


Economic Analysis of Dry-Milling Technologies

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DOE Grant # DE-FG36-04G014220

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The Dry Mill Ethanol Model

- We have developed a descriptive engineering (process) model to incorporate a fair amount of detail on costs and conversion efficiencies at each step of the production process.
- The model contains flexibility to enter certain key variables in more than one way; e.g., DDGS price can be a function of corn and SBM or independent

The Dry Mill Ethanol Model

- The dry mill model is composed of several modules:
  - Variables and assumptions (3 pages)
  - Process
  - Equipment size and costs
  - Total fixed cost
  - Revenue and variable cost
  - Finance
  - Benefit cost

The Dry Mill Ethanol Model

- The **variable** module is where users input all variable and assumptions - biological, mechanical, and economic - about the ethanol production process. The assumptions fall into three primary categories: technical process, economic assumptions, and parameters.
- The most important assumptions are the choice-variables. The yearly output and number of hours of operation per year directly affect the size of the equipment needed and the flow rate of operation.

The Dry Mill Ethanol Model

- All cells are color coded for ease of use

Variable Color Coding	
Direct Input	Constant Input
Calculation	
Trigger	Function Value
Information and/or Description	
Flow Rate In	Flow Rate Out
Flow Rate In = Out	
look up table	

The Dry Mill Ethanol Model

- Types of assumptions:
  - Plant operation
  - Conversion
  - Equipment (RTD, No., temperature)
  - Physical property
  - Solid percentages
  - Distillation/evaporation
  - Grain composition
  - Economic and price assumptions
  - Loan parameters

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Dry Mill Process Assumptions:

Plant Operation

Plant Variable	Excel Name	Value
Name Plate Gallons per Year	tcap	40,000,000
Actual Gal Produced per Year	cap	38,000,000
Operational Hours per Day	hours	24
Operational Days per Year	days	365
Operational Hours per Year	ophours	8322
% Utilization	Utiliz	95%

Plant Operation Assumptions

1	
If D13 = 1 then actual GPY = Capacity X	95%
If D13 = 0 then actual GPY =	39,452,055
with number of operation hours =	24
with number of operation days =	360

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The Dry Mill Ethanol Model

Currently Using Function Price		Manual Price	Function Price
1	EtOH Price = f(gas)	$1.90	$1.46
160	Gasoline (cents/gallon)	P-value = 0	R2 = .62
Currently Using Manual Price		**Manual Price**	**Function Price**
0	DDGS Price = f(SBM, corn)	$60	$60
150	SBM (dollars/ton)	P-value = 0	Adj R2 = .73
84	Corn (dollars/ton)	P-value = 0	
Currently Using Manual Price		**Manual Price**	**Funtion Price**
0	Jet Cooker Price = f(Tcap)	$100,000	$118,531
40000000	Total Capacity (mgy)		

The Dry Mill Ethanol Model

- In the **process** module, yearly output of ethanol is converted to hourly flow rates using conversion efficiency rates and other assumptions. The per hour output is fed backwards through the processing modules to find the amounts and flow rates required for this level of production.
- Energy and water use is tracked in the process module.

The Dry Mill Ethanol Model

	Yields						
	Input	Intermediate Products		Products			
	Corn	Starch	Glucose	CO2	EtOH		DDGS
	Pounds	Pounds	Pounds	Pounds	Pounds	Gallons	Pounds
Theoretical	1.00	0.75	0.83	0.41	0.43	0.06	0.25
Conversion	56.00	39.09	43.39	21.22	22.17	3.36	13.03
Actual Conversion	56.00	39.09	41.23	**17.14**	**17.91**	**2.72**	**17.75**
Product / Input	100%	75%	79%	32.89%	34.37%		34.06%

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The Dry Mill Ethanol Model

Avg. Utility Use / Gal of EtOH Produced		
Utility	Unit	
Energy	Thermal (Mbtu)	33,557
	Electrical (kWh)	1.14
Water	fresh (gal)	4.90
	backset (gal)	1.22
	Total (gal)	6.12

The Dry Mill Ethanol Model

- In the **equipment size and cost** module, the size of the equipment needed is calculated from flow rates, electrical and heating requirements, that vary with plant capacity.
- Tank and reactor sizing is estimated through use of total capacity flow rates and residence time (RTD).
- The estimated cost of individual pieces of equipment is calculated using their respective size estimates.

The Dry Mill Ethanol Model

- In the **total fixed cost** module, the sum of equipment costs is used to calculate total fixed capital investment for the plant.
- Two methods were used to calculate total capital cost:
  - Fixed cost investment percentage (FCI)
  - Ratio of delivered equipment cost (RDE)
  - The RDE method works better for small plants between 10 and 40 mil. gal., and the FCI method is better for plants exceeding 65 mil. gal.
  - Between 40 and 65 mil. gal., a combination of the two approaches was used.

Description	FCI Cost Est.	RDE Cost Est.
Purchased Equipment	$10,272,307	$10,272,307
Pur. Equip Instillation	$3,588,579	$4,827,984
Instrumentation	$4,216,580	$3,698,031
Piping	$3,274,578	$6,985,169
Electrical	$2,063,433	$1,129,954
Buildings (service)	$2,063,433	$1,849,015
Yard Improvements	$807,430	$1,027,231
Service Facilities (instld)	$6,190,299	$7,190,615
Total Direct Capital Costs	$32,476,639	$36,980,306
Engineering & Supervision	$3,364,293	$3,389,861
Construction Expense	$4,126,866	$4,211,646
Legal Expense	$807,430	$410,892
Contractors Fee	$807,430	$2,259,908
Contingency	$3,274,578	$4,519,815
Total Indirect Capital Costs	$12,380,597	$14,792,122
Capital Cost Estimate	**$44,857,236**	**$51,772,428**

The Dry Mill Ethanol Model

- In the **revenue and variable cost** module, the flow rates from the process module are used to calculate annual variable costs and input usage plus annual revenue and outputs.
- In the **finance** module, the fixed costs are combined with finance assumptions and annual revenue and variable costs to produce annual cash flows. Nominal financing flows are deflated to be compatible with the costs and returns, which are in real terms.
- The **benefit-cost** module calculates the return to equity under different assumptions.

The Dry Mill Ethanol Model

Yearly Revenues					
Product		**$**	**per**	**Yearly Output**	**Yearly Revenue**
EtOH:					
	denatured	$1.46	gal	41,424,658	**$60,517,282**
	hydous	$1.39	gal	41,267,840	
	anhydrous	$1.46	gal	39,452,055	
DDGS:					
	wet	$30.00	ton	603,607,399	
	dry	$60.00	ton	257,696,990	**$7,730,910**
Other:					
	CO2	$6.00	ton	248,795,775	**$746,387**
	Subsidies	$0.00	gal	39,452,055	$0
Total Annual Revenue					**$68,994,579**

Financial Table

Information			Calculations		
Loan Info:	Loan Years	15		Total Capital Costs	$51,772,428
	Expected Life of Plant	25	(+)	Working Capital	$7,765,864
	Years till Operational	3	(=)	Capital Invst	**$59,538,292**
Loan Info:	Year (1) Invst / Total Invst	60%	(+)	Accrued Interest	$2,582,567
	Year (2) Invst / Total Invst	40%	(=)	Total Cptl Invst	**$62,120,860**
	Initial Equity / Capital Invst	40.0%	**Lender Equity Requirement**		**$24,848,344**
	Initial Loan / Capital Invst	60.0%	**Total Loan Ammount**		**$37,272,516**
	Sweep Pmnt / Profits	40%		Year 1	$22,363,509
	Working Capital / Total Invst	15%		Year 2	$14,909,006
Rates:	Discount	12.0%	**Scheduled An. Loan Pmnt**		**$4,354,531**
	Real Discount	8.7%	**Profits (gross)**		**$10,752,144**
	Inflationary	3.0%		Net	$6,397,613
	Interest	8.0%		Sweep Payment	$2,559,045
	Real Interest	4.9%		other	$3,838,568

The Dry Mill Ethanol Model: Capital Costs Comparisons

Capital Cost Estimates			
	DM Model Estimates		BBI Estimates
Nameplate Gallons	Total Fixed Cost	$ / Gallon	$ / Gallon
100,000,000	103,500,000	1.04	1.05
85,000,000	88,114,000	1.04	1.05
65,000,000	72,746,000	1.12	1.15
50,000,000	60,439,000	1.21	1.25
40,000,000	51,772,000	1.29	1.35
30,000,000	41,398,000	1.38	1.45
20,000,000	30,813,000	1.54	1.65
15,000,000	25,256,000	1.68	1.75
10,000,000	19,297,000	1.93	1.95

The Dry Mill Ethanol Model

- With the estimates of total costs, variable costs, and revenue, the financing of the plant can be calculated. At different interest rates, loan terms, and sets of assumptions, the NPV, IRR, and cash flows are computed.

Future Activities

- Our future work will consist of refining the base version of the model, building the module(s) for evaluating new technologies, and incorporating uncertainty into the model by using input distributions of key uncertain variables and conducting Monte Carlo simulation to obtain the inherent uncertainty in key output variables.
- A draft user's guide for the model including an explanation of all the equations is being produced. It will be checked by our colleagues.