Biomass Densification, Logistics and Use to Produce Heat and Electricity

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My Work at the U of M---
Economic Analysis of:

- Production of ethanol and biodiesel
- Biomass to produce electricity
- Pyrolysis of grasses to produce bio-oils and chemicals
- Use of biomass to provide process heat and power at fuel ethanol plants
- Biomass densification
- Production, use of Korean High Oil Corn
- Wind production
- Wind- biodiesel hybrids
- Comparison of conventional, cellulosic ethanol production

Time of Dramatic Changes 2005-2009

- High Ag Prices, High Energy Prices, Weak $US
- Rapid Growth in Liquid Fuels, Biofuels, esp. ethanol
  – Accompanying Changes in Crop Mix in U.S.
- Policy Changes Promoting Ethanol Production

  -2005 Energy Policy Act

  -2007 Energy Independence and Security Act

  -2008 Farm Bill
- Stock Market Sell-off and Plummeting Crude Oil and Farm Commodity Prices
- Approximately 20% of ethanol capacity was in bankruptcy in 2009--- with recovery and new owners
- Expect substantial opportunities to the electric power markets – some may be local with wind and biomass power

Topics for Today's Discussion

- Follow Eric Woodford's material on the harvest of corn stover, corncobs
- Discuss Corn Stover Logistic system using various densification methods
- Discuss Use of Corn Stover at Ethanol Plants as way to produce process heat and electricity for the plants and for sale to the grid
- Mention related research at the U of M

Biomass Densification

- Ethanol coproducts
  - DDGS – distillers dried grain with solubles

- “syrup” – solubles

- Corn stover
- Corn cobs

Biomass Densities

- Round bales – 4 to 6 lb/ft^3 (package density)
- Large rectangular bales – 8 to 12 lb/ft^3 (package density)
- Chopped or ground, non compacted corn stover – 3 to 6 lb/ft^3 (bulk density)

Densification – Options?

- Higher density bales (packages) – re-baling
- Bale to bulk – chopping or coarse grinding
  - non compacted – 3 to 6 lb/ft^3
  - roll compacted – 12 to 15 lb/ft^3
- Further (fine) grinding
  - briquetted – 28 to 33 lb/ft^3
  - pelleted – 32 to 38 lb/ft^3

Biomass Bulk Densities

Material	Bulk Density, lb/ft^3
Compacted biomass	12 to 15
Briquettes	28 to 33
Pellets	32 to 38
Corncobs	10 to 12
Shelled corn	45

Desirable Characteristics of Densified Biomass

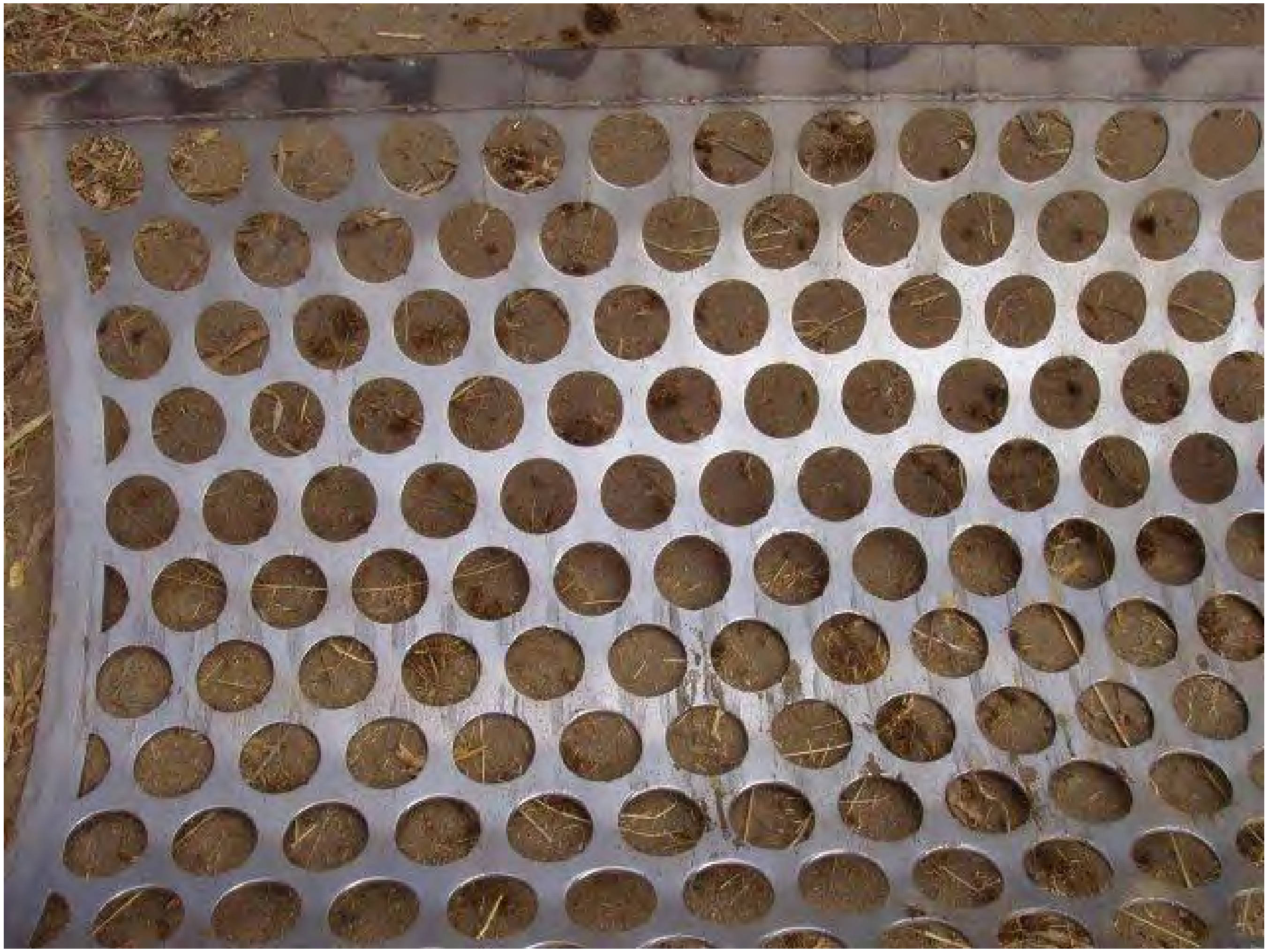
- Increased bulk density
- High durability of individual products (pellets of briquettes)
- Consistent and relatively small product (pellet or briquette) size – easier to handle, feed into a burner, and automate

Size Reduction – Tub Grinding

RotoChopper

Tub Grinder

Tub Grinder Screen



Corn stover from 8 inch screen at 19% MC

Bulk density of 3 lb/ft^3

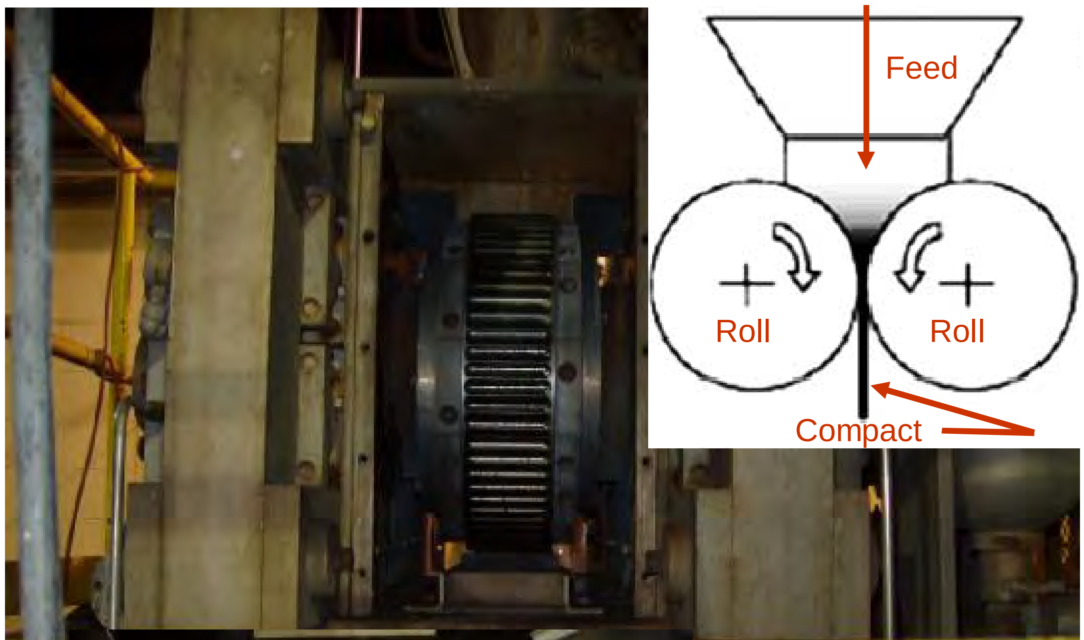
Corn stover from ¾ inch screen at 11% MC

Bulk density of 6 lb/ft^3

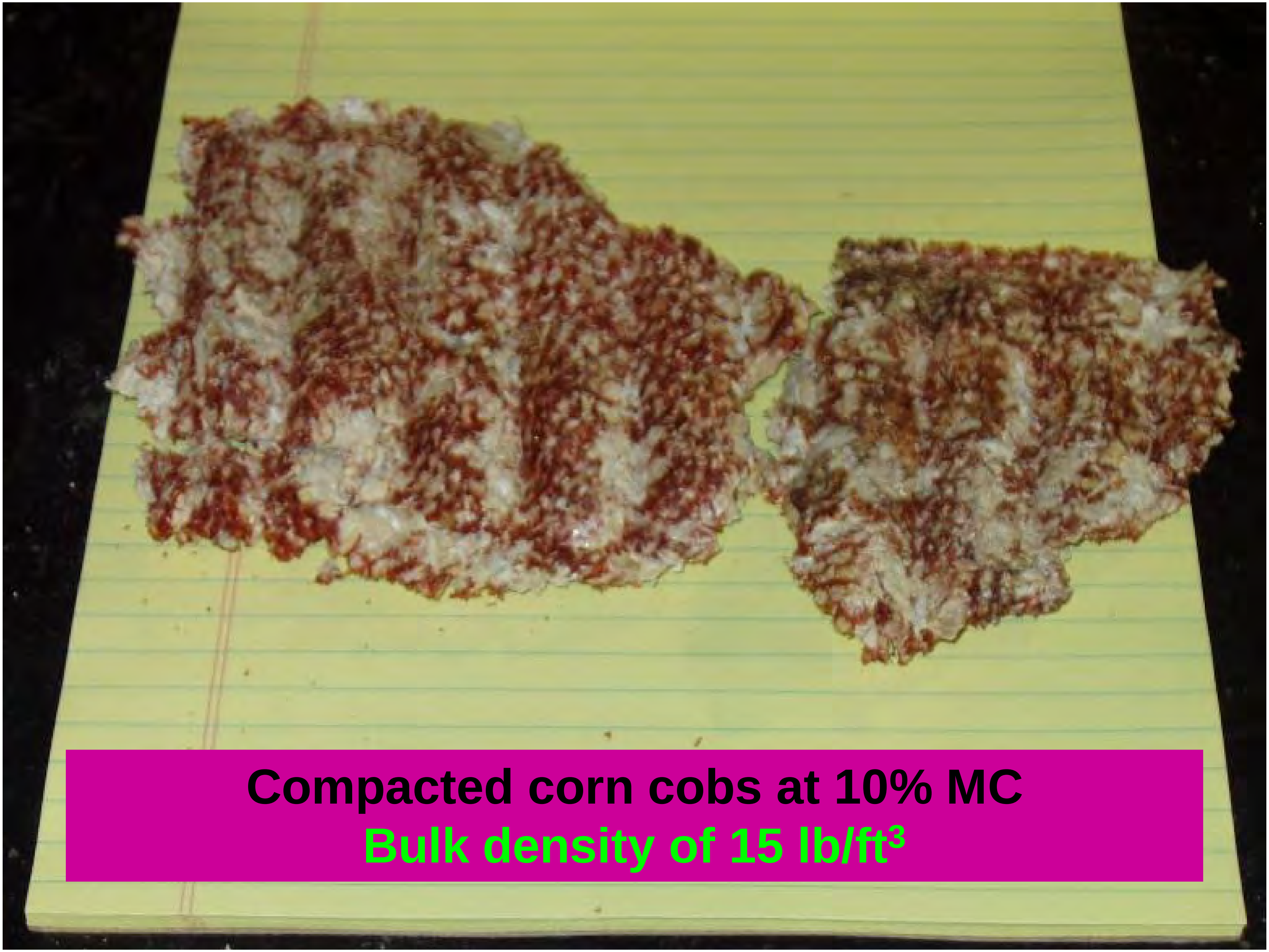
Grasses from 8 inch screen at 12% MC

Bulk density of 5 lb/ft^3

Roll-Press Compaction

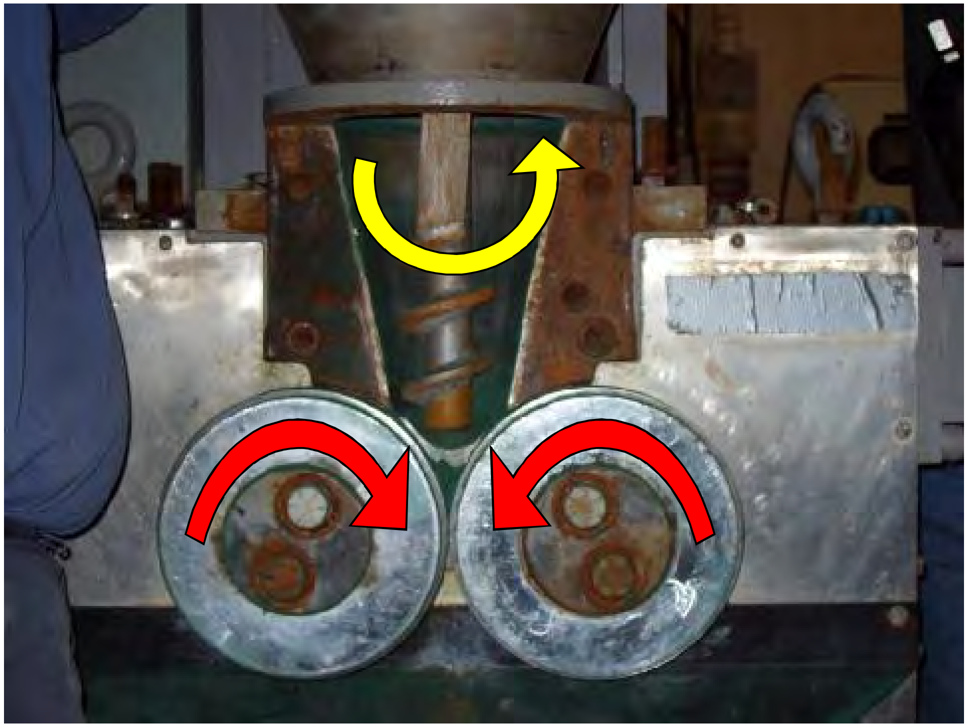


Roll Compacted Corn Stover



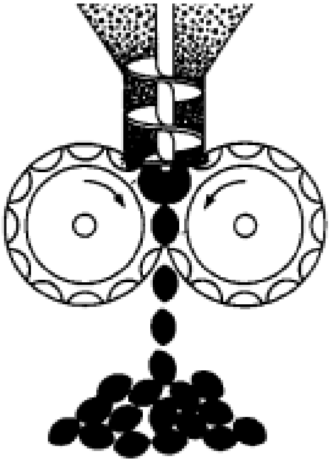
Compacted corn cobs at 10% MC
Bulk density of 15 lb/ft^3

Roll Press Briquetting



Screw feeder and rolls

Bepex International LLC, Minneapolis, MN



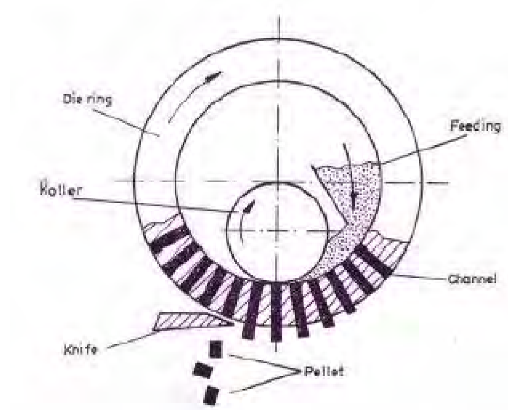
Briquetting Process

Almond shaped pockets

Pelleting Mill

40 HP pelleting mill at AURI, Waseca, MN

Die and Rolls



Pelleting - extrusion

Pellets/Briquettes

Characteristics

	Bulk Density, lb/ft^3	Durability	Consistency	Size
Compacted	12-15	Low	Large range of shapes/sizes	Large
Briquettes (good)	25-30	Good	Medium	Medium
Briquettes (better)	30-35	Better	High	Medium
Pellets	35-40	Best	High	Small

Relative Energy and Capacity

	Screen (particle) size, inch	Relative Energy,%			Relative Capacity, %
		Chopping/ Grinding	Densify	Total	
Compacted	3	30	5	35	
Briquettes (good)	1	40	5	45	
Briquettes (better)	0.5	55	10	65	
Pellets	0.25	65	35	100	

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		Chopping/ Grinding	Densify	Total	
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Relative Energy and Capacity

	Screen (particle) size, inch	Relative Energy,%			Relative Capacity, %
		Chopping/ Grinding	Densify	Total	
Compacted	**3**	**30**	**5**	**35**	**100**
Briquettes (good)	**1**	**40**	**5**	**45**	**80**
Briquettes (better)	**0.5**	**55**	**10**	**65**	**40**
Pellets	**0.25**	**65**	**35**	**100**	**15**

Densification Summary

- Reducing particle size (grinding) is important and has by far the largest energy requirement in the overall densification process
- Higher quality (durability and bulk density), smaller size products (briquettes or pellets) are more costly to produce

Corn Stover Logisics

Agricultural –
One harvest per year

Industrial –
Requires supply throughout the year

Agricultural vs Industrial

Agricultural Scale System – Biomass Source

(Harvest 4-6 weeks in fall)

Collection / Transport to Local Storage

- Shredding and raking
- Baling (round bales)
- Bale storage near field
- Nutrient replacement

Industrial Scale System – Biomass User

(Supply throughout the year)

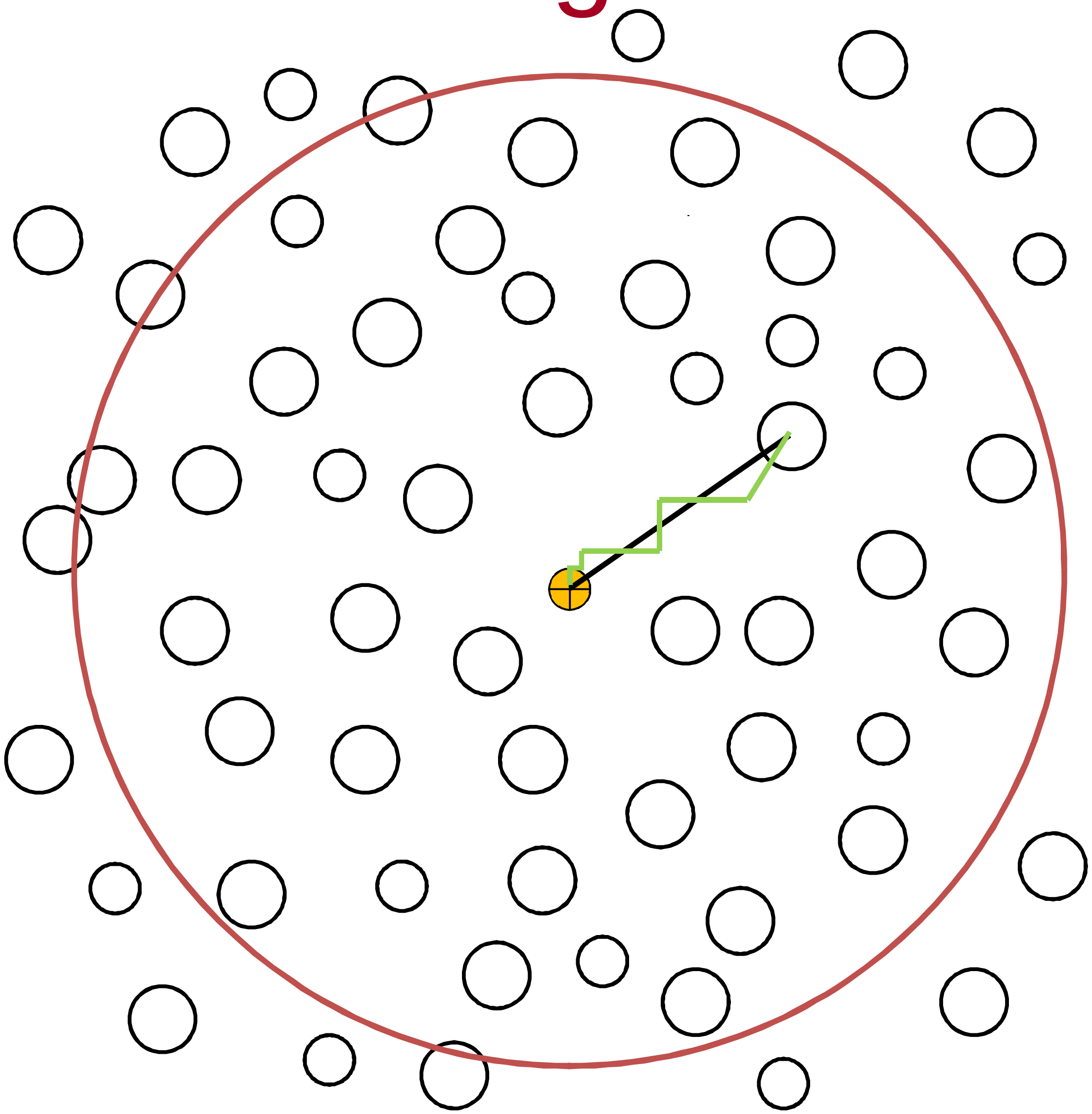
Processing (Bale to Bulk)/Truck Transport from Local Storage

- Tub (coarse) grinding (portable unit)
- Roll-press compaction (portable unit)
- Truck transport in 25-ton loads to users (15 lb/ft^3 bulk density)

Heat and Power using Stover at a Corn Ethanol Plant

- 50 million gallons ethanol per year
- 400 to 600 tons per day of stover
  - 16 to 24 truckloads (25 tons each) of compacted bulk biomass per day or
  - 640 to 960 bales (1250 lbs each) per day
- 60 truckloads of corn per day
- 20 truckloads of DDGS per day

Logistics Pattern



One Way Hauling Distance (black line) with 1.3 Winding Factor (green line)

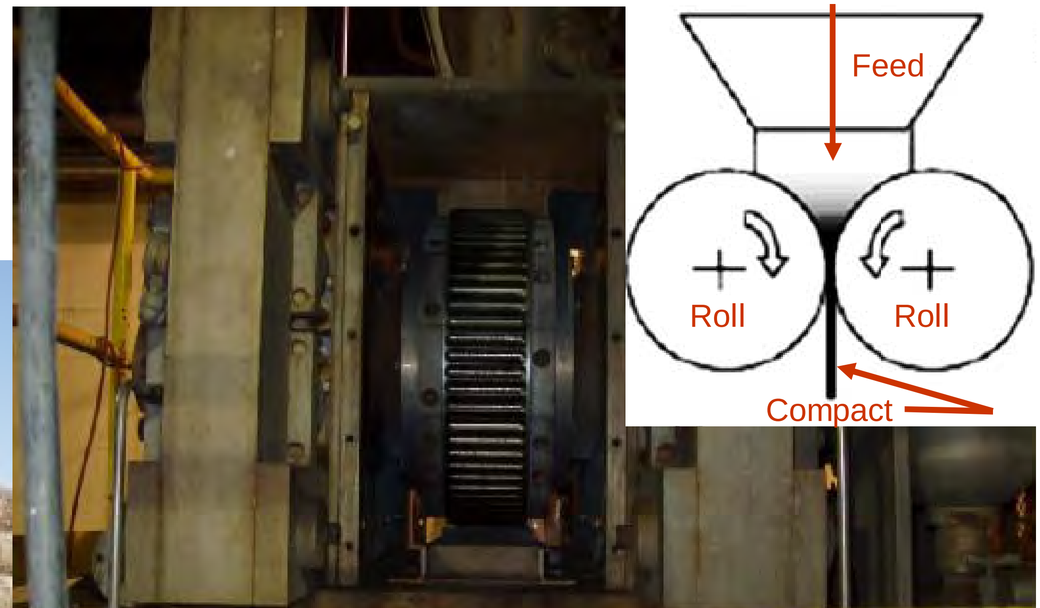
30 Mile Radius – 52 Mile Average Round Trip Hauling Distance

Harvesting/Transport to Local Storage

Local Storage Cost and Storage Loss Assumptions

- Bales stored in rows end to end in a north-south orientation, 3 ft between rows of bales
- Storage cost – 33¢/ton based on $200/acre land rent
- Storage loss – 5% average assumed for all storage (1 to 11 months). Equivalent to assuming 5% more stover delivered to storage than is removed .

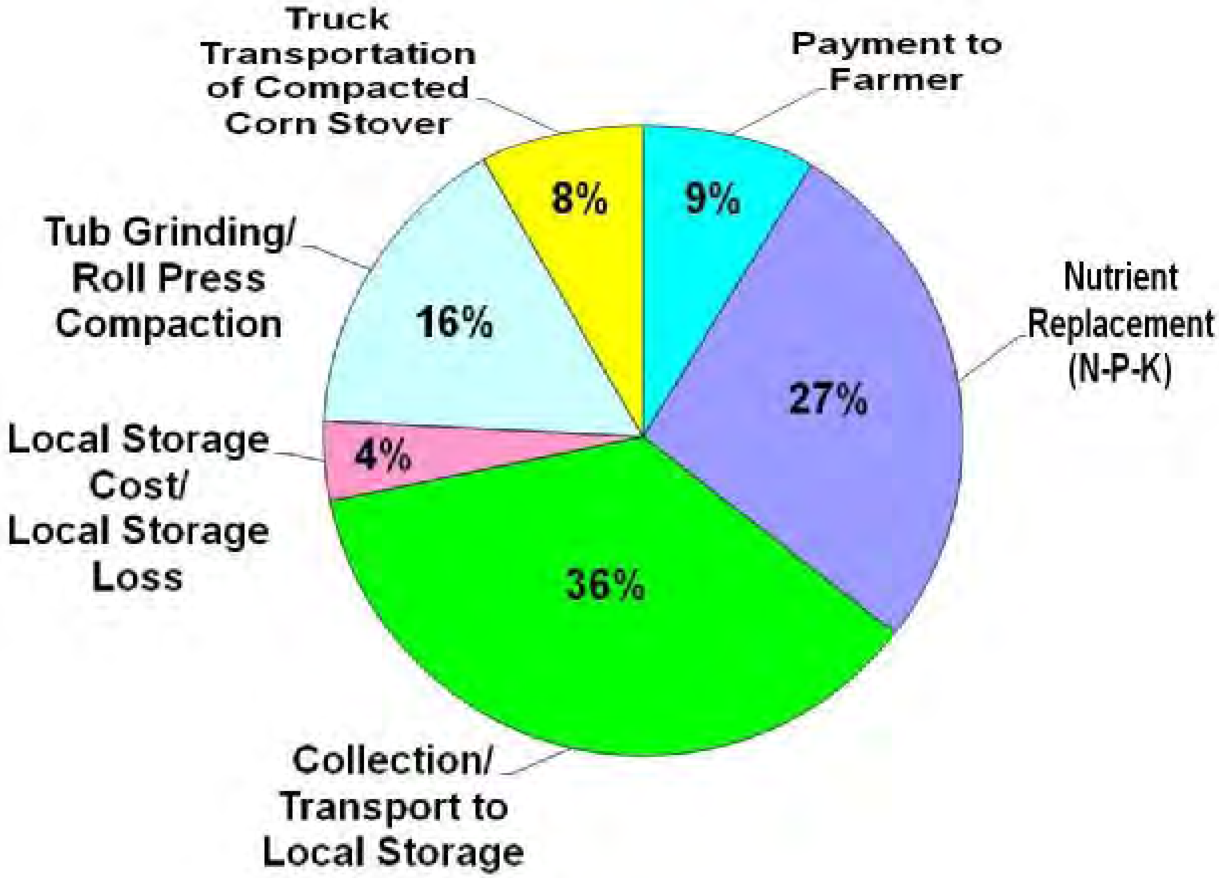
Tub-Grinding/Roll-Press Compaction



Transport from Local Storage to End User

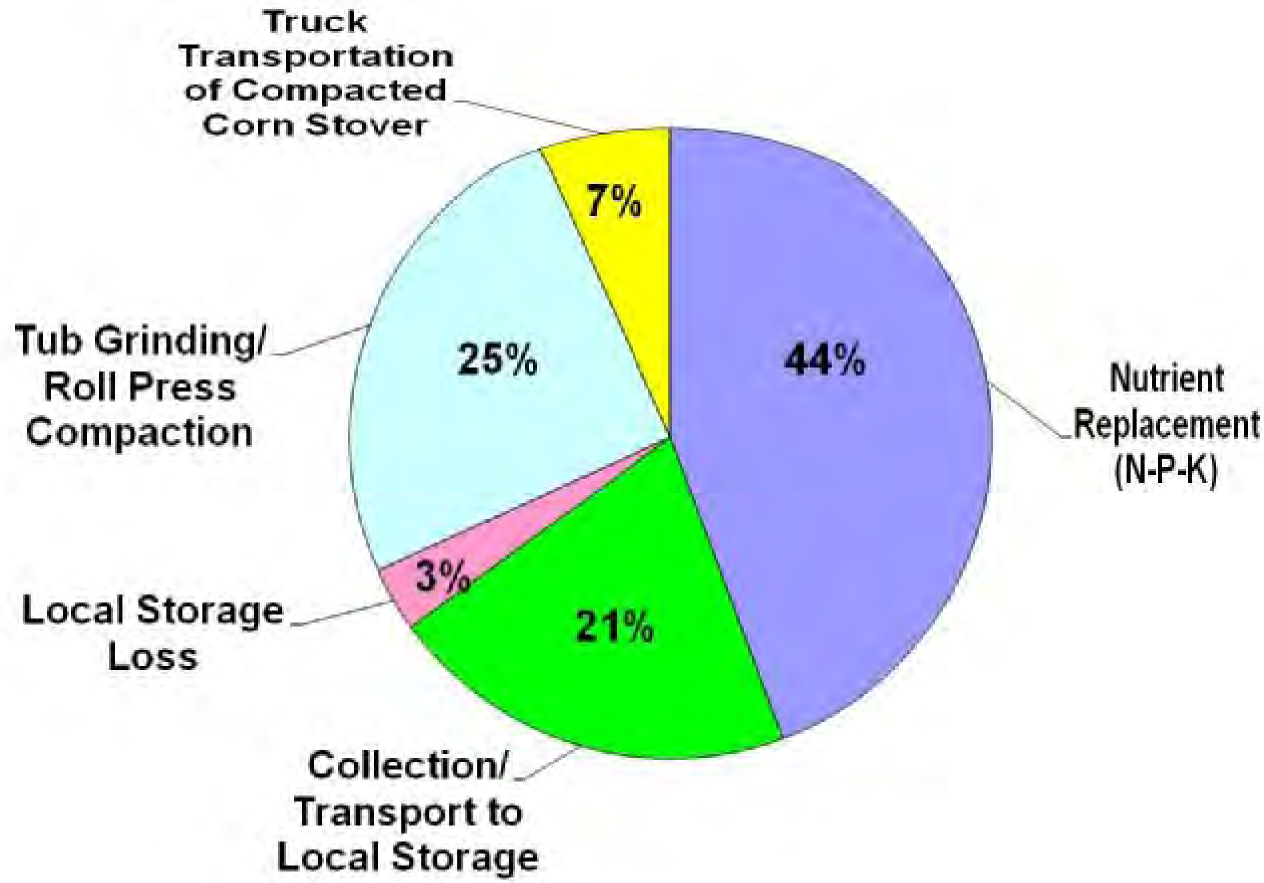
- Bulk transport in 25-ton truck loads (15 lb/ft^3)
- Average round trip distance equals 52 miles – average distance for a maximum radius of 30 miles with 1.3 winding factor
- $6.40/ton average transport cost

Total Cost



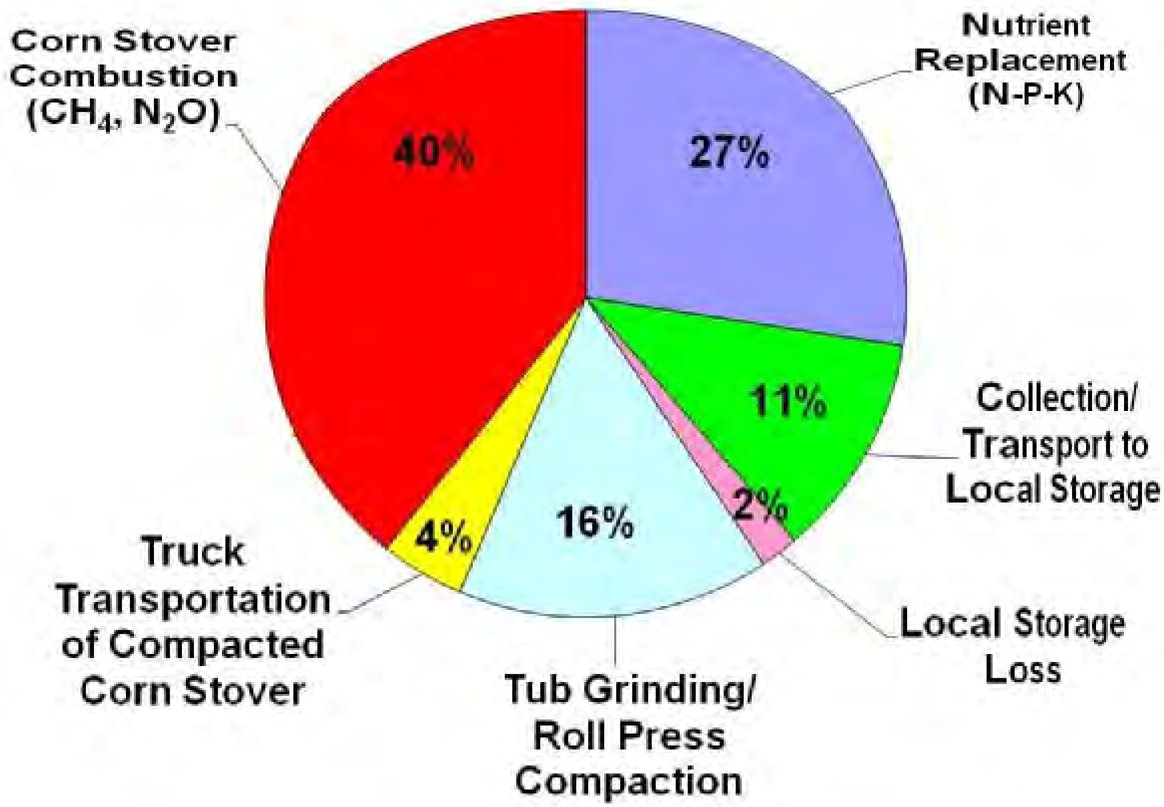
$77/ton of corn stover delivered (MC = 15% w.b.)

Life-Cycle Fossil Energy Consumption



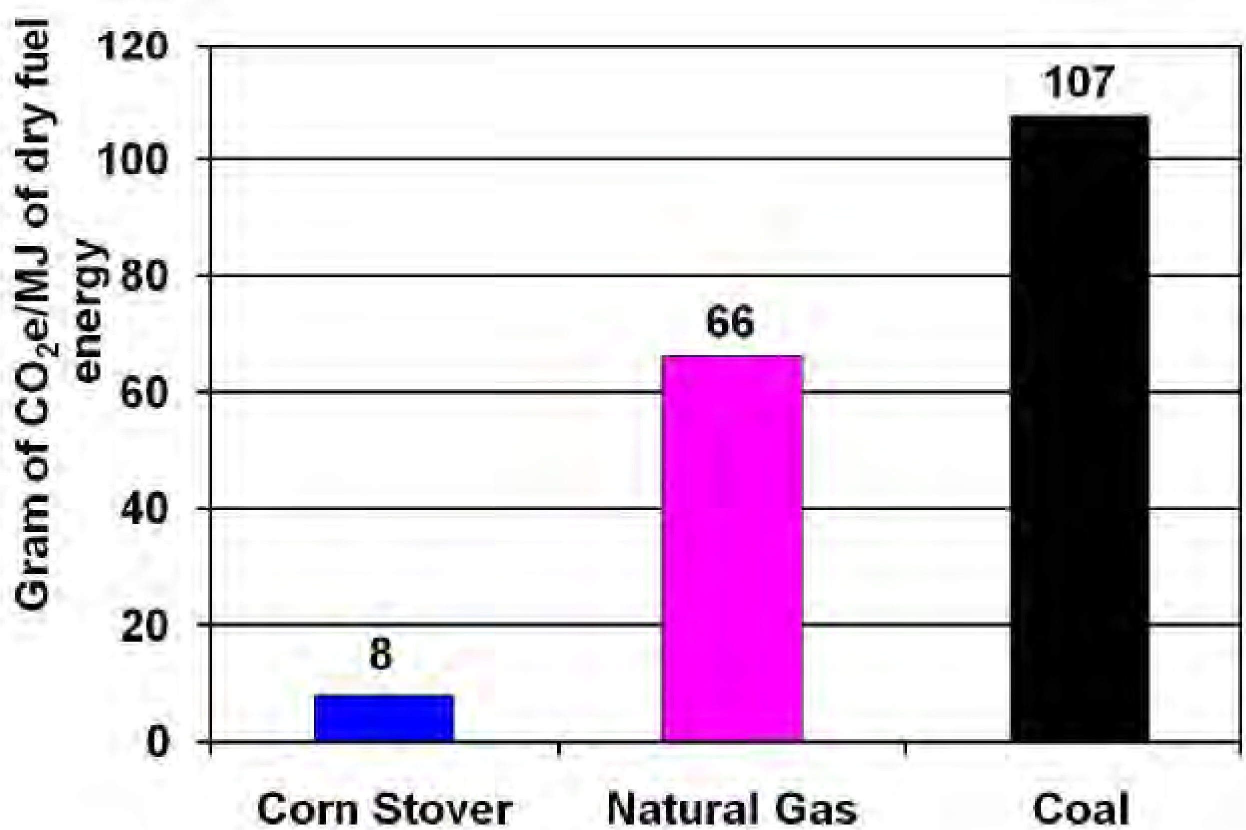
1101 MJ/dry tonne (i.e., 7% of dry corn stover energy)

Life-Cycle GHG Emission



134 kg of CO_2e/dry tonne of corn stover
(includes combustion emission, but not SOC)

Life-Cycle GHG Emission



8 g of CO_2e/MJ of dry corn stover
(includes combustion emission, but not SOC)

Biomass for Combined Heat and Power at Ethanol Plants

Discussion:

- Past research done at U of M that models use of biomass for process heat, CHP, and CHP + sales of power to grid
- On-going research using IGCC to produce even more electricity for sale to grid
- Discuss economic, energetic and environmental performance of CHP at ethanol plants

Project Objectives

Determine Technical Feasibility of Using Biomass to Provide Process Heat and Electricity at Ethanol Plants

Determine Economic Sensitivity of Using Biomass with Appropriate Technologies under Various Economic Conditions

www.biomassCHPethanol.umn.edu

Biomass Fuel for Dry-Grind Plants

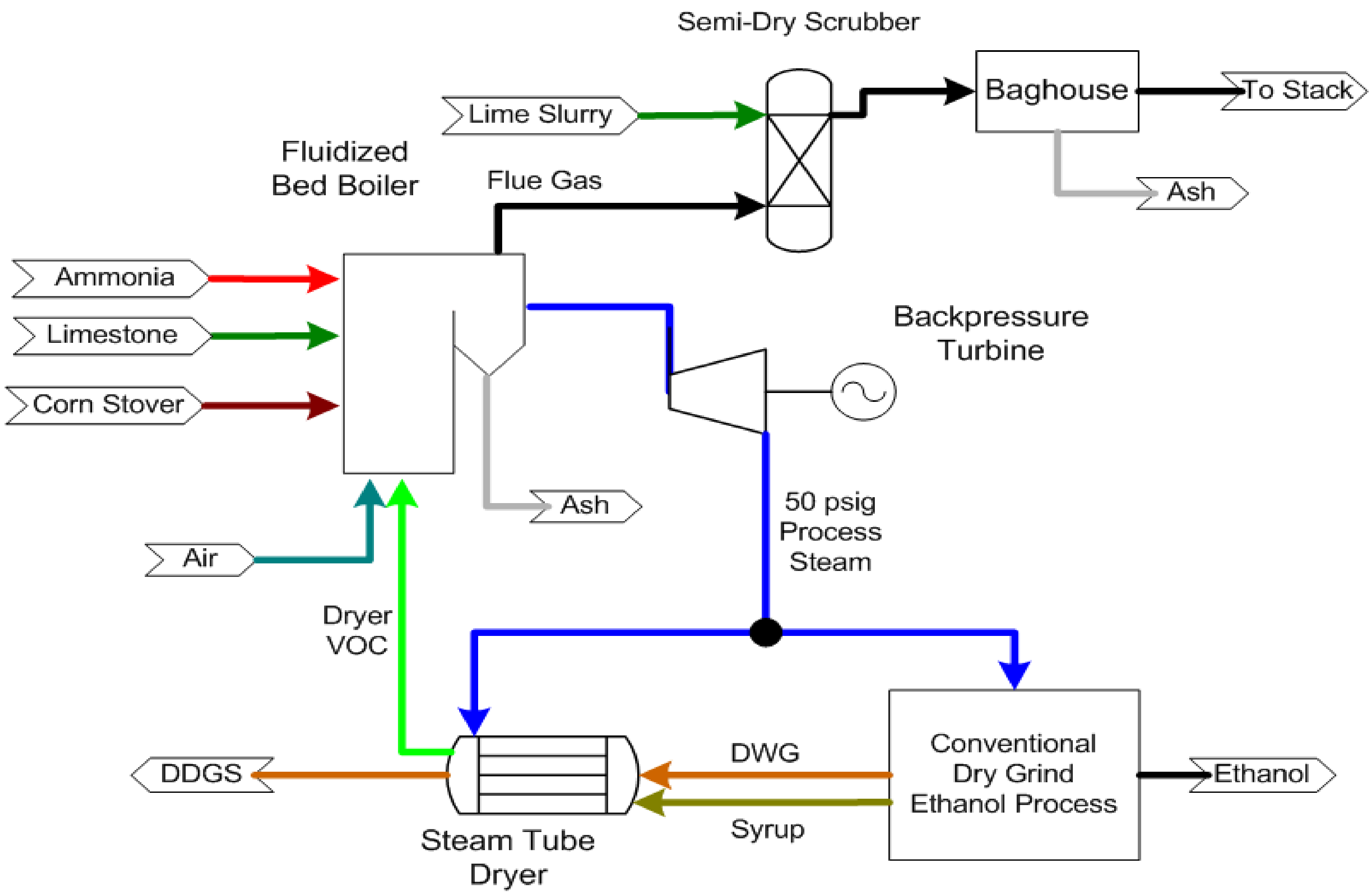
- Reduce energy costs, Improve ROI--$$$
- Generate reliable power for the grid
- Improve Renewable Energy Ratio
  - Defined as: Energy Out / Fossil Energy In
- Lower the overall greenhouse gas emissions from ethanol production

3 Biomass Fuels and 3 Levels of Intensity of Use

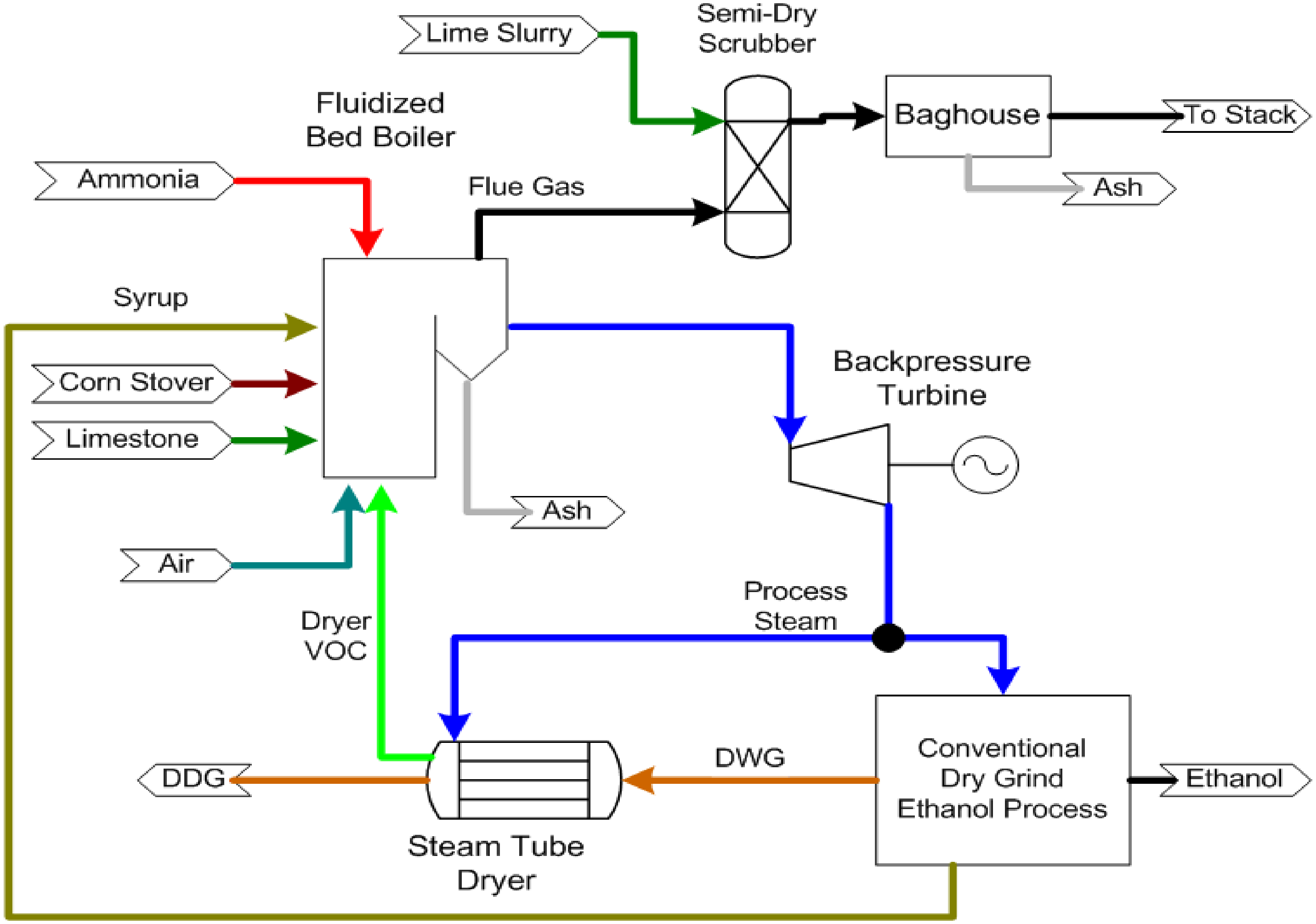
- **Corn Stover Combusted in Fluidized Bed**
- **DDGS Gasified in Fluidized Bed**
- **Syrup + Stover Combusted in Fluidized Bed**

- **Process Heat**
- **Combined Heat and Power (CHP)**
- **CHP + Sales of Power to the Grid**

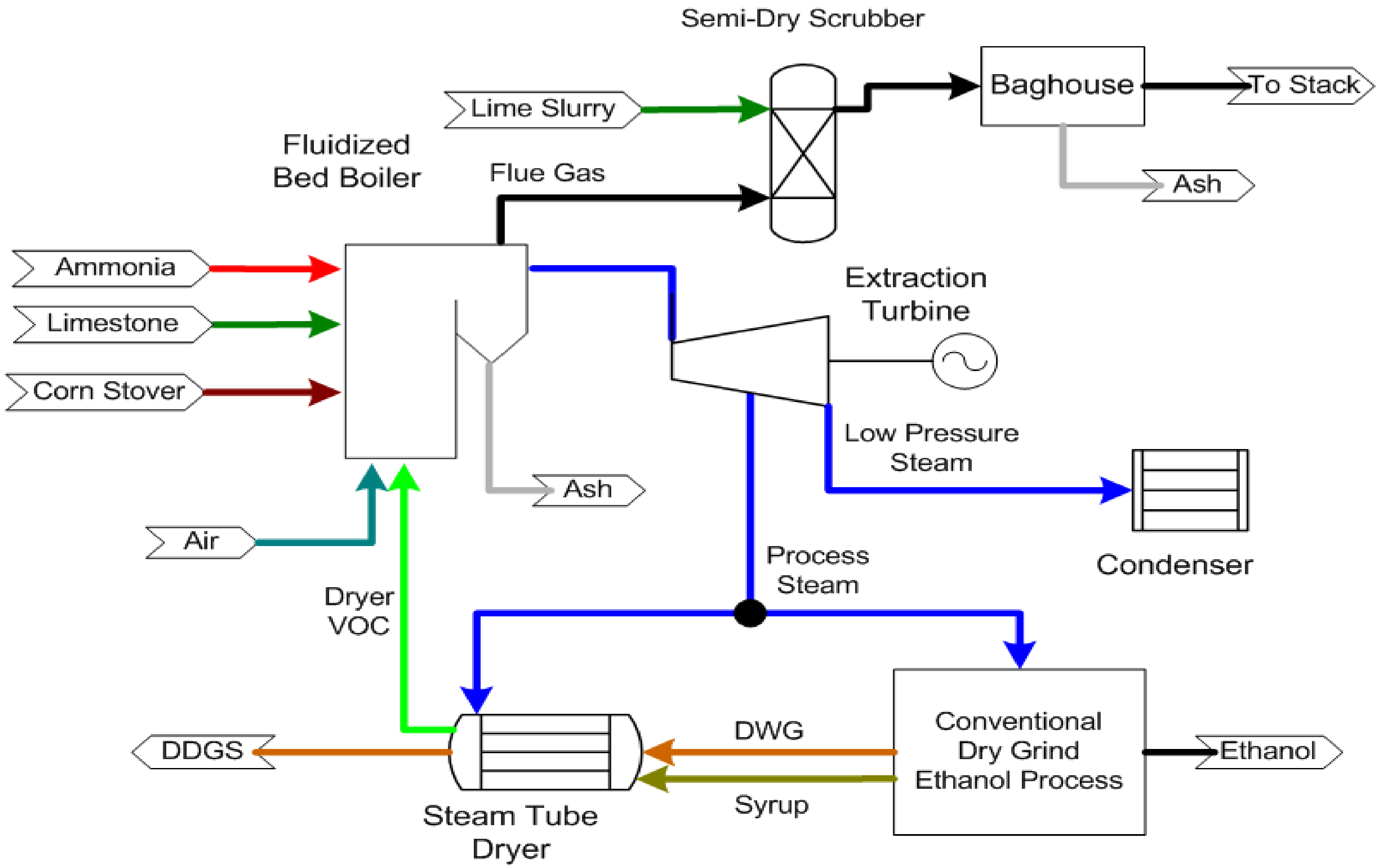
Corn Stover Combustion, Level 2: CHP



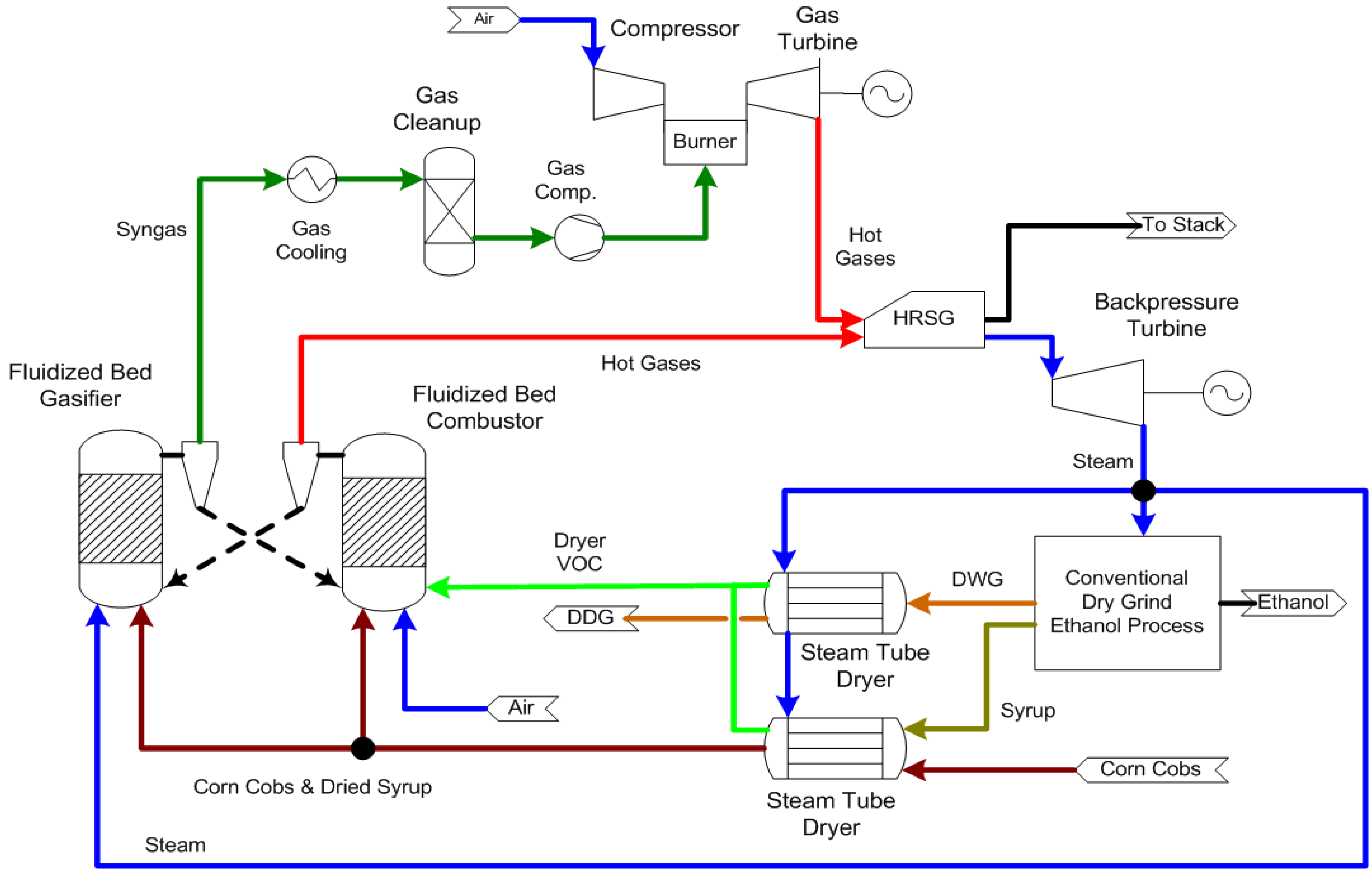
Syrup and Corn Stover Combustion, Level 2: CHP



Corn Stover Combustion, Level 3: CHP + Grid

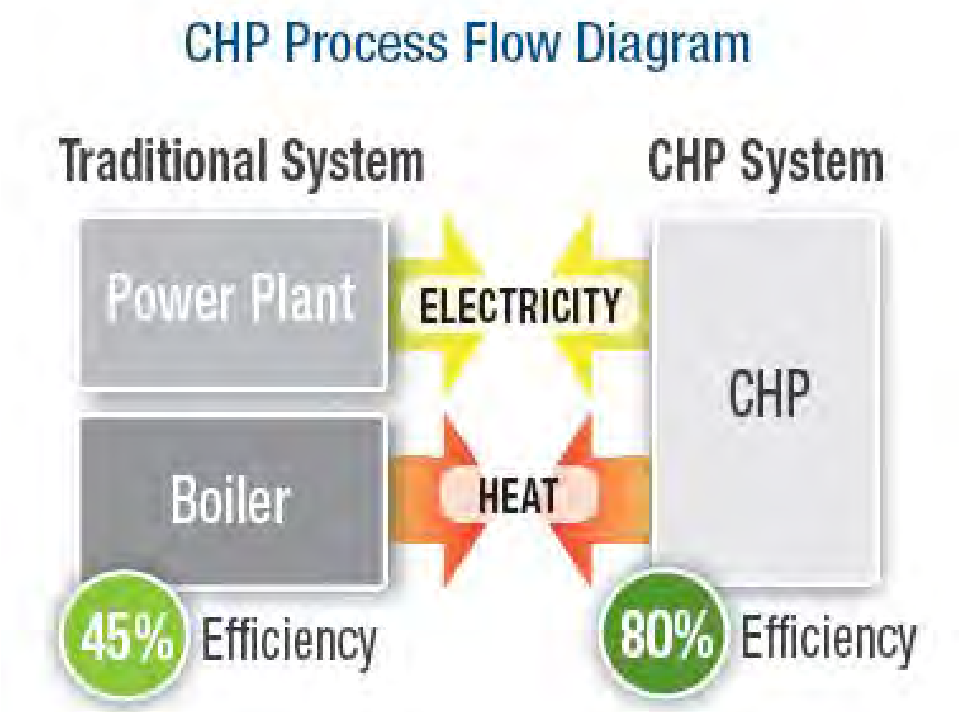


Integrated Gasification Combined Cycle (FERCO SilvaGas™ Process)

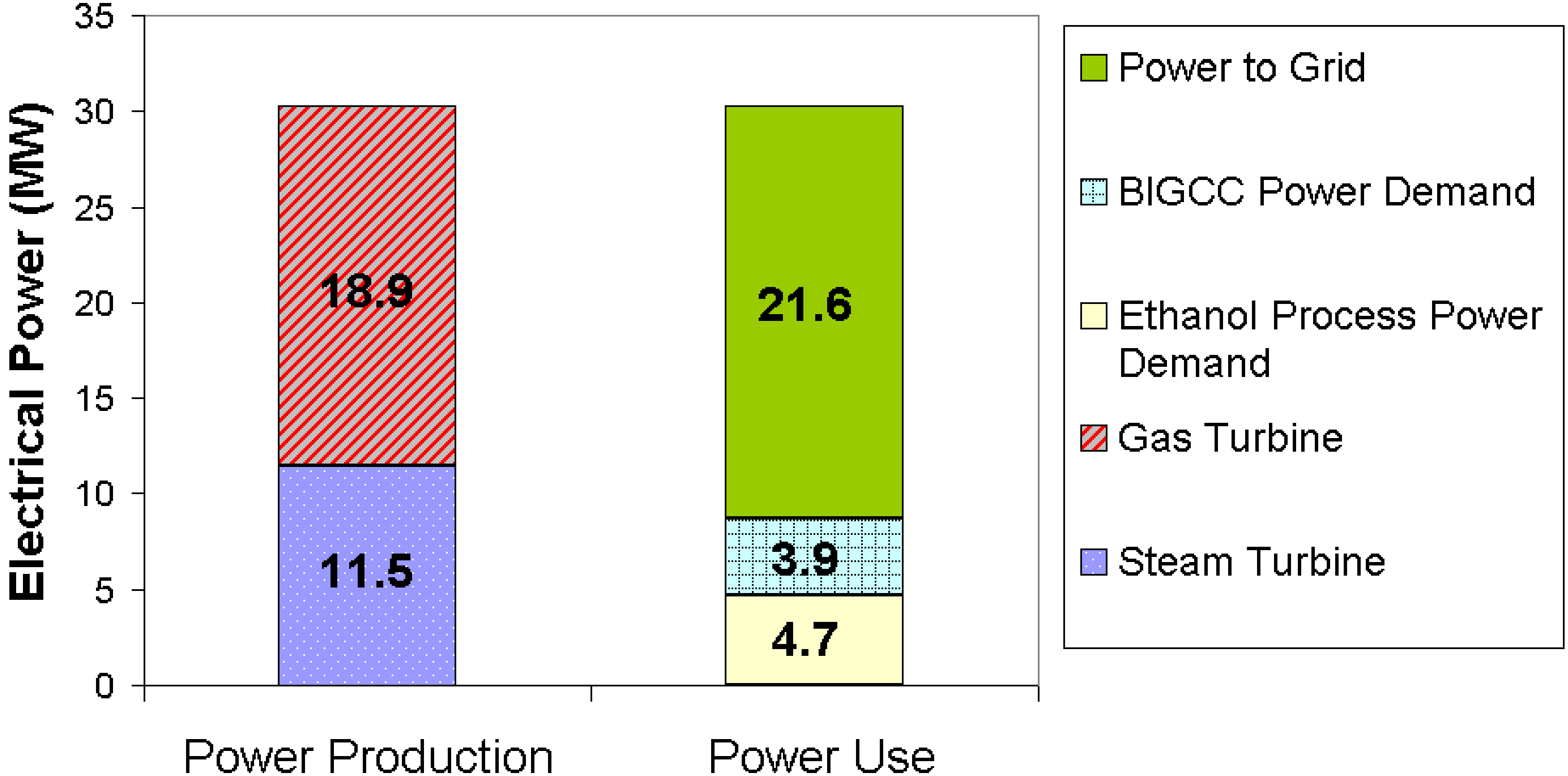


U.S. Dept. of Energy Encourages CHP

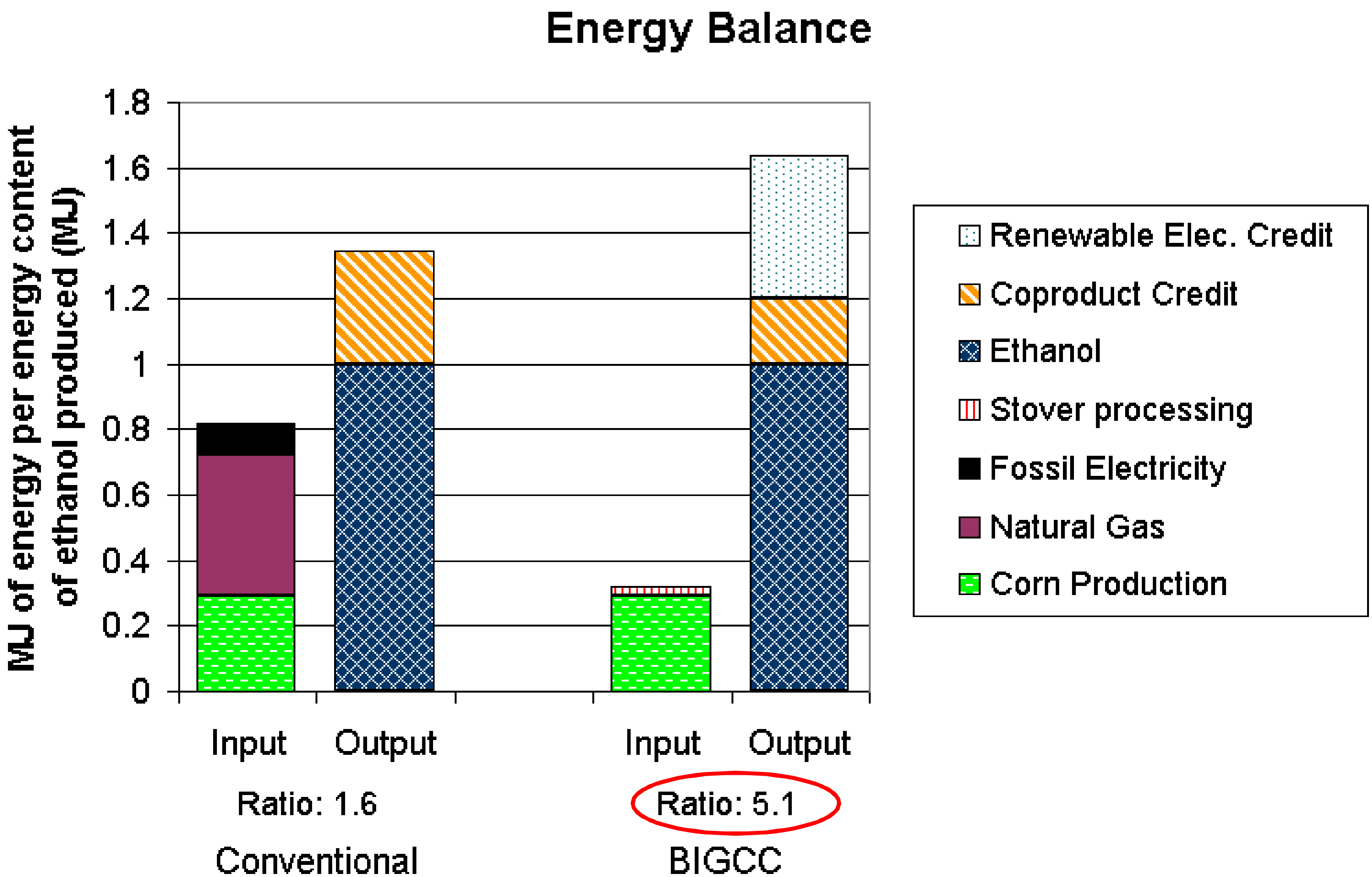
- Utilize Process Heat before or after using to generate electricity- cuts GHG by 53%.
- Requires greater investment, coordination with power utilities.
- Source: Combine Heat and Power: Effective Energy Solutions for a Sustainable Future, ORNL. http://www.osti.gov/bridge



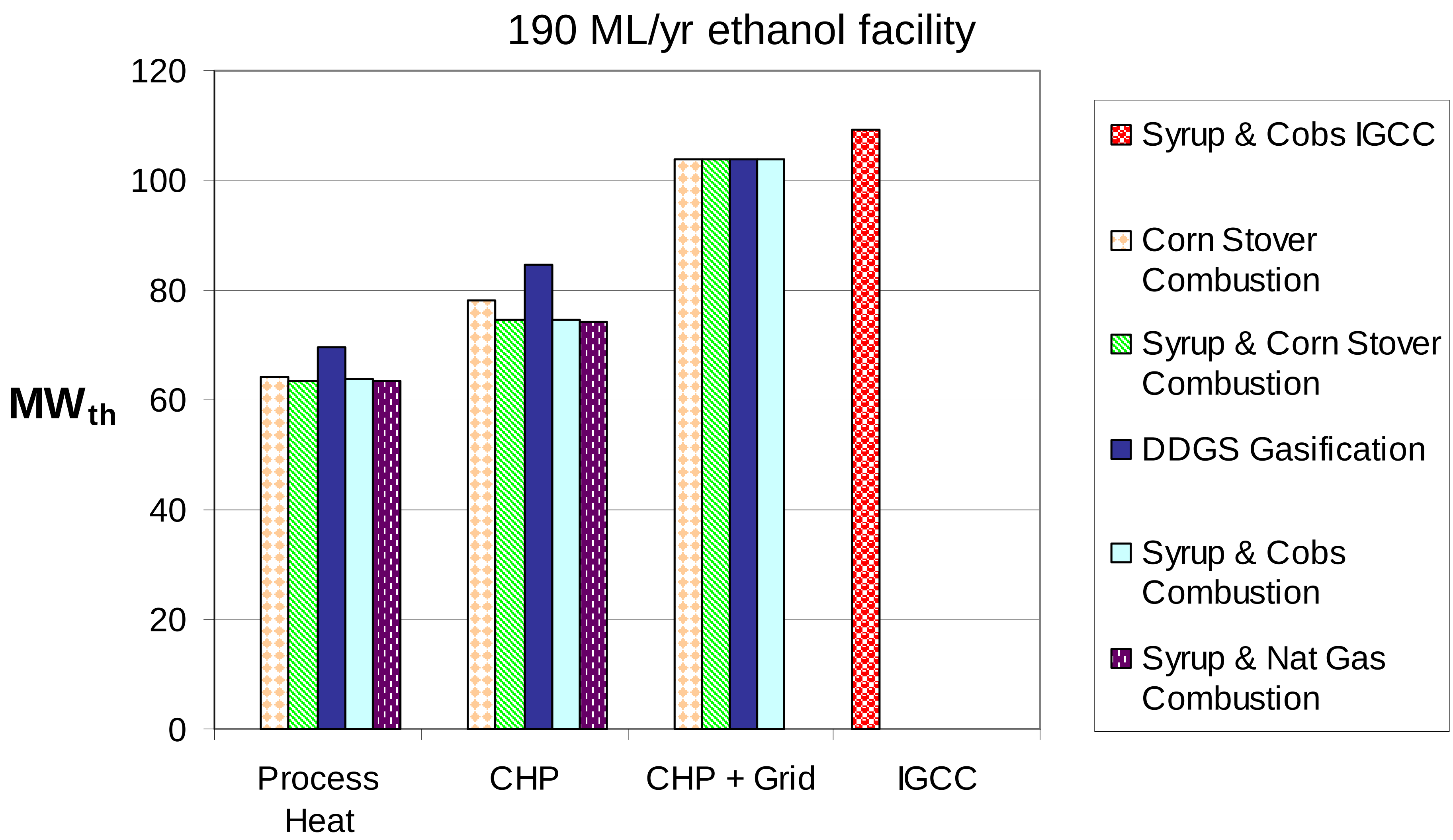
Electricity Production and Use



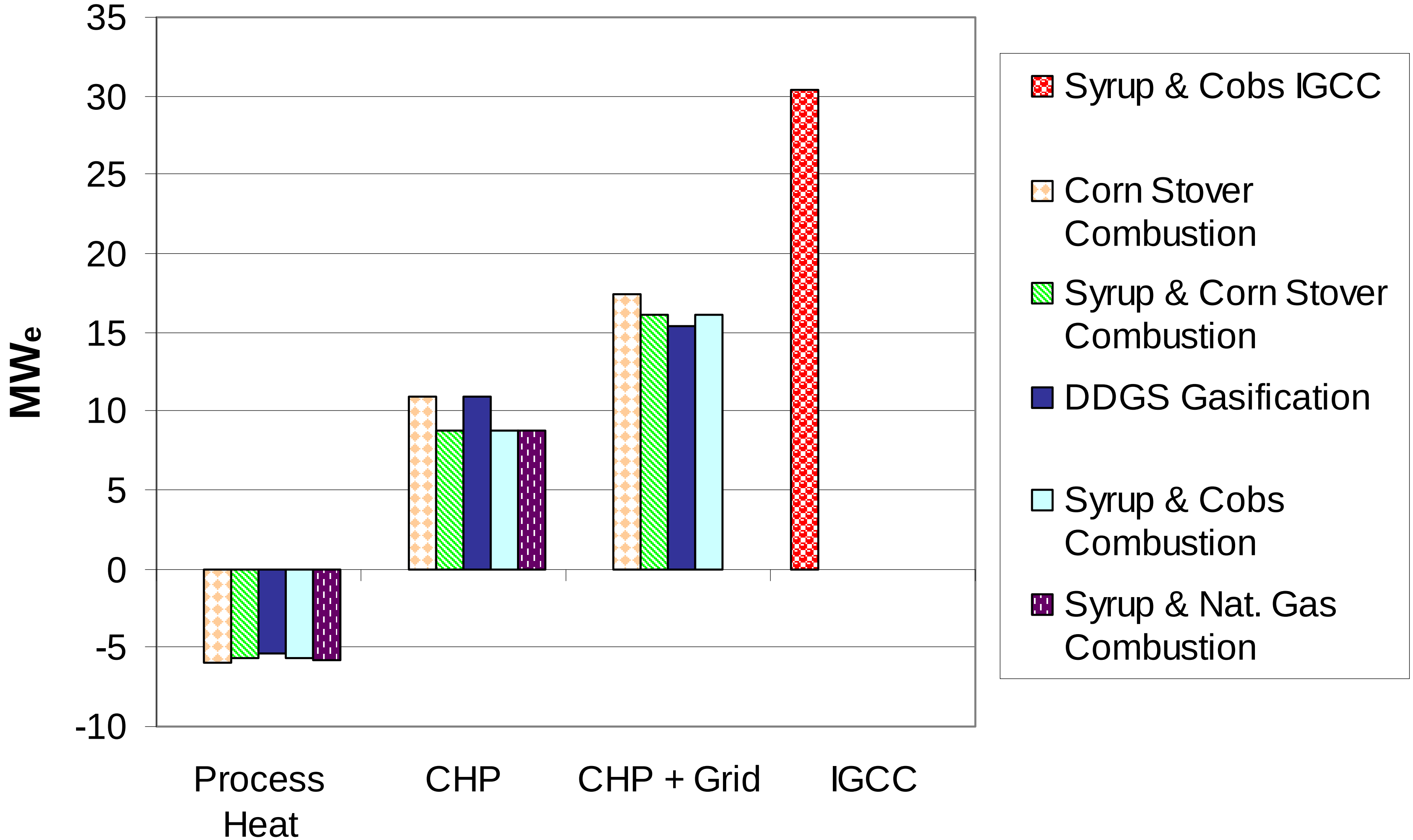
190 million liter (50 MMgal) per year ethanol facility

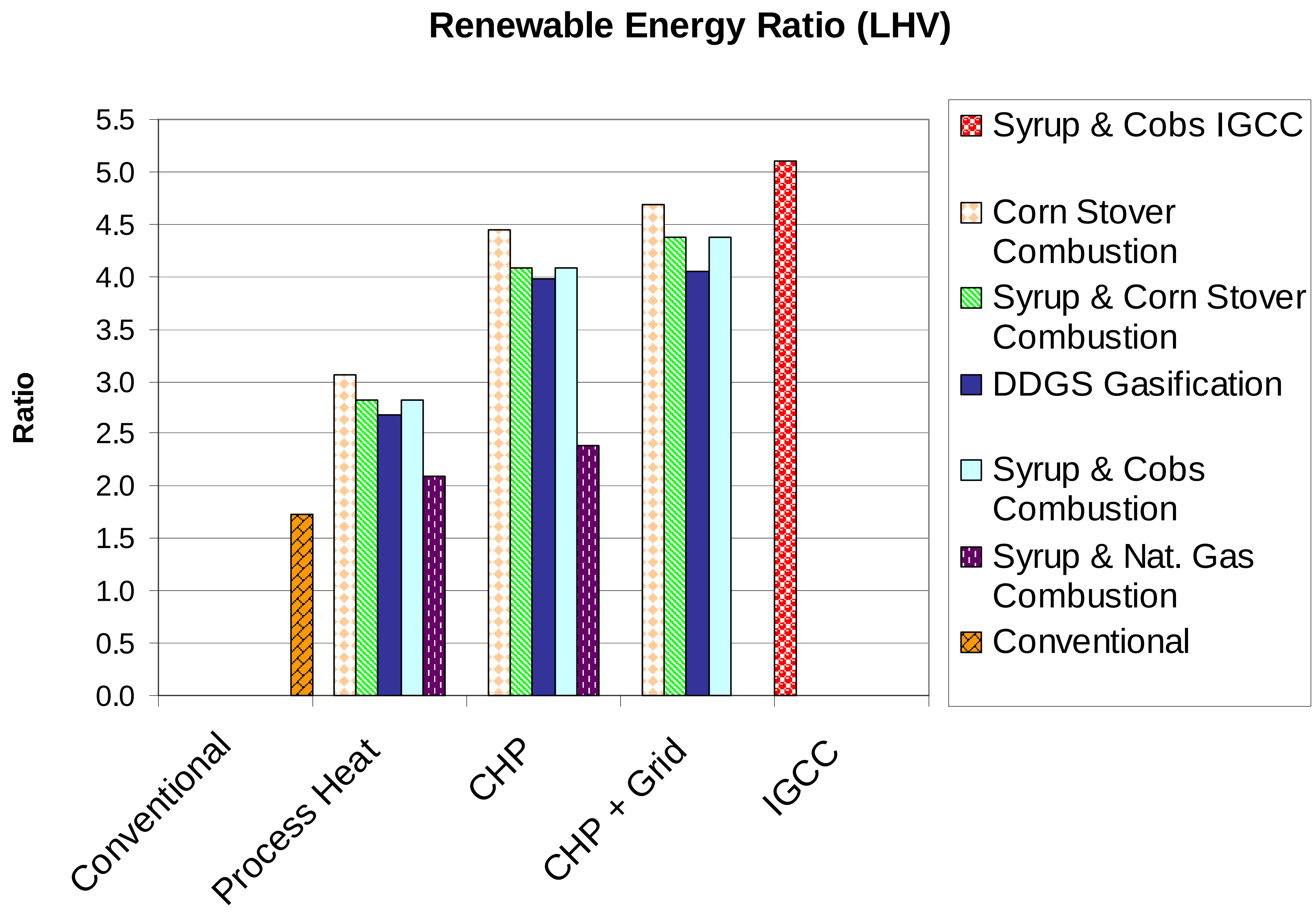

Energy Balance
MJ of energy per energy content of ethanol produced (MJ)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Renewable Elec. Credit
Coproduct Credit
Ethanol
Stover processing
Fossil Electricity
Natural Gas
Corn Production
Input
Output
Input
Output
Ratio: 1.6
Ratio: 5.1
Conventional
BIGCC

Fuel Energy Input Rate



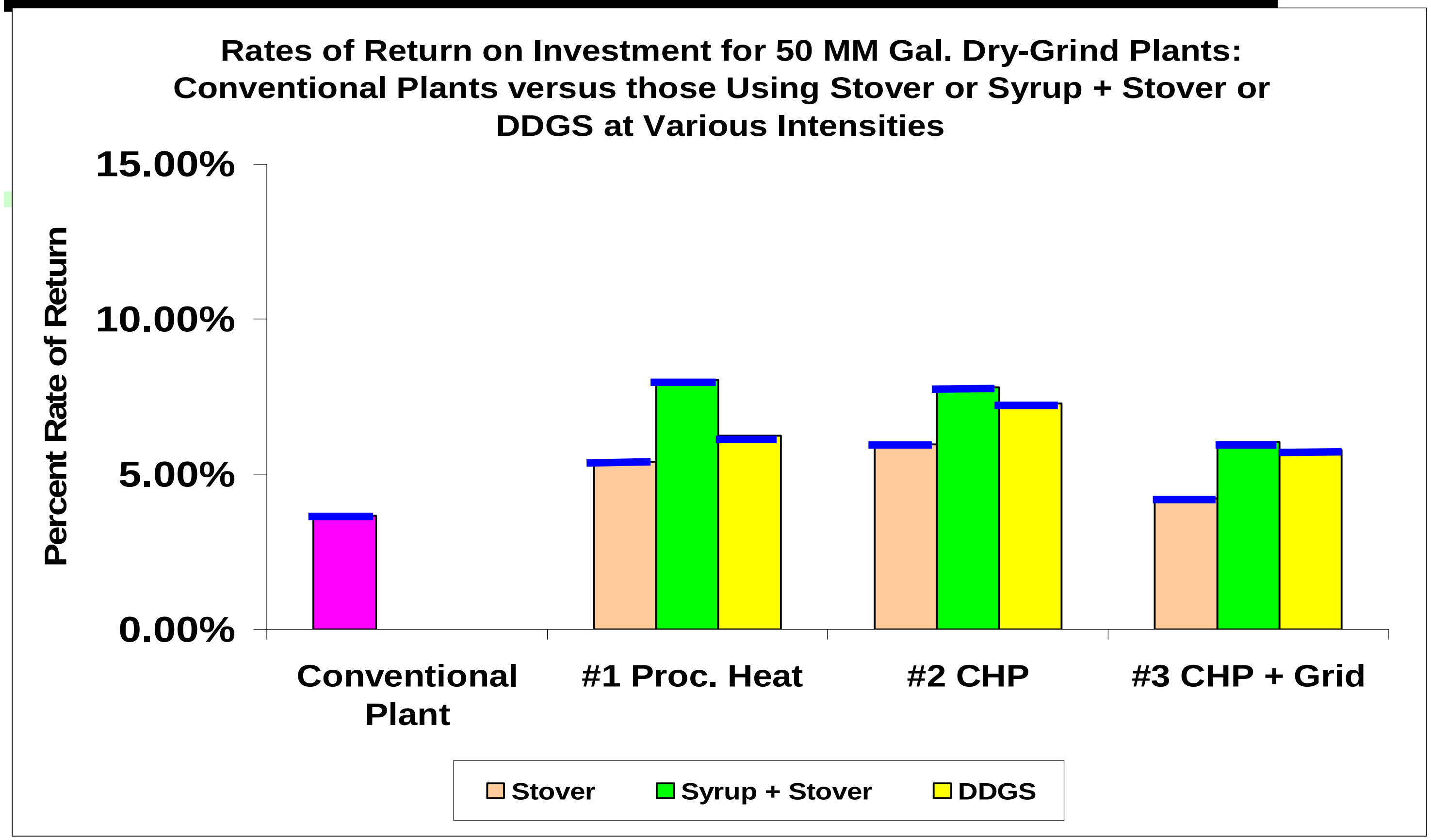
Gross Electricity Generation (and Use)




Renewable Energy Ratio (LHV)
Ratio
5.5
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
IGCC
Syrup & Cobs IGCC
Corn Stover Combustion
Syrup & Corn Stover Combustion
DDGS Gasification
Syrup & Cobs Combustion
Syrup & Nat. Gas Combustion
Conventional

Baseline ROR's for 50 MM Gallon Plant

Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
3.66%	5.40%	5.97%	4.21%	Stover
	8.04%	7.80%	6.05%	Syrup + Stover
	6.25%	7.28%	5.79%	DDGS



GHG Emissions of Ethanol using Corn Stover as a Fuel

	Convent. Corn Ethanol	CHP	CHP + Grid	BIGCC
GHG Reduction	52%	82%	92%	115%
GHG Reduction with CO_2 Sequst.	85%	116%	126%	149%

GHG Emissions of Ethanol using Syrup and Corn Stover as a Fuel

	Convent. Corn Ethanol	CHP	CHP + Grid	BIGCC
GHG Reduction	52%	75%	86%	111%
GHG Reduction with CO_2 Sequst.	85%	108%	120%	145%

Amount of Biomass Required, %

	DDGS	Corn stover		Syrup + stover	
		Ethanol corn acres	All corn acres*	Ethanol corn acres	All corn acres*
Process heat	70%	27%	9%	9%	3%
CHP	80%	30%	10%	12%	4%
CHP + grid	100%	40%	13%	27%	9%

*Assumes 1/3 of corn acres go for ethanol

Changes on the Land and in the Soil

Biomass Harvest Rates Must Consider Maintenance of Relic Soil Organic Carbon

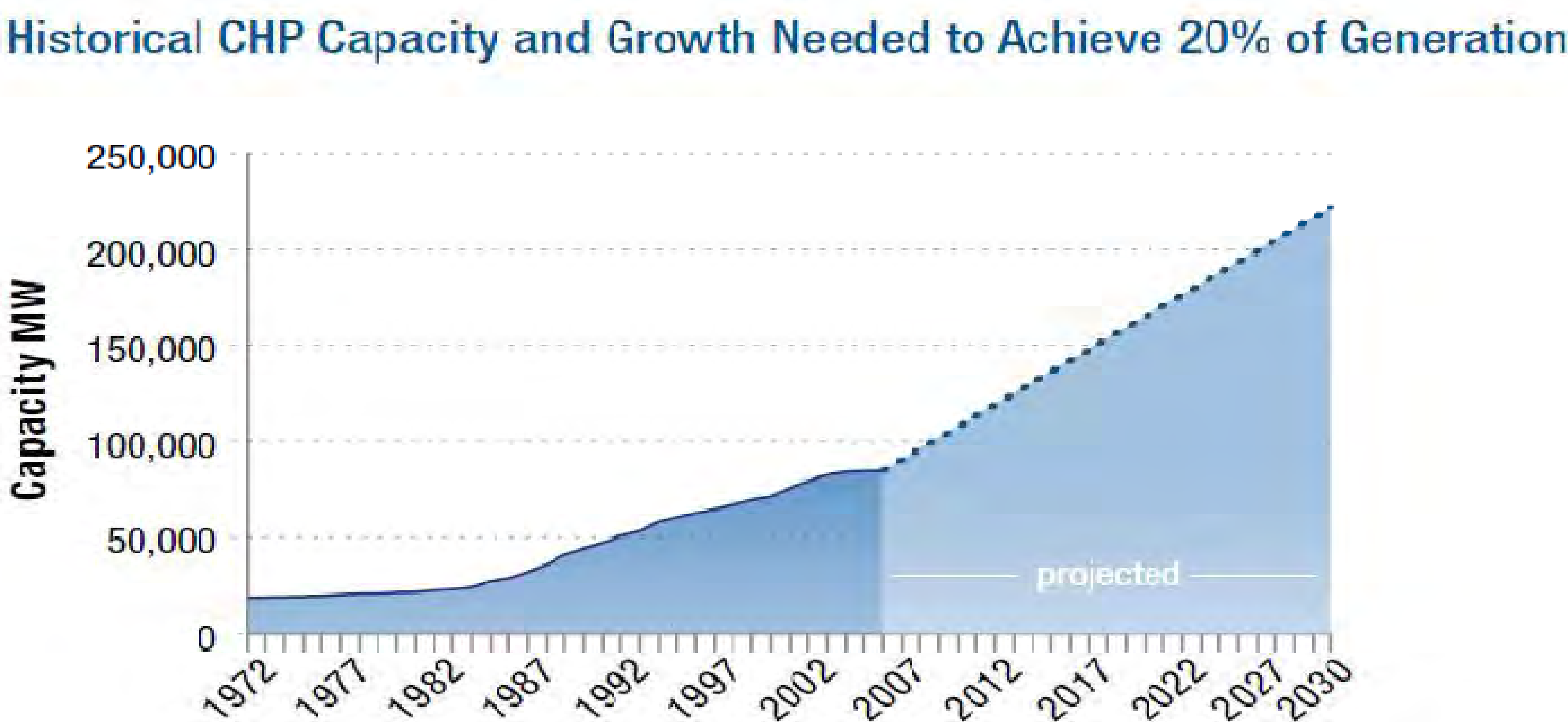
- Preservation of relic soil organic carbon is key issue associated with biomass harvest
- Removal of 70% of corn stover in half the years growing corn should maintain SOC

Will Logistical Requirements be too difficult? No!!!

- Heat and Power using Stover for 50 million gallons ethanol per year
- 400 to 500 tons per day of stover
  - 16 to 20 truckloads (25 tons each) of briquettes or pellets per day or
  - 640 to 800 bales (1250 lbs each) per day
- 60 truckloads of corn per day
- 20 truckloads of DDGS per day

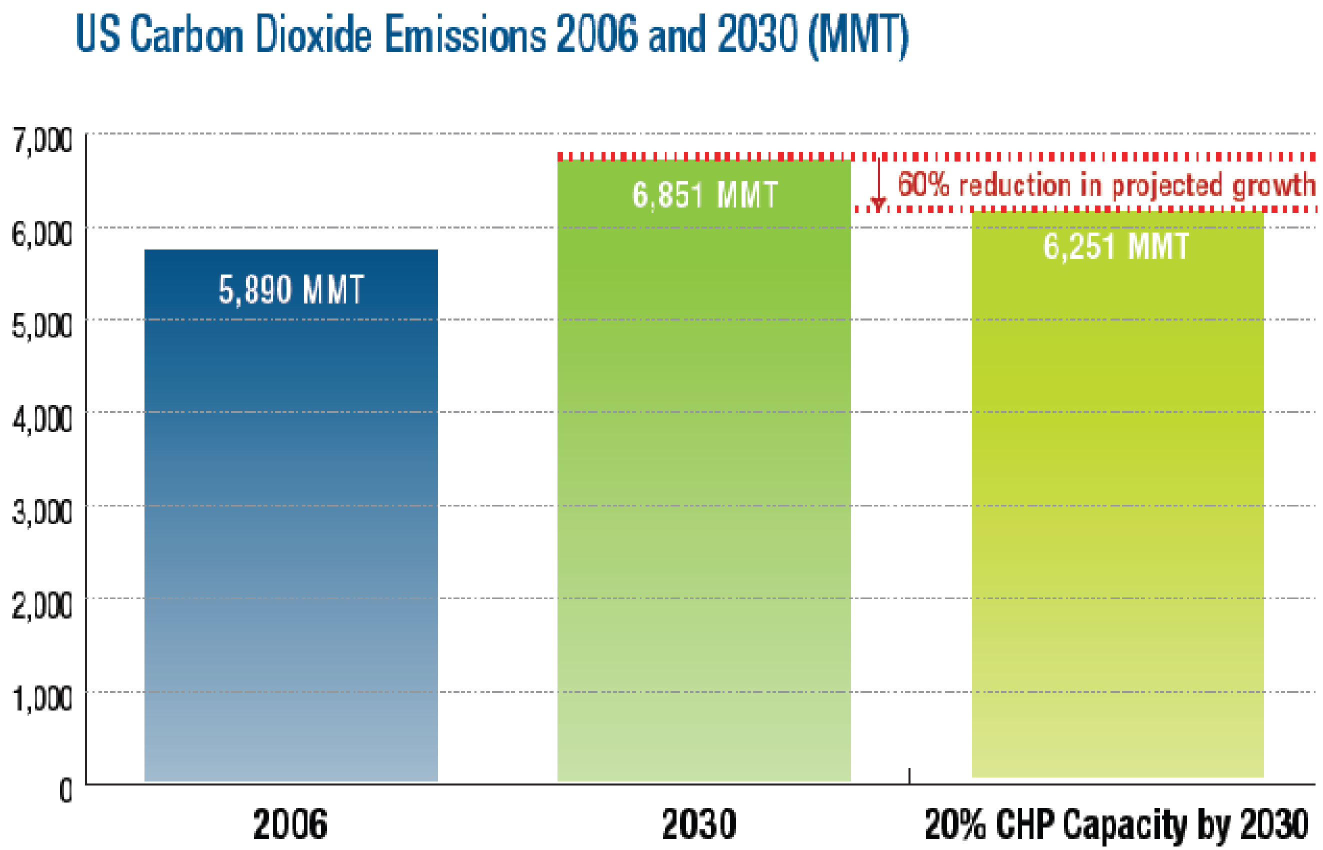
DOE Goal: CHP Expansion from 9% to 20% of U.S. Capacity by 2030

Source: Combine Heat and Power: Effective Energy Solutions for a Sustainable Future, ORNL. http://www.osti.gov/bridge



U.S. CO2 Emissions 2006-2030 and Effect of 20% CHP

Source: Combine Heat and Power: Effective Energy Solutions for a Sustainable Future, ORNL. http://www.osti.gov/bridge



Source: DOE EIA AEO 2008 and internal analysis

Summary

- Using biomass as a fuel producing CHP requires implementation of known technologies.
- Plentiful biomass supplies are at or near plants.
- Logistics are not a deal-breaker, but expect stover to cost about $80 per ton as a densified product at the plant.
- GHG emissions of the ethanol can be vastly improved when CHP is implemented at dry-grind plants. Corn ethanol can equal Brazilian sugar cane-based ethanol in GHG reductions.
- CHP Implementation is expected to become more common in the U.S. as GHG reduction targets become formalized.

Use of Biomass at Ethanol Plants

- **<u>Technically feasible</u>** and **<u>fiscally prudent</u>**, especially when policies favoring low carbon fuel standards are adopted.
- **<u>Improves energy balance</u>** and **<u>drastically reduces the carbon footprint</u>** of ethanol produced from corn.
- Each 1 Billion gallons of ethanol capacity can produce 300 MWe for the grid, probably 600 MWe for IGCC.
- Use of biomass as a fuel at ethanol plants can be a **<u>bridge technology</u>** to other technologies for biofuels production.

Thanks!

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http://www.apec.umn.edu/staff/dtiffany/