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Economics of Oilseed Crops and Their Biodiesel Potential in Oregon's Willamette Valley

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Executive Summary

This study assesses the economic potential of biodiesel production in the Willamette Valley for six oilseeds as potential feedstocks: canola, flax, camelina, yellow mustard, sunflower, and safflower. We evaluate costs and returns from feedstock production, oilseed crushing, and biodiesel processing. Our analysis is based on the best available information on cost of production, yield, other technical parameters, market prices, and government subsidies and tax credits.

The oilseeds examined differ considerably in productivity (seed yield per acre and oil yield per pound of seed) and in production costs and revenues. Yields in the Willamette Valley are estimated to range from 1,600 pounds/acre for camelina to 3,100 pounds/acre for winter canola. Production cost estimates range from $279/acre for spring camelina to $475/acre for winter canola.

We frame the economic assessments in three main ways:

- With current costs and returns, excluding government subsidies;
- With government subsidies included; and
- With the full "social cost" of production and subsidies included.

Omitting government subsidies, we find that production costs exceed revenues for all six biodiesel options. Compared to biodiesel wholesale prices in Portland of about $2.50/gallon in 2007, biodiesel produced in the Willamette Valley would cost an estimated $5.82/gallon for flax feedstock, $6.84/gallon for winter canola, and $12.94/gallon for yellow mustard.

When we include federal and state subsidies paid to growers or blenders on a per-gallon basis (thus excluding, for the moment, tax credits on capital expenditures), producers and blenders would receive additional revenues of $2.30 to $3.10/gallon. This, however, is still insufficient to break even for any of these six biofuels in the Willamette Valley. Only in the case of winter canola, and only if it were grown and processed on an improbably large scale, would subsidies achieve a breakeven point.

However, when Oregon's tax credit for capital investments is included, and assuming producers can take full advantage of it, these additional subsidies give rise to positive net revenues for three of the six biofuels. The revenues to growers and blenders including these subsidies range from $6.62 to $8.40/gallon.

The relatively high estimates for biodiesel production cost are due, in part, to the small scale assumed for processing. Land availability constrains production in the Willamette Valley; requirements for buffer areas and crop rotation limit potential acreage to an estimated 53,000 acres, or perhaps 4.4 million gallons of biodiesel annually. At these levels, the average cost of crushing and processing will be significantly higher than for processors with annual capacities of 10 million gallons or higher.

The third perspective from which to view the economics of biodiesel is to include the full "social cost" of production, processing, and government subsidies. Subsidies are paid by taxpayers and thus give rise to indirect costs (see discussion of public economics, page 31). When the indirect costs of subsidies are added to production costs, the total social cost of biodiesel production in the Willamette Valley is estimated at $5.53 to $12.95/gallon.

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These social cost estimates, however, are difficult to interpret without some kind of benchmark against which they can be compared. Given the public motivation for promoting biofuels, we need to evaluate their costs in relation to those public goals.

For example, one central motivation for government biofuel policy is to reduce dependence on fossil fuel by shifting to renewable energy sources. Thus, the private cost or return per gallon of biofuel will not be an adequate measure of progress toward this objective, for two reasons. First, biofuel production makes energy available to consumers, but it also uses energy during production and processing. So, we need to take account of the energy used to produce biofuels, especially fossil fuel energy, when we evaluate their net contribution to reducing use of fossil fuels. Second, there are alternative approaches to reducing society's use of fossil fuels, and so we need to compare the cost of achieving those goals by promoting biofuels with the cost of achieving them by other means.

For this we used a cost-effectiveness analysis, comparing the cost of substituting biodiesel to the cost of increasing the gas tax or raising fuel-economy standards in order to achieve the same reduction in fossil fuel use. Our analysis finds that promoting biodiesel produced in the Willamette Valley is more expensive: from 37 to 98 times more expensive than a gas tax increase, for a given reduction in fossil fuel use, and 20 to 53 times more expensive than raising fuel economy standards. In other words, raising fuel economy standards could achieve 20 to 53 times as much toward energy independence as these biodiesel options for the same cost.

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I. Introduction

This report contains economic information and analysis conducted to evaluate oilseed crops that can be grown in canola-restricted production zones of Oregon's Willamette Valley for use in on-farm oil extraction/biodiesel production or as feedstock for larger scale commercial oil extraction plants. We gathered information on feedstock production (crop enterprise budgets), extracting oil from feedstocks, and converting feedstocks to biodiesel for on-farm biodiesel production. The crops are canola (winter and spring), flax (linseed or solin/linola), camelina, yellow mustard, safflower, and sunflower.

We describe the economic potential and limitations of oilseed-to-biodiesel production and processing at various scales and under Valley conditions. We compare costs and breakeven points based on estimates of production and processing cost, market prices for oils and meals, and prices of gasoline and petroleum diesel. We also account for existing federal, state, and local subsidies and taxes.

II. Feedstock Production, Oilseed Content, and Extraction Yields

Oregon, and more specifically the Willamette Valley, has little experience growing canola, oilseed flax, camelina, yellow mustard, safflower, or sunflower, though field trials have been conducted on all these crops, mostly in northeast Oregon, near Pendleton. Also near Pendleton, canola has been grown commercially for crushing and biodiesel production since 2006, and there has been other, limited commercial production (a few thousand acres) of canola in the past 15 years. Experience with fiber flax in the Willamette Valley was extensive historically but has been limited recently, and experience with oilseed flax is minimal.

To investigate the potential for successfully growing these crops in the Willamette Valley as biodiesel feedstocks, and to estimate realistically their agronomic and economic potential, we relied on local experience and information, and on reports with relevant estimates and evaluations. Crop yields, for example, vary according to geographically sensitive conditions (e.g., irrigated vs. dryland cropping, rainfall, and soil). Therefore, when possible, data were collected from Oregon and from the Willamette Valley. Since local experience is limited, we collected additional information from field trials in Washington, Idaho, and North Dakota where relevant oilseeds are grown. We also drew data—for example, on oil content and fatty-acid compositions for different types of oilseeds—from university Extension reports of field trials and grower experiences. In some cases, we consulted growers in Oregon to corroborate estimates such as yield per acre or oil content.

Markets are very thin for oil and meal derived from most of these oilseeds; as a result, market price data are limited. We relied on data from the National Agricultural Statistical Service (NASS) of the U.S. Department of Agriculture (USDA) for national average crude oil and meal prices in a number of cases. Canola seed, oil, and meal prices are easily obtained from industry and market sources in Canada and the U.S. upper Midwest.[1] The Agricultural Marketing Service

[1]Canola seed, oil, and meal prices are compiled by Statistics Canada and are reported, for example, monthly from Canola Canada, FOB Vancouver, BC. Also, the Northern Canola Growers Association reports daily cash prices for North Dakota and Altona, Manitoba.

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(AMS) of the USDA also compiles some price information for Portland feedstock meal. Some price information was obtained directly or indirectly from local sellers. When prices were not readily available, we derived values from the observed high correlation between price and protein content (as estimated based on NASS data and discussed below).

Oilseed varieties and their characteristics

Canola *(Brassica napus* L.)

Crop practices Canola is a type of rapeseed developed in Canada to have a low euricic acid and glucosinolate content. Both winter and spring varieties have been developed. Most canola in the United States is produced in North Dakota. A Brassica crop, it can cross pollinate with other Brassicas such as rutabaga, Chinese cabbage, broccoli rabe, and turnip (Myers 2006) unless buffer distances are adequate. In addition, it is problematic to grow canola among infestations of mustard-family weeds. Canola grows on most soil types but requires good drainage. The emerging crop is very susceptible to soil crusting; seedbed preparation is important. Canola is susceptible to blackleg and Sclerotinia stem rot. If not rotated with resistant crops, seed treatment may be necessary.

Oregon currently restricts canola cultivation to General Production Areas—which do not include the Willamette Valley. The same rules permit growing canola in Protected Districts only with a special permit from the Oregon Department of Agriculture and only when several requirements are met (e.g., seed certification and minimum distance from cross-pollinating crops). In General Production Areas, canola may be grown no more than 2 in every 5 years on the same plot of land. In Protected Districts, canola can be grown no more than 1 in every 4 years.

Planting should be in mid-September for fall crops and as early as possible in spring for spring crops. Later fall plantings are susceptible to stand loss and later spring plantings to significant yield reductions, depending on spring and summer rain patterns. Responses to fertilizer and soil fertility are similar to those for small grains; however, canola is a heavy user of sulfur. In a 2,000 pounds/acre crop, for example, about 12 and 15 pounds/acre of sulfur are in the straw and seed, respectively. Canola competes well with weeds, and herbicides are registered for use in the crop.

Seed, meal, and oil Most canolas grown in Oregon are *B. napus* types. Seed size ranges from 80,000 to 135,000 seeds/pound, depending on variety. (Seed size can significantly affect seeding rate in pounds per acre.) Seed shattering at harvest is a potential problem, so crops commonly are swathed or “pushed” (mechanically bent over without cutting the stem) when seed moisture is about 35 percent. Canola is handled and stored like flax; tight containers are necessary to avoid loss in transit. Canola meal has about 38 percent protein. Canola oil is high in oleic acid, which makes it competitive with other cooking oils (Berglund & McKay 2002), a market in which it is well established. The oil also is a high-grade lubricant and fuel additive; conversion to biodiesel, therefore, is just one of its several potential end uses.

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Flax *(Linum usitatissimum* L.)

Crop practices There are both fiber and oilseed varieties of flax. Fiber varieties were grown in Oregon in the 1800s and 1900s, until the advent of synthetic fibers and of other, more profitable crops such as grass seed. Oilseed flax can grow in a variety of climates but in cool climates has a higher oil content. The crop does best on well-drained soils. Winter flax is less sensitive than canola to planting date and can be planted later in the fall. The crop fares poorly against weeds, and registered herbicides in the U.S. currently are limited.

Seed, meal, fiber, and oil With sufficient moisture, winter flax can yield 2,000 to 3,000 pounds/acre of seed; spring flax without irrigation typically yields 1,800 to 2,400 pounds/acre. Oilseed flax has both high- and low-linolenic varieties, called linseed and linola or solin, respectively. Solin varieties have been developed in Canada and are not yet released for use in the United States (Ehrensing 2008b). Flax oils are high in omega-3 fatty acids and have significant value in the food oil market. Cold-pressed flax meal also has a high omega-3 fatty-acid content and may have increased value in feed markets. Flax seeds are used in a number of high-value food applications such as flax flour rich in omega-3s, flax meal sold as a food additive, and flax oil supplements. Local food markets for these products might exist in Oregon. Linoleum flooring materials, derived from flax, are common in the "green" building materials market, and there may be possibilities for small-scale, local production of linoleum. Work has been done in Europe on using fiber from oilseed flax in industrial applications, such as automotive and recreational vehicle parts. These uses, if feasible, could increase fuel savings because flax fiber weighs less than fiberglass.

Camelina *(Camelina sativa* L.)

Crop practices Camelina has been grown for millennia in parts of Europe, but U.S. experience with it is limited. In Montana, researchers and growers have grown it for 4 to 5 years; in Idaho, Washington, and Oregon, it's been grown more broadly since 2005. Camelina does not yet have Generally Regarded As Safe (GRAS) status from federal agencies for use as human or animal feed—a significant obstacle at present—but evaluations are underway, and results may be known in a year or so.

Camelina generally is grown as a summer annual crop but can be a winter crop in milder climates such as in the Willamette Valley. Camelina has a short season (less than 100 days) and can survive drought and lower rainfall better than most other oilseed crops. Broadcast seeding is possible. No commercial variety has been released in the United States. However, Montana State University notes that, as of January 2008, the U.S. Food and Drug Administration (FDA), Montana industries, and the Montana Department of Agriculture are working to establish GRAS and Association of American Feed Control Officials (AAFCO) status for camelina. Camelina is resistant to blackleg (a disease common in Brassicas such as canola), has few insect problems, and competes well with weeds if grown at high densities (except for perennial weeds, which may be difficult to control). No herbicides are registered to date, but research needed for registration is underway.

Seed, meal, and oil Camelina seeds are small (220,000 to 450,000 seeds/pound), and oil content is 29 to 41 percent. Montana reports yields of 1,800 to 2,000 pounds/acre in dryland areas with 16 to 18 inches of precipitation, and Idaho reports 1,700 to 2,200 pounds/acre in areas with 20 to 24 inches. Little work has been done to breed higher yielding varieties. Camelina oil is considered

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high quality—high in omega-3 fatty acids and low in saturated fatty acids—and has been used as cooking oil in Europe and in cosmetics, soaps, and soft detergents. Anecdotal reports say camelina oil sells to cosmetic markets for about $5/gallon. Its meal has 45 to 47 percent protein (near or above soybean meal's) and 10 to 11 percent fiber. However it also contains glucosinolates which can be detrimental to animal health (Ehrensing 2008a; McVay & Lamb 2007). With many varieties and growing conditions, there remains substantial uncertainty about the oil and glucosinolate content.

Yellow mustard *(Sinapis alba* L.)

Crop practices Yellow mustard is a spring-seeded crop that grows best in cool areas (less than 85°F); though it is tolerant to frost, severe frosts can destroy the crop. As it is a different genus, it will not cross pollinate with Brassicas. It performs best on well-drained soils and is more drought tolerant than many other oilseed crops. Commercial varieties include Gisiba, Tilney, and Idagold. Herbicides are available for use in yellow mustard, though experience in eastern Oregon suggests few weed, insect, or disease problems. However, the crop is susceptible to many of the same diseases as Brassicas, which must be considered in crop rotations. Like other oilseeds, yellow mustard could be a valuable rotation crop in a cereal or grass cropping system.

Seed, meal, and oil Yellow mustard seed is relatively small, about 100,000 seeds/pound. Fallow trials in Pendleton and Moro yielded 1,100 to 1,700 pounds/acre (Wysocki & Corp 2002). The primary market for mustard seed has been in the condiment industry; a limited number of contracts are available annually. The oil is high in long-chain fatty acids (see discussion of fatty acids, page 16) so biodiesel made from mustard would have properties different from biodiesel from most other oilseeds. Mustard meals from current varieties are high in glucosinolates; hence, feed use would be limited.

Safflower *(Carthamus tinctorius* L.)

Crop practices A crop once grown for its dye now is grown for its oil in parts of Canada and the United States (50 percent of U.S. acreage is in California). Safflower is drought resistant and can be planted in irrigated and dryland areas as long as soils are well drained. Cool, wet soils delay uniform emergence, and periods of heavy rain can increase disease levels and reduce yields. The crop competes poorly with weeds, especially during early growth; timely use of herbicides is critical. Safflower is susceptible to many of the same diseases as the other oilseed crops, so rotations including these crops must be carefully considered. Safflower also has been reported to extract moisture from deep in the soil, reducing yields for crops following safflower in rotation; these effects, however, have not been well documented.

Seed, meal, and oil Safflower meal (extracted using the hexane process, which yields more oil) has about 24 percent protein with hulls and 40 percent without hulls. Trials of dryland fallow safflower in Montana yielded 37 to 42 percent seed oil content and about 1,600 pounds/acre of seed as a 3-year average (Armah-Agyeman et al. 2002). Safflower is a common food oil, and the meal can be fed readily to livestock. Oil composition is similar to that of other vegetable oils such as soy and sunflower, and biodiesel from safflower is expected to have properties similar to soy biodiesel's.

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Sunflower *(Helianthus annuus* L.)

Crop practices Sunflower grows in a variety of soil conditions but needs well-drained soils with a high water-holding capacity. Most likely it would need at least supplemental irrigation in the Willamette Valley to consistently optimize yields. Sunflower is a long-season crop planted in late spring; in eastern Oregon it has matured extremely late. Sunflower does not compete well with weeds; herbicides are necessary, and a number are registered. Like other oilseeds, it is susceptible to *Sclerotinia* diseases, and rotations need to be considered carefully.

Seed, meal, and oil Harvest usually is late September to October. Loss from seed shattering and birds can be reduced by harvesting at moisture contents as high as 25 percent; however, the seed then needs to be dried. Desiccants can hasten seed drying but must be applied after the plant reaches maturity. Average yields in North Dakota are around 1,300 pounds/acre. Oil content of the seed is reported at 38 to 50 percent, and seed meal is about 20 percent protein (Berglund 1995). Sunflower oils are common food oils, and the meal can be fed readily. Oil composition is similar to that of other vegetable oils, such as soy and safflower, and biodiesel from sunflower is expected to have properties similar to soy biodiesel's.

Growing conditions in Oregon's Willamette Valley

Growing conditions in western Oregon (Willamette Valley) and Washington are unique in North America and rare in the world. It is a modified Mediterranean climate with cool, wet winters and warm, dry summers. Most of the rest of the country has a modified continental climate with cold, dry winters and hot, wet summers. Mild winter conditions in the Willamette Valley permit the production of fall-seeded crops, and dry summer conditions tend to reduce many plant diseases that are important in areas with warm, wet summers. Together, these conditions permit the production of cereals, grass seed, vegetable seed crops, vegetable crops using irrigation, and a host of ornamental horticultural crops.

Comparing temperature and precipitation at Corvallis, OR, with Des Moines, IA, the latter the heart of the "cornbelt," may be instructive. Monthly precipitation and temperature averages for Corvallis and Des Moines are in figures 1 and 2. Note the much greater annual variation in temperatures in Des Moines compared to Corvallis: winters are much colder and summers, especially low temperatures, are much warmer in Des Moines. Precipitation patterns also differ dramatically in Corvallis and Des Moines. In fact, they are almost reversed: Corvallis receives most of its precipitation in winter, while Des Moines receives most in summer.

Figure 1. Monthly mean temperatures in Corvallis, OR, and Des Moines, IA.

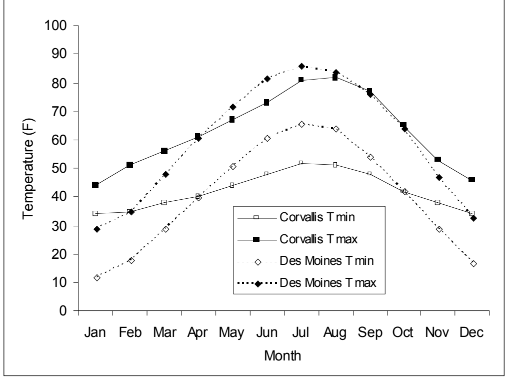
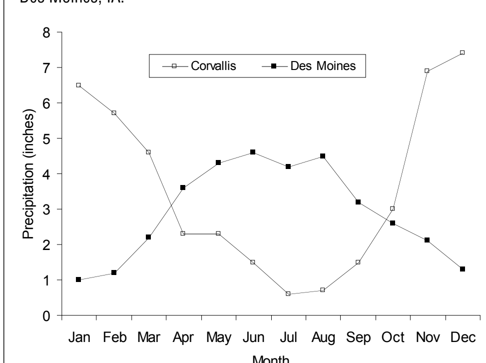


Figure 2. Monthly mean precipitation in Corvallis, OR, and Des Moines, IA.



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These striking climate differences just as dramatically affect the adaptation of potential biofuel crops. For example, summer nights in Des Moines are 10° to 15°F higher than in Corvallis, so some summer crops such as field corn or soybeans do not mature in the Willamette Valley. On the other hand, the relatively warm winter temperatures in the Willamette Valley favor fall planting and winter growth of many temperate crops.

Another unique Willamette Valley growing condition is an average winter temperature near, but above, freezing. The chilling (vernalization) requirement of crops can readily be met with temperatures in this range, yet crops can continue to grow. This allows seed production of some biennial crops (crops that typically require 2 years for growth) to satisfy a chilling requirement in a single growing season.

Most of Des Moines' annual precipitation is in summer, while Corvallis is quite dry in summer—less than 4.5 inches of rain in June–September compared to more than 16 inches in Des Moines in the same period. Thus, many crops in the Willamette Valley require irrigation for maximum yield, while irrigation is rare in Iowa.

Crop and production summary

Table 1 compares oilseeds on a per-acre basis for seed and oil yield, oil content, and seed, oil, and meal prices expected in the Willamette Valley. We include variants of canola and flax: winter and spring canola (which differ by planting dates and variety), and the high- and low-linolenic varieties of flax, which are linseed and solin, respectively. Seed yields vary significantly among the crops, from 1,600 to 3,100 pounds/acre. Estimates for winter and spring canola and yellow mustard seed yield are based on recent field trials in the Willamette Valley. Yields for flax, camelina, and safflower come via Oregon State University; camelina data are from a 20- to 24-inch annual rainfall area in Idaho; and the safflower data are from fallow trials in Montana. North Dakota State University (NDSU) trials indicate potential yields on sunflowers, albeit in an environment substantially different from Oregon's.

Oil content can vary significantly among and within oilseed types. It also varies by region due to climate and other environmental factors. For example, spring canola in Oregon has significantly lower oil content (32 percent) than that from North Dakota and Canada (43 percent)[2]. We have assumed here that spring and winter canola have the same oil content. Further investigation would be valuable to provide a basis for additional differentiation among oilseeds and to confidently estimate the expected oil content for these oilseeds in Oregon.

Oil yield per acre depends on three factors:

- Seed yield per acre (which is affected by harvest and transportation losses),
- Oil content of the seed, and
- Efficiency of the extraction method.

For the kinds of small-scale, cold-press expeller crushing technologies this study investigated, crushing efficiencies of 80 percent are typical, based on data from Madison Farms, Echo, OR.

[2] See details at www.ag.ndsu.nodak.edu/langdon/06data/canola-rr-2.htm and at www.ag.ndsu.nodak.edu/carringt/06data/2006canolacn.pdf

Table 1. Estimated oilseed yield and value per acre.

Oilseed type	Seed yield (lb/acre)		Oil content (%)		Oil yield (gal/acre)*	Market price			Value ($/acre)		
	Avg.	Range	Avg.	Range		Seed ($/lb)	Oil ($/gal)	Meal ($/ton)	Seed	Oil	Meal
Canola											
Winter	3,100 [a]	2,400–4,500	32 [g]	26–42	104	0.140 [g]	2.38 [k]	141 [k]	434	247	163
Spring	1,585 [c]	1,000–3,000	32 [g]	26–42	53	0.140 [g]	2.38 [k]	141 [k]	222	126	83
Flax											
Linseed	2,500 [d]	2,000–3,000	43 [h]	40–45	112	0.110 [k]	3.33 [k]	125 [k]	277	374	102
Solin/linola	2,500 [d]	2,000–3,000	43 [h]	40–45	112	0.110 [k]	2.635 [p]	125 [k]	277	296	102
Camelina	1,600 [b]	1,600–2,200	35 [d]	29–41	58	0.095 [l]	2.855 [q]	161 [s]	152	167	93
Yellow mustard	1,700 [a]	600–1,800	25 [i]	24.5–33	44	0.130 [m]	1.32 [r]	60 [r]	221	59	41
Safflower	1,600 [e]	1,131–1,900	39 [e]	37–42	65	0.126 [n]	5.57 [k]	87 [t]	202	363	48
Sunflower	1,750 [f]	1,000–3,300	44 [j]	37–49	80	0.139 [o]	2.89 [k]	77 [k]	243	232	44

* At 7.66 lb of seed per gallon of oil, extracted at 80% efficiency.

[a] Chastain, T.G., et al. (2007).
[b] Karow, R. (2007).
[c] Average of spring canola values from (a) and (b).
[d] Ehrensing, D. (2008a).
[e] Armah-Agyeman, G., et al. (2002).
[f] Median of range; D. Ehrensing, personal comm. 2007.
[g] Communication with Oregon crushers.
[h] Ehrensing, D. (2008b).
[i] North Central Research Extension Center (2006b).
[j] North Central Research Extension Center (2006c).
[k] Economic Research Service, USDA. (2007).
[l] Yates, S.A. (2007).
[m] Wysocki, D., & M.K. Corp (2002).
[n] Schmierer J.D., et al. (2005).
[o] Haugen, R., A. Swenson, & R. Ashley (2007).
[p] Average of canola and sunflower oil for representative consumptive use.
[q] Average of canola and linseed oil to represent oil high in omega-3 fatty acids.
[r] National Renewable Energy Laboratory (2003).
[s] Regression estimate from 2006 prices for similar meals; 46% protein; see note (d).
[t] Regression estimate from 2006 prices for similar meals; 24% protein.

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Note that the expeller is less efficient on seeds with lower oil content. Data from one plant in Oregon indicated that a 10-percent drop in seed oil content lowered extraction efficiency about 10 percent also, compounding the oil yield reduction.

Seed prices come from a variety of sources and include local contract prices (canola); enterprise budgets from NDSU (linseed and sunflower) and University of California at Davis (safflower); OSU Extension (yellow mustard); and Capital Press, Salem, OR (camelina).

NASS average flaxseed and sunflower seed prices for the last 3 years correlate well with the aforementioned prices.

The NASS 3-year average for canola seed, however, is lower than the 14 cents/pound contract price that growers are being offered for 2008 production in Oregon, and lower than the 17 cents/pound new contract price for June/July 2008 delivery in North Dakota (fall 2007 pricing). Prices from Statistics Canada for FOB Vancouver in 2006 and early 2007 fluctuated between 10 and 15 cents/pound.

Flaxseed prices are estimated at around 11 cents/pound in NDSU's budgets, but recent conversations with crushers of flaxseed in the Midwest indicate bids of around 18 cents/pound. We used NDSU's estimate, considering it more reliable than incomplete transactions (bids).

The market for yellow mustard seed is relatively small, and because prices fluctuate quite a bit—between 8 and 18 cents/pound (Wysocki & Corp 2002)— table 1 reflects a median price. We didn't find a source for a seed price specifically for linola. We assumed it to be the same as for linseed, because linola is not yet registered for use in the United States.

Various uses of vegetable oils and meals have different values including industrial uses (linseed oil for paint thinners, etc.) and animal and human food (high-protein feedstock meal, omega-3 "fortified" meal, omega-3 oil tablets, cosmetics[3]). The latter can be much higher valued (e.g., linseed oil tablets compared to crude linseed oil).

Most meal and crude oil prices come from NASS except those for camelina, yellow mustard, and safflower (meal). Canola meal prices in northeast Oregon have ranged from $135 to $200/ton in the last couple of years.

Camelina is a relatively new crop to the United States. The FDA has not approved its oil for human consumption, and AAFCO has not approved using more than 3 percent camelina meal in animal feed. If camelina had those approvals, however, and given its high linolenic content (though not as high as linseed), we estimated its oil price by averaging canola and linseed flax oil prices. We estimated camelina and safflower meal prices using a simple linear regression based on NASS protein and price data for 2006. However, the camelina estimate may need to be discounted for its high glucosinolate content.[4] We did not find unique prices for linseed and linola meal and oil. One industry expert thought their oil value would differ due to their different fatty-acid compositions, but their meal value should be about the same. Thus, we averaged the prices of canola and sunflower to estimate the value of linola oil.

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[3] One Midwest producer indicated that he was selling unrefined, cold-pressed camelina oil for cosmetics and feed for about $5/gallon, but he was not selling any for biodiesel.

[4] One Midwest producer stated that the glucosinolate content of his camelina seed was lower than that of canola. He also noted that his seeds' glucosinolate content did not result in a lower, discounted price. That producer reported selling cold-pressed meal with a 10 to 12 percent oil content for nearly $300/ton.

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We did not find meal and oil prices for yellow mustard, because its high glucosinolate content renders it unusable as food oil and animal feed. In table 1 (page 13), we estimated the meal's worth at 3 cents/pound and the oil's value as equivalent to inedible tallow's (National Renewable Energy Laboratory 2004).[5]

Choice of extraction method may have implications for uses and prices for both oil and meal. NASS prices most likely are based on using a hexane crusher process, which extracts about 99 percent of the oil from the seed, leaving almost none in the meal. The cold-press extraction method, an "organic" expeller process, leaves 8 to 13 percent of oil in the meal. The meal's higher oil content, and in some cases its omega-3 fatty-acid content, and the "organic" process might generate a price premium—or the higher oil content might generate a discount, because the oil is not good for ruminants such as cows and sheep (Chad Mueller, personal communication).

A crusher in Washington estimated canola meal extracted without hexane was worth $20 to $30/ton more than hexane-extracted meal from Canada; however, no such premium is included in table 1.

As mentioned previously for flax seed, there also may be food markets for the seed of these FDA-approved crops. At least one Oregon company uses specialty seeds to make food product additives and garnishes. Such use could provide a very high value—though small—market for oilseed crop seeds. There are also possibilities for seed stock production of some oilseeds. Even though the Willamette Valley is a Protected District, it may yet have seed production possibilities for a number of oilseeds. Brassica oilseed stocks, for example, typically sell for at least two to three times more than oilseed for crush.

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[5] There is some research exploring mustard's potential use as an organic herbicide and, in some cases, as a pesticide for crops unaffected by the glucosinolate content (Brown & Morra 2005), which indicates a possible niche market. A University of Idaho researcher judges that much higher prices might be possible ($400 to $500/ton) as an organic nitrogen fertilizer (soil amendment). That use, unlike a bioherbicide, may require no new governmental certification, though some states require registration of fertilizers and soil amendments.

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Oil fatty-acid composition and biodiesel [6]

Understanding plant-based biodiesel chemistry requires understanding the chemical makeup of its parent material, vegetable oil.

Fats and oils contain a glycerol molecule (a type of alcohol) bonded to three fatty-acid chains, a structure commonly called a triglyceride. In biodiesel manufacturing, the fatty acids are separated from the glycerol to create free fatty acids which then are bonded to either methyl or ethyl alcohol, depending on which is used in the manufacturing process.

Different fats and oils contain different types of fatty-acid chains. Table 2 indicates the fatty-acid chain composition of the oils under study. Chains differ in the number of carbon atoms and of carbon–carbon "double bonds." (Double bonds play an important part in the stability of biodiesel.) Table 2 shows fatty-acid chains designated by both the number of carbon atoms and the number of double bonds; e.g., 18:1 indicates 18 carbon atoms and 1 double bond.

Soybean oil, for example, has five types of chains:

- 8 percent with 16 carbon atoms and no double bond (palmitic acid, 16:0)
- 3 percent with 18 carbon atoms and no double bond (stearic acid, 18:0)
- 25 percent with 18 carbon atoms and 1 double bond (oleic acid, 18:1)
- 55 percent with 18 carbon atoms and 2 double bonds (linoleic acid, 18:2)
- 8 percent with 18 carbon atoms and 3 double bonds (linolenic acid, 18:3)

[6] The discussion in this section, compiled by Russ Karow, is adapted from Brevard Biodiesel (http://www.brevardbiodiesel.org/iv.html), Wikipedia, and other sources.

Table 2. Oilseeds and their fatty-acid composition.

	Fatty-acid content (%) of each oil by type of fatty-acid chain*							
Oilseed	16:0	18:0	18:1	18:2	18:3	20:0	20:1	22:1
Canola								
Winter [a]	6	0	61	22	7	0	0	0
Spring [a]	6	0	61	22	7	0	0	0
Flax								
Linseed (high-linolenic) [b]	5	3	16	15	60	0	0	1
Solin/linola (low-linolenic) [b]	10	5	16	65	2	0	0	0
Camelina [a]	8	3	17	23	31	0	12	3
Yellow mustard [c]	3	1	28	10	10	0	11	32
Safflower [d]	7	2	14	77	0	0	0	0
Sunflower [b]	6	4	17	72	0	0	0	0
Soybean (for comparison) [d]	14	2	23	56	4	0	0	0

* Fatty-acid chain types are described as X:Y, where X is the number of carbon atoms and Y the number of double bonds.

[a] Ehrensing, D. (2008a).

[b] Ehrensing, D. (2008b).

[c] Canola, Rapeseed and Mustard Breeding Group, University of Idaho (2003).

[d] Demirbas, A. (2002).

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Carbon chain length and the presence or absence of double bonds affect the chemical behavior of fats and oils. A double bond normally introduces a "kink" in the fatty-acid chain. Fats, which tend to be solid at room temperature, often have shorter carbon fatty acid chains and tend to have fewer double bonds. This results in straighter chains, which allows for the "packing" that a solid requires. Oils, which tend to be liquid at room temperature, usually have more double bonds, with corresponding kinks in their fatty-acid chains and less "packing." It is possible to "hydrogenate" an oil to remove double bonds and make it more solid at room temperature. The opposite is also possible.

Most plant-derived fatty acids are 8 carbons or longer and have an even number of carbon atoms. (In contrast, the bulk of a typical gasoline consists of molecules with between 5 and 12 carbon atoms.) Most liquid plant oils (soybean, canola, safflower, sunflower, etc.) are composed of predominantly 18-carbon fatty acids. Longer chain fatty acids, such as those found in camelina, mustard, and meadowfoam, give these oils unique hydrating and stability properties.

Biodiesel from different source oils contains different proportions and types of fatty acid chains, and so their chemical properties differ. For example, soybean oil has a melting point of 3.2°F while canola oil melts at 14°F. Palm oil (an oil with 45 percent palmitic acid) melts at 95°F.

Melting point and oxidative stability are concerns in biodiesel. For example, palm oil will be a sludge or solid at common Oregon winter temperatures, and in a factory setting this makes it more difficult than liquids to deal with.

Fatty acids that have no double bonds are termed "saturated"; for example, stearic acid. These chains contain the maximum number possible of hydrogen atoms per carbon atom. Fatty acids that have double bonds are "unsaturated"; for example, linoleic acid. These chains do not contain the maximum number of hydrogen atoms possible due to the double bond(s) on some carbon atoms. One double bond is "monounsaturated"; more than one double bond is "polyunsaturated."

The location and number of double bonds are important because they influence reactions that can destabilize the fatty-acid chain. The interaction of oxygen molecules with the fatty-acid chain, called "oxidation," destabilizes oil and biodiesel. The oxidation rates of linoleic and linolenic fatty acids are 27 times and 77 times greater, respectively, than oleic acid's. After oxidation, hydroperoxides (one hydrogen atom and two oxygen atoms) are attached to the fatty-acid chain. In a food oil, this leads to rancidity. In biodiesel, these degraded chains can "polymerize," hooking together into various substances including insoluble gums that clog up parts.

To be used as a motor fuel, any biodiesel must meet the standards of the American Society for Testing and Materials (ASTM). If a vegetable oil can be manipulated, processed, or combined with additives so that it meets ASTM standards, then the fuel will have access to the marketplace. These processes, however, can add significant costs.

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Benefits from crop rotations with oilseeds

Crop rotation often is promoted to reduce pests such as diseases, nematodes, and weeds and to increase crop yields. Oilseeds have been promoted as rotational crops, in part because they may have beneficial effects on subsequent crops.

Oilseed crops may have a positive, neutral, or negative effect on cereal crops, depending on the crop and pest in question. For example, safflower has been shown to reduce the population of *Pratylenchus neglectus*, a root-lesion nematode—obviously a positive effect (Smiley 2000). However, safflower is a deeply rooted crop that can extract moisture from deeper in the soil profile than many other oilseed crops (Beech & Leach 1989), and wheat yield reductions after safflower have been reported (Tonks & Esser 2005). A rotational benefit might be expected from oilseed crops in fields where take-all, Cephalosporium stripe, eyespot (strawbreaker foot rot), and cereal cyst nematode are important pests.

In contrast, Brassica species are good hosts for *P. neglectus,* and populations can grow to highly damaging levels after a mustard crop—clearly a negative effect (Sheedy et al. 2006).

Brassica species (canola, mustard, etc.) are fully susceptible to Rhizoctonia root rot, an important disease of wheat, and canola and mustard do not break up the Rhizoctonia disease cycle in a wheat-based system (Schillinger et al. 2006).

Crop rotations can also be beneficial if they have biofumigation effects on subsequent plantings. A biofumigation benefit from canola or mustard, however, is available only if plants are thoroughly incorporated into soil while foliage is immature; i.e., as a green manure. When plants are grown for seed production, the roots release only a very small amount of glucosinolate, and the rotational benefit is no different from that of other nonhosts of specific pathogens.

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III. Crop Enterprise Budgets for Oilseed Production

Information on crop production inputs, technologies, yields, and costs is presented here and integrated in crop enterprise budgets, discussed below. Although a wide range of assumptions may be appropriate to different areas (e.g., soils, oilseed varieties, and agronomic techniques), we have included only those that appear most relevant to the Willamette Valley.

Data sources and methods

Enterprise budgets for the six oilseeds of interest were developed by a team from two OSU departments, Crop & Soil Science and Agricultural & Resource Economics. Budgets are patterned after other, similar crop budgets for the Willamette Valley, with refined assumptions about crop practices, inputs, and cost factors (e.g., disking, fertilizer, and tractor costs). We used the Mississippi State Budget Generator (MSBG) software.

Budgets were developed based on Willamette Valley conditions and commonly used techniques. For example, tractors selected are similar to those in Willamette Valley enterprise budgets for grasses and grains. Costs include transporting the crop to a crusher in Portland but not the cost of storage and cleaning, which are assumed to be part of crushing costs. In addition, both till and no-till options were included, as was the choice of winter versus spring planting times for several of the oilseed crops.

Because oilseed-growing experience in the Willamette Valley is very limited, these budgets are based largely on estimates and judgments of OSU Extension and research faculty, rather than on the experiences of farmers in the region.

Land costs are included as annual rental rates. These vary in the Willamette Valley due to factors such as soil class and availability of irrigation. Average rents vary by county from as high as $240/acre for class 1 irrigated land to less than $50/acre for class 4 nonirrigated lands. We used a value of $125/acre to represent the cost (or opportunity cost) of relatively high value lands, the kind on which oilseeds would likely be grown in the Willamette Valley.

An item for miscellaneous costs of $30/acre was included for insurance and any other costs unaccounted for elsewhere. Certain pesticides in the enterprise budgets have not yet been registered for use in the United States; pesticide listings are for cost estimate purposes only—their listing does not constitute a recommendation for use. As is always the case, using any pesticide requires carefully reading and strictly adhering to the pesticide label.

Summary information on crop enterprise budgets

Table 3 (page 20) summarizes the oilseed crop enterprise budgets. Each oilseed crop's more detailed budget is found in appendix tables A1 to A8 (pages 38–45). Yields and price assumptions reflect various sources of information and were chosen in consultation with the leading local oilseed agronomist[7] who also helped develop the budgets.

[7] Dr. Daryl Ehrensing, Department of Crop & Soil Science, OSU.

Table 3. Enterprise budget summaries for various oilseed crops.

Costs and revenues	Oilseed crop							
	Camelina [a]	Canola [b]	Canola [c]	Flax [b]	Flax [d]	Yellow mustard [c]	Safflower [d]	Sunflower [e]
Variable cost ($/acre)	111.81	274.10	270.48	202.71	159.70	269.47	159.70	208.19
Fixed cost ($/acre)	166.81	200.87	202.68	188.72	176.89	202.68	176.89	188.72
Land rent ($/acre)	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00
Other ($/ac)	41.81	75.87	77.68	63.72	51.89	77.68	51.89	63.72
Total costs ($/acre)	278.62	474.97	473.16	391.43	336.59	472.15	336.59	396.91
Yield (lb/acre)	1,600	3,100	1,585	2,500	2,000	1,700	1,600	1,750
Seed price ($/lb)	0.095	0.140	0.140	0.111	0.111	0.130	0.126	0.139
Cost ($/lb)	0.174	0.153	0.299	0.157	0.168	0.278	0.210	0.227
Total revenue ($/acre)	152.00	434.00	221.90	277.25	221.80	221.00	201.92	243.25
Net revenue ($/acre)	- 126.62	- 40.97	- 251.26	- 114.18	- 114.79	- 251.15	- 134.67	- 153.66
Revenue net of variable costs ($/acre)	40.19	159.90	- 48.58	74.54	62.10	- 48.47	42.22	35.06

[a] Spring planted; broadcast over grass seed sod; no irrigation.

[b] Winter planted; regular tillage; no irrigation.

[c] Spring planted; regular tillage; no irrigation.

[d] Spring planted; no tillage; no irrigation.

[e] Spring planted; regular tillage; irrigated.

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These enterprise budgets indicate negative net revenues for all the oilseed crops at current prices. Winter canola has the highest variable cost but fares the best of all crops in terms of net revenue, due to its expected large yield. Yellow mustard, on the other hand, fares worst due to its low expected yield and high variable costs. Camelina has the lowest variable and fixed costs but also the lowest price and thus lowest revenue.

Land rent is higher in the Willamette Valley than in other regions where some of these oilseeds are grown. That is due to the relatively high profitability for growing other crops and, hence, a high "opportunity cost" for growing these oilseed crops. (See appendix table A9, page 46, for a set of summary crop enterprise budgets for crops currently grown in the Willamette Valley.) Thus, rent is a larger portion of the enterprise budgets' fixed costs compared to those in comparator regions. For example, NDSU's budgets estimate land rent at only $26/acre and WSU's at $37 to $75/acre. UC Davis estimated the land rent where their safflower was grown at $50/acre; only their sunflower budget's land rent was comparable to the Willamette Valley's, at $110/acre.

Although the budgets here show negative net returns, they do not reflect government subsidies which may lower costs of production or raise market prices. These effects are considered below and in the summary discussion that begins on page 29.

Government incentives: subsidies and taxes

A number of government programs encourage oilseed production for biodiesel. These programs alter the private profitability of oilseed production in direct and indirect ways. The main effect is to lower the costs for oilseed growers and biodiesel processors—while at the same time raising the costs borne by taxpayers. Oilseed growers can benefit directly from subsidies or tax credits related to their production or investments. They also can benefit indirectly by incentives paid to oilseed crushers or biofuel processors, because these incentives can alter the prices paid to producers in ways that effectively share the government subsidies among growers, processors, and consumers.

Federal and state programs to encourage biodiesel production are detailed in appendix B, page 47. Oregon's House Bill 2210, passed in 2007, includes a tax credit for producers of "biofuel raw materials" which include oilseed crops, grain crops, and woody biomass; the credit is applicable January 1, 2007 until January 1, 2013. Each feedstock has a tax credit. For oilseed crops, the credit is a significant 5 cents/pound. A farmer who crushes the oilseeds and delivers the oil to an Oregon processor could receive an additional 10 cents/gallon producer tax credit. If, for example, 30 pounds of seed are required per gallon of oil, this producer tax credit amounts to $1.60/gallon of oil.

These Oregon programs add to the existing federal programs encouraging biofuels. They include, for biodiesel, a $1/gallon federal subsidy (tax credit) on biodiesel blending (processing) and an additional 10 cents/gallon for small producers (up to 15 million gallons/year). While the federal credits are paid directly to blenders rather than growers, they augment demand for biodiesel feedstocks which may drive up oilseed prices and thereby benefit growers. The benefits of the subsidy, after all market adjustments are accounted for, therefore will be "shared" to some extent among growers, processors, and also by lower prices to consumers. Indeed, whether the subsidy is paid directly to the grower or processor is unlikely, in many market situations, to affect which group ends up benefiting from it.

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Besides programs that lower variable costs to growers and processors, a number of tax incentives subsidize capital investments in biofuel production. Included here are a federal program that could provide a 30-percent tax credit, up to $30,000, on farm refueling equipment, and renewable energy system grants of up to $500,000.

In addition, Oregon's Business Energy Tax Credit (BETC) pays up to 50 percent of the cost of a renewable energy system, up to $20 million. The tax credit is a dollar-for-dollar credit against income taxes owed, and is claimed over 5 years (10 percent in each of the first 5 years). Eligible costs include capital costs to plant, grow, harvest, store, crush or concentrate, and transport crops directed to production of ethanol or biodiesel. Farm equipment costs can be included as prorated capital expenditures to the extent that they are used to produce biofuels. Initial capital investments may be claimed only once; however, existing equipment may be eligible for the tax credit if "dedicated" to biofuel crop production.

To take advantage of the BETC, however, farmers must apply for a tax credit precertification before buying equipment and supplies or before planting a crop. The grower must specify the crops, equipment, acreage, and estimated annual biofuel production over the next 5 years, as well as the biofuel producer to which the biofuel crop will be delivered. As noted above, new equipment is eligible only once; after the 5-year tax credit period, those benefits would no longer be available. Moreover, all costs must be documented with receipts; if costs exceed $50,000, an independent certified public accountant must verify the costs. For a farmer interested in growing a biodiesel feedstock in occasional rotation with crops such as wheat, the acreage eligible over a 5-year period may be relatively small. If so, program benefits may be small relative to the risks and administrative burdens involved. Growers' participation in this program will become more apparent over the next several years.

Because this program is relatively new, and because it involves significant commitments, planning, and administration on the farmer's part, it is difficult to know how many will participate. That in turn makes it difficult to estimate the average subsidy per gallon. For example, direct capital costs (fixed expenses for equipment but not including land) account for about 15 percent of the cost per acre of feedstock production, based on our crop enterprise budgets. These cost shares, when reimbursed at a 50-percent rate, could represent a subsidy of up to 28 cents/gallon of flax oil or up to 85 cents/gallon for yellow mustard.

The BETC also applies to capital costs associated with crushing operations and biofuel processing. Based on estimated cost breakdowns for small-scale crushing and processing, 46 percent of crushing and processing costs could be eligible, or about 74 cents/gallon. A BETC of 50 percent would be an additional 37 cents/gallon. Thus, when feedstock production, crushing, and processing are combined, the maximum BETC credit appears to range from $1.19/gallon for flax to $1.76/gallon for yellow mustard.

The effects of per-pound or per-gallon subsidies are straightforward and are included in our main summary discussion of the economics of each oilseed (and in table 4, opposite). It is more difficult to estimate the average contribution of tax-credit programs for capital investments and expenses for individual growers. They will depend on the scale and type of operation. Table 5 (page 24) summarizes economic estimates including the maximum benefit under BETC.

In addition to these subsidy programs, producers and processors will benefit from programs that do not involve direct payments to either growers or processors. For example, the Renewable

Table 4. Summary of economic estimates for biodiesel production in Oregon's Willamette Valley.

	Oilseed and assumed annual production rate (gal/yr)								
	Winter canola		Spring canola		Flax	Camelina	Yellow mustard	Sunflower	Safflower
Costs ($/gal unless noted otherwise)	(0.5 MM)	(5 MM)	(0.5 MM)	(5 MM)	(0.5 MM)	(0.5 MM)	(0.5 MM)	(0.5 MM)	(0.5 MM)
Feedstock production ($/lb of seed)	0.15	0.15	0.30	0.30	0.16	0.17	0.28	0.23	0.21
Conversion (lb seed/gal of oil) [a]	30.00	30.00	30.00	30.00	22.00	27.00	38.00	22.00	25.00
Feedstock production ($/gal)	4.59	4.59	9.00	9.00	3.52	4.70	10.64	5.06	5.25
Crushing	1.05	1.00	1.05	1.00	1.05	1.05	1.05	1.05	1.05
Processing to biodiesel	1.25	0.70	1.25	0.70	1.25	1.25	1.25	1.25	1.25
Total processing cost	2.30	1.70	2.30	1.70	2.30	2.30	2.30	2.30	2.30
Total cost of biofuel	6.89	6.29	11.30	10.70	5.82	7.00	12.94	7.36	7.55
Revenues ($/gal unless noted otherwise)									
Biodiesel wholesale price FOB Portland	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Coproduct price ($/lb)	0.071	0.071	0.071	0.071	0.063	0.081	0.030	0.044	0.039
Coproduct credit	1.57	1.57	1.57	1.57	0.91	1.59	0.92	0.61	0.65
U.S. blenders, small producer tax credit	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Oregon renewable fuels tax credit (HB 2210)	1.60	1.60	1.60	1.60	1.20	1.45	2.00	1.20	1.35
Total subsidies [b]	2.70	2.70	2.70	2.70	2.30	2.55	3.10	2.30	2.45
Total revenue including subsidies	6.77	6.77	6.77	6.77	5.71	6.64	6.52	5.41	5.60
Net private revenue	- 2.82	- 2.22	- 7.23	- 6.63	- 2.41	- 2.91	- 9.52	- 4.25	- 4.40
Net revenue including subsidies	- 0.12	0.48	- 4.53	- 3.93	- 0.11	- 0.36	- 6.42	- 1.95	- 1.95
Social cost [c]	6.13	5.53	10.54	9.94	5.60	6.18	12.95	7.44	7.63
To achieve breakeven returns for processor without subsidies would require either:									
a feedstock price to blenders of ($/lb):	0.06	0.08	0.06	0.08	0.05	0.07	0.03	0.04	0.04
or grower subsidy per acre of ($/acre)	292.00	230.00	379.00	348.00	266.00	173.00	422.00	330.00	280.00

[a] Conversion (lb seed/gal of oil) based on oil in seed estimates and 80% extraction efficiency. Oil content may vary from the figures assumed here.

[b] Does not include subsidies for capital such as the 50% tax credit under Oregon's BETC for up to $20 million for new renewable energy systems.

[c] This includes the indirect costs of the public funds used to subsidize production (the "excess burden of taxation").

Table 5. Summary of economic results when including the maximum benefits from Oregon Business Energy Tax Credit.

	Oilseed and assumed annual production rate (gal/yr)								
	Winter canola		Spring canola		Flax	Camelina	Yellow mustard	Sunflower	Safflower
Costs ($/gal unless noted otherwise)	(0.5 MM)	(5 MM)	(0.5 MM)	(5 MM)	(0.5 MM)	(0.5 MM)	(0.5 MM)	(0.5 MM)	(0.5 MM)
Feedstock production ($/lb of seed)	0.15	0.15	0.30	0.30	0.16	0.17	0.28	0.23	0.21
Conversion (lb seed/gal of oil) [a]	30.00	30.00	30.00	30.00	22.00	27.00	38.00	22.00	25.00
Feedstock production	4.59	4.59	9.00	9.00	3.52	4.70	10.64	5.06	5.25
Crushing	1.05	1.00	1.05	1.00	1.05	1.05	1.05	1.05	1.05
Processing to biodiesel	1.25	0.70	1.25	0.70	1.25	1.25	1.25	1.25	1.25
Total processing cost	2.30	1.70	2.30	1.70	2.30	2.30	2.30	2.30	2.30
Total cost of biofuel	6.89	6.29	11.30	10.70	5.82	7.00	12.94	7.36	7.55
Revenues ($/gal unless noted otherwise)									
Biodiesel wholesale price FOB Portland	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Coproduct price ($/lb)	0.071	0.071	0.071	0.071	0.063	0.081	0.030	0.044	0.039
Coproduct credit	1.57	1.57	1.57	1.57	0.91	1.59	0.92	0.61	0.65
U.S. blenders, small producer tax credit	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Oregon renewable fuels tax credit (HB 2210)	1.60	1.60	1.60	1.60	1.20	1.45	2.00	1.20	1.35
Oregon Business Energy Tax Credit [b]	1.27	1.04	1.63	1.39	1.19	1.26	1.76	1.21	1.30
Total subsidies	3.97	3.74	4.33	4.09	3.49	3.81	4.86	3.51	3.75
Total revenue including subsidies	8.04	7.81	8.40	8.16	6.90	7.90	8.28	6.62	6.90
Net private revenue	- 2.82	- 2.22	- 7.23	- 6.63	- 2.41	- 2.91	- 9.52	- 4.25	- 4.40
Net revenue including subsidies	1.15	1.52	- 2.90	- 2.54	1.08	0.90	- 4.66	- 0.74	- 0.65
Social cost [c]	6.51	5.84	11.03	10.36	5.95	6.56	13.48	7.80	8.03

[a] Conversion (lb seed/gal of oil) based on oil in seed estimates and 80% extraction efficiency. Oil content may vary from the figures assumed here.

[b] Includes estimate of maximum possible subsidy from the 50% tax credit under Oregon's BETC for up to $20 million for new renewable energy systems.

[c] This includes the indirect costs of the public funds used to subsidize production (the "excess burden of taxation").

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Fuels Standard of the U.S. Energy Policy Act of 2005 requires fuel producers to produce 7.5 billion gallons of renewable energy annually by 2012. This and other regulatory programs will increase demand for feedstocks, which in turn will have a positive effect on prices for biodiesel and oilseed.

IV. Oil Extraction and Biodiesel Processing

Overview

There are, at most, three major steps in extracting oil from seed: heating, crushing, and further processing. First, the seed may be heated or left cold before pressing through a mechanical crusher—i.e., hot pressed or cold pressed. Second, the seed passes through some type of press which presses oil into one container and directs seed meal into another. Third, and optionally, a chemical or mechanical process may be used to increase oil yield.

In a chemical process, hexane is used to separate the remaining oil from the seed meal. In a mechanical process, the remaining meal is prepared for recrushing by passing it through an extruder which heats the meal to the point that seed cell walls break, facilitating further oil removal. The hexane process increases oil removal efficiency to nearly 99 percent, compared to approximately 80-percent efficiency in a strictly cold-pressed process. However, the U.S. Environmental Protection Agency (EPA) lists hexane as a hazardous air pollutant. The crushing facility must take steps to contain emissions and to ensure worker safety, thereby increasing production costs (Kenkel et al. 2006).

This study assumes a cold-press expeller process, for several reasons. First, using hexane increases production costs and complicates the feasibility of small-scale, on-farm production. Second, an extruder can be many times more costly than a regular expeller, making it infeasible for smaller operations. Third, using a hot-press mechanism increases input costs (i.e., energy) to a degree not justified currently. Last, the bulk of small-scale crushing in Oregon, from which we drew for this study, uses a cold-press expeller process.

Transesterification is the most common way to convert vegetable oil low in free fatty acid into biodiesel. The first step in this simple process is to mix alcohol with a catalyst such as potassium hydroxide. Next, these are combined with the vegetable oil to create a mixture of biodiesel and glycerin. The mixture then is cleaned using water to remove glycerin and any remaining catalyst. The biodiesel itself can go on for further testing and purification, while the glycerin–catalyst mix goes to an evaporator to release the remaining alcohol. Some procedures are more complex; for example, they may incorporate steps to reuse as much leftover catalyst as possible, instead of evaporating it; the catalyst may also be used as a crop fertilizer.

Cost of oil extraction and biodiesel processing

Our analysis relies on a wide range of economic estimates of the cost of oil extraction and biofuel processing. A number of studies on canola and soybean are available, and a "meta analysis" draws on them to provide a useful set of estimates for current purposes. These estimates, from national studies by universities, researchers, and consulting firms, also are compared to local evidence and estimates to provide a degree of "ground truthing."

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Both the extraction (crushing, or extrusion and pressing) and processing (esterification) operations have significant economies of scale; average cost per gallon declines for larger processing plants. Large operations may function more efficiently by using more durable equipment and by automating tasks.

Figures 3 and 4 describe evidence from studies of biodiesel production with soybeans and canola. These clearly indicate that average biodiesel processing cost is minimized in plants producing more than 10 million gallons/year. Most estimates for these larger plants indicate that crushing and processing costs are about 50 cents/gallon and total processing cost is about $1/gallon. One report estimated crushing costs at less than 30 cents/gallon in a large plant (27 million gallons/year) producing both soy and canola oil (Shumaker 2003).

Figure 3. Scale economies for oilseed crushing (extrusion and pressing): Summary of estimates from various studies.

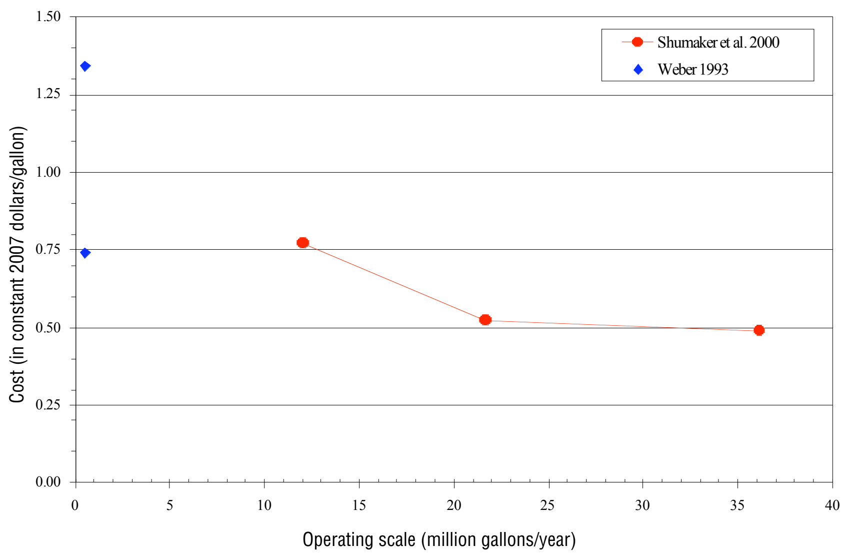
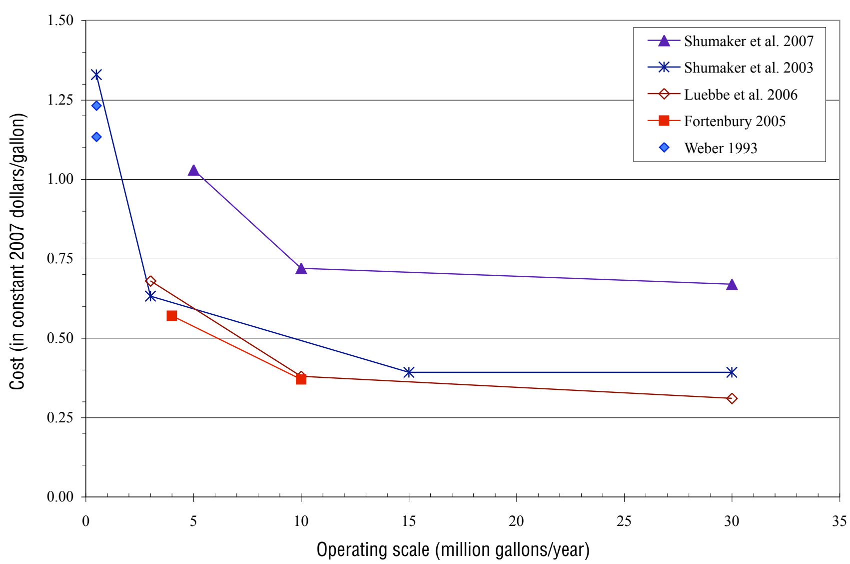


Figure 4. Scale economies for biodiesel processing (esterification): Summary of estimates from various studies.



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In smaller operations, more likely in the Willamette Valley, per-gallon processing costs are significantly higher. The increase is modest for plants in the 5-million-gallon range. However, for small-scale community or on-farm plants of 0.5 million gallons/year, the pattern in figures 3 and 4 suggests $1.05/gallon to crush and $1.25/gallon to process, for a total of about $2.30/gallon.

A 5-million-gallon/year plant in the Willamette Valley would require about 50,000 acres of canola, or 5 percent of the total acreage for *all* crops normally harvested in the Valley. Currently only about 3,000 acres of canola are grown in all of Oregon, nearly all with irrigation in northeast Oregon.

To estimate the potential acreage for growing oilseeds, we began with the average annual acreage currently producing grains, grass seed, and legumes in each Willamette Valley county (Oregon Agricultural Information Network). We estimated the percentage available for oilseed planting (table 6) at about 53,000 acres annually, in a 1-year-in-4 rotation. Given an average yield of 2,500 pounds/acre, and an oil yield of 1 gallon per 30 pounds of seed, maximum production potential is 4.38 million gallons/year (table 6). At less than 5 million gallons/year for the entire Willamette Valley, it is questionable whether centralized crushing and processing would achieve the scale economies necessary to keep average costs low. Moreover, it is unlikely that the entire production would be shipped to a single location for crushing and blending. Therefore, costs based on the lower volume, 0.5 million gallons/year, are likely more realistic for the Willamette Valley.

These cost estimates are consistent with information provided locally by individuals and organizations in the region's nascent biofuel industry. In one case, a Washington State producer with a small oil crushing operation (less than 1 million gallons/year) indicated he would charge $70/ton, or about $1/gallon, to crush someone else's canola. This producer, apparently with excess crushing capacity, would want to cover his marginal cost (including wear and tear on equipment) for this operation but not necessarily his average cost (including fixed costs, which are already paid). For small operations of this kind, we expect that marginal cost will be below

Table 6. Estimated potential annual production of biodiesel in Oregon's Willamette Valley.

County	Acreage currently in grains, grass seed, and legume seed	Area available to plant Brassica (%)	Oilseed production acreage *	Oil yield (gal/yr)
Benton	41,060	80	8,212	684,333
Clackamas	11,878	30	891	74,234
Lane	32,191	100	8,048	670,651
Linn	162,710	50	20,339	1,694,896
Marion	81,088	0	0	0
Multnomah	1,658	100	415	34,549
Polk	71,242	0	0	0
Washington	52,051	100	13,013	1,084,385
Yamhill	64,151	10	1,604	133,648
Total	**518,028**	**41**	**52,520**	**4,376,697**

* Assuming 1-in-4-year rotation.

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average cost. If we are correct, then the average cost in this case is more than $1/gallon. Available information from other sources on average cost of canola crushing appears consistent with the patterns in figures 3 and 4.

On-farm biodiesel processing and use

The possibility that farmers who grow biodiesel feedstocks can also benefit by producing and using biodiesel on-farm is of considerable interest. On-farm production and use could enable some farmers to be more self-reliant in fuel, and would avoid certain fossil fuel costs such as transportation and retail markup. On-farm crushing capacity could also be used to crush oilseeds for other growers, making the operator a net seller of oil or biodiesel.

The economies of scale discussed above and reflected in figures 3 and 4 suggest, however, that the cost per gallon for small-scale crushing and processing are significantly higher than for larger operations. At or below 0.5 million gallons/year, crushing and processing costs are likely to be more than $1/gallon higher than for consolidated operations of 5 or 10 million gallons/year.

The reasons for scale economies include the higher maintenance cost on small-scale equipment such as presses to crush oilseeds, and the fact that capital costs generally rise more slowly than the volume of production as the scale of operation is increased. Substitutions can be made between capital and labor as well, but there are limits to these trade-offs; and large-scale operations tend to be able to take the greatest advantage of substituting relatively low-cost capital for relatively high-cost labor.

A farmer's decisions on biodiesel production generally will be influenced by prices, costs, and potential returns compared to using the land and other resources in other ways. First, the decision to grow oilseeds rather than other crops will be influenced by the opportunity cost of land, thus taking account of the market prices for seed, oilseed oil for the biodiesel markets, edible oil, and meal. Second, the market price for biodiesel (or petroleum diesel) compared to on-farm production and processing costs will influence farmers' decisions regarding investments in on-farm crushing and processing. These decisions also may be affected by changes in seed and meal prices relative to the cost of crushing and the price of oil. In a market where centralized (larger) crushing operations can produce oil for 50 cents/gallon less, this may affect farmers' competitiveness.

Government subsidies can improve the economic calculations for farmers, as discussed earlier (see also the following section and appendix B). These, however, are available to both on-farm and off-farm operations and thus may not provide on-farm producers with an advantage over larger operations. Indeed, the federal tax credit for blenders may encourage importing oil feedstock from Canada (where canola, for example, is grown at lower cost than in Oregon).[8] However, isolated or localized markets (e.g., for animal feed) may be less affected by these large-scale operations.

[8] For example, Imperium Renewables recently opened a $75-million, 50-million-gallon/year plant in Grays Harbor, WA, to process biodiesel using imported oils such as canola oil from Canada. The operation will not benefit Northwest U.S. growers of canola or other seeds but *will* benefit from the federal biofuel blending credit of $1/gallon.

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V. Summary of Biodiesel Economics and Discussion

The economics of biodiesel encompass both a private and a public dimension. In the private dimension, success requires that incentives for producers, blenders, and consumers be sufficient to compete in the marketplace with the alternatives available (e.g., alternative uses of land, labor, and capital, and alternative fuel choices for consumers). In the public dimension, success is defined in terms of the public goals that motivate government's intervention (i.e., subsidies) and whether biodiesel will achieve the public goals in a cost-effective manner, when compared to other options.

It is important to evaluate both dimensions. If the public evaluation is highly favorable but the market incentives are inadequate, no biodiesel will be produced. On the other hand, if market prices generate strong interest among producers and consumers, but the social gains are very small, or the costs are very high compared to other approaches, then the activity may not represent a good use of scarce public resources.

This report assesses the economic prospects for oilseed production in the Willamette Valley. Our summary should be seen as tentative, however, given the limited information available in some cases. As additional information becomes available, estimates can be refined.

Cost of biodiesel production

Per gallon, biodiesel from oilseeds produced in the Willamette Valley is estimated to cost from \$6.29 to more than \$12.94. These costs do not include "coproduct credits," such as income generated from the sale of meal, which would affect a farmer's profitability. Although in some cases coproduct credits can be substantial, we did not include them in these summary cost figures for two reasons: first, because the rationale for promoting oilseed production is not to produce more coproducts but to produce renewable energy; second, because it's uncertain whether local animal feed markets could absorb significant quantities of these coproducts as animal feed given nutritional considerations and the size of local herds, which limit demand.

For example, two large corn ethanol processing plants will be operating soon in Oregon, at Clatskanie and Hermiston, with a combined capacity of more than 100 million gallons/year. The additional coproduct animal feed (distiller dry grains, or DDG) from those operations will meet most or all of the demand in Oregon, which could significantly affect the local market for DDG and have significant spillover effects (lower prices) for other types of coproduct meal generally used as animal feed.

Government subsidies substantially affect the commercial viability of biodiesel. Several points are worth noting regarding the distribution of the benefits from these programs. For example, oilseed growers may benefit from subsidies paid directly to them, but if these programs stimulate increased production, which in turn leads to lower market prices, the benefits to them may be reduced. Or, if subsidies to blenders lead to increased demand for feedstocks, the resulting higher seed prices could benefit growers, too. Finally, tax credits for capital investments may benefit some farmers, but there is uncertainty about which producers, or how many growers or processors, will be able to take advantage of these particular programs.

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Table 4 (page 23) summarizes costs for two different scales of crushing and processing for canola, which appears to have the greatest interest and potential for increased production in the short term. The two scales are 0.5 million and 5 million gallons/year. For all other oilseeds, only the smaller scale was used to estimate crushing and processing costs. The larger scale is included for comparison, but a single Willamette Valley operation of this scale is unrealistic.

Cost estimates per gallon depend greatly on the seeds' oil content and on crushing efficiency. For example, cost per gallon declines by more than $1 in locations such as Canada and North Dakota where canola's oil content is 43 percent rather than the 32 percent reported in Oregon (Madison Farms, in Echo), and when extraction efficiency is 100 percent rather than 80 percent. Information on oil content for Oregon-grown oilseeds was available for only canola. Oil content of other oilseeds grown in Oregon may differ from those assumed here. Sources on oil content for flax are from Canada, and from North Dakota for yellow mustard and sunflower. In no other case were data available from Oregon.

Operating scale also markedly affects average cost. Centralizing the crushing and processing at larger facilities may lower these costs significantly. Combined crushing and processing costs are estimated at $2.30 for a 0.5-million-gallon/year plant, but these could be reduced to $1.70/gallon for a 5-million-gallon/year plant, or only $1/gallon for a 10-million-gallon/year plant.

The private costs of producing biodiesel, as compared to market biodiesel prices, can be presented in several useful ways. From a blender's perspective, we could ask: What would the feedstock price have to be for biodiesel production to break even at current market prices? As shown in table 4 (page 23), we estimate feedstock prices would have to be 50 to 90 percent lower than current market prices.[9] From a grower's perspective, we could ask: What per-acre subsidy would allow growers and processors to break even on producing biodiesel? In table 4, we show that, given the $125/acre opportunity cost of land, a subsidy of between $173 and $422/acre would be necessary.

Private economics with subsidies and coproduct credits

The private returns to producers and processors of biofuels will, in fact, include the offsets or credits they can receive for sale of coproducts and from government subsidies. Coproduct credit estimates vary from 61 cents/gallon of biodiesel for sunflower to $1.59/gallon for camelina. Coproduct credits are included in our summary of private economic returns in table 4 (page 23), under "Net private revenue." At a production rate of 0.5 million gallons/year, net private returns range from -$2.41/gallon for flax to -$9.52/gallon for yellow mustard.

In table 4, under "Total subsidies," we also include the per-gallon federal and state tax credits for production or blending. Estimates range from $2.30/gallon for flax and sunflower to $3.10/gallon for yellow mustard. The largest portion of these is due to Oregon's HB 2210. Even when both coproduct credits and government subsidies are included, net revenue for producing biofuel from these oilseeds remains negative except for winter canola when produced at a level that enables large-scale processing (5 million gallons/year). In that case, we estimate revenues would exceed costs by 48 cents/gallon.

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[9] For both these hypothetical computations, we have included coproduct credits.

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Finally, to the extent that growers and processors take advantage of federal and state tax credits on capital costs (discussed on page 21), net revenues for each oilseed will be more favorable to producers; see table 5 (page 24), which includes estimated maximum payments under the Oregon BETC. Then, positive net revenues are generated for winter canola, flax, and camelina.

Public economics

In this section, we consider the full cost of biodiesel production with current subsidies available to growers and processors. The full social cost with these programs in place includes the indirect cost of subsidies because they are financed through taxation. Public finance economics recognizes that taxes introduce distortions and thus inefficiencies in the economy; as a result, an additional cost is associated with any government program funded with taxes. The cost is referred to as the “deadweight loss” or “excess burden” of the tax.

To finance biofuel subsidies, governments must either raise funds through additional taxation or reduce funding for other programs. In either case, there is a cost of financing the program. Extensive literature on the topic estimates the cost in the United States ranges from 20 to 40 cents per dollar of tax revenue. This means that for every dollar paid in subsidies, the public pays an additional 20 to 40 cents in added distortionary cost associated with the subsidies’ financing (see, for example, Browning 1987). We used a value of 30 cents per dollar of public funds to estimate the “Social cost” in tables 4 and 5.

For the subsidy assumptions included in table 4, we estimate the social cost to be between $5.53 and $12.95/gallon. If we assume growers take full advantage of BETC tax credits, social costs are somewhat higher because of the indirect cost of the additional subsidy. These social cost estimates range from $5.84 to $13.48/gallon (table 5, page 24).

The second step in our evaluation of biodiesel opportunities considers the motivating social benefits, such as reducing dependence on fossil fuels and slowing greenhouse gas emissions. To quantify these benefits is extremely difficult, and any estimate would be controversial. We take an alternative approach, called a cost-effectiveness analysis. It takes as given the desired social objective (e.g., reductions in fossil fuel dependence and in greenhouse gas emissions) and compares the costs of alternative approaches to achieving that goal (i.e., cost per unit of gain). In the same way that a farmer may compare the cost of different ways to plow or irrigate a field, the public is interested in knowing which approach to reducing fossil fuel use can achieve the most at the lowest cost.[10]

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[10] On the question of reducing greenhouse gas emissions, recent scientific uncertainty has arisen about whether substituting biofuel for fossil fuel reduces greenhouse gas emissions at all. The uncertainty is due to nitrous oxide emissions that occur when nitrogen fertilizer, used in oilseed production, reacts with soil microbes. Nitrous oxide is a greenhouse gas 300 times more potent than carbon dioxide (the principal greenhouse gas created from fossil fuel use). Depending on the level of nitrous oxide emissions resulting from feedstock production, biodiesel could have a positive or negative effect on greenhouse gas emissions (Times of London Online, September 22, 2007).

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To compare biofuel promotion with other approaches to reducing fossil fuel use, we compare their social costs in terms of a standard metric, a reduction in use of 1 million BTUs of fossil fuel energy inputs. We know that the energy contained in 1 gallon of canola biodiesel, net of the energy used to produce it, is approximately 48,000 BTUs (Jaeger, Cross, & Egelkraut 2007). Precise estimates for other oilseeds are unavailable. Using the canola-based value for all biodiesel options considered here, we can estimate the added cost and the reduction in fossil fuel energy inputs when substituting biodiesel for petroleum diesel. These values (table 7) range from $64.46 to $172.35/million BTUs. We compare these with estimates from studies of alternative policy approaches, such as increasing the gas tax and tightening automobile fuel economy standards. Those studies estimate a cost of $1.75/million BTUs for a gas tax increase and $3.22/million BTUs for raising fuel economy standards.

Comparing these estimates to those for biodiesel, in table 7, indicates that promoting biodiesel production in the Willamette Valley is a more expensive way to achieve these goals. Indeed, compared to a gas tax increase, biodiesel promotion is estimated to cost between 37 and 98 times as much for a given reduction in fossil fuel use. When compared to raising fuel economy standards, biodiesel is estimated to cost 20 to 53 times as much. Stated alternatively, for a given overall cost, raising fuel economy standards could achieve 20 to 53 times as much toward energy independence as these biodiesel options.[11]

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[11] These results, indicating biodiesel is not a cost-effective way to reduce fossil fuel consumption (or greenhouse gas emissions), are consistent with results of an analysis of rapeseed-based biodiesel for the European Community (Frondel & Peters 2007).

Table 7. Cost effectiveness of biodiesel versus alternative ways to reduce fossil fuel use.

Comparison points	Petroleum diesel	Winter canola	Spring canola	Flax	Camelina	Yellow mustard	Sunflower	Safflower
Cost per gallon ($)	1.75	6.89	11.30	5.82	7.00	12.94	7.36	7.55
Cost per MM BTUs in fuel ($)	13.26	58.34	95.68	49.28	59.25	109.57	62.32	63.93
Fossil fuel energy input per unit of energy in fuel (MM BTU/MM BTU) [a]	1.15	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Cost of substituting biodiesel energy in fuel for petroleum diesel ($/MM BTUs) [b]		45.08	82.42	36.02	46.00	96.31	49.06	50.67
Change in fossil fuel input for above (BTU/BTU)		0.56	0.56	0.56	0.56	0.56	0.56	0.56
Cost of reducing fossil fuel (input) use with biodiesel substitution ($/MM BTU)		80.68	147.50	64.46	82.31	172.35	87.80	90.68
Comparison with alternative approaches to reducing fossil fuel use ($/MM BTUs) [c]		Ratio (%) of cost of reduced fossil fuel use for biodiesel compared to other approaches						
Raising the gas tax	1.75	4,610	8,429	3,684	4,704	9,849	5,017	5,182
Increasing fuel economy standards	3.22	2,506	4,581	2,002	2,556	5,353	2,727	2,816

[a] Based on estimates of 118,000 BTUs/gal for biodiesel with Net Energy Balance (NEB) ratio of 0.59; see Jaeger, Cross, & Egelkraut (2007).

[b] Petroleum diesel is assumed to contain 132,000 BTUs/gal and to have a NEB ratio of 1.15.

[c] Gas tax and fuel economy standards from West & Williams (2005) and National Research Council (2002).

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Appendix A. Oilseed Crop Enterprise Budgets

This appendix contains tables summarizing the assumptions and costs for enterprise budgets for each crop evaluated. Summary enterprise budgets for crops currently grown in the Willamette Valley also are included.

Table A1. Winter canola:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. rate (hr/ac)	Times over	Mo.	Power unit cost ($) Direct	Power unit cost ($) Fixed	Equip. cost ($) Direct	Equip. cost ($) Fixed	Allocated labor Hrs.	Allocated labor Cost ($)	Operating or durable input Amt.	Operating or durable input Price ($)	Operating or durable input Cost ($)	Total cost ($)
PLOW				1	Sep										
Moldboard plow	6 bottom	310	0.196			16.16	6.54	1.77	2.66	0.21	2.81				29.94
DISK				1	Sep										
Disk	20	310	0.097			10.26	3.23	0.82	2.04	0.1	1.39				17.74
FALL HERBICIDE				1	Sep										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Treflan	pint											2	2.75	5.50	5.50
DISK-IN TREFLAN				1	Sep										
Disk	20	310	0.097			10.26	3.23	0.82	2.04	0.1	1.39				17.74
HARROW & ROLL				1	Sep										
Dixon harrow	21 ft	310	0.076			4.52	2.56	0.21	0.52	0.08	1.1				8.91
+ Roller	21 ft		0.076					0.30	0.75						1.05
PLANT				1	Sep										
Drill	13 ft	140	0.139			4.93	3.50	0.96	1.92	0.15	2.45				13.76
Canola seed	lb											6	2.00	12.00	12.00
16-20-0	ton											0.05	360.00	18.00	18.00
Ammonium sulfate	ton											0.05	220.00	11.00	11.00
SPRING FERTILIZER				1	Jan										
Fertilizer buggy	80		0.056			1.38	1.02			0.06	0.8				3.20
46-0-0 urea	ton											0.12	410.00	49.20	49.20
Boron	lb											1	2.15	2.15	2.15
SPRING HERBICIDE				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Select 2EC	oz											5	1.45	7.25	7.25
INSECTICIDE				0.3	May										
Success (spinosad)	oz											1.2	5.31	6.37	6.37
Custom aerial application	acre											0.3	12.50	3.75	3.75
WINDROWING				1	Jun										
Swather	150		0.163			5.76	6.88			0.18	1.63				14.27
Combine	200		0.333	1	Jul	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Jul							3,500	0.00	17.50	17.50
Miscellaneous	acre			1	Jul							1	30.00	30.00	30.00
Land rent	each			1	Dec				125			1			125.00
Pickup	each			1	Jan				4.07			0.0006			4.07
Application	mile							2.25		0.1	1.6	5			3.85
Totals						72.18	61.87	7.13	139	1.45	17.43			162.72	460.33
Interest on operating capital															14.64
Unallocated labor															0
Total specified cost															474.97

[a] Regular till, mid-Willamette Valley, 2006.

Table A2. Spring canola:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. rate (hr/ac)	Times over	Mo.	Power unit cost ($)		Equip. cost ($)		Allocated labor		Operating or durable input			Total cost ($)
						Direct	Fixed	Direct	Fixed	Hrs.	Cost ($)	Amt.	Price ($)	Cost ($)	
PLOW				1	Sep										
Moldboard plow	6 bottom	310	0.196			16.16	6.54	1.77	2.66	0.21	2.81				29.94
DISK				1	Sep										
Disk	20	310	0.097			10.26	3.23	0.82	2.04	0.1	1.39				17.74
VOLUNTEER CONTROL				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.25	17.00	4.25	4.25
PREPLANT HERBICIDE				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Treflan	pint											2	2.75	5.50	5.50
DISK-IN TREFLAN				1	Feb										
Disk	20	310	0.097			10.26	3.23	0.82	2.04	0.1	1.39				17.74
HARROW & ROLL				1	Feb										
Dixon harrow	21 ft	310	0.076			4.52	2.56	0.21	0.52	0.08	1.10				8.91
+ Roller	21 ft		0.076					0.30	0.75						1.05
PLANT				1	Feb										
Drill	13 ft	140	0.139			4.93	3.50	0.96	1.92	0.15	2.45				13.76
Canola seed	lb											6	2.00	12.00	12.00
16-20-0	ton											0.025	360.00	9.00	9.00
Ammonium sulfate	ton											0.025	220.00	5.50	5.50
SPRING FERTILIZER				1	Apr										
Fertilizer buggy	80		0.056			1.38	1.02			0.06	0.80				3.20
46-0-0 urea	ton											0.1	410.00	41.00	41.00
Boron	lb											1	2.15	2.15	2.15
PREEMERGENCE HERBICIDE				1	Apr										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Select 2EC	oz											5	1.45	7.25	7.25
INSECTICIDE				1	Jun										
Custom aerial application	acre											1	12.50	12.50	12.50
Success (spinosad)	oz											4	5.31	21.24	21.24
WINDROWING				1	Jul										
Swather	150		0.163			5.76	6.88			0.18	1.63				14.27
Combine	200		0.333	1	Jul	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Jul						1.00	900	0.00	9.50	9.50
Miscellaneous	acre			1	Aug							1	30.00	30.00	30.00
Land rent	each			1	Dec				125.00			1			125.00
Pickup	each			1	Jan				4.07			0.0006			4.07
Application	mile							2.25		0.1	1.60	5			3.85
Totals						73.30	63.68	7.13	139.00	1.48	17.90			159.89	460.90
Interest on operating capital															12.26
Unallocated labor															0
Total specified cost															473.16

[a] Regular till, in grass rotation, nonirrigated, mid-Willamette Valley, 2006.

Table A3. Spring camelina:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. rate (hr/ac)	Times over	Mo.	Power unit cost ($) Direct	Power unit cost ($) Fixed	Equip. cost ($) Direct	Equip. cost ($) Fixed	Allocated labor Hrs.	Allocated labor Cost ($)	Operating or durable input Amt.	Operating or durable input Price ($)	Operating or durable input Cost ($)	Total cost ($)
SPRAYING				1	Nov										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.375	17.00	6.38	6.38
SPRAYING				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.25	17.00	4.25	4.25
PLANT & FERTILIZE				1	Feb										
Fertilizer buggy	80		0.056			1.38	1.02			0.06	0.80				3.20
Camelina seed	lb											3	1.00	3.00	3.00
16-20-0	ton											0.025	360.00	9.00	9.00
Ammonium sulfate	ton											0.025	220.00	5.50	5.50
SPRAYING				1	Apr										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Select 2EC	oz											5	1.45	7.25	7.25
Combine	200		0.333	1	Jul	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Jul							2000	0.00	10.00	10.00
Miscellaneous	acre			1	Aug							1	30.00	30.00	30.00
Land rent	each			1	Dec				125			1			125.00
Pickup	each			1	Jan				4.07			0.0006			4.07
Application	mile							2.25		0.10	1.60	5			3.85
Totals						21.41	37.74	2.25	129.07	0.63	7.13			75.38	272.98
Interest on operating capital															5.64
Unallocated labor															0
Total specified cost															278.62

[a] Broadcast seeding over grass-seed sod, nonirrigated, mid-Willamette Valley, 2006.

Table A4. Spring flax:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. Rate (hr/ac)	Times over	Mo.	Power unit cost ($) Direct	Power unit cost ($) Fixed	Equip. cost ($) Direct	Equip. cost ($) Fixed	Allocated labor Hrs.	Allocated labor Cost ($)	Operating or durable input Amt.	Operating or durable input Price ($)	Operating or durable input Cost ($)	Total cost ($)
SPRAYING				1	Oct										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.375	17.00	6.38	6.38
SPRAYING				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.25	17.00	4.25	4.25
PLANT & FERTILIZE				1	Feb										
No-till drill	15 ft	130	0.1			3.56	2.48	2.31	5.79	0.11	1.43				15.57
Flax seed	lb											40	0.12	4.80	4.80
16-20-0	ton											0.025	360.00	9.00	9.00
Ammonium sulfate	ton											0.025	220.00	5.50	5.50
SPRAYING				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Spartan	oz											4	3.56	14.25	14.25
FERTILIZING				1	Apr										
Fertilizer buggy	80		0.056			1.38	1.02			0.06	0.80				3.20
46-0-0 urea	ton											0.05	410.00	20.50	20.50
SPRAYING				1	Apr										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Select 2EC	oz											5	1.45	7.25	7.25
Curtail M	gal											0.0117	41.00	0.48	0.48
Combine	200		0.333	1	Jul	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Jul							2000	0.00	10.00	10.00
Miscellaneous	acre			1	Aug							1	30.00	30.00	30.00
Land rent	each			1	Dec				125			1			125.00
Pickup	each			1	Jan				4.07			0.0006			4.07
Application	mile							2.25		0.10	1.60	5			3.85
Totals						26.09	42.03	4.56	134.86	0.77	9.03			112.41	328.98
Interest on operating capital															7.61
Unallocated labor															0
Total specified cost															336.59

[a] No-till, nonirrigated, mid-Willamette Valley, 2006.

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Table A5. Spring yellow mustard:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. Rate (hr/ac)	Times over	Mo.	Power unit cost ($) Direct	Power unit cost ($) Fixed	Equip. cost ($) Direct	Equip. cost ($) Fixed	Allocated labor Hrs.	Allocated labor Cost ($)	Operating or durable input Amt.	Operating or durable input Price ($)	Operating or durable input Cost ($)	Total cost ($)
PLOW				1	Sep										
Moldboard plow	6 bottom	310	0.196			16.16	6.54	1.77	2.66	0.21	2.81				29.94
DISK				1	Sep										
Disk	20	310	0.097			10.26	3.23	0.82	2.04	0.1	1.39				17.74
VOLUNTEER CONTROL				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.25	17	4.25	4.25
PREPLANT HERBICIDE				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Treflan	pint											2	2.75	5.50	5.50
DISK-IN TREFLAN				1	Feb										
Disk	20	310	0.097			10.26	3.23	0.82	2.04	0.1	1.39				17.74
HARROW & ROLL				1	Feb										
Dixon harrow	21 ft	310	0.076			4.52	2.56	0.21	0.52	0.08	1.10				8.91
+ Roller	21 ft		0.076					0.30	0.75						1.05
PLANT				1	Feb										
Drill	13 ft	140	0.139			4.93	3.50	0.96	1.92	0.15	2.45				13.76
Yellow mustard seed	lb											6	2	12	12.00
16-20-0	ton											0.025	360	9	9.00
Ammonium sulfate	ton											0.025	220	5.50	5.50
SPRING FERTILIZER				1	Apr										
Fertilizer buggy	80		0.056			1.38	1.02			0.06	0.80				3.20
46-0-0 urea	ton											0.1	410	41	41
Boron	lb											1	2.15	2.15	2.15
PREEMERGENCE HERBICIDE				1	Apr										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Select 2EC	oz											5	1.45	7.25	7.25
INSECTICIDE				1	Jun										
Custom aerial application	acre											1	12.50	12.50	12.50
Success (spinosad)	oz											4	5.31	21.24	21.24
WINDROWING															
Swather	150		0.163			5.76	6.88			0.18	1.63				14.27
Combine	200		0.333	1	Jul	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Jul							1700		8.50	8.50
Miscellaneous	acre			1	Aug							1	30	30	30
Land rent	each			1	Dec				125.00			1			125
Pickup	each			1	Jan				4.07			0.0006			4.07
Application	mile							2.25		0.1	1.60	5			3.85
Totals						73.3	63.68	7.13	139	1.48	17.90			158.89	459.90
Interest on operating capital															12.25
Unallocated labor															0
Total specified cost															472.15

[a]Conventional tillage, in grass rotation, nonirrigated, mid-Willamette Valley, 2006.

Table A6. Winter flax:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. Rate (hr/ac)	Times over	Mo.	Power unit cost ($) Direct	Power unit cost ($) Fixed	Equip. cost ($) Direct	Equip. cost ($) Fixed	Allocated labor Hrs.	Allocated labor Cost ($)	Operating or durable input Amt.	Operating or durable input Price ($)	Operating or durable input Cost ($)	Total cost ($)
PLOW				1	Sep										
Moldboard plow	6 bottom	310	0.196			16.16	6.54	1.77	2.66	0.21	2.81				29.94
DISK				1	Sep										
Disk	20	310	0.097			10.26	3.23	0.82	2.04	0.1	1.39				17.74
HARROW & ROLL				1	Sep										
Dixon harrow	21 ft	310	0.076			4.52	2.56	0.21	0.52	0.08	1.10				8.91
+ Roller	21 ft		0.076					0.30	0.75						1.05
PLANT				1	Sep										
Drill	13 ft	140	0.139			4.93	3.50	0.96	1.92	0.15	2.45				13.76
Flax seed	lb											40	0.12	4.80	4.80
16-20-0	ton											0.04	360.00	14.40	14.40
Ammonium sulfate	ton											0.03	220.00	6.60	6.60
FALL HERBICIDE				1	Sep										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Spartan	oz											4	3.56	14.25	14.25
SPRING FERTILIZER				1	Jan										
Fertilizer buggy	80		0.056			1.38	1.02			0.06	0.80				3.20
46-0-0 urea	ton											0.06	410.00	24.60	24.60
SPRAYING				1	Feb										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Select 2EC	oz											5	1.45	7.25	7.25
Curtail	gal											0.0117	40.25	0.47	0.47
Combine	200		0.333	1	Jul	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Jul							2500	0.00	12.50	12.50
Miscellaneous	acre			1	Jul							1	30.00	30.00	30.00
Land rent	each			1	Dec				125.00			1			125.00
Pickup	each			1	Jan				4.07			0.0006			4.07
Application	mile							2.25		0.1	1.60	5			3.85
Totals						56.16	51.76	6.31	136.96	1.16	14.41			114.87	380.47
Interest on operating capital															10.96
Unallocated labor															0
Total specified cost															391.43

[a] Conventional tillage, nonirrigated, mid-Willamette Valley, 2006.

Table A7. Spring safflower:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. Rate (hr/ac)	Times over	Mo.	Power unit cost ($) Direct	Power unit cost ($) Fixed	Equip. cost ($) Direct	Equip. cost ($) Fixed	Allocated labor Hrs.	Allocated labor Cost ($)	Operating or durable input Amt.	Operating or durable input Price ($)	Operating or durable input Cost ($)	Total cost ($)
SPRAYING				1	Nov										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.4
Roundup	gal											0.375	17	6.38	6.38
SPRAYING				1	Mar										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.4
Roundup	gal											0.25	17	4.25	4.25
PLANT & FERTILIZE				1	Apr										
No-till drill	15 ft	130	0.1			3.56	2.48	2.31	5.79	0.11	1.43				15.57
Safflower seed	lb											30	0.7	21	21
46-0-0 urea	ton											0.1	410	41	41
SPRAYING				1	May										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.4
Select 2EC	oz											5	1.45	7.25	7.25
Combine	200		0.333	1	Sep	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Sep							1500	0	7.50	7.5
Miscellaneous	acre			1	Sep							1	30	30	30
Land rent	each			1	Dec				125			1			125
Pickup	each			1	Jan				4.07			0.0006			4.07
Application	mile							2.25		0.1	1.6	5			3.85
Totals						23.59	39.2	4.56	134.86	0.68	7.76			117.38	327.35
Interest on operating capital															8.87
Unallocated labor															0
Total specified cost															336.22

[a] No-till, nonirrigated, mid-Willamette Valley, 2006.

Table A8. Spring sunflower:[a] Estimated per-acre resource use and costs for field operations.

Operation or operating input	Size or unit	Power unit size (hp)	Perf. Rate (hr/ac)	Times over	Mo.	Power unit cost ($)		Equip. cost ($)		Allocated labor		Operating or durable input			Total cost ($)
						Direct	Fixed	Direct	Fixed	Hrs.	Cost ($)	Amt.	Price ($)	Cost ($)	
SPRAYING				1	Nov										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.25	17	4.25	4.25
SPRAYING				1	Apr										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Roundup	gal											0.25	17	4.25	4.25
PLANT & FERTILIZE				1	May										
No-till drill	15 ft	130	0.1			3.56	2.48	2.31	5.79	0.11	1.43				15.57
Sunflower seed	acre											1	15	15	15
16-16-16	ton											0.15	380	57	57
SPRAYING				1	May										
Spray buggy	60		0.026			1.12	1.81			0.02	0.47				3.40
Spartan	oz											5	3.56	17.81	17.81
FERTILIZER				1	Jun										
Spin spreader	50	140	0.023			0.72	0.59	0.10	0.28	0.02	0.41				2.10
46-0-0 urea	ton											0.10	410	41	41
Combine	200		0.333	1	Sep	16.67	31.29			0.38	3.32				51.28
Transport to Portland	lb			1	Sep							2000		10	10
Miscellaneous	acre			1	Sep							1	30	30	30
Land rent	each			1	Dec				125			1			125
Pickup	each			1	Jan				4.07						4.07
Application	mile							2.25		0.10	1.60	5			3.85
Totals						24.22	39.72	4.60	135.79	0.70	8.12			179.31	391.38
Interest on operating capital															9.53
Unallocated labor															0
Total specified cost															400.91

[a] No-till, nonirrigated, mid-Willamette Valley, 2006.

Table A9. Enterprise budget summaries for crops currently grown in the Willamette Valley.

Costs and revenues	Perennial ryegrass,[a] south valley (lb)	Perennial ryegrass,[a] north valley (lb)	Tall fescue (lb)	Annual ryegrass[b] (lb)	Annual ryegrass[c] (lb)	Annual ryegrass[d] (lb)	Winter wheat[b] (bu)
Variable cost ($/acre)	500.69	529.51	434.92	394.99	264.17	333.72	438.53
Fixed cost ($/acre)	278.39	343.23	425.24	221.53	185.09	193.75	300.36
Land rent ($/acre)	150.00	175.00	150.00	90.00	90.00	90.00	150.00
Other ($/acre)	128.39	168.23	275.24	131.53	95.09	103.75	150.36
Total costs ($/acre)	779.08	872.74	860.16	616.52	449.26	527.47	738.89
Yield (lb/acre)	1400.00	1700.00	1400.00	2000.00	1750.00	1850.00	100.00
Product price ($/lb or $/bu)	0.600	0.600	0.450	0.220	0.220	0.220	7.000
Cost ($/unit)	0.556	0.513	0.614	0.308	0.257	0.285	7.389
Total revenue ($/acre)	840.00	1020.00	630.00	440.00	385.00	407.00	700.00
Net revenue ($/acre)	60.92	147.26	- 230.16	- 176.52	- 64.26	- 120.47	- 38.89
Revenue over variable costs ($/acre)	339.31	490.49	195.08	45.01	120.83	73.28	261.47

[a] Bale-and-flail tillage, nonirrigated

[b] Conventional tillage, nonirrigated

[c] Volunteer, nonirrigated

[d] No-till, nonirrigated

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Appendix B. Summary of Current Biodiesel Tax Incentive Programs

Federal tax incentives

Biodiesel and Ethanol (VEETC) Tax Credit / Volumetric "Blender" Tax Credit

The American Jobs Creation Act of 2004 (Public Law 108-357) was extended by the Energy Policy Act of 2005 (§1344) to enable a credit of 51 cents/gallon of ethanol (190 proof or greater), $1/gallon of agribiodiesel, and 50 cents/gallon of waste-grease biodiesel. The credit, based on the percentage of ethanol or biodiesel in the mixture, is provided to blenders certified by the IRS. For example, one receives a credit for agribiodiesel of $1/gallon of B100 or 10 cents/gallon of B10, which contains 10 percent agribiodiesel. The credit expires December 31, 2008.

Small Agribiodiesel Producer Tax Credit

The Energy Policy Act of 2005 (§1345) allows producers of up to 60 million gallons/year to receive a tax credit of 10 cents/gallon of agribiodiesel produced, up to 15 million gallons.

Alternative Fuel Refueling Infrastructure Tax Credit

The Energy Policy Act of 2005 (§1342) provides a tax credit equal to 30 percent of the cost of alternative refueling property, up to $30,000 for business property. Qualifying alternative fuels are natural gas, propane, hydrogen, E85, or biodiesel mixtures of B20 or more. Buyers of residential refueling equipment can get a tax credit for $1,000. Non-taxpaying entities can pass the credit back to the equipment seller. The credit is effective on equipment put into service after December 31, 2005. It expires December 31, 2009.[i]

Rural Renewable Energy Systems and Energy Efficiency Improvements Grants and Guaranteed Loans

In 2005, the USDA. Office of Rural Development made money available for grants and guaranteed loans toward renewable energy systems and energy efficiency improvements in rural areas. Applicants must provide 75 percent of eligible project costs. Eligible projects include biofuels, hydrogen, and energy efficiency improvements, as well as solar, geothermal, and wind.[ii] Grant requests may be from $2,500 to $500,000 for renewable energy systems and $1,500 to $250,000 for energy efficiency improvements. Guaranteed loans may be awarded up to $10 million per borrower. Applications for funds in 2008 are due at various times depending on whether one is applying for a grant, guaranteed loan, or combination package.[iii]

State of Oregon Tax Incentives

Small-scale Energy Loan Program (Oregon Department of Energy)

The Oregon Department of Energy makes low-interest loans for projects that produce energy from renewable resources, that conserve energy resources, or that use recycled materials to create products. Small loans usually take 2 to 3 weeks to approve. Approval of larger loans may take

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2 months or longer. A citizen advisory committee reviews major loans.[iv] This program does not have a sunset date.

Business Energy Tax Credit (House Bill 2211, included in House Bill 3201)

The Business Energy Tax Credit now covers 50 percent of renewable energy systems and has a limit of $20 million (previously, 35 percent and $10 million). The bill applies to projects constructed or installed after January 1, 2007 and before January 1, 2016. It also applies to capital inputs for feedstock production, crushing, and processing toward biofuels. Capital expenses are reimbursed over a 5-year period.

Tax Credit for Producers of Biofuel Raw Materials (House Bill 2210)

This bill encourages the use of biological material (including biofuels and electricity) through a variety of tax credits for producers of plant or animal material used as biofuel or used to produce biofuel, and to collectors of forest products, wood wastes, waste grease, wastewater biosolids, and other organic material used as biofuel or to produce biofuel[v] (applicable January 1, 2007 to January 1, 2013).

- Oilseed crops: 5 cents/pound
- Grain crops: 90 cents/bushel
- Virgin oil or alcohol delivered to and based from Oregon: 10 cents/gallon
- Used cooking oil or waste grease: 10 cents/gallon
- Wastewater biosolids: $10/wet ton
- Woody biomass: $10/green ton
- Yard debris and municipally generated food waste: $5/wet ton
- Animal manure or rendering offal: $5/wet ton.[vi]

Rural Renewable Energy Development Zones (House Bill 2210)

The bill also defines a rural renewable energy development zone wherein certain property tax exemptions are available and extends the zone to include places where biofuels as well as electricity are produced. The amount may not exceed $250 million and applies only to exemptions first claimed for "a tax year that begins after January 1 following the date of adoption of the resolution described in subsection 2 of this section." [vi]

Renewable Fuel Standards (House Bill 2210)

The bill requires biofuel testing—e.g., meeting ASTM D 6751 standards—the final specifications and frequencies of which will be determined by the director of the Oregon Department of Agriculture. It also establishes that when biodiesel fuel production from sources in Oregon, Washington, and Montana reaches at least 5 million gallons per year, all retail, nonretail, and wholesale dealers in the state will be required within 3 months to sell diesel with at least 2 percent biodiesel (or another renewable diesel) by volume. When production reaches 15 million gallons per year, dealers will be required to sell diesel with at least 5 percent biodiesel. Similarly, when ethanol production reaches 40 million gallons/year, all dealers will have to sell gasoline with at least 10 percent ethanol by volume.

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Biofuel Consumer Income Tax Credit (House Bill 2210)

The bill provides a tax credit for consumers who purchase biofuels and biomass solids for fuel. For biodiesel and ethanol–gasoline blended fuels, the tax credit is 50 cents/gallon up to $200 per Oregon-registered motor vehicle per tax year; for solid biofuel (e.g. high-density wood pellets) the tax credit may not exceed $200 per taxpayer in one tax year.[v] The bill also provides a tax credit of 5 cents/gallon of B20 used for heating oil, up to $200/year per taxpayer. The tax credit is applicable from January 1, 2007 to January 1, 2012.

Other Oregon tax incentives

Portland biofuels incentives

The City of Portland mandated a citywide renewable fuels standard (RFS) which requires a minimum of B5 fuel to be sold by fuel marketers to fuel vendors in the city beginning July 1, 2007. After August 15, 2007, all diesel fuel sold by fuel vendors must be B5. After July 1, 2010, a minimum of B10 biodiesel must be sold by fuel marketers and vendors in the city. After November 1, 2007, gasoline sold in the city must be E10. Finally, when the amount of biodiesel from Oregon-based canola, flax, sunflower, safflower, and cooking oil (palm oil is specifically excluded) reaches 2.5 million gallons then 50 percent of the biodiesel used to meet the city's RFS will have to come from these sources.[vii]

Endnotes—Appendix B

[i] U.S. Department of Energy, Energy Efficiency and Renewable Energy (2007). "State & Federal Incentives & Laws, Alternative Fuel Infrastructure Tax Credit." Accessed online August 10, 2007. http://www.eere.energy.gov/afdc/progs/view_ind_fed.cgi?afdc/351/0

[ii] U.S. Department of Energy, Energy Efficiency and Renewable Energy (2007). "State & Federal Incentives & Laws, Renewable Energy Systems and Energy Efficiency Improvements Grant." Accessed online August 10, 2007. http://www.eere.energy.gov/afdc/progs/view_ind_fed.cgi?afdc/327/0

[iii] Office of the Federal Register (2008). Federal Register. Vol. 73, No. 45. Accessed online March 6, 2008. http://www.rccess.gpo.gov/2007/pdf/E7-5198.pdf

[iv] Oregon.gov (2007). "Biomass Energy Home Page Biomass Energy Incentives." Accessed online August 10, 2007. http://www.oregon.gov/ENERGY/RENEW/Biomass/incentive.shtml

[v] Oregon Department of Energy (2007). "House Bill 2210 Enrolled: Biofuels Bill, Section by Section Summary." Accessed online August 10, 2007. http://oregon.gov/ENERGY/docs/HB2210—Biofuels.pdf

[vi] 74th Oregon Legislative Assembly (2007). "House Bill 2210." Accessed online August 10, 2007. http://www.leg.state.or.us/07reg/measpdf/hb2200.dir/hb2210.en.pdf

[vii] Auditor's Office, City of Portland, Oregon (2007). "Chapter 16.60 Motor Vehicle Fuels." Accessed online August 10, 2007. http://www.portlandonline.com/auditor/index.cfm?c=28608

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