

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



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# 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:



**Minnesota Agricultural  
Experiment Station**  
UNIVERSITY OF MINNESOTA



# 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



# Focus on Economic Analysis

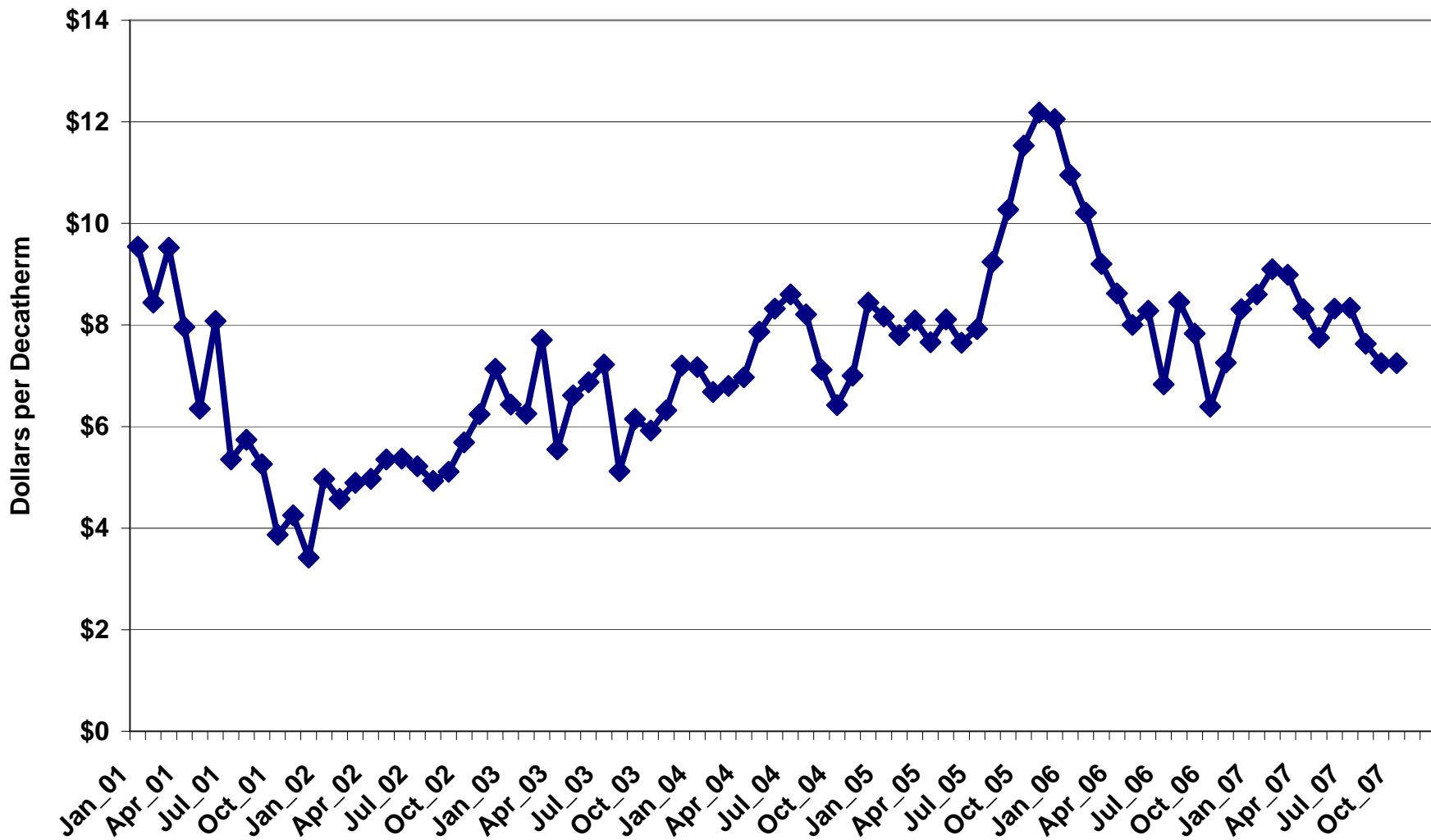
1. Economic analysis after technical steps of biomass characterization, emissions control standards, Aspen Plus estimation of machine capacities for individual technology bundles.
2. Capital Costs estimated by AMEC.
3. Spreadsheets were developed to model the ROR's on investment needed to replace natural 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----

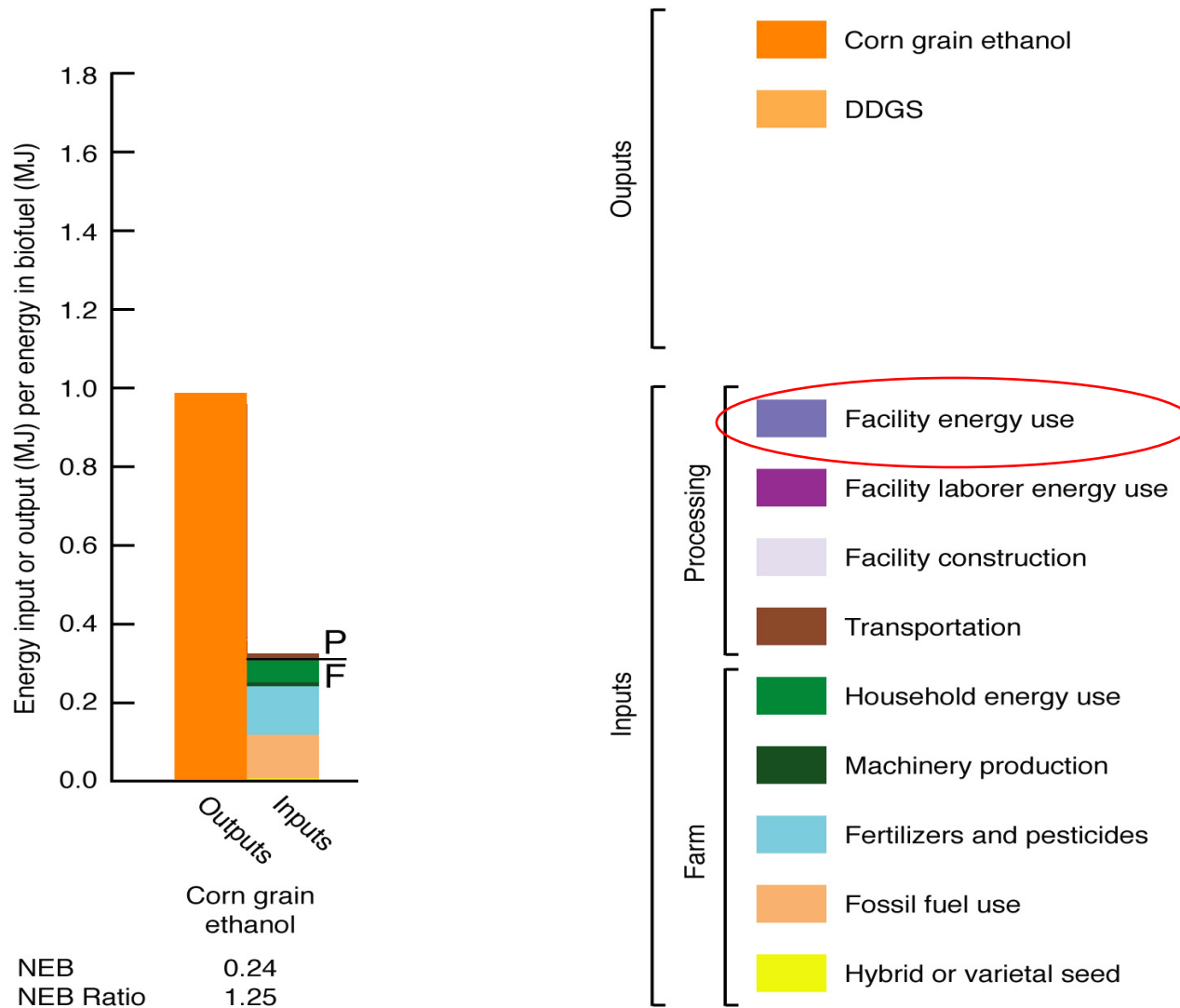
- Natural Gas is a great fuel.
- – except for price levels and volatility. At higher NG prices, ethanol profits are threatened.
- Natural Gas is the second largest cost of ethanol production after corn in typical dry-grind plants.
- Natural Gas is a fossil fuel; contributes GHG.



## Iowa natural Gas Industrial Price (Source: Energy Information Administration)



# Motivations for Using Biomass



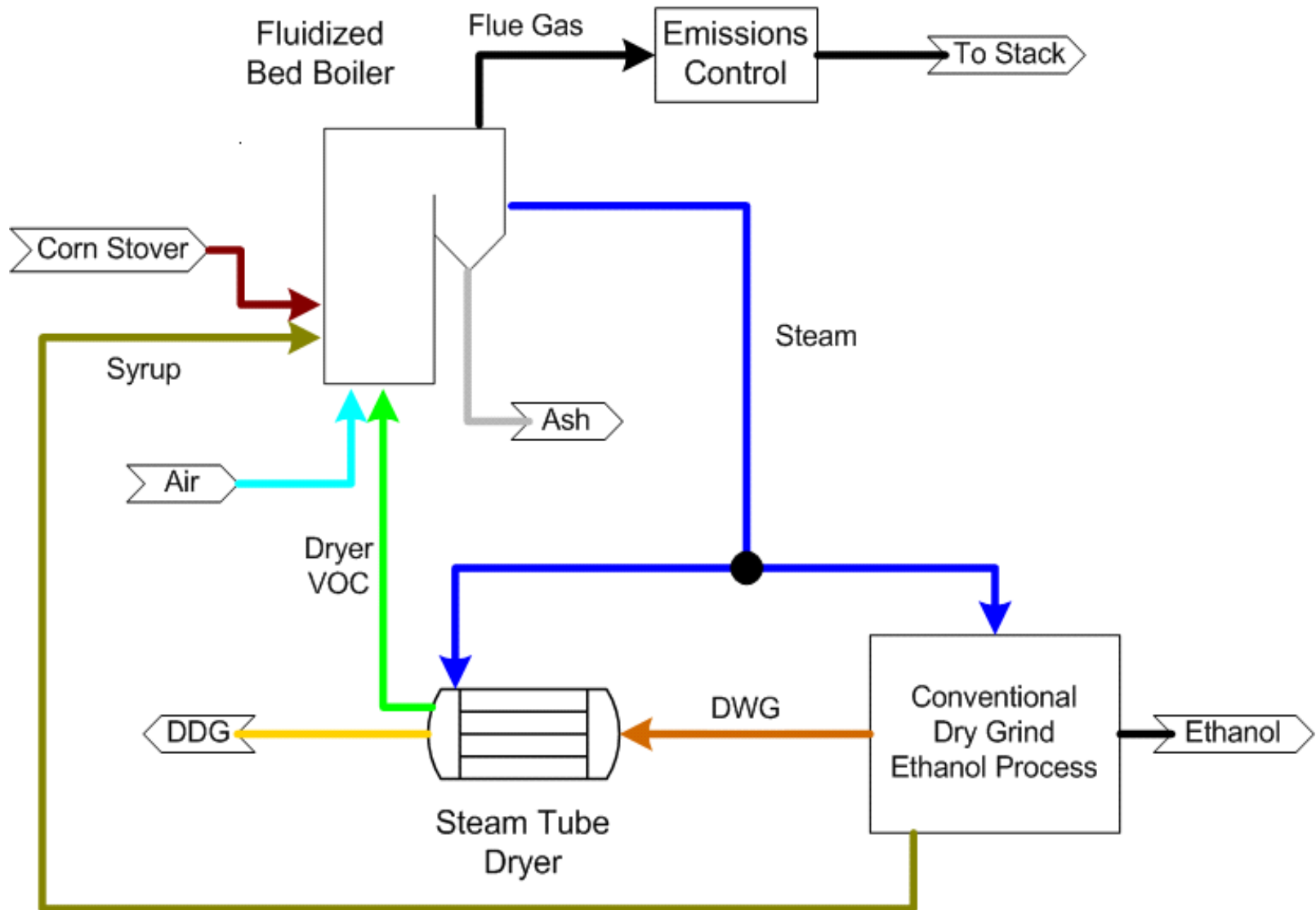
Hill, Nelson, Tilman,  
Polasky, and Tiffany.  
PNAS. Vol. 103, no.  
30, 2006



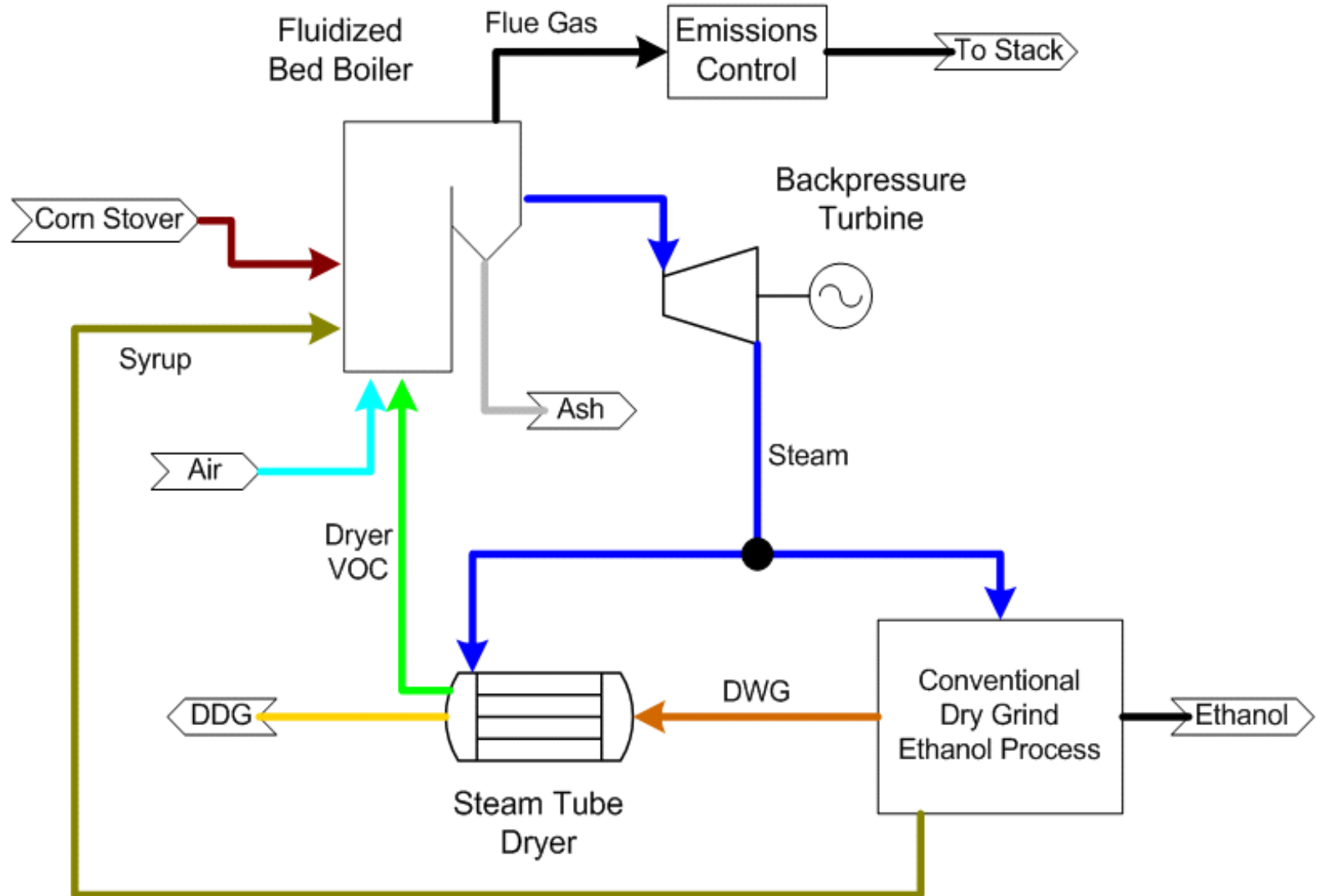
# Motivations for Using Biomass

- Potential to improve Renewable Energy Ratio
  - Defined as:  $\text{Energy Out} / \text{Fossil Energy In}$
- 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

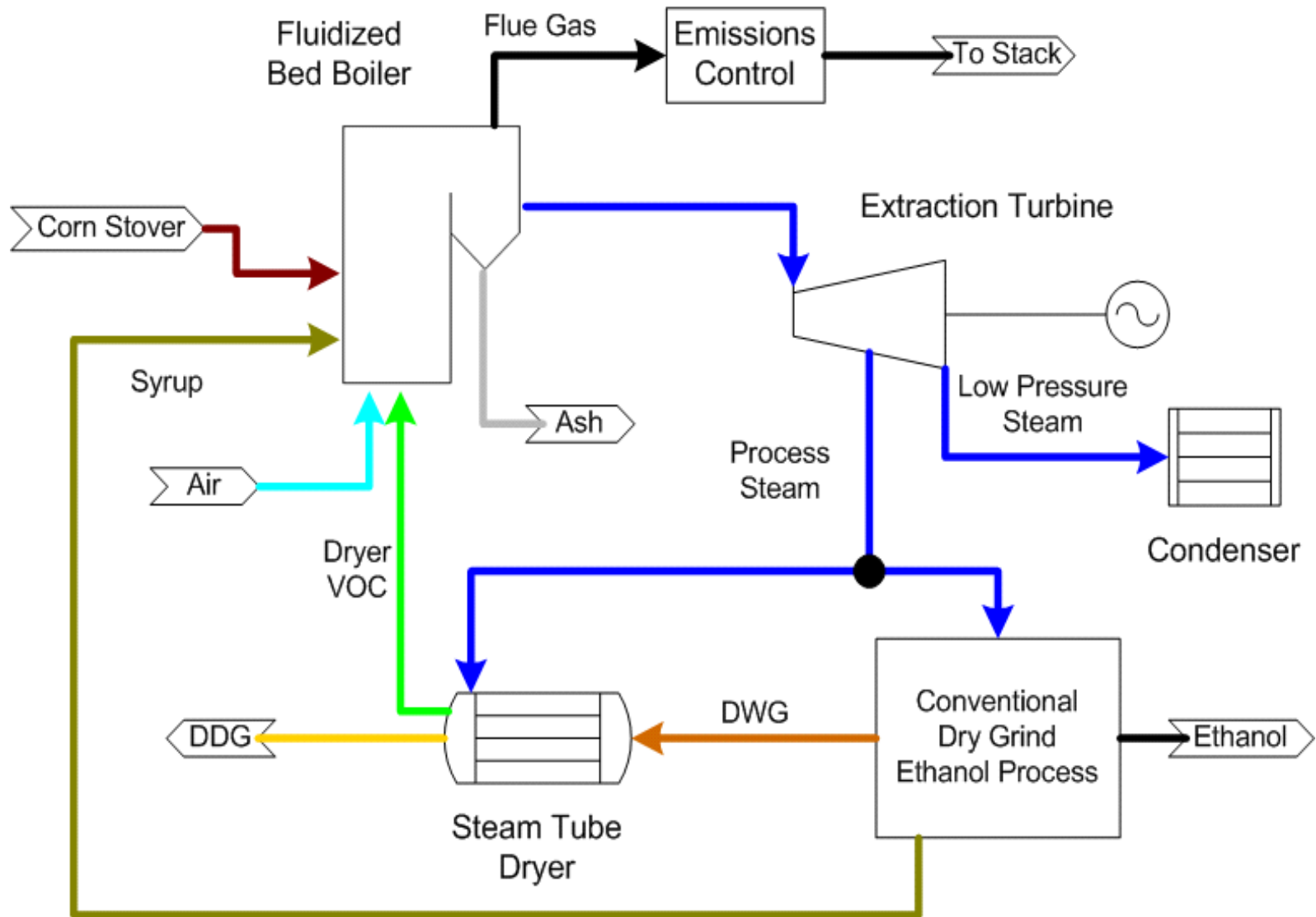
# Syrup + Stover-Level #1



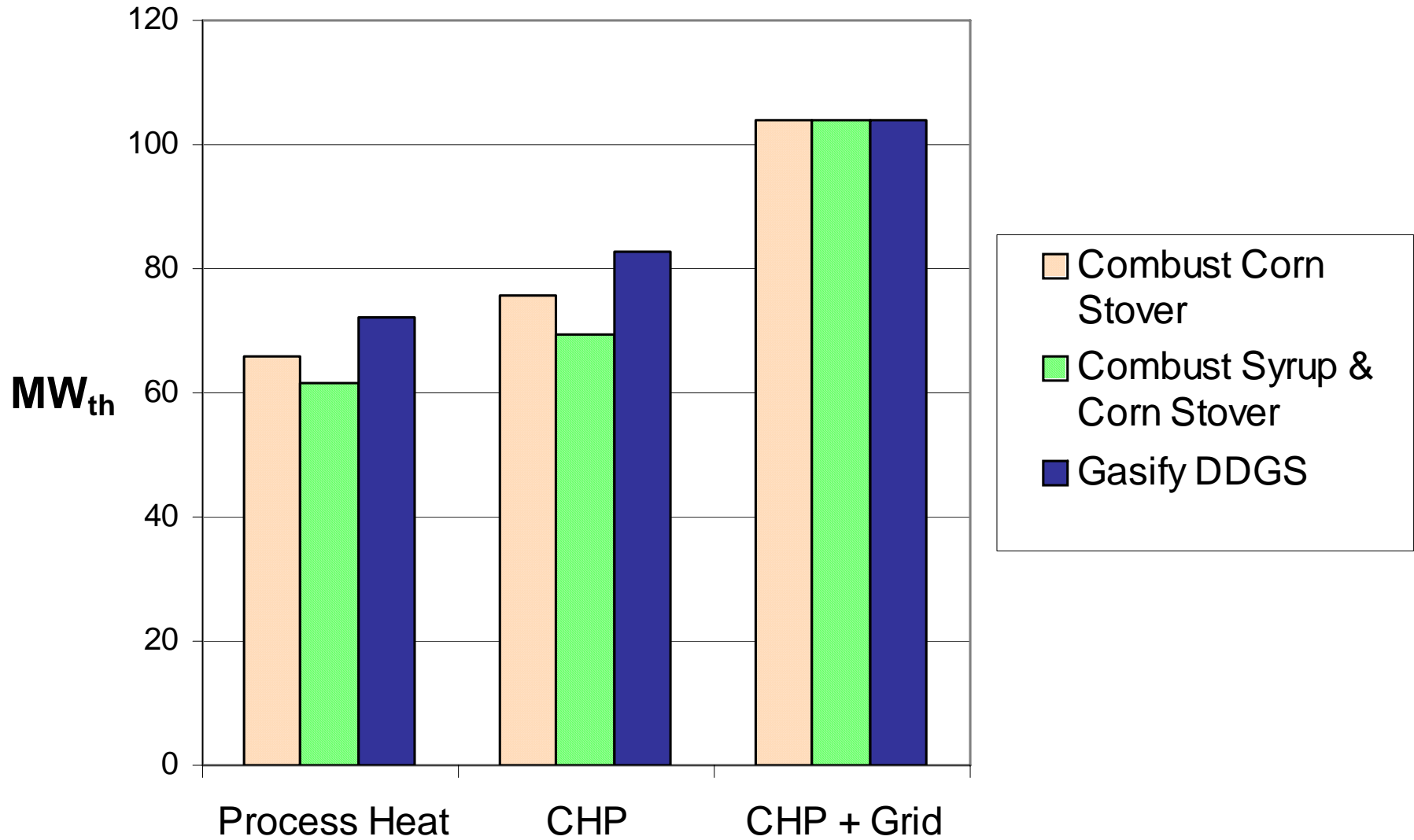
# Syrup + Stover-Level #2



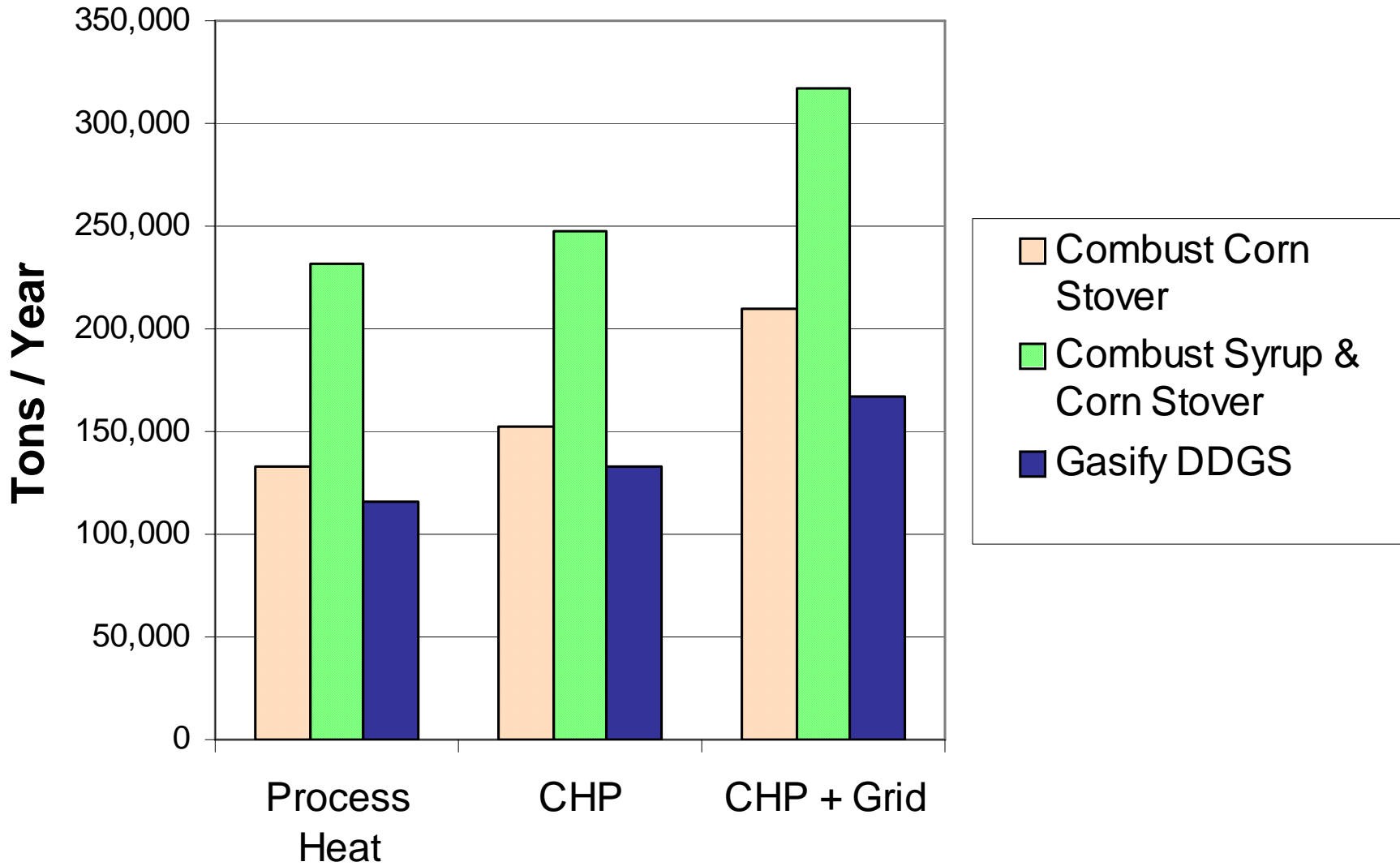
# Syrup + Stover-Level #3



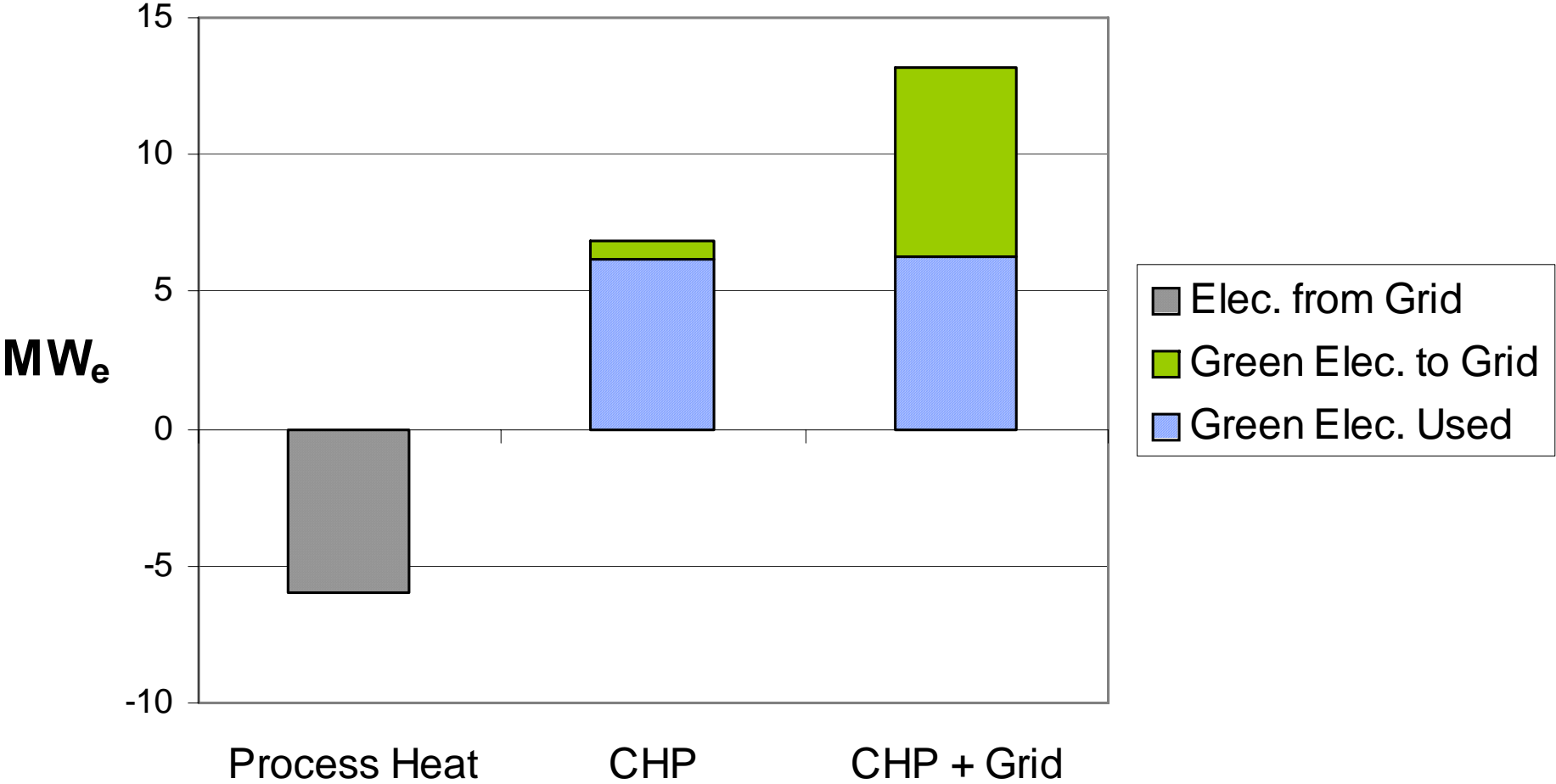
# Biomass Fuel Energy Input (HHV)



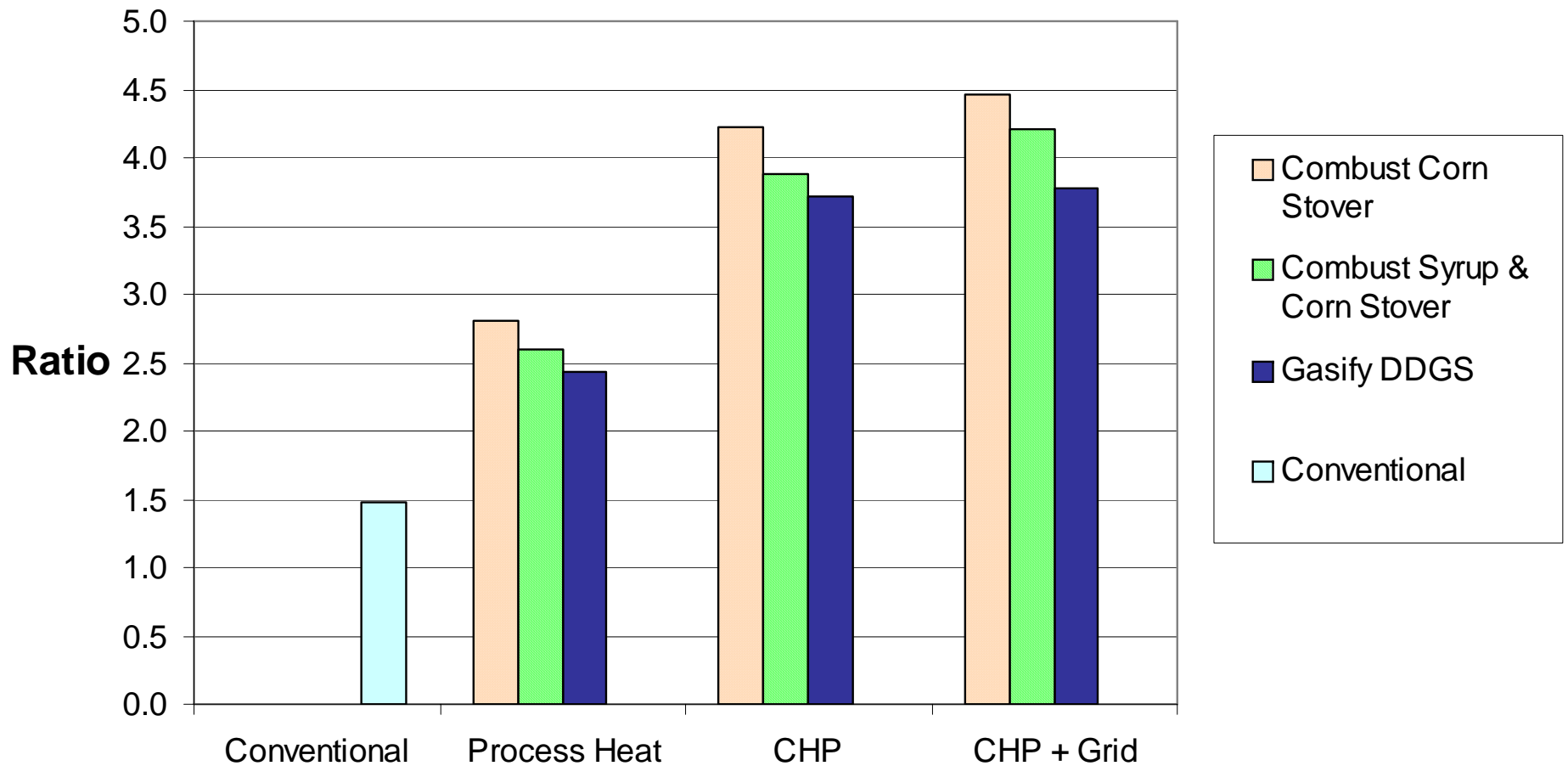
# Biomass Fuel Use (Wet Basis)



# Corn Stover Combustion: Electricity Balance



## Renewable Energy Ratio (LHV)





# Establishing Baseline Assumptions



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# 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)**



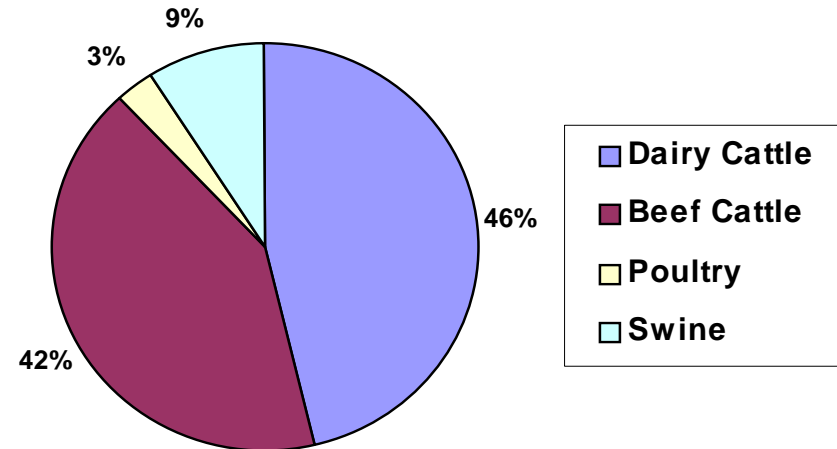
- *The Economics of Harvesting and Transporting Corn Stover for Conversion to Fuel Ethanol: A Case Study for Minnesota*  
Petrolia, Daniel R.

# 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

2006 North American Distillers Grains Consumption  
by Livestock Class

(Source: Commodity Specialists Co.)



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

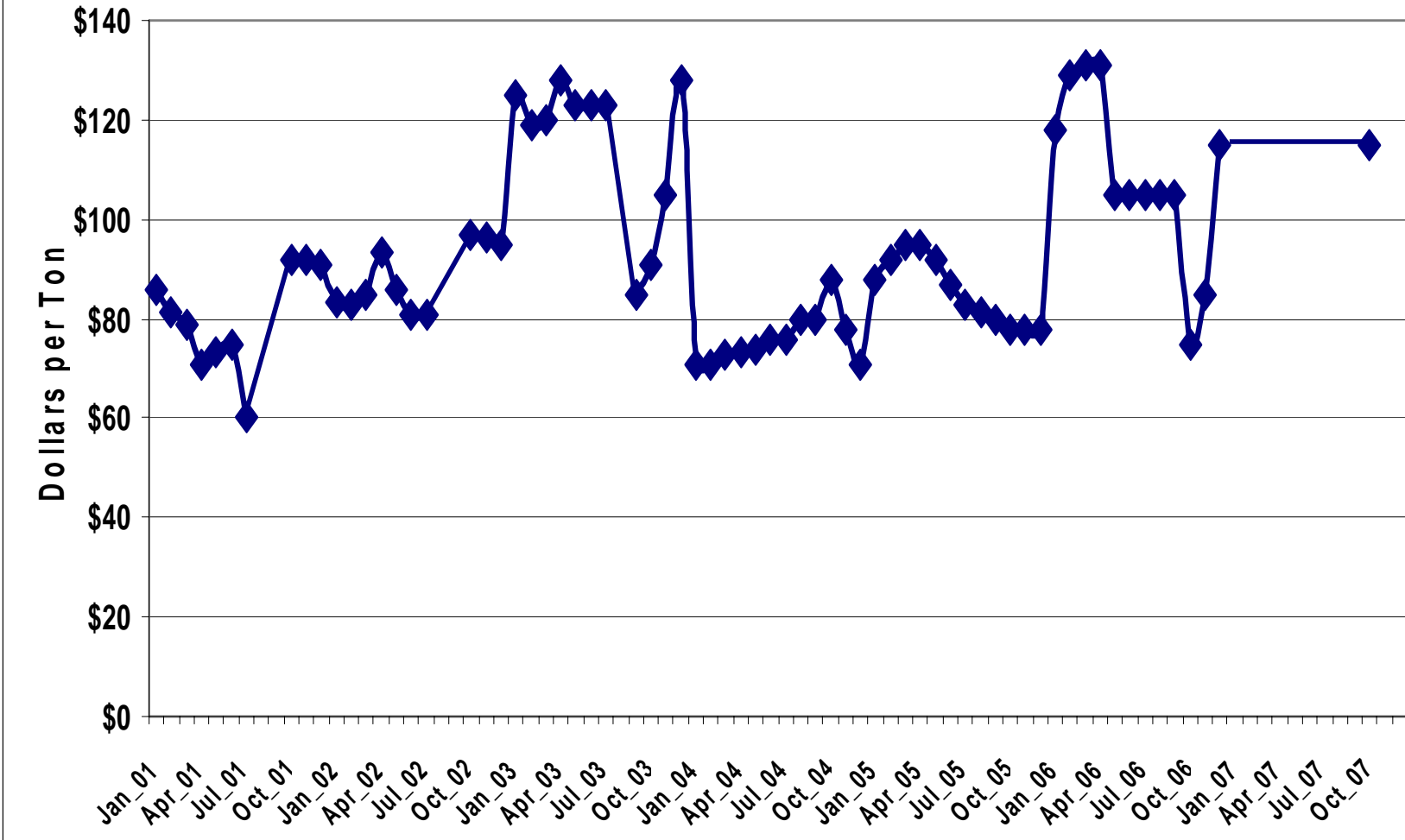
## Co-Product Usage Possibilities for U.S. Animal Species

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

|         | Grain-Consuming Animal Units (Millions) | <u>Max. Rate of Inclusion In Diet</u> | 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)



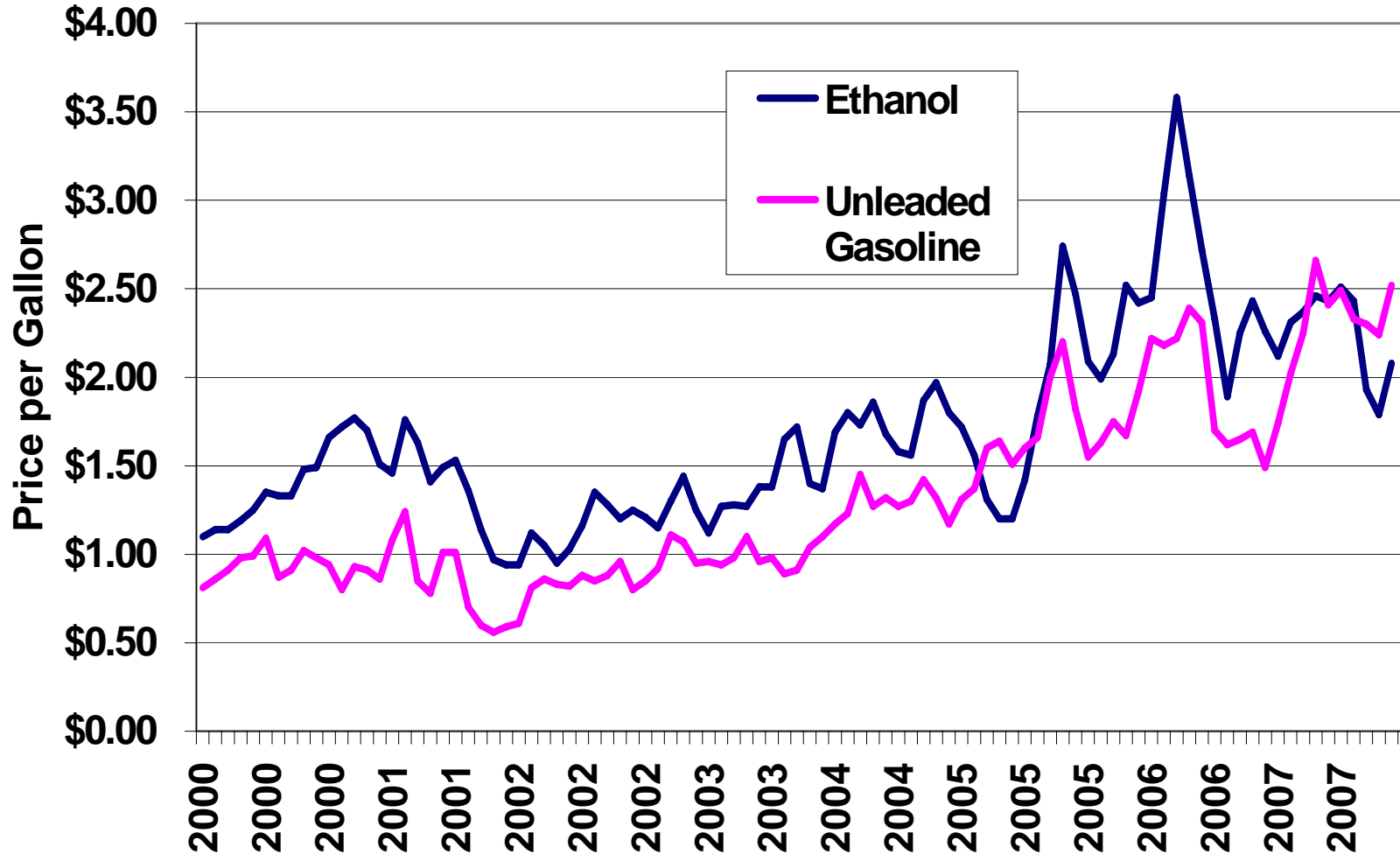
# Ethanol Prices



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# Ethanol and Unleaded Gasoline Rack Prices F.O.B. Omaha, Nebraska, 2000-2007

Sources: Nebraska Ethanol Board, Nebraska Energy Office



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# 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.

| <u>Refiners<br/>Acquisition<br/>Cost \$/Barrel</u> | <u>Wholesale<br/>Gasoline<br/>Price \$/Gallon*</u> | <u>Ethanol Price Indicated<br/>as BTU substitute<br/>with VEETC</u> |
|--|--|---|
| 50   | 1.49   | 1.50  |
| 60   | 1.78   | 1.70  |
| 70   | 2.07   | 1.89  |
| 80   | 2.36   | 2.08  |
| 90   | 2.65   | 2.28  |
| 100  | 2.94   | 2.47  |

\*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

|                   | <u>Net Cost /Gallon For New Construction</u> |                 |
|-------------------|--|-----------------|
| <u>Corn Price</u> | <u>50mmgpy</u>                               | <u>100mmgpy</u> |
| \$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



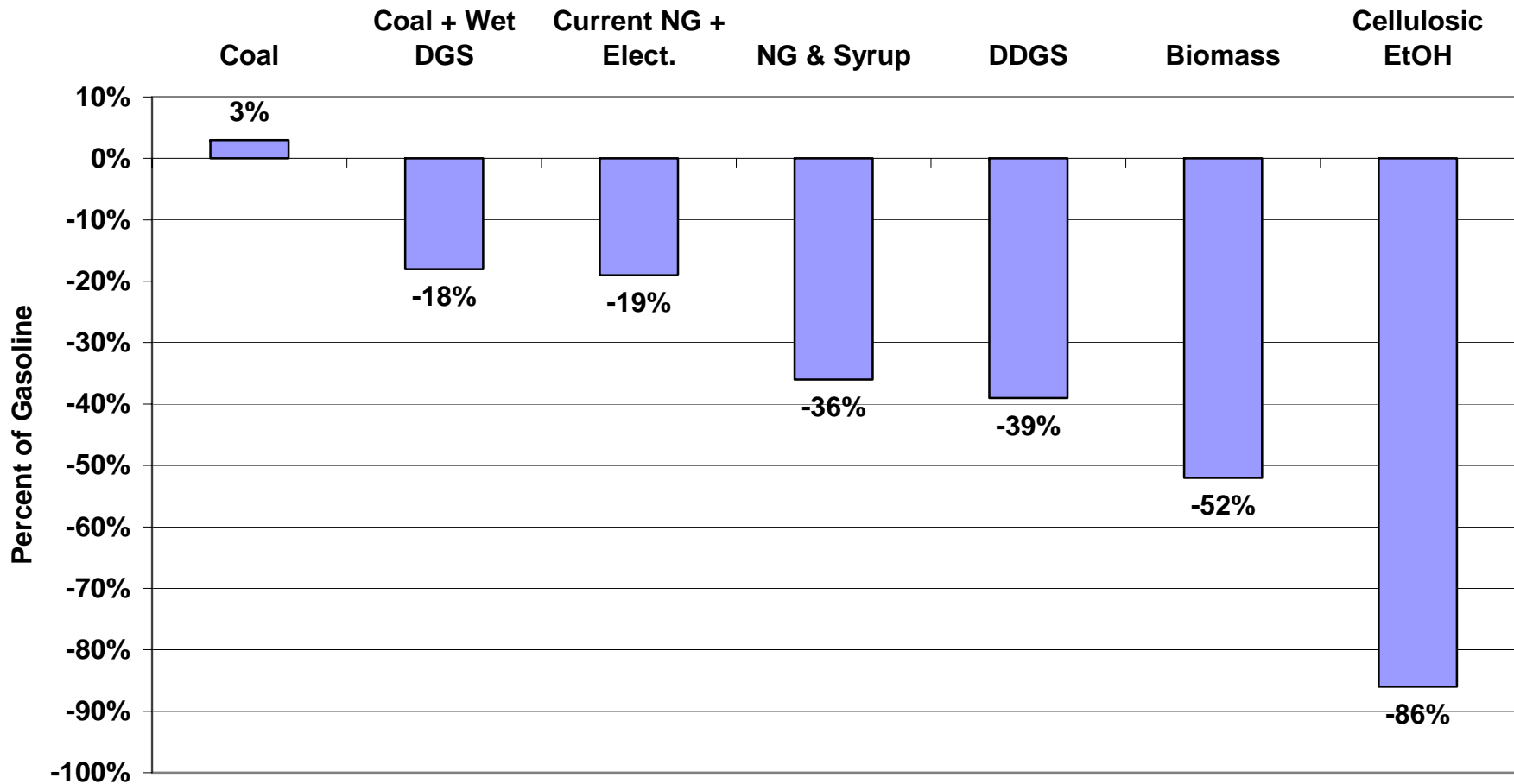
- Lower carbon intensity of fuels for passenger vehicles 10% by 2020 in grams of carbon emitted per BTU used. (LCA)
- Replace 20% of on-road gasoline with lower-carbon fuels
- **Triples CA renewable fuels market**
- Goal of producing 20% of biofuels in CA by 2010, 40% by 2020
- Use more hybrid vehicles
- 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

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

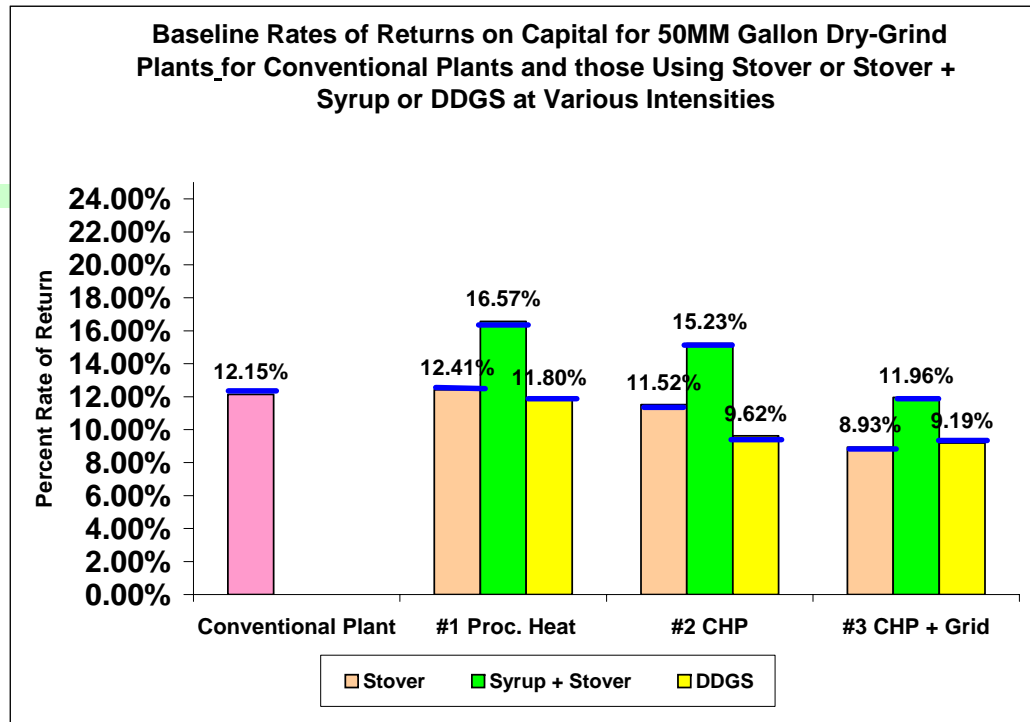
# Additional Operating Costs with Biomass

- 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.

| <b>Assumptions Common Across All Processes</b>      |             | 1/10/2008       |
|---|-------------|-----------------|
| <b>INSTALLED COSTS</b>                              | Active Val. | Base Val.       |
| <b>Debt-Equity Assumptions</b>                      |             |                 |
| 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              |
| <b>Output Market Prices</b>                         |             |                 |
| 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          |
| <b>Government Subsidies</b>                         |             |                 |
| 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<br>0.25 |
| <b>Feedstock Delivered Prices Paid by Processor</b> |             |                 |
| Corn Price (\$ per bu.)                             | \$3.50      | \$3.50          |
| <b>Energy Prices</b>                                |             |                 |
| 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          |
| <b>Operating Costs/Input Prices</b>                 |             |                 |
| Denaturant Price / gal                              | \$1.80      | \$1.80          |
| Denat/100 gal Anhyd.                                | 5           | 5               |
| <b>Feedstock-to-Ethanol Conversion Yields</b>       |             |                 |
| 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

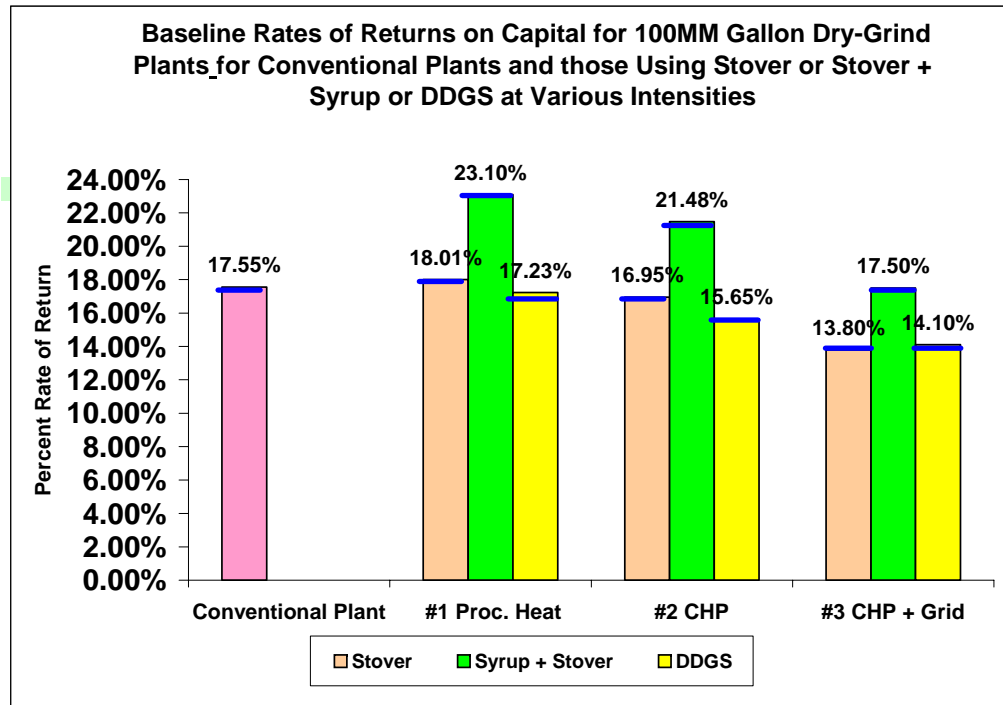
## Years to Payback Additional Investment

| 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 |                |
|--------------------|---------------|--------|---------------|----------------|
| 17.55%             | 18.01%        | 16.95% | 13.80%        | Stover         |
|                    | 23.10%        | 21.48% | 17.50%        | Syrup + Stover |
|                    | 17.23%        | 15.65% | 14.10%        | DDGS           |

100MM Gal



## Years to Payback Additional Investment

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

100MM Gal

# 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

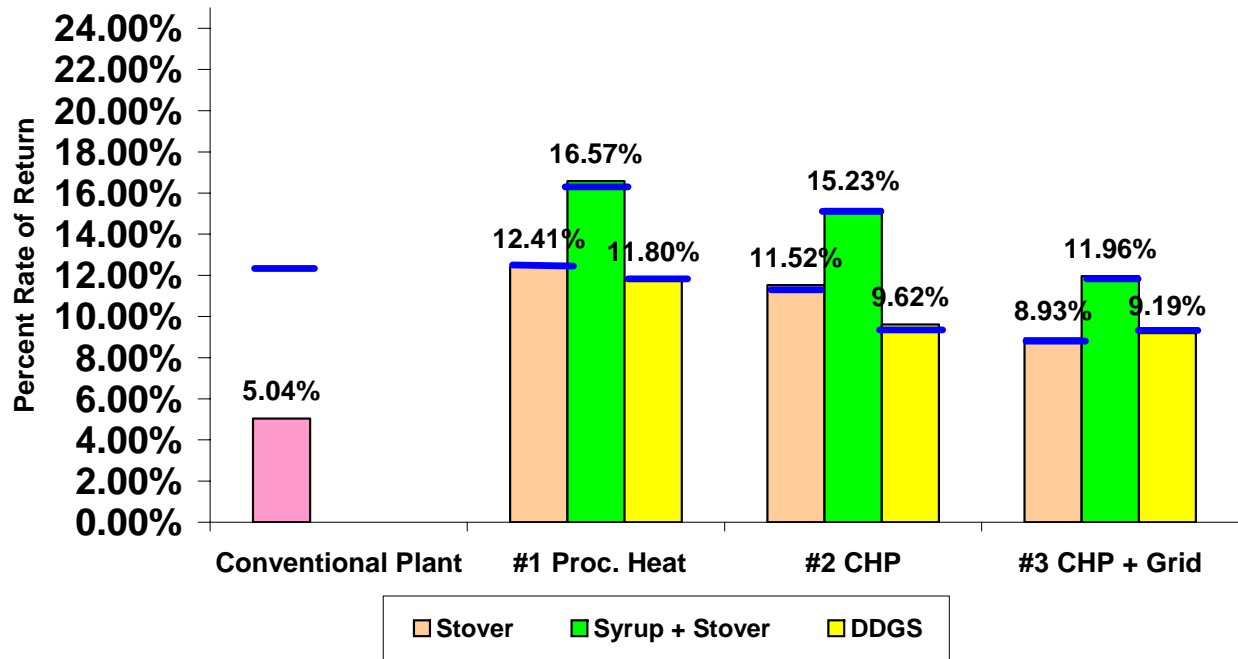


# Natural Gas Rises from \$8.00 to \$12.00 per DkTh

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

50MM Gal

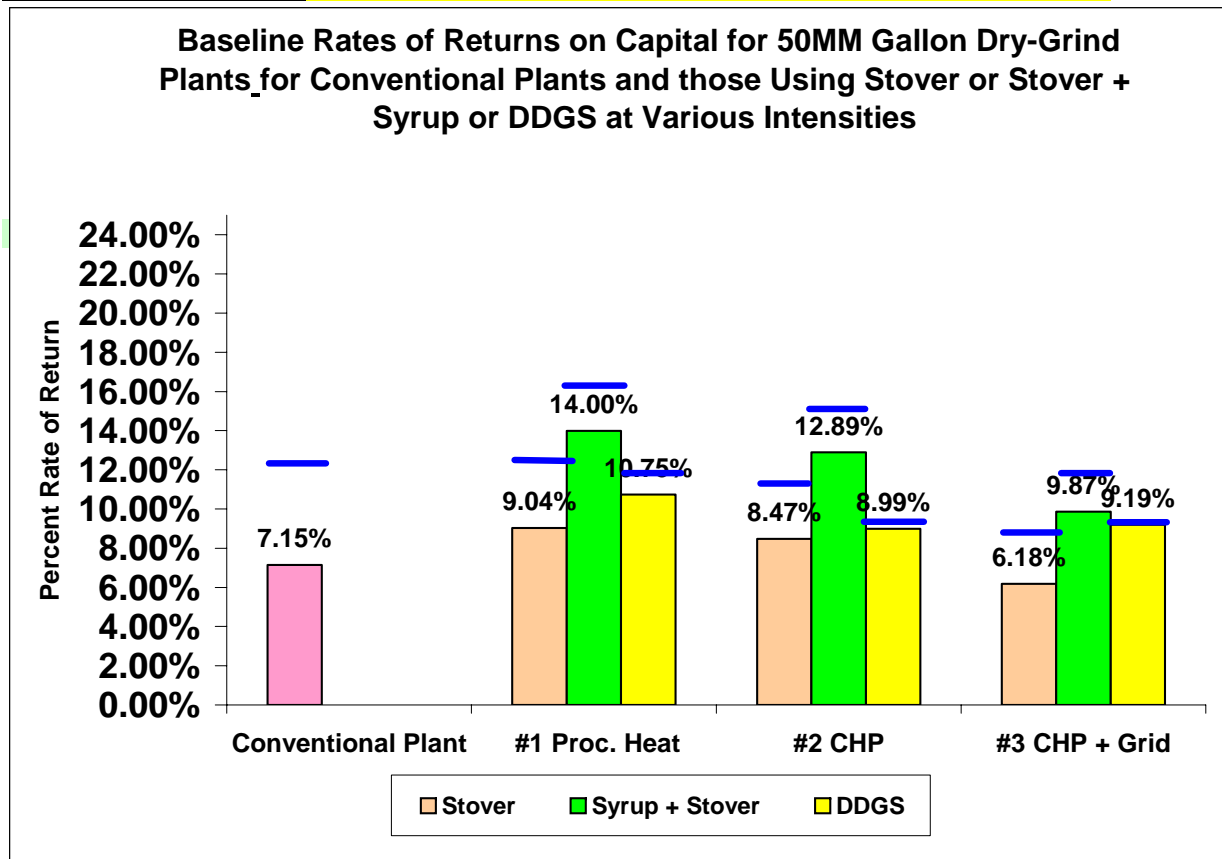
Baseline Rates of Returns on Capital for 50MM Gallon Dry-Grind Plants for Conventional Plants and those Using Stover or Stover + Syrup or DDGS at Various Intensities



# DDGS Price Shifts from \$100 to \$70 per Ton

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

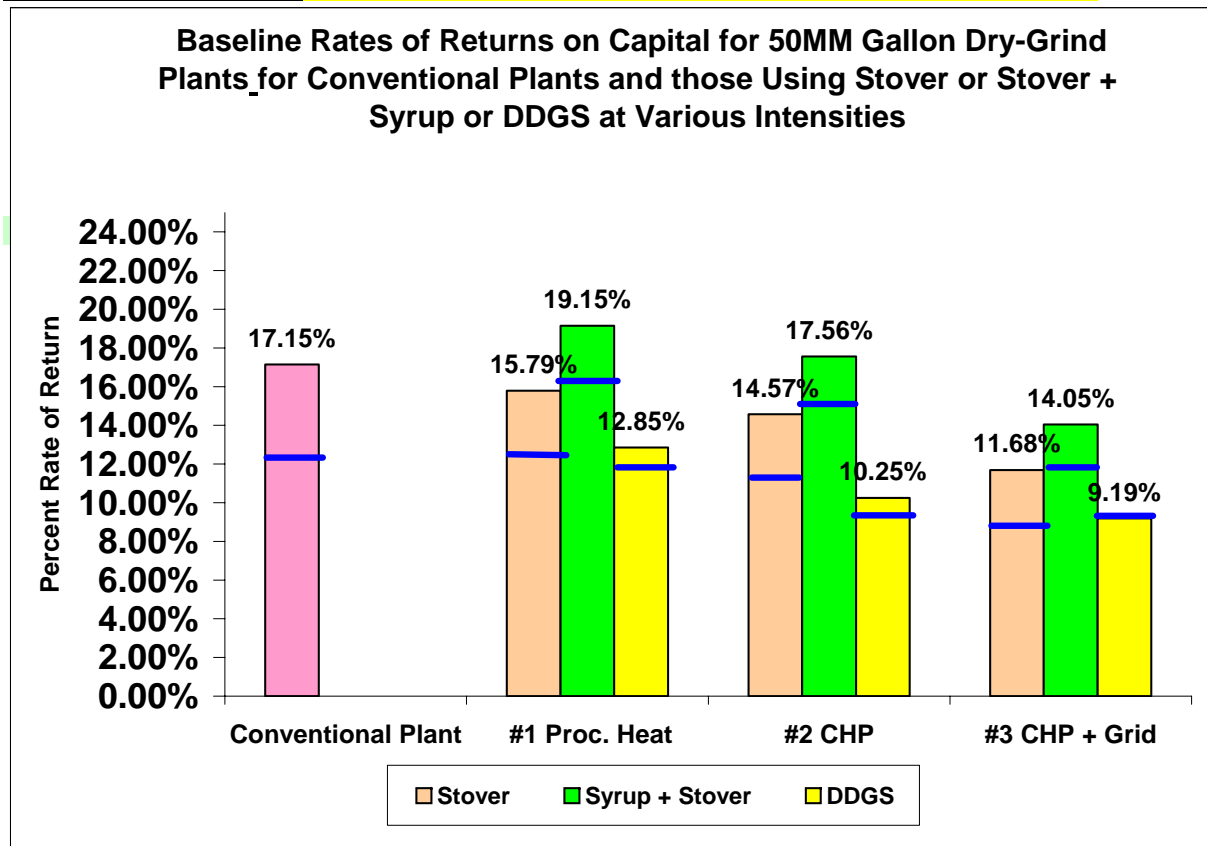
50MM Gal



# DDGS Price Rises from \$100 to \$130 per ton

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

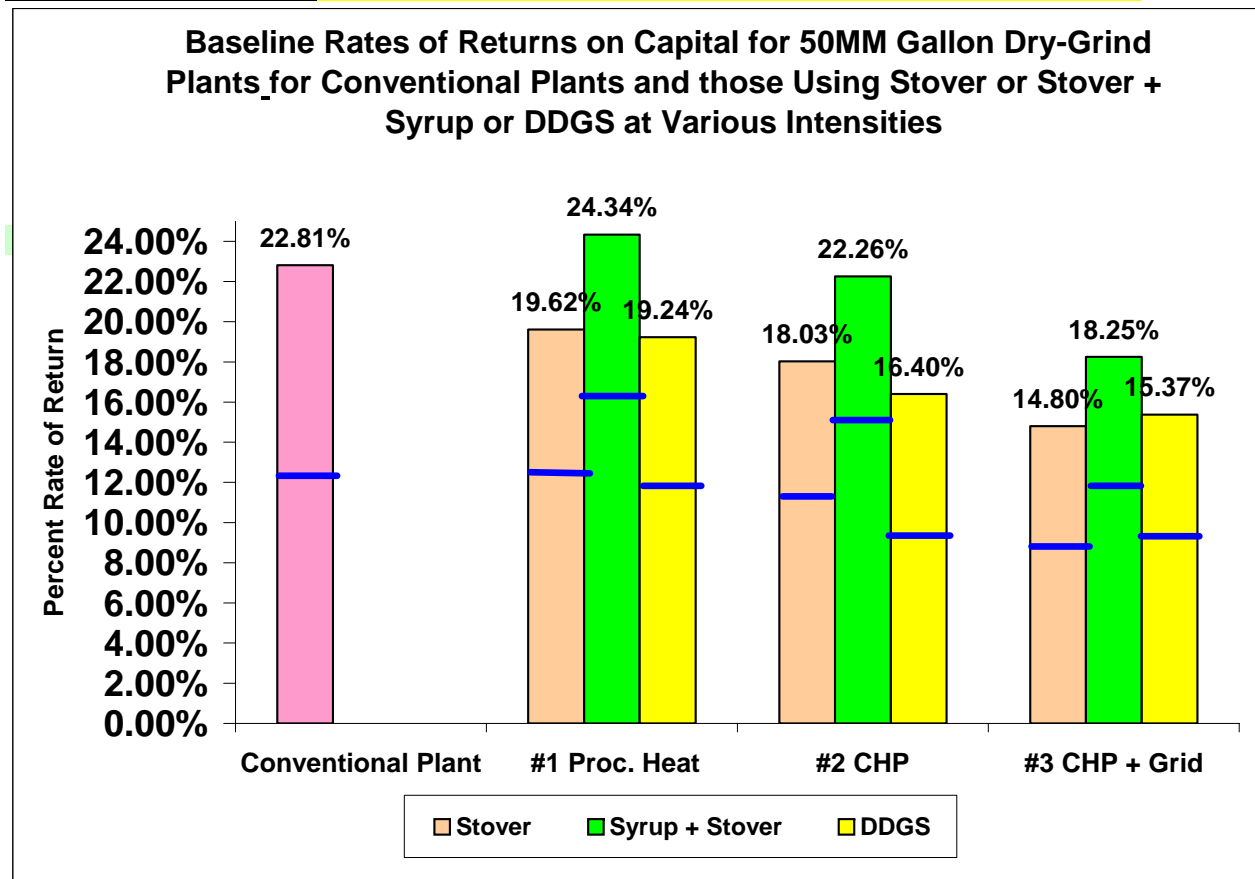
50MM Gal



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

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

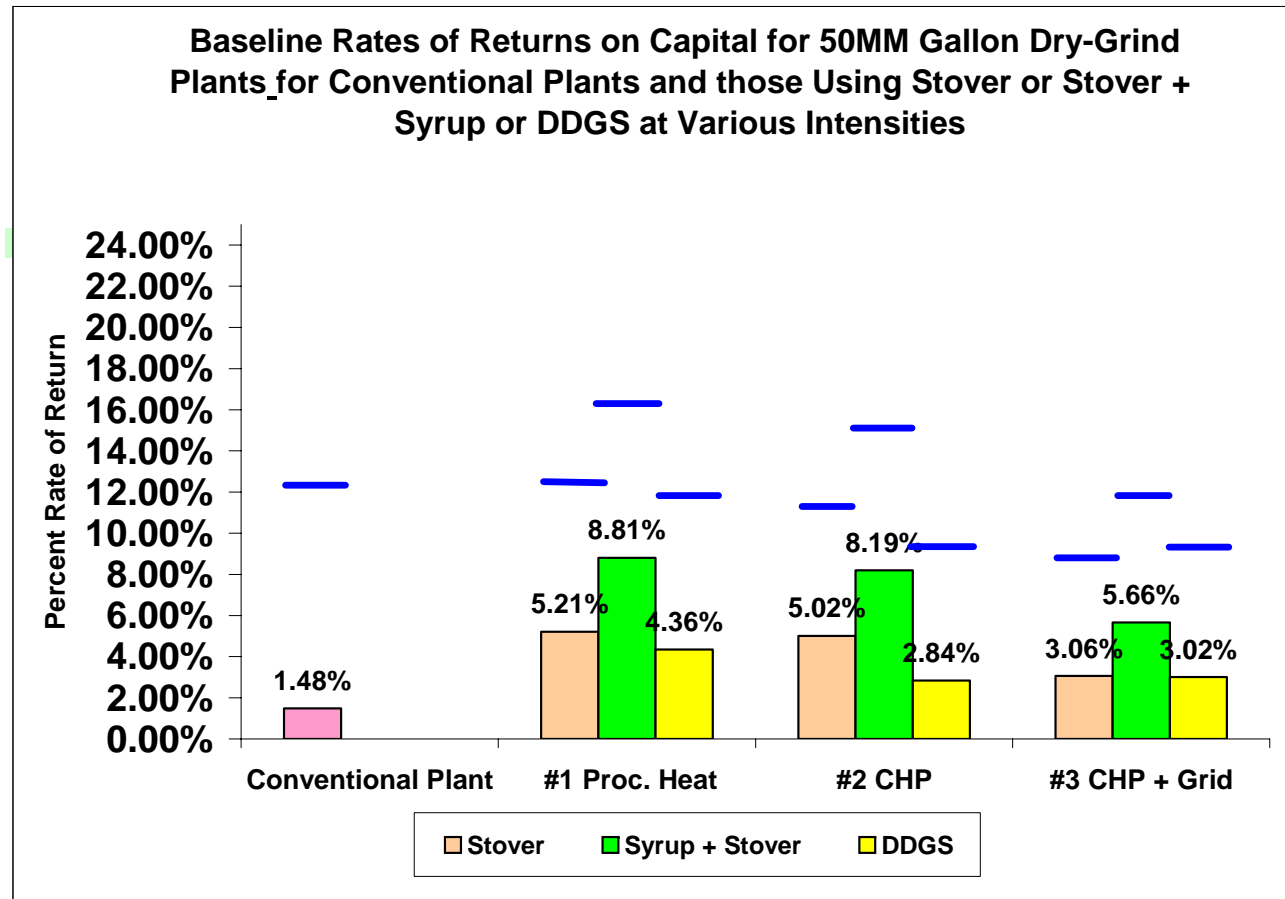
50MM Gal



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

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

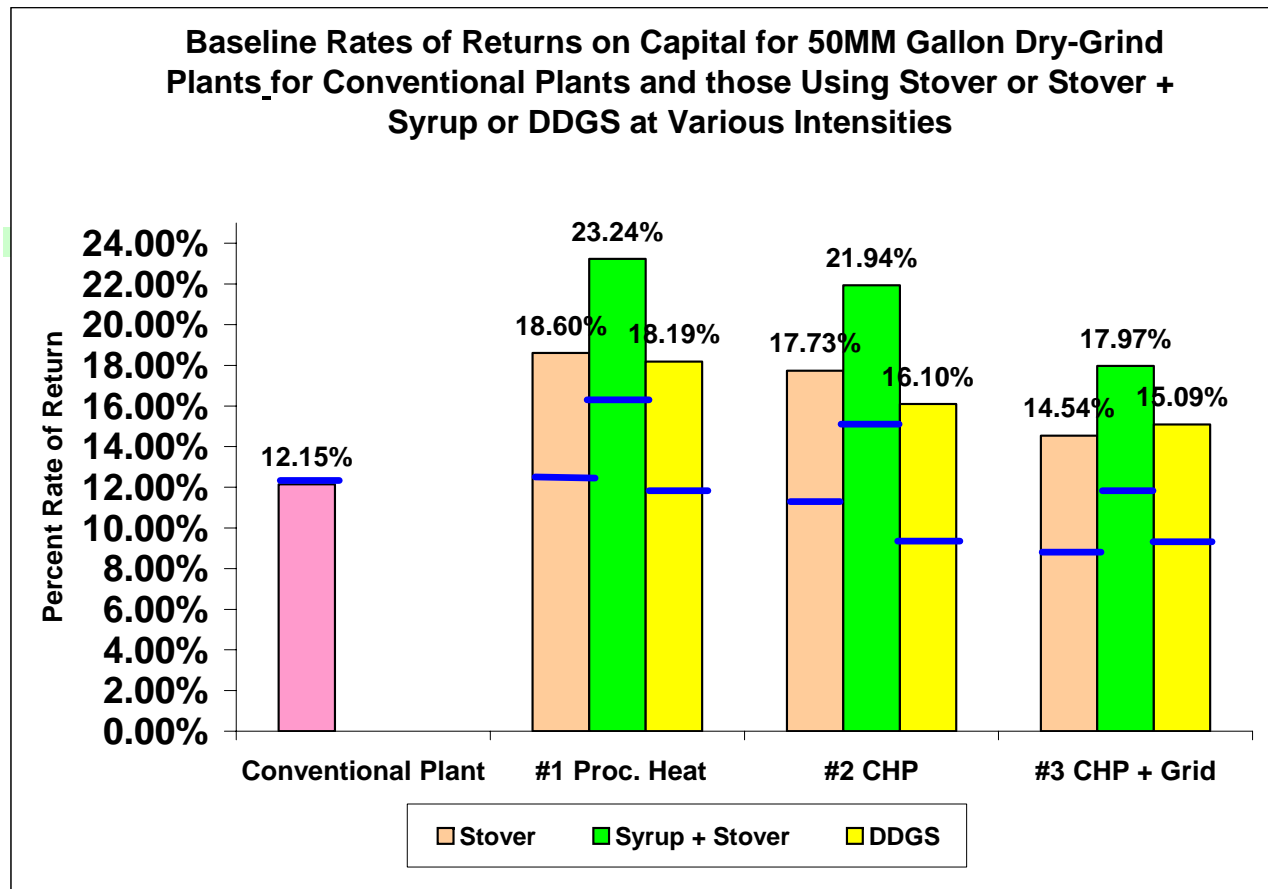
50MM Gal



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

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

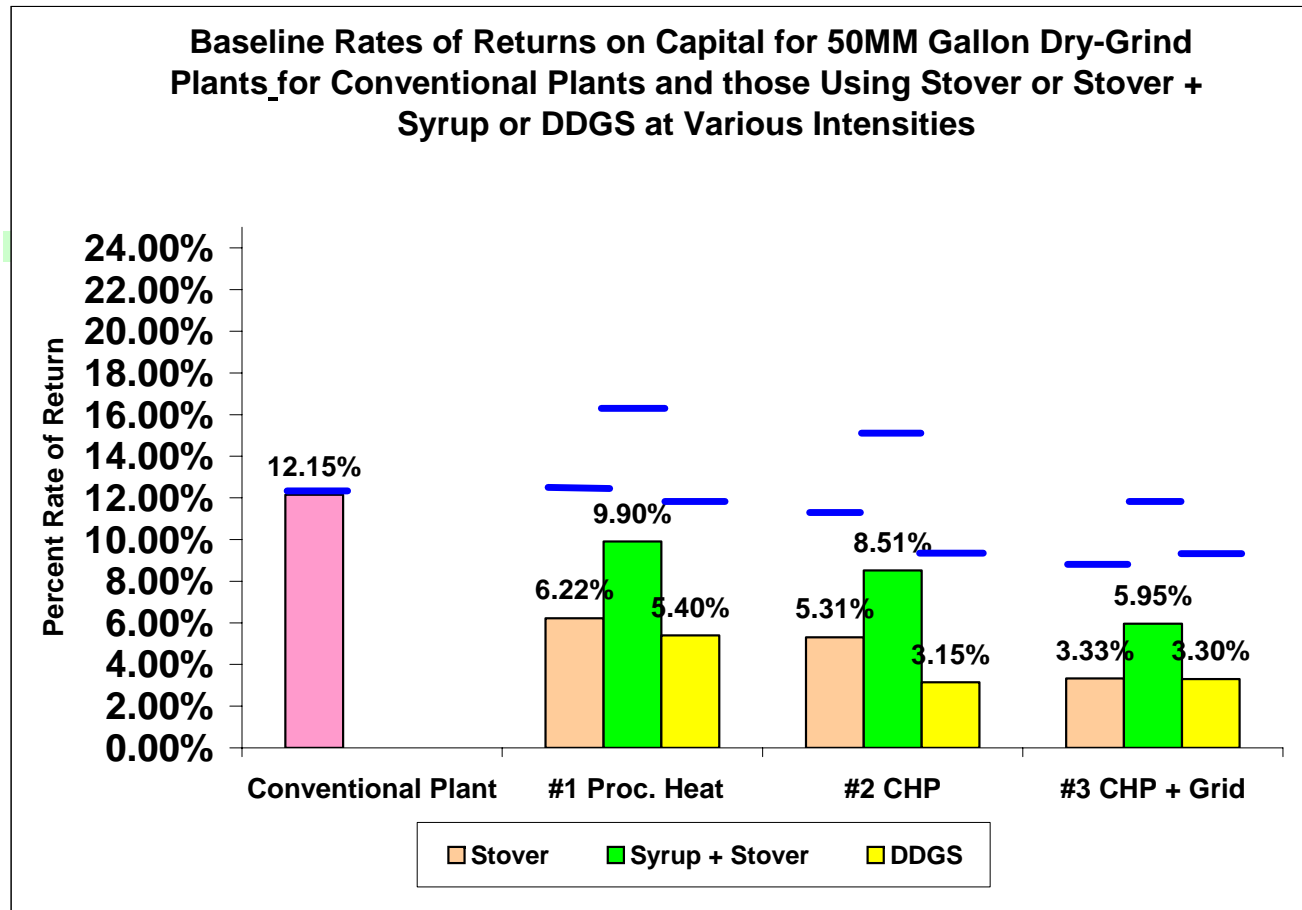
50MM Gal



# Low Carbon Premium is Zero

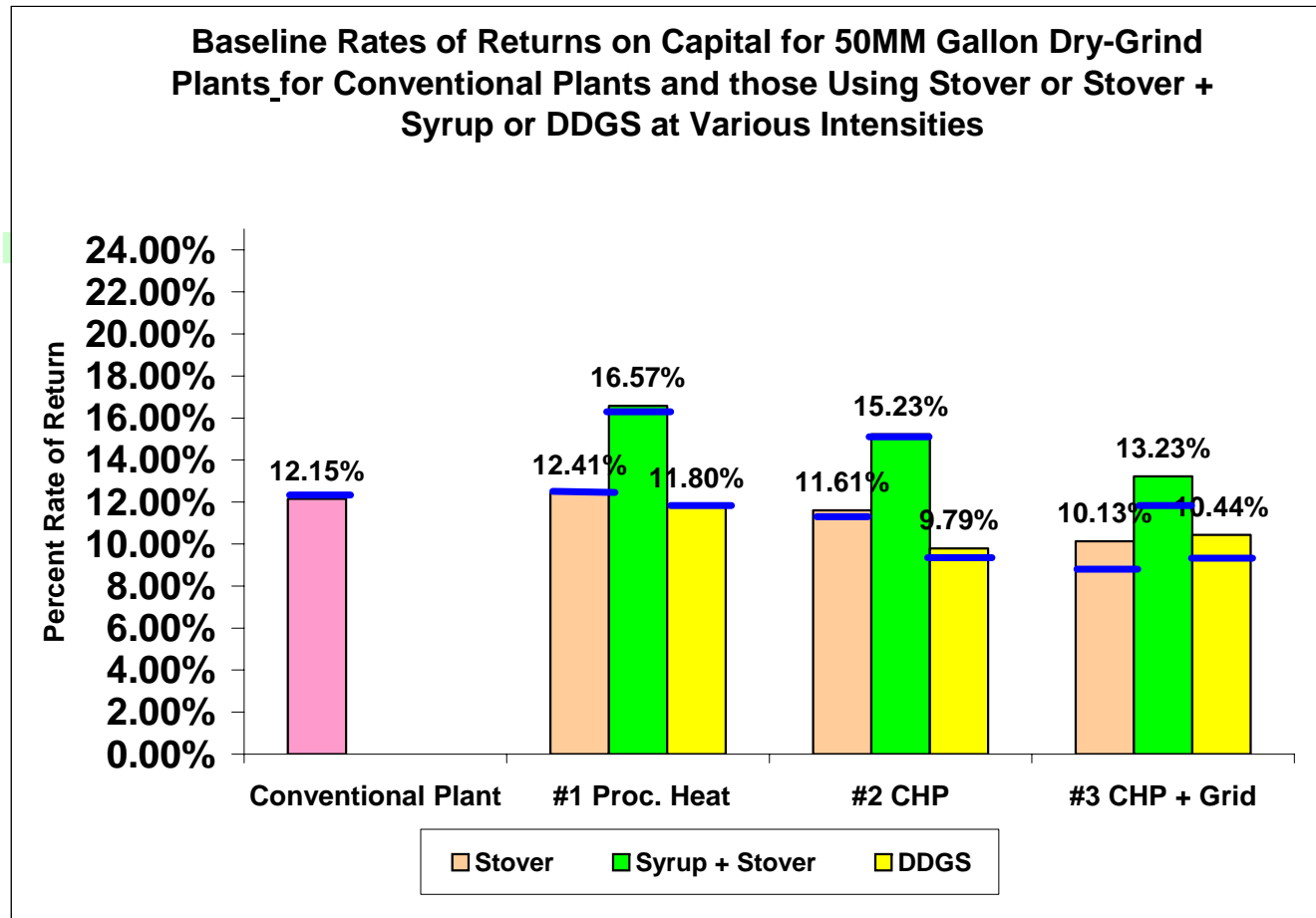
| Conventional Plant | #1 Proc. Heat | #2 CHP | #3 CHP + Grid |                |
|--------------------|---------------|--------|---------------|----------------|
| 12.15%             | 6.22%         | 5.31%  | 3.33%         | Stover         |
|                    | 9.90%         | 8.51%  | 5.95%    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

50MM Gal



# 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           |

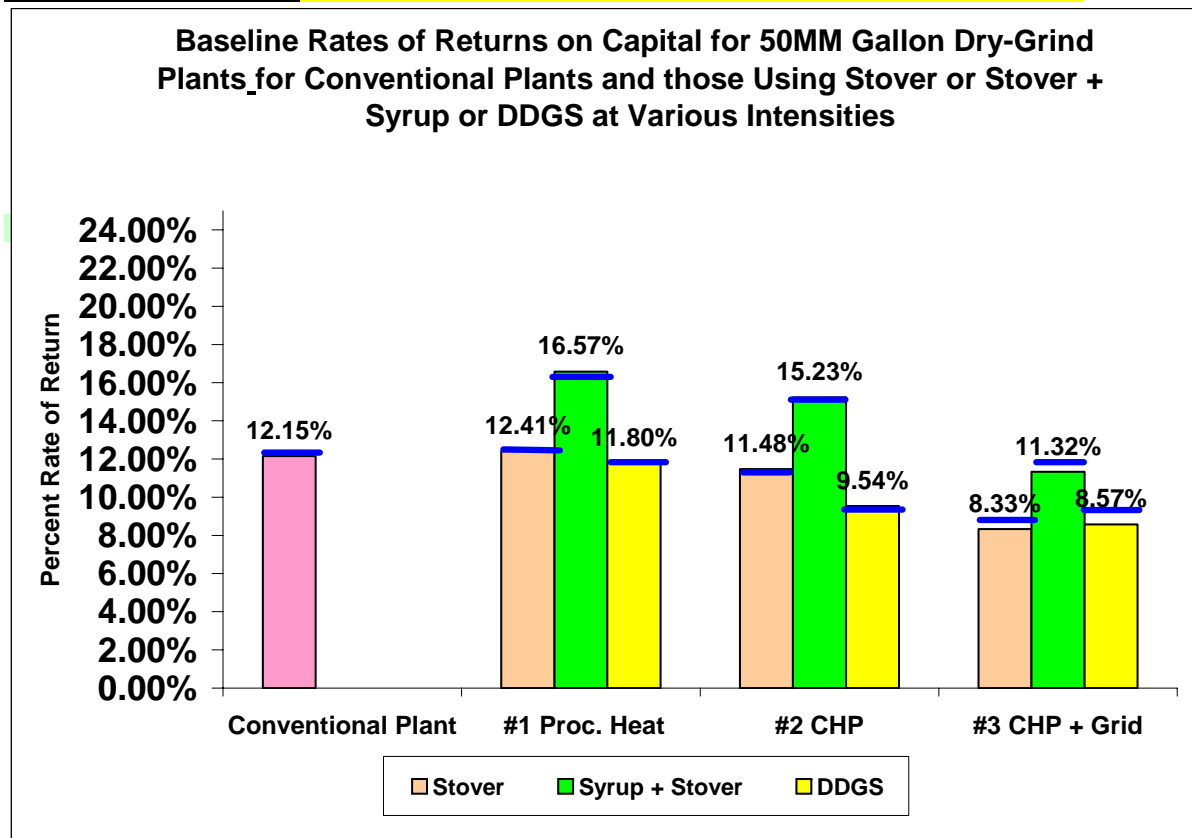




# Electricity Purchase Price Falls from \$.06 to \$.04/ KWH

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

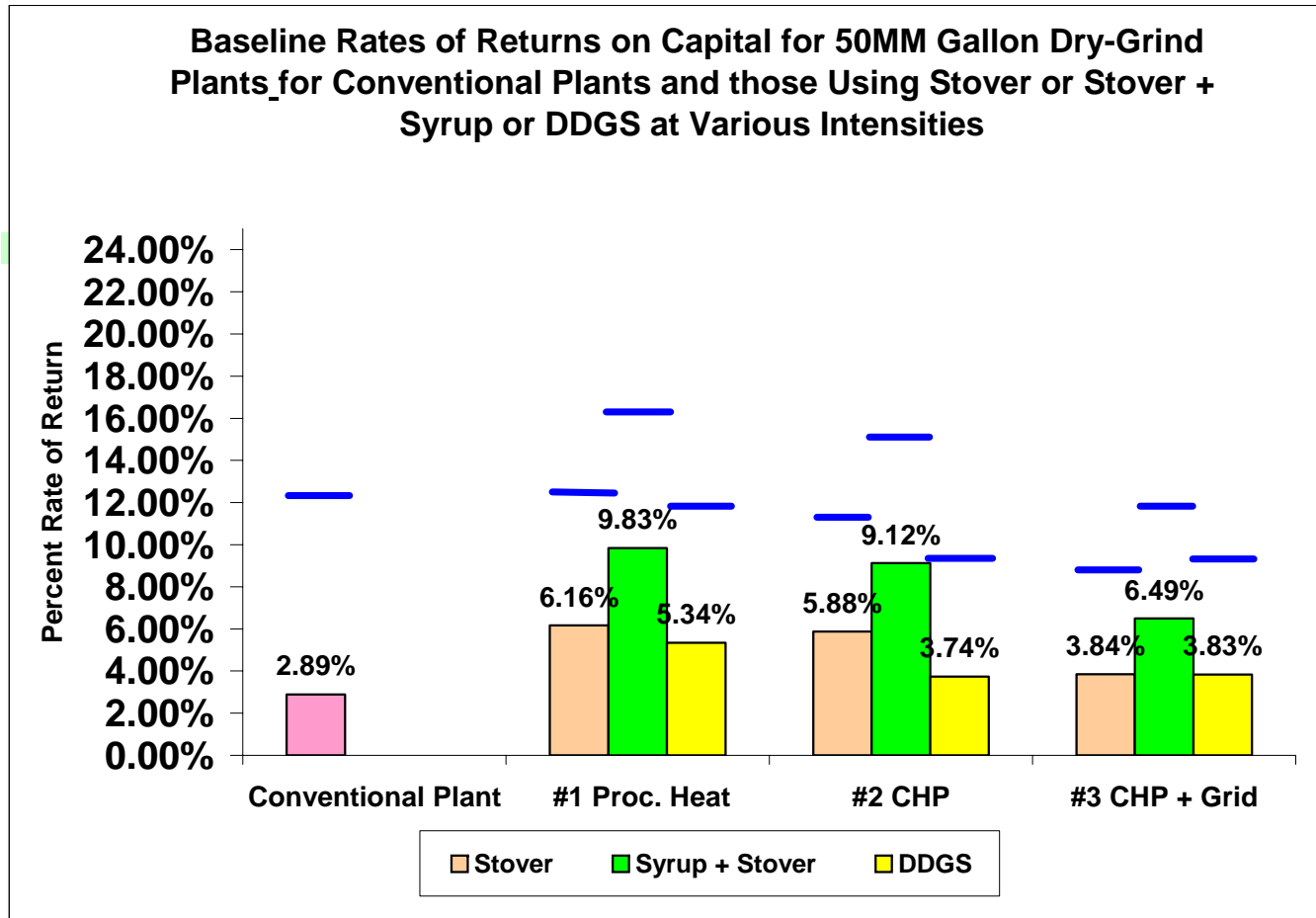
50MM Gal



# Corn Price Shifts from \$3.50 to \$4.00/bushel

| 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           |

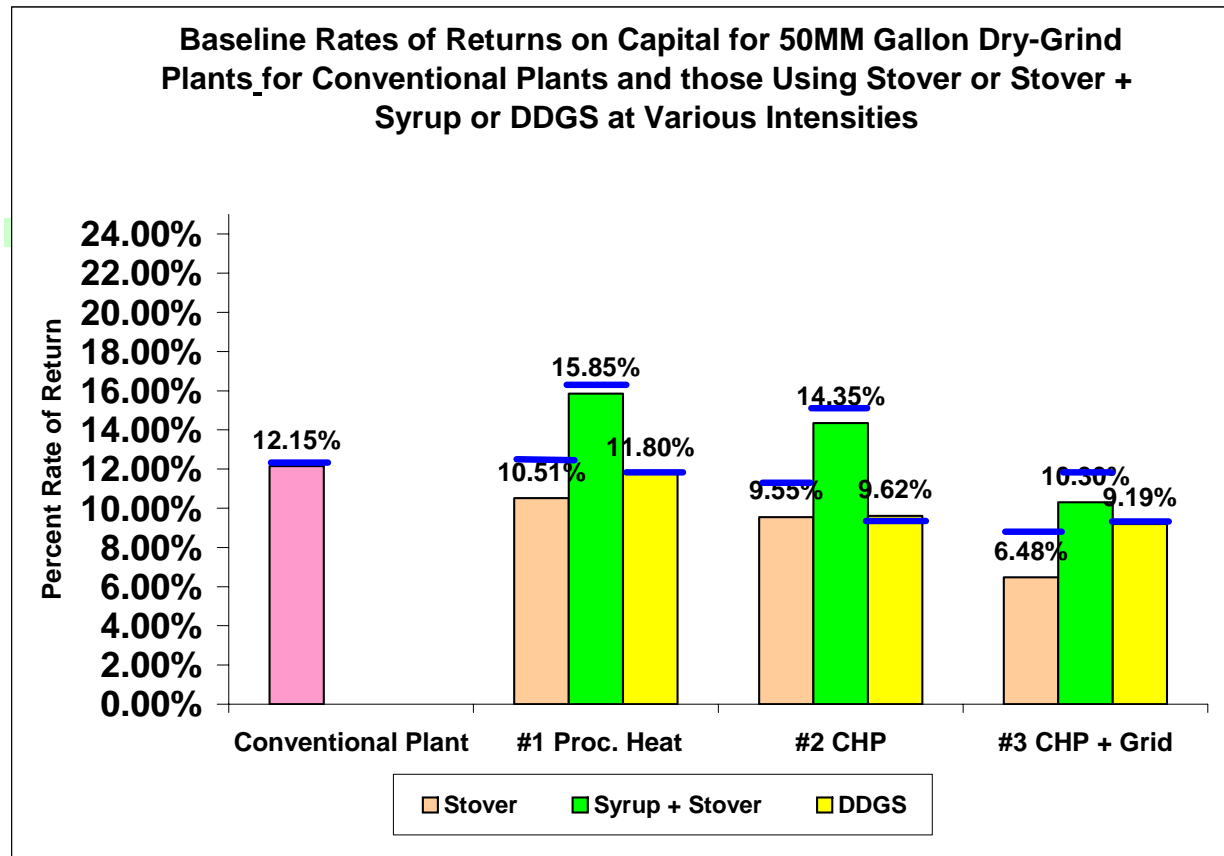
50MM Gal



# Stover Price Rises from \$80 to \$100 per Ton

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

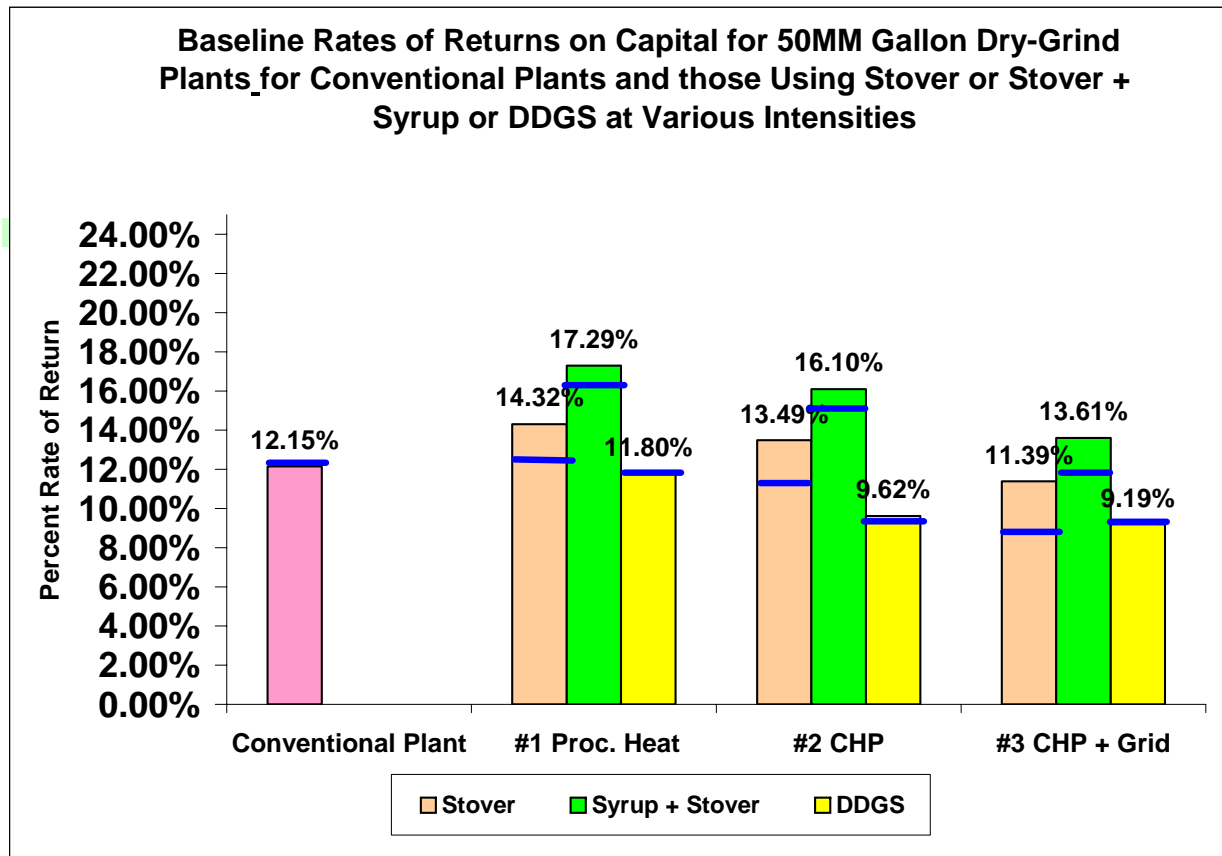
50MM Gal



# Stover Price Drops from \$80 to \$60 per Ton

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

50MM Gal



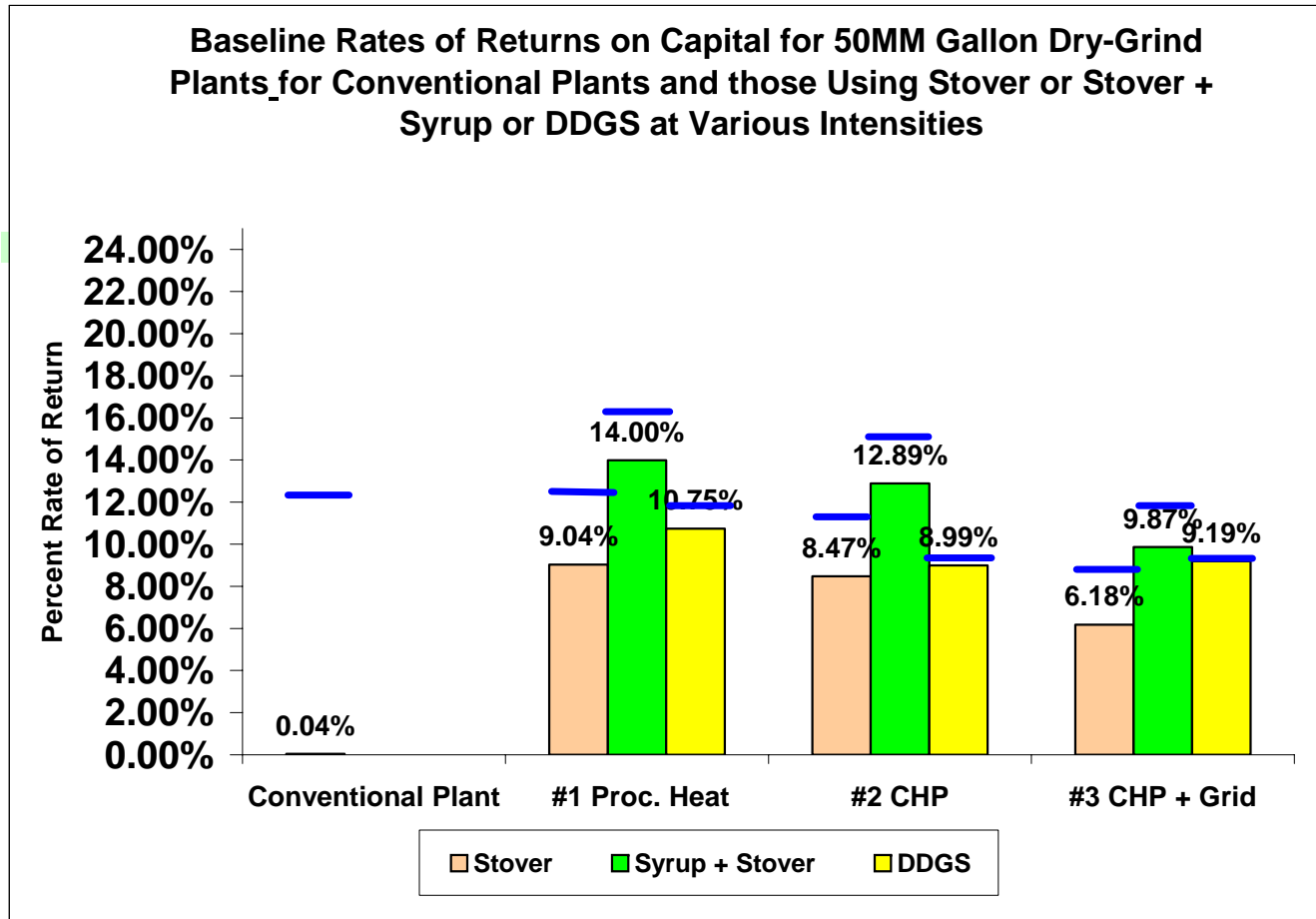
# IMPROVED BREAKEVENS WITH BIOMASS

- Q: How High Can Corn Price Rise with the Biomass Cases Still Breaking Even?
- A: \$4.74 per bushel (\$4.31 in 100MM gal. plant)
- 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 **technically feasible and fiscally prudent**, 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](http://www.biomassCHPethanol.umn.edu)



## BIOMASS FOR ELECTRICITY AND PROCESS HEAT AT ETHANOL PLANTS

- Acknowledgement
- This is a product of work supported by a grant entitled “Generating Electricity with Biomass Fuels at Ethanol Plants” funded by the Xcel Energy Renewable Development Fund. More information can be found at the project website: [www.biomassCHPethanol.umn.edu](http://www.biomassCHPethanol.umn.edu)

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Minnesota Feb. 12, 2008