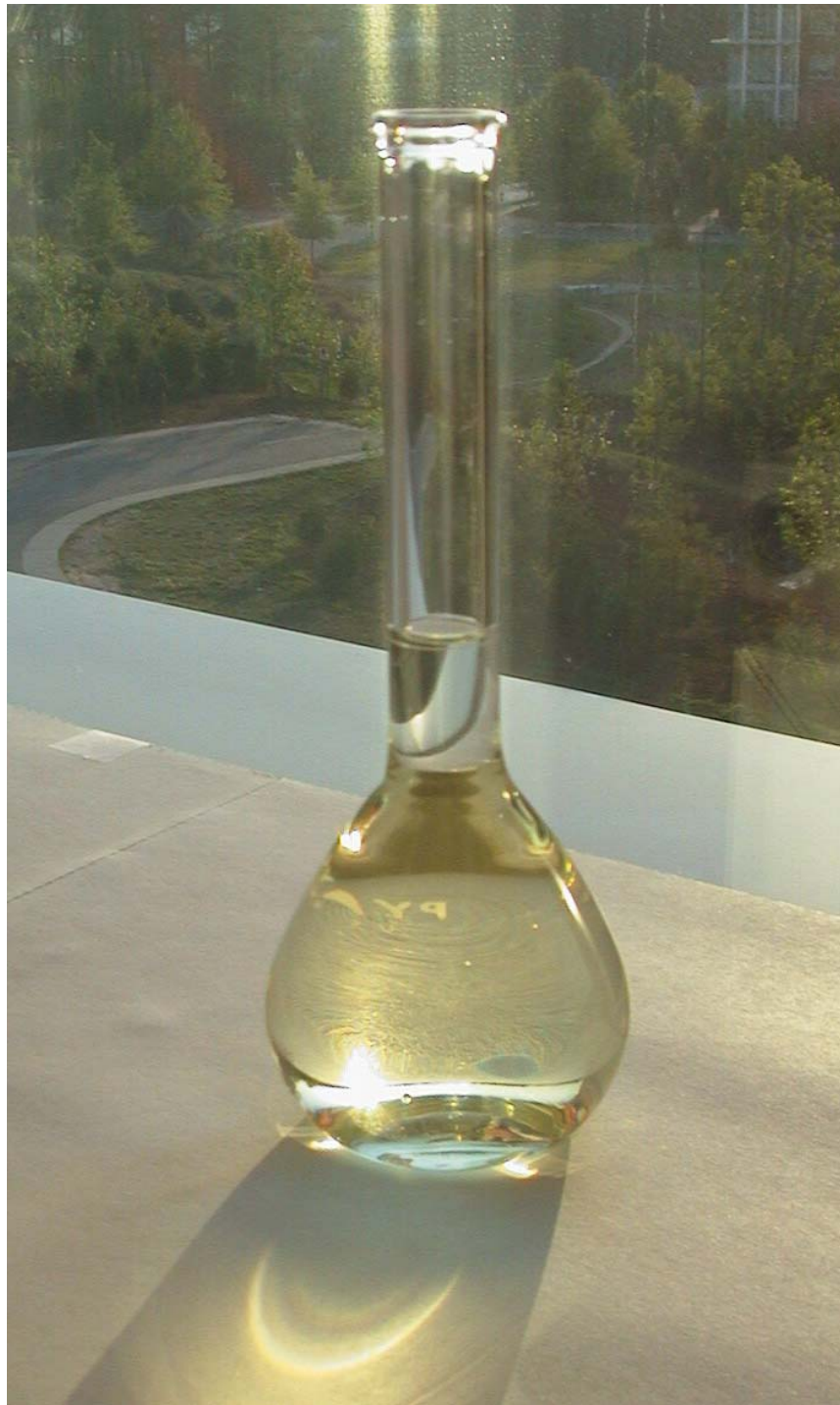

Executive Summary

Centia™ – An Innovative Technology for Converting any Renewable Oil into High-Value Biofuels



Changing the Balance of Power

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Overview

Diversified Energy Corporation (DEC) and North Carolina State University (NCSU) are developing a patent-pending technology for converting oils derived from any triglyceride feedstock (like agriculture crops, animal fats, algae, energy crops, waste greases, etc.) to high-value biofuels. The technology, termed Centia™ (a derivation of “green power” in Latin), integrates a sequence of three steps as shown in **Figure 1** to produce biogasoline, Jet A-1/JP-8 (aviation fuel), and renewable diesel. Unlike ethanol and transesterification-based biodiesel, the biofuels produced from Centia™ will replicate the chemical structure of their petroleum-derived counterparts, therefore enhancing performance and eliminating required modifications to distribution infrastructures, storage techniques, and engines. The process steps are either extensions of existing commercial systems or based on recent technology demonstrations by DEC-NCSU.

Feedstock costs can often contribute as much as 60 - 80% to the cost of producing biofuels. For this reason, a key attribute of Centia™ is its ability to utilize a wide variety of inputs. This provides the owner and operator of a biofuels plant the flexibility to use the most attractive feedstock at any given time or location. Centia™ can utilize oils from crops being used today for the manufacture of biodiesel – like soybean, canola, palm, and jatropa, among others. In addition, the process will be perfectly suited to use up-and-coming feedstocks like algal oils. Lastly, the process can use oils from sources that are generally perceived as having a lower market value, such as waste greases and animal fats (e.g., beef tallow, hog lard, and chicken grease). The ability of Centia™ to use any triglyceride feedstock is therefore a *key* process discriminator.

Centia™ also provides flexibility in the type of biofuel produced. One excellent target market is the aviation industry because of its economic sensitivity to crude oil prices and the current lack of bio-based fuel alternatives. **Figure 2** shows one example of the challenges faced by this industry – for the first time ever fuel costs have exceeded labor costs for U.S. airlines. Reactions from the commercial aviation industry, U.S. and foreign governments, and the military have led to calls for increased investments in alternative aviation fuels. The U.S. Air Force has

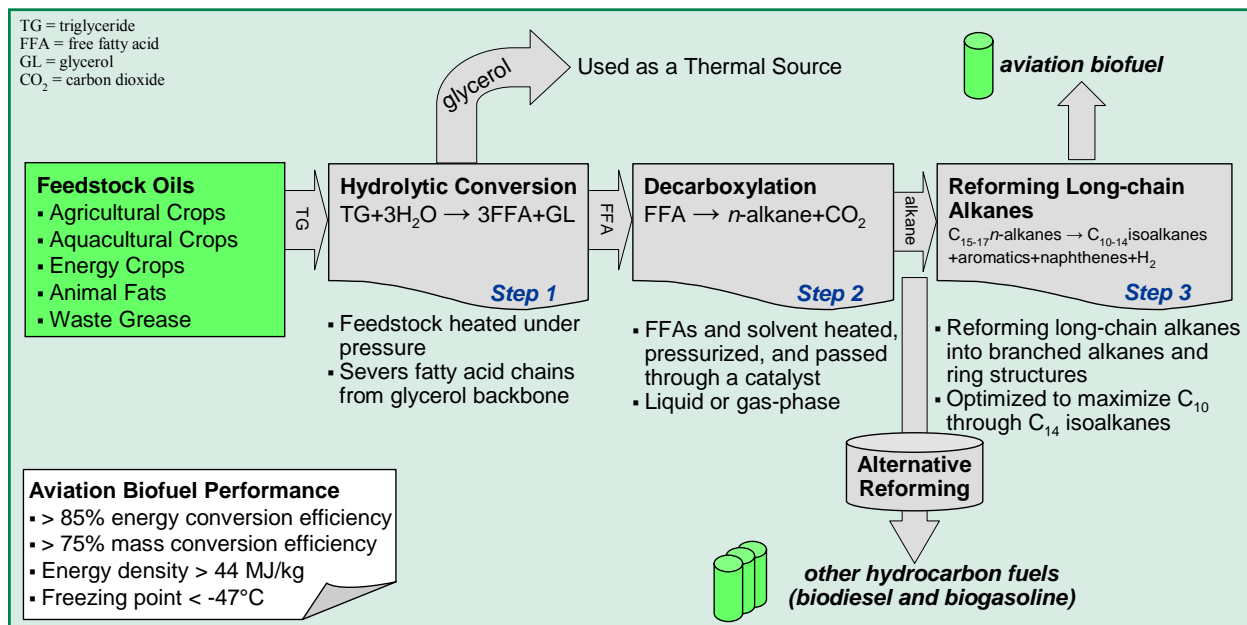


Figure 1: 3-Step Centia™ Biofuels Process

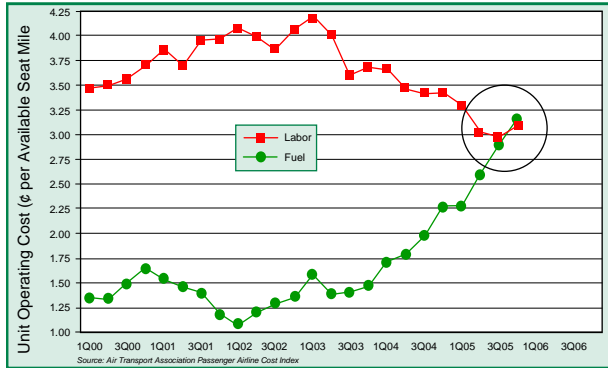


Figure 2: U.S. Airlines Unit Operating Costs

stated that for every \$10/barrel increase in the cost of crude oil, the impact is \$600M in fuel expenses.¹ Yet creating biofuels for aviation use is technically challenging. Aviation fuels must withstand the harsh operating environment of aircraft – high energy densities, robust cold-flow properties, and stringent kinetic and combustion characteristics represent just a few of the unique properties required for JP-8 or Jet A-1. Centia™ has been specifically tailored to produce a fuel that is jet-fuel compliant, and to do so in a manner

that is highly efficient, affordable, and scalable to commercial volumes. The market potential is enormous, with the world consuming approximately 73B gallons/year of jet fuel and the U.S. accounting for about 1/3 of that demand.

In addition to biojet fuel, since the Centia™ process produces *n*-alkanes (the building block of fuels) in Step #2, these normal paraffins can be cracked, reformed, and aromatized differently to create a variety of other biofuel types. By varying the catalyst, temperature, pressure, and kinetics in Step #3, Centia™ can produce other biofuels that mimic their petroleum-derived counterparts. A renewable biodiesel (or additive) could be produced to address the cold weather, oxidation, and degradation issues with today’s biodiesel (fatty acid methyl ester) products. Alternatively, the *n*-alkanes could be processed to produce a biogasoline. This high-octane biogasoline would be chemically similar to petroleum derived gasoline, therefore being compliant with existing distribution systems, fueling infrastructure, and gasoline vehicle engines. This output flexibility ultimately translates into lower risks and enhanced economics for owners and operators of Centia™ biofuel plants.

Key Attributes and Competitive Differentiation

Centia™ is based on a multi-step thermal, pressurized, and catalytic process whose primary attributes include:

- **Feedstock Flexibility** – the first Centia™ step is designed to accommodate any triglyceride feedstock. As such, the process has the flexibility to accommodate oils (or a mix of oils) deemed the most available and cost-effective at any given time or in any geographic location. Oils from agriculture crops, animal fats, algae, energy crops, waste greases, among others, are all acceptable with only operational modifications required.
- **Fuel Output Flexibility** – the third Centia™ step produces fuels capable of meeting strict aviation specifications (e.g., Jet A-1/JP-8), solving cold weather and other issues associated with biodiesel, or being distributed and utilized in vehicles as a direct substitute to petroleum-derived unleaded gasoline.
- **High Efficiency** – the process is expected to deliver an end-to-end energy conversion efficiency of greater than 85%, a mass conversion efficiency in excess of 75%, and utilize roughly one-half the external energy of other conventional biofuel processes. This translates into higher yields and lower costs, an imperative for commercial viability and broad market adoption.

- **“100% Green” Solution** – Centia™ does not require the addition of any form of fossil fuel as a component of the biofuel produced. In fact, the production process itself can be designed to operate without consuming fossil fuels as a heat source.
- **Maturity** – process Steps #1 and #3 are extensions from the commercial marketplace and have been replicated by DEC-NCSU at lab scale. Step #2 builds upon recent NCSU-DEC technology demonstrations – *n*-alkanes have been successfully produced from Free Fatty Acids (FFAs). NCSU has also developed and demonstrated a patent-pending burner that can safely burn the glycerol generated from Step #1, using the resulting heat as a thermal source back into the process. **Figure 3** shows the results from biogasoline testing where the objective was to crack *n*-alkanes to resemble the carbon number distribution of traditional unleaded gasoline. This was demonstrated at a Step #3 mass conversion efficiency in excess of 90% and was not being optimized.
- **Scalability** – nothing inherent in the Centia™ approach will prevent scaling to large commercial volumes, ranging from 10M – 50M+ gallons/year. Scalability has been a central driver in the design and engineering of the system.
- **Affordability** – preliminary analysis shows biofuels could be produced at production costs (\$/gallon) competitive with, if not lower than traditional biofuels plants. Since feedstock costs must be added to these production costs, this reinforces the value of feedstock flexibility.

Path Forward

Multiple patents have been submitted for the technology. DEC has licensed the technology from NCSU on an exclusive worldwide basis. While lab-scale testing has validated the science and produced encouraging results, the next prudent step is a fully integrated, end-to-end engineering model at approximately 10 – 20 liters/hour in scale. This 18-month demonstration at NCSU would showcase the production of multiple fuels from a variety of sources and characterize the quality and composition of those fuels in engine tests. As shown in **Figure 4**, a majority of the infrastructure and expertise is in place to begin this effort upon securing adequate

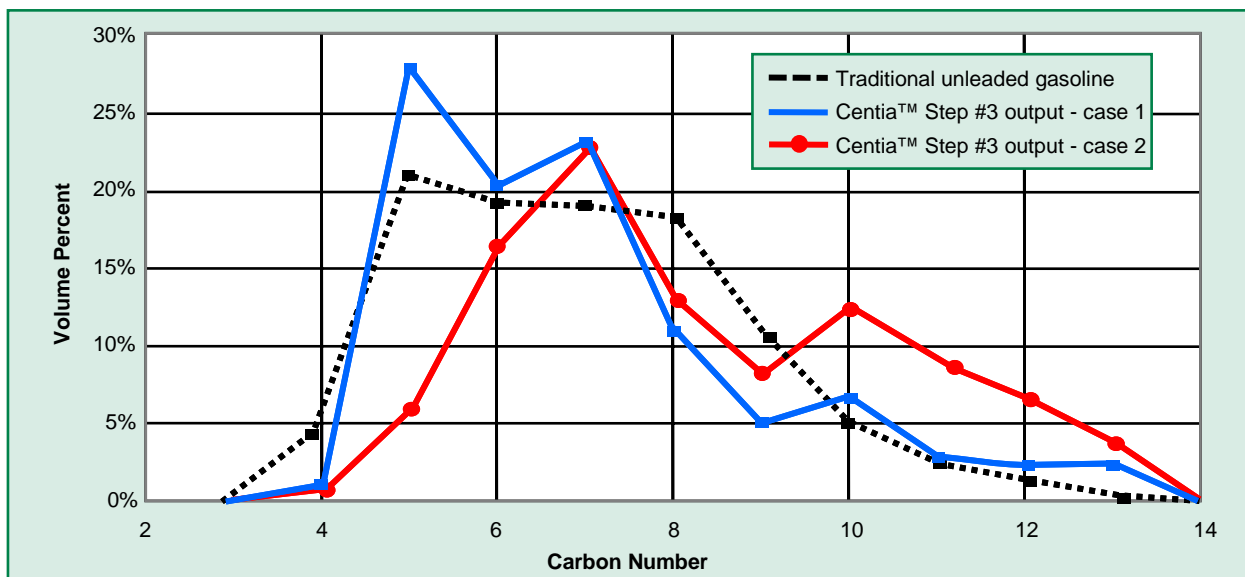


Figure 3: Biogasoline Results Closely Align to Traditional Unleaded Gasoline Carbon Number Distribution

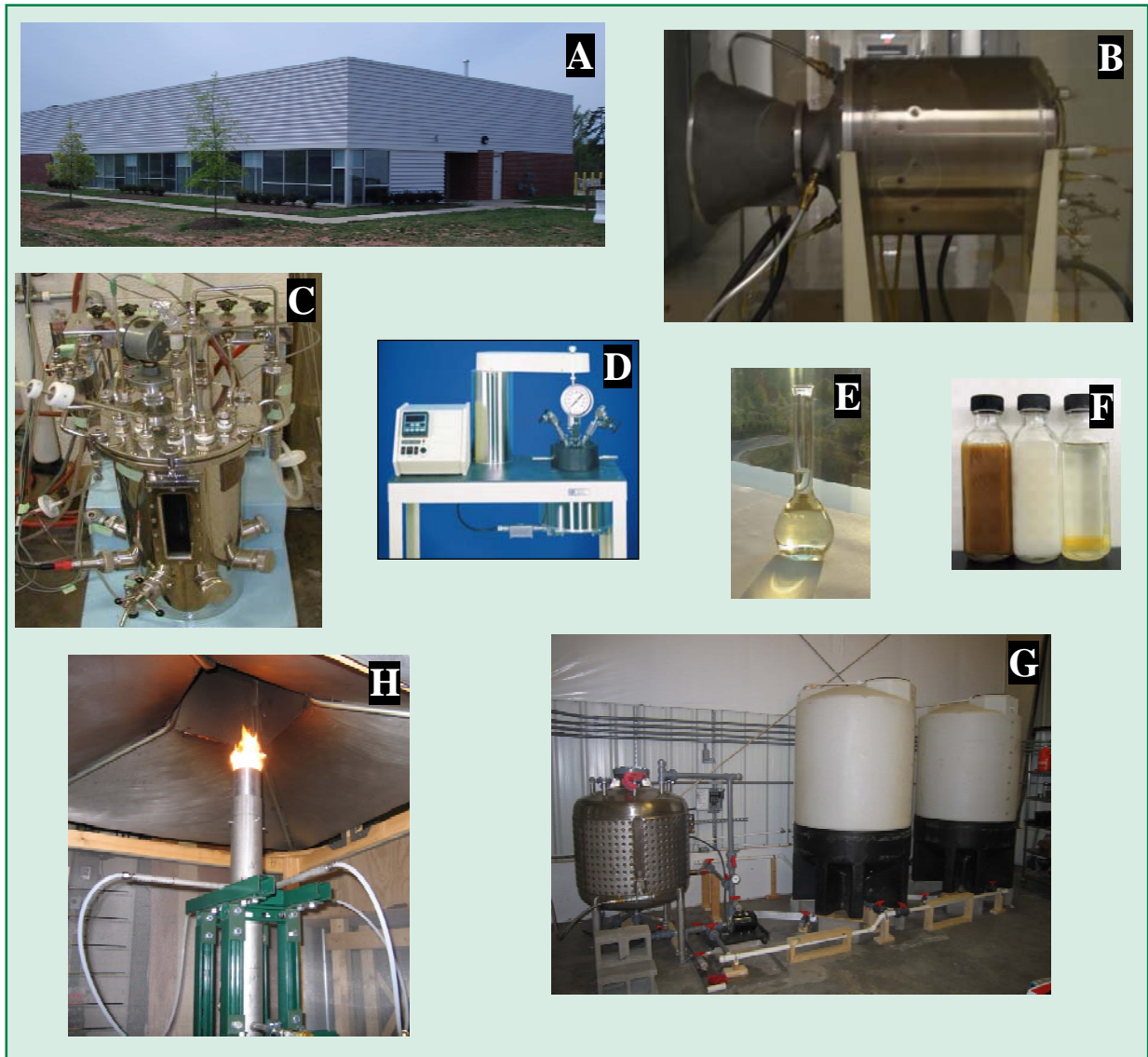


Figure 4: A – Centia™ development facility in Raleigh, NC; B – jet engine for biofuels testing; C – instrumented reactor; D – example of commercially available reactors for engineering model; E – preliminary fuels output from Centia™ Step #3; F and G – example of team’s pedigree in biodiesel manufacturing and animal fats to fuels; H – proprietary glycerol burner in action, used for thermal recovery and increasing system efficiency

funding. A team of five supporting companies have been identified, shown in **Figure 5**, to support the engineering model development and prepare for the introduction of commercial systems. DEC is seeking investors and strategic partners to support this effort.

In the interim, NCSU is executing on a R&D grant from the Biofuels Center of North Carolina (www.biofuelscenter.org) to conduct on-going Centia™ development work.








Team Member	Specialty/Experience
	<ul style="list-style-type: none"> • Program Management • Systems Engineering • Commercialization • Economics
	<ul style="list-style-type: none"> • Principal Subcontractor • Key Technology Holder • Catalyst Development
	<ul style="list-style-type: none"> • Catalyst Scaling and Commercialization
	<ul style="list-style-type: none"> • Fuel Plant Design and Construction • Fuel Plant O&M
	<ul style="list-style-type: none"> • Specialized Engineering and Biofuels Development • Systems Engineering
	<ul style="list-style-type: none"> • Fuel Qualification • Proven Alternative Fuels Work
	<ul style="list-style-type: none"> • Systems Engineering • Practical Process Engineering

Figure 5: Centia™ Project Team

Company Profiles

- Diversified Energy Corporation -

Diversified Energy Corporation (www.diversified-energy.com) is a privately held company specializing in the advancement of a series of promising alternative and renewable energy technologies – an advanced coal gasification technique with feedstock flexibility and attractive economics targeted for industrial applications, a biofuels conversion process that can take any renewable oil and produce transportation fuels that “look” just like their petroleum counterpart, and an algal biomass cultivation system that is scalable and economical. The company is focused on completing research and development on these technologies, building first-of-a-kind pilot commercial

plants, and then eventually constructing, operating, and/or selling large-scale projects based on these technologies. The business approach relies heavily on forming partnerships with technology, construction, and financial providers so that end-to-end solutions can be delivered to the marketplace.

Diversified Energy Corporation is led by a team of executives with significant experience in the aerospace, energy, and high-technology markets. The team's core expertise is in designing, developing, and delivering innovative technology solutions for government and commercial customers, with a track record well in excess of several billion dollars. The leadership team is complemented by an engineering, projects, and business staff with a demonstrated pedigree of innovation and successful delivery. The company is applying this record of rigorous systems engineering and business acumen to transform creative energy ideas into reality today. The company was formed in 2005 and is headquartered in Gilbert, Arizona.

- North Carolina State University -

A nationally recognized leader in science and technology with historic strengths in agriculture and engineering, North Carolina State University (NCSU, www.ncsu.edu) provides a high-quality education in the humanities and social sciences, design, education, life sciences, management, natural resources, physical and mathematical sciences, textiles and veterinary medicine. Whether educating students for the 21st century, improving lives through life-altering research, or partnering with communities, business, and government to create jobs, NC State's commitment to innovation creates a culture of excellence that spreads to every facet of the university and affects people's lives in relevant, powerful ways.

NC State's Office of Technology Transfer manages the University's patent and technology portfolio, currently consisting of 552 U.S. Patents and approximately 1600 proprietary technologies. Forming partnerships with innovative companies such as Diversified Energy

fulfills NC State's mission of getting academic discovery to the market for the greater public good. The university has spun-out over 50 companies based on technologies developed at the institution.

- BASF -

As the world's leading provider of catalysts to the biodiesel industry, BASF (www.basf.com) brings expertise in the practical issues of designing, scaling and O&M of catalysts in commercial applications. They also are the world's leader in hydrogenation catalysts, directly applicable to this project.

- Lauren Engineers and Constructors -

A design and build engineering company, Lauren (www.laurenec.com) offers over 20 years experience in energy-related projects. They specialize in conducting early design trades to enhance the long-term performance, costs, and O&M of plants.

- Southwest Research Institute -

Southwest Research Institute (www.swri.edu) provides over 50 years experience in qualifying aviation fuels and led the qualification of the only synthetic fuel approved for aviation use.

- Turner Engineering -

Turner Engineering brings hands-on experience in fabricating biofuels facilities.

- Chambers Process Engineering -

CPE (www.cpe.net) delivers responsive and customized process engineering to the team, with specialization in high-pressure/temperature equipment.

¹ <http://www.flightglobal.com>, "US Air Force to Use Synthetic Fuel Across Fleet by 2011," story by Jeffrey Decker, 8/7/13.