Biodiesel from Palm Oil Waste

PEP Review 2025-13

Chin Kee Kee, **Research and Analysis Manager, Process Economics Program**

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Glossary

¢/gal	Cents per gallon
¢/kWh	Cents per kilowatt-hour
¢/lb	Cents per pound
¢/Mgal	Cents per thousand gallons
$/Mlb	Dollars per thousand pounds
°C	Degree Celsius
°F	Degree Fahrenheit
Al	Aluminum
approx.	Approximately
atm	Atmospheres
BD	Biodiesel
BFD	Block flow diagram
BFW	Boiler feed water
bhp	Brake horsepower
BLI	Battery limits investment
Btu	British thermal units
Capex	Capital expenditure
CD	Connemann continuous deglycerolization
CO_2	Carbon dioxide
cP	Centipoise
CPKO	Crude palm kernel oil
CPO	Crude palm oil
CSTR	Continuous stirred tank reactor
CW	Cooling water
dia.	Diameter
EFB	Empty fruit bunch
EUDR	EU Regulation on Deforestation-free Products
FAME	Fatty acid methyl esters
FCC	Fluid catalytic cracking
FFA	Free fatty acids
FFB	Fresh fruit bunches
FOB	Free on board
ft	Feet
ft^3	Cubic feet
g	Grams
G&A	General and administrative
gal	Gallons
gal/lb	Gallons per pound
Gcal/h	Gigacalories per hour
GHSV	Gas hourly space velocity
gpm	Gallons per minute
h^{-1}	Per hour
HDPE	High-density polyethylene
HPA	Heteropoly acids
h	Hours
HVAC	Heating, ventilating and air conditioning
ILUC	Indirect land-use change
K	Potassium
kg	Kilograms
kg/m^3	Kilograms per cubic meter
kJ	Kilojoules
KOH	Potassium hydroxide
kPa	Kilopascals
kW	Kilowatt
kWh	Kilowatt-hour

lb	Pounds
lb/h	Pounds per hour
lb/lb	Pounds per pound
lb/y	Pounds per year
LDH	Layered double hydroxide
m	Meters
M	Thousand
max.	Maximum
mg KOH/g	Milligrams of potassium hydroxide per gram
Mg-Al	Magnesium-aluminum
Mgal	Thousand gallons
min.	Minimum
Mlb	Thousand pounds
Mlb/h	Thousand pounds per hour
mm	Millimeters
mm^2/s	Square millimeters per second
MMBtu/h	Millions British thermal units per hour
mmHg	Millimeters of mercury
MMt	Million metric tons
mol%	Molar percent
mPa	Megapascals
NaY zeolite	Sodium form of Y-type zeolite
O	Oxygen
Opex	Operational expenditure
P	Phosphorus
PEP	Process Economics Program
PFAD	Palm fatty acid distillate
PFD	Process flow diagram
PK	Palm kernel
PKO	Palm kernel oil
PKS	Palm kernel shell
PO	Palm oil
POM	Palm oil mill
POME	Palm oil mill effluent
ppb	Parts per billion
PPF	Palm pressed fiber
ppm	Parts per million
ppmw	Parts per million weight
psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
RED II	Renewable Energy Directive
RBDPO	Refined, bleached, and deodorized palm oil
ROI	Return on investment
RPO	Refined palm oil
s	Second(s)
SCF	Standard cubic feet
SCM	Standard cubic meter
SPO	Sludge palm oil
sq ft	Square feet
SS	Stainless steel
t	metric tons
t/h	metric tons per hour
t/y	metric tons per year
TFC	Total fixed capital
USGC	US Gulf Coast
vol%	Volume percent

w/w	Weight for weight
wt%	Weight percent
y	year
Zr	Zirconium

Abstract

Biodiesel, a methyl ester of fatty acids, is derived from renewable feedstocks, such as virgin vegetable oil, animal fats, and used cooking oil. It serves as an alternative fuel, blended with petroleum-based diesel for use in compression ignition engines. The biofuel industry is positioned for growth, driven by biodiesel's capacity to enhance energy security and reduce emissions, thus playing a crucial role in combating climate change.

The choice of biodiesel feedstock is influenced by regional availability and economic factors. In the US, soybean oil is the predominant feedstock, while Europe commonly uses rapeseed and sunflower oils. In tropical countries, such as Malaysia and Indonesia, palm oil is the primary feedstock. These preferences are influenced by local agricultural practices and crop availability.

The shift from conventional palm oil to palm oil waste feedstock for biodiesel production presents a sustainable alternative that addresses environmental and economic concerns. Utilizing waste materials from palm oil milling and refining, such as palm sludge oil and palm fatty acid distillate, reduces the reliance on virgin palm oil, thereby mitigating deforestation and greenhouse gas emissions associated with its cultivation.

Biodiesel production has been extensively covered in previous Process Economics Program (PEP) reports and reviews. PEP Report 251 (2004) detailed the economics of two processes: the Connemann continuous deglycerolization process and transesterification via homogeneous alkaline catalysis. Subsequently, the Axens Esterfip-H process and the Catilin process were covered in PEP Report 251A (2007) and PEP Review 2009-5, respectively. More recently, PEP Review 2024-08 focused on the production of biodiesel from palm oil through the homogeneous alkaline catalysis process.

This review will cover the production of biodiesel from palm oil waste through esterification using homogeneous acid catalysts, followed by transesterification via homogeneous alkaline catalysis. The production economics assessment presented in this review is based on a plant located in the US Gulf Coast (USGC) region, with an annual production capacity of 100,000 t/y of biodiesel.

The technological and economic assessments of the process are PEP’s independent interpretation of a potential commercial process based on information presented in open literature, such as patents or technical articles. Although they may not reflect in whole or in part the actual plant configuration, we do believe that they are sufficiently representative of the process and process economics within the range of accuracy required for a conceptual process design evaluation.

Contacts

Rajiv Narang

Executive Director, Process Economics Program
rajiv.narang@spglobal.com

Chin Kee Kee

Research and Analysis Manager, Process Economics Program
keekee.chin@spglobal.com

CONTACTS

Europe, Middle East, Africa: +44 (0) 203 367 0681
Americas: +1 800 332 6077
Asia-Pacific: +60 4 296 1125

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