

# Biodiesel from Palm Oil Waste

**PEP Review 2025-13**

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

To learn more or to request a demo, visit [www.spglobal.com/commodityinsights](https://www.spglobal.com/commodityinsights).

# Table of contents

<b>1</b>	<b>Introduction</b>	<b>9</b>
<b>2</b>	<b>Summary</b>	<b>10</b>
	Techno-economic aspects	10
	Environmental aspects	11
<b>3</b>	<b>Technology review</b>	<b>12</b>
	Biodiesel	12
	Biodiesel supply and demand	12
	Biodiesel feedstock	13
	Palm oil waste for biodiesel production	14
	Palm oil milling and refining processes	14
	Palm oil milling process	15
	Palm oil refining process	16
	Sludge palm oil	16
	Palm fatty acid distillate	16
	Biodiesel quality	17
	Chemical reactions	18
	Esterification	18
	Transesterification	19
	Catalysts	20
	Homogeneous catalysis	20
	Base catalysts	20
	Acid catalysts	20
	Heterogeneous catalysis	21
	Base catalysts	21
	Acid catalysts	22
	Process overview	22
<b>4</b>	<b>Biodiesel production from palm oil waste</b>	<b>25</b>
	Process design basis	25
	Process description	26
	Section 100 – Feed pretreatment	26
	Section 200 – Biodiesel synthesis	26
	Section 300 – Biodiesel recovery	27
	Section 400 – Glycerin recovery package	27
	Process discussion	35
	Capacity	35
	Feedstock	35
	Catalysts	35

Esterification	35
Transesterification	35
Reactor	35
Biodiesel purification	36
Methanol recovery	36
Materials of construction	37
Product quality	37
Cost estimates	37
Fixed capital costs	37
Production cost	37
Byproduct credit	38
Co-processing with palm oil waste	38
Environmental footprint	46
<b>Appendix A — Design and cost basis</b>	<b>47</b>
Design conditions	48
Cost basis	48
Capital investment	48
Project construction timing	49
Available utilities	49
Production costs	50
Effect of operating level on production costs	50
<b>Appendix B — Cited references</b>	<b>51</b>
<b>Appendix C — Process flow diagrams</b>	<b>53</b>

## Tables

Table 2.1 Key performance metrics and economics summary	10
Table 2.2 Environmental performance factors	11
Table 3.1 Biodiesel and diesel specifications	18
Table 4.1 Design bases and assumptions	25
Table 4.2 Biodiesel from palm oil waste — Major streams flow	28
Table 4.3 Biodiesel from palm oil waste — Utility summary	32
Table 4.4 Biodiesel from palm oil waste — Major equipment	33
Table 4.5 Biodiesel from palm oil waste — Total capital investment	39
Table 4.6 Biodiesel from palm oil waste — Capital investment by section	40
Table 4.7 Biodiesel from palm oil waste — Variable cost	42
Table 4.8 Biodiesel from palm oil waste — Production cost	43
Table 4.9 Environmental performance factors	46

# Figures

Figure 3.1 FAME biodiesel demand by region	12
Figure 3.2 FAME biodiesel demand projection	13
Figure 3.3 Vegetable oils fatty acid profile	14
Figure 3.4 Palm oil milling process	15
Figure 3.5 RPO, SPO and PFAD prices	17
Figure 3.6 Block flow diagram of biodiesel production from palm oil waste	24
Figure 4.1 Mixer-settler	36
Figure 4.2 Investment versus plant capacity	44
Figure 4.3 Net production cost and product value of biodiesel versus palm oil price	44
Figure 4.4 Net production cost and product value of biodiesel versus sludge palm oil price	45
Figure 4.5 Net production cost versus operating level as a fraction of design capacity	45
Figure 4.6 Product value versus operating level as a fraction of design capacity	46

# Appendix C Figures

Figure 5.1 Process flow diagram 1 of 2 — Biodiesel from palm oil waste	54
Figure 5.1 Process flow diagram 2 of 2 — Biodiesel from palm oil waste	55

## 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 <sub>2</sub>	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 <sup>3</sup>	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 <sup>-1</sup>	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 <sup>3</sup>	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 <sup>2</sup> /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  
keekkee.chin@spglobal.com

## CONTACTS

**Europe, Middle East, Africa:** +44 (0) 203 367 0681

**Americas:** +1 800 332 6077

**Asia-Pacific:** +60 4 296 1125

[www.spglobal.com/commodityinsights/en](http://www.spglobal.com/commodityinsights/en)

[www.spglobal.com/en/enterprise/about/contact-us.html](http://www.spglobal.com/en/enterprise/about/contact-us.html)

© 2025 by S&P Global Inc. All rights reserved.

S&P Global, the S&P Global logo, S&P Global Commodity Insights, and Platts are trademarks of S&P Global Inc. Permission for any commercial use of these trademarks must be obtained in writing from S&P Global Inc.

You may view or otherwise use the information, prices, indices, assessments and other related information, graphs, tables and images ("Data") in this publication only for your personal use or, if you or your company has a license for the Data from S&P Global Commodity Insights and you are an authorized user, for your company's internal business use only. You may not publish, reproduce, extract, distribute, retransmit, resell, create any derivative work from and/or otherwise provide access to the Data or any portion thereof to any person (either within or outside your company, including as part of or via any internal electronic system or intranet), firm or entity, including any subsidiary, parent, or other entity that is affiliated with your company, without S&P Global Commodity Insights' prior written consent or as otherwise authorized under license from S&P Global Commodity Insights. Any use or distribution of the Data beyond the express uses authorized in this paragraph above is subject to the payment of additional fees to S&P Global Commodity Insights.

S&P Global Commodity Insights, its affiliates and all of their third-party licensors disclaim any and all warranties, express or implied, including, but not limited to, any warranties of merchantability or fitness for a particular purpose or use as to the Data, or the results obtained by its use or as to the performance thereof. Data in this publication includes independent and verifiable data collected from actual market participants. Any user of the Data should not rely on any information and/or assessment contained therein in making any investment, trading, risk management or other decision. S&P Global Commodity Insights, its affiliates and their third-party licensors do not guarantee the adequacy, accuracy, timeliness and/or completeness of the Data or any component thereof or any communications (whether written, oral, electronic or in other format), and shall not be subject to any damages or liability, including but not limited to any indirect, special, incidental, punitive or consequential damages (including but not limited to, loss of profits, trading losses and loss of goodwill).

ICE index data and NYMEX futures data used herein are provided under S&P Global Commodity Insights' commercial licensing agreements with ICE and with NYMEX. You acknowledge that the ICE index data and NYMEX futures data herein are confidential and are proprietary trade secrets and data of ICE and NYMEX or its licensors/suppliers, and you shall use best efforts to prevent the unauthorized publication, disclosure or copying of the ICE index data and/or NYMEX futures data.

Permission is granted for those registered with the Copyright Clearance Center (CCC) to copy material herein for internal reference or personal use only, provided that appropriate payment is made to the CCC, 222 Rosewood Drive, Danvers, MA 01923, phone +1-978-750-8400. Reproduction in any other form, or for any other purpose, is forbidden without the express prior permission of S&P Global Inc. For article reprints contact: The YGS Group, phone +1-717-505-9701 x105 (800-501-9571 from the U.S.).

For all other queries or requests pursuant to this notice, please contact S&P Global Inc. via email at [ci.support@spglobal.com](mailto:ci.support@spglobal.com)