Technical Note

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The potential impact of VG Energy's lipid oxidation inhibitors on the economics of algal biofuels

Prepared for VG Energy

VG Energy has recently announced that it has been able to translate a research discovery related to cancer treatment into a potential breakthrough for biofuels made from algae. Laboratory experiments show that molecules which can disrupt the burning of fats (lipids) in tumor cells can also encourage microscopic plant cells like algae to accumulate and even secrete fats. These fats can be used to produce diesel and jet fuel substitutes for traditional petroleum fuels. This note summarizes a preliminary analysis aimed at understanding the potential for exploiting these findings in commercial technology. The scenarios evaluated include:

- Enhanced production of higher value oils such as omega-3-fatty acids in open pond algae systems
- Enhanced production of fats for oil produced as a feedstock for biofuels in open pond algae systems
- Scenarios that take advantage of observed oil secretion in VG-treated algae to permit non-destructive recovery of oil and recycle of algae to ponds.

The enhanced production scenarios are compared with scenarios based on literature values for currently achievable productivity levels of algal open pond systems. The results show that VG Energy's discovery could transform algae technology from being a negative rate of return proposition to being an attractive and profitable venture. There are many caveats that go with such a statement. The preliminary nature of this analysis, which has a wide margin of error associated with it, and the uncertainty of how these early lab results will translate into practical process schemes are chief among them. Furthermore, while the high price of nutritional markets makes them an attractive near term target for the technology, it is important to bear in mind that any new technologies will face stiff competition from existing commercial producers. It is in the fuel markets that VG Energy's technology show the promise to compete with crude oil in today's market.

Caveats

Any one considering this analysis should understand that it is preliminary and subject to significant error. The available performance data is simply too thin at this point to give this estimate more than an order-of-

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magnitude precision. That said, it signals a green light to move forward. Among the things I have not accounted for in this analysis is the value of recycling algae.

Evaluating the economics of algal oil

The basics of an open pond algal oil production system are shown in Figure 1. Algae are grown in shallow ponds in which an aqueous suspension of algae circulates in a raceway pattern to maintain mixing and turnover of algae at the surface to improve access to sunlight for photosynthesis. CO₂ from a waste source such as a power plant or ethanol plant is sparged into each pond. Nitrogen, phosphate, potassium and iron are added to support growth. Growth rates are measured in grams of algae per day per square meter, with typical values ranging 10 to 20.



Figure 1: The US Department of Energy's concept of algae for biofuels

The algae can accumulate large amounts of carbohydrates (sugars and starches), lipids (fats) or protein depending on the species and the condition under which they are grown. Of particular interest to energy technologists is the ability to achieve high levels of lipid content in these fast growing simple plants. The combination of rapid growth and oil production makes algae technology potentially more productive than even the fastest growing oil crops in the world such as oil palm.

This analysis only considers open pond systems. They represent the lowest cost and simplest design of an algae production system. Many companies are currently working on new so-called photobioreactor systems. These designs may change the economic landscape for algae given the extent to which they can lead to improved light capture, better control of (and therefore independence from regional) climate conditions, and increased concentration of algal biomass. The obvious trade-off for such systems is cost. Even the simplest step toward enclosing algae production systems (plastic covers or greenhouse type enclosures) dramatically increase the capital cost of the system.

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Table 1 summarizes other key inputs and assumptions in the analysis. The analysis is based on a process engineering model developed in the form of an Excel® spreadsheet several years ago. The model incorporates two downstream process options. In the first option (shown in Figure 2), a conventional hexane extraction is used to recover the oil. This is an energy intensive process that requires two stages of water removal followed by drying of the algal biomass prior to extraction. Dried biomass from extraction is assumed to have value as a fertilizer coproduct. Note that CO_2 is not free. It is assumed to cost \$80 per metric ton.

Item	Assumption	Comment
Financial parameters	 10% rate of return on investment (after inflation) 10 year depreciation 20 year plant life time 40% tax rate 	This model starts with the minimum rate of return on capital that is required and then calculates the associated minimum selling price for oil. All parameters are adjustable by the user.
Pond design	Open pond raceways per Benneman (1996) and Weissman (1987)	The costs of these ponds is roughly \$20,000 per hectare. This is an aggressive assumption—costs could be higher.
CO ₂ source	CO ₂ is recovered CO ₂ from a power plant	The cost of CO_2 delivered to the facility is assumed to be \$80 per metric ton of CO_2 . This is an adjustable user input.
Process options	 Conventional hexane extraction versus a novel three phase centrifugal extraction (per Benemann 1996 report) Centrifugal extraction uses anaerobic digester. Methane from the digester is used to generate electricity and nutrient rich effluent is recycled to the ponds. Optional recycle of biomass from the centrifugal extractor back to the ponds. 	Benemann (1996) introduced a centrifugal extractor based on technology used at a commercial Beta carotene facility for recovery of oil without the need for drying or hexane. In this case, the wet solids and aqueous stream from the centrifugal extractor are sent to a digester producing methane (burned for electricity) and a recycle stream with recovered nutrients. VG Energy's early observations are that the cells actually secrete the neutral lipids. This allows for the possibility of recycling live biomass back to the production ponds/bioreactors.

Table 1. Key	process assumptions
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Figure 2. Case 1 conventional hexane extraction and drying for oil and fertilizer coproduct recovery

The second option (shown in Figure 3) is a much lower cost and lower energy alternative that uses a three phase centrifugal extractor to directly remove the oil from a wet paste of algal biomass. Such an approach has been used in a commercial process for recovering neutraceutical grade beta carotene from open pond algae systems. It's use for high yield recovery of total neutral lipids from algae has not been demonstrated. Thus, this second option represents an unproven but plausible scenario. Liquids and biomass from the extractor in this second option are sent to an anaerobic digester, which produces methane used for heat and power production. It also generates a CO₂ stream and a liquid effluent containing some of the nutrients (nitrogen, phosphate and potassium), both of which can be recycled to the growth ponds and used to reduce total nutrient supply costs.

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Figure 3. Cases 2 and 3 based on centrifugal extractor for oil/water/biomass separation with and without recycle of algae to growth ponds

Table 2 summarizes performance assumptions for the base case (literature value) scenario and the VG Energy improved performance assumptions. These values come from an earlier analysis by Professor James Richardson at Texas A&M, who derived them from discussions with Dr. Karen Newell at VG Energy.

Table 2. Algae performance assumptions

Parameter	Base case	VG improved case
Total lipid content (% dry weight of algae)	40%	40%
Lipid product expression	13% of total lipid	39% of total lipid
Algal biomass productivity (g/ sq m/day)	10	60
Cost of VG Energy process chemical additive	\$0.037 per gallon of oil	\$0.037 per gallon of oil
Market targets for lipid products	High value oils at \$10 to 4 Neutral lipids competing w barrel.	0 per gallon. ith crude oil at \$90 per

Lipid products recovered from the algae fall into two market categories: High value oil products such as omega-3-fatty acids for use in food products and generic triglycerides (neutral lipids) that can be used as a feedstock for biofuels production. The high value oils could range in value from \$10 to \$40 per gallon. Neutral lipids for biofuels production must be competitive with current crude oil prices, which would be around \$2.14 per gallon (\$90 per barrel).

Findings

Tables 3 summarizes the findings of this analysis. The results are expressed as a minimum selling price of the algal lipid product required to meet a 10% real rate of return on capital.

	Light li	mited	Not light	limited
	\$ per gallon	\$ per barrel	\$ per gallon	\$ per barrel
Hexane extraction base case	\$41.72	\$1,752	\$41.72	\$1,752
Centrifugal extraction base case	\$32.87	\$1,381	\$32.87	\$1,381
Hexane extraction with VG additive	\$6.69	\$281	\$6.69	\$281
Centrifugal extraction with VG additive	\$4.14	\$174	\$4.14	\$174
Centrifugal extraction 25% biomass recycle	\$3.84	\$161	\$3.51	\$147
Centrifugal extraction 50% biomass recycle	\$3.59	\$151	\$2.87	\$121
Centrifugal extraction 75% biomass recycle	\$3.32	\$139	\$2.24	\$94
Centrifugal extraction 100% biomass recycle	\$2.96	\$124	\$1.59	\$67
NOTES:	"Light limited" concentration grams per liter All recycle cas	refers to requ be maintained to permit suf es assume us	lirement that d between 0.5 ficient light pe se of VG addit	the cell 5 and 0.6 enetration. ive

Table 3. Minimum selling price of oils

The improved performance scenarios with the VG additive all fall well below the low end of the high value oil market benchmark of \$10 per gallon. Of greater interest is how the VG additive scenarios, with the addition of recycle made possible by the ability to non-destructively recover oil secreted by the algae, fare against price of crude oil as a feedstock for fuel production. As Figure 2 shows, oil futures have been highly unstable, reaching a high of around \$140 per barrel in mid 2008 and dropping to under \$40 per barrel after the economic collapse in late 2008. As the economy as slowly begun to rebound, oil prices have once again climbed. Even before the recent unrest in the Middle East, prices were back in the \$70-\$84 per barrel range. USDOE's long term estimates for oil price are conservatively low at \$135 per barrel in the year 2010.



Figure 2. Minimum prices for algal oil

Figure 3 shows compares selected scenarios of improved performance and recycle of biomass with the VG additive, high value oil price ranges and petroleum prices. At 75% recycle levels (cases 3a and 3b), algal oil prices are \$94 to \$139 per barrel, easily within range of DOE oil price projections for 2035, and almost competitive with current oil futures prices. At the theoretical (but not likely practical) maximum for recycle rate of 100%, the price of algal oil competes favorably at only \$67 per barrel.

Case 1: Base growth (no additive) Case 2: VG improved growth 0% recycle Case 3a: VG improved growth 75% recycle with light limitation* Case 3b: VG improved growth 75% recycle no light limitation* Case 4b: VG improved growth 100% recycle no light limitation*



*Light limitation refers to the requirement that algal biomass concentration be maintained at a lower level of 0.5 to 0.6 grams per liter. Under no light limitation, no constraint is placed on biomass concentration

Figure 3. Comparison of selected results for VG additive with market prices for oils.

Conclusions

The introduction of VG Energy's additives offers the ability to knock down the cost of algal oil production by almost a factor of ten as a result of productivity improvements. If oil secretion currently observed in the lab can be fully demonstrated in larger scale growth systems, there is a potential for further decreasing costs by another factor of roughly two. These represent dramatic changes in the economics of algae technology, and are truly game-changing. A lot of work remains to be done to establish the robustness of the VG Energy's lab results, but these preliminary economic analyses show that the promise of the technology warrants further investment and investigation.

Discussion

There are two major benefits to VG Energy's discovery: 1) the ability to maintain and even increase growth rates of algae while also increasing the relative amount of lipid produced per unit of biomass; and 2) the observation that the algae actually secrete the lipids as they accumulate in the cell. The economic repercussions of higher growth and lipid production are obvious. The ability to get cells to secrete the lipids offer some less obvious advantages. First, it improves the ease with which lipids can be separated from the water and biomass coming out of the growth systems. Second, it opens up the possibility that oil can be separated and recovered from the algae in a non-destructive way. This is important because it means that it is now possible to recycle living cells back to growth system. The system no longer has to completely replace biomass that is lost in conventional destructive processes for recovery of lipids.

This analysis has been done in such a way that we can evaluate these benefits separately. In particular, results are presented for:

- A conservative base case growth rate and oil production with conventional extraction
- A conservative base case growth rate and oil production with centrifugal extractor and recycle options
- Enhanced growth rate and oil production with conventional extraction

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• Enhanced growth rate with centrifugal extractor and recycle options

Each of these cases are further split into two scenarios. One in which the ability to get light into the system limits the concentration of biomass to 0.5-0.6 grams per liter, and one in which limit limitations are ignored and the cell concentration is allowed to increase with increasing recycle rate. Maintaining cell concentration at a lower level is achieved by reducing the residence time of the growth reactors as recycle rate is increased.

All of the analysis results are presented in Tables 4 thru 7.

Table 4. Analysis results for base case, with light limitations

	Total cost per gallon	Coproduct credit	Electricity credit	Net cost	Biomass level (g/l)	Residence time (days)	Oil Production (gallons per year)	Oil per acre
Hexane	\$52.40	\$10.68	\$0.00	\$41.72	0.5	10	470,706	191
Centrifuge	\$38.18	\$0.00	\$5.31	\$32.87	0.5	10	470,615	191
25% recycle	\$30.91	\$0.00	\$3.91	\$27.00	0.5	7.7	617,269	250
50% recycle	\$23.81	\$0.00	\$2.50	\$21.31	0.5	5.2	896,700	363
75% recycle	\$16.49	\$0.00	\$1.10	\$15.39	0.5	2.9	1,638,374	663
100% recycle	\$9.29	\$0.00	\$0.00	\$9.29	0.5	0.5	9,476,739	3,837

Table 5. Analysis results for base case, with no light limitations

	Total cost per gallon	Coproduct credit	Electricity credit	Net cost	Biomass level (g/l)	Residence time (days)	Oil Production (gallons per year)	Oil per acre
Hexane	\$52.40	\$10.68	\$0.00	\$41.72	0.5	10	470,706	191
Centrifuge	\$38.18	\$0.00	\$5.31	\$32.87	0.5	10	470,615	191
25% recycle	\$29.57	\$0.00	\$3.96	\$25.61	0.66	10	617,269	250
50% recycle	\$20.96	\$0.00	\$2.61	\$18.35	0.95	10	896,700	363
75% recycle	\$12.36	\$0.00	\$1.26	\$11.10	1.74	10	1,638,374	663
100% recycle	\$3.75	\$0.00	\$0.00	\$3.75	10.07	10	9,476,739	3,837

Table 6. Analysis results for VG improved performance, with light limitations

	Total cost per gallon	Coproduct credit	Electricity credit	Net cost	Biomass level (g/l)	Residence time (days)	Oil Production (gallons per year)	Oil per acre
Hexane	\$9.88	\$3.19	\$0.00	\$6.69	0.6	2	8,472,716	3,430
Centrifuge	\$6.07	\$0.00	\$1.93	\$4.14	0.6	2	8,471,068	3,430
25% recycle	\$5.27	\$0.00	\$1.43	\$3.84	0.6	1.6	10,760,396	4,356
50% recycle	\$4.52	\$0.00	\$0.93	\$3.59	0.6	1.15	14,745,370	5,970
75% recycle	\$3.75	\$0.00	\$0.43	\$3.32	0.6	0.72	23,417,882	9,481
100% recycle	\$2.96	\$0.00	\$0.00	\$2.96	0.6	0.3	56,860,435	23,020

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	Total cost per gallon	Coproduct credit	Electricity credit	Net cost	Biomass level (g/l)	Residence time (days)	Oil Production (gallons per year)	Oil per acre
Hexane	\$9.88	\$3.19	\$0.00	\$6.69	0.6	2	8,472,716	3,430
Centrifuge	\$6.07	\$0.00	\$1.93	\$4.14	0.6	2	8,471,068	3,430
25% recycle	\$4.95	\$0.00	\$1.44	\$3.51	0.76	2	10,760,396	4,356
50% recycle	\$3.83	\$0.00	\$0.96	\$2.87	1.04	2	14,745,370	5,970
75% recycle	\$2.71	\$0.00	\$0.47	\$2.24	1.66	2	23,417,882	9,481
100% recycle	\$1.59	\$0.00	\$0.00	\$1.59	4.03	2	56,860,435	23,020

Table 7. Analysis results for VG improved performance, with no light limitations

Figures 4 and 5 show net and total cost results for each of data sets. There are a few points to note.

- First, that, as recycle rate increases, the relative difference between net and total cost declines. That is because recycling reduces the amount of biomass available for coproduct and electricity production.
- Second, the impact of recycling of the algal biomass is much greater for the low base case productivity scenarios. To understand this, just consider that if 80% of the biomass recycled, that means that the reactor volume needed to grow algae drops by a factor of 5. At lower growth rates, the starting cost of the growth reactors (that is, without recycle) is much higher than the starting cost of the enhanced growth system.
- Third (and really the inverse of the second point), the relative cost savings as a function of recycle rate is much lower for the higher growth rate scenarios.
- Fourth, the difference between conventional hexane and centrifugal extraction processes is much greater for the higher growth rate scenarios. This makes sense since, under higher growth rates, the cost of the growth systems is lower and the savings associated with downstream recovery steps represent a larger portion of the total cost of the system.
- Finally, if light limitations require the growth reactors to be operated so as to maintain lower cell concentrations, the benefit of recycling the biomass is reduced by roughly a factor of 2, as can be seen by comparing the cases a) and b) in each of the figures.

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Figure 4. Base growth rate and oil production scenarios



Figure 5. VG enhanced growth rate and oil production scenarios

Appendix

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Table A1 summarizes the model assumptions used by Dr. James Richardson at Texas A&M (shaded in yellow) as well as calculations based on those assumptions. Numbers in red are explicit model inputs for this analysis. The percent of triglyceride available for extraction as a fuel feedstock or as a high value product is calculated as:

%Oil = %High Value Oil x %Lipid

For the literature case shown in Table 1, the percent of extractable oil is

13% x 40% = 5.2%

For the improved performance cases in Table 1, the percent of extractable oil is

39% x 40% = 16%

	Lit case	HVO \$40 Chem 1	HVO \$40 Chem 2	HVO\$10 Chem 1	HVO \$10 Chem 2
Facility size acre ft	500	500	500	500	500
Depth ft	0.667	0.667	0.667	0.667	0.667
Depth m	0.203	0.203	0.203	0.203	0.203
Pond acres	750	750	750	750	750
Pond hectares	304	304	304	304	304
High value oil %	13%	39%	39%	39%	39%
Compound cost \$ per gal oil produced		\$0.375	\$0.0375	\$0.375	\$0.0375
Biomass volumetric productivity (g/liter/day)	0.049	0.29	0.29	0.29	0.29
Biomass areal productivity (g/sq m/day)	9.959	58.943	58.943	58.943	58.943
Total annual production (gal/AF/year)	1,325	3,972	3,972	3,972	3,972
Lipid %	40%	40%	40%	40%	40%
Extractable Oil (HVO) as % of biomass	5.2%	15.6%	15.6%	15.6%	15.6%
No harvests per year	60	91.25	91.25	91.25	91.25
Volume ponds harvested per cycle (%)	50%	25%	25%	25%	25%
Price HVO	\$40.00	\$40.00	\$40.00	\$10.00	\$10.00

Table A1. Assumptions for algae oil production system.

The spreadsheet model used in this analysis calculates a complete material and energy balance for all flows in the production system up to and including recovery of products and coproducts. A sample material balance summary sheet is shown on the next page.



Figure A1. Mass balance summary sheet example output

Summary reports for each case analyzed are presented in the subsequent pages.

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		_
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	33,000,000	RI	SULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	470,706	_	
Desired rate of return	10.00%		Total Capital	\$67,767,620		
Depreciation years	10	Options blocked out	Total Operating Cost	\$14,640,305		
Analysis Period (years)	20		Capital per Annual Gallon	\$143.97		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.00	Dedicated algae	Annualized Capital	\$21.26	\$303	\$10,006
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$31.10	\$444	\$14,640
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$52.36	\$747	\$24,646
Fixed Charge Rate	0.148	options blocked out	Credit Algae Coprod	\$10.68	\$152	\$5,028
0			Credit Elec	\$0.00	\$0	\$0
Algae Pond O	perational Data		Net Cost	\$41.68	\$594.49	\$19,618
Pond Depth cm	20		Cost per barrel of oil	\$1,750.48		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$60.00 1	:	\$60.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				
Percent biomass recycle	100%	None 1x	\$50.00 -	:	\$50.00 -	
Retention Time days	10	Other	\$30.00			
Pond Algae Concentration g/l	0.50	Settler 50x			\$40.00 -	
Single Pond Flow lpd	4,000,000		\$40.00 -	· · · ·	\$40.00	
Total Pond Flow Ipd	200,000,000	Secondary Dewater				
Pond volume liters	40,000,000	Centrifuge 20% solids	\$30.00		\$30.00 -	
		Centrifuge 20% solids	\$52.36			
		Membrane Filtration	\$20.00 \$4	41.68	\$20.00	
	Other Inputs		\$20.00			
Electricity Cost	\$0.10	Natural Gas			t10.00	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$10.00 -		\$10.00	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$10.68			
Soy meal price per mt	\$200.00	Solar	\$0.00		\$0.00	
Land Price per acre	\$3,000.00	None	30.00 × × × ×	x		
Total to Pond Acres	1.50		COST OF TOT A FLEE CO	»* _	0	Constant
Water Price per acre-ft	\$20.00	Oil Recovery	otal ecorredit Net		Operating =	Capital
Water Price per cu m	\$0.016	Hexane	alea			
Kadam (1997) cost	\$40.00	Hexane	edit.'			
Inflation adjusted	\$49.46	W/O/S Centrifuge	<u> </u>			
		Other	Base case with Hexa 10 day residence	ne Extracti	ion	
		Yellow indicates input	0.5 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	0.5 g/1 bioinass			
	0.00000		0% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	9,476,739		
Desired rate of return	10.00%		Total Capital	\$66,464,365		
Depreciation years	10	Options blocked out	Total Operating Cost	\$25,407,255		
Analysis Period (years)	20		Capital per Annual Gallon	\$7.01	•	
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.00	Dedicated algae	Annualized Capital	\$1.04	\$15	\$9,813
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$2.68	\$38	\$25,407
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$3.72	\$53	\$35,221
Fixed Charge Rate	0.148	options sidence due	Credit Algae Coprod	\$0.00	\$0	\$0
0			Credit Elec	\$0.00	\$0	\$0
Algae Pond O	perational Data		Net Cost	\$3.72	\$53.00	\$35,221
Pond Depth cm	20		Cost per barrel of oil	\$156.09		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sq m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$4.00 1		\$4.00	-
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x			ća 50 -	
Percent biomass recycle	100%	None 1x	\$3.50 -		ŞS.50	
Retention Time days	10	Other			\$3.00 -	
Pond Algae Concentration g/l	10.07	Settler 50x	\$3.00 -		40.00	
Single Pond Flow lpd	198,640		¢2.50 -		\$2.50 -	
Total Pond Flow lpd	9,932,000	Secondary Dewater	\$2.50			
Pond volume liters	40,000,000	Centrifuge 20% solids	\$2.00 - 63.72		\$2.00 -	
		Centrifuge 20% solids	\$3.72	33.7 2	61.50	
		Membrane Filtration	\$1.50 -		\$1.50	
	Other Inputs				\$1.00 -	
Electricity Cost	\$0.10	Natural Gas	\$1.00 -		VIIIO	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	¢0.50		\$0.50 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$0.50			
Soy meal price per mt	\$200.00	Solar	\$0.00 \$0.00\$0.00		\$0.00	
Land Price per acre	\$3,000.00	None		x		
Total to Pond Acres	1.50		Cost of the the	ဝုိ		
Water Price per acre-ft	\$20.00	Oil Recovery	otal corredit Net		Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Traileas Cr.			
Kadam (1997) cost	\$40.00	Hexane	adit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cler			
	4.0					
		Other	Base case with Cent	rifugal Extr	actor	
			10 day residence			
		Vellow indicates input	10 day residence			
Natural Cas Drive and Mil	0.00000470	Plus indicates input	0.5 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
Network One Drive Dr	0.000007		0% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Econor	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	617,269	_	
Desired rate of return	10.00%		Total Capital	\$78,585,087		
Depreciation years	10	Options blocked out	Total Operating Cost	\$7,474,571		
Analysis Period (years)	20		Capital per Annual Gallon	\$127.31		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$18.80	\$268	\$11,603
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$12.11	\$173	\$7,475
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$30.91	\$441	\$19,078
Fixed Charge Rate	0.148	options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
Ũ			Credit Elec	\$3.91	\$56	\$2,413
Algae Pond O	perational Data		Net Cost	\$27.00	\$385.00	\$16,664
Pond Depth cm	20		Cost per barrel of oil	\$1,133.86		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$35.00 1	:	\$35.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				
Percent biomass recycle	25%	None 1x	\$30.00	;	\$30.00 -	
Retention Time days	7.7	Other				
Pond Algae Concentration g/l	0.50	Settler 50x	\$25.00 -		\$25.00 -	
Single Pond Flow lpd	3,960,597					
Total Pond Flow lpd	198.029.870	Secondary Dewater	\$20.00		\$20.00 -	
Pond volume liters	40,000,000	Centrifuge 20% solids	\$20100			
		Centrifuge 20% solids	\$15.00 \$30.91		\$15.00 -	
		Membrane Filtration	, , , , , , , , , , , , , , , , , , ,	52 <mark>7.0</mark> 0		
	Other Inputs		\$10.00 -		\$10.00 -	
Electricity Cost	\$0.10	Natural Gas	\$10.00			
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$5.00 -		\$5.00 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$5.00			
Soy meal price per mt	\$200.00	Solar	\$0.00		\$0.00	
Land Price per acre	\$3,000.00	None	30.00	× '		
Total to Pond Acres	1.50		Cost of the the	çer		
Water Price per acre-ft	\$20.00	Oil Recovery	atal cor edit wet	-	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Le Mar C.			
Kadam (1997) cost	\$40.00	Hexane	dit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cler			
, ,	+					
		Other	Base case with Cent	rifugal Extr	actor	
			77 day rasidance			
		Vellow indicates input	7.7 day residence			
Notural Car Drive and Mil	0.00000470	Plus indicates input	0.50 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	250/			
Natural Cas Driss ray Dtu	0.000007		25% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	ESULTS
Econor	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	896,700	_	
Desired rate of return	10.00%		Total Capital	\$87,884,319		
Depreciation years	10	Options blocked out	Total Operating Cost	\$8,371,842		
Analysis Period (years)	20		Capital per Annual Gallon	\$98.01		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$14,47	\$206	\$12,976
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$9.34	\$133	\$8,372
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$23.81	\$340	\$21,348
Fixed Charge Rate	0.148	options sidence due	Credit Algae Coprod	\$0.00	\$0	\$0
ů l			Credit Elec	\$2.50	\$36	\$2,244
Algae Pond O	perational Data		Net Cost	\$21.30	\$303.82	\$19,104
Pond Depth cm	20		Cost per barrel of oil	\$894.79		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$25.00	:	\$25.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				
Percent biomass recycle	50%	None 1x				
Retention Time days	5.2	Other	\$20.00 -		\$20.00	
Pond Algae Concentration g/l	0.50	Settler 50x				
Single Pond Flow lpd	4.037.154				15 00	
Total Pond Flow lpd	201,857,692	Secondary Dewater	\$15.00 -		\$15.00	
Pond volume liters	40,000,000	Centrifuge 20% solids	¢22.01			
		Centrifuge 20% solids	\$25.61	\$21.30	\$10.00	
		Membrane Filtration	\$10.00 -		,10.00	
	Other Inputs					
Electricity Cost	\$0.10	Natural Gas	65 00 -		\$5.00 -	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$5.00		· ·	
Natural Gas Price per MMBtu	\$7.00	Natural Gas				
Soy meal price per mt	\$200.00	Solar	\$0.00 \$0.00		\$0.00	
Land Price per acre	\$3,000.00	None	30.00	× '		
Total to Pond Acres	1.50		Cost of thet	్		
Water Price per acre-ft	\$20.00	Oil Recovery	otal cor edit wet	-	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Le Mar C.			
Kadam (1997) cost	\$40.00	Hexane	dit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cle			
, ,	+					
		Other	Base case with Cent	rifugal Extr:	actor	
			E 2 day residence			
		Vellow indicatos input	5.2 day residence			
Natural Cas Driss	0.00000470	Plus indicates appulation	0.50 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	500/			
Natural Cas Driss ray Dtu	0.000007		50% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	ESULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	1,638,374	_	
Desired rate of return	10.00%		Total Capital	\$110,549,686		
Depreciation years	10	Options blocked out	Total Operating Cost	\$10,686,614		
Analysis Period (years)	20		Capital per Annual Gallon	\$67.48		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$9.96	\$142	\$16,323
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$6.52	\$93	\$10,687
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$16.49	\$235	\$27,009
Fixed Charge Rate	0.148	options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$1.10	\$16	\$1,809
Algae Pond O	perational Data		Net Cost	\$15.38	\$219.35	\$25,200
Pond Depth cm	20		Cost per barrel of oil	\$646.00		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$18.00 1		\$18.00	_
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x			\$16.00 -	
Percent biomass recycle	75%	None 1x	\$16.00 -		,10.00	
Retention Time days	2.9	Other	\$14.00 -		\$14.00 -	
Pond Algae Concentration g/l	0.50	Settler 50x			±12.00 -	
Single Pond Flow lpd	3,962,000		\$12.00 -		\$12.00	
Total Pond Flow Ipd	198,100,000	Secondary Dewater	¢10.00 -		\$10.00 -	
Pond volume liters	40,000,000	Centrifuge 20% solids	\$10.00		¢0.00	
		Centrifuge 20% solids	\$8.00 \$16.49	\$15.38	\$8.00	
		Membrane Filtration	¢5.00 -		\$6.00 -	
	Other Inputs		\$6.00			
Electricity Cost	\$0.10	Natural Gas	\$4.00 -		\$4.00	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas			\$2.00 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$2.00		42.00	
Soy meal price per mt	\$200.00	Solar	\$0.00 \$0.00	0	\$0.00	
Land Price per acre	\$3,000.00	None	× × ×	x		
Total to Pond Acres	1.50		LOS prot the	C05-	On anothing	Conital
Water Price per acre-ft	\$20.00	Oil Recovery	Kotal ecorredit Net	•	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	AIRS			
Kadam (1997) cost	\$40.00	Hexane	edit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cr.			
			Deep sees with Car	tuifer and Frate	o oko u	
		Other	Base case with Cen	tinugai Extr	actor	
			2.9 day residence			
		Yellow indicates input				
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	0.50 g/l biomass			
			75% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	9,476,739		
Desired rate of return	10.00%		Total Capital	\$356.697.704		
Depreciation years	10	Options blocked out	Total Operating Cost	\$35,369,095		
Analysis Period (years)	20		Capital per Annual Gallon	\$37.64	•	
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$5.56	\$79	\$52,666
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$3.73	\$53	\$35,369
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$9.29	\$132	\$88,035
Fixed Charge Rate	0.148	Options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
5			Credit Elec	\$0.00	\$0	\$0
Algae Pond O	perational Data		Net Cost	\$9.29	\$132.48	\$88,035
Pond Depth cm	20		Cost per barrel of oil	\$390.16		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$10.00 1		\$10.00	_
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x	ća og 🔲		\$9.00 -	
Percent biomass recycle	100%	None 1x	\$9.00		40.00	
Retention Time days	0.5	Other	\$8.00 -		\$8.00	
Pond Algae Concentration g/l	0.50	Settler 50x	\$7.00 -		\$7.00 -	
Single Pond Flow lpd	3.972.800		\$7.00		¢6.00	
Total Pond Flow lpd	198,640,000	Secondary Dewater	\$6.00 -		\$6.00	
Pond volume liters	40,000,000	Centrifuge 20% solids	\$5.00 - 60.20	¢0.20	\$5.00 -	
		Centrifuge 20% solids	\$9.29	Ş9.29	\$4.00 -	
		Membrane Filtration	\$4.00		¢2.00	
	Other Inputs		\$3.00 -		\$3.00	
Electricity Cost	\$0.10	Natural Gas	\$2.00 -		\$2.00 -	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$2.00		\$1.00 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$1.00 -		\$1.00	
Soy meal price per mt	\$200.00	Solar	\$0.00 \$0.00\$0.0	10	\$0.00	-
Land Price per acre	\$3,000.00	None	X X 4	x		
Total to Pond Acres	1.50		LOS prot tile	05	On continue	Conital
Water Price per acre-ft	\$20.00	Oil Recovery	Lota e Co. Legit Ne	-	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Alle			
Kadam (1997) cost	\$40.00	Hexane	edit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	0,0			
		01	Base case with Cen	trifugal Extr	actor	
		Other	O E deservatido			
		Nelley, le directe a la put	0.5 day residence			
		reliow indicates input	0.50 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
Natural Cas Drive care Dtu	0.000007		100% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	R	SULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	617.269		
Desired rate of return	10.00%		Total Capital	\$74.022.294		
Depreciation years	10	Options blocked out	Total Operating Cost	\$7.323.472		
Analysis Period (years)	20		Capital per Appual Gallon	\$119.92		
Tax Rate	40.00%	Growth Scenario	Supital per Annual Sulion	Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Canital	\$17.71	\$253	\$10 929
Canital Recovery Factor	0 117	Dedicated algae	Operating Cost	\$11.86	\$169	\$7 323
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$29.57	\$422	\$18,253
Fixed Charge Rate	0.148	Options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
Tixed onlarge rate	0.140		Credit Flec	\$3.96	\$56	\$2 445
Algae Pond O	perational Data		Net Cost	\$25.61	\$365.20	\$15,807
Pond Depth cm	20		Cost per barrel of oil	\$1 075 55	\$000.20	\$10,001
Single Pond Area ha	20	Primary Dewater	obst per barrer er en	\$1,070.00		
Evanoration Rate cm/day	0.6	Settler 50x				
Area Productivity a/sa m-d	10	1 Belt Filter 70x				
% Linid Content	5%	Foam Fraction 100x	\$30.00 1 🗂		\$30.00	
Total Pond Area (incr. 10 ha)	1000	Microstrainer 10x	<i>\$50.00</i>			
Percent biomass recycle	25%	None 1x			\$25.00 -	
Retention Time days	10	Other	\$25.00 -		<i>Ş</i> 25.00	
Pond Algae Concentration g/	0.66	Settler 50x				
Single Pond Flow Ind	3 049 660	Settler Sox	\$20.00 -		\$20.00 -	
Total Pond Flow Ind	152 483 000	Secondary Dewater				
Pond volume liters	40,000,000	Centrifuge 20% solids	¢15.00 -¢20.57		\$15.00 -	
Tona volume mers	40,000,000	Centrifuge 20% solids	\$15.00 \$25.57	25 61		
		Membrane Filtration	, i i i i i i i i i i i i i i i i i i i	25.01	¢10.00	
	Other Innuts	Membrane i madon	\$10.00 -		\$10.00	
Electricity Cost	\$0.10	Natural Gas				
Plant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$5.00 -		\$5.00 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	40.00 A			
Sov meal price per mi	\$200.00	Solar	\$3.96		\$0.00	
L and Price per acre	\$3,000,00	None	\$0.00 + \$0.00			
Total to Pond Acres	1.50	None	COST NOO EVEC O	o st		
Water Price per acre-ft	\$20.00	Oil Recovery	tal cop dit wet	·	Operating 📒	Capital
Water Price per cum	\$0.016	W/O/S Centrifuge	TO BBE CLE IT			
Kadam (1997) cost	\$40.00	Hexane	dit A.			
Inflation adjusted	\$49.66	W/O/S Centrifuge	Cles.			
initation adjusted	φ 1 3.40	W/O/O Centinuge				
		Other	Base case with Cent	rifugal Extr	actor	
		Other	10			
		Nelley, le directe a la put	10 day residence			
		reliow indicates input	0.66 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
			25% recycle			
Natural Gas Price per Btu	0.000007					

SheebanBoyce, LLC

		CO2 Sourcing				
		Power Plant-CO2 Recov		\$2006		
INPOTS		Power Plant-CO2 Recov	Total Biomass Production		RE	SULTS
Econom	ic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	896,700	_	
Desired rate of return	10.00%	Outlines blacked aut	Total Capital	\$73,783,914		
Depreciation years	10	Options blocked out	Total Operating Cost	\$7,904,901		
Analysis Period (years)	20		Capital per Annual Gallon	\$82.28	·	
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$12.15	\$173	\$10,894
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$8.82	\$126	\$7,905
Present Value Depreciation	0.614	Options blocked out	Total Cost	\$20.96	\$299	\$18,799
Fixed Charge Rate	0.148		Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$2.61	\$37	\$2,343
Algae Pond Op	erational Data		Net Cost	\$18.35	\$261.71	\$16,456
Pond Depth cm	20		Cost per barrel of oil	\$770.76		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sq m-d	10	1 Belt Filter 70x			tar oo -	
% Lipid Content	5%	Foam Fraction 100x	\$25.00		\$25.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				_
Percent biomass recycle	50%	None 1x			\$20.00 -	
Retention Time days	10	Other	\$20.00 -	_	20.00	
Pond Algae Concentration g/l	0.95	Settler 50x				
Single Pond Flow Ipd	2,099,320		447.00		\$15.00 -	
Total Pond Flow Ipd	104,966,000	Secondary Dewater	\$15.00			
Pond volume liters	40,000,000	Centrifuge 20% solids				
		Centrifuge 20% solids	\$20.96		\$10.00 -	
		Membrane Filtration	\$10.00 \$1	8.35		
_	Other Inputs					
Electricity Cost	\$0.10	Natural Gas	\$5.00 -		\$5.00 -	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas				
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$2.61			
Soy meal price per mt	\$200.00	Solar	\$0.00 \$0.00	1	\$0.00	
Land Price per acre	\$3,000.00	None	A 20 . 20 . 2	Ļ.		
Total to Pond Acres	1.50		alco' opto in the too	_	Operating	Canital
Water Price per acre-ft	\$20.00	Oil Recovery	Tota se creo. Ne		operating -	cupitai
Water Price per cu m	\$0.016	W/O/S Centrifuge	Alle .			
Kadam (1997) cost	\$40.00	Hexane	redit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	C.			
			Deep sees with Contri	formed Forte		
		Other	Base case with Centri	nugai extr	actor	
			10 day residence			
		Yellow indicates input				
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	0.95 g/l biomass			
			50% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTE		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	ESULTS
Econor	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	1,638,374		
Desired rate of return	10.00%		Total Capital	\$73,151,198		
Depreciation years	10	Options blocked out	Total Operating Cost	\$9,448,147		
Analysis Period (years)	20		Capital per Annual Gallon	\$44.65		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$6.59	\$94	\$10,801
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$5.77	\$82	\$9,448
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$12.36	\$176	\$20,249
Fixed Charge Rate	0.148	Options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$1.26	\$18	\$2,072
Algae Pond O	perational Data		Net Cost	\$11.09	\$158.22	\$18,177
Pond Depth cm	20		Cost per barrel of oil	\$465.96		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$14.00	:	\$14.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				
Percent biomass recycle	75%	None 1x	\$12.00	:	\$12.00 -	
Retention Time days	10	Other		•		
Pond Algae Concentration g/l	1.74	Settler 50x	\$10.00 -		\$10.00 -	
Single Pond Flow lpd	1,148,980					
Total Pond Flow Ipd	57,449,000	Secondary Dewater	\$8.00		\$8.00 -	
Pond volume liters	40.000.000	Centrifuge 20% solids	0.00			
		Centrifuge 20% solids	\$6.00 \$12.36		\$6.00 -	
		Membrane Filtration	0.00	\$1 <mark>1.0</mark> 9		
	Other Inputs		\$4.00 -		\$4.00 -	
Electricity Cost	\$0.10	Natural Gas	94.00			
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$2.00 -		\$2.00 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$2.00			
Sov meal price per mt	\$200.00	Solar	\$0.00 \$1.20	5	\$0.00	
Land Price per acre	\$3,000.00	None	\$0.00			
Total to Pond Acres	1.50		Cost Noo effec	- ⁰⁵¹		
Water Price per acre-ft	\$20.00	Oil Recovery	atal Covedit Net	•	Operating	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	10 N836 (12 .			
Kadam (1997) cost	\$40.00	Hexane	dit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cler			
initation adjusted	¢10110	in oro continugo				
		Other	Base case with Cent	trifugal Extr	actor	
			10 days residence			
		Vollow indicators input	10 day residence			
	0.00000.070	Tellow Indicates Input	1.74 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
	0.000007		75% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTE		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Econor	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	9,476,739	_	
Desired rate of return	10.00%		Total Capital	\$66,464,365		
Depreciation years	10	Options blocked out	Total Operating Cost	\$25,757,894		
Analysis Period (years)	20		Capital per Annual Gallon	\$7.01		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$1.04	\$15	\$9,813
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$2.72	\$39	\$25,758
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$3.75	\$54	\$35,571
Fixed Charge Rate	0.148	Options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$0.00	\$0	\$0
Algae Pond O	perational Data		Net Cost	\$3.75	\$53.53	\$35,571
Pond Depth cm	20		Cost per barrel of oil	\$157.65		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	10	1 Belt Filter 70x				
% Lipid Content	5%	Foam Fraction 100x	\$4.00 1		\$4.00	-
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x			40.50	
Percent biomass recycle	100%	None 1x	\$3.50 -		\$3.50	
Retention Time days	10	Other			\$3.00 -	
Pond Algae Concentration g/l	10.07	Settler 50x	\$3.00 -		\$5.00	
Single Pond Flow Ipd	198.640		62.52		\$2.50 -	
Total Pond Flow Ind	9,932,000	Secondary Dewater	\$2.50			
Pond volume liters	40,000,000	Centrifuge 20% solids	\$2.00 - 63.75	40 PF	\$2.00 -	
		Centrifuge 20% solids	\$3.75	\$3.75	44.50	
		Membrane Filtration	\$1.50 -		\$1.50	
	Other Inputs				\$1.00	
Electricity Cost	\$0.10	Natural Gas	\$1.00 -		\$1.00	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	40.50		\$0.50 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$0.50			
Sov meal price per mt	\$200.00	Solar	\$0.00		\$0.00	_
Land Price per acre	\$3,000.00	None	30.00	*		
Total to Pond Acres	1.50		Cost Noo ther C	્રે		
Water Price per acre-ft	\$20.00	Oil Recovery	otal cor edit Net	-	Operating	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	AL NEAL CL.			
Kadam (1997) cost	\$40.00	Hexane	dith			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cler			
	• • • • • •					
		Other	Base case with Cent	rifugal Extr	actor	
			10 day residence			
		Vollow indicators input	10 day residence			
	0.00000.070	Tellow Indicates Input	10.07 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
	0.000007		100% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	198,000,000	RI	SULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	8,472,716		
Desired rate of return	10.00%		Total Capital	\$120,017,611		
Depreciation years	10	Options blocked out	Total Operating Cost	\$66,822,685		
Analysis Period (years)	20		Capital per Annual Gallon	\$14.17	•	
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$2.09	\$89	\$17,720
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$7.89	\$337	\$66,823
Present Value Depreciation	0.614	Options blocked out	Total Cost	\$9.98	\$427	\$84,543
Fixed Charge Rate	0.148	options sidence due	Credit Algae Coprod	\$3.19	\$136	\$27,012
ů.			Credit Elec	\$0.00	\$0	\$0
Algae Pond O	perational Data		Net Cost	\$6.79	\$290.56	\$57,531
Pond Depth cm	20		Cost per barrel of oil	\$285.19		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sq m-d	60	1 Belt Filter 70x				-
% Lipid Content	16%	Foam Fraction 100x	\$10.00 1		\$10.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x	¢0.00		\$9.00 -	
Percent biomass recycle	0%	None 1x	\$5.00		¢0.00	
Lipid secretion	2	Other	\$8.00 -		\$8.00	
Retention Time days	1.7	Settler 50x	\$7.00 -	_	\$7.00 -	
Pond Algae Concentration g/l	0.51		\$7.00		\$6.00	
Single Pond Flow lpd	23,529,412	Secondary Dewater	\$6.00		\$0.00	
Total Pond Flow Ipd	1,176,470,588	Centrifuge 20% solids	\$5.00 - \$9.98		\$5.00 -	
Pond volume liters	40,000,000	Centrifuge 20% solids			\$4.00 -	
		Membrane Filtration	\$4.00 -	¢6 70		
			\$3.00 -	JU.75	\$3.00	
	Other Inputs	Natural Gas	\$2.00		\$2.00 -	
Electricity Cost	\$0.10	Natural Gas	\$3.19		\$1.00 -	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$1.00 -		\$1.00	
Natural Gas Price per MMBtu	\$7.00	Solar	\$0.00	o	\$0.00 +	-
Soy meal price per mt	\$200.00	None	5. 6. X	~		
Land Price per acre	\$3,000.00		LOS protection	~ى	On continue -	Conital
Total to Pond Acres	1.50	Oil Recovery	total eccited Net	· · · · · · · · · · · · · · · · · · ·	Operating =	Capital
Water Price per acre-ft	\$20.00	Hexane	AIRS			
Water Price per cu m	\$0.016	Hexane	edit			
Kadam (1997) cost	\$40.00	W/O/S Centrifuge	00			
Inflation adjusted	\$49.46	Other Yellow indicates input	VG Improved Hexai 2 day residence 0.6 g/l biomass	ne Solvent I	Extractio	n
		Bide indicates calculation				
Natural Gas Price per MJ	0.00663472		0% recycle			

SheebanBoyce, LLC

		CO2 Sourcing				
		Power Plant-CO2 Recov		\$2006		
INFOID		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	8,471,068	_	
Desired rate of return	10.00%	Ontions blocked out	Total Capital	\$168,607,155		
Depreciation years	10	Options blocked out	Total Operating Cost	\$26,487,864		
Analysis Period (years)	20		Capital per Annual Gallon	\$19.90	•	
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$2.94	\$126	\$24,895
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$3.13	\$134	\$26,488
Present Value Depreciation	0.614	Options blocked out	Total Cost	\$6.07	\$260	\$51,383
Fixed Charge Rate	0.148		Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$1.93	\$83	\$16,367
Algae Pond O	perational Data		Net Cost	\$4.13	\$176.84	\$35,015
Pond Depth cm	20		Cost per barrel of oil	\$173.61		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sq m-d	60	1 Belt Filter 70x			ć7.00 -	
% Lipid Content	16%	Foam Fraction 100x	\$7.00		\$7.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x			¢c.00	
Percent biomass recycle	0%	None 1x	\$6.00 -		\$6.00	
Lipid secretion	Yes	Other			ćr. 00	
Retention Time days	2	Settler 50x	\$5.00 -		\$5.00	
Pond Algae Concentration g/I	0.60			_	¢4.00	
Single Pond Flow Ipd	20,000,000	Secondary Dewater	\$4.00 -		\$4.00	
Total Pond Flow Ipd	1,000,000,000	Centrifuge 20% solids			¢2.00	
Pond volume liters	40,000,000	Centrifuge 20% solids	\$3.00 - \$6.07		\$3.00	
		Membrane Filtration			¢2.00	
	.		\$2.00 - 5	4.13	\$2.00	
	Other Inputs	Natural Gas			¢1.00	
Electricity Cost	\$0.10	Natural Gas	\$1.00 - \$1.93		\$1.00	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas			¢0.00	
Natural Gas Price per MMBtu	\$7.00	Solar	\$0.00 \$0.00	₽,	\$0.00	
Soy meal price per mt	\$200.00	None	and and all a	Š.		
Land Price per acre	\$3,000.00	0 1 5	all copie atter at C	· _	Operating 🗧	Capital
Iotal to Pond Acres	1.50	Oil Recovery	TOL BE CLED NO			
Water Price per acre-ft	\$20.00	W/O/S Centrifuge	it Alb			
Water Price per cu m	\$0.016	Hexane	Cleon			
Kadam (1997) cost	\$40.00	W/O/S Centrifuge	Ŭ			
			VG Improved Centrif	ugal Extra	ction	
Inflation adjusted	\$49.46	Other	vo improved centri	ugai Litti a	CHOIT	
			2 day residence			
		Yellow indicates input	0.6 g/l biomass			
		Blue indicates calculation	0.0 g/i biomass			
			0% recycle			
Natural Gas Price per MJ	0.00663472					

SheebanBoyce, LLC

		CO2 Sourcing				
		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	92000	RE	SULTS
Econor	nic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	10 760 396		190119
Desired rate of return	10 00%	Tower Flanc Direct Flac Gas	Total Capital	\$185 759 780		
Depreciation years	10.00%	Options blocked out	Total Operating Cost	\$29 243 820		
Appleciation years	10		Conital per Approal College	\$23,243,020		
Analysis Period (years)	20	Counth Countrie	Capital per Annual Gallon	\$17.26	Alexa (
lax Rate	40.00%	Growth Scenario	Annualized Operited	Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$2.55	\$109	\$27,427
Capital Recovery Factor	0.117	Dedicated aldae	Operating Cost	\$2.72	\$116	\$29,244
Present Value Depreciation	0.614	Options blocked out	Total Cost	\$5.27	\$225	\$56,671
Fixed Charge Rate	0.148		Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$1.43	\$61	\$15,401
Algae Pond O	perational Data		Net Cost	\$3.84	\$164.09	\$41,270
Pond Depth cm	20		Cost per barrel of oil	\$161.09		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sq m-d	60	1 Belt Filter 70x			\$6.00 -	
% Lipid Content	16%	Foam Fraction 100x	\$6.00		\$0.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				
Percent biomass recycle	25%	None 1x	\$5.00		\$5.00 -	
Retention Time days	1.6	Other	45100			
Pond Algae Concentration g/l	0.61	Settler 50x			\$4.00 -	
Single Pond Flow Ipd	19,681,125		\$4.00 -		Ş4.00	
Total Pond Flow Ipd	984,056,250	Secondary Dewater				
Pond volume liters	40,000,000	Centrifuge 20% solids	\$3.00 -		\$3.00 -	
		Centrifuge 20% solids	\$5.27			
		Membrane Filtration	42 A2		\$2.00	
	Other Inputs		\$2.00	\$3.84	12.00	
Electricity Cost	\$0.10	Natural Gas			44.00	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$1.00		\$1.00	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$1.43			
Sov meal price per mt	\$200.00	Solar	to oo \$0.00		\$0.00	
Land Price per acre	\$3,000,00	None	\$0.00			
Total to Pond Acres	1.50		COST NOO EVEL	్రా		
Water Price per acre-ft	\$20.00	Oil Recovery	tal Cor edit Net	- -	Operating 🗧	Capital
Water Price per cum	\$0.016	W/O/S Centrifuge	TO NOSE CLO I			
Kadam (1997) cost	\$40.00	Hexane	ditA			
Inflation adjusted	\$49.66	W/O/S Centrifuge	Clee			
initation adjusted	\$49.40	W/O/S Centinuge				
		0.1	VG Improved Centri	ifugal Extra	ction	
		Other				
			1.6 day residence			
		Yellow indicates input	0.61 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	0.01 8/1 010111855			
			25% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	ESULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	14,745,370	_	
Desired rate of return	10.00%		Total Capital	\$219,738,367		
Depreciation years	10	Options blocked out	Total Operating Cost	\$34,177,526		
Analysis Period (years)	20		Capital per Annual Gallon	\$14.90		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$2.20	\$94	\$32,444
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$2.32	\$99	\$34,178
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$4.52	\$193	\$66,622
Fixed Charge Rate	0.148	options sidence due	Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$0.93	\$40	\$13,690
Algae Pond O	perational Data		Net Cost	\$3.59	\$153.58	\$52,932
Pond Depth cm	20		Cost per barrel of oil	\$150.77		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	60	1 Belt Filter 70x				
% Lipid Content	16%	Foam Fraction 100x	\$5.00 1		\$5.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x	¢4.50		\$4.50 -	
Percent biomass recycle	50%	None 1x	\$4.50		¢4.00	
Retention Time days	1.15	Other	\$4.00 -		\$4.00	
Pond Algae Concentration g/l	0.60	Settler 50x	\$3.50 -		\$3.50 -	
Single Pond Flow lpd	19,982,261		\$3.50		\$2.00	
Total Pond Flow Ipd	999,113,043	Secondary Dewater	\$3.00 -		\$5.00	
Pond volume liters	40,000,000	Centrifuge 20% solids	\$2.50		\$2.50 -	
		Centrifuge 20% solids	\$4.52		\$2.00 -	
		Membrane Filtration	\$2.00	\$3.59	¢1.50	
	Other Inputs		\$1.50 -		\$1.50	
Electricity Cost	\$0.10	Natural Gas	\$1.00 -		\$1.00 -	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$1.00		¢0.50 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$0.50 - \$0.9	3	\$0.50	
Soy meal price per mt	\$200.00	Solar	\$0.00 \$0.00		\$0.00	_
Land Price per acre	\$3,000.00	None	2. 6 X	x		
Total to Pond Acres	1.50		LOS OFOL HE	05	O	Constral
Water Price per acre-ft	\$20.00	Oil Recovery	Cotal eco, redit Net	~ –	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Alea			
Kadam (1997) cost	\$40.00	Hexane	edit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	<u> </u>			
Natural Cas Price per M I	0.00662472	Other Yellow indicates input	VG Improved Centr 1.15 day residence 0.60 g/l biomass	ifugal Extra	ction	
Natural Gas Price per MJ	0.00003472	blue indicates calculation	50% recycle			
Natural Gas Price per Btu	0.000007		50% recycle			

		CO2 Sourcing				
INDUTS		Power Plant-CO2 Recov		\$2006		
INPUTS		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Econor	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	23,417,882		
Desired rate of return	10.00%		Total Capital	\$291,711,819		
Depreciation years	10	Options blocked out	Total Operating Cost	\$44,849,387		
Analysis Period (years)	20		Capital per Annual Gallon	\$12.46	l	
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$1.84	\$79	\$43,071
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$1.92	\$82	\$44,849
Present Value Depreciation	0.614	Options blocked out	Total Cost	\$3.75	\$161	\$87,921
Fixed Charge Rate	0.148		Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$0.43	\$18	\$9,979
Algae Pond O	perational Data		Net Cost	\$3.33	\$142.39	\$77,941
Pond Depth cm	20		Cost per barrel of oil	\$139.79		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sq m-d	60	1 Belt Filter 70x				
% Lipid Content	16%	Foam Fraction 100x	\$4.00		\$4.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x			¢2 50 -	
Percent biomass recycle	75%	None 1x	\$3.50 -		\$5.50	
Retention Time days	0.72	Other	40.00		\$3.00 -	
Pond Algae Concentration g/l	0.60	Settler 50x	\$3.00 -		1	
Single Pond Flow lpd	20,096,389		\$2.50 -		\$2.50 -	
Total Pond Flow Ipd	1,004,819,444	Secondary Dewater	\$2.50			
Pond volume liters	40,000,000	Centrifuge 20% solids	\$2.00 - \$2.75		\$2.00 -	
		Centrifuge 20% solids	Ş3.75	\$3.33	¢1 E0 -	
		Membrane Filtration	\$1.50 -		\$1.50	
	Other Inputs				\$1.00 -	
Electricity Cost	\$0.10	Natural Gas	\$1.00 -		Ŷ1.00	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	¢0.50		\$0.50 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$0.50	2		
Soy meal price per mt	\$200.00	Solar	\$0.00		\$0.00	-
Land Price per acre	\$3,000.00	None	S. 6. X	x		
Total to Pond Acres	1.50		LOS OPIO SELECT	ංී	Operating	Conital
Water Price per acre-ft	\$20.00	Oil Recovery	LOLS C LEDIN Net	·	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Algo			
Kadam (1997) cost	\$40.00	Hexane	edit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	0.			
		Other	vG Improved Centr	ifugal Extra	ction	
			0.72 day residence			
		Yellow indicates input	o. / 2 day residence			
Natural Gas Price per M.I	0.00663472	Blue indicates calculation	0.60 g/l biomass			
Haturar Ous I noe per Mo	0.00000472	Bide indicates calculation	75% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INPUTS		Power Plant-CO2 Recov		\$2006		
		Power Plant-CO2 Recov	Total Biomass Production	0	RI	ESULTS
Econor	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	56,860,435		
Desired rate of return	10.00%		Total Capital	\$560,370,222		
Depreciation years	10	Options blocked out	Total Operating Cost	\$85,707,595		
Analysis Period (years)	20		Capital per Annual Gallon	\$9.86		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$1.46	\$62	\$82,739
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$1.51	\$64	\$85,708
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$2.96	\$127	\$168,446
Fixed Charge Rate	0.148	options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
0			Credit Elec	\$0.00	\$0	\$0
Algae Pond O	perational Data		Net Cost	\$2.96	\$126.74	\$168,446
Pond Depth cm	20		Cost per barrel of oil	\$124.42		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity q/sq m-d	60	1 Belt Filter 70x				_
% Lipid Content	16%	Foam Fraction 100x	\$3.00 1 🥅		\$3.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				
Percent biomass recycle	100%	None 1x	¢2 E0 -		\$2.50 -	
Retention Time days	0.3	Other	\$2.50			
Pond Algae Concentration g/l	0.60	Settler 50x			¢2.00	
Single Pond Flow lpd	19,864,000		\$2.00 -		\$2.00	
Total Pond Flow lpd	993,200,000	Secondary Dewater				
Pond volume liters	40,000,000	Centrifuge 20% solids	\$1.50 - \$2.96	\$2.96	\$1.50 -	
		Centrifuge 20% solids				
		Membrane Filtration	44.00		\$1.00 -	
	Other Inputs		\$1.00			
Electricity Cost	\$0.10	Natural Gas			40 F0	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$0.50 -		\$0.50 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas				
Soy meal price per mt	\$200.00	Solar	\$0.00 - \$0.00\$0.00	n 📕	\$0.00	
Land Price per acre	\$3,000.00	None	30.00	x		
Total to Pond Acres	1.50		Cost or oc the			
Water Price per acre-ft	\$20.00	Oil Recovery	oral coredit Net	· · · · · · · · · · · · · · · · · · ·	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	1° NB3C CI.			
Kadam (1997) cost	\$40.00	Hexane	dit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cle			
	••••••					
		Other	VG Improved Centr	ifugal Extra	ction	
			0.20 day racidance			
		Vellow indicators input	0.50 day residence			
Natural Cas Drive and Mil	0.00000.470	Plus indicates input	0.60 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	1000/			
Network Cas Dries and Dtu	0.000007		100% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INPUTS		Power Plant-CO2 Recov		\$2006		_
		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Economic Parameters		Power Plant-Direct Flue Gas	Total Oil Production	10,760,396	_	
Desired rate of return	10.00%		Total Capital	\$166,665,481		
Depreciation years	10	Options blocked out	Total Operating Cost	\$28,611,504		
Analysis Period (years)	20		Capital per Annual Gallon	\$15.49		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$2.29	\$98	\$24,608
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$2.66	\$114	\$28,612
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$4.95	\$212	\$53,220
Fixed Charge Rate	0.148	options sidence due	Credit Algae Coprod	\$0.00	\$0	\$0
0			Credit Elec	\$1.44	\$62	\$15,535
Algae Pond O	perational Data		Net Cost	\$3.50	\$149.83	\$37,684
Pond Depth cm	20		Cost per barrel of oil	\$147.09		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	60	1 Belt Filter 70x				_
% Lipid Content	16%	Foam Fraction 100x	\$5.00 1 🥅		\$5.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x	64.50		\$4.50 -	
Percent biomass recycle	25%	None 1x	\$4.50		¢4.00	
Retention Time days	2	Other	\$4.00 -		\$4.00	
Pond Algae Concentration g/l	0.76	Settler 50x	\$3.50 -		\$3.50 -	
Single Pond Flow lpd	15,744,900		\$3.50		\$2.00	
Total Pond Flow lpd	787,245,000	Secondary Dewater	\$3.00		\$5.00	
Pond volume liters	40,000,000	Centrifuge 20% solids	\$2.50 - \$4.95		\$2.50 -	
		Centrifuge 20% solids	£2.00		\$2.00 -	
		Membrane Filtration	\$2.00	\$3.50	¢1.50	
	Other Inputs		\$1.50 -		\$1.50	
Electricity Cost	\$0.10	Natural Gas	\$1.00 -		\$1.00	
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$1.00 \$1.44	4	\$0.50	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$0.50		\$0.50	
Soy meal price per mt	\$200.00	Solar	\$0.00 \$0.00		\$0.00	_
Land Price per acre	\$3,000.00	None	× >	x		
Total to Pond Acres	1.50		LOS prot the		On anothing	Consider
Water Price per acre-ft	\$20.00	Oil Recovery	Cotal ecor redit Net	-	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Algar			
Kadam (1997) cost	\$40.00	Hexane	edit.			
Inflation adjusted	\$49.46	W/O/S Centrifuge	<u> </u>			
		Other	VG Improved Centr	ifugal Extra	ction	
			2 day residence			
		Vellow indicators input	2 day residence			
	0.00000.070	Tellow indicates input	0.76 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
Natural Gas Price per Btu	0.000007		25% recycle			

		CO2 Sourcing				
INPUTS		Power Plant-CO2 Recov		\$2006		
		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Econor	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	14,745,370	_	
Desired rate of return	10.00%		Total Capital	\$163,285,659		
Depreciation years	10	Options blocked out	Total Operating Cost	\$32,308,070		
Analysis Period (years)	20		Capital per Annual Gallon	\$11.07		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$1.64	\$70	\$24,109
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$2.19	\$94	\$32,308
Present Value Depreciation	0.614	Options blocked out	Total Cost	\$3.83	\$164	\$56,417
Fixed Charge Rate	0.148		Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$0.96	\$41	\$14,086
Algae Pond O	perational Data		Net Cost	\$2.87	\$122.82	\$42,331
Pond Depth cm	20		Cost per barrel of oil	\$120.57		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sq m-d	60	1 Belt Filter 70x			** • • •	
% Lipid Content	16%	Foam Fraction 100x	\$4.00 1 👝		\$4.00 -	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x			\$2.50 -	
Percent biomass recycle	50%	None 1x	\$3.50 -		\$5.50	
Retention Time days	2	Other	40.00		\$3.00 -	
Pond Algae Concentration g/l	1.04	Settler 50x	\$3.00 -	•		
Single Pond Flow Ipd	11,489,800		\$2.50 -		\$2.50 -	
Total Pond Flow Ipd	574,490,000	Secondary Dewater	\$2.50			
Pond volume liters	40,000,000	Centrifuge 20% solids	\$2.00 - \$3.83		\$2.00 -	
		Centrifuge 20% solids			\$1.50 -	
		Membrane Filtration	\$1.50 -	\$2.87	\$1.50	
	Other Inputs				\$1.00 -	
Electricity Cost	\$0.10	Natural Gas	\$1.00			
'lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$0.50 - \$0.96	5	\$0.50 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$0.50 \$0.50			
Soy meal price per mt	\$200.00	Solar	\$0.00		\$0.00 +	-
Land Price per acre	\$3,000.00	None	S. 6. 5.	~		
Total to Pond Acres	1.50		LOS OPO TELE	_ م	Operating	Conital
Water Price per acre-ft	\$20.00	Oil Recovery	LOLS C LEDIN NET	· · · · · · · · · · · · · · · · · · ·	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	Algo			
Kadam (1997) cost	\$40.00	Hexane	edit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	0.			
		Other	VG Improved Centr 2 day residence	ifugal Extra	ction	
	0.00000.070	reliow indicates input	1.04 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
Natural Gas Price per Btu	0.000007		50% recycle			

SheebanBoyce, LLC

		CO2 Sourcing				
INPUTS		Power Plant-CO2 Recov		\$2006		
		Power Plant-CO2 Recov	Total Biomass Production	0	RI	SULTS
Economic Parameters		Power Plant-Direct Flue Gas	Total Oil Production	23,417,882		
Desired rate of return	10.00%		Total Capital	\$155,930,140		
Depreciation years	10	Options blocked out	Total Operating Cost	\$40,352,919		
Analysis Period (years)	20		Capital per Annual Gallon	\$6.66		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$0.98	\$42	\$23,023
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$1.72	\$74	\$40,353
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$2.71	\$116	\$63.376
Fixed Charge Rate	0.148	Options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
5			Credit Elec	\$0.47	\$20	\$10,934
Algae Pond O	perational Data		Net Cost	\$2.24	\$95.81	\$52,442
Pond Depth cm	. 20		Cost per barrel of oil	\$94.05		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	60	1 Belt Filter 70x				
% Lipid Content	16%	Foam Fraction 100x	\$3.00 1		\$3.00	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x				
Percent biomass recycle	75%	None 1x	42.50		\$2.50 -	
Retention Time days	2	Other	\$2.50		1	
Pond Algae Concentration g/l	1.66	Settler 50x			40.00	
Single Pond Flow Ind	7.234.700	Could Cox	\$2.00 -		\$2.00	
Total Pond Flow Ipd	361 735 000	Secondary Dewater				
Pond volume liters	40,000,000	Centrifuge 20% solids	\$1.50		\$1.50 -	
	10,000,000	Centrifuge 20% solids	\$2.71			
		Membrane Filtration		\$2.24	\$1.00 -	
	Other Inputs		\$1.00 -		\$1.00	
Electricity Cost	\$0.10	Natural Gas				
Plant Recov CO2 Cost oper mt	\$50.00	Natural Gas	\$0.50 -		\$0.50 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	\$0.47	7		
Sov meal price per mt	\$200.00	Solar	to oo \$0.00		\$0.00	
Land Price per acre	\$3,000,00	None	\$0.00 - \$0.00			
Total to Pond Acres	1.50	110110	Con Noo the	رم ^ع د .		
Water Price per acre-ft	\$20.00	Oil Recovery	atal OP edit Net	~	Operating 🗧	Capital
Water Price per cum	\$0.016	W/O/S Centrifuge	TO NOSE CLE Y			
Kadam (1997) cost	\$40.00	Hexane	dith			
Inflation adjusted	\$49.66	W/O/S Centrifuge	Cler			
initation adjusted	φ+5.+0	W/O/O Centinuge				
		Other	VG Improved Centr	ifugal Extra	ction	
		Other				
			2 day residence			
		Yellow indicates input	1 66 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation	1.00 g/1 biomass			
			75% recycle			
Natural Gas Price per Btu	0.000007					

		CO2 Sourcing				
INPUTS		Power Plant-CO2 Recov		\$2006		
		Power Plant-CO2 Recov	Total Biomass Production	0	RI	ESULTS
Econo	mic Parameters	Power Plant-Direct Flue Gas	Total Oil Production	56,860,435	_	
Desired rate of return	10.00%		Total Capital	\$127,566,121		
Depreciation years	10	Options blocked out	Total Operating Cost	\$71,375,102		
Analysis Period (years)	20		Capital per Annual Gallon	\$2.24		
Tax Rate	40.00%	Growth Scenario		Oil (gal)	Algae (mt)	Pond (ha)
Additive cost (\$ per gallon oil)	\$0.04	Dedicated algae	Annualized Capital	\$0.33	\$14	\$18,835
Capital Recovery Factor	0.117	Dedicated algae	Operating Cost	\$1.26	\$54	\$71,375
Present Value Depreciation	0.614	Ontions blocked out	Total Cost	\$1.59	\$68	\$90,210
Fixed Charge Rate	0.148	options blocked out	Credit Algae Coprod	\$0.00	\$0	\$0
			Credit Elec	\$0.00	\$0	\$0
Algae Pond O	perational Data		Net Cost	\$1.59	\$67.88	\$90,210
Pond Depth cm	20		Cost per barrel of oil	\$66.63		
Single Pond Area ha	20	Primary Dewater				
Evaporation Rate cm/day	0.6	Settler 50x				
Area Productivity g/sg m-d	60	1 Belt Filter 70x				_
% Lipid Content	16%	Foam Fraction 100x	\$1.60 1		\$1.60	
Total Pond Area (incr 10 ha)	1000	Microstrainer 10x			¢1.40	
Percent biomass recycle	100%	None 1x	\$1.40 -		\$1.40	
Retention Time days	2	Other			\$1.20 -	
Pond Algae Concentration g/l	4.03	Settler 50x	\$1.20 -		91.20	
Single Pond Flow Ind	2,979,600		ć1 00		\$1.00 -	
Total Pond Flow Ipd	148,980,000	Secondary Dewater	\$1.00			
Pond volume liters	40,000,000	Centrifuge 20% solids	\$0.80 - \$1.59	\$1.59	\$0.80 -	
		Centrifuge 20% solids			40.00	
		Membrane Filtration	\$0.60 -		\$0.60	
	Other Inputs				\$0.40	
Electricity Cost	\$0.10	Natural Gas	\$0.40 -		\$0.40	
lant Recov CO2 Cost oper mt	\$50.00	Natural Gas	40.00		\$0.20 -	
Natural Gas Price per MMBtu	\$7.00	Natural Gas	Ş0.20 -		VOILO	
Sov meal price per mt	\$200.00	Solar	\$0.00 S0.00\$0.00	n 📕	\$0.00	
Land Price per acre	\$3,000,00	None	30.00	× 1		
Total to Pond Acres	1.50		Cost Noo elec	්		
Water Price per acre-ft	\$20.00	Oil Recovery	oral corredit Net	· •	Operating =	Capital
Water Price per cu m	\$0.016	W/O/S Centrifuge	10 N836 (1			
Kadam (1997) cost	\$40.00	Hexane	dit			
Inflation adjusted	\$49.46	W/O/S Centrifuge	Cler			
	••••••					
		Other	VG Improved Centr	ifugal Extra	ction	
		Oulei	2 day residence			
		Vellow indicators input	2 day residence			
	0.00000.000	Tellow Indicates Input	4.03 g/l biomass			
Natural Gas Price per MJ	0.00663472	Blue indicates calculation				
Natural Oce Drive Di	0.000007		100% recycle			
Natural Gas Price per Btu	0.000007					