A. Management Report

1. DOE award number and name of the recipient

   DOE Award Number DE-SC0005315
   Name of Recipient: The University of Tulsa

2. Project Title and name of the Principal Investigator

   Project Title: Green Fuels from Algae
   Principle Investigator: Daniel Crunkleton

3. Date of Report and Period of Report

   Date of Report: December 3, 2012
   Period of Report: September 15, 2010 – September 14, 2012

4. Comparison of actual accomplishments with established objectives and reasons why goals were not met

   N/A

5. Discussion of major activities, significant results, major finding and conclusions, key outcomes

   Catalytic Cracking

   A full set of catalytic cracking data for ginger oil on three zeolite systems, MFI, BEA, and FAU has been collected, analyzed, published in an MS thesis, and sent for publication where it awaits reviews at the journal Applied Catalysis A. High yields of gasoline fractions were obtained on virtually all the materials, but the highest yields were found on MFI with SiO_2/Al_2O_3 = 280. Gasoline fractions were favored when zeolites with high SiO_2/Al_2O_3 were used compared to the same zeolite phases with lower SiO_2/Al_2O_3. High gasoline yields were accompanied by lower coke yields in all cases on all materials we studied.

   We conclude that a potential route to produce renewable fuels, especially gasoline, from algae is via conversion of sesquiterpenes, the primary components of ginger oil, which may be produced by genetically engineered algae.

   Genetic Engineering of Algae

   Five genetically engineered strains of the microalgae *Chlamydomonas reinhardtii* have been created. The genes *dxr*, *crtE*, *crtB*, codon-optimized *crtE*, and codon-optimized *crtB* were integrated into the chloroplast genome

of *C. reinhardtii* to create five separate genetically engineered strains. The incorporation of these genes into the chloroplast genome should result in increased concentrations of carotenoids such as neoxanthin, violaxanthin, lutein, and β-carotene. Preliminary results indicate that some of these carotenoids are increased significantly compared to the wild-type strain, but a more thorough analysis is needed to confirm these results. We are currently working to develop an LC-MS method to quantify the production of selected carotenoids from these engineered strains.

Simulation/Optimization/Multiscaled Modeling

We completed a comprehensive literature review and developed an extensive database, which contains the technologies that could be used to produce "green fuels" from algae and their performance parameters. Using the database, we built an appropriate Algae Fuel Production Superstructure, a framework for comparing different technology routes from algae to green fuels. We translated this superstructure into a 0^{th} order optimization model that focuses on biodiesel production from algae. The objective of the model is to minimize the biodiesel production cost and it utilizes high-level aggregated technology performance data resulting in linear programming model. The solution of the 0^{th} order optimization model suggests that the algae growth costs are the highest percentage of the total biodiesel production cost. Based on this result, we focused on incorporating detailed algae growth process models to identify the optimum algae growth technology. To date, our model incorporates detailed tubular photobioreactor, column photobioreactor and flat-plate photobioreactors. We are currently compiling the details and the solution of this model in a technical paper.

6. Cost Status

A breakdown of the originally budgeted items, along with the current balance is given in the following chart:

	Budget	Expenses
Senior/Key Personnel	106,389.00	124,425.00
Other Personnel	339,953.00	319,948.94
Equipment	5,534.00	15,261.63
Domestic Travel	21,000.00	14,390.78
Foreign Travel	12,000.00	8,353.68
Materials and Supplies	39,321.00	61,953.30
Indirect Costs	204,803.00	184,666.67
Total Direct and Indirect Costs	729,000.00	729,000.00

7. Schedule Status

The project is currently complete.

8. List any changes in approach or aims

   Catalytic Cracking: None

   Genetic Engineering of Algae: None

   Simulation/Optimization/Multiscaled Modeling: We focused on algae growth and biofuel production steps of the algae-to-fuels supply chain during this first year. We plan to incorporate logistics upon completion of these studies.

9. Actual or anticipated problems or delays

   Catalytic Cracking: None

   Genetic Engineering of Algae: None

   Simulation/Optimization/Multiscaled Modeling: One of the challenges regarding model development is the lack of data in the literature regarding different technologies. However, our models are built so that we can incorporate the data quickly as they become available.

10. Absence or changes of key personnel: None

11. Products or technology transfer activities
    a. Publications, conference papers, other public releases of results

       Catalytic Cracking
       Yang He; Sean E Barnes, Daniel W Crunkleton, and Geoffrey L. Price "Comparison of ginger oil conversion over MFI, BEA, and FAU", submitted to Applied Catalysis A: General.

       Yang He, M.S. Thesis 2011, "Conversion of Ginger Oil to Gasoline Via Catalytic Cracking"

       Genetic Engineering of Algae
       Johannes, T.W. Green Fuels from Algae. 57th International Instrumentation Symposium, St. Louis, MO, June 2011.

       Laizure, M. and Johannes, T.W. Genetic Engineering of Algae to Produce Biofuels. Oklahoma EPSCOR 16th Annual Research Day at the Capitol, Oklahoma City, OK, March 2011. (poster)

       Laizure, M. and Johannes, T.W. Genetic Engineering of Algae to Produce Biofuels. AIChE National Meeting, Salt Lake City, UT, November 2010. (poster)

Simulation/Optimization/Multiscaled Modeling

Smith, J., Crunkleton, D., and Cremasci, S., “Stability of a Two-Phase Column Bioreactor for Algae Growth,” AIChE Annual Meeting, October 28-November 2, 2012, Pittsburgh, PA.

Smith, J., Neto, A., Cremaschi, S., Crunkleton, D., “CFD-Based Optimization of a Flooded Bed Algae Bioreactor,” Industrial & Engineering Chemistry Research, (in review).

Yadala, S., and Cremaschi, S. (2011), "Modeling and Optimization of Algae Based Biodiesel Production", 2011 AIChE Annual Meeting, October 16-21, 2011, Minneapolis, MN.

Yadala, S., and Cremaschi, S., (2011), “An Optimization Model to Minimize the Production Cost of Biodiesel from Algae”, 56th Annual Pentasectional Meeting of the American Chemical Society, 12 March 2011, Bartlesville, OK.

Yadala, S., and Cremaschi, S., (2011), “An Optimization Model to Minimize the Production Cost of Algae Based Biodiesel”, 14th Annual TU Student Research Colloquium, 28 March – April 1 2011, Tulsa, OK.

b. Web sites that list results of project: None

c. Networks or collaborations fostered: None

d. Technologies and Techniques: None

e. Inventions or Patent Applications: None

f. Other products (databases, physical collections, audio or video, software or netware, educational aids or curricula, instruments, equipment)

Simulation/Optimization/Multiscaled Modeling: Transport/Kinetic model of algae growth in bubbled columns