# Biomass Oil Analysis

**Course Number:** CH-02-600

**PDH:** 9

**Approved for:** AK, AL, AR, FL, GA, IA, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

## State Board Approvals

Florida Provider # 0009553 License #868
Indiana Continuing Education Provider #CE21800088
Maryland Approved Provider of Continuing Professional Competency
New Jersey Professional Competency Approval #24GP00025600
North Carolina Approved Sponsor #S-0695
NYSED Sponsor #274

**Course Author:** Mathew Holstrom

## How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.
After the course has been purchased, review the technical material and then complete the quiz at your convenience.
A Certificate of Completion is available once you pass the exam (70% or greater).
If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).
If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.

# 1 DOE Goals and Objectives Relative to the Oil Platform Analysis

## Learning Objectives

By the end of this section, you will be able to:

- **Identify** the federal research and development goals that framed early biomass oil platform analysis.
- **Explain** how biomass oils are chemically related to triglycerides, fatty acids, methyl esters, and glycerol.
- **Evaluate** why biorefinery coproducts can improve project economics without necessarily reducing fuel production costs.
- **Compare** the research and development needs of mature oleochemical firms with less-diversified biodiesel and feedstock producers.

Executive Summary: Biomass oils can contribute to petroleum displacement, but the engineering and economic case depends on feedstock cost, fuel production cost, coproduct value, market incentives, and available supply. A biorefinery strategy can improve investment returns through higher-value products, but it does not automatically make biomass-derived fuels cost-competitive with petroleum distillates.

## Federal Energy Goals and the Biomass Oil Platform

The biomass oil platform was evaluated within the broader federal objective of reducing petroleum dependence and encouraging the development of a domestic biobased industry. The United States Department of Energy's Office of Energy Efficiency and Renewable Energy invested in research intended to achieve two broad goals:

- **Dramatically reduce, or potentially end, dependence on foreign oil**
- **Encourage the creation of a domestic bioindustry**

Within that broader effort, the Office of the Biomass Program invested in research and development to support the same goals and to achieve two program outcomes:

- **Establish commercial biorefinery technology by 2010**
- **Commercialize at least four biobased products**

 

Although the Office of the Biomass Program also had goals related to sugars and syngas, those platforms are outside the scope of this section. The focus here is the biomass oil platform, which includes fats, oils, greases, and related lipid feedstocks.

The program faced a practical investment problem that engineers often encounter in technology development: many possible technical pathways existed, but available resources were limited. Therefore, research investments had to be directed toward options with the highest probability of success, the largest expected impact, or both. The engineering analysis had to address not only technical feasibility, but also cost, scale, market penetration, policy support, and the ability to produce fuels and coproducts at commercially relevant volumes.

## Biomass Oil Feedstocks and Triglyceride Chemistry

For this section, **biomass oils** include lipids from the following feedstock categories:

- Animal fats
- Fish and poultry oils
- Plant oils
- Recycled cooking greases

The primary compound of interest in these feedstocks is **triacylglycerol**, more commonly called **triglyceride**. Most biomass oils contain approximately **95% triglycerides**, with smaller quantities of phosphatides, sterols, antioxidants, and other minor compounds.

Triglycerides consist of three long hydrocarbon chains, called **fatty acids**, attached to a glycerol molecule through carboxyl groups. These fatty acid chains typically contain **6 to 24 carbon atoms**. In chemical terms, triglycerides are **glycerol esters of fatty acids**. When the fatty acid chains are separated from the glycerol backbone, they may be referred to as **fatty acids** or **free fatty acids**, depending on the technical context and audience.

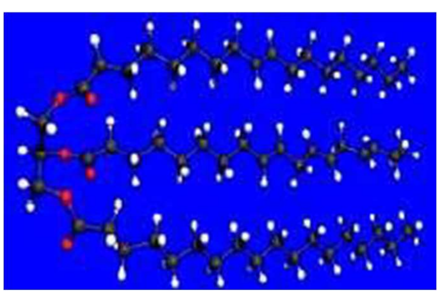

Figure 2. Triglyceride Molecule

This chemistry matters because the same basic biomass oil feedstock can be directed into multiple technical pathways. The oil may be processed into fatty acids, converted into methyl esters, used as a fuel blending component, or converted into other chemical products. The product pathway selected affects feedstock quality requirements, processing costs, fuel properties, coproduct value, and petroleum displacement potential.

## Key Engineering and Policy Questions

Biomass oils can displace imported petroleum, but the extent of that displacement depends on several linked technical and economic questions. The major questions for engineers and program planners include:

- How much petroleum can be displaced in the short run?
- How much petroleum can be displaced in the long run?
- At what cost can the displacement be achieved?
- Can those costs be reduced?
- What technical barriers limit market penetration?
- What technical barriers limit the supply of biomass oils?
- Which coproduct research and development investments would move the industry forward?
- Which coproduct investments would not provide meaningful industry benefit?
- What policy support is needed?
- What are the likely benefits?
- What type of research and development program, if any, should be supported?

These questions show why biomass oil evaluation is not simply a fuel chemistry issue. It requires an integrated assessment of feedstock supply, fuel conversion technology, coproduct markets, production cost, public policy, and the ability of industry participants to finance and operate commercial facilities.

## Biorefinery Economics and the Role of Coproducts

Biorefinery technology can improve the economics of firms that produce energy products along with higher-value biobased coproducts. The basic principle is similar to petroleum refining. In petroleum refining, much of the profit may come from a relatively small portion of the petroleum barrel that is converted into high-value petrochemicals, while the low-value bulk fuels help pay for the feedstock.

The same economic logic can apply to biomass biorefineries. Producing only fuel can be financially difficult because bulk fuel markets are low-margin, commodity markets. New fuels also face market risk, technical risk, infrastructure barriers, and customer acceptance issues. Investors generally require higher expected returns to compensate for those risks. If a facility can produce higher-value biobased products in addition to fuel, the overall rate of return may improve enough to attract investment.

However, the strategy depends on one critical condition: **the fuel price must still cover the cost of producing the fuel**. Coproducts can improve total project economics, but they do not automatically subsidize a fuel that is structurally uneconomic.

💡 Design Tip: In feasibility evaluations, engineers should separate **fuel production cost** from **overall facility profitability**. A biorefinery may be profitable because of coproducts, but that does not necessarily mean the fuel stream is cost-competitive with petroleum distillates.

Fuel markets are particularly challenging because they involve fungible bulk goods with narrow margins. The source material notes that margins can frequently be less than **0.25 cents per gallon**. Under those conditions, a new fuel that has higher production costs than the petroleum fuel it displaces will generally require incentives, mandates, purchasing preferences, or some other market support.

Higher rates of return can attract investors and lead to additional production capacity. If biobased fuels generate profit, that profit can encourage additional investment, additional facilities, and eventually a larger biofuel supply. For this reason, biomass biorefineries often need biobased coproducts to become financially attractive in fuel markets.

At the same time, biorefinery technology should not be misunderstood. It does **not** inherently reduce the production cost of the fuel. The fuel must still be sold at a price that covers the feedstock cost plus the appropriate share of capital and processing costs. If the fuel portion of the business cannot do that, future facilities may expand only the more profitable product lines rather than the fuel line.

If biomass fuel production costs exceed the market price of competing petroleum fuels, incentives will be needed to sell the biomass fuel at a price customers will accept. Those incentives should be structured to promote industry stability. At a minimum, the source section indicates that the incentive structure should provide a **five-year window** so capital improvements can be paid off.

# Oleochemical Plants as Mature Biomass Oil Biorefineries

The biomass oil platform differs from some other biomass platforms because commercial biomass oil biorefineries already exist. These facilities are more commonly known as **oleochemical plants**. Because oleochemical plants are mature commercial technologies, the research and development rationale differs from the rationale for emerging technologies such as biomass sugars or syngas.

In the United States in 2001, biomass oil biorefineries consumed approximately **2.6 billion pounds** of biomass oils and produced nearly **4 billion pounds** of oil-derived products. These products included soaps, detergents, lubricants, solvents, explosives, and other industrial and consumer products. Some of the earliest biomass oil biorefineries were established before the Civil War. Procter and Gamble is an example of a company historically associated with this type of biomass oil biorefinery model.

Oleochemical plants purchase a wide variety of biomass oils based on price and composition. They then convert those oils into a large number of industrial and consumer products. Appendix A of this course provides additional background on the oleochemical industry, platform compounds, derivative markets, and key research initiatives.

# Fatty Acids, Methyl Esters, Glycerol, and Biodiesel

Biomass oils are generally processed through one of two major chemical pathways:

1. **Hydrolysis**, which produces fatty acids and glycerol.
2. **Conversion to fatty acid methyl esters**, which produces methyl esters and glycerol.

The fatty acids and methyl esters serve as **platform chemicals**. They can be used as building blocks for many derivative chemical technologies that produce higher-value products. Methyl esters are also one of the primary biomass oil fuel pathways. When methyl esters are used as diesel fuel substitutes or blending components, they are commonly known as **biodiesel**.

Current methyl ester technology is mature. The source section describes the technology as nearly **90 years old**, continuous, and capable of using any feedstock. It can achieve fatty acid conversion to esters at yields of **99.7% or better**. Glycerol is produced as a byproduct and has traditionally been a high-value product requiring limited chemical modification.

For modern large-scale methyl ester plants with capacities of approximately **30 to 50 million gallons per year**, production costs excluding feedstock are identified as approximately **30 cents per gallon** of ester product. That cost includes capital, interest, depreciation, and rate of return. Although there are many ways to produce methyl esters, process changes have limited ability to reduce total cost substantially because feedstock cost dominates the economics.

🧮 Calculation Note: When evaluating biodiesel economics, the engineer should distinguish between **conversion cost excluding feedstock** and **total production cost including feedstock**. The source section identifies approximately 30 cents per gallon as the non-feedstock cost for large-scale methyl ester production, but total cost depends heavily on biomass oil feedstock price.

# Why Biodiesel Expansion Depends on Incentives

Because biodiesel production costs often exceed the market prices of the petroleum distillate fuels they displace, expansion of methyl ester production depends heavily on incentives. This is especially important for firms focused on biodiesel fuel rather than higher-value oleochemical derivatives.

Oleochemical manufacturers generally prefer to convert methyl esters into higher-value products rather than sell them into low-margin fuel markets. Within the oleochemical sector, methyl ester capacity will usually expand only as demand for higher-value coproducts expands. Much of the new methyl ester capacity described in the source section was established outside the United States, where feedstock production and demand for oleochemical products were expanding and where feedstocks were less expensive.