Biodiesel Production Efficiency

Challenge Problem and Resources

Developed by:

The teachers, students, and mentors in the
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1. CHALLENGE PROBLEM: BIODIESEL PRODUCTION EFFICIENCY

Biodiesel is an important part in our nation's liquid fuel supply chain. The Energy Independence and Security Act of 2007 calls for an increase in production of biofuels from 9 billion gallons to 36 billion gallons by 2022 with biodiesel being a major constituent of this overall renewable fuel supply (EPA's Office of Transportation and Air Quality, 2012). Biodiesel has numerous environmental and human health advantages when compared to traditional diesel fuels: reduced hydrocarbon and carbon monoxide emissions, reduced exhaust particulate matter toxicity and mutagenicity, biodegradable, negligible sulfur content, as well as carbon dioxide consumption during feed stock photosynthesis (Peterson & Reece, 1996). While there are significant efforts to investigate, design and refine biofuel production from various feed stocks, utilization of waste food oils is well defined and involves relatively simple chemistry; transesterification. However, the economics of converting waste oil into biodiesel has been challenging for many small, localized manufacturers. Most small-batch processors of biodiesels are manually intensive, requiring close monitoring of the system throughout the manufacturing process.

Small businesses, schools, and communities could benefit from localized production of biodiesel. Efforts, such as Dr. Robert Gilbert's at Sinclair Community College, leverage fryer oil to manufacture biodiesel for use in the college's grounds keeping equipment. Local fuel cooperatives hold the promise of increased access to renewable fuels for small communities. Small businesses could both avoid costs for disposal of waste oil and supplement their own liquid fuel needs. A small-scale, cost effective processor design would be valuable for small businesses, local cooperatives and community initiatives. Presently, the capital costs for stand-alone batch systems range from $1,500 to $10,000 depending on capacity and degree of automation. Low end systems have operator costs upwards of $8/gallon, which is simply too expensive to operate. Highly automated systems can drive that cost down to $1.22/gallon. These systems have favorable returns on investments (~4000 gallons), but leaves the small manufacturer with a significant production quota to fulfill. The focus of this challenge is to create a cost effective, small-scale processer that would help individuals or small organizations to produce their own environmentally friendly biofuels.

1.1. THE TOOLS

Computation tools including mathematical, physical, or logical models should be used in simulations to model the economics of individual elements and the overall system. Computational tools common to many engineering problems will be beneficial in addressing this challenge:

- Excel
- Scripting Languages (MATLAB, SciLab, Octave, Python™, etc.)
- Physical Models (http://turnerbiodiesel.com/student_biodiesel_lab-starter_kit)

There are many websites that explain how to produce biodiesel and offer equipment for processing. Here are a few poignant links to help individuals address this challenge problem:

- http://www.collectivebiodiesel.org/presentations/2008presentations/JohnBush_chemistry .pdf
- http://utahbiodieselsupply.com/
- http://www.make-biodiesel.org/Introduction/

1.2. THE SOLUTION

Construct a small scale model of a biofuels processor that maximizes return on investment. Evaluate the economics of the model through graphical analyses, mathematical models, or other means to document the cost effectiveness.

1.3. SAFETY CONSIDERATIONS

Transesterification of seed oils involves a number of hazardous chemicals; operation of physical models should be conducted by individuals familiar with the risks associated with these chemicals. It is imperative for participants operating physical models to thoroughly review Material Safety Data Sheets for all reactants, intermediates, products, and by-products of this processor. The *"collectivebiodiesel"* link included in the *"Tools"* section of this challenge problem provides the fundamental chemistry associated with biodiesel production. It is essential reading for anyone considering operating a physical model. Starting reactants include triglycerides from the selected seed oil (corn oil, rapeseed oil, waste fryer oil, etc), methanol or ethanol, and potassium hydroxide or sodium hydroxide. The target products include biodiesel (methyl esters) and glycerol, while both free fatty acids and soap can be formed as by-products. Finally, the methoxide ion (or ethoxide ion) is an important catalyst intermediate for this reaction. Chemical hazards should constrain the design and operation of physical models; it is essential that all physical models include measures to minimize these risks.