Economics of Biomass Gasification/Combustion at Fuel Ethanol Plants

Douglas G. Tiffany
R. Vance Morey
Matt De Kam
University of Minnesota

ASABE Conference
Minneapolis, MN
June 20, 2007

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:

Xcel Energy

Minnesota Agricultural Experiment Station
University of Minnesota

My Talk Today

- Describe Methods for Economic Comparisons of "Technology Bundles" and levels of biomass intensity
- Establish Baseline Conditions; Defend my Assumptions
- Show Results for Corn Stover Combustion
- Show Results for Syrup + Stover Combustion
- Demonstrate the impact of specific variables on ROR of the "technology bundles."
- Describe Analysis to Come--------

College of Food, Agricultural and Natural Resource Sciences
SOLUTION▸DRIVEN SCIENCE™

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

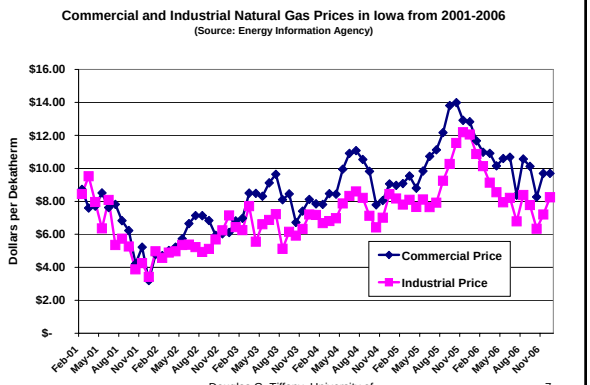
CHIPPEWA VALLEY ETHANOL COMPANY, LLC.

Economic Analysis

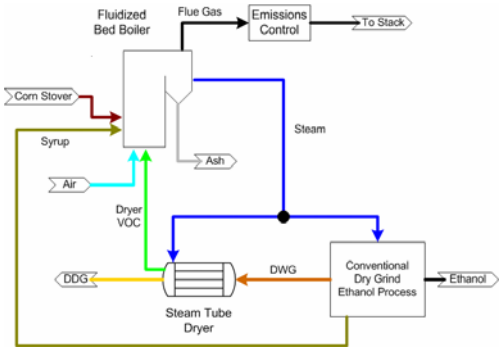
1. Economic analysis after technical steps of biomass characterization, emissions control standards, Aspen Plus estimation of machine capacities for individual technology bundles.
2. Cost estimation was performed by AMEC.
3. Spreadsheets were developed to model the ROR's of replacing natural gas with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

What Everyone Knows----

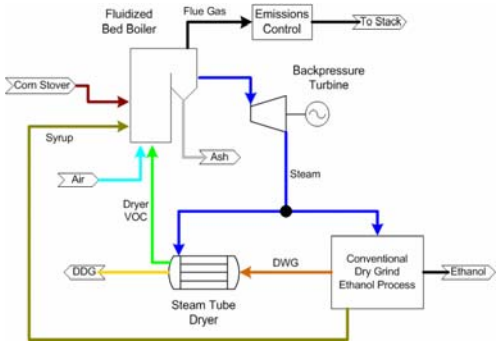
- Natural Gas is a great fuel.
- – except for price levels and volatility. At higher levels ethanol profits are threatened.
- Natural Gas is the second largest cost of ethanol production after corn in typical dry-grind plants.
- Natural Gas is a fossil fuel; contributes GHG.



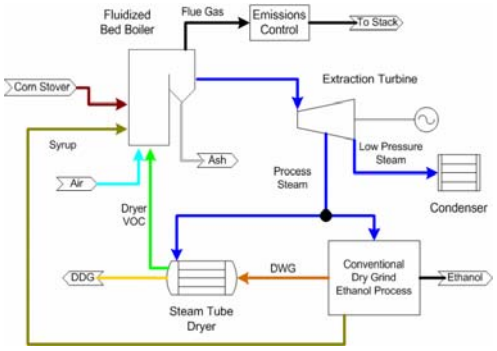
Syrup + Stover-Level #1



Syrup + Stover-Level #2



Syrup + Stover-Level #3



Establishing Baseline Assumptions

Biomass Has Costs

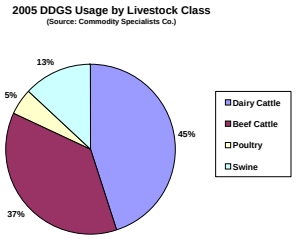
- Opportunity Costs as Feed, Bedding, or Soil Enhancer
- Procurement Costs
- Transportation
- Storage
- Handling
- Emissions
- Ash Disposal
- However----, reliable, well-located supplies
- Stover Baseline at $80 / Ton (densified)

- ***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



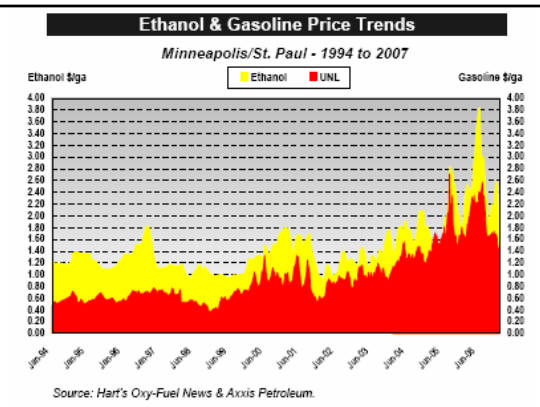
When producing 10 Billion Gallons of Ethanol, 28.3 Million Metric tons of Co-Product Feeds with be Available by 2010/11

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

Ethanol Prices



The Ethanol Plant Receives a Netback Price (Rack Prices Minus Marketing Costs)

- **Ethanol prices used to have a premium of $0.25 over the wholesale price of gasoline, but currently trades at a discount to RBOB by $.50 per gallon.**

Refiners Acquisition Cost $/Barrel	Wholesale Gasoline Price $/Gallon*
40	1.20
50	1.49
60	1.78
70	2.07
80	2.36

*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

	Net Cost /Gallon For New Construction	
Corn Price	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

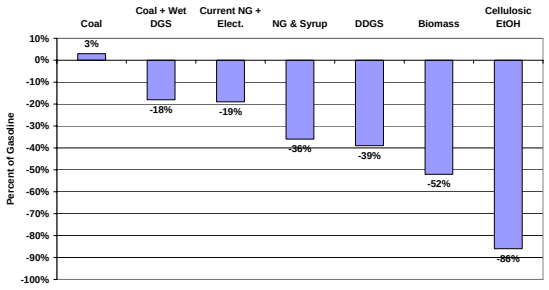
- Lower carbon intensity of fuels for passenger vehicles 10% by 2020 in grams of carbon emitted per BTU used. (LCA)
- Replace 20% of on-road gasoline with lower-carbon fuels
- Triples CA renewable fuels market
- Goal of producing 20% of biofuels in CA by 2010, 40% by 2020
- Use more hybrid vehicles
-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

Pending :

- DDGS Combusted in Fluidized Bed
- Corn Stover Combusted in Stoker-Grate

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

Nameplate Installed Costs for Technology Bundles in Plants of 50 MM and 100 MM Gallons

	Conventional Plant	Stover #1	Stover #2	Stover #3	Syrup + Stover #1	Syrup + Stover #2	Syrup + Stover #3
50 MM Cost/Gal.	$2.25	$2.82	$3.13	$3.46	$2.71	$3.02	$3.35
50 MM Total Cost	$112.50	$141.00	$156.50	$173.00	$135.25	$150.75	$167.25
100 MM Cost/ Gal.	$1.83	$2.29	$2.54	$2.81	$2.20	$2.45	$2.72
100 MM Total Cost	$182.76	$229.06	$254.24	$281.04	$219.71	$244.89	$271.70
Capacity Factors Applied	1.20	1.06	1.06	1.06	1.06	1.06	1.06

Cost Reductions or Revenue Gains

- Reduced Natural Gas Purchases
- Reduced Electricity Purchases
- Premium for "Low Carbon" Ethanol Produced ($.20- $.50)
- Sales of Nutrients in Ash of 0-18-28 ($200/T.)
- Sale of Renewable Electricity to the Grid
- Becoming a QF by being able produce 65% Firm power during prime periods of 9:00 A.M.- 9:00 P.M. Monday-Friday, excluding holidays.
- Power payments and Capacity Payments--- ($.125 for 2006 for QF during prime hours summer months)

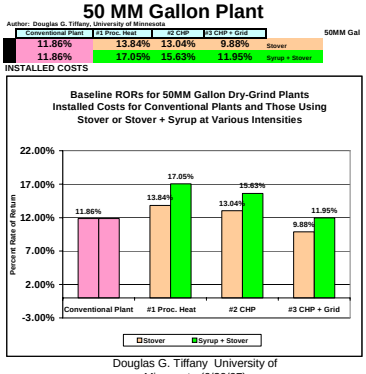
Additional Operating Costs with Biomass

- Biomass Costs Must Include---
  - Procurement Activities for Corn Stover
  - Drying of Corn Stover / DDGS before Storage or Use
  - Densification of Stover for Transportation
  - Storage of Biomass
- Additional Labor to Handle Combustion, Maintenance
- Use of Limestone for Sulfur Capture @ $20/ T.
- Use of Ammonia to reduce NOx @ $500/T.
- Replacement of Sand in Fluidized Bed

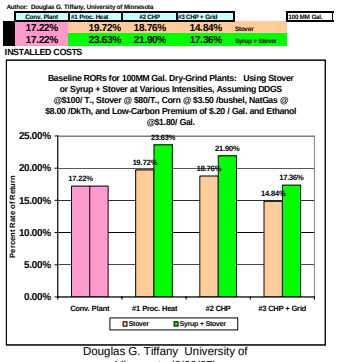
Assumptions Common Across All Processes 6/4/2007

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	$0.06
Value of Ash ($ 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	$0.10
Feedstock Delivered Prices Paid by Processor		
Corn Price ($ 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



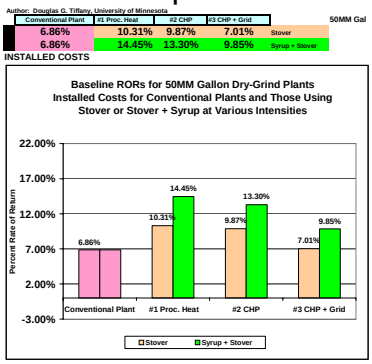
Baseline ROR's Using Installed Capital Costs for 100 MM Gallon Plant



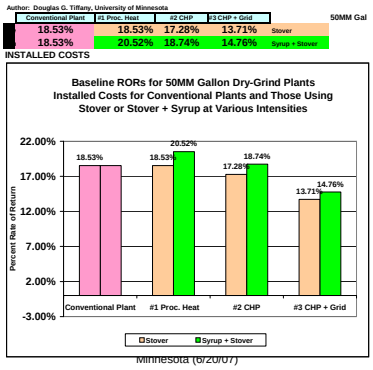
Testing Sensitivity of Technology Bundles

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

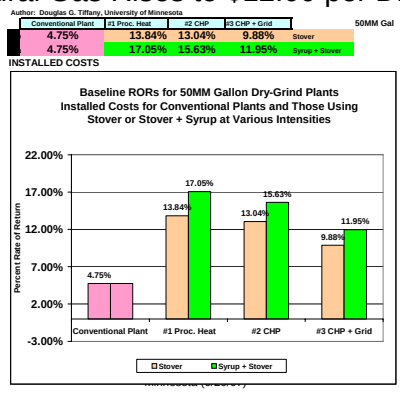
DDGS Price Shifts from $100 to $70 per Ton



DDGS Rise to $140/Ton ($4.00 Corn)



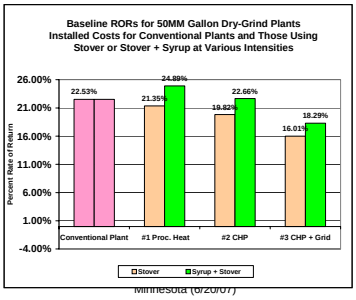
Natural Gas Rises to $12.00 per DkTh



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

Author: Douglas G. Tiffany, University of Minnesota

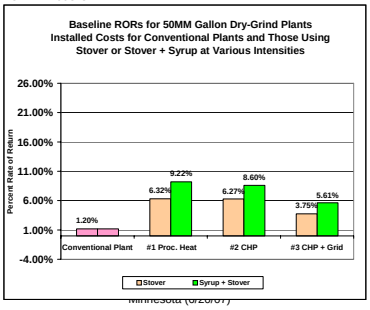
	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
INSTALLED COSTS	22.53%	21.35%	19.82%	16.01%	Stover
	22.53%	24.89%	22.66%	18.29%	Syrup + Stover



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

Author: Douglas G. Tiffany, University of Minnesota

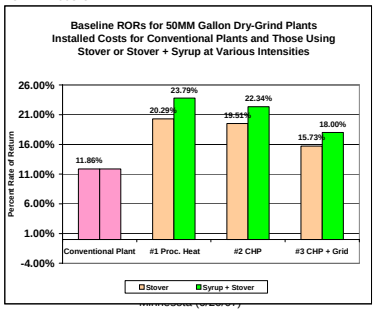
	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
INSTALLED COSTS	1.20%	6.32%	6.27%	3.75%	Stover
	1.20%	9.22%	8.60%	5.61%	Syrup + Stover



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

Author: Douglas G. Tiffany, University of Minnesota

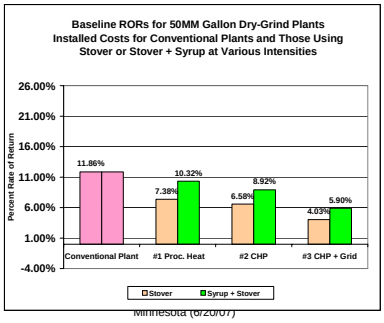
	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
INSTALLED COSTS	11.86%	20.29%	19.51%	15.73%	Stover
	11.86%	23.79%	22.34%	18.00%	Syrup + Stover



Low Carbon Premium is Zero

Author: Douglas G. Tiffany, University of Minnesota

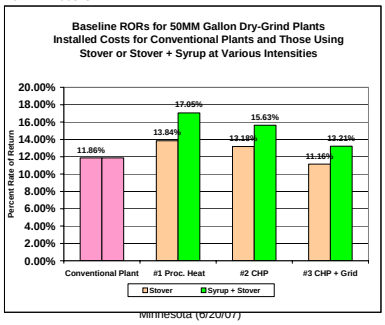
	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
INSTALLED COSTS	11.86%	7.38%	6.58%	4.03%	Stover
	11.86%	10.32%	8.92%	5.90%	Syrup + Stover



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

Author: Douglas G. Tiffany, University of Minnesota

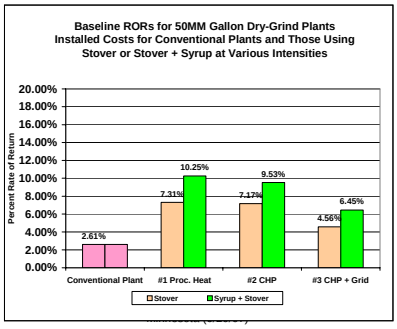
	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
INSTALLED COSTS	11.86%	13.84%	13.18%	11.16%	Stover
	11.86%	17.05%	15.63%	13.21%	Syrup + Stover



Corn Price Shifts from $3.50 to $4.00/bushel

Author: Douglas G. Tiffany, University of Minnesota

	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
INSTALLED COSTS	2.61%	7.31%	7.17%	4.56%	Stover
	2.61%	10.25%	9.53%	6.45%	Syrup + Stover

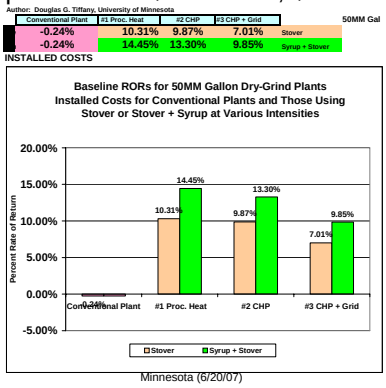


IMPROVED BREAKEVENS WITH BIOMASS

- Q: How High Can Corn Price Rise with the Biomass Cases Still Breaking Even?
- A: $4.78 per bushel
- Q: How much money would the conventional plant lose at that price of corn?

A: $13,300,000 per year.

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



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, and possibly DDGS and possibly other sources can be used to improve energy balance and the carbon footprint of ethanol produced from corn.

Thanks!!

Please Check our Website for Further Information.

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