# Solid Biomass For Cogeneration IPRO 349

#### December 5, 2008

## Importance

- The U.S. is moving towards sustainability.
- Biomass popular, but unexplored.
- Increase in demand and a decline in production of natural gas. <sup>[1]</sup>
- Potential energy from stover is greater than natural gas, propane, and heating oil.<sup>[2]</sup>
- Places value on stover which was once considered waste.

Increasing demand and natural production decline create growing need for significant new production capacity 140 120 IEO 2008 Demand Range PER DAY Unconventional 100 and biofuels **Required New** MILLION BARRELS Capacity 80 2015 30 - 45 MBOE/D Conventional non OPEC 2030 60 70-100 MBOE/D 4-7% Production Decline Conventional OPEC **Existing Production** Capacity 20 2007 2015 2030

Matlock, Mark, 2008 NWU Presentation

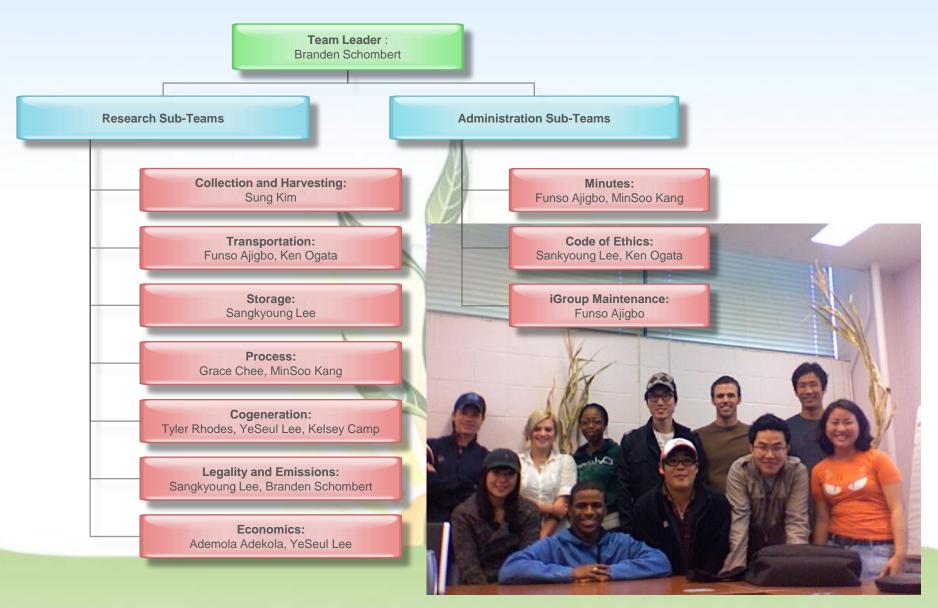
### Problem Statement

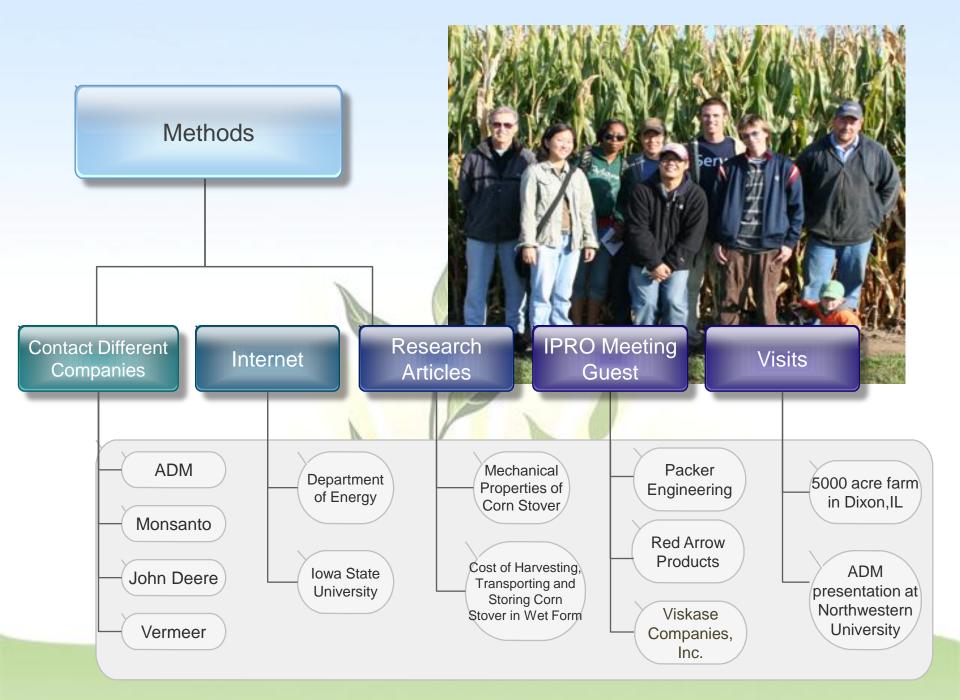
There is a need for a practical method to efficiently convert corn stover to usable energy via cogeneration.

# Objectives

- Investigate pathways for small scale conversion of stover to usable energy
- Research different tools, equipment, and processes to develop a cost, time, and energy efficient process
- Determine the cost and energy efficiency of each step of the system
- Develop a detailed system for a small scale CHP process

# Methodology





# Ethics

- Seven layers of Ethics
- Law
  - Must abide by all EPA regulations
- Professional Code of Ethics
  - Must not represent our team falsely. Rather, be smart when contacting companies.
- Community
  - Corn for food waste for fuel

#### Large Scale versus Small Scale

- Mini debate on whether this project should focus on small or large scale
  - Hope that both small and large scale systems will eventually be implemented
- Divided into 2 groups and presented pros and cons of each option
- Results of mini debate:
  - Large scale left as recommendation for next IPRO
  - Small scale was chosen for following reasons...

## Results

#### Small Scale Benefits

- Conventional
- Transportation
- Simpler equipment
- Smaller investment
- Profitability

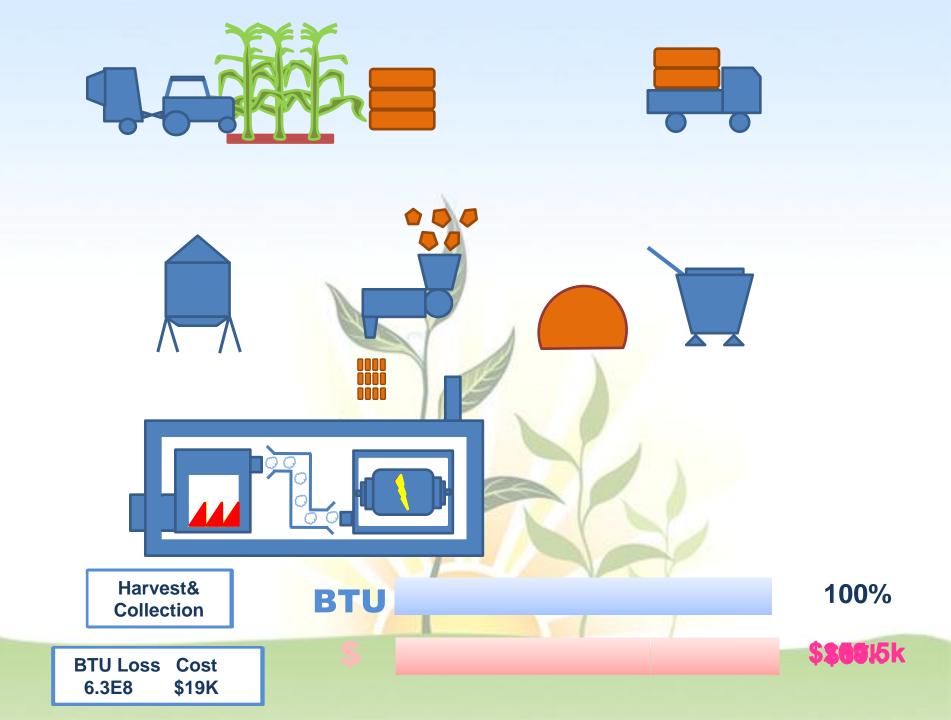
#### Disadvantages

- Not as efficient
- Gasification too complex and impractical

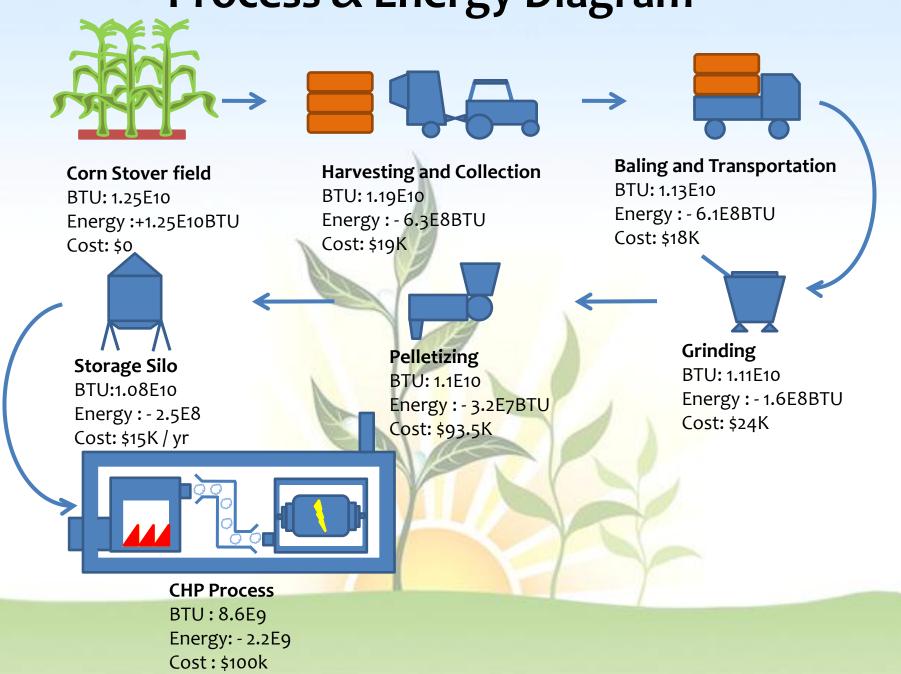
#### Large Scale Benefits

- Create jobs
- Large localized facility
- Gasification
  - Higher energy yields<sup>[3]</sup>
  - Easier to transport/store
  - More efficient operation
- Disadvantages
  - Complicated logistics
  - Large investment
  - More complicated processes

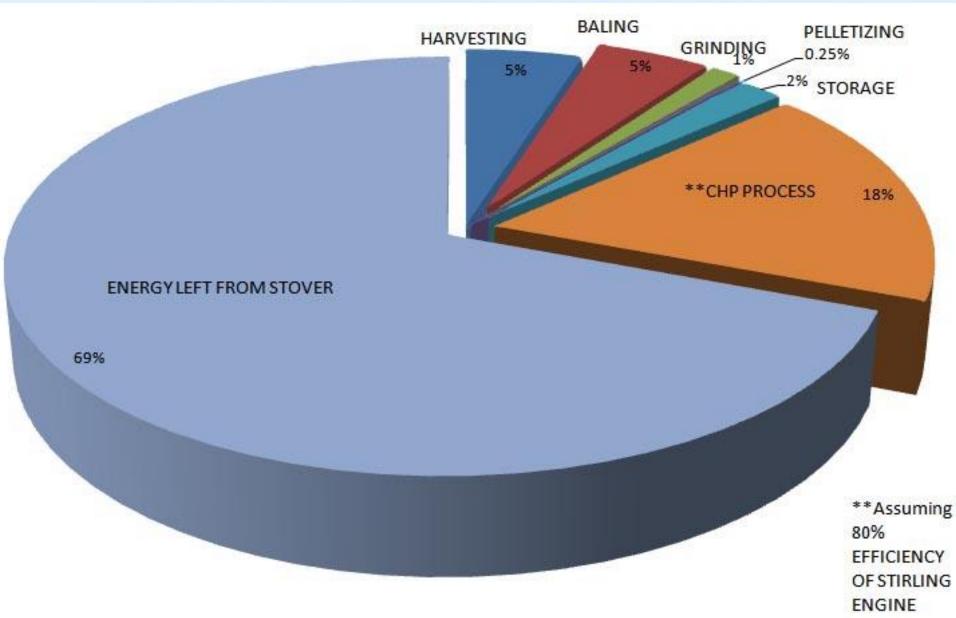
# Process Flow Chart



#### **Process & Energy Diagram**



# Energy



## Excel Screenshot

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## Proposal of Best Combination

- Large square bales
- Shenk Rotogrinder for bale grinding
- La Meccanica for pelletizing
- Harvestore silo for pellet storage
- Stirling engine for CHP

## Large Square Bales



http://www.newhollandmediakit.com/images/newsreleases/H9880\_ABW\_1.jpg

• Dimensions: 4ft x 4ft x 8ft<sup>[4]</sup>

•1200 lbs

•Variable Loading Mechanisms

## Shenk Livestock - 760 Rotogrind



http://www.shenklivestock.com

- Price : ~ \$19,800
- Minimum HP of Tractor : 65HP
- Average HP : 80HP
- Grinder Weight : 3500lb
- •Capacity : 5 30 ton/hour

X capacity depends on the type and condition of material, how finely it is being ground, and the size of the tractor.

### La Meccanica - CLM 630N



http://www.lameccanica.it

- Main Motor Power : 160 200 kW
- Capacity : 12/18 (min/max, ton/hr)

#### Technical features

Animal feed industry	Main Motor power	Capacity (min/max)				
CLM 200	7.7 - 11.0 - 15.0 kW	150 kg/h	300 kg/h			
CLM 304	30 - 37 - 45 kW	1.5 Ton/h	2.5 Ton/h			
CLM 420.075	37 - 55 kW	2.5 Ton/h	5.0 Ton/h			
CLM 420.100	75 - 90 - 110 kW	4.0 Ton/h	6.0 Ton/h			
CLM 420.150 HD	75 - 90 - 110 kW	6.0 Ton/h	8.0 Ton/h			
CLM 520.180 ST	110 - 132 kW	8.0 Ton/h	10.0 Ton/h			
CLM 520.220	160 - 200 kW	8.0 Ton/h	10.0 Ton/h			
CLM 520 HD	160 - 200 kW	8.0 Ton/h	12.0 Ton/h			
CLM 630.220	160 kW	10.0 Ton/h	15.0 Ton/h			
CLM 630 N	160 - 200 kW	12.0 Ton/h	18.0 Ton/h			
CLM 630 G	200 - 250 KW	14.0 Ton/h	20.0 Ton/h			
CLM 800 P	250 - 280 kW	12.0 Ton/h	22.0 Ton/h			
CLM 935 M	300 - 350 kW	Up to 35.0	00 Ton/h			

http://www.pelletmills.com

#### Harvestore Silo

- Steel Silo
- Material : glass-fused-to-steel sheets
- •Capacity: 1000 tons ~ 43000 ft<sup>3</sup>

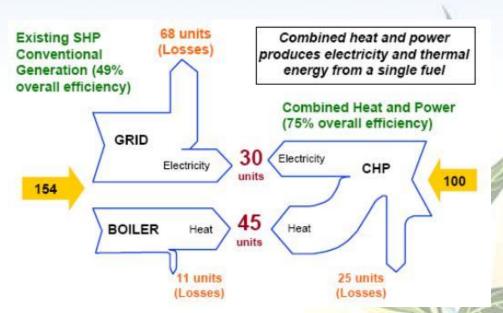


http://www.harvestore.com



http://www.harvestore.com

#### Why use CHP?



Vartiainen, E et al, 2002; Gaia Group Oy, 2004; Obernberger, I., 2004

- Increased efficiency of energy conversion and use
- Lower emissions to environment, in particular of CO2, the main greenhouse gas

 An opportunity to move towards more decentralized forms of electricity generation

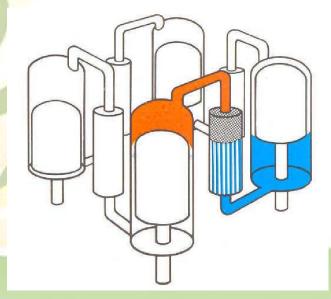
•High efficiency by avoiding transmission losses and increasing flexibility in system use

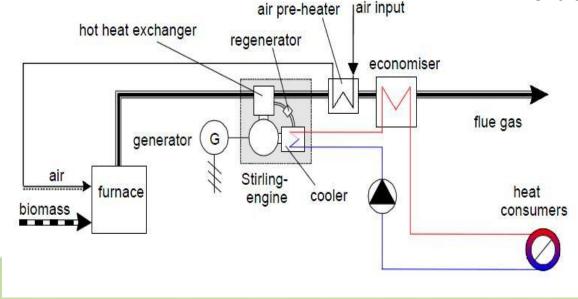
#### Stirling Denmark - SD 5 Stirling Engine

- 80% energy efficient
  - 10 kWe capacity
  - 40 kWth capacity
- \$100,000 for plant construction
- input 24 to 32 pounds/hour<sup>[5]</sup>



SD5-Stirling Engine from Stirling Denmark





Henrik Carlsen, Technical University of Denmark

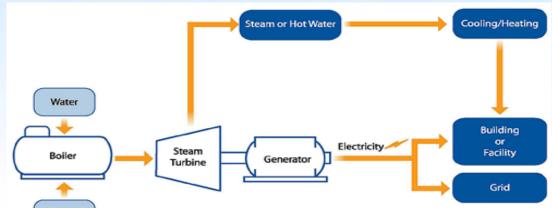
www.epa.gov

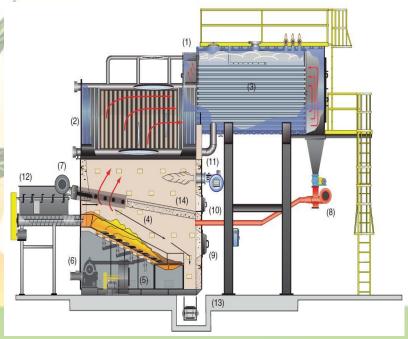
#### Hurst Boiler & Welding Co., Inc. - CAT # B-08

- 60% energy efficient
  - 50 kWe capacity
  - 250 kWth capacity
- \$250,000\*(estimated)
- •Currently larger scale operation/multiple farm investment
- Research for smaller scale is concurrent (1-10kW)<sup>[6]</sup>



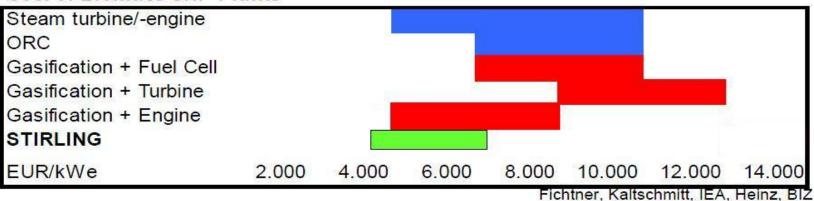
50 kW GE Steam Turbine



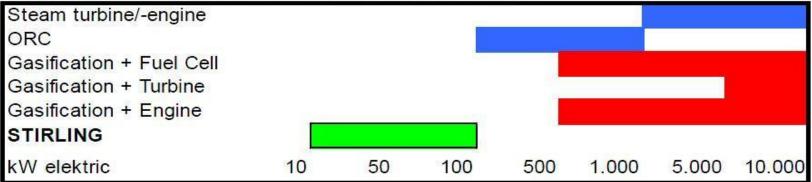


Hurst RG Biomass Fired Boiler

#### Cost of Biomass CHP-Plants



#### **Comparison of Technologies - Power Output Potential**



	Diesel/gas engine	Micro turbine	Stirling engine	ORC turbine	Steam engine
Capacity range (kW,)	15-10000	25-250	10-150	200-1500	20-1000
Electrical efficiency (%)	30-38	15-35	15-35	10-20	10-20
Thermal efficiency (%)	45-50	50-60	60-80	70-85	40-70
Overall efficiency (%)	75-85	75-85	80-90	<mark>85-9</mark> 5	75-85
Heat production (°C)	85-100	85-100, steam	60-80	80-100	85-120
Lifetime (h)	25000-60000	50000-75000	50000-60000	?	> 50000

Vartiainen, E et al, 2002; Gaia Group Oy, 2004; Obernberger, I., 2004

# Problems

#### Correspondence

- Information is still being researched by companies that have been contacted
- "Smart" relations
- Size Reduction
  - Properly scaling model for 400 acre farm
  - Current equipment ideal for large scale operations

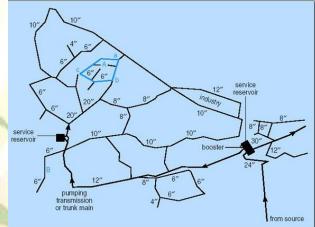
- Standardization
  - Size consistencies between input and output of processes
  - Consistent units of measure

# To Do - Recommendations

- Equipment ordering specifications & conditions for test installation
- Unit operations safety review
- Website and interactive database

#### Examine options:

- Possible piping of stover slurry for transport
- 2. Nitrogen byproduct use (cost/benefit)



- 3. Look into gasification (energy potential is 9:1)
- 4. Expand models: Small to large scale

## References

- 1. Matlock, Mark, 2008, Northwestern University Presentation
- 2. Jannasch, R. "Switchgrass Fuel Pellet Production in Eastern Ontario: A Market Study." Resource Efficient Agricultural Production (REAP). Canada, Dec. 2001.
- 3. "The GTI Gassification Process" Sept. 2007
- 4. Engineering Aspects of harvesting corn stover for bioenergy, Sokansanj
- 5. BIOS Bioenergy Systems, Austria 2003
- 6. Tina Kaarsberg and Joseph Roop, "Combined Heat and Power: How Much Carbon and Energy Can It Save for Manufacturers?"

# Acknowledgements

- Mark Matlock Archer Daniels Midland
- Peter J. Schubert, Ph.D Packer Engineering
- John McKinney Packer Engineering
- Paul DuCharme Red Arrow Products
- Mr. and Mrs. Andy Pratt Dixon Farm Owners
- Jay Van Roekel Vermeer
- Dave Shenk Shenk Livestock
- Christopher Scott Pelheat
- Larry Bubb California Pellet Mills
- Jennifer Keplinger IPRO

# Questions?

