Use of Distillers By-Products & Corn Stover as Fuels for Ethanol Plants

Douglas G. Tiffany
University of Minnesota
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TRANSITION TO A BIO ECONOMY
Integration of Agricultural and Energy Systems

Project Objectives

1. Determine Technical Feasibility of Using Biomass to Provide Process Heat and Electricity at Ethanol Plants
2. Determine Economics of Competing Choices of Feedstocks and Technologies under Various Economic Conditions
3. Our Sponsors:

Today's Discussion

- Review Methods for Economic Comparisons of "Technology Bundles" and levels of biomass intensity
- Review Baseline Conditions; Defend my Assumptions

  -Fed. Renewable Energy Credit

  -Low Carbon Fuel Standard Premiums
- Demonstrate the impact of specific variables on ROR of the "technology bundles."

Participating Plants

- Ace Ethanol------------- Stanley, WI
- Badger State Ethanol--------Monroe, WI
- Corn Plus--------------- Winnebago, MN
- Chippewa Valley-------------- Benson, MN
- Agri-Energy-------Luverne, MN

AGRI-ENERGY, LLC We Buy Corn

BADGER STATE ETHANOL

CHIPPEWA VALLEY ETHANOL COMPANY, LLC.

CVEC

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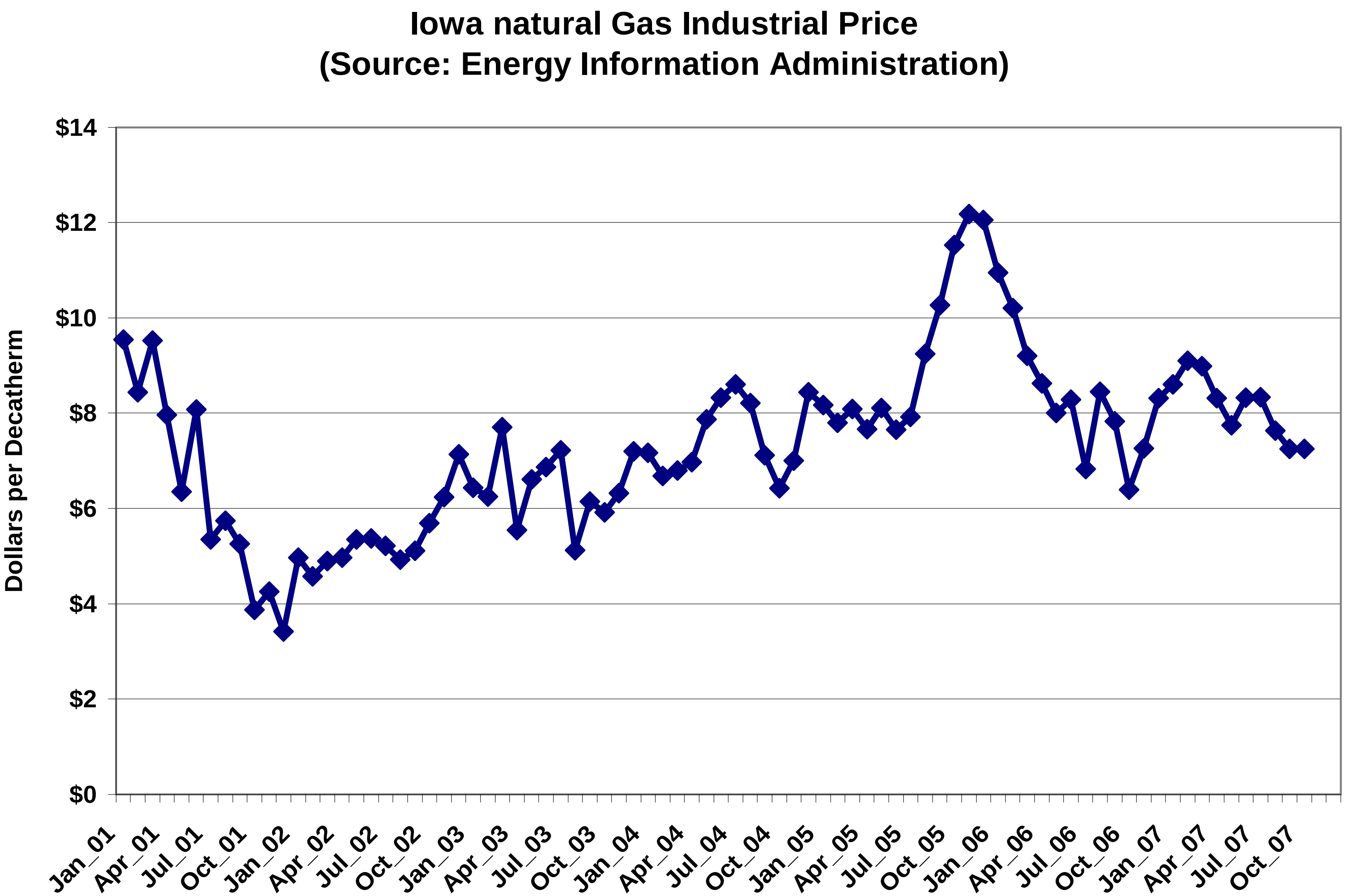
Focus on Economic Analysis

1. Economic analysis after technical steps of biomass characterization, emissions control standards, Aspen Plus estimation of machine capacities for individual technology bundles.
2. Capital Costs estimated by AMEC.
3. Spreadsheets were developed to model the ROR's on investment needed to replace natural gas with biomass fuels in dry-grind ethanol plants for various technology bundles and fuels.
4. Sensitivity analysis of key variables was conducted.

What Everyone Knows----

- Natural Gas is a great fuel.
- – except for price levels and volatility. At higher NG prices, ethanol profits are threatened.
- Natural Gas is the second largest cost of ethanol production after corn in typical dry-grind plants.
- Natural Gas is a fossil fuel; contributes GHG.


Iowa natural Gas Industrial Price
(Source: Energy Information Administration)
Dollars per Decatherm
$14
$12
$10
$8
$6
$4
$2
$0
Jan_01
Apr_01
Jul_01
Oct_01
Jan_02
Apr_02
Jul_02
Oct_02
Jan_03
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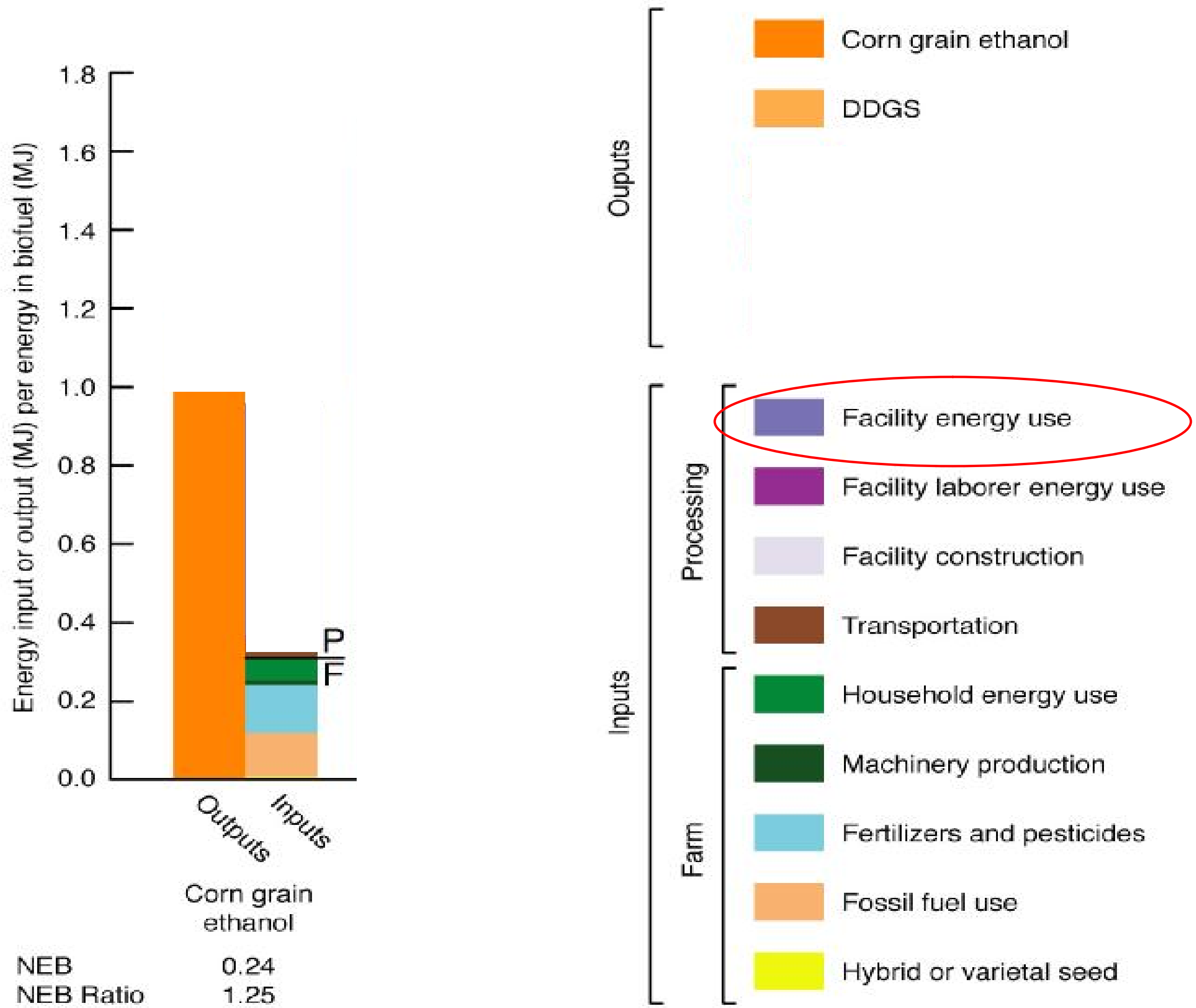
Motivations for Using Biomass

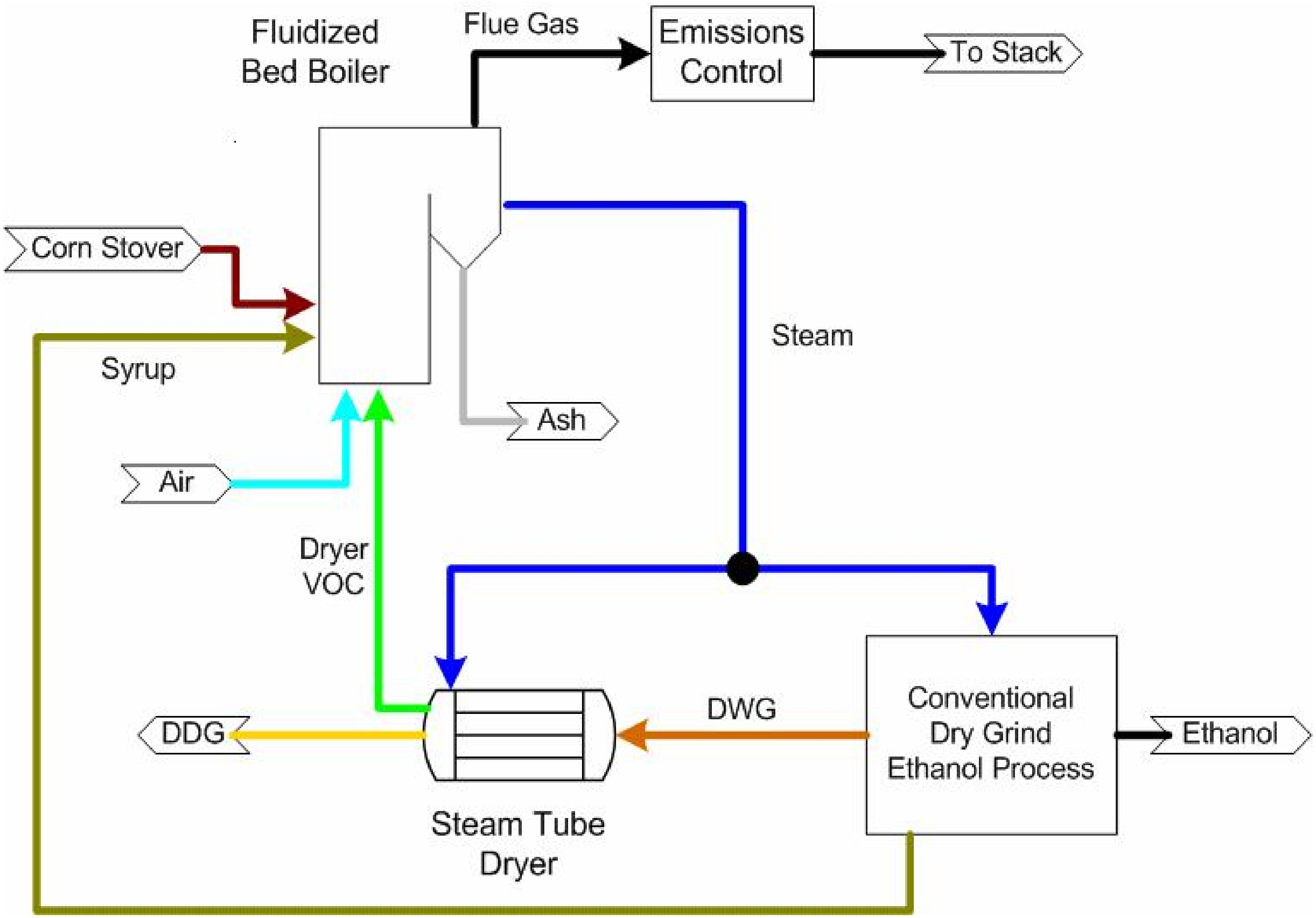


Hill, Nelson, Tilman, Polasky, and Tiffany. PNAS. Vol. 103, no. 30, 2006

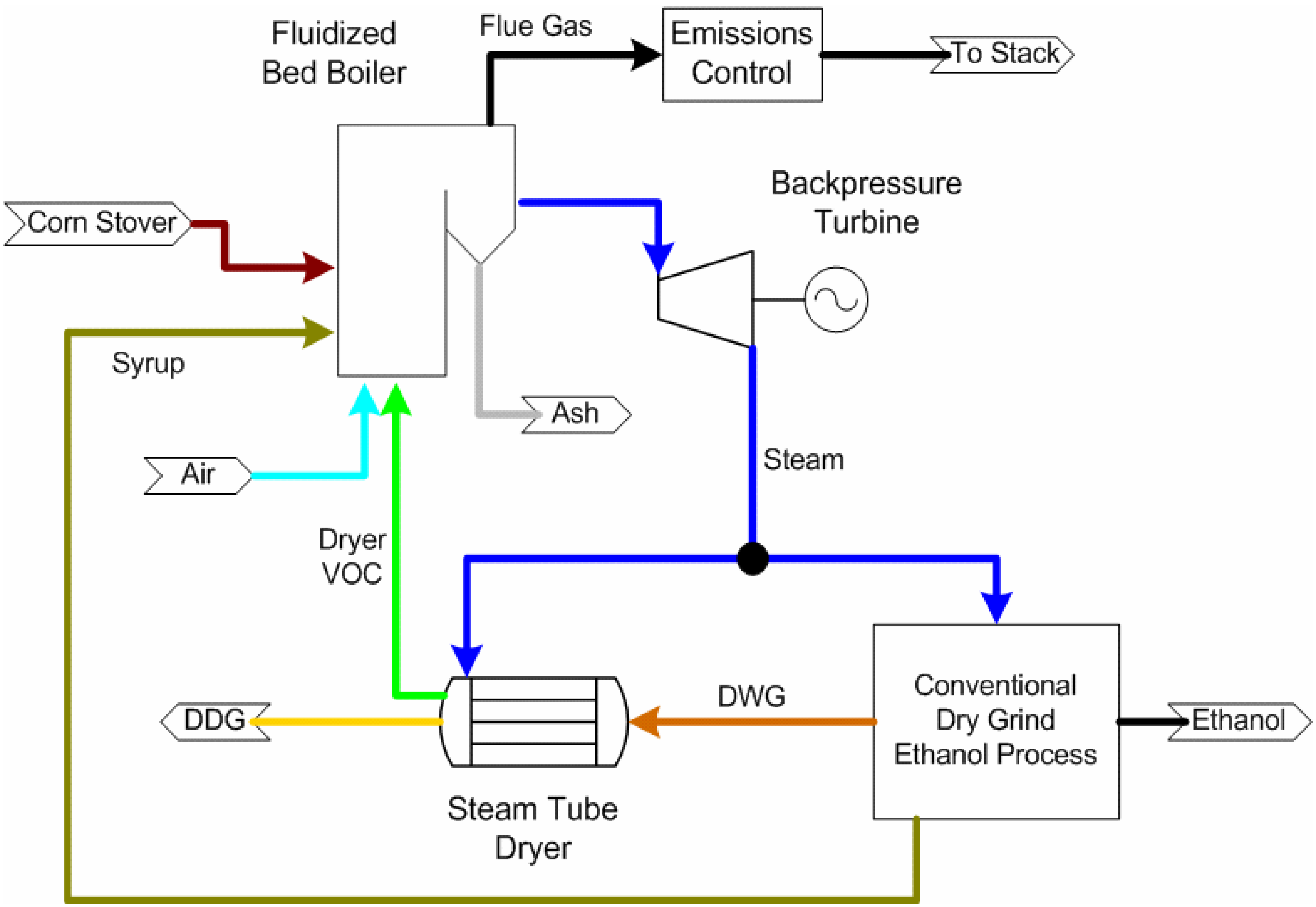
Motivations for Using Biomass

- Potential to improve Renewable Energy Ratio
  - Defined as: Energy Out / Fossil Energy In
- Potential for **2.4** to **4.8** Renewable Energy Ratio depending on conversion efficiency (Morey et al. 2006)
- Generate reliable power for the grid
- Lower the overall greenhouse gas emissions from ethanol production

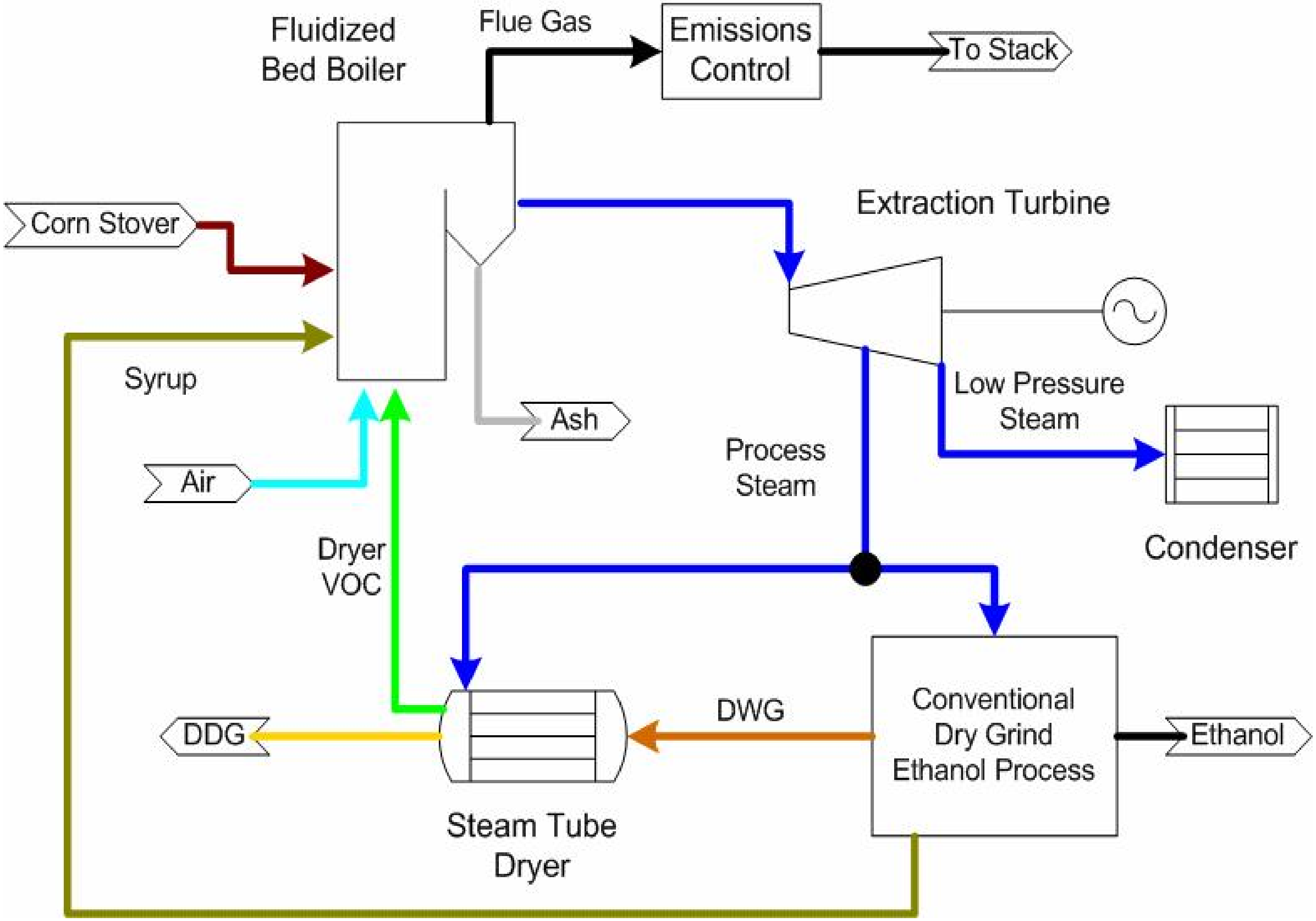
Syrup + Stover-Level #1



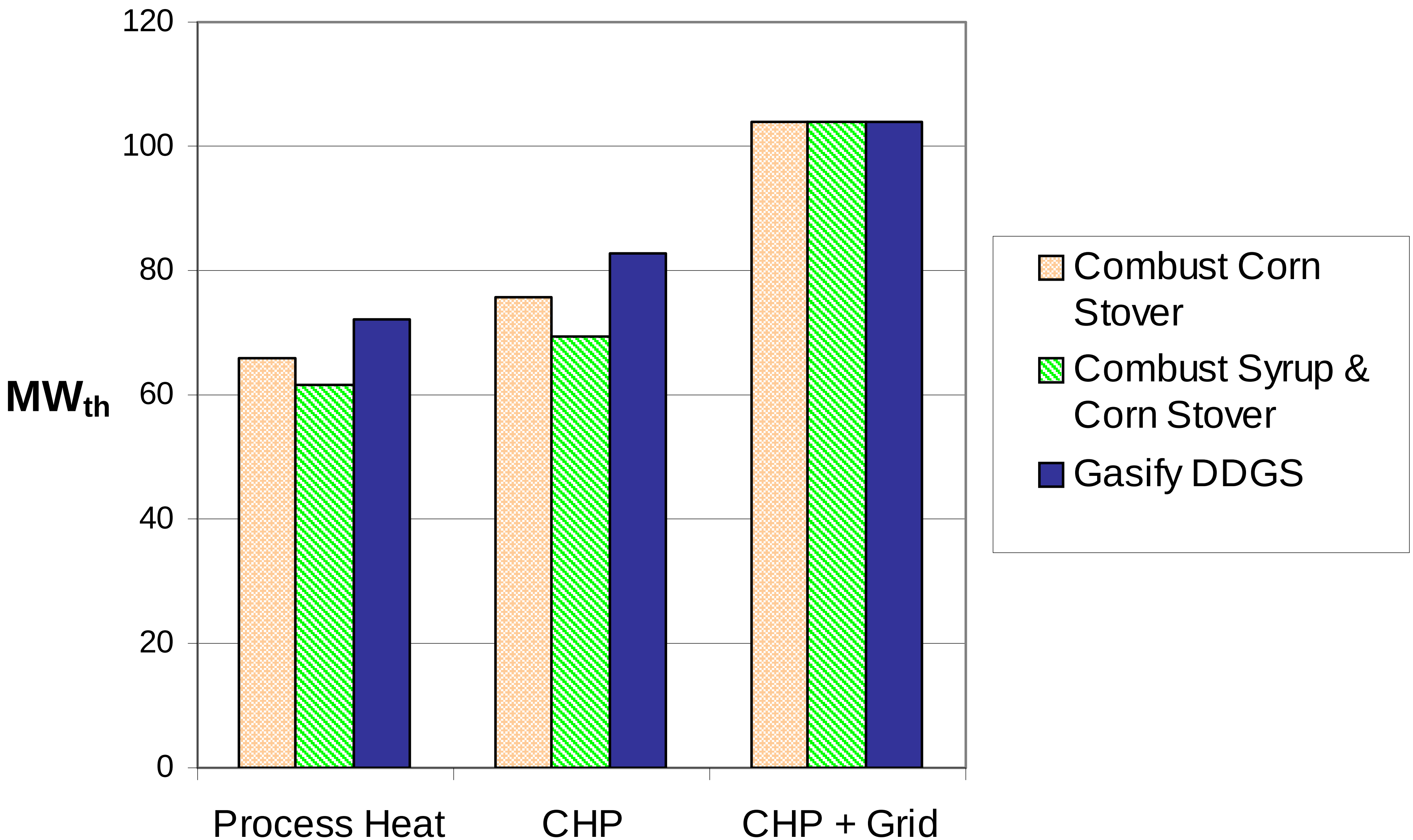
Syrup + Stover-Level #2

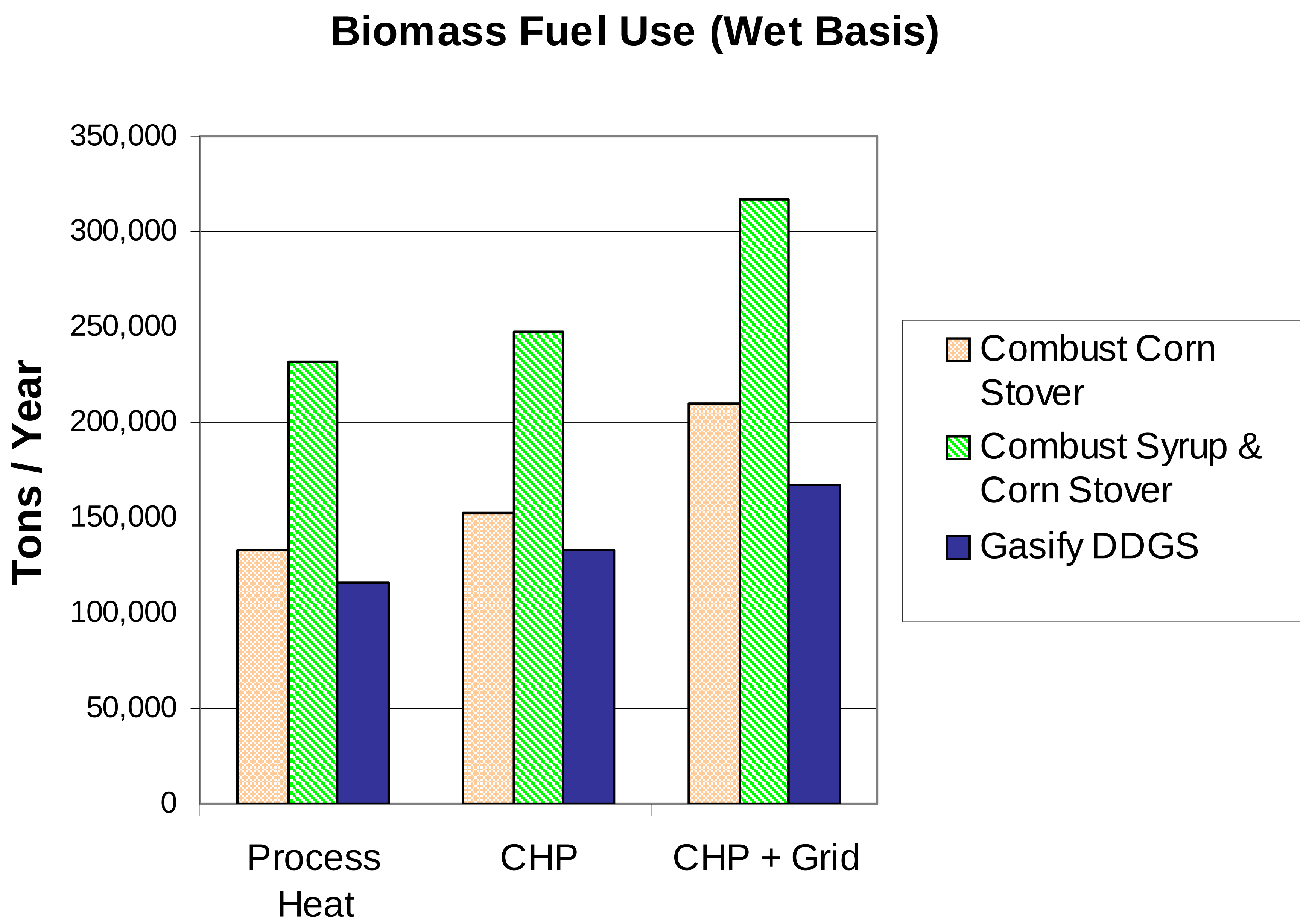


Syrup + Stover-Level #3



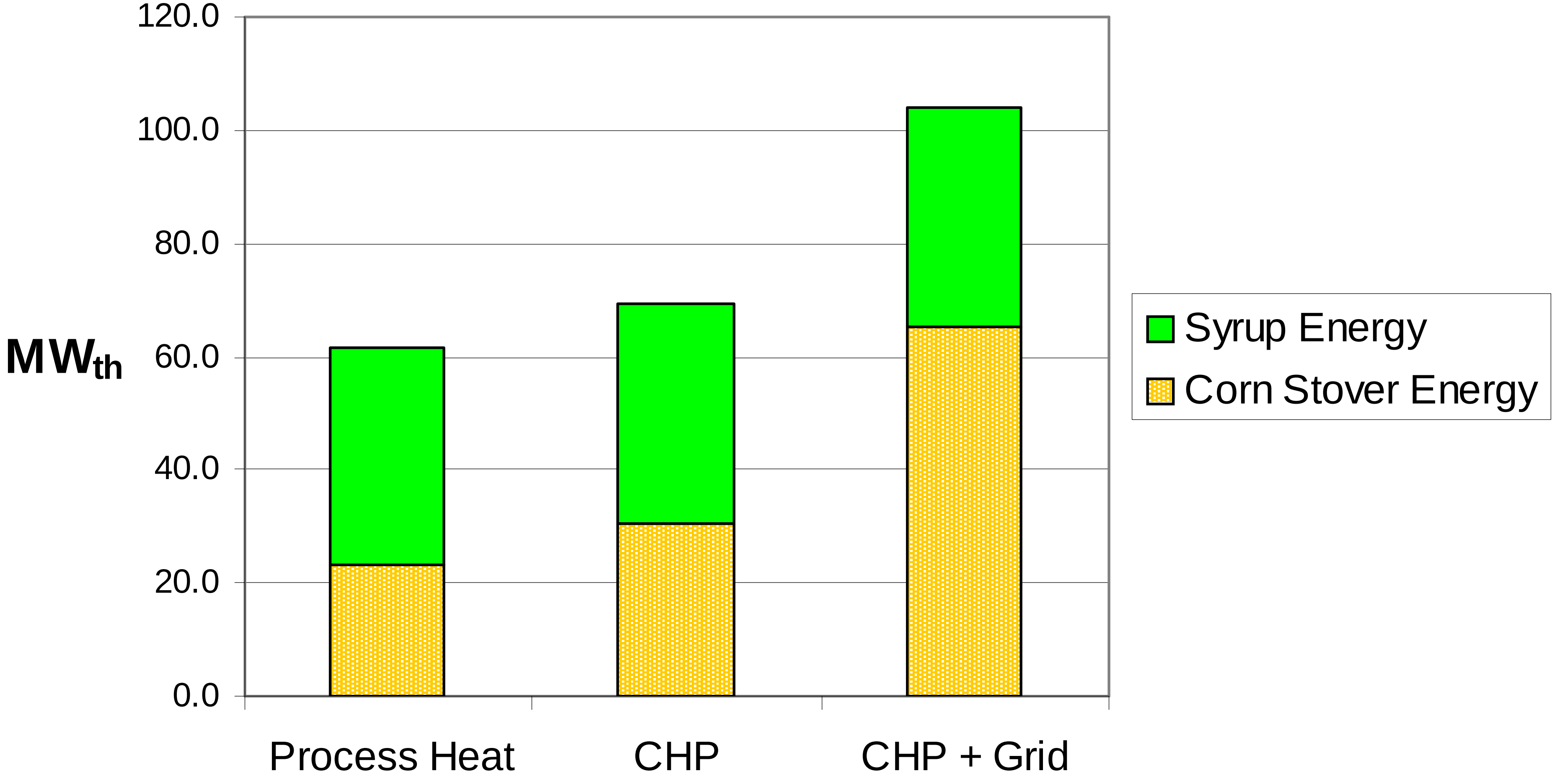
Biomass Fuel Energy Input (HHV)

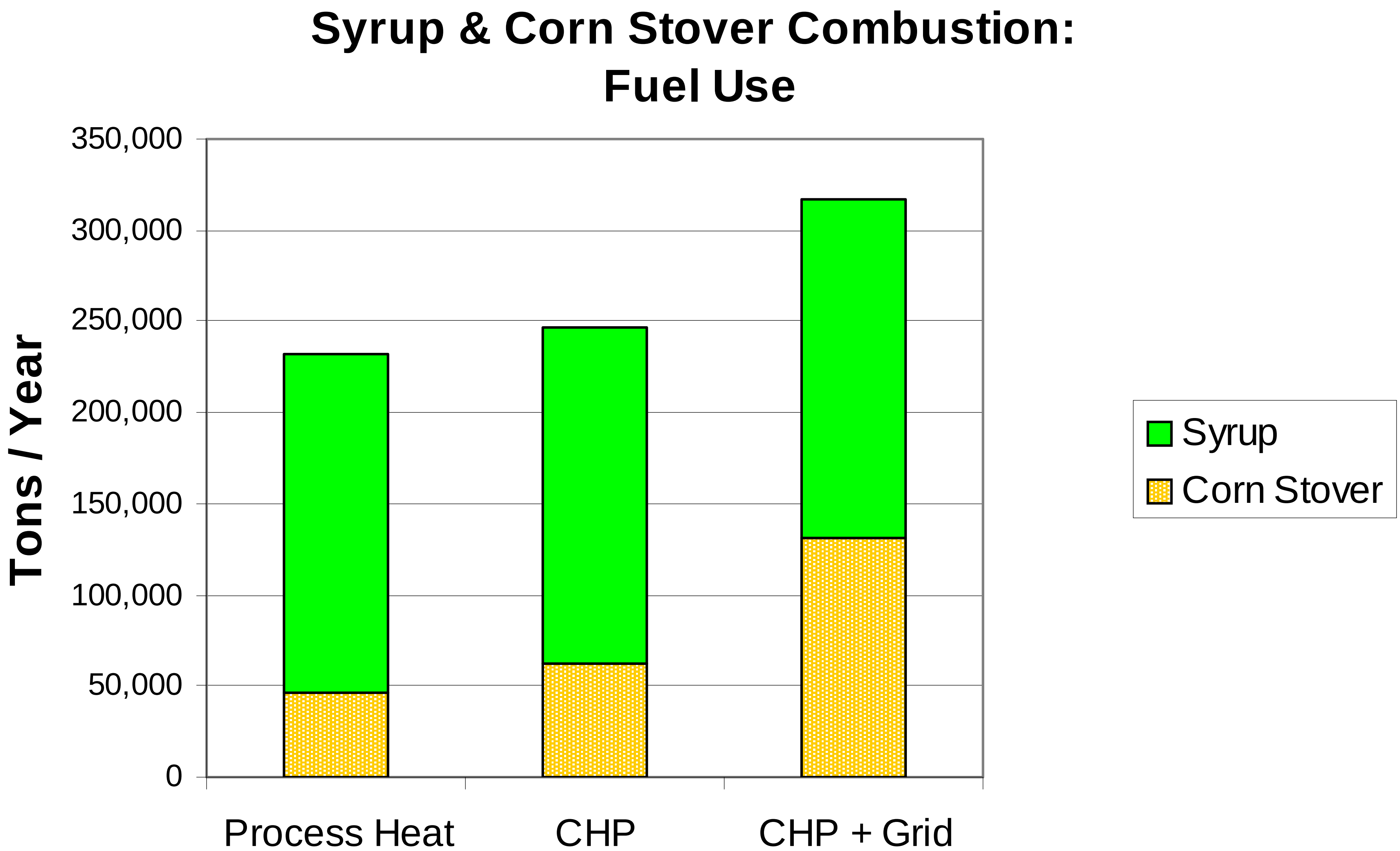




Biomass Fuel Use (Wet Basis)
Tons / Year
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Process Heat
CHP
CHP + Grid
Combust Corn Stover
Combust Syrup & Corn Stover
Gasify DDGS

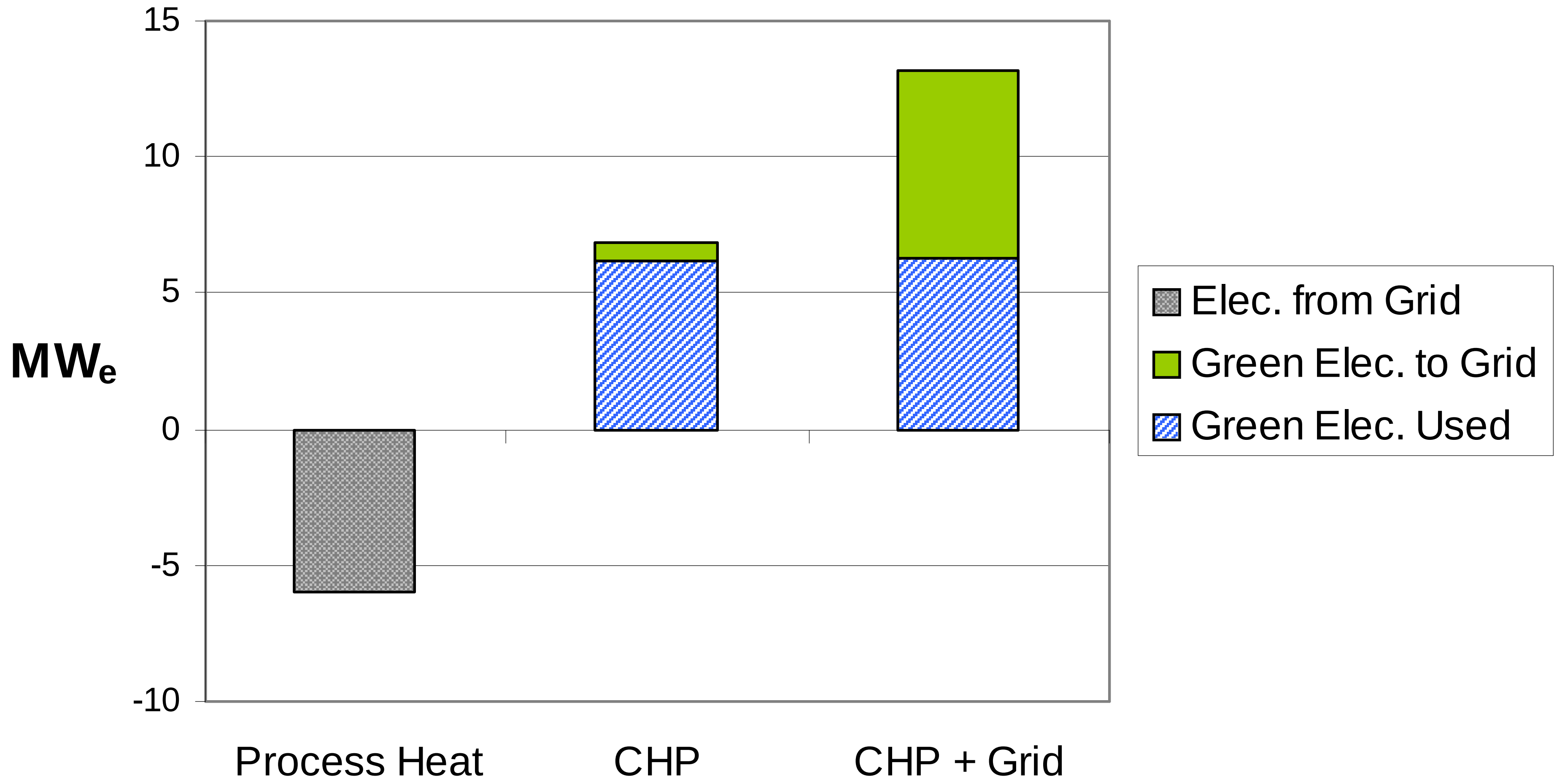
Syrup & Corn Stover Combustion: Fuel Energy Contribution



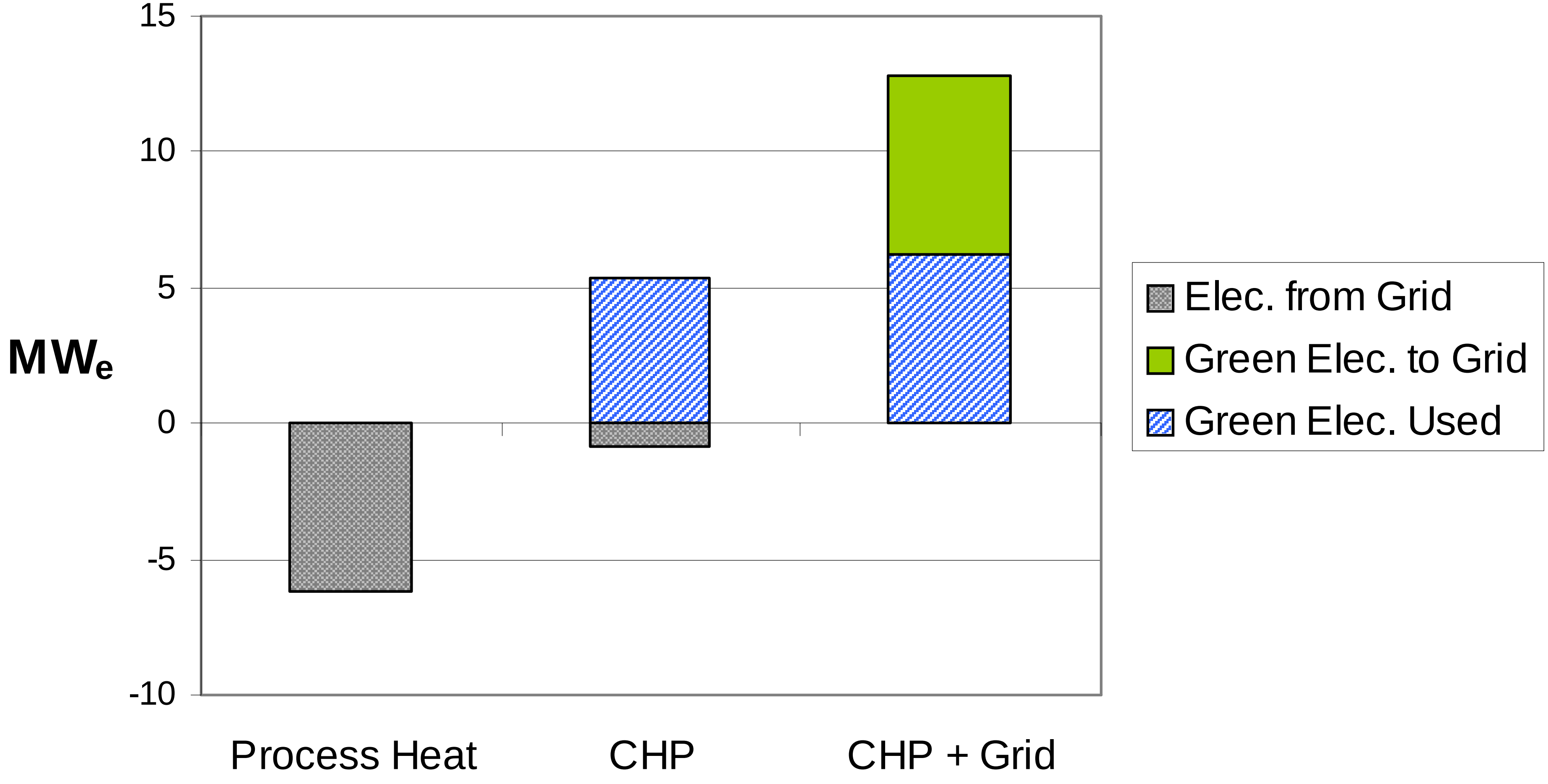


Syrup & Corn Stover Combustion:
Fuel Use
Tons / Year
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Process Heat
CHP
CHP + Grid
Syrup
Corn Stover

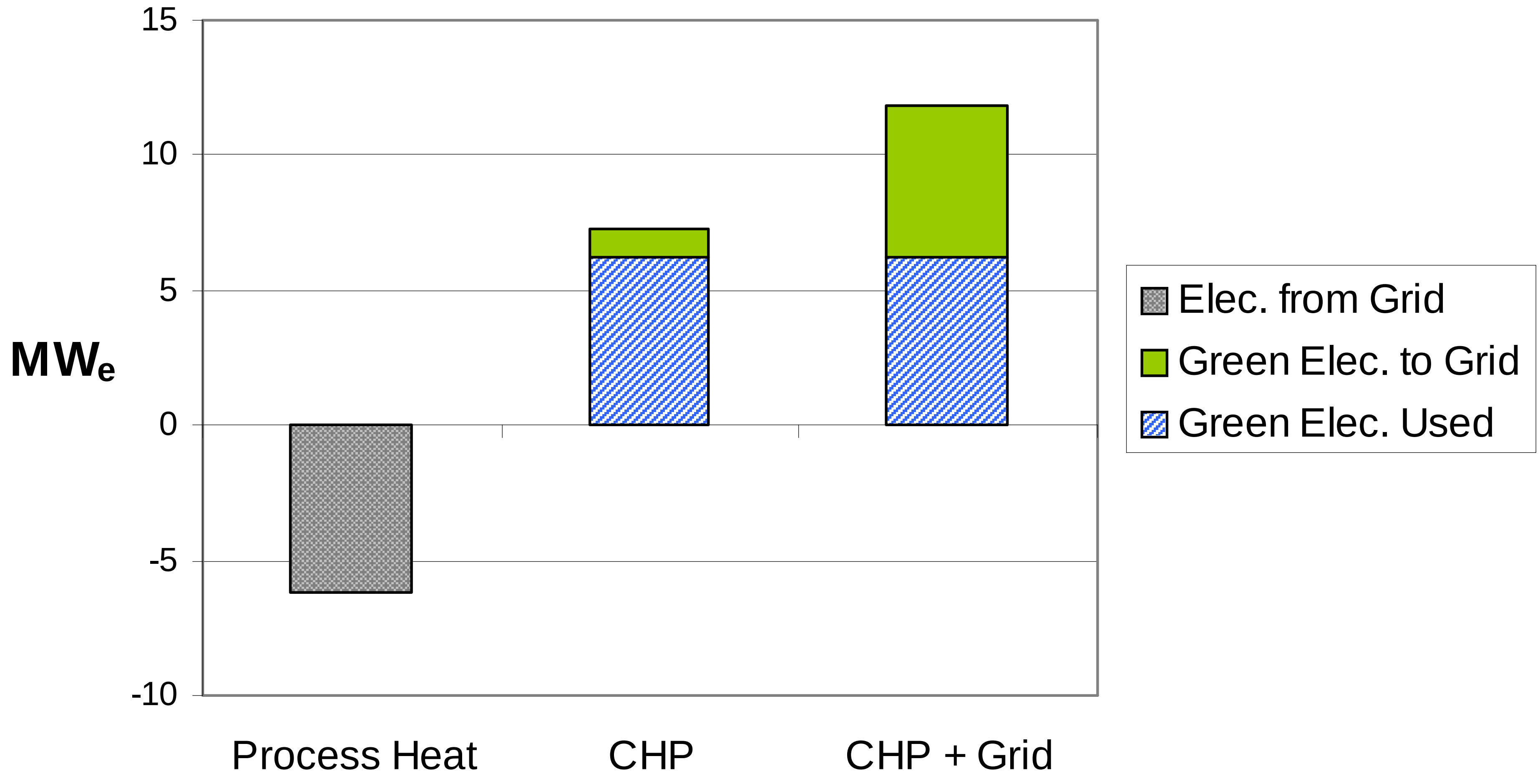
Corn Stover Combustion: Electricity Balance

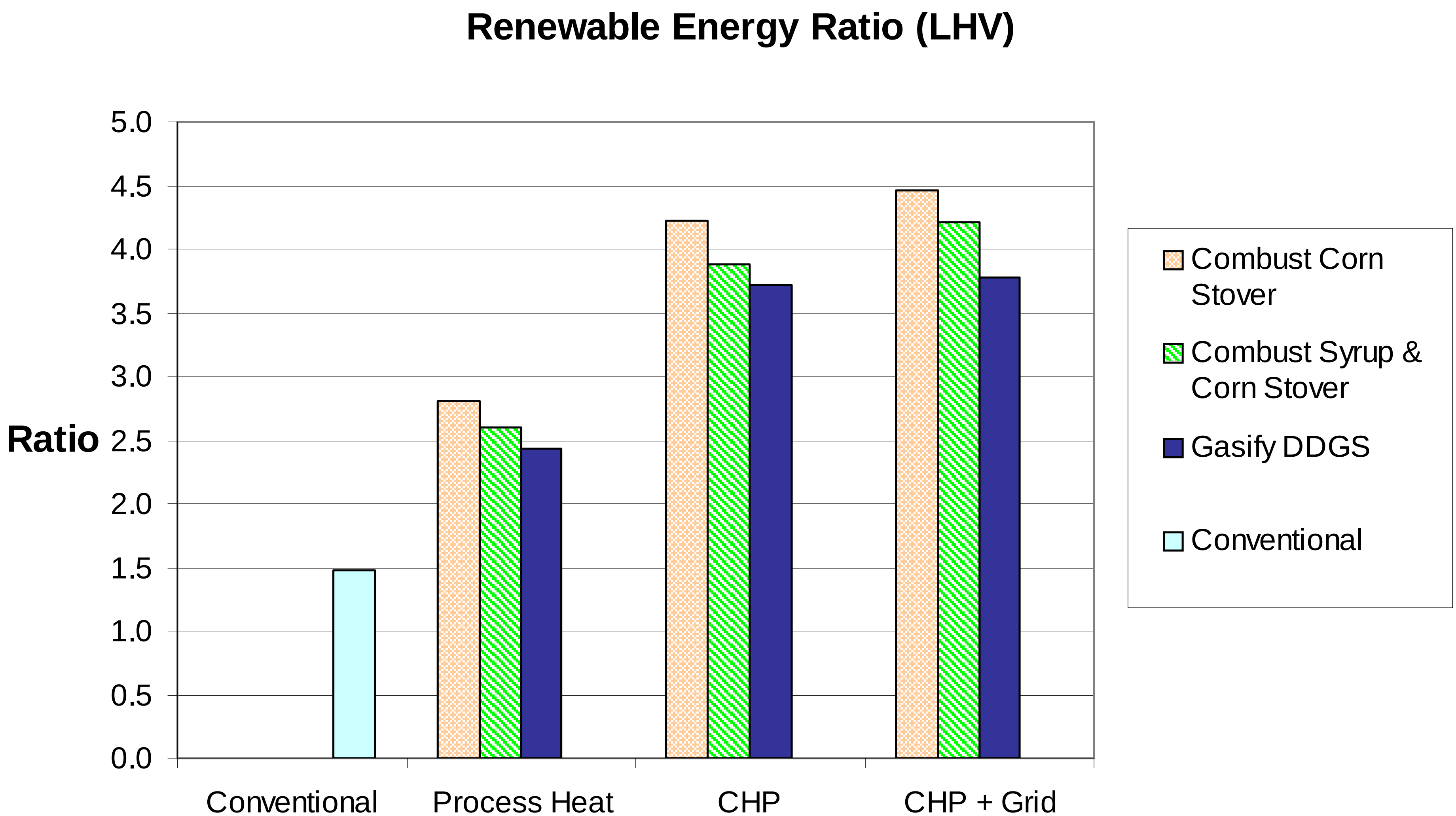


Syrup & Corn Stover Combustion: Electricity Balance



DDGS Gasification: Electricity Balance




Renewable Energy Ratio (LHV)
Ratio
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Conventional
Process Heat
CHP
CHP + Grid
Combust Corn Stover
Combust Syrup & Corn Stover
Gasify DDGS
Conventional

Establishing Baseline Assumptions

Biomass Has Costs

- Opportunity Costs as Feed, Bedding, or Soil Enhancer

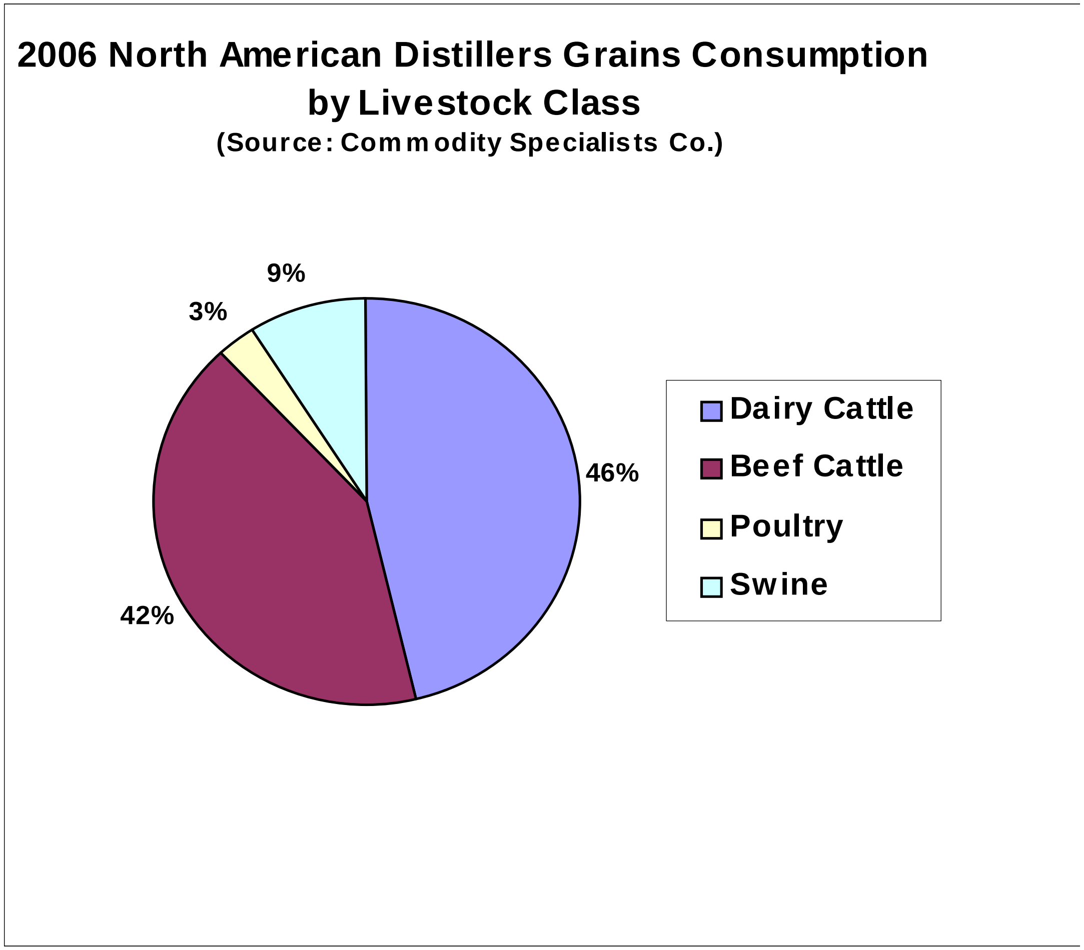
- Procurement Costs
- Transportation
- Storage
- Handling
- Emissions
- Ash Disposal
- However----, reliable, well-located supplies
- Stover Baseline at $80 / Ton (densified)

- ***The Economics of Harvesting and Transporting Corn Stover for Conversion to Fuel Ethanol: A Case Study for Minnesota*** Petrolia, Daniel R.

Distillers Dried Grains and Solubles

- Mid-level protein
- 28% Crude Protein
- 8.8% Fat
- 8.3% Fiber

- Poorer bulk density than corn
- Subject to greater variation than soybean meal

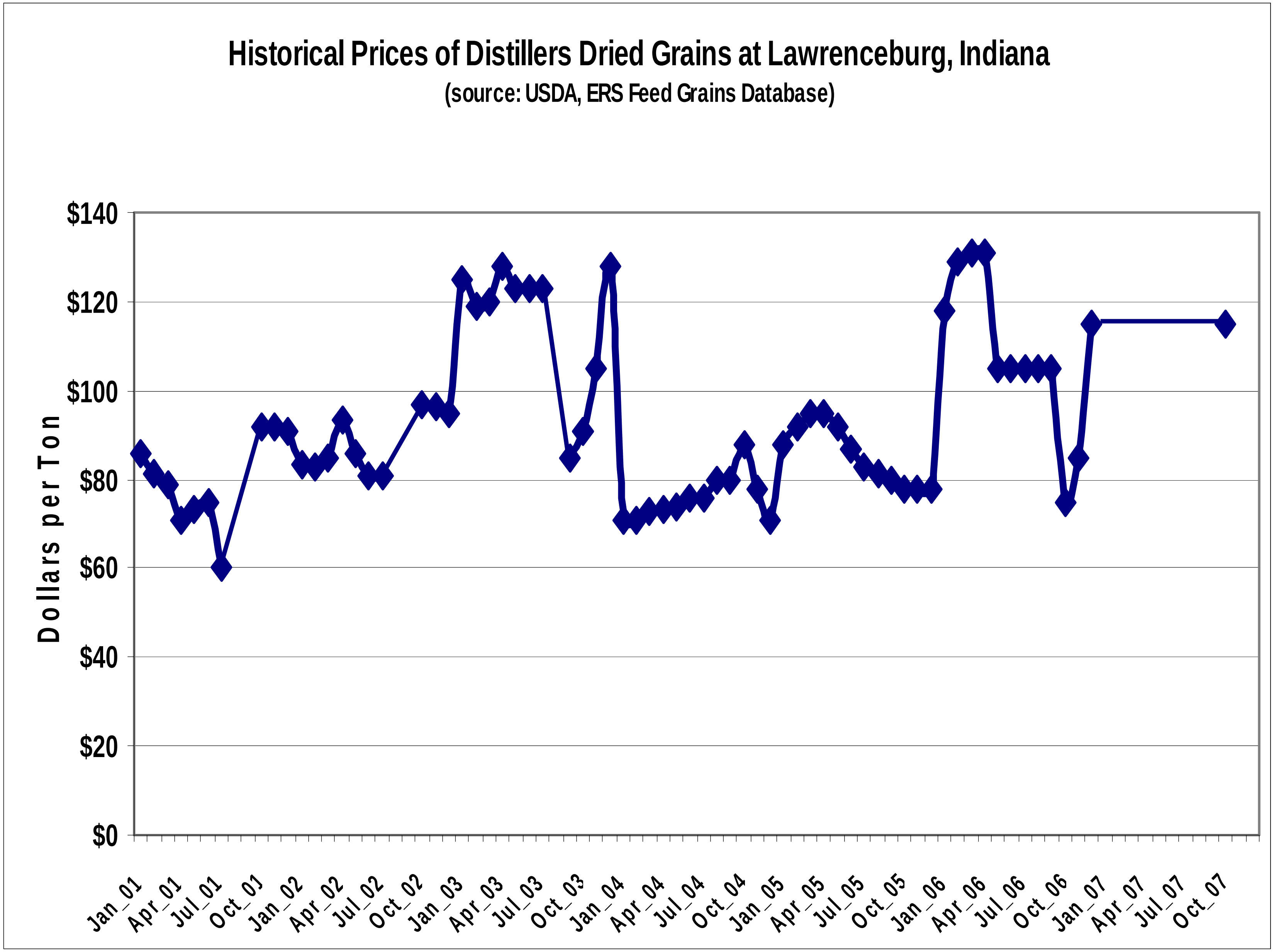


When producing 10 Billion Gallons of Ethanol, 28.3 Million Metric tons of Co-Product Feeds with be Available by 2010/11

Co-Product Usage Possibilities for U.S. Animal Species

(Based on Geoff Cooper, NCGA, Distillers Grains Quarterly, 1st 2006)

	Grain-Consuming Animal Units (Millions)	Max. Rate of Inclusion In Diet	1,000 metric Tons by % Market Penetration		
			50%	75%	100%
Dairy	10.2	20%	1,887	2,831	3,774
Beef	24.8	40%	9,176	13,764	18,352
Pork	23.8	20%	4,348	6,521	8,695
Poultry	31.1	10%	2,877	4,315	5,754
Total			18,288	27,431	36,575



Historical Prices of Distillers Dried Grains at Lawrenceburg, Indiana
(source: USDA, ERS Feed Grains Database)
Dollars per Ton
$140
$120
$100
$80
$60
$40
$20
$0
Jan_01
Apr_01
Jul_01
Oct_01
Jan_02
Apr_02
Jul_02
Oct_02
Jan_03
Apr_03
Jul_03
Oct_03
Jan_04
Apr_04
Jul_04
Oct_04
Jan_05
Apr_05
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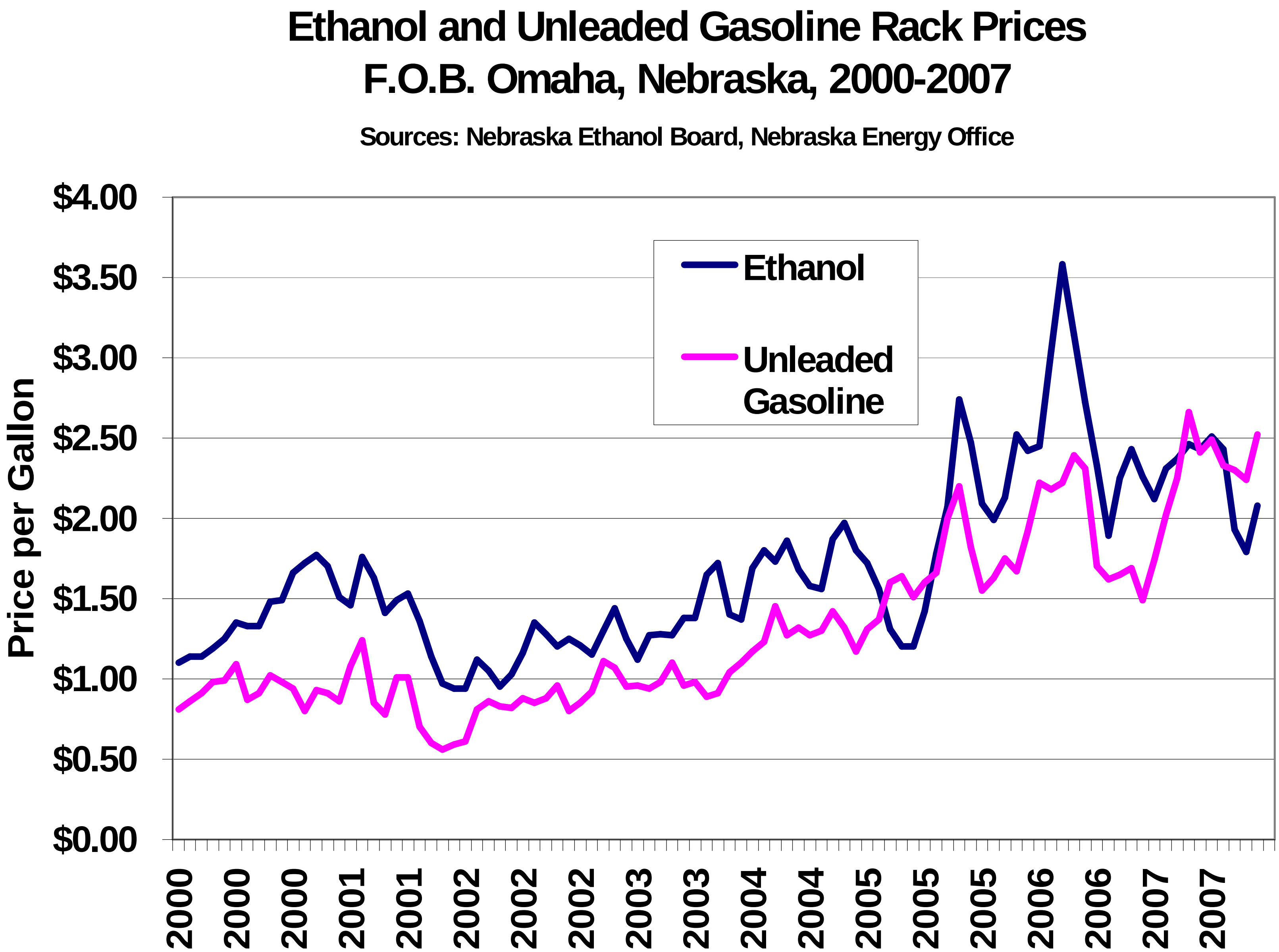
Oct_07

Ethanol Prices


Ethanol and Unleaded Gasoline Rack Prices
F.O.B. Omaha, Nebraska, 2000-2007
Sources: Nebraska Ethanol Board, Nebraska Energy Office
Price per Gallon
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
Ethanol
Unleaded Gasoline
2000
2000
2000
2001
2001
2002
2002
2002
2003
2003
2004
2004
2005
2005
2005
2006
2006
2007
2007

The Ethanol Prices Received at the Plant May Approach BTU substitute level plus Blenders Credit of $.51/ gallon.

- Ethanol prices used to have a premium of $0.25 over the wholesale price of gasoline, but seems to be headed for equivalence as a BTU substitute.

Refiners Acquisition Cost $/Barrel	Wholesale Gasoline Price $/Gallon*	Ethanol Price Indicated as BTU substitute with VEETC
40	1.20	1.31
50	1.49	1.50
60	1.78	1.70
70	2.07	1.89
80	2.36	2.08

*Wholesale price of Regular gasoline = $0.036 + $0.029(Price of Crude oil/bbl)

Source: McCullough, Robert and Daniel Etra. *When Farmers Outperform Sheiks: Why Adding Ethanol to the U.S. Fuel Mix Makes Sense.* McCullough Research, Portland, Oregon, April, 2005, 12pp

Ethanol Industry Is Expected to Continue Expanding Until Profits are Diminished by Higher Capital and Operating Costs, especially Corn Price:

- Net cost per gallon of ethanol depends on price of corn and fuel for the plant

Corn Price	Net Cost /Gallon For New Construction 50mmgpy	100mmgpy
$2.00	$1.40	$1.31
3.00	1.64	1.55
4.00	1.88	1.79
5.00	2.12	2.03
6.00	2.36	2.27

- Each increase of $1.00 per mmbtu in Natural Gas increases the cost per gallon $0.034
- The profit opportunities will be reduced if the blenders credit of $0.51/gallon is reduced.

Valuable Incentive: California's Low Carbon Fuel Standard

- Lower carbon intensity of fuels for passenger vehicles 10% by 2020 in grams of carbon emitted per BTU used. (LCA)
- Replace 20% of on-road gasoline with lower-carbon fuels
- Triples CA renewable fuels market
- Goal of producing 20% of biofuels in CA by 2010, 40% by 2020
- Use more hybrid vehicles
- Purchase of carbon credits from power generators who produce "low-carbon" electrons for plug-in hybrid vehicles

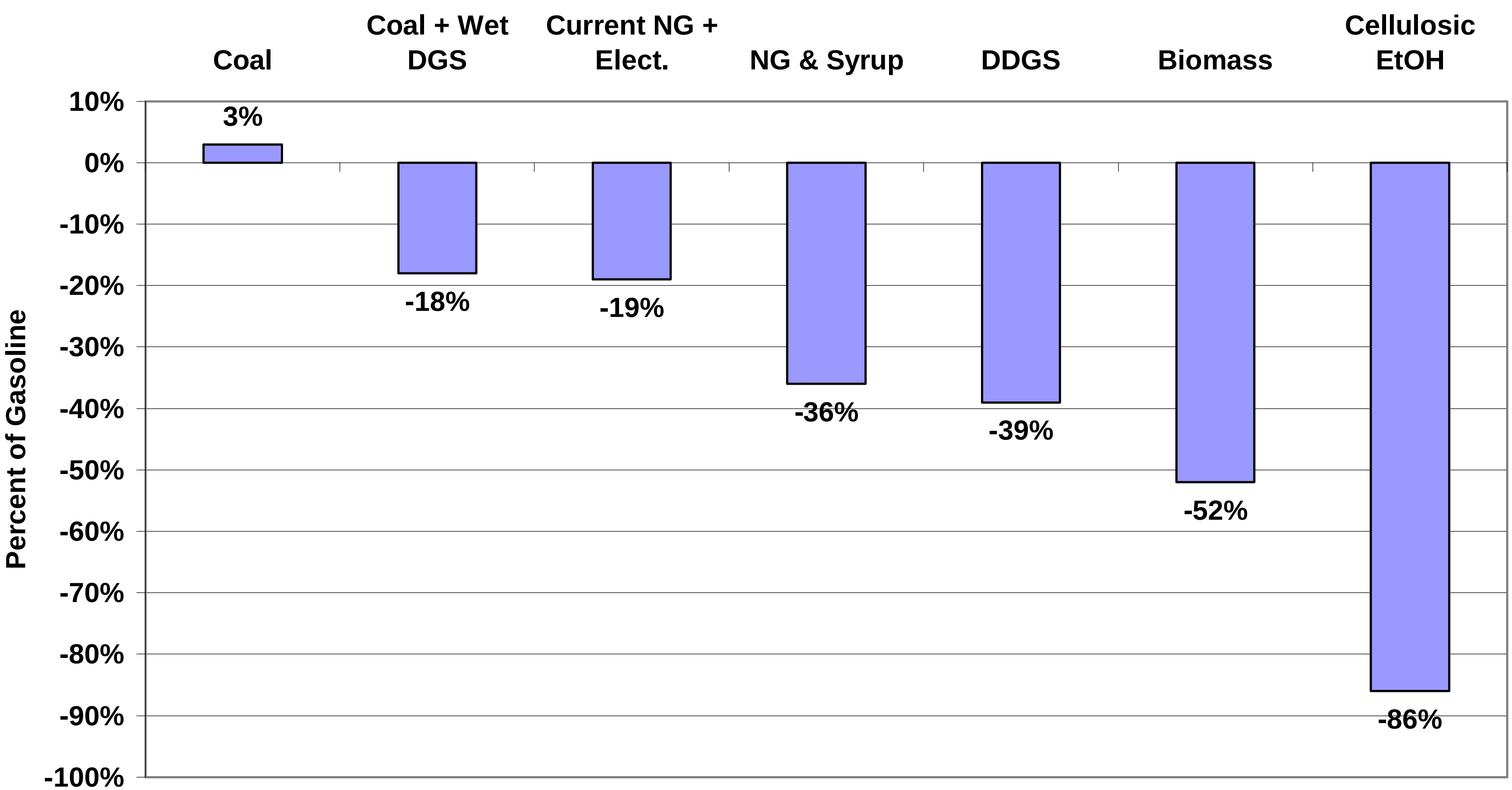
California’s Ethanol-Related Strategies to Achieve LCFS

- Increase blending of ethanol from today's 5.7 percent by volume to 10 percent.
- Sell high blend ethanol (85 percent ethanol, 15 percent gasoline) for use in Flex Fuel Vehicles (FFVs).

- Switch to Low-Carbon ethanol made from cellulosic materials (e.g., agricultural waste, switchgrass) that has 4-5 times lower GHG emissions than today's corn. *
- Source: Farrell et al., "Ethanol Can Contribute to Energy and Environmental Goals," *Science* , Jan 27, 2006.

Well to Wheels Greenhouse Gas Emissions Changes by Fuel Ethanol Relative to Gasoline

Source: Wang, Wu and Huo, Environmental Research Letters 2 (2007)



Estimating Value of LCFS Premium

- Ethanol produced at plants using biomass for process heat and electricity can be 3 X more effective in reducing GHG than ethanol produced at conventional plants.
- One gallon of ethanol produced by using biomass can substitute for three conventional gallons.
- The shipping cost of two gallons to California (or elsewhere) can be saved.
- The premium for California delivery could be \$.40- \$.50 per gallon of biomass-processed ethanol based on current shipping costs of \$.20-\$.25 per gallon.
- For ethanol delivery to states closer to high production states, the premium should be less.
- Average shipping cost in U.S. was approximately \$.09 per gallon, (EPA, Sept. 2006), before shipping congestion worsened.
- Avg. premium if LCFS were adopted nation-wide could be approximately \$.20 per gallon.

Technologies and Feedstocks Discussed Today

- **Syrup + Stover Combusted in Fluidized Bed**
- **Corn Stover Combusted in Fluidized Bed**
- **DDGS Gasified in Fluidized Bed**

Cases: Using Biomass to Replace:

1. Process Heat for Plant
2. Process Heat and Electricity Needs of Plant
3. Process Heat, Electricity Needs of Plant with Sales to the Grid

Additional Capital Costs

- Installed Estimates by AMEC with escalation and contingency factors applied
  - Capital Costs for Biomass Handling, Storage
  - Capital Costs of Biomass Combustion Equip.
  - Capital Costs of Electrical Generator
  - Capital Costs- Emissions Control Equipment for Biomass
  - Capital Costs for Ash Handling, Processing

Capital Costs of Technology Bundles

	50 Million Gallon Plants		100 Million Gallon Plants	
	Capital Cost of Plant	Cost/Nameplate Gallon	Capital Cost of Plant	Cost/Nameplate Gallon
Conventional	**$ 112,500,000**	$2.25	**$ 182,756,789**	$1.83
Stover1	**$ 147,120,000**	$2.94	**$ 238,997,145**	$2.39
Stover2	**$ 162,938,000**	$3.26	**$ 264,693,562**	$2.65
Stover3	**$ 180,590,000**	$3.61	**$ 293,369,321**	$2.93
Syrup+Stover1	**$ 136,522,000**	$2.73	**$ 221,780,643**	$2.22
Syrup+Stover2	**$ 150,769,000**	$3.02	**$ 244,924,963**	$2.45
Syrup+Stover3	**$ 168,372,000**	$3.37	**$ 273,521,121**	$2.74
DDGS1	**$ 142,465,000**	$2.85	**$ 231,435,075**	$2.31
DDGS2	**$ 156,279,000**	$3.13	**$ 253,875,985**	$2.54
DDGS3	**$ 171,637,000**	$3.43	**$ 278,825,129**	$2.79

Revenue Gains / Cost Savings

- Reduced Natural Gas Purchases
- Reduced Electricity Purchases
- Premium for “Low Carbon” Ethanol Produced ($.20- $.40) per gallon
- Sales of Nutrients in Ash of 0-18-28 ($200/T.)
- Sale of Renewable Electricity to the Grid ($.06/KWH)
- Credit for Renewable Electricity of ($.019 /KWH)
- Potential for More Valuable DDG product without solubles (20% premium assumed)

Additional Operating Costs with Biomass

- Biomass Costs Must Include---
  - Procurement Activities for Corn Stover
  - Drying of Corn Stover / DDGS before Storage or Use
  - Densification of Stover for Transportation & Handling
  - Storage of Biomass
- Additional Labor and Maintenance
- Use of Limestone for Sulfur Capture @ $20/ T.
- Use of Ammonia to reduce NOx @ $500/T.

Assumptions Common Across All Processes

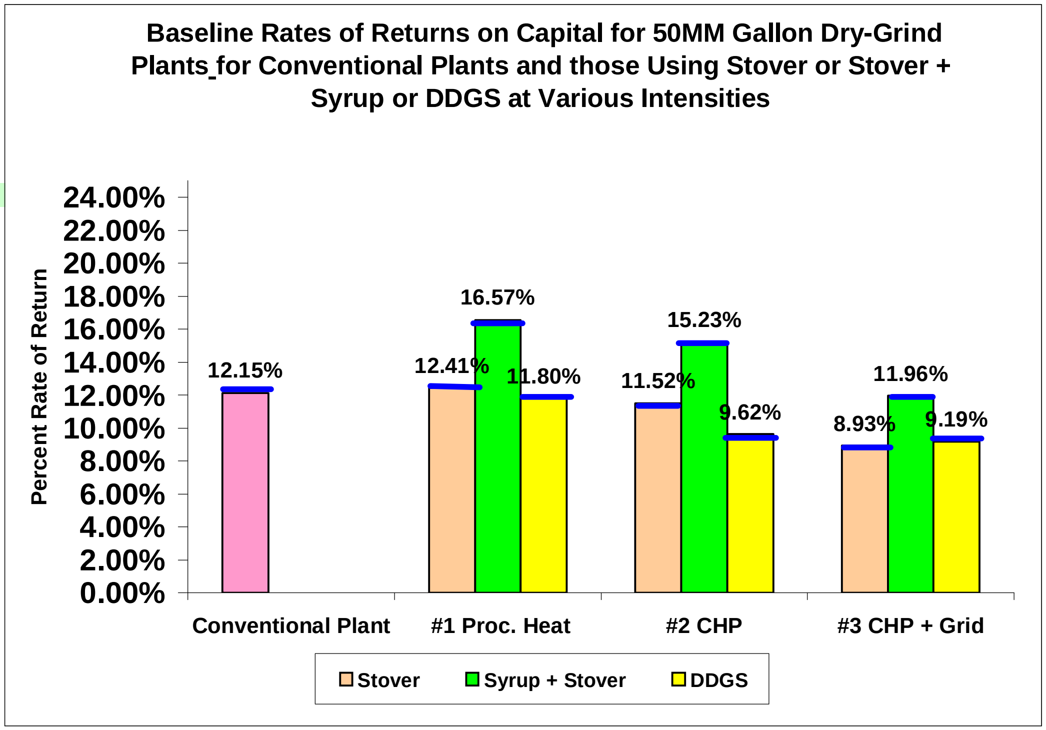
1/10/2008

INSTALLED COSTS

	Active Val.	Base Val.
Debt-Equity Assumptions		
Factor of Equity	**40%**	40%
Factor of Debt	60%	60%
Interest Rate Charged on Debt	**8%**	8%
Investor Required Return on Equity	**12%**	12%
Depreciation based on asset life (years)	**15**	15
Output Market Prices		
Ethanol Price (denatured price) $/gal.	**$1.80**	$1.80
DDGS Price $/T	**$100.00**	$100.00
Electricity Price (Plant is Seller) ($ per kWh)	**$0.06**	$0.06
MN Renew. Energy Prod. Incent. ($/kWh)	**$0.000**	$0.000
Value of Ash ($ per Ton)	**$200.00**	$200.00
CO2 Price ($ per Ton liq. CO2)	**$8.00**	$8.00
Max. Premium for Low-Carbon ($.00 per gallon)	**$0.20**	$0.20
Government Subsidies		
Federal Small Producer Credit ($/gal.)	**$0.10**	$0.10
RFS Ethanol Tradable Credit ($/gal.)	**$0.10**	$0.10
Fed. Renew Elect Cred Closed-Loop ($/kWh)	**$ 0.019**	$0.019
		0.25
Feedstock Delivered Prices Paid by Processor		
Corn Price ($ per bu.)	**$3.50**	$3.50
Energy Prices		
Natural Gas Price ($ per 1,000,000 Btu)	**$8.00**	$8.00
Stover Purchased @ ($ per dry Ton)	**$80.00**	$80.00
Electricity Price (Plant is Buyer) ($ per kWh)	**$0.06**	$0.06
LP (Propane) Price ($ per gallon)	**$1.10**	$1.10
Operating Costs/Input Prices		
Denaturant Price / gal	**$1.80**	$1.80
Denat/100 gal Anhyd.	**5**	5
Feedstock-to-Ethanol Conversion Yields		
Ethanol Yield (anhydrous gal per bushel)	**2.75**	2.75

Baseline ROR's Using Installed Capital Costs for 50 MM Gallon Plant

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
12.15%	12.41%	11.52%	8.93%	Stover
	16.57%	15.23%	11.96%	Syrup + Stover
	11.80%	9.62%	9.19%	DDGS



Years to Payback Additional Investment

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
Not Applicable	7.5	9.9	27.6	Stover
	2.7	4.1	8.6	Syrup + Stover
	9.5	31.9	28.0	DDGS

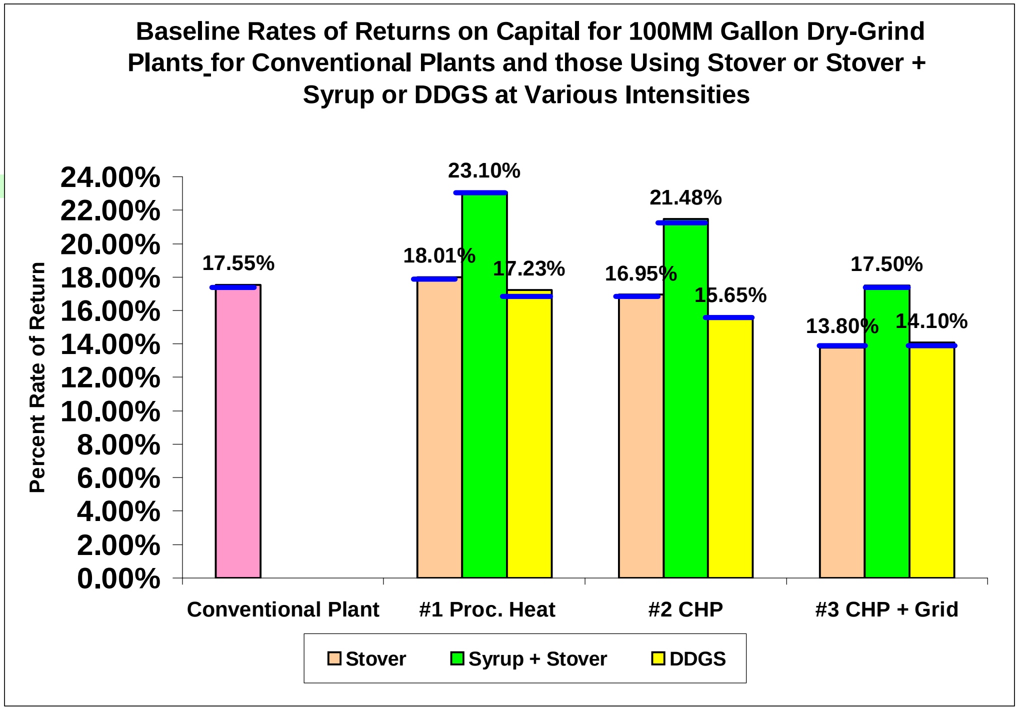
Years to Payback: Additional Investment Above Conventional in 50MM Gallon Plants

Years to Payback Additional Investment

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
Not Applicable	7.5	9.9	27.6	Stover
	2.7	4.1	8.6	Syrup + Stover
	9.5	31.9	28.0	DDGS

Baseline ROR's Using Installed Capital Costs for 100 MM Gallon Plant

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid		100MM Gal
17.55%	18.01%	16.95%	13.80%	Stover	
	23.10%	21.48%	17.50%	Syrup + Stover	
	17.23%	15.65%	14.10%	DDGS	



Years to Payback Additional Investment

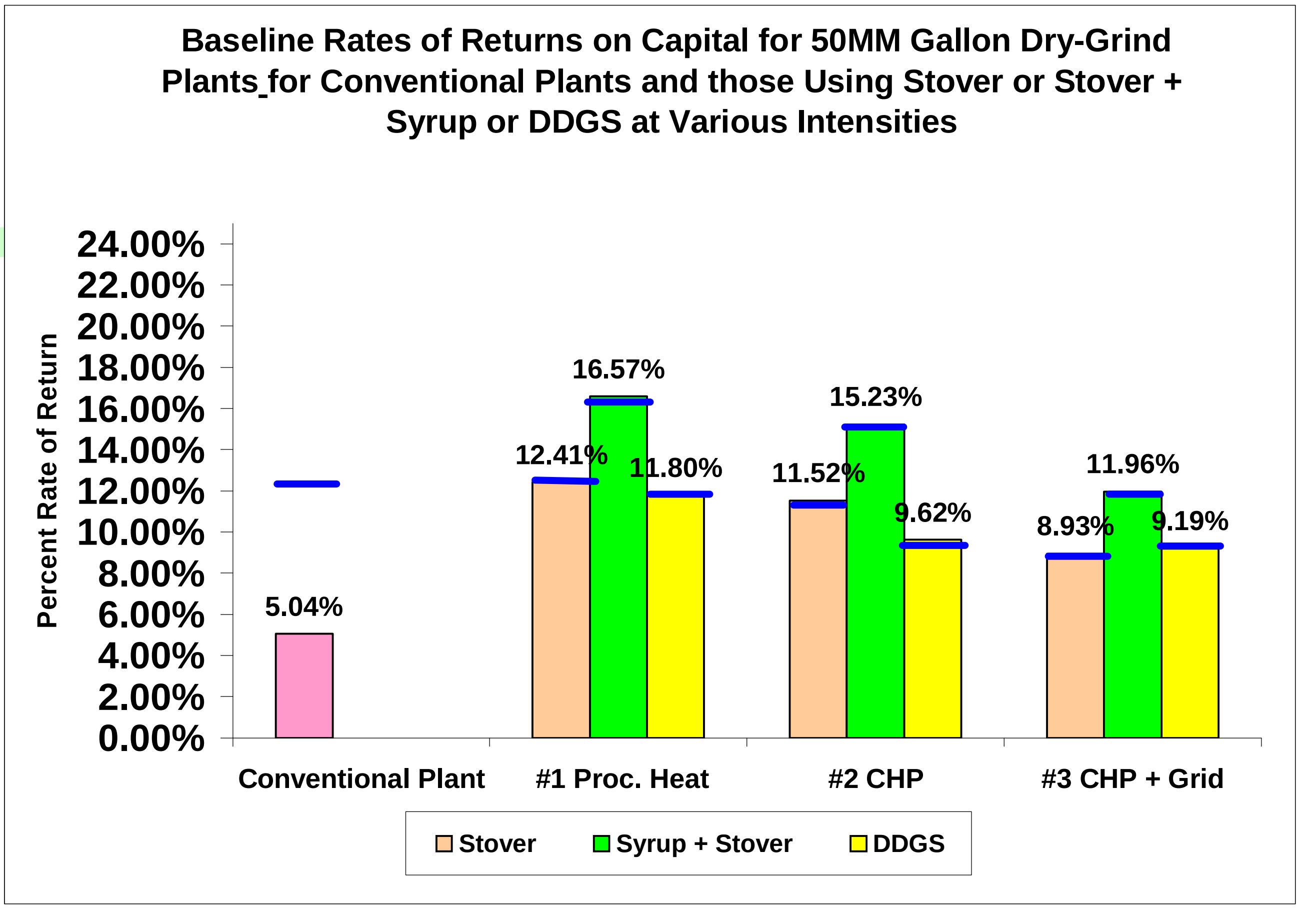
Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	100MM Gal
Not Applicable	5.1	6.4	13.1	Stover
	2.0	3.0	5.7	Syrup + Stover
	6.2	9.3	13.3	DDGS

Testing Sensitivity of Technology Bundles

- **--**DDGS price
- --Corn Stover price
- --Natural gas price
- --Ethanol Price
- -- Premiums for Low-Carbon Imprint
- --Electricity Selling Price
- --Corn Price

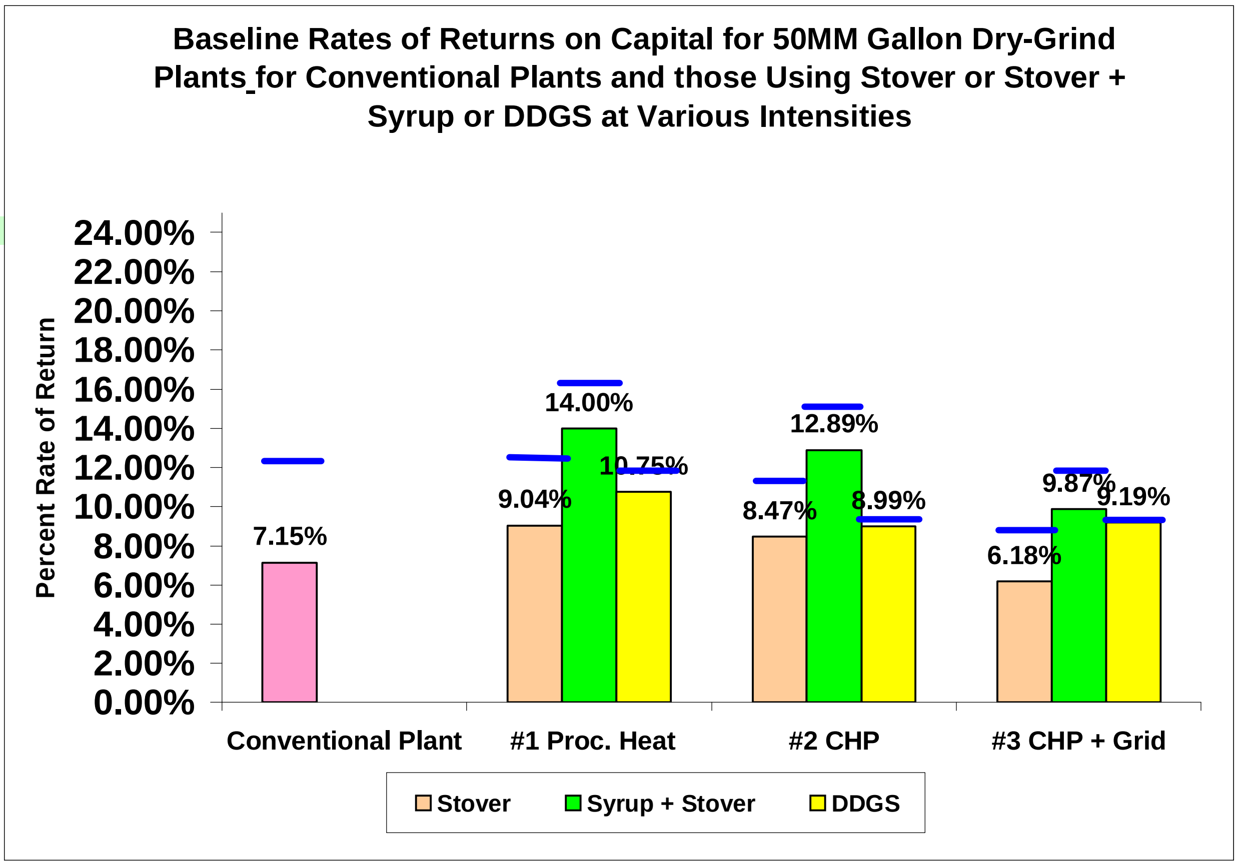
Natural Gas Rises from $8.00 to $12.00 per DkTh

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
5.04%	12.41%	11.52%	8.93%	Stover
	16.57%	15.23%	11.96%	Syrup + Stover
	11.80%	9.62%	9.19%	DDGS



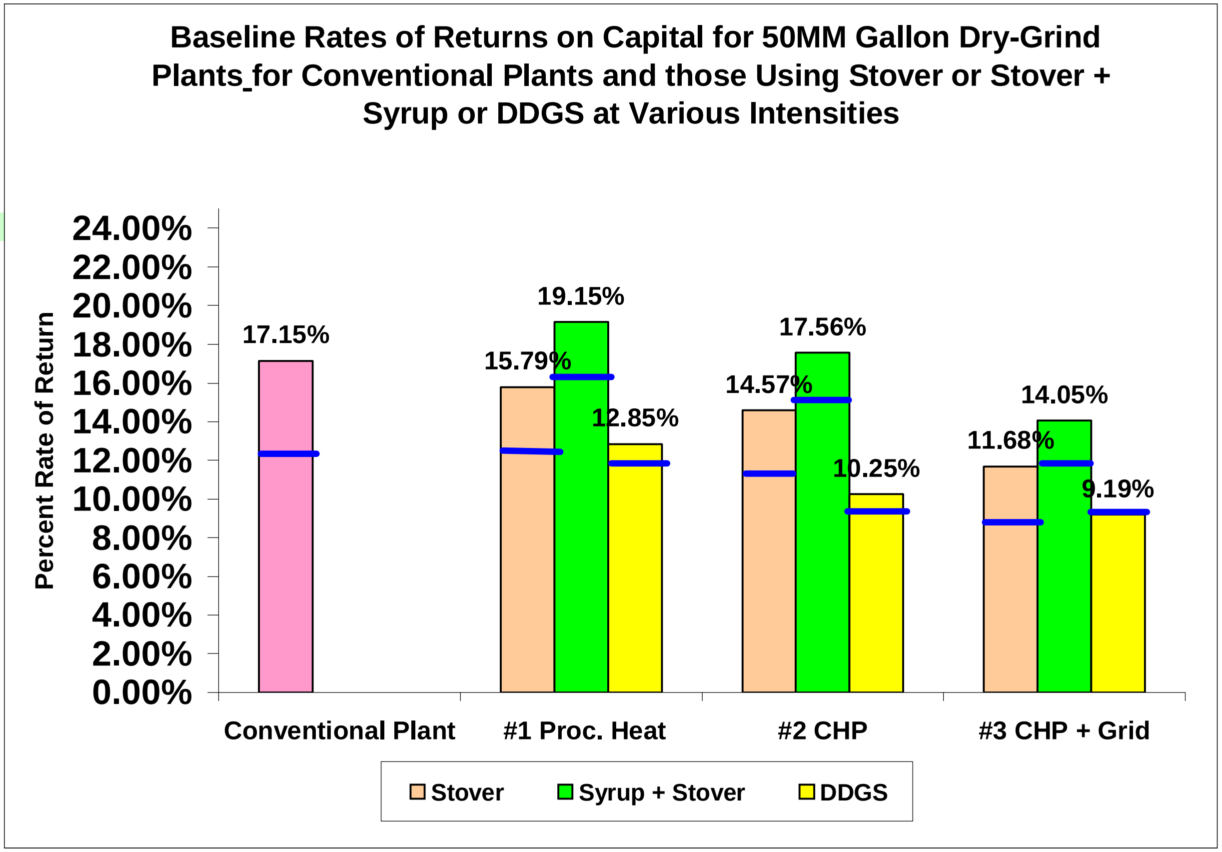
DDGS Price Shifts from $100 to $70 per Ton

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid		50MM Gal
7.15%	9.04%	8.47%	6.18%	Stover	
	14.00%	12.89%	9.87%	Syrup + Stover	
	10.75%	8.99%	9.19%	DDGS	



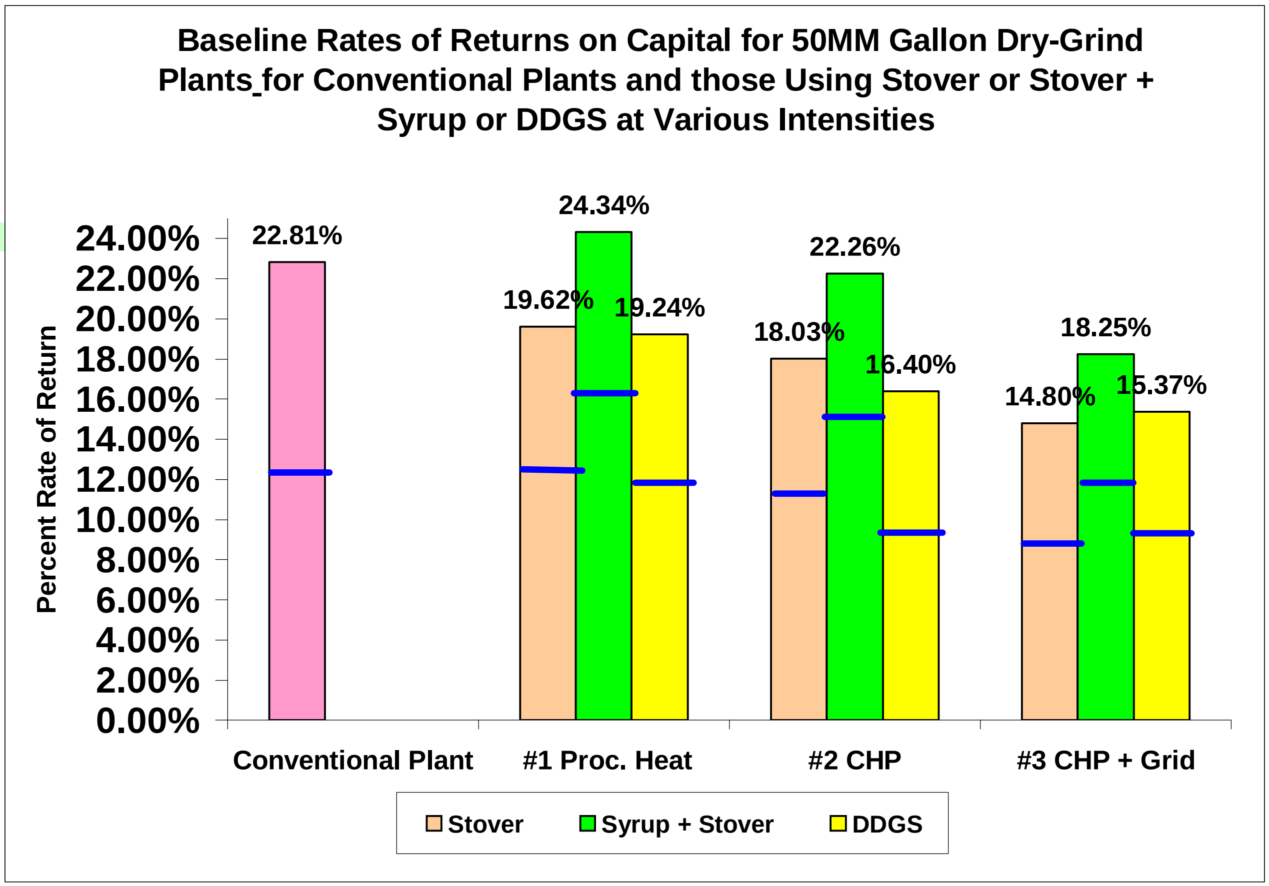
DDGS Price Rises from $100 to $130 per ton

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid		50MM Gal
17.15%	15.79%	14.57%	11.68%	Stover	
	19.15%	17.56%	14.05%	Syrup + Stover	
	12.85%	10.25%	9.19%	DDGS	



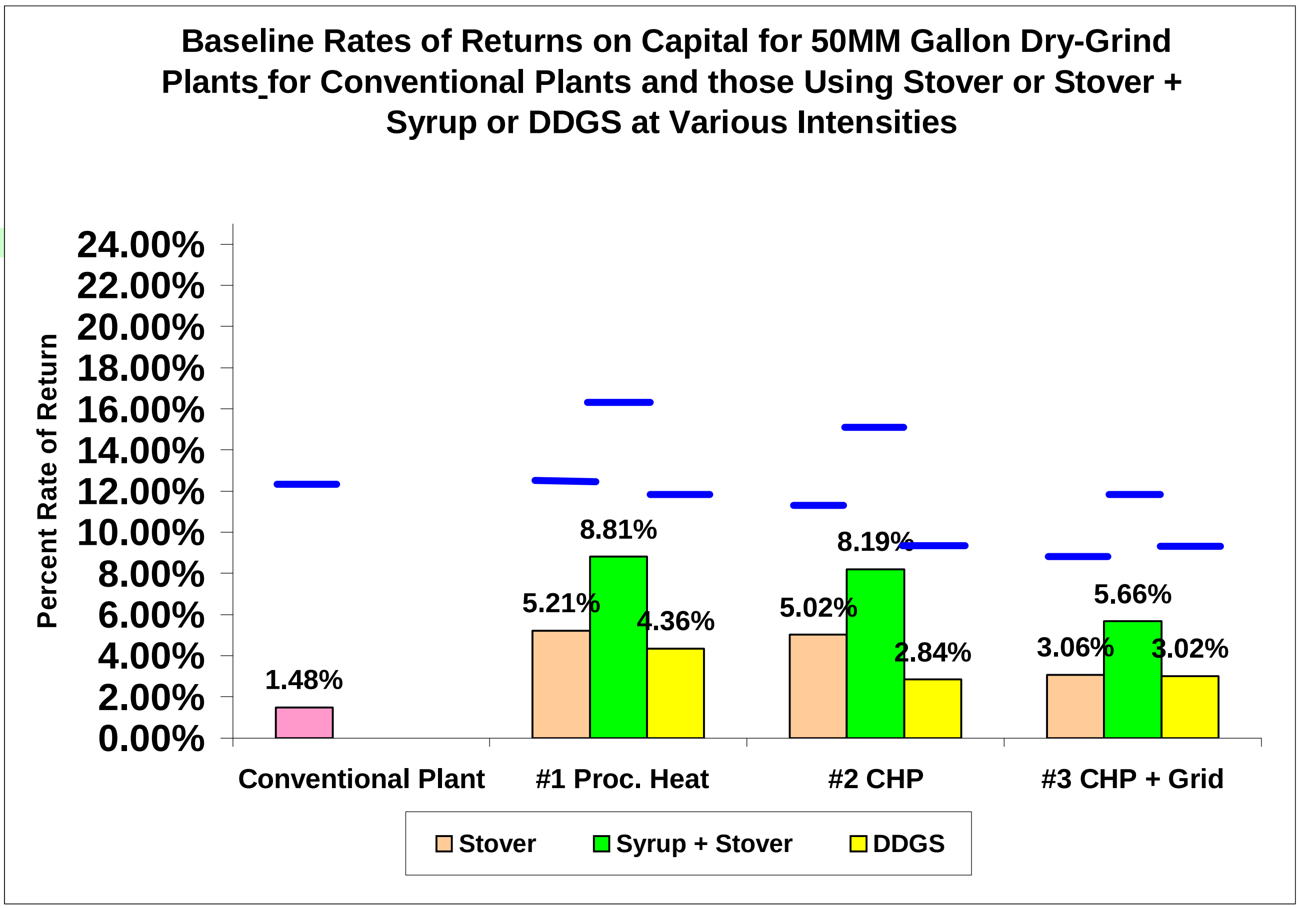
Ethanol Price Rises from $1.80 to $2.00/ gal. at Plant

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid		50MM Gal
22.81%	19.62%	18.03%	14.80%	Stover	
	24.34%	22.26%	18.25%	Syrup + Stover	
	19.24%	16.40%	15.37%	DDGS	



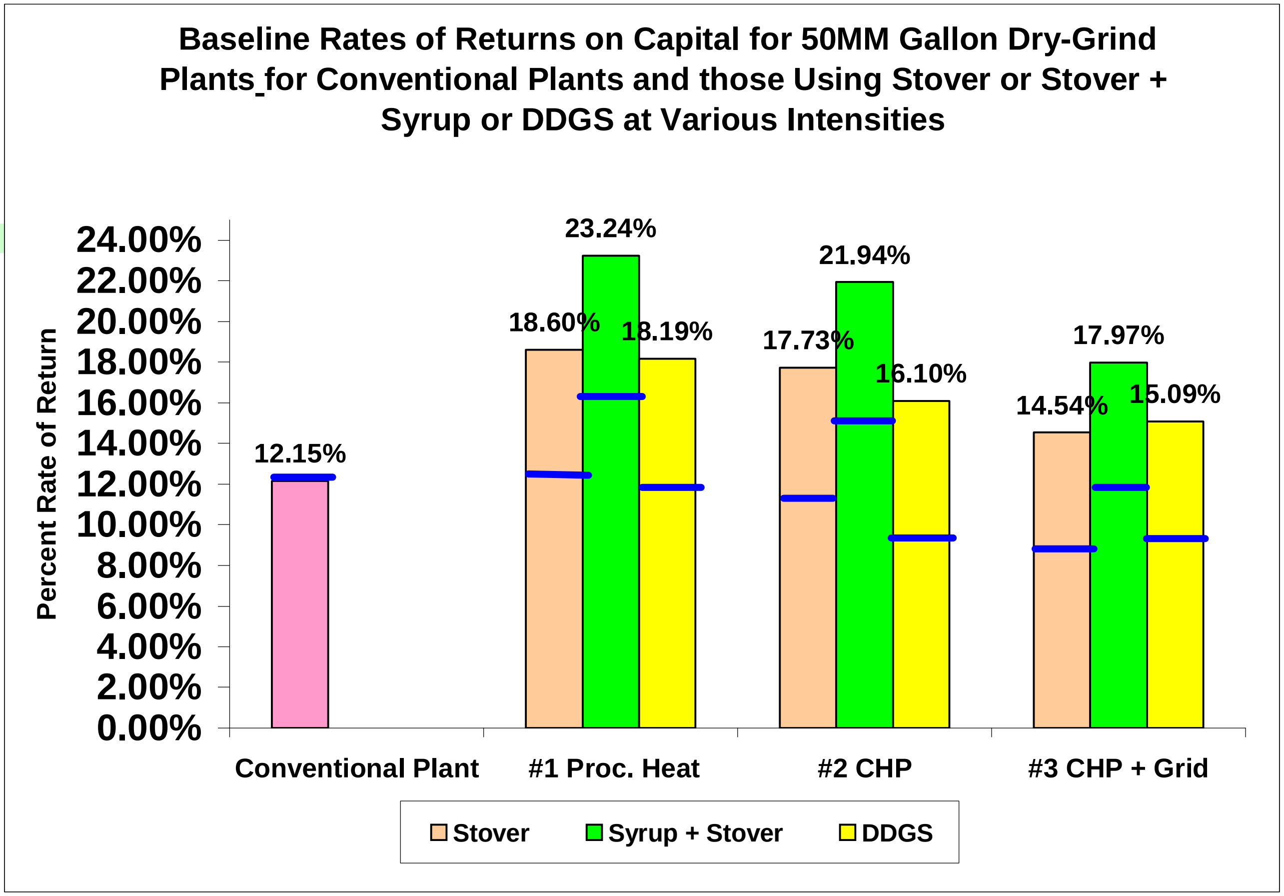
Ethanol Price Shifts from $1.80 to $1.60/ gal. at Plant

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid		50MM Gal
1.48%	5.21%	5.02%	3.06%	Stover	
	8.81%	8.19%	5.66%	Syrup + Stover	
	4.36%	2.84%	3.02%	DDGS	



Low Carbon Premium Rises from $.20 to $.40/Gal.

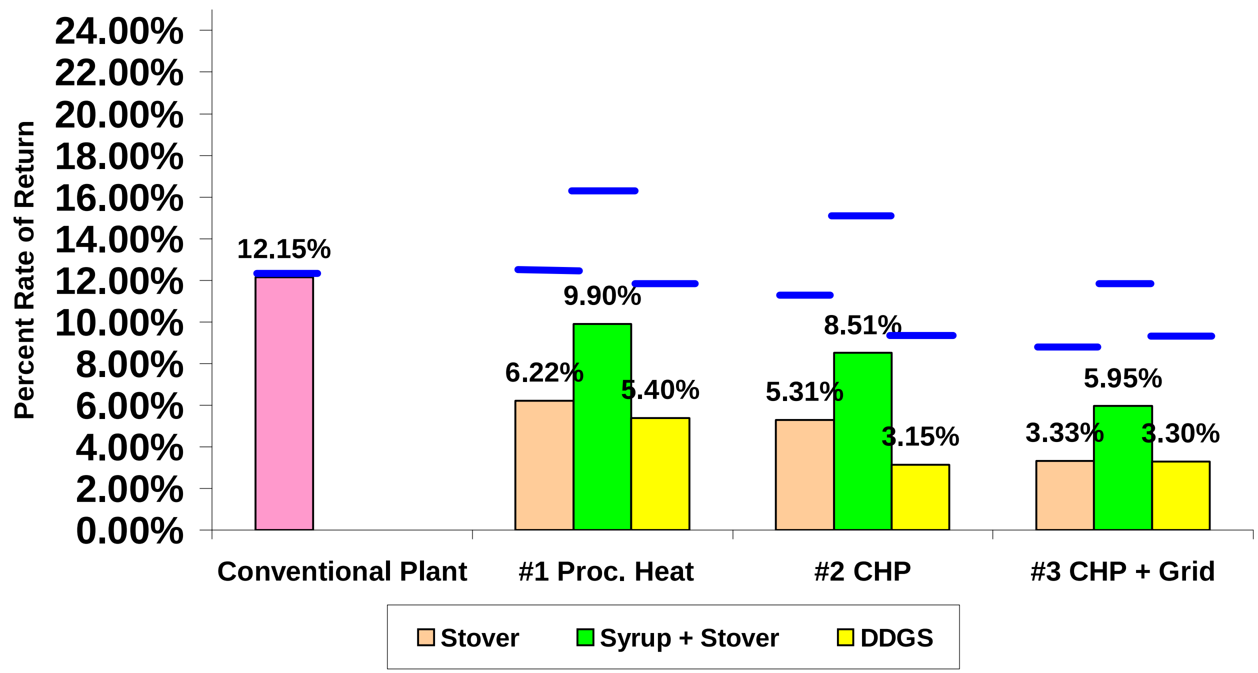
Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid		50MM Gal
12.15%	18.60%	17.73%	14.54%	Stover	
	23.24%	21.94%	17.97%	Syrup + Stover	
	18.19%	16.10%	15.09%	DDGS	



Low Carbon Premium is Zero

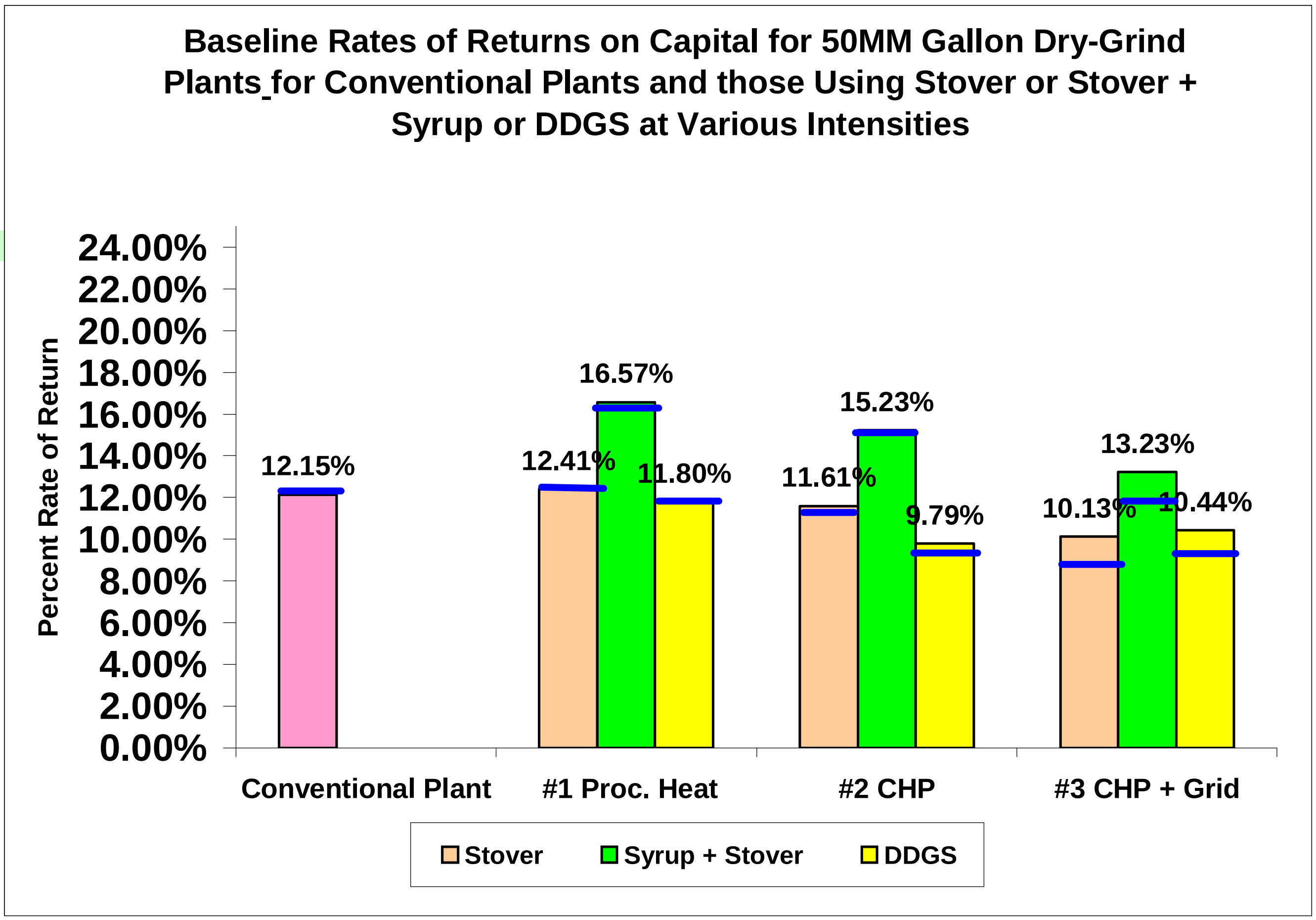
Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
12.15%	6.22%	5.31%	3.33%	Stover
	9.90%	8.51%	5.95%	Syrup + Stover
	5.40%	3.15%	3.30%	DDGS

Baseline Rates of Returns on Capital for 50MM Gallon Dry-Grind Plants for Conventional Plants and those Using Stover or Stover + Syrup or DDGS at Various Intensities



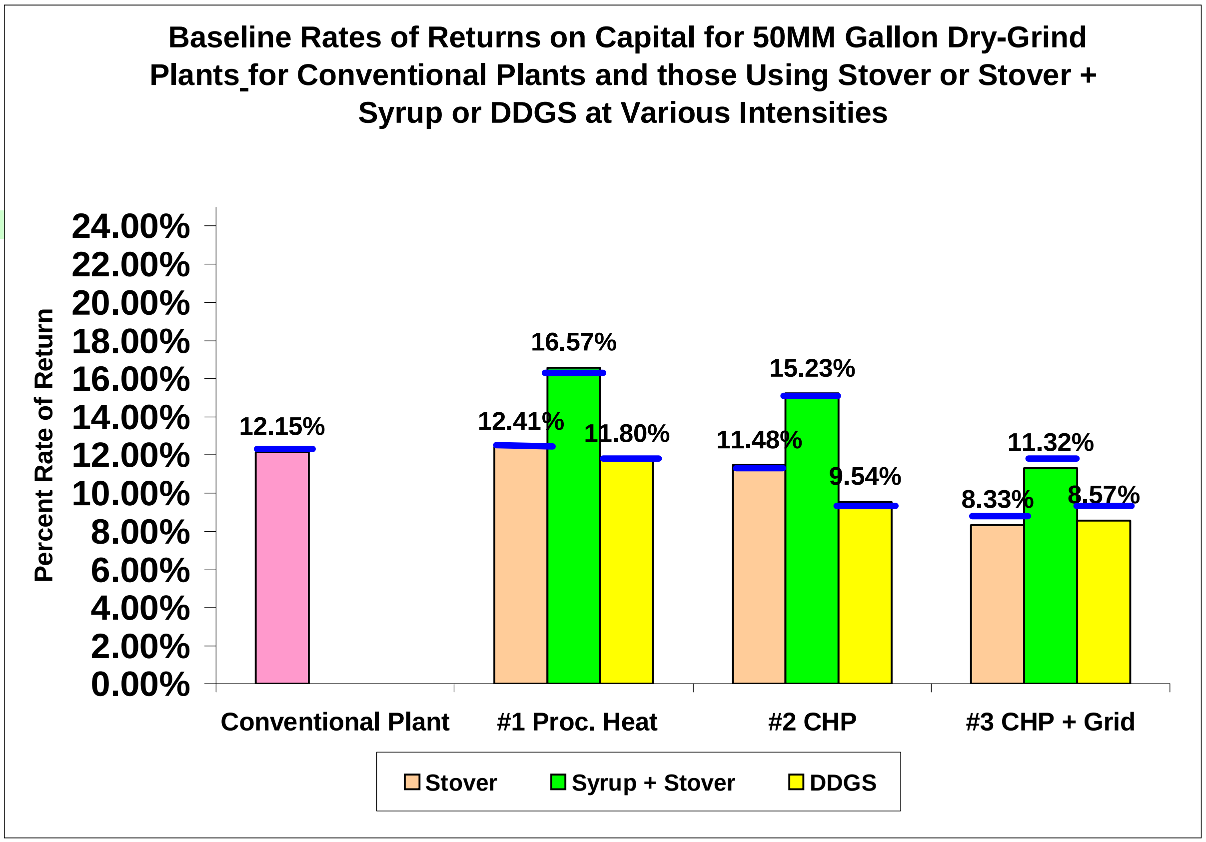
Price for Power Produced Shifts from $.06 to $.10/KWH

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
12.15%	12.41%	11.61%	10.13%	Stover
	16.57%	15.23%	13.23%	Syrup + Stover
	11.80%	9.79%	10.44%	DDGS



Electricity Purchase Price Falls from $.06 to $.04/ KWH

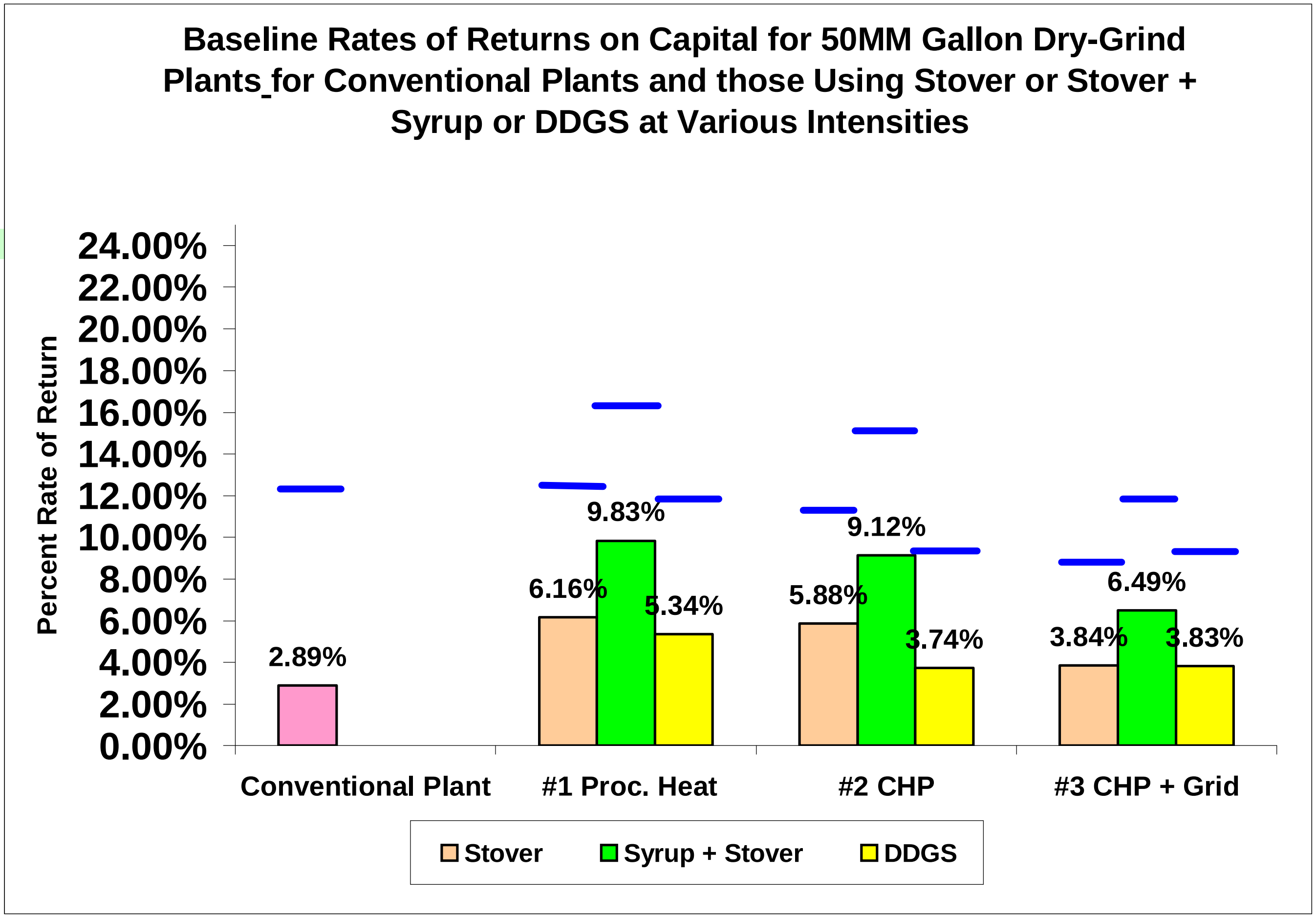
	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid		50MM Gal
	12.15%	12.41%	11.48%	8.33%	Stover	
		16.57%	15.23%	11.32%	Syrup + Stover	
		11.80%	9.54%	8.57%	DDGS	



Corn Price Shifts from $3.50 to $4.00/bushel

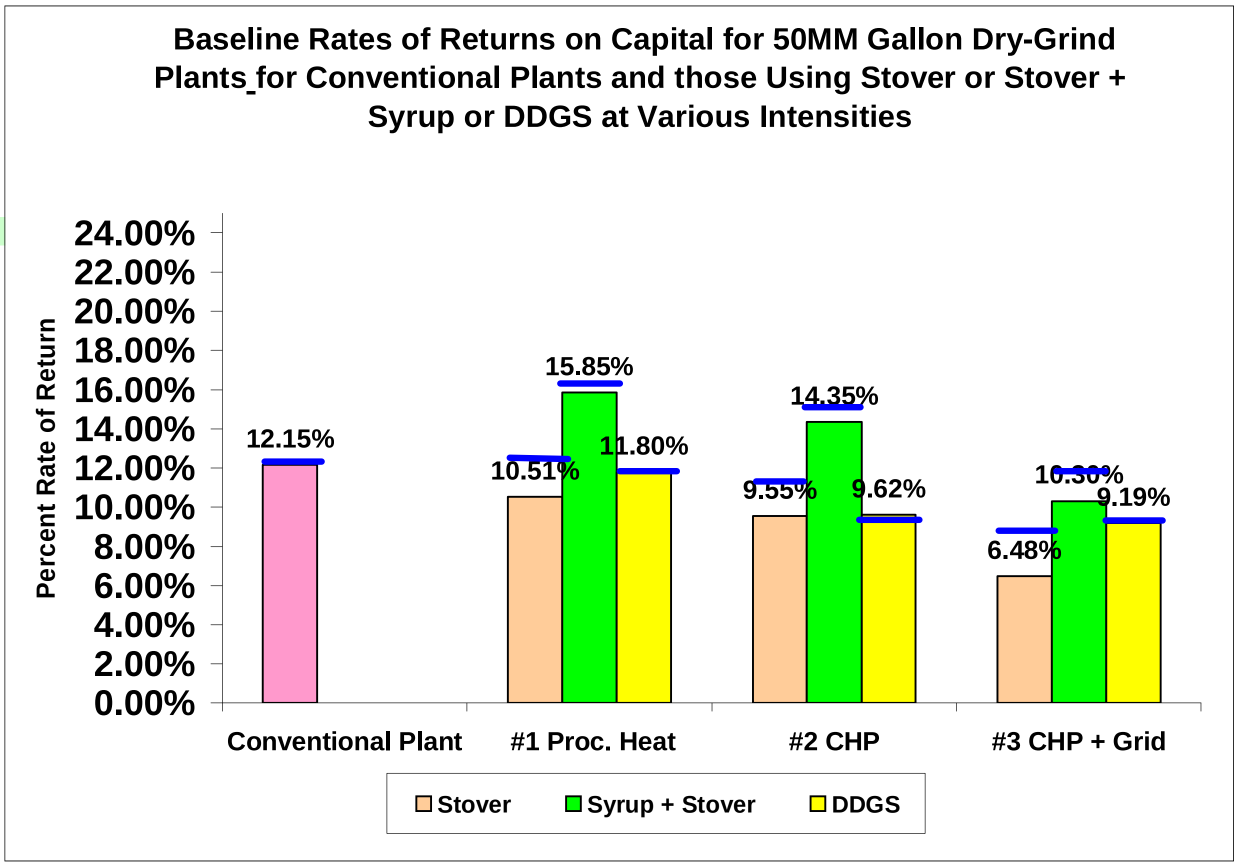
50MM Gal

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	
2.89%	6.16%	5.88%	3.84%	Stover
	9.83%	9.12%	6.49%	Syrup + Stover
	5.34%	3.74%	3.83%	DDGS



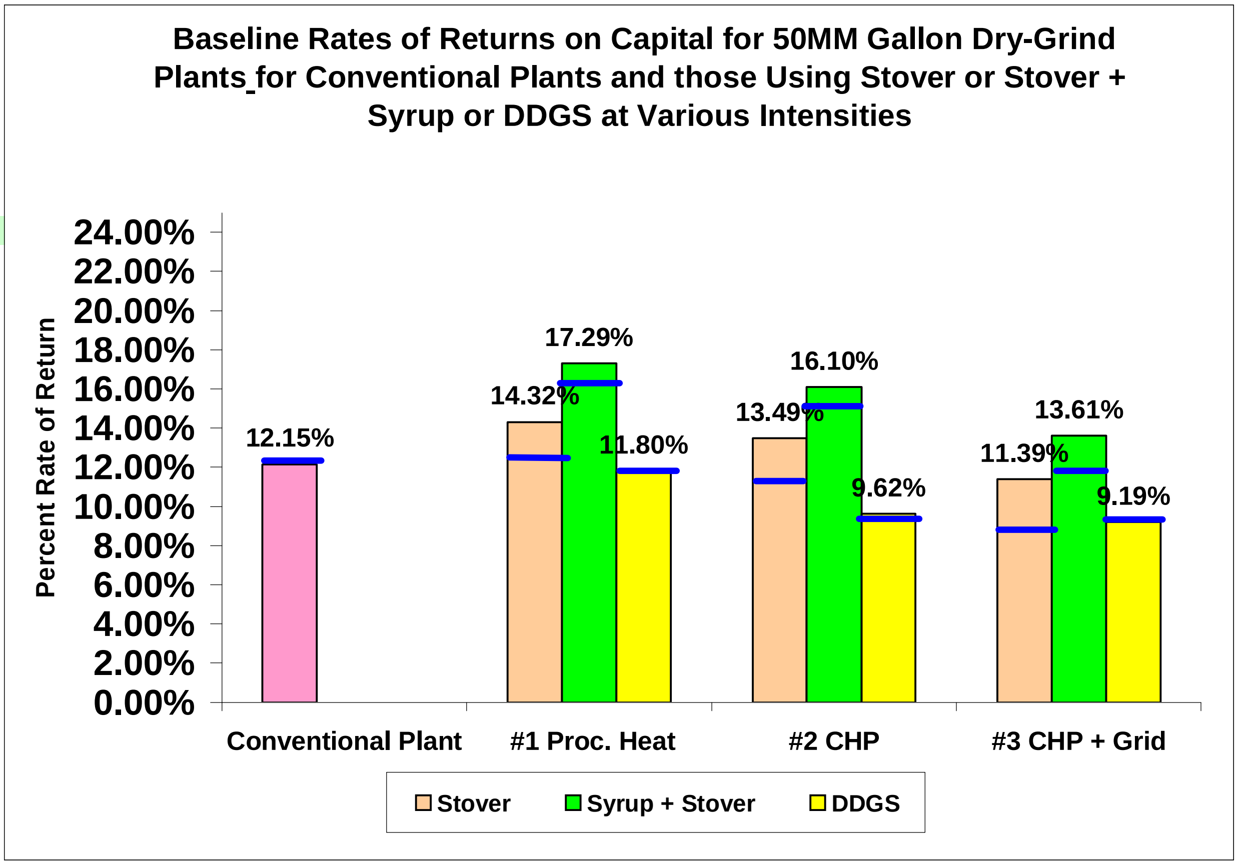
Stover Price Rises from $80 to $100 per Ton

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
12.15%	10.51%	9.55%	6.48%	Stover
	15.85%	14.35%	10.30%	Syrup + Stover
	11.80%	9.62%	9.19%	DDGS



Stover Price Drops from $80 to $60 per Ton

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
12.15%	14.32%	13.49%	11.39%	Stover
	17.29%	16.10%	13.61%	Syrup + Stover
	11.80%	9.62%	9.19%	DDGS



IMPROVED BREAKEVENS WITH BIOMASS

- Q: How High Can Corn Price Rise with the Biomass Cases Still Breaking Even?

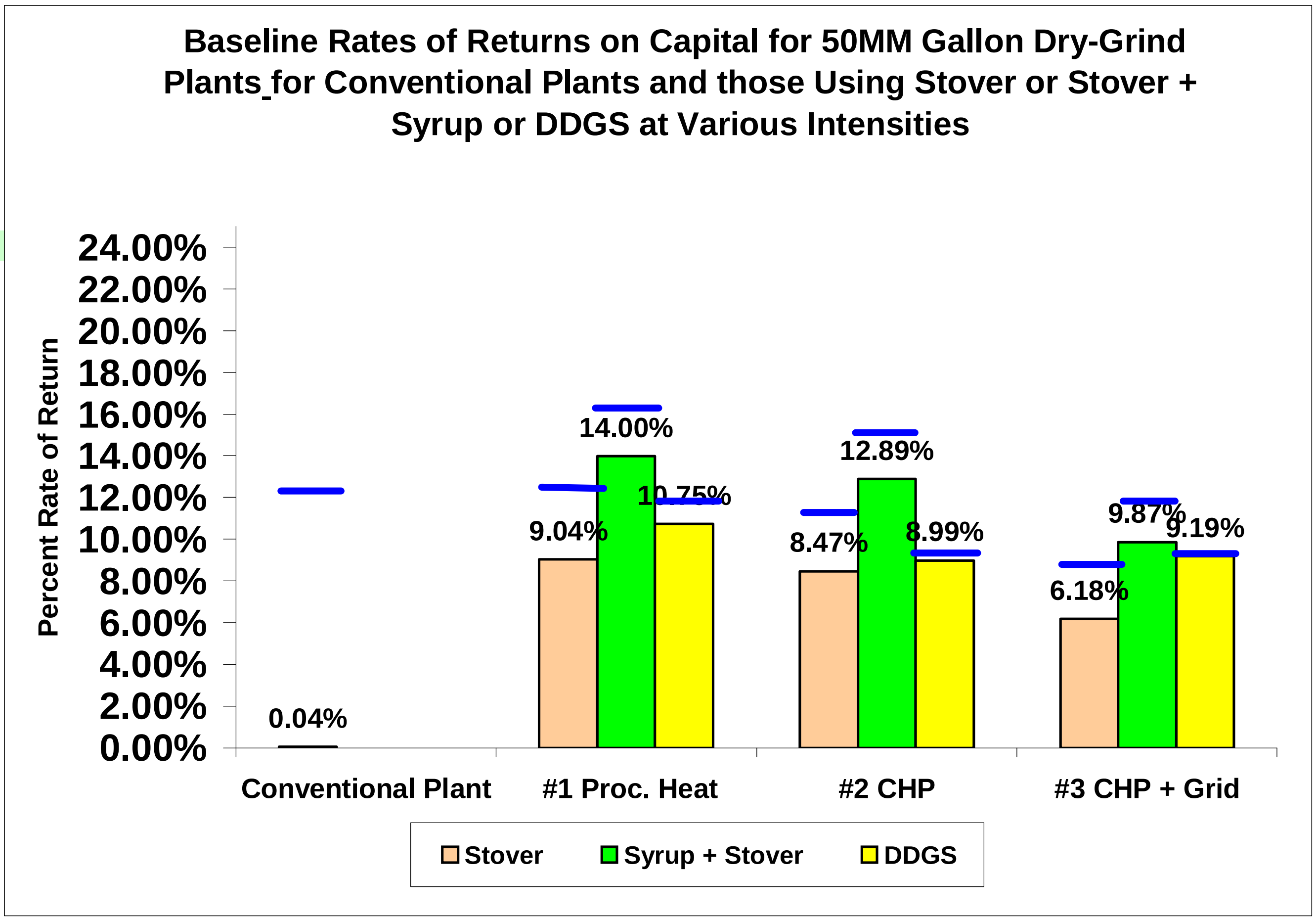
- A: $4.74 per bushel

- Q: How much money would the 50 MM gallon conventional plant lose at that price of corn?

A: $12,159,424 per year.

Multiple Factors: $70 DDGS, $12.00 N.G.

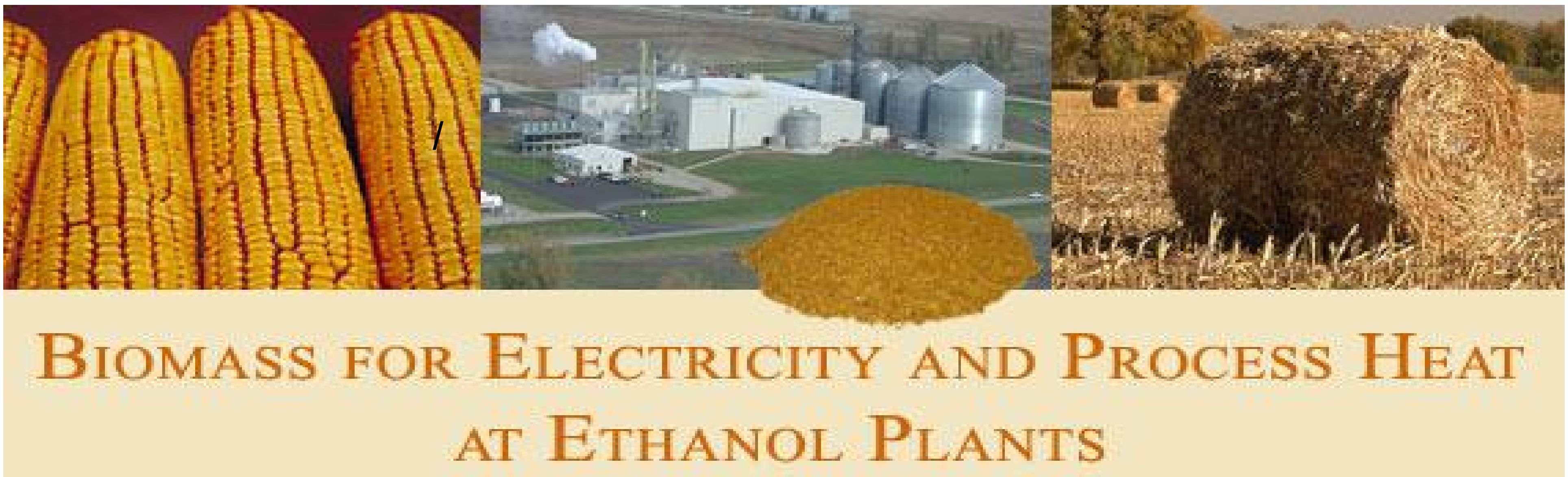
Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
0.04%	9.04%	8.47%	6.18%	Stover
	14.00%	12.89%	9.87%	Syrup + Stover
	10.75%	8.99%	9.19%	DDGS



Summary

- Utilization of readily available biomass in the form of by-product syrup and corn stover at dry-grind ethanol plants is **<u>technically feasible</u>** and **<u>fiscally prudent</u>**, especially when policies favoring low carbon fuel standards are adopted.
- Biomass in the form of syrup, stover, DDGS and possibly other sources can be used to improve energy balance and drastically reduce the carbon footprint of ethanol produced from corn.
- Dry-grind ethanol plants of 50MM gal. per year capacity can produce and sell 5-7 MW of electricity for the grid.

Thanks!!
Please Check our Website for Further Information.
www.biomassCHPethanol.umn.edu



- Acknowledgement
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