Homegrown Fuel

Economic Feasibility of Commercial-Scale Biodiesel Production in Vermont

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Prepared for
Vermont Biofuels Association
Vermont Sustainable Agriculture Council
Vermont Sustainable Jobs Fund

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Introduction

The Feed & Fuel Project was created by the Vermont Biofuels Association and the Vermont Sustainable Jobs Fund in 2006, and has been generously funded by the High Meadows Fund and the Maverick Lloyd Foundation. It is a multi-year effort to determine the economic viability of a farm-derived distributed liquid biofuels, livestock feed, and food-grade oil co-production system in strategically identified locations around Vermont.

The overall intent of the Feed & Fuel Project is to foster locally owned, community- and/or farm-based biofuels and feed/food projects that will generate both revenue and alternative sources of livestock feed for farmers and renewable energy, while helping to create job opportunities, localize energy production, and protect and improve Vermont's natural and social environments.

In its first year, the Project commissioned two research projects. *Homegrown Feed, Food & Fuel: The Market Potential of Farm-Scale Oilseed Crop Products in Vermont* identifies the amount of oilseed crops that could be grown in the state and under what conditions. The report is a synthesis of what farmers and researchers have learned to-date about growing, harvesting, and processing oilseed crops for use as livestock feed and food-grade oil and in the production of biodiesel.

The second report, *Homegrown Fuel: Economic Feasibility of Commerical-Scale Biodiesel Production in Vermont*, explores the feasibility of small-scale biodiesel production, its environmental impacts and the effects of key macro and micro-economic variables on the venture, especially the rising cost of crude oil and livestock feed. This research project also received funding from the Vermont Sustainable Agriculture Council.

Project partners contracted with the **Gund Institute for Ecological Economics at the University of Vermont** to update an earlier biodiesel feasibility study conducted by Dr. Kenneth Mulder. In 2003, Dr. Mulder designed a simulation model to evaluate the economic and environmental effects of small-scale biodiesel production in the state of Vermont, which generated encouraging results. However, in order for the data to continue to be useful to farmers, entrepreneurs and others, it required significant updating to reflect the rapid change in crude oil and grain prices and new oilseed crop production data from New England generated over the last three years. We are grateful for Dr. Mulder's continued involvement in the update of this research, as he donated a considerable amount of time in supervising the research team of Galen Wilkerson and Emily Stebbins and in writing the final analysis.

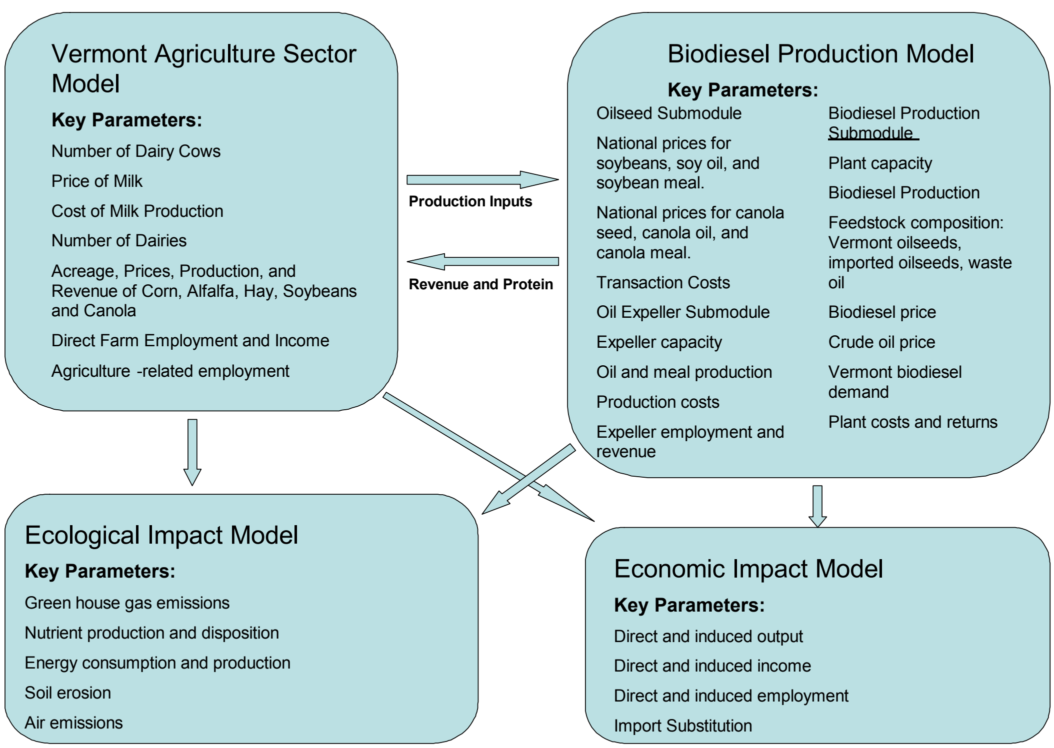
A. Methodology

The Ecological-Economic Simulation Model

The first assessment of the feasibility and impact of a biodiesel facility in the state of Vermont used a dynamic ecological-economic simulation model developed by Dr. Kenneth Mulder at the University of Vermont in 2003. This model was designed expressly to consider the ecological and economic impacts of a biodiesel production facility in the state of Vermont, and to predict the microeconomic feasibility of such a facility. The model was then recalibrated and updated for 2007 as part of this project.

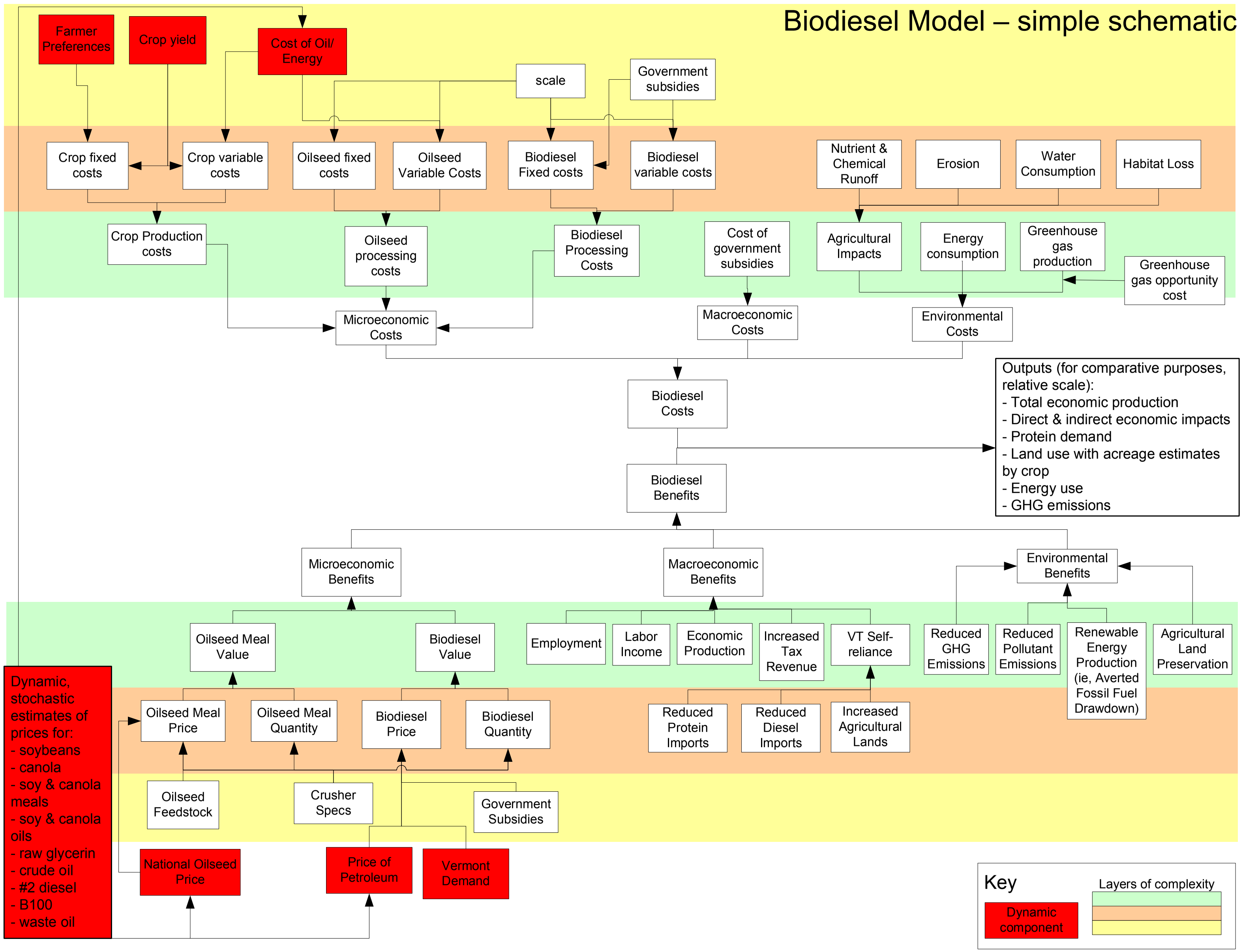
The model is comprised of four primary modules, simulating separate and related components: (1) an econometric model of the Vermont agricultural economy; (2) a biodiesel production module that includes an econometric model of national oilseed markets; (3) an environmental impact model that calculates changes in energy consumption and production and greenhouse gas emissions; and (4) a macroeconomic impact model that uses an input-output framework to estimate changes in direct and indirect employment, production, income, and tax revenues. Figures 1 and 2 give a schematic of the model and show the various levels of variables calculated by the model. Full details of the model's development and calibration can be found at Dr. Mulder's 2004 report, *An Ecological Economic Assessment of a Proposed Biodiesel Industry for the State of Vermont*.[1]

Figure 1. Four Primary Modules of the Ecological-economic Simulation Model



1 Mulder, K.M. 2004. An Ecological Economic Assessment of a Proposed Biodiesel Industry for the State of Vermont. Final report for USDA grant NRCS 68-3A75-3-143, Aim 3.

Figure 2. Major Variables in the Ecological-Economic Simulation Model



Model Modifications

Mulder's original model[2] was modified for this project in several important ways. First, this version of the model uses a private ownership structure, and does not consider a cooperative, farmer-owned business structure, which was included as an option in the original model. This decision was made in order to more accurately reflect all the transaction costs that will be incurred regardless of the ownership structure. Since it is conceivable that a "New Generation" cooperative could trim operating costs through the creative management of member/owner contributions, and pass the savings on to its members through discounts, patronage dividends or other mechanisms, further study of the Co-op option is recommended.

Second, the original work was done in 2003, with the model runs starting in 2002. This version of the model was updated to start in 2006. Third, it was verified that the predictions of the original model were consistent with actual, observed data for the last four years. Finally, the parameters of several key input variables were modified from the original analysis to reflect current trends. For example, based on trends and industry consensus at the time, Mulder did not consider oil prices above $45 a barrel in Y2000 dollars,[3] nor did he consider the possibility that demand for biofuels could shift the market for oilseeds into a new domain marked by significantly higher prices.

Therefore, the following five input variables were modified for the 2007 model update:

► **Crude oil price** – There is much debate about the future price of crude oil. On the one hand, oil depletion scenarios ("Peak Oil"), based on an accounting of known oil reserves, indicate a point of declining global production within 3 to 10 years which, when combined with growing world demand, will result in a new era of sustained high energy prices. Conversely, the Energy Information Agency (EIA) and a number of economists believe that the current high prices for oil will spur increased exploration and recovery efficiency, bringing prices back down to the trend levels of the last two decades. Therefore, the model considers three different levels of crude oil prices to reflect this degree of uncertainty in predicting future energy supplies: (1) a "low-price" case based on EIA forecasts, or $45 per barrel in 2017, (2) a "medium-price" case in which prices rise to $75 per barrel in 2017, and (3) a "high-price" case in which prices rise to $125 per barrel in 2017.

► **Oilseed prices** – There is also some indication that increased crude oil and natural gas prices will continue to raise the cost of fertilizers and fuel. Higher sustained energy costs as well as greater demand for biofuels and meat products could result in significantly higher global prices for oilseeds, such as soybeans and canola. This

2 Full details of the model's development and calibration can be found at Dr. Mulder's 2004 report, "An Ecological Economic Assessment of a Proposed Biodiesel Industry for the State of Vermont." Final report for USDA grant NRCS 68-3A75-3-143, Aim 3. Report available at: www.vermontbiofuels.org

3 All model calculations and outputs are done using Y2000 dollars to account for inflation. All model output should be interpreted accordingly.

model therefore includes two levels for oilseed prices: (1) a "baseline" trend extrapolated from past data, and (2) prices 25% higher than the baseline trend.

► **Plant capacity** – This model considers two different sizes of a biodiesel production facility: 500,000 and 2.5 million gallons of annual capacity. The smaller plant size is more feasible given the potential for oilseed production in the state, whereas the larger plant size provides greater economies of scale, and was first deemed feasible in the 2003 Mulder study.

► **Farmer willingness** – Perhaps the most difficult component of the model to estimate is the degree to which Vermont farmers are willing to plant oilseed crops. As part of his earlier work, Mulder conducted a survey of Vermont dairy farmers in an attempt to estimate an acreage response curve for soybean and canola production in the state.[4] The model uses this response curve to consider three levels of farmer response—best, average, and worst case—with the best and worst cases based on the upper and lower bounds of a 90% confidence interval for the response curve.

► **State subsidies** – Although there is no imminent legislation to enact state-level subsidies for biodiesel production in Vermont, the model includes for the presence of a $0.25/gallon new capacity credit in some scenarios.

Developing the Scenarios

Six scenarios were developed for simulation modeling by combining different levels of the input variables discussed above. The scenarios fall into three categories based on resource (energy, food and feed) availability, and then consider two levels of Vermont response or involvement for each category. The scenarios are described below and summarized in Table 1.

1. Resource Predictability:
Scenario #1 contemplates a world of relative price stability and little change from past trends in energy and food prices. Concerns about peak oil and global warming turn out to be largely unfounded. Productivity increases in agriculture and fossil fuel extraction ensure that supply keeps up with demand. Prices follow historical trends with few spikes or crashes. Oil prices hold steady around $45 a barrel in 2017. Oilseed prices continue to slowly decline in real terms.

<u>Minimum VT involvement</u>:

- A private firm constructs a 500,000-gallon biodiesel plant in Vermont.
- In general, Vermont farmers do not respond to supply the plant with oilseeds, transferring minimal acreage from hay and forage crops to oilseed crops.
- The state does not subsidize biodiesel production.

4 Mulder, 2004, Op. cit.

Maximum VT involvement:

- A private firm constructs a 2,500,000-gallon biodiesel plant in Vermont.
- Vermont farmers transfer modest acreage from hay and forage crops to oilseed crops.
- The state gives the firm a new-capacity credit of $0.25 per gallon of annual production capacity.

2. Resource Constraints:

Scenario #2 considers meaningful but gradual shifts in the global fuel and food economy as energy resources are constrained. Oil prices reach $75 a barrel by 2017. Increasing petroleum prices and rising demand for protein, food, and biofuels raises the price of oilseeds by 25%.

Minimum VT involvement:

- A private firm constructs a 500,000-gallon biodiesel plant in Vermont.
- Vermont farmers transfer modest acreage from hay and forage crops to oilseed crops.
- The state does not subsidize biodiesel production.

Maximum VT involvement:

- A private firm constructs a 2,500,000-gallon biodiesel plant in Vermont.
- Vermont farmers transfer substantial acreage from hay and forage crops to oilseed crops.
- The state gives the firm a new capacity credit of $0.25 per gallon of annual production capacity.

3. Resource Emergency:

Scenario #3 considers significant changes in global energy and food markets due to resource scarcity. Oil prices reach $125 a barrel by 2017. Petroleum scarcity and rising demand for protein, food, and biofuels raises the price of oilseeds by 25%.

Minimum VT involvement:

- A private firm constructs a 500,000-gallon biodiesel plant in Vermont.
- Vermont farmers transfer modest acreage from hay and forage crops to oilseed crops.
- The state does not subsidize biodiesel production.

Maximum VT involvement:

- A private firm constructs a 2,500,000-gallon biodiesel plant in Vermont.
- Vermont farmers transfer substantial acreage from hay and forage crops to oilseed crops.
- The state gives the firm a new capacity credit of $0.25 per gallon of annual production capacity.

Table 1. Scenario Descriptions

	1 – "Resource Predictability"		2 – "Resource Constraints"		3 – "Resource Emergency"	
Variables	Min. VT action	Max. VT action	Min. VT action	Max. VT action	Min. VT action	Max. VT action
Crude oil price	Low – EIA forecast	Low – EIA forecast	Medium- $75/barrel	Medium - $75/barrel	High - $125/barrel	High - $125/barrel
Oilseed prices	Baseline	Baseline	High	High	High	High
Plant capacity (gallons)	500,000	2.5 million	500,000	2.5 million	500,000	2.5 million
Farmer Willingness	Worst case	Average case	Average case	Best case	Average case	Best case
State Subsidies	None	Capacity credit of $0.25/gal	None	Capacity credit of $0.25/gal	None	Capacity credit of $0.25/gal

Scenario Simulations

The model is a stochastic simulation model, meaning that many of the primary variables in the model, such as U.S. commodity prices and crop yields are allowed to vary randomly within a defined range to better simulate real-world market fluctuations and price volatility. Thus, in order to understand the dynamics of each scenario, the model was run 100 times per scenario, with each run of the model yielding predictions from 2006 to 2020. For each year, the average value and standard deviation over all 100 runs was calculated for all variables of interest. This yielded a large amount of data; only the averages and standard deviations for year five (2011) are reported here, for selected variables.

Full results, including averages and standard deviations for 138 variables for all fifteen years, are available for review upon request. Descriptions of all the model variables are given in Appendix A, with the primary variables of interest highlighted.

B. Results

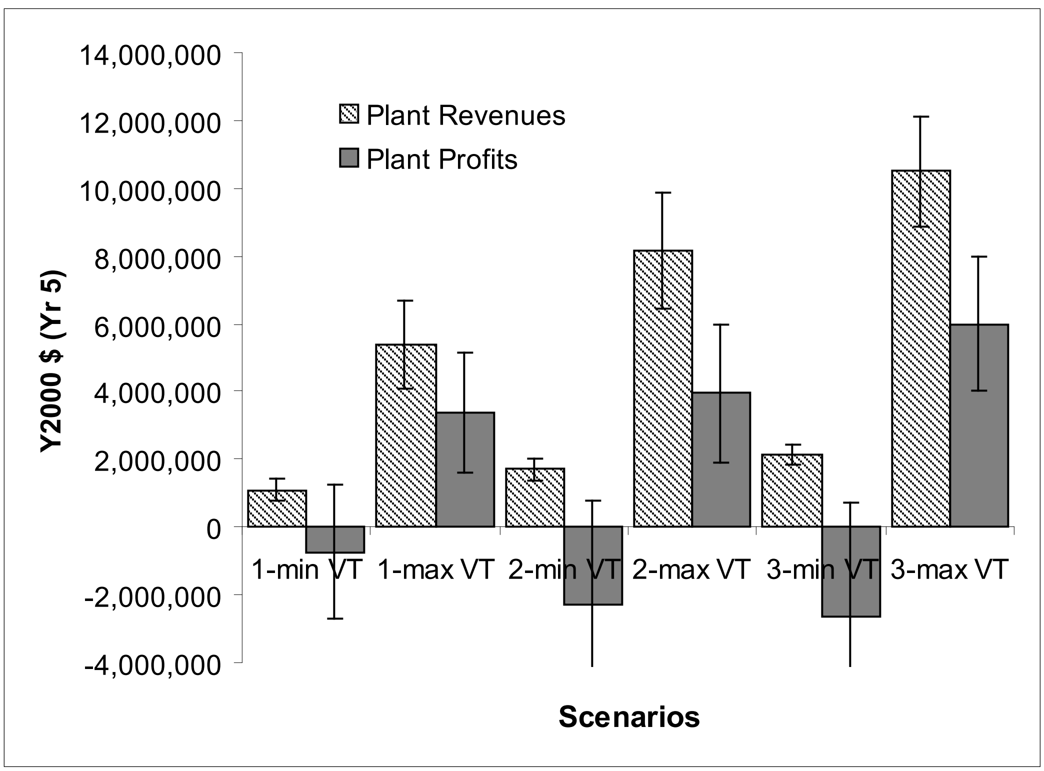
The results under each scenario for key variables of interest are displayed in Figures 3-10. Each figure shows the average value of the variable in year five (2011) for each scenario. All dollar amounts are in year-2000 dollars, and error bars are set equal to one standard deviation. The scenarios are labeled along the horizontal axis, with the number indicating the resource availability, and the min/max indicating the level of Vermont involvement (e.g., "1-min VT" indicates scenario #1, "Resource Predictability," with minimal Vermont involvement).

Microeconomic Feasibility

Profitability
Figure 3 shows that both plant revenues and plant profits are heavily dependent upon the scale of the biodiesel plant, with the 2.5-million gallon plant consistently profitable and the 500,000-gallon plant consistently losing money, although there is some chance a smaller plant will be profitable. The impact of the price of crude oil and oilseeds on plant revenues is also apparent, as revenues increase steadily with the price of oil in scenario #2 and #3. Profits also increase with crude oil price, but not to the same degree, because of the increased cost to the facility for the oilseed feedstock.

The model includes links from the cost of crude oil to the cost of other production inputs, such as fertilizers and transportation. While agricultural inputs and energy costs affect the cost of biodiesel feedstock production, given that biodiesel is a near-substitute for diesel fuel, the price of biodiesel increases proportionally to the price of crude oil (averaging a $.60 - $.90 per gallon premium over diesel fuel at any given time), whereas the costs of production increase only fractionally. *Thus, the model predicts a strong increase in profits with a rise in the price of oil.*

Figure 3. Revenues and Profits of the Biodiesel Facility

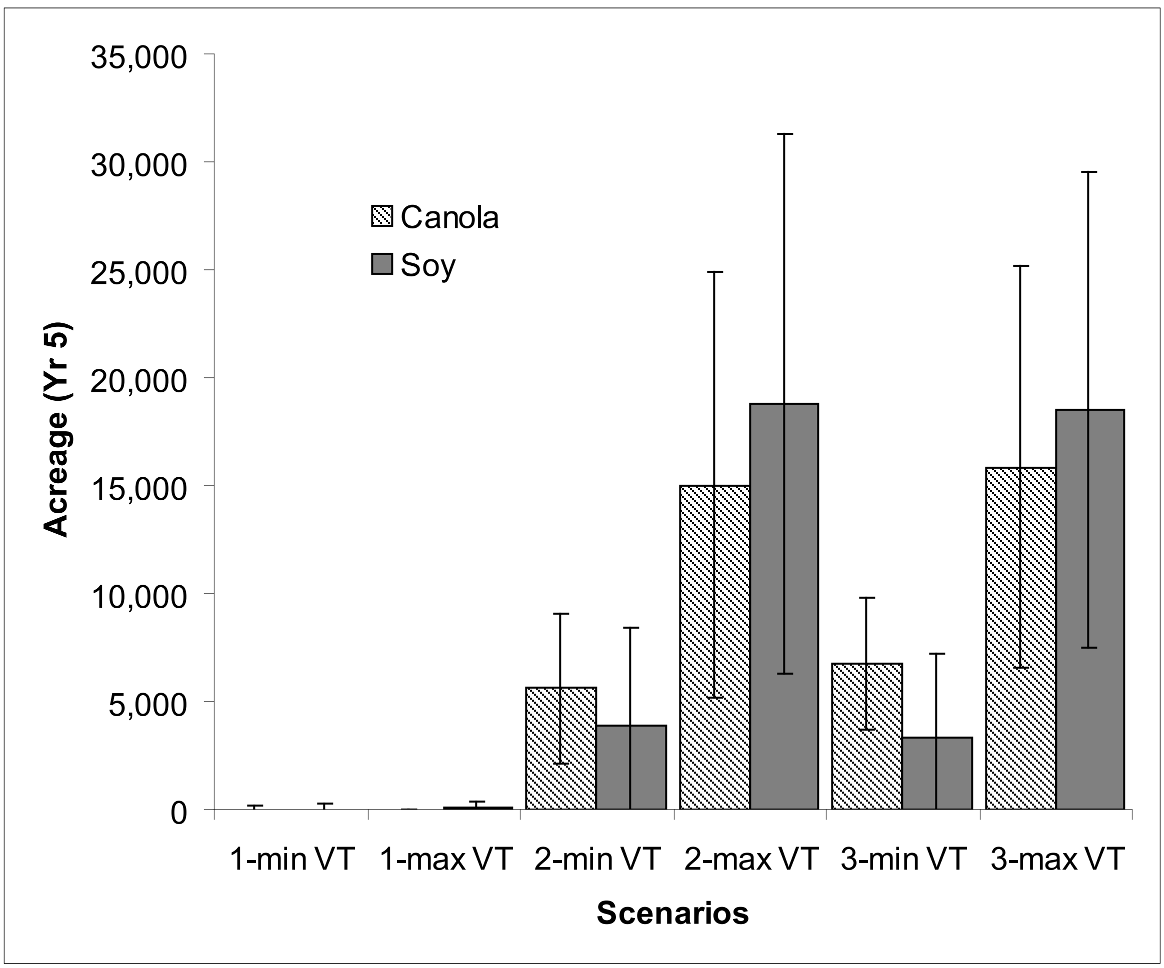


Macroeconomic Impact

Oilseed acres

Figure 4 shows how important the price of oilseeds and the willingness of Vermont farmers to plant oilseed crops are to the impact of biodiesel production on the state's agricultural economy. Under scenario #1, even with an increased willingness on the part of Vermont farmers to grow oilseeds, there is practically no oilseed production in the state. This is because, per the survey results from Mulder's 2003 work, the baseline-projected oilseed prices (at $200 per ton) were not high enough to induce Vermont farmers to plant oilseeds. There is little history of oilseed production in the state, and therefore much of the needed technical knowledge and infrastructure is lacking. Thus, a higher-than-average price level (i.e. $225 per ton and higher in 2003) was needed to induce farmers to produce these crops. Under scenarios #2 and #3, and based on the 2003 Mulder survey, the updated model projects that with the higher prices expected to be paid for oilseeds and biodiesel in 2011, Vermont farmers could be induced to plant up to 35,000 acres of soy and canola.

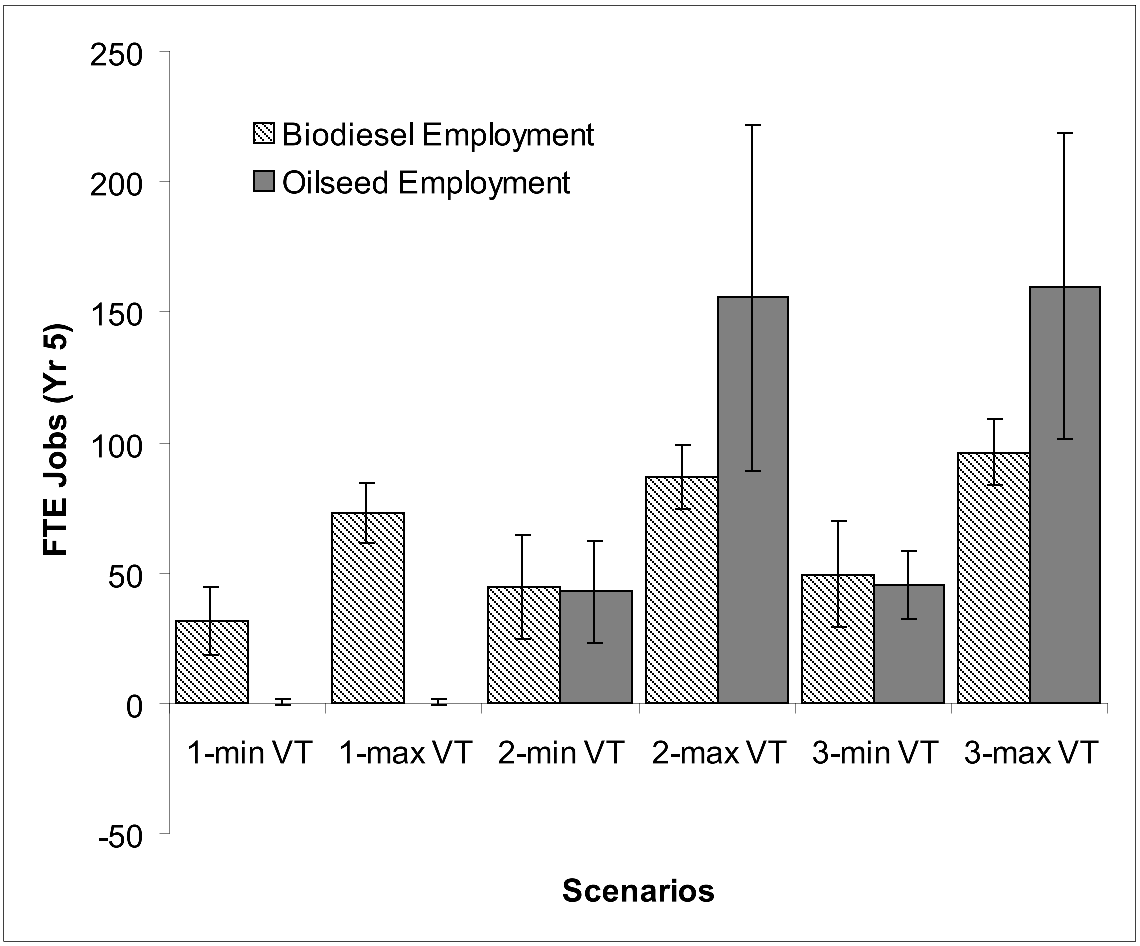
Figure 4. Projected Oilseed Acreage in Vermont



Job creation

The consequences of low farmer involvement can be seen in Figure 5, which shows total employment impacts in the state from oilseed and biodiesel production. Biodiesel production alone is predicted to produce 25 to 100 jobs, whereas high levels of oilseed production in the state, in conjunction with value-added processing, have the potential of tripling the employment impact in 2011.

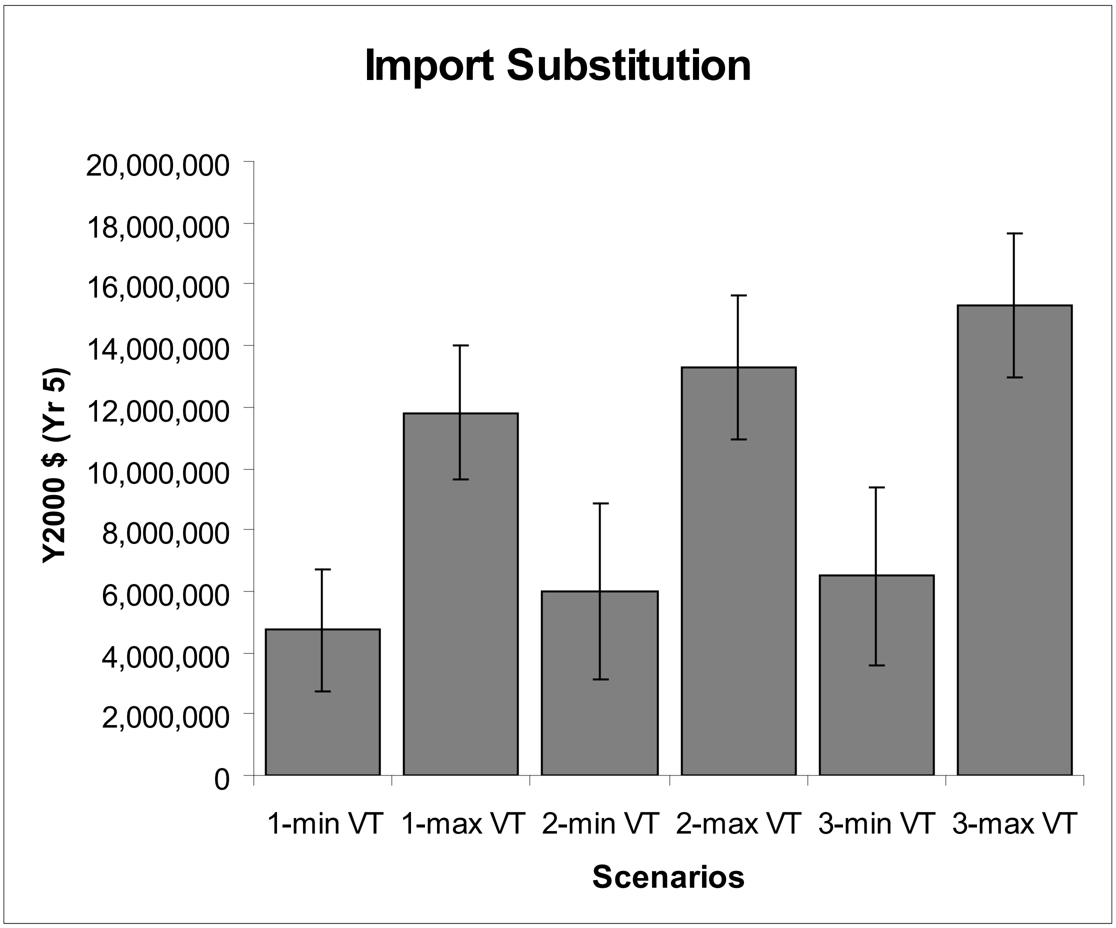
Figure 5. Total Employment Impacts (Direct, Indirect, and Induced) of the Biodiesel and Oilseed Industries in Vermont



Import substitution

As shown in Figure 6, the level of Vermont involvement strongly affects the degree of self-sufficiency the state derives from biodiesel production. Import substitution measures the total value of out-of-state goods that would be replaced by Vermont products under a given scenario. Assuming a maximum level of involvement, the state could replace between $10 and $15 million worth of imports. Such an increase in local production and purchasing would have additional economic and social benefits through a multiplier effect, as shown in Figure 6.

Figure 6. Value of Out-of-state Imports Replaced by In-state Production

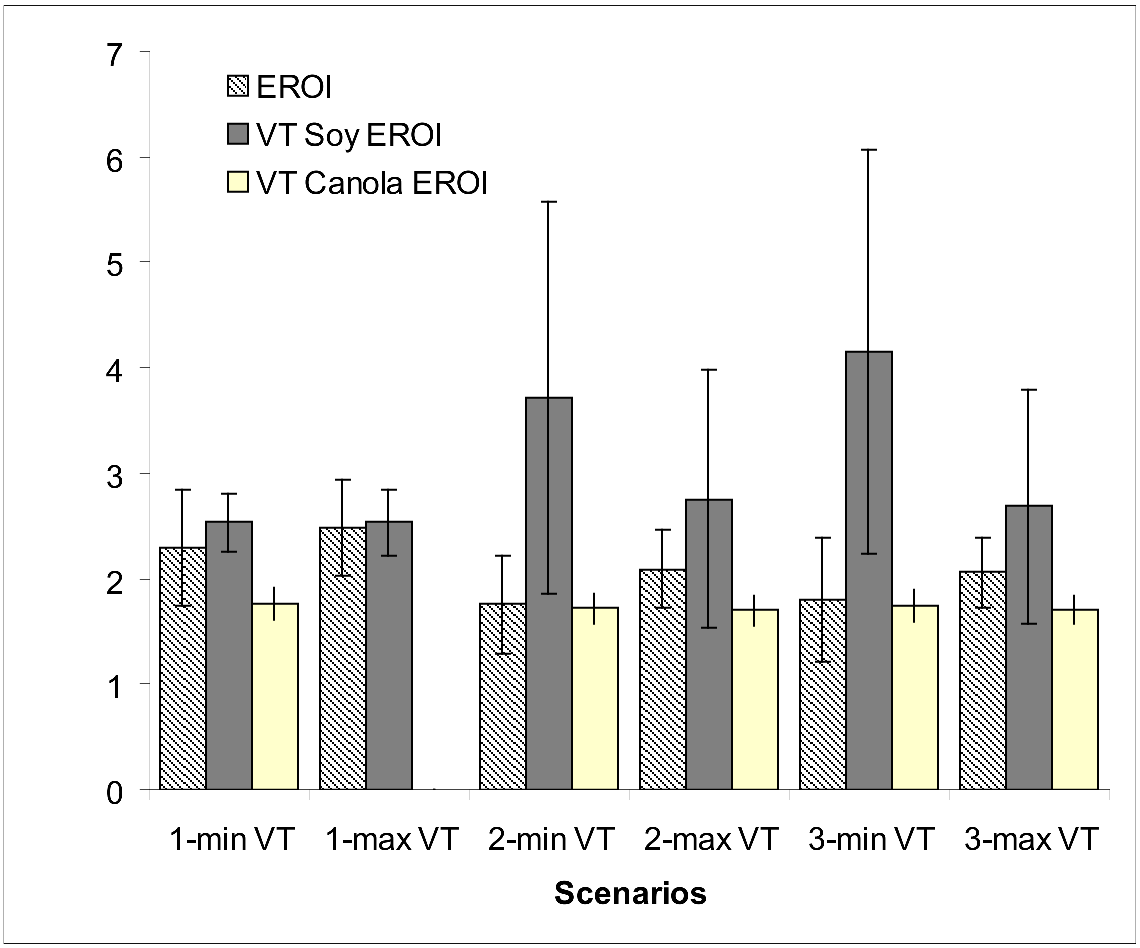


Environmental Impacts

Energy return on energy invested (EROEI)

Figure 7 illustrates that the model was programmed to generate data in order to evaluate the predicted energy return on energy investment (EROEI) for biodiesel production in Vermont. Of note is that the EROEI of soybeans is consistently higher that the EROEI of canola, largely due to the leguminous nature of soybeans and the obviated need for nitrogen fertilizers. The EROEI of Vermont soybeans shows the best energy return across the board, although all measures are well above one-to-one, implying that biodiesel production could yield a significant amount of net energy. Under certain conditions (scenarios #2 and #3), the returns on energy yields are as high as 3:1 and 4:1 respectively.

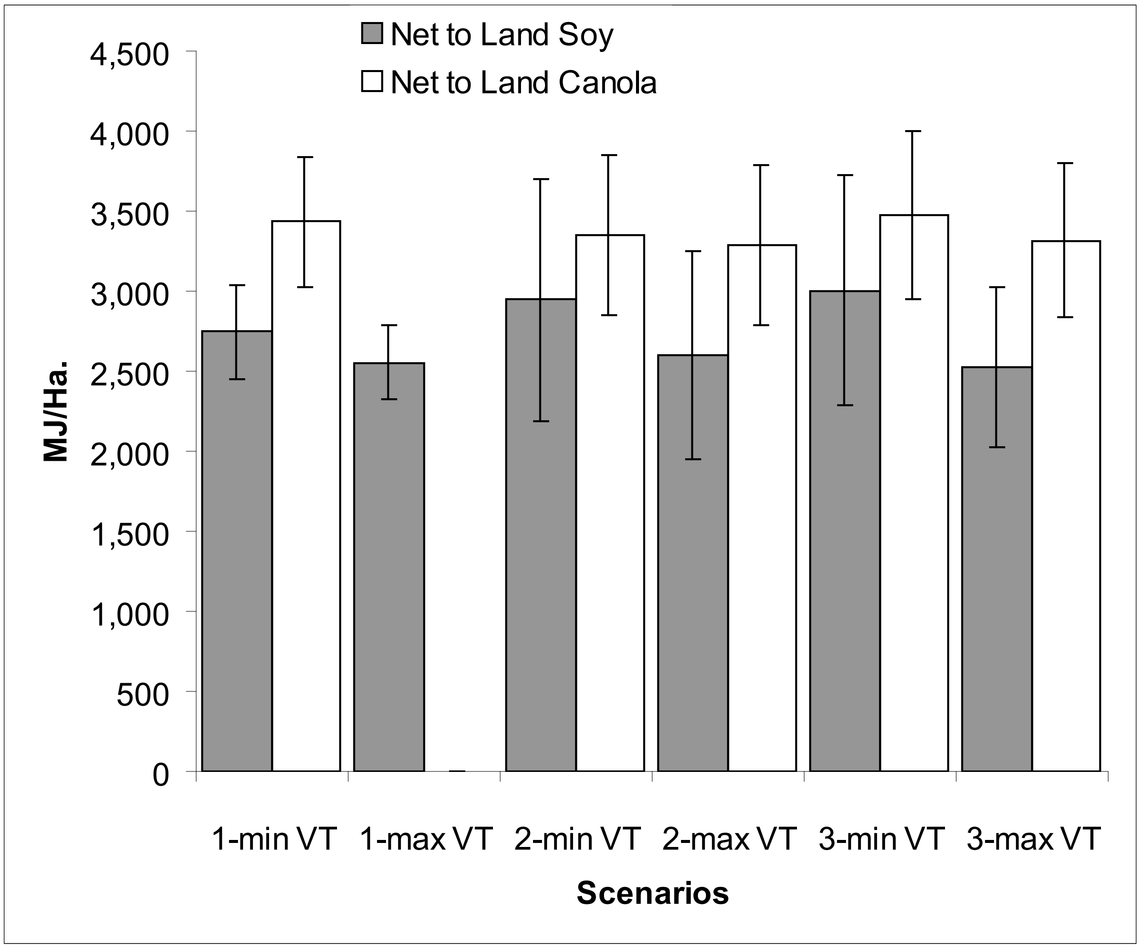
Figure 7. Energy Return on Energy Investment for Biodiesel Production in Vermont



Energy return per acre

Figure 8 displays the net energy produced per unit of land. Interestingly, although canola has a lower EROEI than soybeans, because of its higher oil yield, canola has a higher net energy yield per unit (acre) of land.

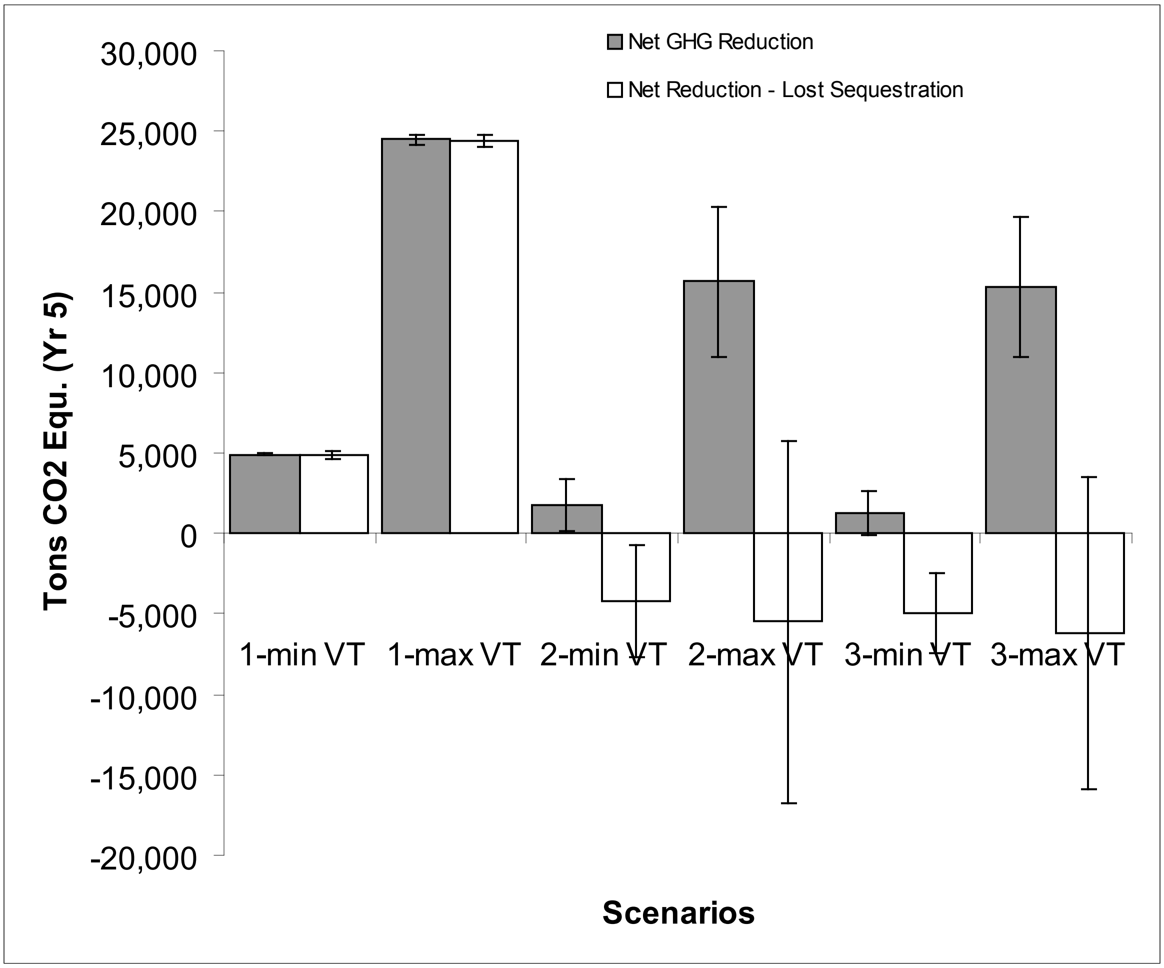
Figure 8. Yield of Net Energy Per Unit of Land



Carbon emissions

As seen in Figure 9, biodiesel production also has a strong potential to reduce Vermont's carbon footprint. This is especially true for the larger plant. The model predicts that a 2.5-million gallon plant can reduce carbon loading by over 15,000 tons a year of CO_2 equivalent. This assumes, however, that land put into oilseed production would have been used for crop production regardless[5]

Figure 9. Reduction in Greenhouse Gas Emissions

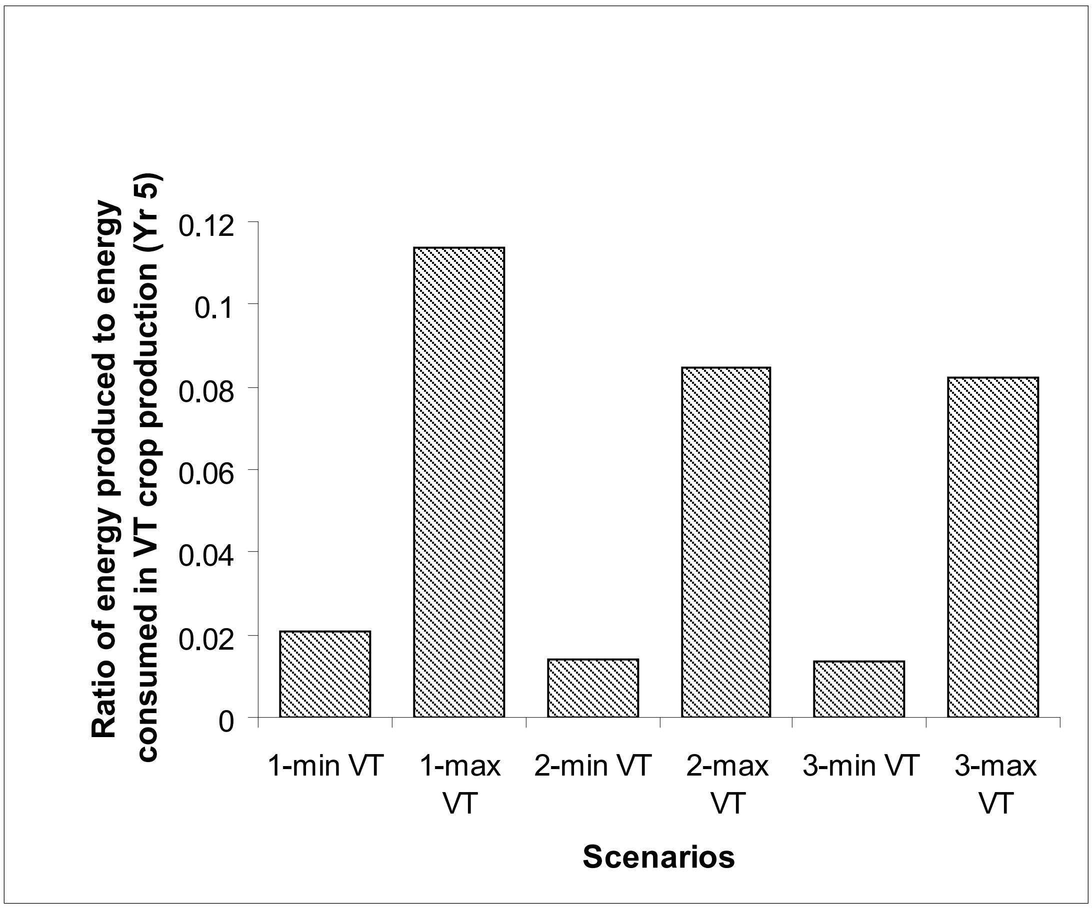


5 In an alternative scenario included in the model, agricultural land was allowed to revert to forest, thereby increasing its carbon sequestration potential. Such a scenario could, for instance, be the result of Climate Change policy, and in this case the model predicts an increase in greenhouse gas emissions.

Oilseed crop value-adding as a portion of total farm energy

Figure 10 illustrates that the highest level of Vermont oilseed production would yield enough net energy to fuel about 10% of total agricultural energy demand, which includes all fuel, electricity and heating. This proportion of net energy return to total energy consumed is at its highest in scenario #1, in which there is a higher level of biodiesel production in the state, relative to oilseed crop production. This ratio decreases under scenarios in which more oilseeds are grown in Vermont, due to the added energy costs of in-state oilseed production.

Figure 10. Ratio of Net Energy Produced to Total Energy Cost of Vermont Crop Production.



Conclusions of the Ecological-Economic Simulation Model

Several conclusions can be drawn based on the results of the simulation modeling of the six scenarios.

► **Economic feasibility of a commercial-scale biodiesel production facility depends heavily on plant capacity.** A 500,000-gallon plant has only a small chance of being profitable, whereas the model consistently predicts that a 2.5-million gallon plant will be profitable under every scenario (i.e., $3 million to $6 million per year, net). In addition, the project researchers suggest that governance models for 'new generation" cooperatives be explored to identify alternative means of distributing capital and operating costs and revenues.

► **Plant revenues, and especially profitability, increase as the price of crude oil rises.** Although a rise in the price of crude oil also causes the price of other inputs—particularly the oilseed feedstock—to rise, the fractional increases in input prices are more than offset by the higher value of the biodiesel product.

► **Vermont farmers will produce oilseed crops only if induced to do so by higher-than-average oilseed prices.** Higher prices are needed in order for farmers to shift to new crops for which technical knowledge and infrastructure is relatively lacking.

► **The greatest potential employment gains can be achieved when Vermont farmers make a strong transition to oilseed crop production**, and the biodiesel plant is able to obtain part of its oilseed feedstock from Vermont sources. Biodiesel production alone is predicted to produce 25 to 100 jobs, whereas high levels of oilseed production in the state have the potential of tripling the employment impact.

► **State involvement in the form of a new-capacity credits or other production incentive is needed** to boost the level of import substitution Vermont can achieve from biodiesel production. Assuming a maximum level of involvement (large plant and capacity credit), the state could replace between $10 and $15 million worth of imports.

► **Biodiesel production under every scenario produces a positive energy return on investment (EROEI).** The EROEI of soybeans is consistently higher that the EROEI of canola, largely due to the leguminous nature of soybeans and the obviated need for nitrogen fertilizers. Canola, however, produces more net energy per unit of land, due to canola's higher oil yield.

► **Biodiesel production has a strong potential to reduce Vermont's carbon footprint**, provided that land is shifted into oilseed production from other crops. The greatest potential greenhouse gas reductions can be achieved with a larger plant; the model predicts that a 2.5-million gallon plant can reduce carbon loading by over 15,000 tons a year of CO_2 equivalent.

► **The model indicates the highest level of Vermont oilseed production would yield enough *net* energy to fuel about 10% of total agricultural energy demand**, which includes all fuel, electricity and heating. When combined with other strategies such as increased energy efficiency and the use of renewables (biomass, wind and solar) in agricultural production, oilseed crops become an important component in reducing Vermont's dependence on fossil fuels and non-renewable energy to power the state's agricultural sector.

Appendix A – List of Model Variables

Key variables of interest are highlighted in yellow.

Variable Name	Description	Units
1. Crop Submodel		
VT Canola Yield	Per acre yield	Tons/acre
VT Canola Production	Total canola production of contracted canola growers	Tons
VT Soy Yield	Per acre yield	Tons/acre
VT Soy Production	Total soy production of contracted soy growers	Tons
Canola Acreage	Acreage planted to canola of contracted growers	Acres
Soy Acreage	Acreage planted to soy of contracted growers	Acres
Canola Revenue	Gross revenue of canola growers contracted with plant.	Y2000$
Soy Revenue	Gross revenue of soy growers contracted with plant.	Y2000$
Soy Net Revenue	Gross revenue minus cash costs	Y2000$
Canola Net Revenue	Gross revenue minus cash costs	Y2000$
Oilseed Revenue	Canola revenue plus soy revenue	Y2000$
Oilseed Value Added	Value added in production of soybeans and canola	Y2000$
Dairy Cows	Number of dairy cows in Vermont	Cows
Real Milk Price	Price of milk	Y2000$/ct.
Milk Production	Milk produced in Vermont	Lbs.
Notes: The model assumes that all oilseed from Vermont purchased for biodiesel was contracted prior to the season. How that contract price is set and how many acres are planted in response to that price are variables that should be inspected by all who want to use the data from this model.		
2. Biodiesel Submodel		
2.A. Oilseed Economics Submodel		
VT Contract Soy Price	Offered contract price by the plant. Currently taken as three year average of national price plus a VT premium.	Y2000$/ton
VT Contract Canola Price	See above.	Y2000$/ton

Variable Name	Description	Units
VT Canola Meal Price	Wholesale value of canola meal from plant.	Y2000$/ton
VT Soy Meal Price	Wholesale value of soybean meal from plant.	Y2000$/ton
National Canola Price	National price.	Y2000$/ton
National Soy Price	National price.	Y2000$/ton
VT Soy Oil Cost	Net cost to the plant of oil from contracted Vermont seed.	Y2000$/gallon
VT Canola Oil Cost	Net cost to the plant of oil from contracted Vermont seed.	Y2000$/gallon
National Canola Oil Cost	Net cost per gallon to the plant of oil from imported seed.	Y2000$/gallon
National Soy Oil Cost	Net cost per gallon to the plant of oil from imported seed.	Y2000$/gallon
National Canola Oil Price	National price.	Y2000$/gallon
National Soy Oil Price	National price.	Y2000$/gallon
Notes: A) Prices for oilseed, oilseed meal, and oil in Vermont and nationally are very important to the costs and revenues of the plant. B) Vermont prices are generally assumed to be national prices plus a transaction cost with the exception of contracted oilseeds.		
2.B. Crusher Submodel		
Tonnage Crushed	Oilseed processed.	Tons
Crusher Oil Production	Oil produced.	Gallons
Soybeans Crushed	Soybeans processed.	Tons
Canola Crushed	Canola processed.	Tons
Soy Meal Production	Soy meal produced.	Tons
Canola Meal Production	Canola meal produced.	Tons
Crusher Protein Production	Protein in oilseed meal.	Tons
Soy Meal Revenue	Gross revenue from sale of soy meal.	Y2000$
Canola Meal Revenue	Gross revenue from sale of canola meal.	Y2000$
Total Crushing Costs	Total costs of operating crusher.	Y2000$
Canola Oil	Canola oil produced.	Gallons
Soy Oil	Soy oil produced.	Gallons
VT Can Meal	Canola meal from VT canola.	Tons
VT Soy Meal	Soybean meal from VT soybeans.	Tons

Variable Name	Description	Units
2.C. Biodiesel Processor Submodel		
Crude Oil Price	Price of crude oil	Y2000$/barrel
National Diesel Price	Wholesale price	Y2000$/gallon
Biodiesel Price	Wholesale price	Y2000$/gallon
Plant Capacity	Annual plant production	Gallon/year
VT Biodiesel Demand	Potential level of BD sales in VT in gallons	Gallon/year
Biodiesel Revenue	Plant revenue from BD sales	Y2000$
Glycerin Revenue	Plant revenue from glycerin sales	Y2000$
Excess Oil Revenue	Plant revenue from sales of excess vegetable oil	Y2000$
Subsidies	Total subsidies from state and fed	Y2000$
Plant Revenue	Total revenue not including subsidies	Y2000$
Raw Oil Demand	Oil requirements of plant	Gallons
Waste Oil Supply	Available supply of waste oil (assumed used)	Gallons
Waste Oil Price	Price of waste oil	Y2000$/gallon
Vegetable Oil Demand	Required vegetable oil inputs for plant to produce at capacity	Gallons
Feedstock Costs	Total costs to plant for oil and methanol	Y2000$
Plant Fixed Costs	Fixed costs assume to be 10% of capital investment	Y2000$
Operating Expenses	Plant annual operating costs.	Y2000$
Total Costs	Total costs per year	Y2000$
Plant Profits	Revenue – costs + subsidies	Y2000$
Notes - All economic calculations are adjusted to Y2000 dollars.		
3. Land Use Submodel		
Total Current Acreage	Acreage in VT currently in cultivation (including hay) or pasture	Acres
Acreage In Cultivation	Acreage currently in cultivation (including hay)	Acres
Available Ag soils	Undeveloped ag soils not currently in production (Rough estimate of land that could be put into production).	Acres
4. Economic Submodel		
4.A. Import Substitution Submodel		
Diesel Replaced	Value of diesel not imported to VT because of BD production.	Y2000$

Variable Name	Description	Units
Import Substitution Revenue	Total value of all goods not imported into VT because of replacement by goods associated with BD production (including the BD).	Y2000$
4.B. Indirect Economic Impact Submodel		
4.B.1. Revenue Submodel		
Total Revenue	Revenue of all ag-related enterprises (dairy, oilseed, and crops).	Y2000$
Crop Revenue	Revenue from crop production including oilseed.	Y2000$
Oilseed Revenue	Revenue from oilseed production.	Y2000$
4.B.2. State and Local Taxes Submodel		
Dairy Taxes	Impact upon state and local taxes of milk production.	Y2000$
Oilseed Taxes	See above.	Y2000$
Crusher Taxes	See above.	Y2000$
Biodiesel Taxes	See above.	Y2000$
Total Taxes	See above.	Y2000$
4.B.3. Direct Labor Income Submodel		
Crusher Labor Income	Wages paid to employees at the oilseed crusher.	Y2000$
Milk Labor Income	See above.	Y2000$
Oilseed Labor Income	See above.	Y2000$
Biodiesel Labor Income	See above.	Y2000$
Direct Labor Income	Sum of the above.	Y2000$
4.C. Total Economic Impact Submodel		
Total Jobs Produced	Direct, indirect and induced jobs produced by the entire system (dairy and biodiesel).	FTE jobs
Total Labor Income	Direct, indirect and induced labor income produced by the entire system (dairy and biodiesel).	Y2000$
Total Output	Direct, indirect and induced economic output of the entire system (dairy and biodiesel).	Y2000$
Total Value Added	Direct, indirect and induced value-added of the entire system (dairy and biodiesel).	Y2000$

Variable Name	Description	Units
Direct Employment	Direct jobs produced by the entire system (dairy and biodiesel).	FTE jobs
Direct Output	Direct economic output of the entire system (dairy and biodiesel).	Y2000$
Direct Value Added	Direct value-added of the entire system (dairy and biodiesel).	Y2000$
4.D. Protein Submodel		
Total Protein Demand	Protein demands of animals associated with the dairy industry.	Tons
In-state Protein Production	Protein produced as oilseed meal on VT acres	Tons
5. Biodiesel Impact Submodel		
Oilseed Labor Income	Total wage impact of oilseed production.	Y2000$
BD Taxes	Total tax impact of BD processor and oilseed crusher.	Y2000$
BD Value Added	Total impact upon state value-added of BD processor and oilseed crusher.	Y2000$
BD Labor Income	Total wage impact of BD processor and oilseed crusher.	Y2000$
BD Output	Total impact upon state economic production of BD processor and oilseed crusher.	Y2000$
BD Employment	Total job impact of BD processor and oilseed crusher.	FTE jobs
Oilseed Employment	Total employment impact of oilseed production.	FTE jobs
Notes - "Total" means direct, indirect, and induced as per the input-output framework.		
6. Environment Submodel		
6.A. Energy Submodel		
Canola Energy	Energy charge for canola production.	MJ
Soy Energy	Energy charge for soy production.	MJ
Milk Energy	Energy charge for dairy production.	MJ
Crusher Energy	Energy charge for oilseed processor.	MJ
Biodiesel Energy	Energy charge for biodiesel processing.	MJ
Crop Energy	Energy charge for crop production (a majority of which goes into milk production).	MJ
Total Energy	System wide energy use.	MJ
Energy Produced	Energy (BD) produced.	MJ

Variable Name	Description	Units
Notes - Total energy is not derived from the sum of the above as there is overlap between the energy in crop production and the energy in milk production.		
6.B. Fertilizer Submodel		
Soy FertN	Nitrogen applied to VT soybeans.	Lbs.
Soy FertP	Phosphorous applied to VT soybeans	Lbs.
Canola FertP	Phosphorous applied to VT canola.	Lbs.
Canola FertN	Nitrogen applied to VT canola.	Lbs.
Annual FertN	System-wide nitrogen applied in VT.	Lbs.
Annual FertP	System-wide phosphorus applied in VT.	Lbs.
6.C. Green House Gas (GHG) Submodel		
Total GHG Emissions	System-wide GHG charge	Tons CO2 equivalent
Vehicle Net Reduction	GHG emissions averted because of diesel replacement.	Tons CO2 equivalent
Sequestration Opportunity Cost	GHG that would be sequestered in VT if all land in current production were allowed to revert to forest.	Tons CO2 equivalent
Net GHG Emissions	Total GHG + Sequ. Opportunity cost – Vehicle Net Reduction	Tons CO2 equivalent
Canola GHG	GHG charge for canola production.	Tons CO2 equivalent
Soy GHG	GHG charge for soy production.	Tons CO2 equivalent
Crusher GHG	GHG charge for oilseed processing.	Tons CO2 equivalent
Biodiesel GHG	GHG charge for BD processing.	Tons CO2 equivalent
BD GHG 1	GHG charge to BD not counting sequestration charge (should be negative due to Vehicle Net Reduction).	Tons CO2 equivalent
BD Sequestration Cost	GHG that would be sequestered if land in oilseed production in VT were allowed to revert to forest.	Tons CO2 equivalent
BD GHG 2	GHG charge to biodiesel counting sequestration cost.	Tons CO2 equivalent
7. Biodiesel Energy Submodel		
Crusher Energy Charge	Life-cycle energy charge for crusher.	MJ
Oil Energy Charge	Life-cycle energy charge for oil inputs not including crusher energy.	MJ

Variable Name	Description	Units
Gross Energy Charge	Gross energy used in oilseed production, crusher and BD processor.	MJ
Total Energy Charge	Fraction of gross energy attributable to BD.	MJ
Net energy Produced	Net energy value of BD production.	MJ
Net to Gross Ratio	Net energy to total energy charge ratio (see report for significance.)	
Energy Return	EROI of BD production.	
Notes - Formulas in this section are complex because of the need to allocate charges between co-products. Portion of oilseed production and processing energy is allocated to oilseed meal and portion of BD processing and oil charge is allocated to the glycerin. - Allocation is by price.		
8. Vermont Biodiesel Energy Submodel		
8.A. Soybean Oil Source		
Net Energy to Land Ratio	Ratio of net energy produced from VT soybeans to the acreage planted	MJ/acre
Total Energy Charge	Energy costs for the BD from VT soybeans	MJ
Energy Produced	Energy produced as BD from VT soy production	MJ
Net Energy Produced	Net energy produced from VT soy production	MJ
Energy Return	EROEI of VT soy biodiesel	
Net to Gross Ratio	Net to Gross ratio of VT soy biodiesel	
8.B. Canola Oil Source		
Total Energy Charge	Energy costs for the BD from VT canola	MJ
Energy Produced	Energy produced as BD from VT canola	MJ
Net Energy Produced	Net energy produced from VT canola production	MJ
Energy Return	EROEI of VT canola BD	
Net to Gross Ratio	Net to Gross ratio of VT canola biodiesel	
Net to Land Ratio	Ratio of net energy produced from VT canola to the acreage planted	MJ/acre