Natural Oil Processing Mill Improvements Pathway
Summary Description

DOE Pathway Objectives

The Biomass Program objective for this pathway is to introduce new low-cost natural oil feedstocks (recycled fats and greases, and new oil seed crops) into today's natural oil processing facilities for increased production of biofuels - defined by the Program as biomass derived liquid transportation fuels that are fungible in today's transportation fuel supply. Biodiesel is the primary biofuel of this pathway.

The use of existing low-cost waste fats and greases is seen as a near-term strategy and the development of advanced low-cost, high oil-content seed crops is seen as a longer term goal. Other opportunities for natural oil processing mill improvements include production of new bioproducts from the refined oil and glycerol by-product streams.

Pathway Overview

The natural oil processing mill improvement pathway block flow diagram shown in Figure 1 outlines the current oil seed refinery process steps and how new processing steps could be incorporated into the existing process. The bold lines highlight the routes to biodiesel; and the dotted lines identify routes to new bioproducts. This diagram is not intended to be all inclusive. Other viable processing options should be considered for addition.

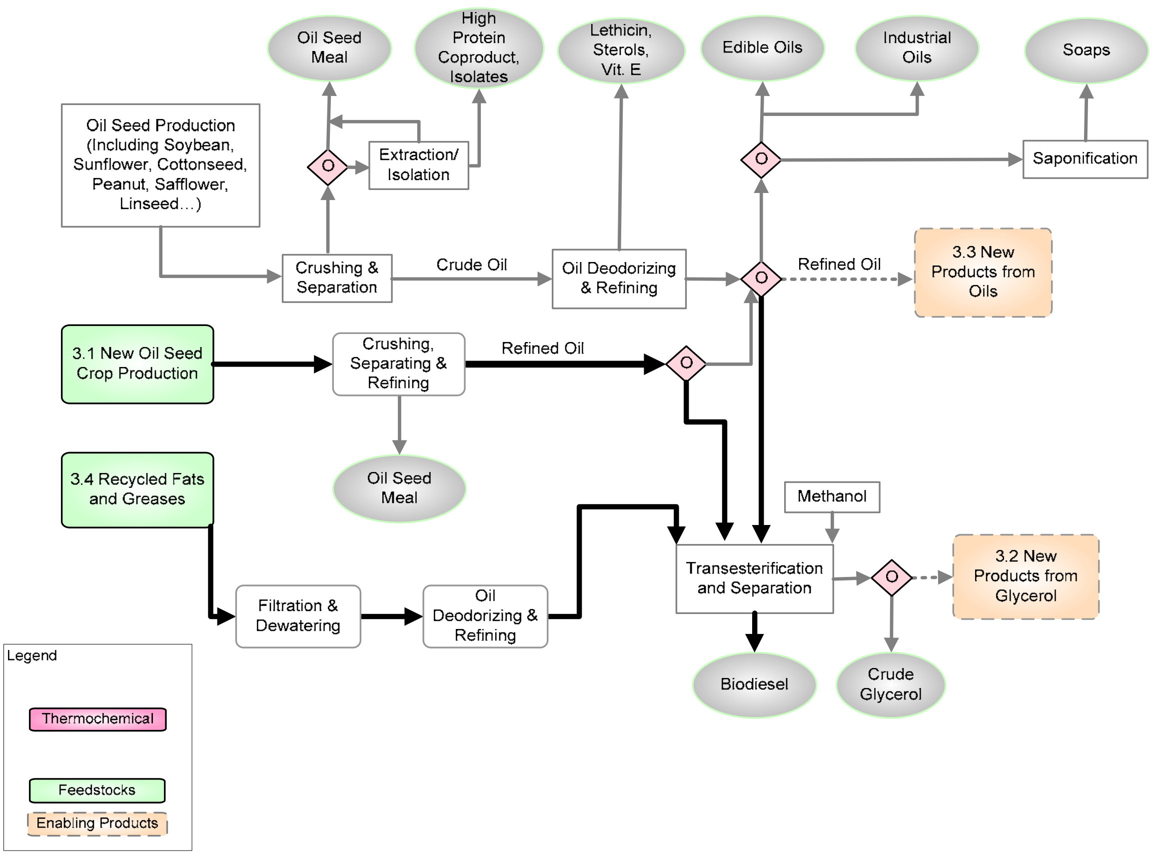

Figure 1: Natural Oil Processing Mill Improvements Pathway Diagram

Existing Oil Seed Refining Process

The first step in the oil seed refining process is to crush the oil seed and recover the crude oil from the cracked seed via mechanical or solvent extraction. The crude oil then goes through a series of purification and conversion processes to remove compounds that impact flavor, odor and quality and produce a variety of oil-based products such as lethicin, edible and industrial oils, and soaps. The refined oil can also be used to produce methyl esters (biodiesel) via transesterification and separation processes. (Recycled greases and fats can be added to the refined oil stream for additional biodiesel production.) Glycerol is a by-product of oil seed refining process that can be further purified for sale to the pharmaceutical and cosmetic industries. Most of the oil seed meal co-product is used as a protein source in animal feeds with only a small fraction further processed for industrial and human consumption.

Natural Oil Processing Mill Improvements for Fuel Production

The natural oil refining process improvements for fuel production are focused on developing and demonstrating low-cost recycled fats and greases, and oil seed feedstocks to produce additional biodiesel in existing biodiesel production facilities. The process improvements are described in Table 1.

Table 1. Natural Oil Processing Mill Improvements for Fuel Production

Process Category	Process Step(s)	Description
Feedstock	3.1 New Oil Seed Production	Produce new oil seed crop feedstocks for biodiesel production to meet biodiesel cost, quality, quantity and sustainability requirements.
Feedstock	3.4 Recycled Fats and Greases	Collect and cleanup waste fats and greases to meet biodiesel cost, quality, quantity and sustainability requirements

The refined oils from the oil seeds and the glycerol by-product stream can also be converted to new bioproducts (Process Steps 3.2 and 3.3).

Soybean Resource Potential

The total soybean output available for bioenergy production, based on projections from the US Department of Energy and the US Department of Agriculture Billion Ton Study[1], is summarized in Table 2. The "Baseline" case is Scenario 1 in the Billion Ton Study based on the National Resources Inventory for 2001. The "High Case, no land use change" is the high yield increase case of Scenario 2 in the Billion Ton Study which does not include land use change and therefore does not include perennial crops. The "High Case, land use change" is the high yield increase case of Scenario 3 in the Billion Ton Study which does include land use change to accommodate perennial crops. Table 7 provides more detailed soybean resource information for all the scenarios and cases evaluated in the Billion Ton Study.

[1] *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. (April 2005). US Department of Energy and US Department of Agriculture. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

Table 2. Soybean Output Available for Biofuel Production [2]

	Harvested Acreage (Million Acres)	Product Yield (Dry Tons/Acre)	Total Annual Soybean Output (Million Dry Tons)	Soybean Output Available for Biofuel Production (Million Dry Tons)
Baseline (2001)	73.0	1.1	80.3	0.2
High Case, no land use change (no perennial crops)				
Soybeans	71.4	1.3	92.8	7.9
Additional Soybeans from double cropping				4.0
High Case, land use change (land moves to perennial crops)				
Soybeans	63.4	1.3	82.4	0[3]
Additional Soybeans from double cropping				4.0

Soy Biodiesel[4] Production Potential

In the U.S., most biodiesel is made from soybean oil or recycled cooking oils. The National Biodiesel Board estimates the 2005 U.S. demand for biodiesel at 75 million gallons, up from 25 million gallons in 2004 (5 million gallons in 2001).[5] Current biodiesel production capacity is significantly higher, at 395 million gallons per year. The total biodiesel fuel potential of soybeans is summarized in Table 3.

The yield of 49.1 gallons of biodiesel per dry ton of soybeans is based on:

- an average soybean oil content of 18 %,
- 100% extraction of the oil,
- 1:1 weight ratio of soy oil input and biodiesel output, and
- biodiesel density of 7.33 lb/gal.

Quantities of biodiesel produced shown in Table 3 are calculated by multiplying the "High Case" feedstock available by the yield. Biodiesel production technology is mature and no significant future yield improvements are assumed.

[2] *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. (April 2005). US Department of Energy and US Department of Agriculture. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

[3] No soybeans available for bioenergy production based on the Billion Ton Study assumption that 8 million acres of soybeans are converted to perennial crops and food requirement demands are also increased by 37 percent, similar to corn.

[4] Due to the presence of the existing biodiesel industry, estimates of biodiesel potential have been developed for all natural oil feedstocks. This is not intended to preclude consideration of other biofuels but rather to serve as a common fuel product to evaluate the relative contribution of different feedstock types as well establish a basis for comparing other biofuel options.

[5] *U.S. Biodiesel Production Capacity*. (May 1, 2006). National Biodiesel Board. http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf

Table 3. Total Fuel Potential of Soybeans[6,7]

	Soybean Output Available for Biofuel Production (Million Dry Tons)	Biodiesel Yield (Gallons per Dry Ton)	Annual U.S. Biodiesel Production (Million Gallons)
Baseline (2001)	0.2	49.1	
High Case, no land use change, no perennial crops			
Soybeans	7.9	49.1	388
Additional Soybeans from double cropping	4.0	49.1	196
TOTAL			584
High Case, land use change due to perennial crops			
Soybeans	0	49.1	0
Additional Soybeans from double cropping	4.0	49.1	196
TOTAL			196

Additional Natural Oil Resources and Biodiesel Potential

Additional biodiesel can be produced from a wide variety of biomass oil feedstocks including oil seeds, animal fats and oils, waste grease, etc.

Other Oil Seeds. The biodiesel production potential for other U.S. oil seed crops based on 2001 production is summarized in Table 4 (soybeans shown for comparison). The values here assume that the entire oil seed crop was available for biodiesel production. The content and composition of oil extracted from oil seeds varies with the plant source. Farmers determine which crops offer the highest returns and the lowest risks of market failure. For the purposes of this evaluation it was assumed that current oil seed crops, except for soybeans, would not provide any significant quantities of feedstock for bioenergy production because more value is derived from their current uses.

Table 4. Fuel Potential of Seed Oils, 2001[8]

Oil Seed Crop	**Acres Harvested (Million Acres)**	**Product Yield (Tons/Acre)**	**Total Annual Output (Million Tons)**	**Biodiesel Production Potential (Million Gallons)**
Soybean	73.00	1.19	86.87	304
Cottonseed	13.05	0.47	6.13	19
Canola	1.45	0.69	1.00	0
Sunflower	2.58	0.67	1.73	63
Peanuts	1.40	1.51	2.11	2
Rapeseed	0.003	0.65	0.002	--
Safflower	0.177	0.68	0.120	5
Mustard (spice)	0.044	0.46	0.020	--

[6] *Biodiesel Production Technology*. (July 2004). Van Gerpen, J.; B. Shanks, R. Pruszko D. Clements; G. Knothe, NREL Subcontract Report: NREL/SR-510-36244.
[7] *Biomass Oil Analysis: Research Needs and Recommendations.* (2004). K.S. Tyson, et al. NREL Report No. TP-510-34796. http://www.nrel.gov/docs/fy04osti/34796.pdf
[8] *Biomass Oil Analysis: Research Needs and Recommendations.* (2004). K.S. Tyson, et al. NREL Report No. TP-510-34796. http://www.nrel.gov/docs/fy04osti/34796.pdf

Recycled Oils and Greases. The Billion Ton Study information on fats and grease supply is summarized in Table 5. An average biodiesel yield of 270 gallons per ton was assumed (see Table 6).

Table 5. Potential Fats and Greases Available for Bioenergy Production[9]

Feedstock	Total Annual Production	Feedstock used or Available for Bioenergy	% of Total used for Bioenergy	Biodiesel Production Potential (millions gallons)
	million dry tons/year	million dry tons/year	%	
Scenario 1: Baseline				
Fats and Greases	3.5	0.9	25.7%	243
All Other Future Scenarios and Cases				
Fats and Greases	5.0	2.0	40.0%	540

Another reference provided more detailed information, summarized in Table 6, on total supply of animal fats, greases and oils available in the US in 2001 that could be used to produce biofuels. The total annual production of 4.1 million tons is comparable to the 3.5 billion tons cited in the Billion Tons Study. The average yield of biodiesel from these feedstocks is 270 gallons per ton. Animal fats and greases are expected to grow by only 0.553 million tons (133 million gallons) by 2016[10], which is again comparable to the future projection in the Billion Ton Study of 5 million tons.

Table 6. Animal Fats, Greases and Oils Supply, in 2001[11]

Oil Source	Total Output (Million Tons)	Biodiesel Production Potential (Million Gallons)
Edible Tallow	0.233	63
Lard	0.043	11
Inedible Tallow and Greases	1.419	383
Other Fats and Oils	0.200	54
Poultry Fat	0.111	30
Fish Oils	0.014	4
Yellow Grease	0.203	55
Trap Grease	1.904	514
Total Animal Fats, Greases and Oils	**4.127**	**1,114**

[9] *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. *Appendix B.* (April 2005). US Department of Energy and US Department of Agriculture. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf,
[10] *Biomass Oil Analysis: Research Needs and Recommendations.* (2004). K.S. Tyson, et al. NREL Report No. TP-510-34796. http://www.nrel.gov/docs/fy04osti/34796.pdf
[11] *Ibid.*

Billion Ton Study Resource Data for All Scenarios

Table 7. Potential Soybean Quantities for Baseline and 4 Cases[12]

Feedstock	Acres Harvested	Average Yield	Total Annual Production	Feedstock used or Available for Bioenergy	% of Total used for Bioenergy
	(million acres)	dry tons/acre/year	million dry tons/year	million dry tons/year	%
Scenario 1: Baseline					
Soybeans	73.0	1.1	80.3	0.2	0.2%
Soybeans - s-dc*				0.0	
Subtotal				0.2	
Scenario 2- Case A: Moderate Crop Yield Increase, No Land Use Change					
Soybeans	71.4	1.2	85.7	2.6	3.0%
Soybeans - s-dc				2.0	
Subtotal				4.6	
Scenario 3- Case A: Moderate Crop Yield Increase, With Land Use Change					
Soybeans	71.4	1.2	85.7	2.6	3.0%
Soybeans - s-dc				2.0	
Subtotal				4.6	
Scenario 2- Case B: High Crop Yield Increase, No Land Use Change					
Soybeans	71.4	1.3	92.8	7.9	8.5%
Soybeans - s-dc				4	
Subtotal				11.9	
Scenario 3- Case B: High Crop Yield Increase, With Land Use Change					
Soybeans	63.4	1.3	82.4	0.0	0.0%
Soybeans - s-dc				4.0	
Subtotal				4.0	

* s-dc indicates soybeans resulting from double cropping with winter wheat.[13]

[12] *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. *Appendix B*. (April 2005). US Department of Energy and US Department of Agriculture. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf,

[13] Personal correspondence with Robert Perlack regarding details of the Billion Ton Study. In the southern most part of the corn belt and particularly in the Southeast double cropping can produce significant amounts of residues. The most common double cropping rotation in the United States is winter wheat and soybeans. However, barley (potentially maturing earlier than winter wheat) and winter canola could be used as the winter crop. In addition to soybeans, cotton, peanuts, and corn and grain sorghum either as grain or silage crops could be used. There are other crops and no-till could be used. 10 million acres double cropped was assumed, with generally the same assumptions used in each of the scenarios.