values assigned by CARB for biodiesel produced from these feedstocks are shown in Table 2.

Table 2: LCFS-Certified Carbon Intensities for Community Fuels Biodiesel

Feedstock	Pathway Description	Current Certified Fuel Pathway Code	Current Certified CI (gCO_2e/MJ)
Corn Oil from Wet DGS	Biodiesel Produced from Midwest Corn Oil; Fuel Produced in California	BDC204	29.42
Tallow	Biodiesel Produced from Tallow (Poultry Fat); Feedstock Sourced in California	BDT206	28.90
Tallow	North American High Energy Rendered Tallow; Biodiesel Produced in California	BDT205	32.34
Used Cooking Oil	High Energy Rendered Used Cooking Oil (UCO); Biodiesel Produced in California	BDU206	16.31

Source: California Air Resources Board[11]

From 2010 to 2013, the average CI of biodiesel produced at the Community Fuels biorefinery was about 70 gCO_2e/MJ and low-CI feedstocks accounted for nearly two percent of the total feedstock volume processed at the biorefinery. Over the duration of this project (December 2014 through May 2020), Community Fuels further reduced the average CI of the biodiesel to nearly 52 gCO_2e/MJ, with a range of about 16 gCO_2e/MJ to 83 gCO_2e/MJ, depending on which feedstocks the refinery processed. Low-CI feedstocks accounted for more than 12 percent of the total feedstock during this period. Over the period covering June 2019 to May 2020, Community Fuels reduced the average CI of the biodiesel even further, to nearly 44 gCO_2e/MJ (representing a 37 percent reduction from the start of the project agreement and more than a 56 percent reduction relative to the is ultra-low sulfur diesel baseline), and low-CI feedstocks accounted for about 36 percent of the total feedstock. Based on the very low CI value for biodiesel produced from corn oil from wet DGS (4.00 gCO2e/MJ) that was valid at the time, the drop in the average biodiesel CI value was not as low as predicted by the original

[11] California Air Resources Board staff. *Current Fuel Pathways*. Updated April 2021. Available at https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/current-pathways_all.xlsx

calculations in the project proposal. This was partially balanced, however, by exceeding the original target of 25 percent for the portion of the total feedstock accounted for by low-CI feedstocks. Over some recent time periods, the project team achieved feedstock blends containing over 55 percent low-CI feedstocks during production operations, far exceeding the original objectives of the project.

Greenhouse Gas Emissions Reductions

Assuming that 35 percent of the total feedstock processed consists of low-CI feedstocks (i.e., the average value attained over the most recent 12 months of operations), the volume of biodiesel produced from low-CI feedstocks when the biorefinery is operating at full capacity would increase to 8.75 million gallons per year. The GHG emission reduction resulting from the use of 8.75 million gallons per year of biodiesel with a CI value of around 44 gCO_2e/MJ is about 62,575 metric tons (MT) of CO2e per year. Community Fuels calculated this value was according to the LCFS regulations, as shown below (all formulas were obtained from the LCFS Regulation)[12]:

- GHG reduction (MT CO_2e) = $(CI_{standard} – CI_{reported}) \times E_{displaced} \times (1.0 \times 10^{-6}$ MT/ g)
    - Where $CI_{standard}$ is the carbon intensity (in gCO_2e/MJ) for the petroleum baseline (ultra-low sulfur diesel)
        - $CI_{standard}$ = 100.45 gCO_2e/MJ
        - $CI_{reported}$ is the adjusted carbon intensity value (in gCO_2e/MJ) of the biodiesel
    - Where CI_i is the average carbon intensity of the biodiesel derived from California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation pathways (43.75 gCO_2e/MJ) and *EER* is the Energy Economy Ratio relative to petroleum diesel (1.0 for biodiesel)
        - $CI_{reported}$ = CIi / EER = 43.75 gCO2e/MJ / 1.0 = 43.75 gCO2e/MJ
        - $E_{displaced}$ = $Ei \times EER$ = 1,103,637,500 MJ x 1.0 = 1,103,637,500 MJ
    - Where E_i is the energy content of the biodiesel (in MJ), obtained by multiplying the gallons of biodiesel used by the energy density of biodiesel (126.13 MJ/gal)
        - E_i = 8,750,000 gal x 126.13 MJ/gal = 1,103,637,500 MJ
- *GHG reduction* = (100.45 gCO_2e/MJ – 43.75 gCO_2e/MJ) x 1,103,637,500 MJ x 1.0 x 10^{-6} MT/g
- *GHG reduction* = ~62,575 MT CO_2e (per year)

Over the projected 20-year lifetime for the project equipment, the total carbon displacement for the project will be about 1.25 million MT of CO_2e. This is about 15 percent lower than the value calculated using the original target of 25 percent of total biodiesel production at the

[12] California Air Resources Board staff. *Unofficial Electronic Version of the Low Carbon Fuel Standard Regulation*. July 2020. Available at https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

biorefinery with the low, pre-revision CI value of 4.00 gCO_2e/MJ for biodiesel produced from corn oil from wet DGS.

Petroleum Displacement

Assuming that 8.75 million gallons per year of biodiesel produced from low-CI feedstocks are introduced into California's diesel fuel supply as the result of this project, the amount of petroleum displaced is calculated as follows:

- Volume of biodiesel x Energy density of biodiesel = Energy content of biodiesel
  - 8,750,000 gal x 126.13 MJ/gal = 1,103,637,500 MJ
- Energy content of biodiesel x Energy economy ratio = Energy content of diesel fuel displaced
  - 1,103,637,500 MJ x 1.0 = 1,103,637,500 MJ
- Energy content of diesel fuel displaced / Energy density of diesel fuel = diesel gallon equivalents displaced
  - 1,103,637,500 MJ / 134.47 MJ/gal = ~8.21 million diesel gallon equivalents displaced per year

This is 40 percent greater than the estimated 6.0 million diesel gallon equivalents displaced per year that Community Fuels calculated in the project proposal based on the introduction of 6.25 million gallons per year of biodiesel from low-CI feedstocks.

Renewable Energy Use

The Port of Stockton's electric supply is designed to provide reliable electric service while moving to meet the State of California's environmental goals. The port provides its tenants with a power content label that identifies the origin of its sources of electric power based on actual data. According to the most recent power content label (from 2018), renewable energy resources supplied 30 percent of the power mix at the port (27 percent from wind and three percent from biomass and biowaste). Community Fuels has evaluated photovoltaic power installations multiple times, but it determined that solar was not economically viable because setting up net metering at the port was not possible.

During the project period, Community Fuels participated in an energy audit performed by California State University, San Francisco's Industrial Assessment Center. The United States Department of Energy, with overall management provided by the Center for Advanced Energy Systems at Rutgers University funded this work. Personnel from Industrial Assessment Center gathered data during a one-day site visit to Community Fuels' biorefinery to evaluate opportunities for energy conservation, waste minimization, and productivity improvement. Following the site visit, Industrial Assessment Center issued a report containing eight non-binding recommendations offered as guidance. Community Fuels accepted two of the recommendations (for insulating hot and cold surfaces) but did not implement the other recommendations because they were price prohibitive or would have resulted in significant disruptions to operations.

CHAPTER 6: Economic Impact

Community Fuels

Community Fuels estimates that it created or retained 18 direct jobs in Stockton as a result of this project. The jobs include one Chief Operating Officer, one plant manager, one production manager, three laboratory technicians, three material handlers, three operators, one plant administrator, one plant engineer, one environment, health and safety manager, one laboratory manager, one logistics manager, and one project manager.

Contracting

It is expected that the work performed under the project also resulted in additional job creation and retention through contractors and suppliers. Community Fuels utilized about 34 subcontractors, which provided employment for around 100 people and injected more than $1 million into the local and state economy. Additionally, this project resulted in more than $6 million going to local and state suppliers.

Business Opportunities

Community Fuels provides preference to contractors and suppliers located within the state of California. Although Community Fuels does sell biodiesel and glycerin outside of California, customers who purchase our products for use within the state are given priority. Community Fuels also is working with multiple companies to develop feedstock opportunities within California.

Tax Revenues

Assuming 8.75 million gallons of biodiesel per year produced from low-CI feedstocks and an average sales price of $3.10 per gallon (before taxes), the project would generate annual revenue of $27 million. At that volume, the project also is expected to generate over $5.65 million of tax revenue per year, including:

- Federal Excise Tax ($0.244 per gallon): $2.14 million per year.
- California Excise Tax ($0.10 per gallon): $875,000 per year.
- State Prepaid Fuel Sales Tax ($0.290 per gallon): $2.54 million per year.
- Property taxes: estimated at over $100,000 per year.

CHAPTER 7: Lessons Learned

Key Project Delays

Project completion fell behind schedule due to interruptions, delays, and uncertainties caused by a number of factors, including unresponsiveness from subcontractors (which forced redesign and new engineering work) and legal proceedings which resulted in two project audits and a stop work order issued by CEC. In addition, the plant manager at the biorefinery (an essential member of the project team) had changed personnel three times over the duration of the project. The time necessary to recruit, hire, and train a new plant manager slowed progress.

Problems related to the steam boiler, alternative product purification system (which was ultimately abandoned), and distillation column, which temporarily caused complete stoppage of production whenever they had to be taken offline, sharply reduced biodiesel production levels. Community Fuels curtailed production due the difficulty of finding qualified personnel to hire as plant operators and the time required to train new operators, which can exceed six months. While the biorefinery is designed for continuous 24/7 operation, this cannot be sustained until more operators are hired and trained. When the biorefinery is fully staffed, operations can go back to continuous mode to take advantage of efficiencies and maximize overall production.

Acid Esterification Reactor

Community Fuels evaluated the technologies currently available for acid-catalyzed esterification, including an analysis of yields, energy usage, capital costs, and operating costs. Community Fuels used the results of this study to develop a model for feedstock pretreatment, which was then validated in Community Fuels' laboratory through production simulations. Community Fuels initially identified a commercially-manufactured system as the optimal solution for feedstock pretreatment. This technology featured flow-through reactors and a proprietary solid catalyst, which reduces the amount of methanol required in the process and allows for continuous operation. Community Fuels provided samples of prospective feedstock to the equipment supplier and was particularly interested in the ability of this technology to address waxes that are apparent in distillers corn oil. The design process had advanced to a mature stage, with installation plans drafted, when the manufacturer suddenly became unresponsive. Over a time period of approximately one year, Community Fuels repeatedly and unsuccessfully attempted to re-engage and move things forward. The technology had to be abandoned.

As an alternative, Community Fuels considered a skid-mounted acid-catalyzed esterification system from a different manufacturer. This offered a turn-key, drop-in system that could be installed quickly, which was considered a major advantage. This option was not feasible, however, as closer technical review indicated that the system was not compatible with the existing level of automation and instrumentation at the biorefinery and could not be integrated successfully.

Community Fuels subsequently worked with engineering contractor Springhouse Consulting to create a customized design for the installation of an additional reactor for the acid esterification reaction that would fully integrate into operations at the biorefinery. The initial design concept included a drying step to reduce the water content of the feedstock, followed by an esterification process using a homogeneous acid catalyst to covert FFA to FAME. Community Fuels thought the drying step to be necessary because of the potential for alternative feedstocks to have high levels of water content, which would inhibit the reversible esterification reaction and reduce the yield of FAME. An existing vessel for feedstock drying had been installed during the initial construction of the Community Fuels biorefinery (Figure 10), but it had not been made operational because the alkali-catalyzed transesterification reaction is less sensitive to water content and the biorefinery had been primarily processing higher-grade feedstocks that did not require further drying before being sent to the transesterification process. Community Fuels planned to make this vessel operational and use it as a dryer for the alternative feedstocks that will be sent to the esterification process.

Figure 10: Existing Vessel Intended for Use as Feedstock Dryer

Source: Community Fuels

During process trials with a large number of diverse alternative feedstocks, Community Fuels observed that the water content of the feedstocks was much lower than anticipated. By circulating the feedstocks in the heated storage tanks, Community Fuels determined that it was possible to reduce the moisture content to levels that were low enough to work with the acid-catalyzed esterification process. Community Fuels therefore decided that the dryer did not need to be included in the feedstock pretreatment system. The existing vessel intended for use as the dryer has been repurposed as a storage tank for recovered FFA.

Methanol Recovery and Purification System Modifications

Community Fuels added custom-fabricated plates to the inside of the existing distillation column with the objective of increasing its efficiency by repeatedly condensing and re-vaporizing distilled vapor; however, after installation of the plates, the distillation column did not function properly. Community Fuels made many modifications, repairs, and adjustments in an attempt to get the system to function as it was designed, but none of them proved to be successful. After removing the plates, however, it was possible to make the distillation column operable again. The distillation column needed to be partially disassembled during the installation and subsequent removal of the reflux plates, which was a major operation that required the use of heavy equipment and specialized contractors (Figure 11).

Figure 11: Disassembly of Distillation Column and Installation of Reflux Plates

Source: Community Fuels

Community Fuels included a coalescer in the original design of the methanol recovery system. Before being sent to the distillation column, raw FAME was passed through the coalescer to remove residual glycerol and other hydrophilic impurities. The coalescer, however, was susceptible to plugging, which made it necessary to stop operations while it was disassembled and cleaned. The plugging issue became more pronounced when processing alternative feedstocks containing higher levels of impurities. Community Fuels removed the coalescer from the system and it is being evaluated for repurposing elsewhere at the biorefinery.

Problems Experienced During Production Trials with Alternative Feedstocks

Several of the existing processes for purifying the biodiesel and glycerin products required modification to handle the higher levels of impurities resulting from the use of alternative feedstocks. The most significant problems encountered during production trials with alternative feedstocks are summarized below.

Glycerin Neutralization

The raw glycerin co-product is strongly alkaline because it contains some residual sodium methoxide catalyst that was used in the transesterification reaction. Sulfuric acid has been used to neutralize the alkaline glycerin in the existing production process. The project team considered modifying the glycerin neutralization process by using hydrochloric acid instead of sulfuric acid. This would result in a higher quality glycerin product and potentially alleviate problems experienced with clogging in the glycerin lines associated with sulfate salts produced during neutralization. (Community Fuels anticipated these issues to become exacerbated by higher levels of impurities in the glycerin when processing alternative feedstocks). Laboratory trials showed favorable results when hydrochloric acid was used to neutralize samples of raw glycerin collected from the production process.

Community Fuels performed preliminary design work to convert from the use of sulfuric acid to the use of hydrochloric acid in the existing glycerin neutralization system. This included meetings with chemical suppliers to determine storage tank sizes, revised system layouts, and a review of any changes required for material handling and unloading procedures. Community Fuels also assessed the intended piping modifications and secondary containment for a new acid tank for compliance with regulations.

During permitting reviews, Community Fuels discovered that the proposed mini-bulk system for storing and utilizing hydrochloric acid would require a concrete pad, strapping, seismic work, etc., which involved significant complexity and expense. The project team considered the alternative of using acetic acid instead of hydrochloric acid, which would entail fewer restrictions and regulations. But feedback received from major glycerin buyers indicated that they would not purchase glycerin neutralized using acetic acid, most only had specifications in place for glycerin neutralized using sulfuric acid or hydrochloric acid, and they were not interested in establishing a new specification for glycerin neutralized with a different acid.

In addition to the technical evaluation, the project team evaluated the full business impact related to switching to hydrochloric acid for glycerin neutralization, including cost, availability of raw materials, and impact to market access and customers. Community Fuels determined that the best option was to keep using sulfuric acid in the glycerin neutralization process for the time being. The project team considered installing a new centrifuge to remove salts from the glycerin stream to prevent buildups that could interfere with flow in the glycerin lines. Community Fuels identified a specific model of centrifuge for the intended purpose, but its high cost made it desirable to find an alternative solution. Addressing the issue of clogging in the glycerin lines by modifying operational procedures made it possible install the additional equipment in the glycerin neutralization system. The project team will continue to evaluate and consider potential centrifuge installation in the future.

FAME Dryer

A spray dryer is used to remove residual water from the FAME product following the wash process. Community Fuels encountered problems with the dryer during in-process trials running higher concentrations of alternative feedstocks. The holes in the spray balls inside the dryer vessel became clogged with a waxy, gelatinous substance that restricted or completely blocked the flow of FAME. Community Fuels installed new spray balls with larger holes in the dryer. This led to improvement but did not completely alleviate the problem. A single-bag filter housing had been installed previously on the outlet line from the dryer to remove solid and semi-solid impurities from the dried FAME stream. A four-bag filter that was removed with the coalescer from the distillation system replaced the single-bag filter (Figure 12). After the modifications, the dryer operated properly when processing FAME produced from any feedstocks other than distillers corn oil.

Figure 12: Filter Housing on the Outlet Line from the FAME Dryer

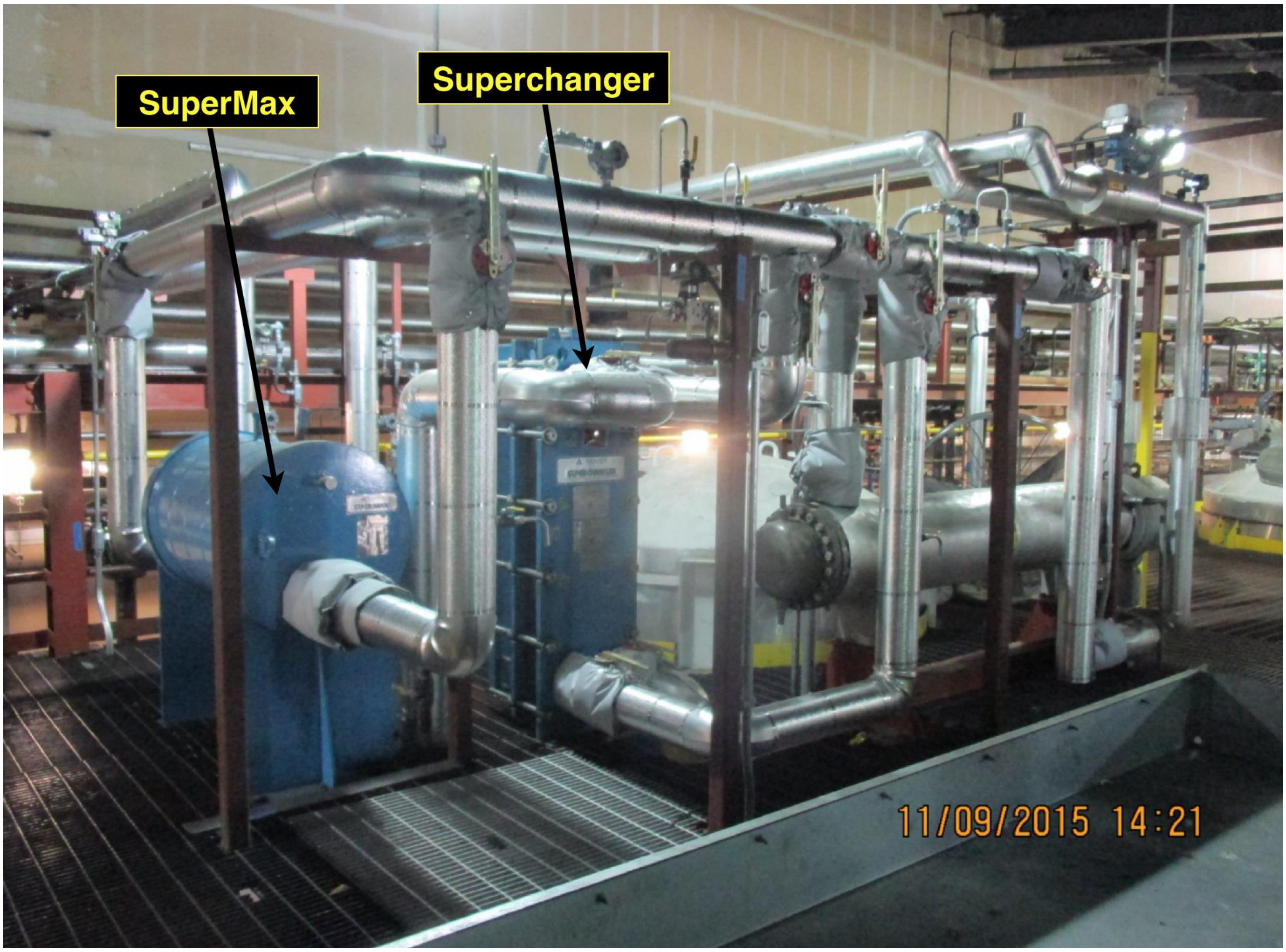
Source: Community Fuels

Winterization

In the winterization process, FAME is chilled so that impurities with high melting points will solidify and come out of solution. The chilled mixture is then sent to a filtration process to remove the solid material. This ensures that the finished biodiesel fuel will have favorable cold flow properties and meet fuel specifications. Prior to this project, Community Fuels used two heat exchangers in the winterization process: an air-cooled, finned-tube heat exchanger and a glycol-cooled, shell-and-tube heat exchanger.

During production trials with alternative feedstocks, Community Fuels observed that the winterization process could become a bottleneck that limited throughput capacity. This is because feedstocks containing higher levels of impurities can result in raw a FAME product with a high cloud point that requires longer chilling times during winterization. To address these issues, Community Fuels installed two new heat exchangers for the winterization process: a water-cooled, welded shell-and-plate heat exchanger (SuperMax) and a glycol-cooled, plate and frame heat exchanger (Superchanger) (Figure 13). The additional cooling capacity provided by these heat exchangers made it possible to lower the FAME temperature more rapidly, reducing the time required for the chilling process and alleviating this production bottleneck when processing higher concentrations of alternative feedstocks.

Figure 13: Heat Exchangers Added to Winterization Process



Source: Community Fuels

Community Fuels installed both fully-operational heat exchangers, but the SuperMax developed a water leak that eventually caused it to fail. It was not repairable. Community Fuels removed the SuperMax and replaced it with a second Superchanger. An additional advantage of the Superchanger heat exchangers is that they can be disassembled in place for cleaning, which makes them suitable for processing a wide range of materials (problems can arise from the formation of coatings on the heat exchanger plates when processing certain feedstocks).

Filtration

A filter press is used to remove solids from the chilled FAME following the winterization process. During production trials processing, the FAME produced from any feedstock other than distillers corn oils damaged the filter press. The permeable conveyor belt in the filter press would become clogged with solid material and lose traction, which caused it to become displaced and torn on several occasions (Figure 14). In addition, the solid material contained in the FAME derived from distiller's corn oil plugged up the piping leading from the filter press to the storage tanks, which required the line to be taken apart and cleaned. Community Fuels repaired the filter press and did not experience problems when processing FAME produced from any other feedstocks besides the distiller's corn oil. Distillers corn oils are expected to contain high levels of waxes, which can be retained in the raw FAME product and lead to difficulties in the purification process. It did not seem likely, however, that waxes alone would have damaged the filter press to the extent observed. Community Fuels staff hypothesized that the wet DGS processed during the project contained additional material that compounded the problems related to the waxes. One possibility is that the wet DGS contained significant amounts of starches that had not reacted completely during the fermentation step in the corn ethanol manufacturing process. This is consistent with the observation of gelatinous material clogging the FAME dryer, winterization heat exchangers, and piping in addition to the filter press.

Figure 14: Damage to Filter Press Components

Source: Community Fuels

Spent media (celite) from the filter press is transferred to a storage bin in the process room. When that bin has filled up, the contents are transferred to a separate bin outside the warehouse for pickup by waste haulers. The spent celite still contains residual biodiesel, which constitutes a waste of product. Community Fuels modified the storage bin in the process room by adding a sloped floor and a bottom drain. This allows residual biodiesel to seep out and be recovered before the spent celite is transferred to the outside storage bin, thereby improving product yields.

CHAPTER 8: Conclusion

The results of the project contribute directly towards achieving the key policy objectives set forth in the CEC's *2014-2015 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* by achieving near-term and long-term reductions in GHG emissions, reducing California's use and dependence on petroleum transportation fuels, increasing the use of alternative and renewable fuels, and producing alternative and renewable low-carbon fuels in California. The project increased efficiency of processing low carbon intensity feedstocks into biodiesel at Community Fuels' biorefinery at Port of Stockton.

The new equipment and operational modifications implemented during this project have improved product yields and extended the upper limit of free fatty acids and other feedstock impurities that can be effectively processed at the biorefinery. This has made efficient processing feasible for a wider range and greater volume of waste greases, agricultural byproducts, and other lower-grade feedstocks with low carbon intensity values. Community Fuels' onsite laboratory analyzed about 105 samples of fats and oils for evaluation as feedstock, and the analyses performed helped to determine the success of feedstocks converting to biodiesel in the full-scale process at Community Fuels' biorefinery.

When running at full capacity using a feedstock blend containing about 35 percent low carbon intensity feedstocks, the biorefinery will produce 8.75 million gallons of biodiesel per year derived from low carbon intensity feedstocks. This volume of biodiesel will result in the displacement of about 8.21 million gallons of petroleum diesel gallon equivalents per year. Community Fuels projected that the associated reduction in greenhouse gas emissions (assuming a carbon intensity value of almost 44 gCO2e/MJ for the biodiesel) will be about 62,575 metric tons of CO_2e per year, with a total reduction of 1.25 million metric tons metric tons of CO_2e over the projected 20-year lifetime of the project equipment.

GLOSSARY

CALIFORNIA AIR RESOURCES BOARD (CARB)—The "clean air agency" in the government of California, whose main goals include attaining and maintaining healthy air quality; protecting the public from exposure to toxic air contaminants; and providing innovative approaches for complying with air pollution rules and regulations.

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 Energy Commission'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.

CARBON DIOXIDE (CO2) - A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent). The major source of CO2 emissions is fossil fuel combustion. CO2 emissions are also a product of forest clearing, biomass burning, and non-energy production processes such as cement production. Atmospheric concentrations of CO2 have been increasing at a rate of about 0.5% per year and are now about 30% above preindustrial levels. (EPA)

CARBON DIOXIDE EQUIVALENT (CO_2e)—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.

DISTILLERS GRAINS WITH SOLUBLES (DGS)—The by-product of ethanol and distillery plants that remain after the starch fraction of corn is fermented and the alcohol is removed.

FATTY ACID METHYL ESTER (FAME)—Esters of fatty acids produced via transesterification of triglycerides or esterification of fatty acids. FAME has physical and chemical properties that make it suitable for use as a fuel for diesel engines. When used in fuel applications, FAME is commonly referred to as biodiesel.

FREE FATTY ACID (FFA)—Long chain carboxylic acids formed by hydrolysis of triglycerides in fats and oils.

GRAMS OF CARBON DIOXIDE EQUIVALENT PER MEGAJOULE OF ENERGY (gCO2e/MJ)—Means grams of carbon dioxide equivalent per megajoule of energy.[13]

GREENHOUSE GAS (GHG)—Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons (HCFCs), ozone (O_3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs). (EPA)

GREENHOUSE GASES, REGULATED EMISSIONS, AND ENERGY USE IN TRANSPORTATION (GREET)—A full life-cycle model sponsored by the Argonne National Laboratory (U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy). It fully evaluates energy and emission impacts of advanced and new transportation fuels, the fuel cycle from well to wheel and the vehicle cycle through material recovery and vehicle disposal need to be considered. It allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis.

HUMAN-MACHINE INTERFACE (HMI)—The hardware or software through which an operator interacts with a controller. An HMI can range from a physical control panel with buttons and indicator lights to an industrial PC with a color graphics display running dedicated HMI software.

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 (GHG) emissions. The LCFS standards are expressed in terms of the "carbon intensity" (CI) of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California to cut greenhouse gas emission 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 1 newton is displaced 1 meter in the direction of the force. It takes 1,055 joules to equal a British thermal unit. It takes about 1 million joules to make a pot of coffee. A megajoule itself totals 1 million Joules.

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13 gCO2e/MJ Definition | Law Insider https://www.lawinsider.com/dictionary/gco2e-mj