Case Study

Biodiesel in Vermont—the environmental impact and the total cost

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I. Introduction

People in the state of Vermont have expressed a desire to maintain their agricultural lands while minimizing their environmental impact, and producing additional revenue streams. One way that these goals might be achieved is with a local biorefinery producing biofuels and biolubricants to be used as substitutes for or additives to petroleum based transportation fuels, lubricants, and heating oils. Replacing imported petroleum products with locally produced bioproducts is a uniquely broad application of Green Chemistry.

To determine the feasibility of this project and ensure that it meets the expressed goals, we performed both a Total Cost Assessment (TCA) and a Life Cycle Assessment (LCA). These analyses provide the basis for a yes or no decision for construction and operation of a new biorefinery. In addition to meeting the goals of the community, the analysis needed to show that the biorefinery would meet corporate goals of profitability, sustainability, use of economical raw materials, and safe and environmentally sound processes and practices.

The venture would use locally produced seed crops, virgin, or waste cooking oils as the feedstock for the biorefinery. A by-product of vegetable oil production by local farmers will be the local production of oil seed meal—currently purchased from out-of-state to feed local dairy cattle. This production was not taken into account in either the LCA or the TCA analysis.

II. Overview of the decision options

We looked at a number of options that might meet the community goals, including a cheese production facility and a cellulosic ethanol facility. However, to simplify the analysis, we decided to limit our options to building the biorefinery or not building it. We then added the option of creating a cooperative structure for control over feedstock costs. We later also performed a TCA of the cellulosic ethanol facility. Details of that analysis are outside of this study.

III. Goal and scope of the analysis

Goal Definition

The goal of this study was to prepare a cradle-to-gate Life Cycle Assessment and a complete gate-to-gate Total Cost Assessment for a project to produce methyl ester fuels and lubricants to be used as substitutes for or additives to petroleum based fuels, lubricants and heating oils. The Total Cost Assessment was used in conjunction with the Life Cycle Analysis as information for a yes or no decision for a new venture for construction and operation of a new facility. We compared the environmental impacts of the bio-based products with the use of existing petroleum-based products. The plant will be built in accordance with federal, state and local codes and regulations and use best available technology to minimize workers' exposure to hazardous materials and minimize environmental impacts in the plant and in the community. A key goal for this venture is the use of locally based raw materials such as vegetable oils and used cooking oils, to benefit the local agricultural community. It is hoped that the venture will encourage farmers to produce oil seed crops to yield vegetable oils as raw materials. A by-product to the farmers who grow the oil seed crops and crush the seeds will be the production of oil seed meal that the dairy based farmers can use as feed meal for their cattle, which is currently purchased by the farm community from out of state. Seed crushing facilities (currently not available in the state) will need to be built by the farm community to process the oil seeds. However the farm and seed crushing portion is not a part of either the LCA or the TCA analysis.

Up to half of the feedstock in the project will come from "yellow grease" or used cooking oil. The remainder, up to 100%, will be virgin oil from oil seed crops. Two alternatives are being investigated: in the first, the virgin oil will be purchased on the open market and be subject to market pricing. In the second option, the farmers will participate on a co-op basis, providing the virgin seed oil at a fixed cost representing the farmers' cost to produce the oil.

Scoping

The scope of the Total Cost Assessment is a plant to produce approximately 2.5 million gallons of methyl esters as ASTM grade on-road diesel fuels, heating oils and lubricants annually. A bi-product of this venture is the production of technical grade 97+ percent pure glycerin, which is produced in the transesterification reaction and which is purified in the facility. Products will shipped in bulk rail and truck container wagons.

In keeping with corporate goals, the facility may be built on existing brownfields. Because the remediation containment costs, permitting, and risks resulting from a brownfields site will vary from site to site, these costs have been omitted from the current TCA. The choice of site could easily form its own TCA.

Design and construction of the biodiesel facility is scheduled to begin in 2005, with production starting 18 months later.

IV. Methodologies and Tools

Life Cycle Assessment

Methodology

LCA is used for assessing the environmental aspects associated with a product over its life cycle. This is a relatively young technique that became popular in the early 1990s[1]. LCA adopts a holistic approach by analyzing the entire life cycle of the product. This encompasses:

- extraction and processing of raw materials
- manufacturing, transportation and distribution
- use/reuse/maintenance
- recycling and composting
- final disposition

As our basis for analysis, we looked at two well-known LCA studies of biodiesel: the National Renewable Energy Laboratories (NREL) publication "An Overview of Biodiesel and Petroleum Diesel Life Cycles" for soy-based production of biodiesel and the Berlin-based Institute for Energy and Environmental Research (IFEU) "Life Cycle Assessment of Biodiesel: Update and New Aspects", which we used as an indicator for the canola biodiesel scenario. Unfortunately, both of these studies used virgin oil, while the planned facility will use a mix of used and virgin oil. We assume that the results can only be more positive for the mixture.

Total Cost Assessment

Introduction to Total Cost Assessment

The Total Cost Assessment Methodology was developed by the American Institute of Chemical Engineers (AIChE) to help its member companies take uncertain environmental and health costs into account in their decision-making process. The methodology itself was developed by a team of chemical and pharmaceutical manufacturers, including Dow Chemical, Merck, and Monsanto. Through their efforts, the methodology was refined so that it would be useful for both EHS professionals and financial professionals within their organizations. The methodology deals with both internal costs (those borne by the company) and external costs (those borne by society), allowing decision-makers to use both aspects as appropriate.

TCA Cost Categories

Traditional decision-making typically focuses on direct and indirect costs that appear on the balance sheet. The TCA model defines three additional cost types, contingent liabilities and internal and external intangibles. Table 1 gives examples of each cost type.

[1] "Life Cycle Assessment Data quality: a conceptual Framework", SETAC/SETAC Foundation, 1994;

While contingent liabilities and internal intangibles (Type III and IV costs) are not typically accounted for on a balance sheet, they are very real costs to a company. External intangibles (Type V) are not direct costs to the company, but it is helpful to include this category, as often the analysis of this category will influence the analysis of Type III and IV costs. One of the most important methodologies in TCA enables companies to estimate Type III, IV, and V costs. This methodology is consistent with sound business decision-making processes yet allows incorporation of variables that do not directly impact the manufacturing process.

Table 1: Environmental, Health, and Safety Cost Types in TCA Model

Cost Type	***Description***	***Examples***
I. Direct costs (recurring and non-recurring)	Manufacturing site costs	Capital investment, operating and maintenance costs, labor, raw materials, and waste disposal costs
II. Indirect costs (recurring and non-recurring)	Corporate and manufacturing overhead costs; costs not directly allocated to product or process.	Reporting costs, regulatory costs, and monitoring costs
III. Future and contingent liability costs	Potential fines, penalties and future liabilities	Fines and penalties caused by noncompliance; clean-up, personal injury, and property damage lawsuits; natural resource damages; industrial accident costs.
IV. Intangible internal costs (Company-paid)	Difficult-to-measure but real costs borne by the company	Cost to promote consumer acceptance; maintaining customer loyalty, worker morale, worker wellness, union relations, corporate image, and community relations.
V. Intangible External costs (Not directly paid by company)	Costs borne by society	Effect of operations on housing costs, degradation of habitat, effect of pollution on human health

Implementation

The methodology includes six steps, using a team approach.

1. *Goal Definition and Scoping.* In the first step of the process, the team agrees upon the options or alternatives to be assessed. The assessment may be across two existing processes or products; it may be between an old way of doing things and a new way of doing them; or it may be between two possible new ways of doing things. The assessment, however, does not need to be limited to two options. The team also agrees upon the purpose of the TCA analysis and the goals of the project result. In nearly all cases there will be corporate, division, or site goals to consider. In addition, the group may wish to consider sustainability, environmental and health goals, and social impacts.

2. *Streamline the Analysis.* In this second phase of the process, the team places limits on the goal and scope to reduce ambiguity about the results. The team may decide to focus on a subset of the lifecycle: gate to gate for example, instead of cradle to grave. Where data gathering may expand the project beyond reasonable expectations, the group may decide to use more accessible data from a similar process as good approximation. The team may decide to focus on a certain set of goals. Some goals may be so important that they can be assigned a "go-no go" limit.
3. *Identify Potential Risks.* In this phase of the analysis, the team identifies the risk scenarios associated with each of the alternatives. Identifying the sources of uncertainty makes it easier to assign an uncertainty to the scenario. The team then identifies the cost drivers (e.g. compliance obligations and remediation costs) for each scenario.
   This phase can be the most difficult in the evaluation, as the team is asked to put costs and probabilities on situations they have not had to evaluate in the past. The team leader or facilitator must guide the discussion away from unusable answers: "I have no idea!" to workable boundaries, such as "the probability is less than 10%." For each Type III, IV, or V cost the group must agree upon probability, frequency of occurrence, and timing of occurrence where relevant data are available.
4. *Conduct Financial Inventory.* In this step, the team assigns a value to each cost in all five categories. Type I and II costs would be the same costs used in a traditional cost comparison. For the remaining costs, the team reviews the risks identified in Step 3 and assigns costs or a range of costs to each cost driver. The methodology provides some guidance with regard to costs; from historical data where available and provides guidelines where historical data is not available. The team then reviews the costs to determine which are the most significant, and assess how that information can best be incorporated into the decision-making process.
5. *Conduct Impact Assessment.* Once all the costs are available, the data is entered into spreadsheets and/or into the automated software program TCAce and the results can be calculated. It is important that the team document all assumptions and results for each scenario and cost decision, especially for important potential impacts that are not currently feasible to cost. The team may choose to do a sensitivity analysis or simply change some assumptions and reassess the results. This step is especially beneficial for costs whose probability is not known with any certainty. Refining and rerunning the calculations gives the team an understanding of the robustness or weakness of the results.
6. *Feedback to Decision Loop.* In this step the results are fed into the decision-making process.

To perform this analysis, we began with the manual spreadsheets provided with the AIChE Total Cost Assessment Methodology Manual. The data from the spreadsheets was then entered into the software tool TCAce provided by Sylvatica. During this process it was discovered that while the different tools were helpful, they did not link to each other, and they did not guide the user through the methodology.

V. Detailed description of the decision options and scenarios

TCA of the Biorefinery

In this assessment we looked at three alternatives: do nothing, build the biorefinery, and build the refinery as a cooperative with local farmers.

Option 0. Do Nothing

The alternative to building the biorefinery is to do nothing. This option carries no costs.

Option 1. Build Biorefinery with purchased virgin seed oil

This option carries the risk of market-based pricing for the virgin seed oil.

Option 2. Build Biorefinery as a cooperative with oil seed farmers

This option allows for more control over feedstock cost, but requires profit-sharing with the farmers. The costs of profit-sharing are not included in this model.

Costs associated with capital and operations

The following are the basic costs associated with building and operating the biorefinery in either Option 1 or Option 2.

Type I and II costs

Total project capital costs (does not include permitting costs): The costs are estimated between $4 million and $6.12 million, with a most likely cost of $5 million. We can model this as a triangular distribution in TCAce with the following calculation: Triangular(4M, 5M, 6.12M). These costs have a 100% probability, and will be spread over the first 18 months. They are a capital investment with a 20-year straightline depreciation. The capital expenditures are expected to have a scrap value of between $50k and $500k if the project closes.

The operational costs, not including feedstock are estimated at $1,194,000 annually, with a 100% probability, beginning in the last half of the second year. These costs include workers compensation costs of $10/$100 annual salary, or $46,000 annually.

Feedstock costs are more complex and vary depending upon the option chosen.

Option 1: The feedstock will come from yellow grease (up to 50%) and virgin oil. Yellow grease pricing runs between $0.15 and $0.20 per pound. Virgin oil has averaged $0.20 per pound over the last decade or so, but has gone as high as $0.40 per pound for a week or less approximately every 5 years. Because the $0.40 spikes constitute less than 0.4% of the time, they have been ignored and the average price of $.20 per pound has been used. Feedstock costs are annual, beginning halfway into the second year of the project.

Option 2: As in Option 1, the feedstock will come from yellow grease (up to 50%) and virgin oil. Yellow grease pricing runs between $0.15 and $0.20 per pound. The virgin oil will be procured from cooperative farmers at a fixed price of $0.09 per pound.

Feedstock costs are annual, beginning halfway into the second year of the project.

Licensing and Reporting:

The legal costs for initial permitting are estimated at 200 hours at $200/hour, first year of project only ($40k first year). In addition there will be annual legal costs of about 60 hours/year at $200/hour ($12k each year). Actual permitting costs include the Vermont ACT 250, which is estimated at $1950 prior to construction and miscellaneous compliance obligations at $5k per year.

Hazardous Substance Handling:

Methanol is the only hazardous substance expected to be used in the facility. Methanol storage and handling costs are included in the capital and operational costs. OSHA training required for employees handling the methanol constitute an additional cost. OSHA 1910 training is estimated at $680/person for a total of 10 operational employees, or a one time first year cost of $6800.

Testing:

The biodiesel will need to be tested to ensure conformance with ASTM Standards. Testing costs range from once per year at $2816, twice per year at 2534.40 each time, to twelve times per year at 1971.20 each time. 100% probability, triangular distribution with a min at $2816, max at $23,654, with $5069 most likely.[2]

Revenues

TCAce works on a cost basis and currently has no input section for benefits and revenues. In order to present a fair presentation of the biorefinery, we have included revenues as negative costs. Revenues for bulk biodiesel fuel are represented as a lognormal distribution with a median at $1.50/gallon for 1.25 million gallons and a standard deviation of 1.5. Revenues for bulk biolubricants are included at $3/gallon for 1.25 million gallons and revenues for glycerine are included at $0.60 per pound for 817,000 pounds of glycerine per year. Revenues begin halfway through the second year.

[2] Testing costs have been provided by Intertek Caleb Brett in a quotation dated June 8, 2004, attached.

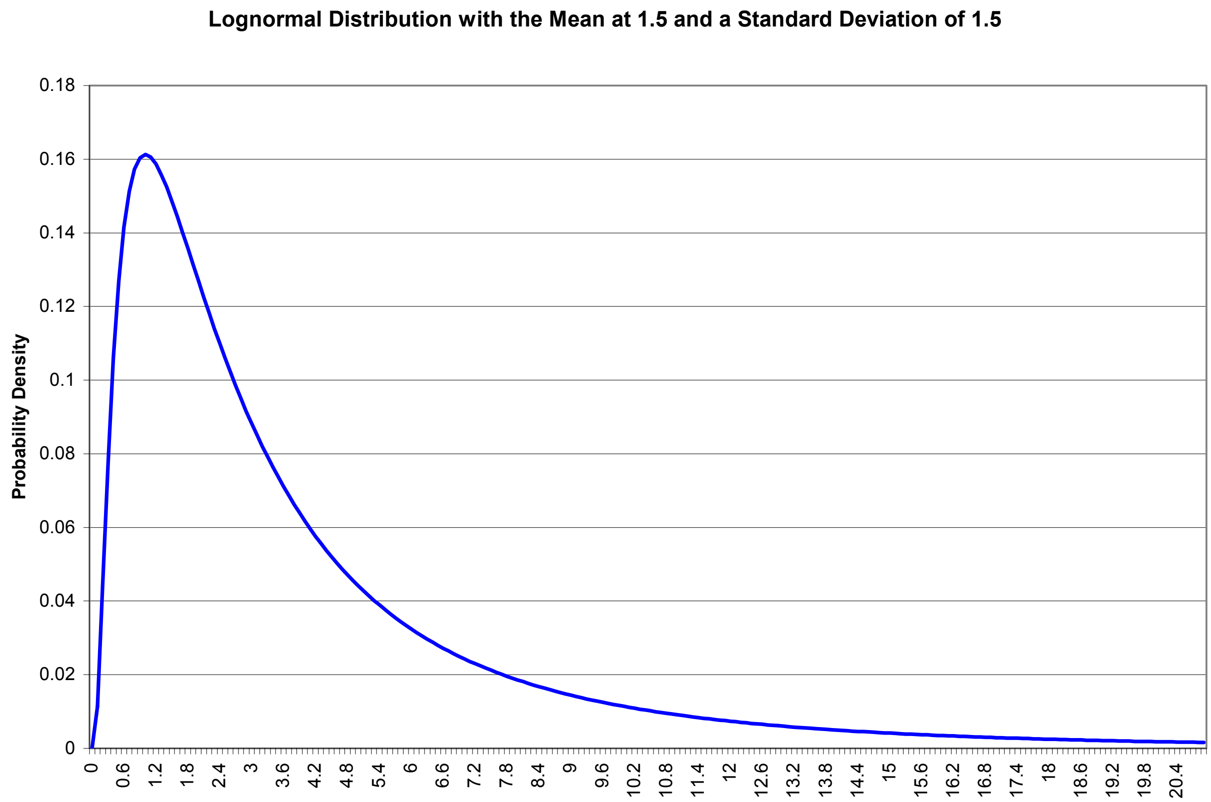

Figure 1: A lognormal distribution with the mean at 1.5 and a standard deviation of 1.5.

Scenario Costs

There are different risks associated with both biorefinery options. These risk carry associated costs. The power of TCAce allows both the risks and the costs to be modeled with complex probability curves.

Scenario 1: Delay due to permitting or other regulatory requirements

Applies to both option 1 and option 2.
In the first scenario, the plant is delayed due to permitting or regulatory requirements. The delay may last up to a year. The most likely scenario is a 6 month delay. During the delay period, the facility will have one management person working to reduce the delay. The salary costs for this person comprise the entire cost of the delay.
Probability of occurrence: 50% in the first year only
Cost range: Triangular distribution with a minimum at 0, maximum at $100k, and most likely scenario at $50k (equivalent to 6 months salary).

Scenario 2: Methanol discharge to air

Applies to both option 1 and option 2.
In the second scenario, the methanol recirculation system or the methanol recovery system develops a leak. The methanol circulates from a storage tank into the reactor and

any methanol not directly used in the reaction is drawn through a ventilation system into a condenser where it is condensed and returned to the storage tank. A second system draws unreacted methanol off the biodiesel and returns it to the storage tank. If either of these systems developed a leak, some methanol would discharge into the air. This scenario has as much as a 10% probability of occurrence each year. Fines associated with a methanol discharge to air could be as high as $25k, but most likely would not be levied due to the low impact of methanol in the air. Moral, on the other hand, could be affected by the discharge (10% probability) with a cost of $5k. Moral may be affected as long as 3 years after the incident. Because operator error might be a factor in this type of discharge, turnover is likely, at a 50% probability (should the scenario occur) and costs of $5k. Turnover may also be a factor up to 3 years after the incident.
Probability of occurrence: 10% each year, beginning in the second year.
Fines: $0-25k
Morale: $4-$6k , 10% prob.
Turnover: $4-$6k , 50% prob

Scenario 3: Massive Methanol discharge to land

Applies to both option 1 and option 2.
A massive methanol discharge to land is unlikely (0.5% probability) because it would require rupture of the methanol tank and the concrete containment system. A lightening strike or terrorist attack might cause this dual failure. The maximum amount of methanol stored on the premise at one time is 24,000 gals, and the assumption is that this entire amount would spill. Much of it would evaporate into the air, where it would cause little impact. The most damaging part of this scenario is that the methanol would seep into ground water, at which point there would be toxic implications.

A methanol discharge to the land and water might result in fines as high as $500k[3]. There is also a high likelihood (80%) that regulators would increase their scrutiny of the facility, resulting in additional costs of up to $2k per year for the year of the discharge and the following 5 years (at 80% probability per year). There is a 10% chance that investor relationships would suffer, with up to $2k cost. Investor relationships may suffer for a total of 6 years. In addition, community relationships might suffer with a 5% probability and up to $1k cost. Community relations may suffer as long as 5 years. Similar to the air discharge, there is a 10% probability of morale problems at a $4-6k cost and a 50% probability of turn-over with a $4-6k cost.

Type V costs to society would be $10k for a ground only release, with an additional cost of $10k for a ground and water release.
Probability 0.5% probability annually, beginning in the second year.
Also to water 20%
Fines: $0-100k for land only, 0-$500k additional if to water also
Regulators: $0 to $2k, with $1k most likely, 10% probability
Investor relationships: $0 to $2k, with $1k most likely, 10% probability
Community: $0-$1k, 50% probability

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3 From the spreadsheets “Industrial risk.xls” and “Judicial Penalties.xls”. These data were gathered as part of the initial AIChE TCA project.

Morale: $4-$6k , 10% prob.
Turnover: $4-$6k , 50% prob
External pollutant costs:
To land: $10k
To ground water $10k

Scenario 4: Employee exposure

Applies to both option 1 and option 2.
The fourth scenario involves an accident where an employee is exposed to methanol. Methanol exposure could result in blindness or fatality. The TCA manual offers an average cost of injury at $26,000 with the average cost of death valued at $790,000. It also gives injury rates in chemical and allied industries at 5.5 per 1000 workers, or 5.5% for 10 workers. An accident will likely lead to morale problems and turnover. There is a 10% probability that an accident will be seen negatively by the community, resulting in higher community relations costs.
Probability of occurrence: 5.5% each year, beginning in the second year.
Liability: $0k-$790,000 with a peak at $26,000 for a single year only.
Morale: $4-$6k , 10% prob.
Turnover: $4-$6k , 50% prob
Community: $0-$1k, 50% probability

Scenario 5: Improper disposal by subcontractor

Applies to both option 1 and option 2.
There is a possibility that wastes from the site will be mishandled by a subcontractor, resulting in liabilities to the refinery. There is a small (1%) probability of improper disposal with a potential liability as high as $100k. Improper disposal by a subcontractor may result in reduced relations with the community and increased scrutiny by regulators.

Probability of occurrence: 1% each year, beginning in the second year.
Liability: $100k
Community: $1k, 10% probability
Regulators: $0 to $2k, with $1k most likely, 10% probability

Scenario 6: Plant Contamination:

Applies to both option 1 and option 2.
Plant contamination is a higher likelihood scenario because it involves failure of only one level of containment. Contamination could occur as many as 5 times per year, with a 1% probability each time. At this time, the probability has been simplified to 3% once per year. Clean up costs could range as high as $100k. Plant contamination could cause reduced morale, higher turnover, community relations issues, and reduced investor/lender confidence.
Probability: Simplified to 3% each year (1%, 5 times per year) beginning in the second year.
Clean up: $100k
Morale: $4-$6k , 10% probability
Turnover: $4-$6k , 50% probability

Community: $0-$1k, 50% probability
Investor relationships: $0 to $2k, with $1k most likely, 10% probability

Scenario 7: Union negotiations
Applies to both option 1 and option 2.
As in any manufacturing business, there is a possibility that employees will want to organize. There is a 30% probability that this will occur each year, and that the negotiation costs will be as high as $10k.
Probability: 30% each year beginning in the second year.
Negotiation costs: $10k

Scenario 8: Product does not meet test criteria
Applies to both option 1 and option 2.
The refinery will test in house on a daily basis, so there is little likelihood (1% per year) that the product will fail. If it failed the failed product could either be sold for non-ASTM uses, such as for off-road or heating oil, or would be recycled through the plant to bring it up to standard. The maximum cost would be a loss of revenue of about $.50 per gallon for a day's worth of production (7000 gallons) or $3500.
Probability: 1% each year, beginning in the second year.
Cost: $3500 per occurrence

VI. Results interpretation

Life Cycle Assessment

As our basis for analysis, we looked at two well-known LCA studies of biodiesel: the National Renewable Energy Laboratories (NREL) publication "An Overview of Biodiesel and Petroleum Diesel Life Cycles" for soy-based production of biodiesel and the Berlin-based Institute for Energy and Environmental Research (IFEU) "Life Cycle Assessment of Biodiesel: Update and New Aspects", which we used as an indicator for the canola biodiesel scenario.

The life cycle of biodiesel from virgin canola oil shows a 78% reduction in greenhouse gas production over the life cycle of petroleum-based diesel, or 18 fewer pounds of CO_2 per gallon of fuel consumed. If we look at soy-based biodiesel, it requires slightly more energy to produce than petroleum diesel: 0.23 MJ required /MJ produced for biodiesel, 0.20 MJ required /MJ produced for petroleum diesel. It also leverages fossil fuels, providing 3.2 MJ per MJ of fossil fuel used.

The life cycles of both canola based and soy based biodiesel reduce production of particles, CO, and SOx by reducing the levels at the tailpipe. The absolute reduction amount varies by vehicle, since some vehicles combust at higher temperatures, changing the emissions. NOx is higher for biodiesel, as are total hydrocarbons. The total hydrocarbon emissions, however, are in the field—tailpipe emissions are actually lower; so they may not be as damaging.

Water use is significantly higher for biodiesel, while emissions to water are lower.

We found these results to be essentially positive, and feel that the added benefit of recycled cooking oil could only make this project less impacting.

Total Cost Assessment Results

Calculations using TCAce can be done two different ways. The first uses the probability times the average value. The second uses a Monte Carlo analysis to produce sample results for a selected sample size. In this case, we used a sample size of 1000 to ensure we captured the effect of very low probability but high cost events, such as a massive methanol discharge to land.

Table 2 shows the expected value of the scenario costs with the discount rate set to zero. The expected value is simply the probability times the cost. We can see that while some costs are quite low, they are not zero (with the exception of those that do not apply to this scenario. This is due to the simplified method of calculation.

Table 2: Expected value of costs for standard biodiesel case. Discount rate set to zero.

Option	**Build Biorefinery**							
Year	**2,005**	**2,006**	**2,007**	**2,008**	**2,009**	**2,010**	**2,011**	**2,012**
Costs								
Capital and Building Costs	3.377M	1,663,000	0	0	0	0	0	0
Operation	0	597,000	1,194,000	1,194,000	1,194,000	1,194,000	1,194,000	1,194,000
Feedstock	0	930,100	1,860,000	1,860,000	1,860,000	1,860,000	1,861,000	1,861,000
Feedstock in Coop scenario	0	0	0	0	0	0	0	0
License and Permits	58,950	17,000	17,000	17,000	17,000	17,000	17,000	17,000
Methanol handling training costs	6,800	0	0	0	0	0	0	0
Testing costs	0	5,257	10,510	10,510	10,510	10,510	10,510	10,510
Bulk BioDiesel Revenues	0	- 1,018,000	- 2,035,000	- 2,035,000	- 2,035,000	- 2,035,000	- 2,035,000	- 2,035,000
Bulk BioLubricant Revenues	0	- 1,875,000	- 3,750,000	- 3,750,000	- 3,750,000	- 3,750,000	- 3,750,000	- 3,750,000
Glycerine Revenues	0	-245,100	-490,200	-490,200	-490,200	-490,200	-490,200	-490,200
Facility idle cost	25,000	0	0	0	0	0	0	0
Fines and penalties for discharge to air	0	625	1,250	1,250	1,250	1,250	1,250	1,250
Fines and penalties for discharge to land and	0	625	1,250	1,250	1,250	1,250	1,250	1,250

Option	Build Biorefinery							
Year	**2,005**	**2,006**	**2,007**	**2,008**	**2,009**	**2,010**	**2,011**	**2,012**
water								
Fines and penalties for employee exposure	0	7,205	14,410	14,410	14,410	14,410	14,410	14,410
Fines and penalties for improper disposal	0	250	500	500	500	500	500	500
Fines and penalties for plant contamination	0	467	934	934	934	934	934	934
Regulator scrutiny	0	0	1	1	2	2	3	3
Investor relationship problems	0	2	7	12	16	21	25	29
Community scrutiny	0	1	3	6	8	11	13	16
Lost morale	0	47	142	239	287	287	287	287
Turn over	0	94	285	476	571	571	571	571
Clean up	0	1,000	2,000	2,000	2,000	2,000	2,000	2,000
Union negotiations	0	150	3,105	5,100	5,100	5,100	5,100	5,100
One day product value-reduction	0	18	35	35	35	35	35	35

Table 3 shows the median costs after running the simulation 1000 times in a Monte Carlo Analysis. Note that many of the costs are zero, because the probability of occurrence is very low.

Table 3: Median costs calculated using Monte Carlo simulation. Note that most scenario costs are expected to be zero. Discount rate is set to zero.

Option	Build Biorefinery							
Year	**2,005**	**2,006**	**2,007**	**2,008**	**2,009**	**2,010**	**2,011**	**2,012**
Costs								
Capital and Building Costs	3,370,000	1,660,000	0	0	0	0	0	0
Operation	0	597,000	1,194,000	1,194,000	1,194,000	1,194,000	1,194,000	1,194,000
Feedstock	0	938,700	1,876,000	1,876,000	1,879,000	1,876,000	1,875,000	1,875,000
Feedstock in Coop scenario	0	0	0	0	0	0	0	0
License and Permits	58,950	17,000	17,000	17,000	17,000	17,000	17,000	17,000
Methanol	6,800	0	0	0	0	0	0	0

handling training costs								
Testing costs	0	4,870	9,740	9,740	9,740	9,740	9,740	9,740
Bulk BioDiesel Revenues	0	-937,500	- 1,875,000	- 1,875,000	- 1,875,000	- 1,875,000	- 1,875,000	- 1,875,000
Bulk BioLubricant Revenues	0	- 1,875,000	- 3,750,000	- 3,750,000	- 3,750,000	- 3,750,000	- 3,750,000	- 3,750,000
Glycerine Revenues	0	-245,100	-490,200	-490,200	-490,200	-490,200	-490,200	-490,200
Facility idle cost	1,369	0	0	0	0	0	0	0
Fines and penalties for discharge to air	0	0	0	0	0	0	0	0
Fines and penalties for discharge to land and water	0	0	0	0	0	0	0	0
Fines and penalties for employee exposure	0	0	0	0	0	0	0	0
Fines and penalties for improper disposal	0	0	0	0	0	0	0	0
Fines and penalties for plant contamination	0	0	0	0	0	0	0	0
Regulator scrutiny	0	0	0	0	0	0	0	0
Investor relationship problems	0	0	0	0	0	0	0	0
Community scrutiny	0	0	0	0	0	0	0	0
Lost morale	0	0	0	0	0	0	0	0
Turn over	0	0	0	0	0	0	0	0
Clean up	0	0	0	0	0	0	0	0
Union negotiations	0	0	0	7,000	7,000	7,000	7,000	7,000
One day product value-reduction	0	0	0	0	0	0	0	0

If we look at the net present value (NPV) calculated using the expected values, we see a favorable return on investment. Figure 2 shows the NPV with the value calculated through the year given. With positive results as early as 2007, the return on investment should be rapid.

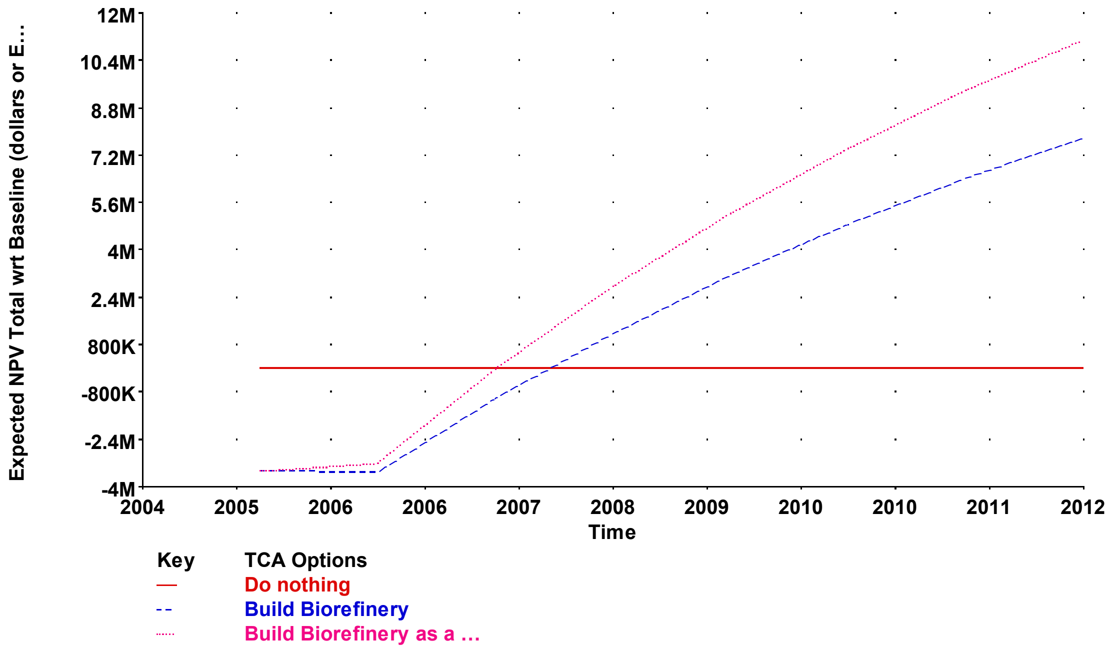

Figure 2: In both biorefinery options, the NPV calculated through 2008 is positive, showing rapid return on investment. Discount rate is set to 0.12.

If we look, however, at all possible scenarios, we find that if things go wrong, the return will not be as high as that shown in Figure 2. Figure 3 shows probable NPV for the first biorefinery option based on the simulation. The bottom line represents 5% of the 1000 simulations. Since 95% of the results are better than this line, we see that there is a high probability for success. If we look at the top line, we see that the return has the possibility to be much higher.

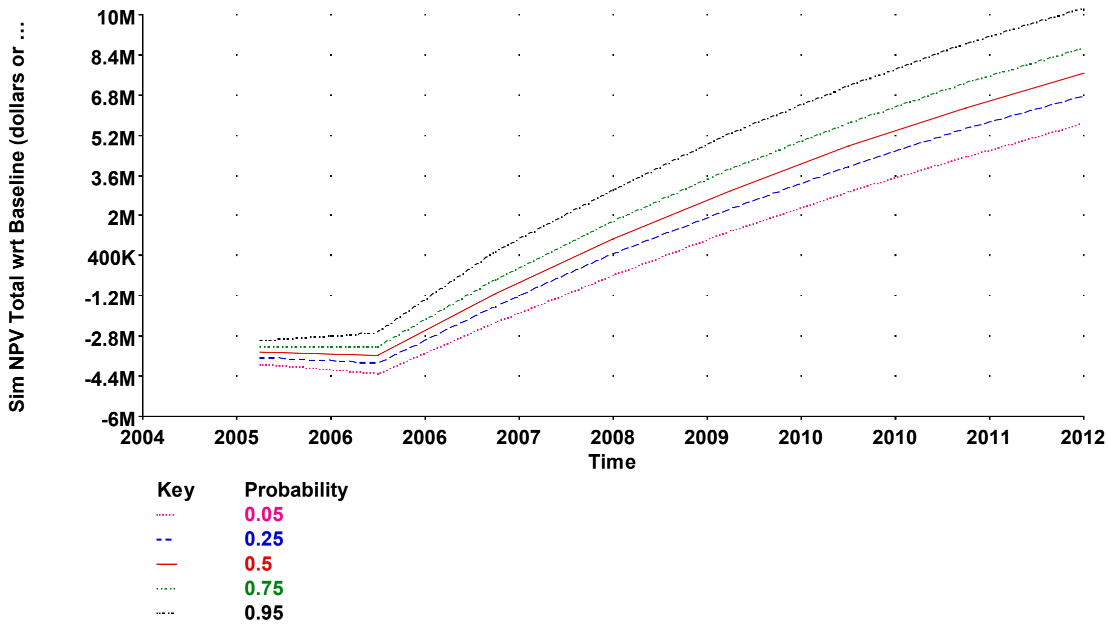

Figure 3: Simulated NPV for the first biorefinery option shows that there is a 95% probability that the NPV will be positive when calculated through about 2009. Discount rate is set to 0.12.

The same results for the Cooperative situation show even better results, based on the lower feedstock prices.

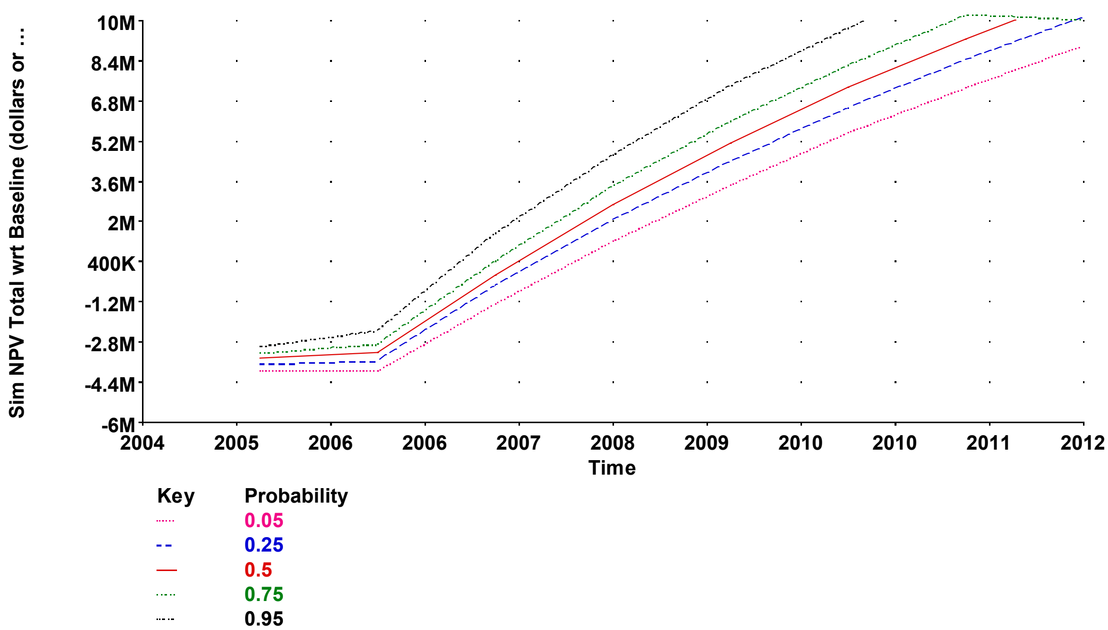

Figure 4: The simulated NPV for the cooperative situation shows a high potential for excellent results.

It is interesting that the most variability in these projections comes from variability in feedstock cost and biodiesel revenues. Very little variability is induced by Type III and IV costs.

Looking at the Type V costs, we found that local use of biodiesel in place of petroleum-based diesel would result in savings to society between $100 and $350 million dollars per year. This savings would come from the reduction in green house gases, human health effects, and ecotoxicity (for example) from burning biodiesel, evaluated in 1996 dollars. The higher savings would be achieved unless there was a massive methanol discharge, which would increase the societal impacts.

The TCA supported the decision to build the facility, as the risks involved in biodiesel production are relatively low

VII. The decision

While both the LCA and the TCA results met the goals of both the community and the corporation, no decision has yet been made regarding the building of the biorefinery. In addition to these options, the company is also looking at building a cellulosic ethanol facility. In addition to LCA and TCA, the company has other tools and considerations to examine before making its final decision.

VIII. Next steps (determining whether the process worked and how it could be made better)

The two analyses helped to confirm the understanding that this facility could be a good way to meet community and corporate goals. The LCA showed that the use of locally produced biodeisel would, in fact, lower the environmental impacts to the community when compared with imported petroleum products. The process of conducting the TCA helped us to identify, quantify, and understand the risks to both company and to society from the building of the biorefinery. It also helped us better understand how critical feedstock costs would be to the profitability of the facility.

The analysis pointed out several areas that could be improved. First, the manual spreadsheets provided with the Total Cost Assessment Methodology Manual pointed to the concept of scenarios, but did not use or build on this concept as described in the manual. TCAce, on the other hand, is based on the scenario concept, making it difficult to enter the data from the manual spreadsheets into the software tool.

A second limitation with TCAce is the calculation of taxes. TCAce assumes that the company is paying taxes, thus a more costly project reduces the taxes paid, increasing the NPV. In this case, the company will not pay taxes until it begins making a profit. Therefore, instead of using the tax function in TCAce, we entered the taxes as a fixed cost. In the future, there may need to be a more complex tax calculation that identifies a point above which taxes must be paid.

IX. Conclusion

The Life Cycle Assessment and Total Cost Assessment analyses of this project provided a good basis for understanding both the environmental improvement that could be made by pursuing the project and the costs and risks associated with it. The methods also identified areas of sensitivity that must be recognized and controlled in order to ensure both environmental performance and profitability. These two methods proved, therefore, to be valuable in the decision-making process, however, are only a few of the methods that need to be used when making a decision of this magnitude. While there were some limitations to the TCA tools, we were able to find a work-around for all of them.