


Economic Analysis of a Modified Dry Grind Ethanol Process with Recycle of Pretreated and Enzymatically Hydrolyzed Distiller's Grains

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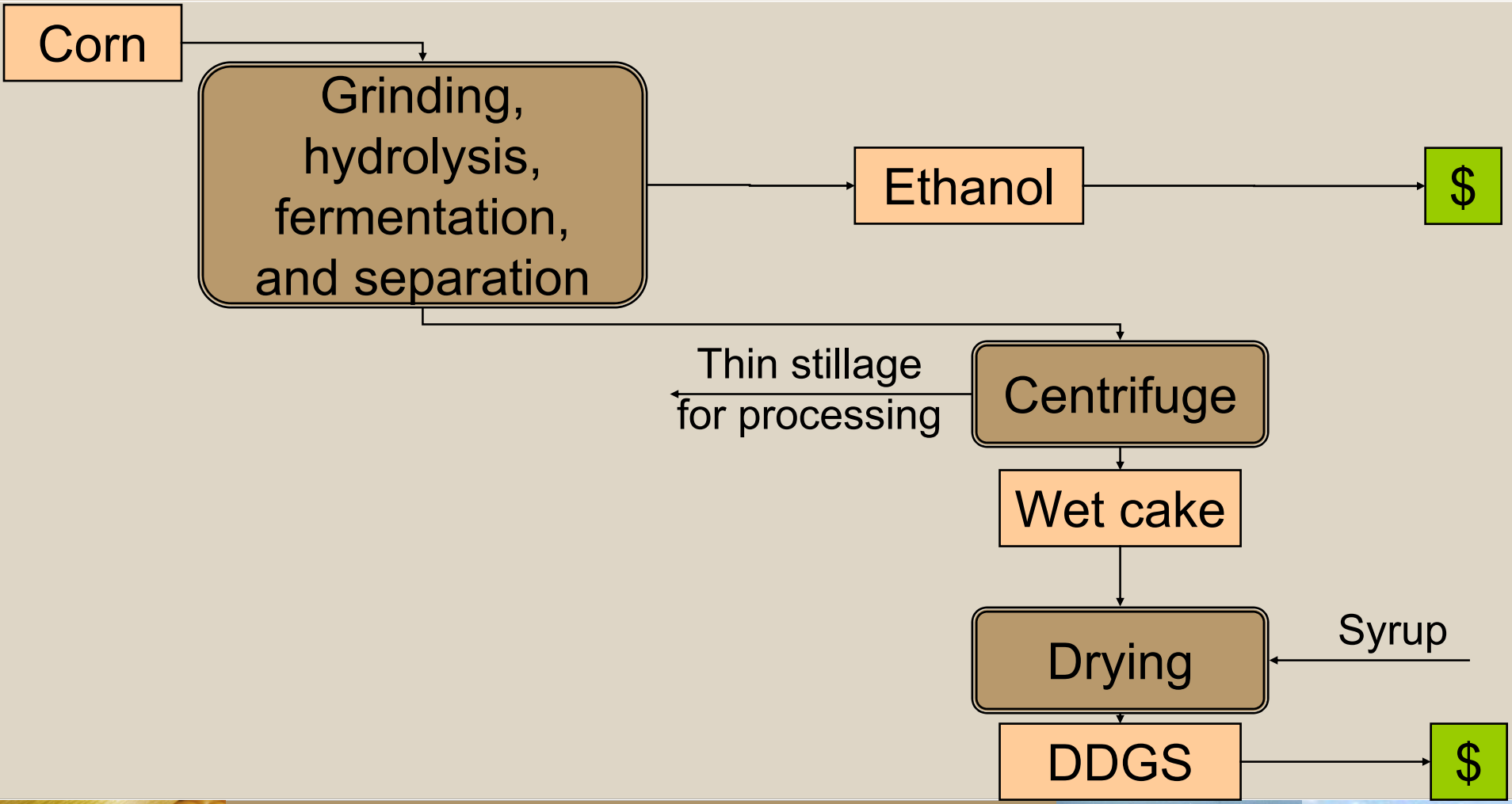
Midwest Consortium for Biobased Products & Bioenergy


Traditional Dry Grind Process



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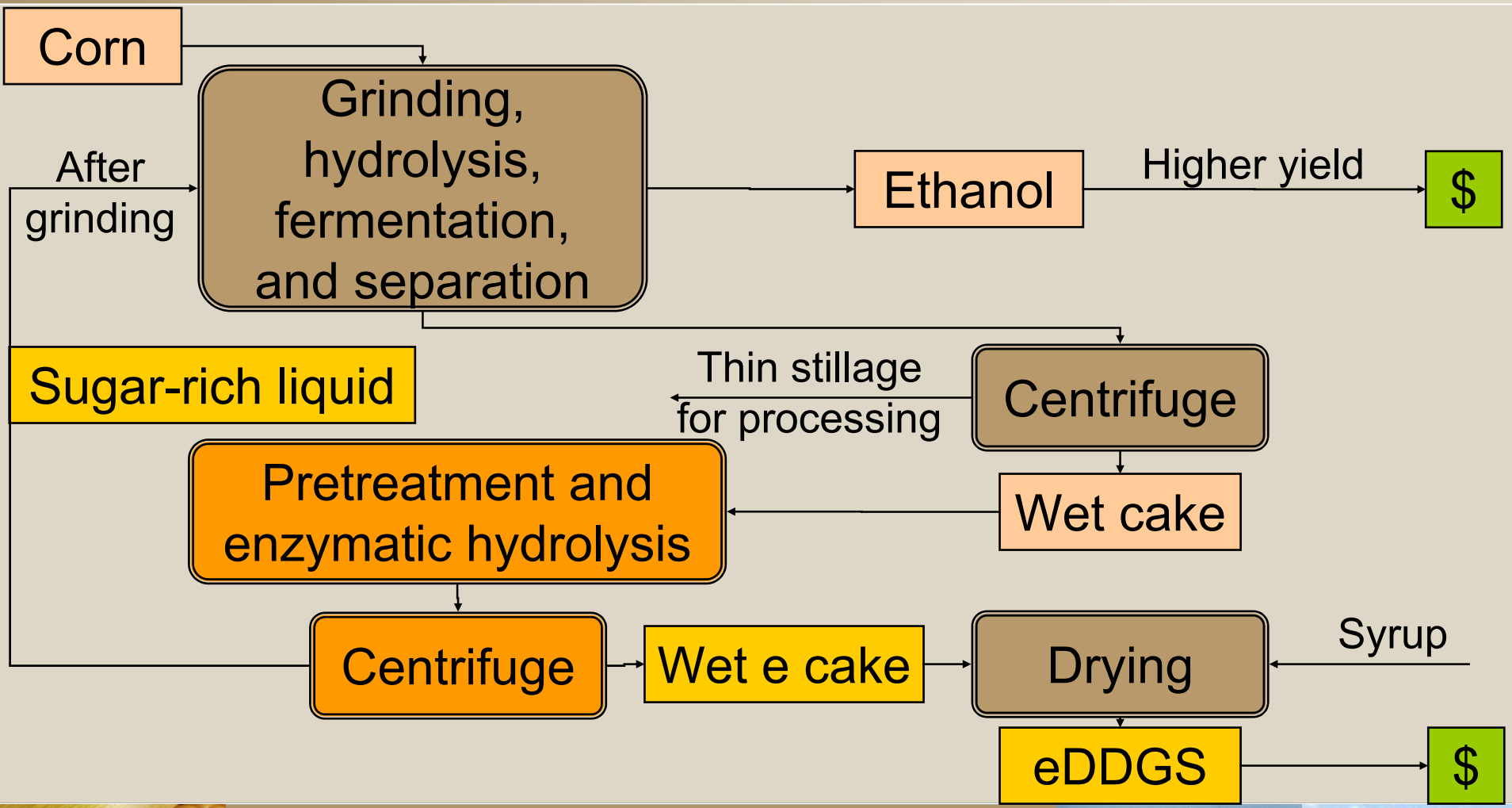
Modified Dry Grind Process



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Summary of Modifications

- Process
  - Wet cake/thin stillage mixture pretreated (jet cooker)
  - Sent to saccharification tank for enzymatic hydrolysis
  - “Pretreated” mixture centrifuged
  - Enhanced wet cake converted to eDDGS
  - Liquid from centrifuge recycled to liquifaction tank
- Final products
  - Higher ethanol yields
  - eDDGS (enhanced DDGS) richer in protein

Hypotheses

- Value added to outputs
  - Higher ethanol yields
  - Higher value of protein-rich eDDGS

- Higher NPV for modified process

  (NPV ≡ Net Present Value of project)

Financial Assumptions

- Equal corn feed basis
- Project years: 25 (2 construction, 23 production)
- Plant size: 100 million gallons (base)
- Debt/equity ratio: 60/40
- Debt interest rate: 8.7%
- Equity return minimum: 12.0%
- Inflation rate: 3.0%

Sources of Financial Change

Financial Changes	NPV (millions)
Traditional process ->	$162.0
Revenue from ethanol	+ ?
Manufacturing costs	- ?
Revenue from DDGS	+/- ?
Pretreatment process ->	= ?

Revenue from Ethanol

	Traditional Process	Modified Process
Ethanol Yield (gal./yr.)	100,000,000	112,670,293
Price ($/gal.)	$2.23*	$2.23*
Revenue ($/yr.)	$223,000,000	$251,254,754
NPV adjustment (millions) →		+ $189.0

*price sensitivity later

Sources of Financial Change

Financial Changes	NPV (millions)
Traditional process ->	$162.0
Revenue from ethanol	+ $189.0
Manufacturing costs	- ?
Revenue from DDGS	+/- ?
Pretreatment process ->	= ?

Manufacturing Costs

- Approach
  - Developed and validated a financial model for the traditional dry grind process (DM Model*)
  - Incorporated a module to model the new technology
  - Matched assumptions of the model to the material balances and determined the impact

*Dale and Tyner, 2006

Traditional Process (DM) Model

- Assumptions concerning physical properties and process reactions are entered

Dry Mill Process Assumptions: Solid / Liquid Percentages		
Product	**Moisture %**	**Solids %**
Corn	15.0%	85.0%
Mash	68%	32%
Beer	87%	13%
Whole Stillage	64%	36%
WDG (Wet Cake)	65%	35%
WDGS	65%	35%
Thin Stillage	88%	12.0%
Syrup	64%	36%
DDGS	15%	85%

Traditional Process (DM) Model

- Economic assumptions are provided

Economic Assumptions: Prices / Values			
Variable		**Unit**	**Value**
Ag Goods	Dent Corn	$ / Ton	$136
	Soy Bean Meal	$ / Ton	$217
Chemicals	Alpha Amalayse	$ / lb	$5.50
	Gluco Amalayse	$ / lb	$3.15
	CO2	$ / Ton	$6.36
Utilities	Gasoline	$ / gal	$2.27

Traditional Process (DM) Model

- The model generates mass and energy balances, sizes and costs the equipment, and compiles other capital costs.

Itemized Expenditures	Cost Estimate	% of FCI
Purchased Equip	$30,015,719	22.9%
Instrumentation	$12,320,863	9.4%
Piping	$9,568,330	7.3%
Electrical	$6,029,358	4.6%
Buildings	$6,029,358	4.6%
Yard Improvement	$2,359,314	1.8%
Service Facilities	$18,088,075	13.8%

Traditional Process (DM) Model

- Input costs, capital costs, and loan terms are finalized, and costs and benefits are summed for each year to calculate NPV.

Year	Costs						
	TCI	Loan		Variable		Total	
	Real	Nominal	Real	Real	Nominal	Real	Nominal
1	35,582,502					35,582,502	36,649,977
2	23,721,668					23,721,668	25,166,318
3		11,912,617	10,901,732	229,165,569	250,415,405	240,067,301	262,328,022
4		11,912,617	10,584,206	229,165,569	257,927,867	239,749,775	269,840,484
5		11,912,617	10,275,928	229,165,569	265,665,703	239,441,497	277,578,320
6		11,912,617	9,976,629	229,165,569	273,635,675	239,142,198	285,548,291
7		11,912,617	9,686,047	229,165,569	281,844,745	238,851,617	293,757,361
...	...	...	...	...	...	...	...
25	(17,187,418)			229,165,569	479,821,812	211,978,152	443,835,176
Net Present Value (benefits net of costs)						**$161,957,921**	**$161,957,921**

Model Validation: DM Model

- Capital Costs
  - DM Model 97% of industry estimate
  - BBI Ethanol Handbook (2004)
- Operating Costs
  - DM Model 103% of industry estimate
  - USDA Cost of Production Survey (2005)

New Technology Module

- Flow, moisture, and energy adjustments
- Equipment resizing
- New equipment (cooker, saccharification tank, and centrifuge)
- Capital/Operating costs and NPV

Manufacturing Costs

Millions of real dollars	Traditional Process	Modified Process
Total Capital Invest	$148.3	$158.5
Operating Costs, Year 3		
-Annual loan payment	$10.9	$11.7
-Grain cost (per yr.)	$136.2	$ 136.2
-New enzymes (per yr.)	$0	$2.5
-Other Costs (per yr.)	$93.0	$102.7
-CO2 revenue (per yr.)	- $2.0	- $2.3
-Total Operating Costs	**$238.1**	**$250.8**
NPV adjustment (millions) →		- $76.5

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Sources of Financial Change

Financial Changes	NPV (millions)
Traditional process ->	$162.0
Revenue from ethanol	+ $189.0
Manufacturing costs	- $76.5
Revenue from DDGS	+/- ?
Pretreatment process ->	= ?

Revenue from DDGS

- Approach
  - Determined nutritional needs in grower swine diet, a large mid-west market with very particular requirements
  - Implemented a linear programming feed model which values DDGS feeds based on their ability to substitute for the various components of swine feed mixtures
  - Determined ratio of shadow values (eDDGS/DDGS) to estimate the value of eDDGS

DDGS Nutrition

- Weight % constraints in swine feed model

	MINIMUM	MAXIMUM
Crude Protein	16.000	
App. Dig. Methionine+Cystine	0.502	
App. Dig. Threonine	0.518	
App. Dig. Tryptophan	0.144	
Calcium	0.720	0.820
Available Phosphorous	0.240	
Crude Fat		8.00
App. Dig. Lysine	0.850	
Isoleucine	0.468	
Valine	0.570	
Vitamin Premix	0.150	0.150

Revenue from DDGS

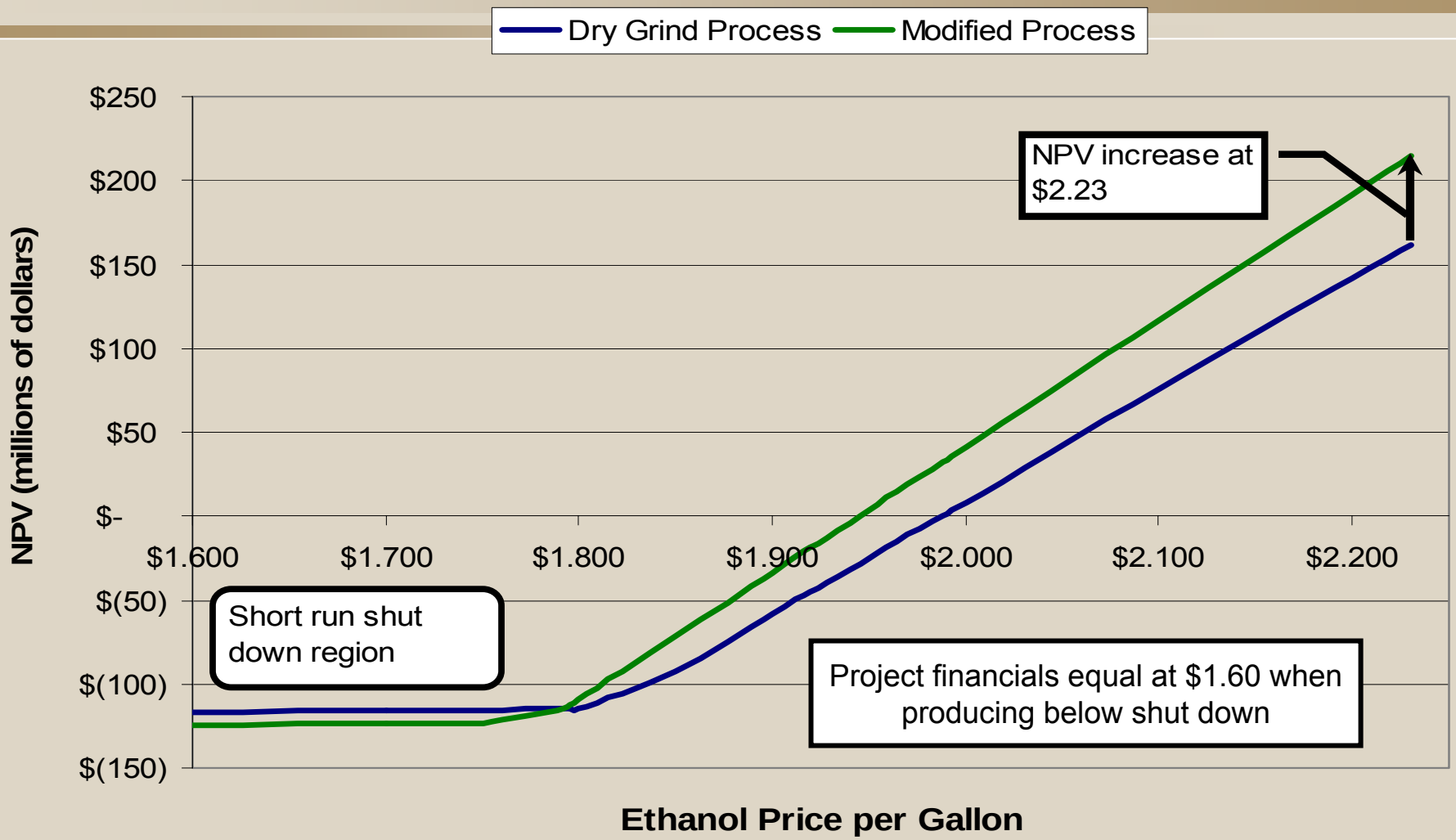
- DDGS/eDDGS used at 12 – 18% in feed

	DDGS	eDDGS
Protein	28.29%	41.20%
Digestible Lysine	0.87%	0.54%
Value ($/ton)	$105.00/ton	$103.38/ton
Output (ton/yr.)	358,997	277,951
Revenue (mil$/yr.)	$37.7	$28.7
NPV adjustment (millions) →		- $59.9

Sources of Financial Change

Financial Changes	NPV (millions)
Traditional process ->	$162.0
Revenue from ethanol	+ $189.0
Manufacturing costs	- $76.5
Revenue from DDGS	- $59.9
Pretreatment process ->	= $214.6 (+32%)

NPV Sensitivity to Ethanol Price



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Economic Conclusions

- The overall project financials are positive as higher ethanol yields of the modified process provide a significant financial boost down to the shut down price (or $1.60 when producing below shut down) and future technical improvements could decrease the breakeven price further.

- The loss of lysine in the wet cake of the modified process holds the eDDGS value flat compared to DDGS, not providing one of the desired benefits.

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