What Will it Take to Make Algae Biofuels Profitable?

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AFPC

NAABB National Alliance For Advanced Biofuels and Bio-products

Statement About the Slides

- These overhead slides have been augmented with text in an attempt to replicate the presentation at the ABO meeting.

Introduction

- We have developed a Monte Carlo simulation model of an open raceway algae farm. The model calculates the CAPEX (capital expense) and OPEX (operating expense) to simulate the annual profits of a farm for 10 years
- CAPEX is calculated by the model based on the engineering specifications of the farm, size of farm, water source, CO2 source, harvesting and extraction method, etc.

Introduction

- Stochastic variables, such as:
  - Temperature and Precipitation
  - Production (g/L/d)
  - Percent oil content
  - Percent of high valued oil
  - Input Prices (nutrients, labor, interest rates, electricity, rates of inflation, etc.)
  - Output Prices (lipids, high valued co-products, lipid extracted algae)

Introduction

- OPEX is calculated each year of the 10 year planning horizon using the business plan assumptions and the stochastic values for all random variables
- In this manner the model incorporates CAPEX and market risk that an algae farm will likely face
- Location of the farm and business plans are scenarios to be analyzed

Introduction

- Output from the Monte Carlo simulation model are probability distributions for Key Output Variables over the 10 year planning horizon
- The output probability distributions are used to calculate the probability of economic success for the farm scenario being analyzed

Objective

- Use the simulation model for a representative commercial-size algae farm in the Southwest to identify values for major control variables that give a 90% chance of economic success for the farm
- Economic success is the probability that net present value (NPV) is positive, so the internal rate of return exceeds the discount rate of 5%.

Methodology

- To test the economic viability of the algae industry, we analyzed the representative algae farm under 11 different scenarios:
  - Four examine alternative facility sizes
  - Four examine alternative water depths
  - Three examine alternative sources of CO_2

Methodology

- First, the simulation model was used to develop a base pathway from accepted values in the literature
- Second, these values were changed until the farm hah a 50% probability of economic success
- Next, individual control variables were changed one at a time until the probability of economic success was 90%

Initial and Base Scenarios

- The values for the major critical control variables under the historical/literature scenario are presented in the first column of the next slide
- The values necessary to give the farm a 50% chance of economic success are in the second column

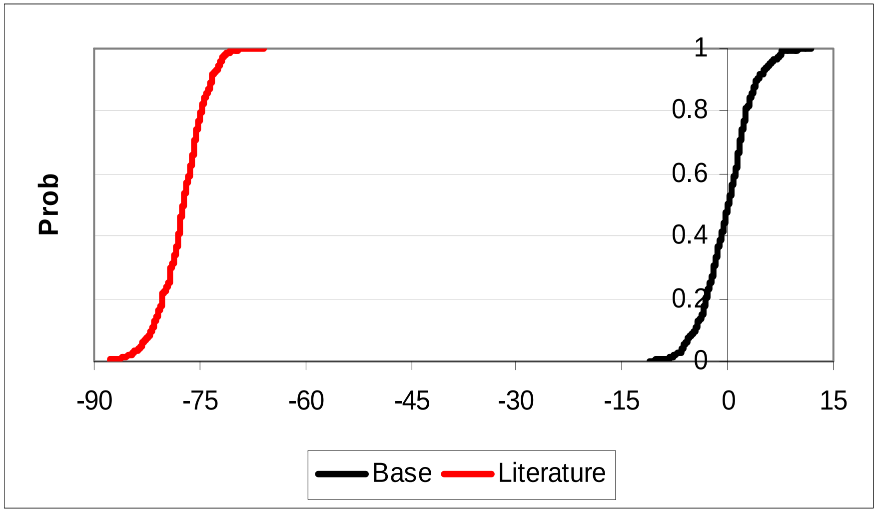
Base Pathways

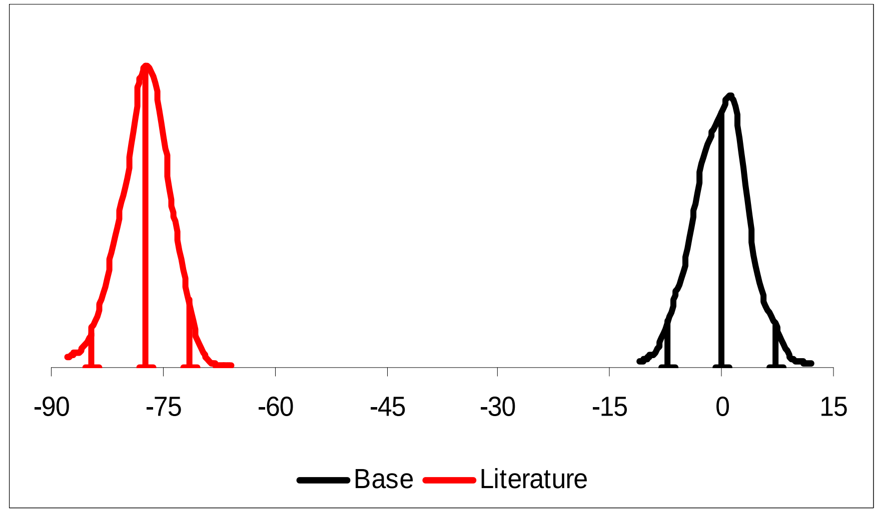
Description	Literature	Base
Facility Size (AF of Water)	500	500
Water Depth (inches)	8	12
High-Value Oil (%)	2.00	5.00
Production Level (g/L/day)		
Min	0.0392	0.09732
Mid	0.0490	0.12165
Max	0.0588	0.14598
Lipid Content (%)		
Min	27.00	36.00
Mid	30.00	40.00
Max	33.00	44.00
Harvest & Extraction Capital Cost Installed (million $)	12.50	12.50

Comparison of Base Scenarios

- The results from simulating the literature and base scenarios are summarized in the next slide
- Cumulative distribution functions (CDF) of the NPV are presented in the left side chart
- Read the CDF as the probability on the Y axis that the NPV will be less than the corresponding value on the X axis
  - There is a 50% chance that NPV wil be less than zero for the base scenario

Comparison with Literature





- Using data from literature, there was <u>no chance</u> of economic success. To improve to a 50% chance of economic success, water depth had to increase from 8 to 12 inches (50% increase), percent high-value oil had to increase by 150%, percent lipid content had to increase by 33% and production had to increase by 148%.

Comparison of Production Scenarios

- Values for the farm's major control variables were changed one at a time until the CDF for the new scenario shifted to the right and crossed the Y axis at 10% (resulting in a 90% chance of economic success)
- The final values for these variables are summarized in the next two slides
- Charts summarizing the simulation results for these scenarios are presented next

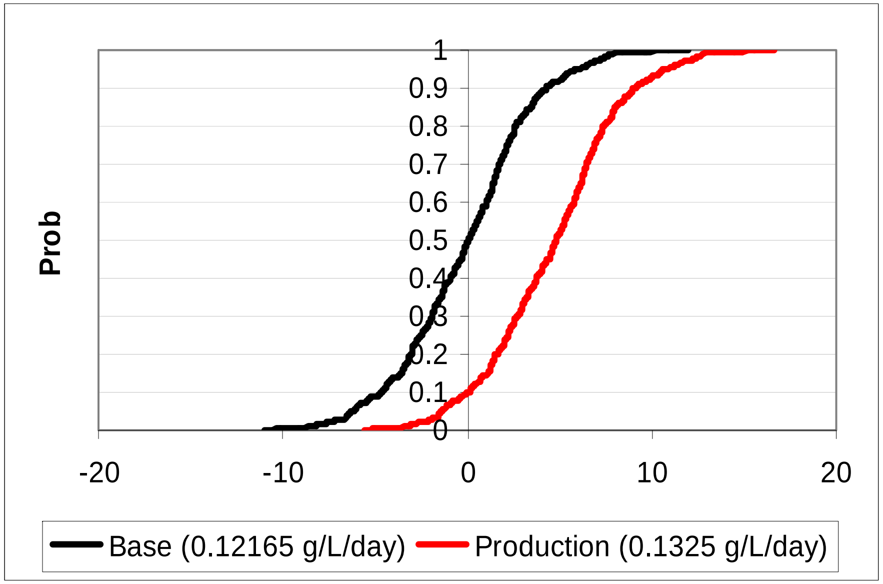
Pathways with 90% Success

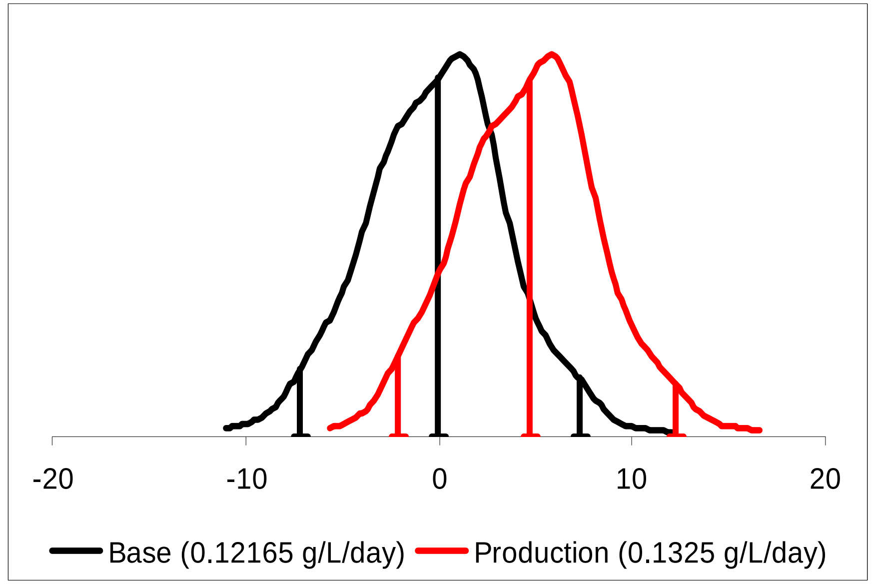
	Pathways with 90% Chance of Success			
Description	**Base**	**Facility Size**	**Facility Size**	**Harvest Capital Cost**
Facility Size (AF of Water)	500	1,725	1,750	500
Water Depth (inches)	12	12	12	12
High-Value Oil (%)	5.00	5.00	5.00	5.00
Production Level (g/L/day)				
Min	0.09732	0.09732	0.09732	0.09732
Mid	0.12165	0.12165	0.12165	0.12165
Max	0.14598	0.14598	0.14598	0.14598
Lipid Content (%)				
Min	36.00	36.00	36.00	36.00
Mid	40.00	40.00	40.00	40.00
Max	44.00	44.00	44.00	44.00
Harvest & Extraction Capital Cost Installed (million $)	12.50	32.50	32.50	6.01

Pathways with 90% Success

Description	Base	Production	Percent Lipid Content	Percent High-Value Oil	Water Depth	Water Depth
		Pathways with 90% Chance of Success				
Facility Size (AF of Water)	500	500	500	500	500	500
Water Depth (inches)	12	12	12	12	14	16
High-Value Oil (%)	5.00	5.00	5.00	6.12	5.00	5.00
Production Level (g/L/day)						
Min	0.09732	0.1060	0.09732	0.09732	0.09732	0.09732
Mid	0.12165	0.1325	0.12165	0.12165	0.12165	0.12165
Max	0.14598	0.1590	0.14598	0.14598	0.14598	0.14598
Lipid Content (%)						
Min	36.00	36.00	41.60	36.00	36.00	36.00
Mid	40.00	40.00	46.22	40.00	40.00	40.00
Max	44.00	44.00	50.84	44.00	44.00	44.00
Harvest & Extraction Capital Cost Installed (million $)	12.50	12.50	12.50	12.50	12.50	12.50

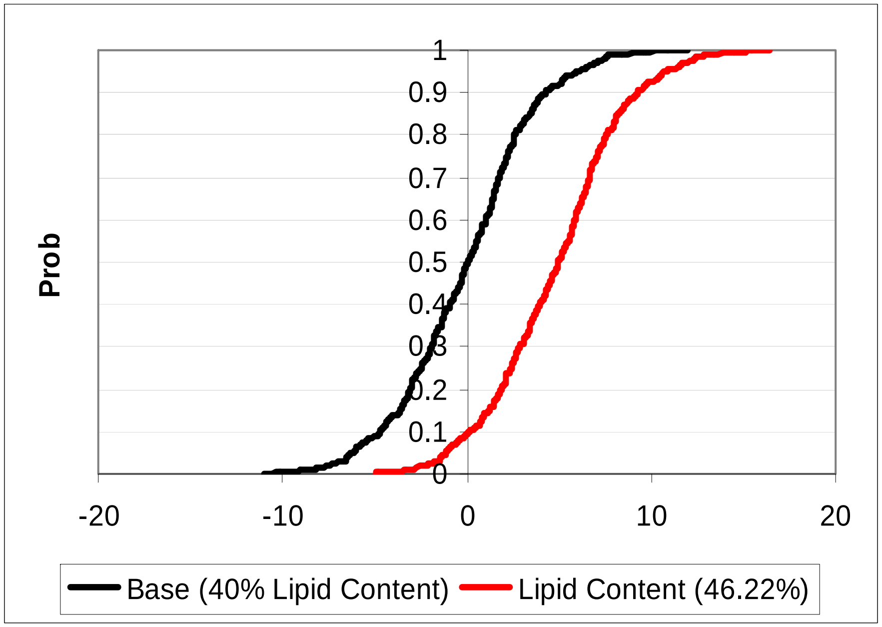
Production Scenario

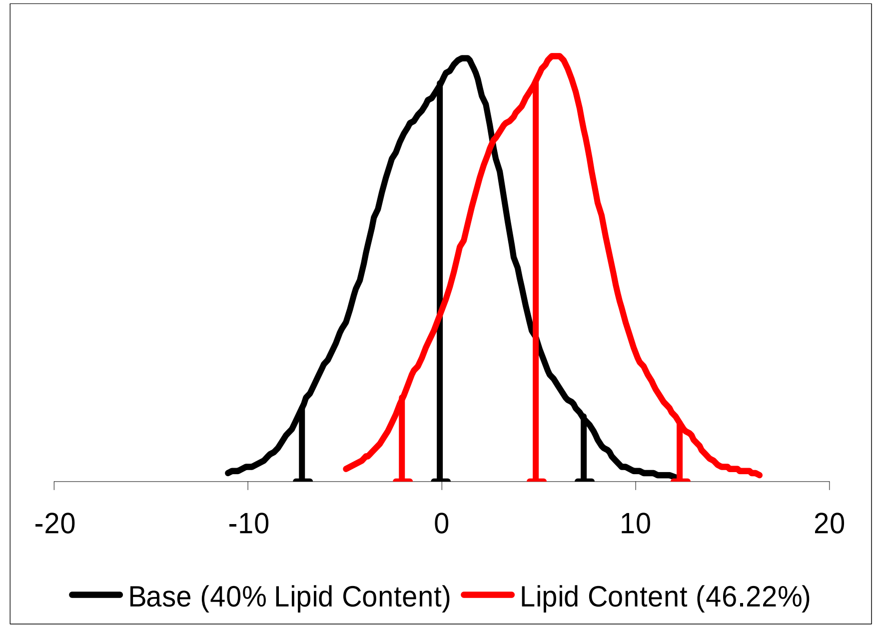




- To increase the probability of economic success from 50% in the base case to 90%, production has to increase from 0.12165 g/L/day (or 37.08 g/m^2/day) to 0.1325 g/L/day (or 40.39 g/m^2/day), an increase of 8.92%.

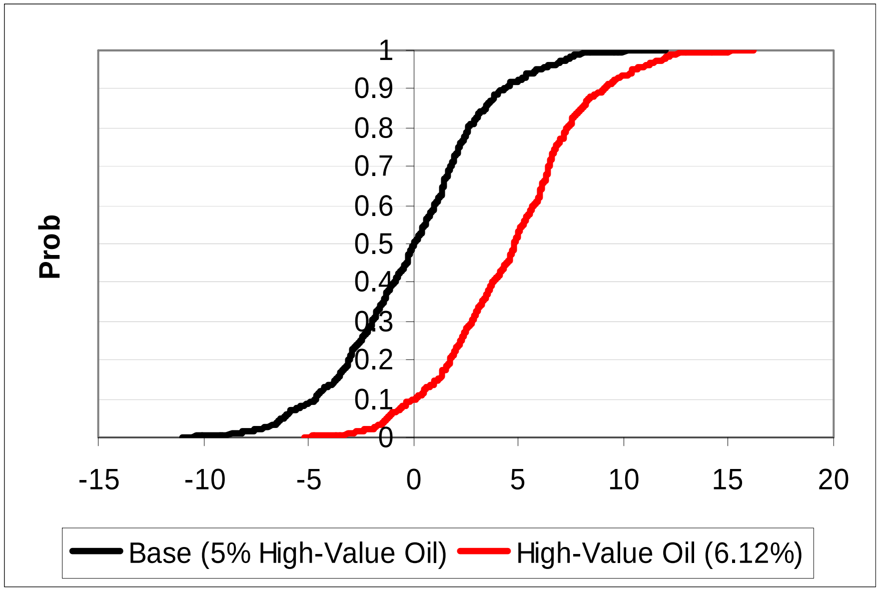
Percent Lipid Content Scenario

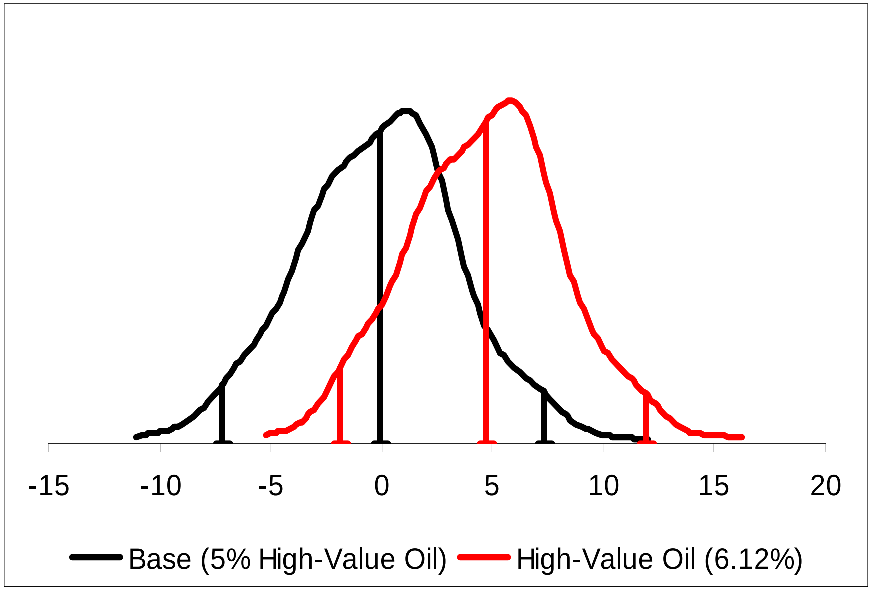




- To increase the probability of economic success from 50% in the base case to 90%, percent lipid content had to increase from 40% to 46.22%, a percent increase of 15.55%.

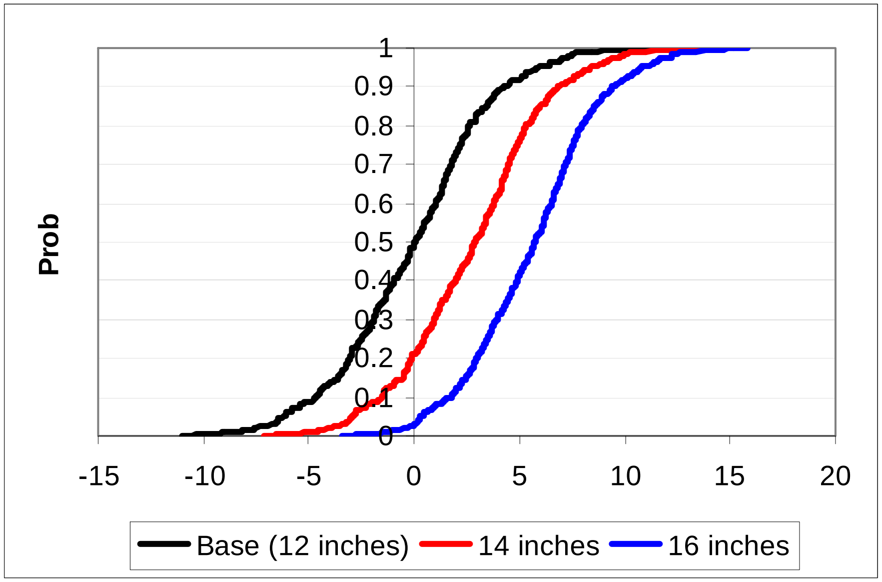
Percent High-Value Oil Scenario

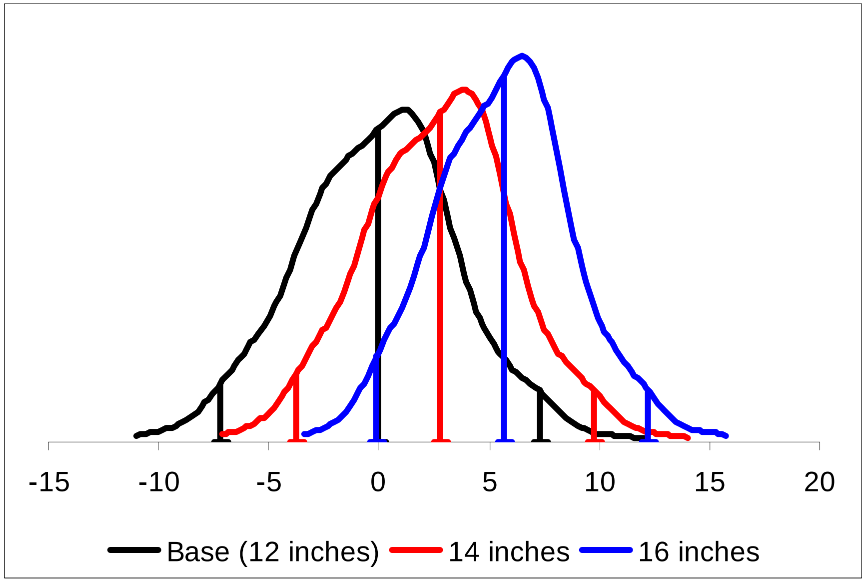




- To increase the probability of economic success from 50% in the base case to 90%, percent high-value oil content had to increase from 5% to 6.12%, a percent increase of 22.4%.

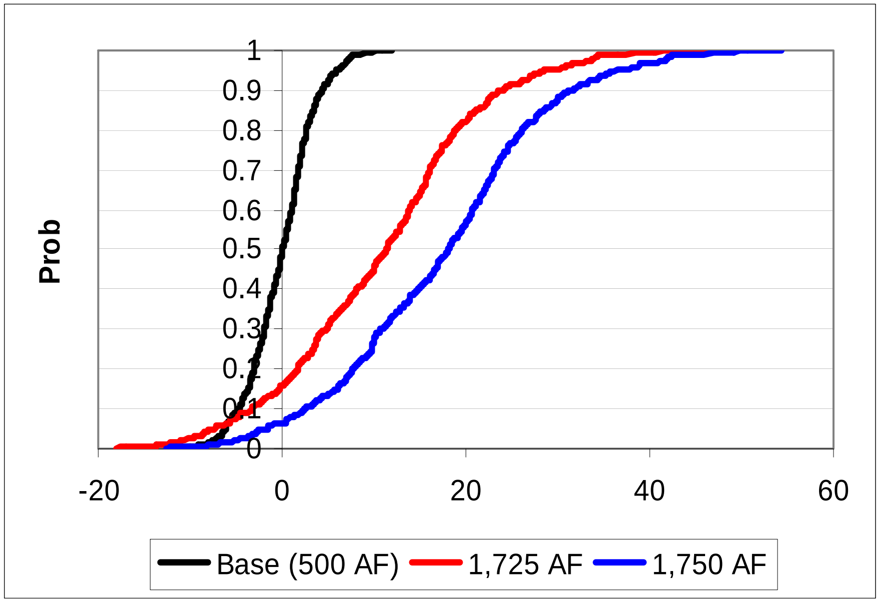
Water Depth Scenario

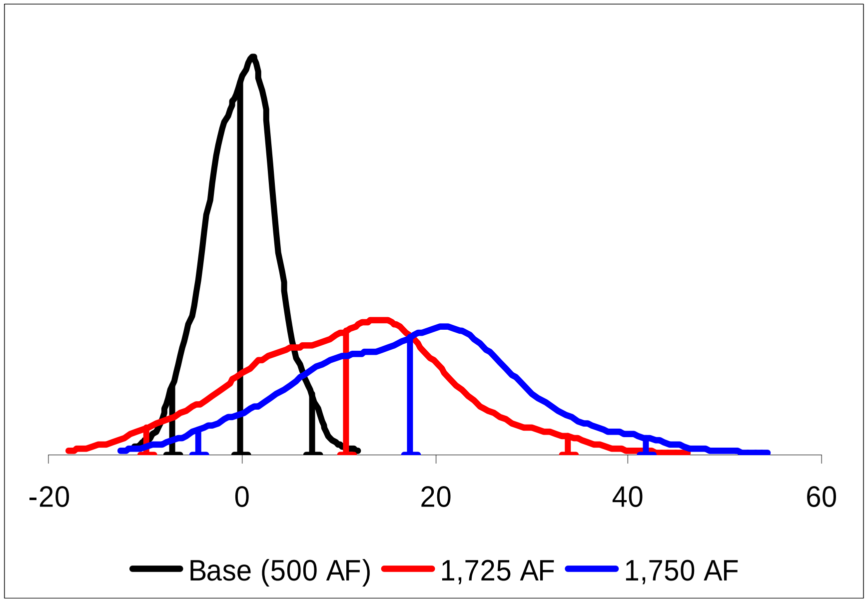




- To increase the probability of economic success from 50% in the base case to 90%, water depth had to increase from 12 inches to between 14 and 16 inches, an increase of between 16.67% and 33.33%.

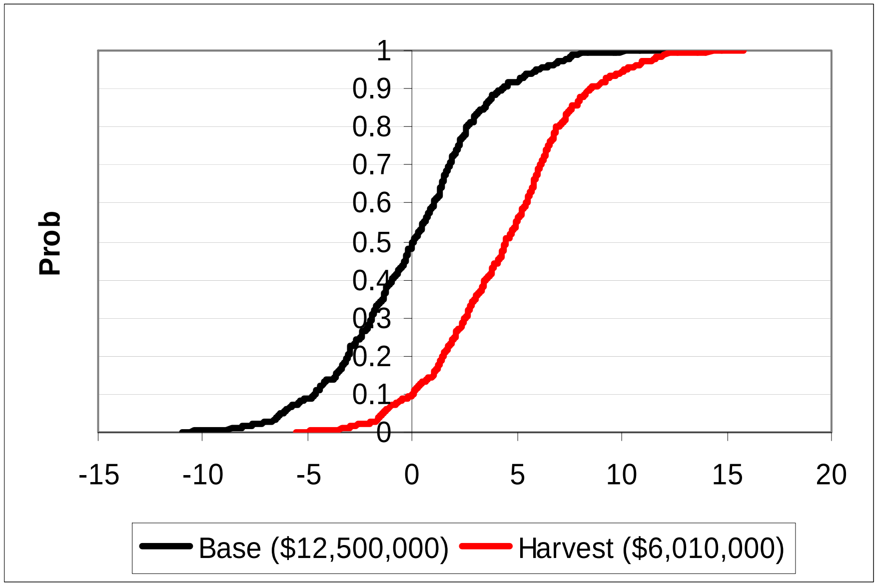
Facility Size Scenario

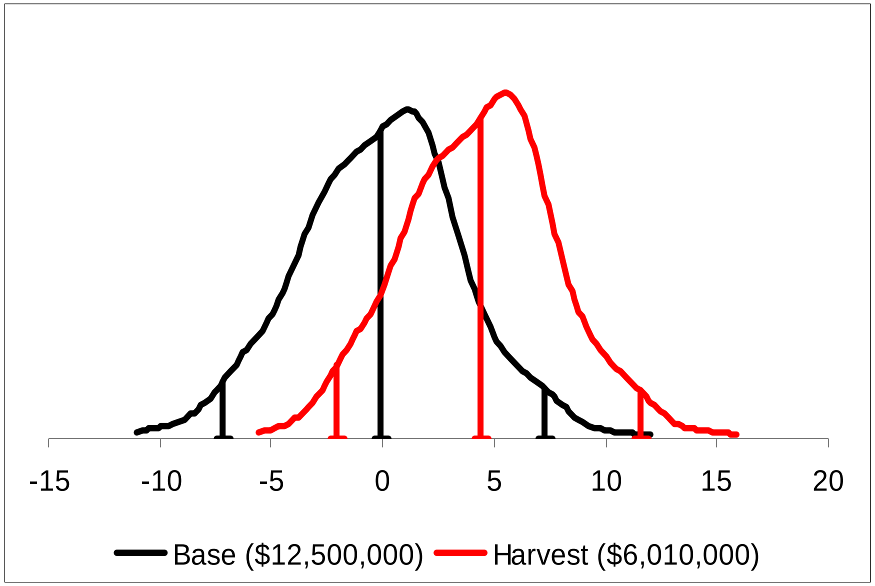




- To increase the probability of economic success from 50% in the base case to 90%, facility size had to increase from 500 acre feet to between 1,725 and 1,750 acre feet, an increase of between 245% and 250%. This indicates that economic success is not very sensitive to facility size.

Harvest Capital Cost Scenario





- To increase the probability of economic success from 50% in the base case to 90%, harvest and extraction capital costs had to decrease from $12,500,000 to $6,010,000, a decrease of 51.92%.

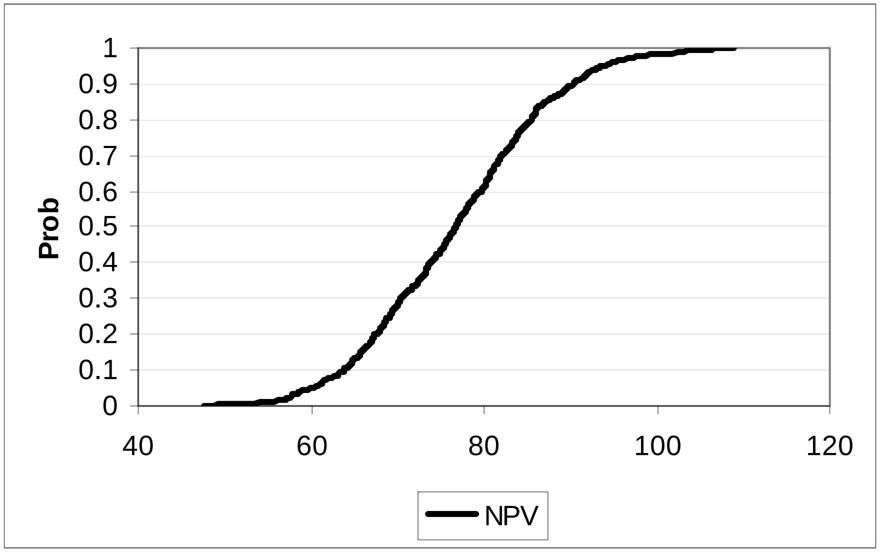
Combination Scenario

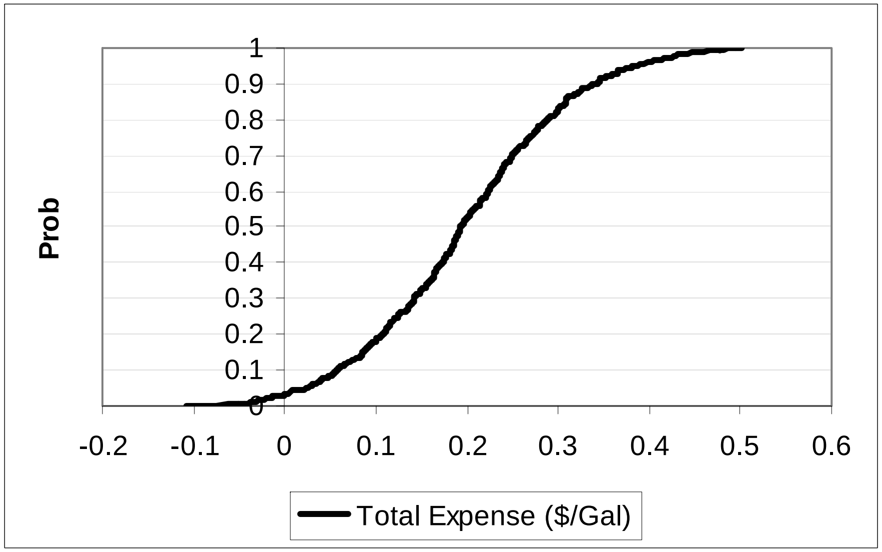
- The next was to simulate a scenario that was a combination of the alternative values for the control variables
- The next slide shows the range of values used for the final scenario. The "maximum" scenario used the assumptions used for each of the previous slides to achieve a 90% chance of economic success (yellow highlighted values in previous tables)
- Time does not permit running the near infinite combination of assumptions so for the "combination" scenario we used the average between the "Base" and "Maximum" scenarios

Multiple Improvements

Description	Literature	Base	Maximum	Combination
Facility Size (AF of Water)	500	500	1,750	1,125
Water Depth (inches)	8	12	16	14
High-Value Oil (%)	2.00	5.00	6.12	5.56
Production Level (g/L/day)				
Min	0.0392	0.09732	0.1060	0.1017
Mid	0.0490	0.12165	0.1325	0.1271
Max	0.0588	0.14598	0.1590	0.1525
Lipid Content (%)				
Min	27.00	36.00	41.60	38.80
Mid	30.00	40.00	46.22	43.11
Max	33.00	44.00	50.84	47.42
Harvest & Extraction Capital Cost Installed (million $)	12.50	12.50	6.01	9.26

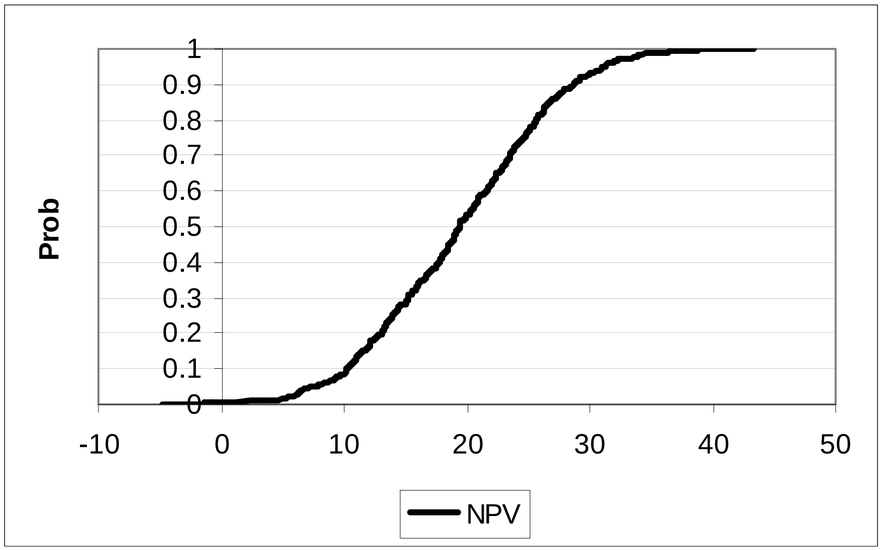
Maximum Improvement

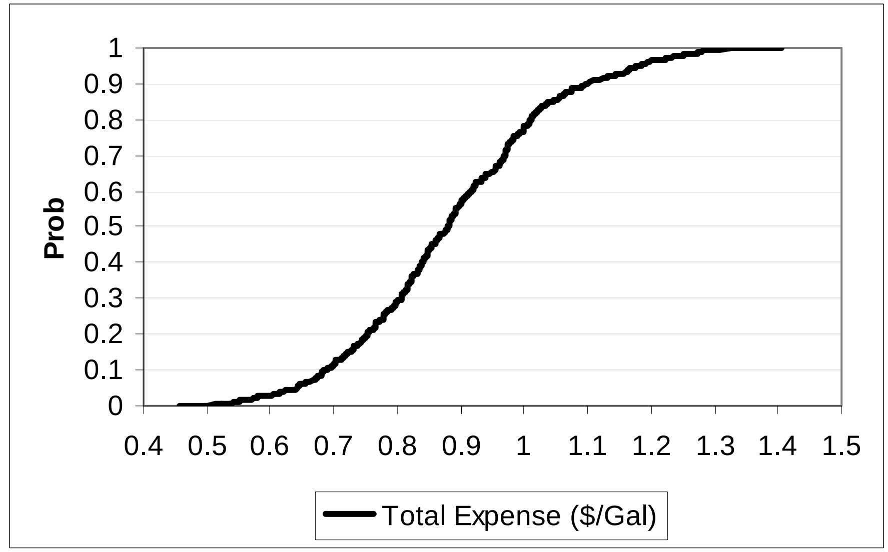




- If all improvements from the previous slides are implemented simultaneously, there is a 100% probability of economic success. There is also a 3.22% probability that revenue from co-products alone will more than offset the total expense of producing algae oil.

Combination of Improvements





- Even if only "average" improvements are made to the variables of interest in the preceding slides, there still is a greater than 99% probability of economic success. There is a 77.8% probability that total expenses will be less than $1 per gallon of algae oil produced.

Conclusion

- Improving significantly upon previous research is important for achieving even a 50/50 probability of economic success.
- Improving that outlook to a 90% probability of economic success will require even greater increases in production levels, percent lipid content, and percent high-value oil content, along with increasing pond water depth. However, maximum improvement on all fronts is required for achieving economic success.
- We must focus on a systems approach to improving the profitability of algae farms.
- Successful ventures will avoid optimizing one variable at a time, but will rely on a systems approach.
- There is a significant need for continued research on: strain selection, cultivation, harvesting, and extraction.

Appendix A

- Net Present Value (NPV) is used to calculate economic success
  - NPV = - Beg Net Worth + PV of Ending Net Worth + ∑(PV of Dividends Paid for 10 years)

    where PV is the present value calculated at a 5% discount rate
- If NPV is positive, the internal rate of return is greater than the discount rate.
- If NPV is positive for 90% of the iterations for the model, then we can say the farm will have a 90% chance of economic success.

Thank you…

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