# Integrating Biomass to Produce Heat and Power at Ethanol Plants


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Project Partners:

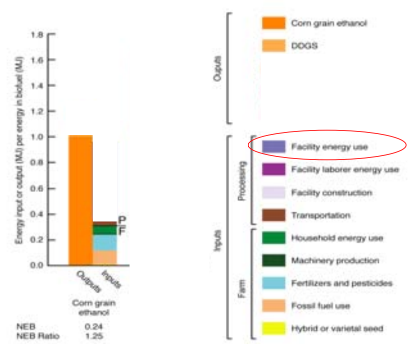
## Overview

- Motivations for using biomass
- Basis for the process models
- Definition of technology combinations
- Modeling results
  - System Performance

## Motivations for Using Biomass

- Improve the renewable energy balance of ethanol
- Energy Ratio Issue
  - Energy out / Energy in
  - Currently in the range of **1.25 – 1.5**

## Motivations for Using Biomass




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

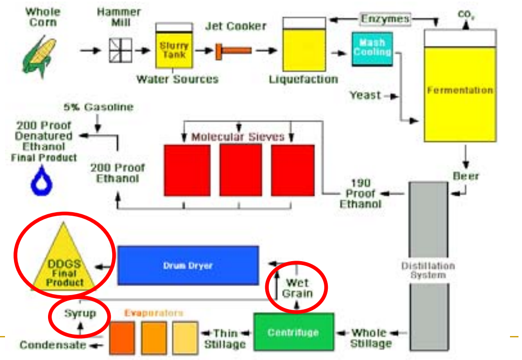
## Motivations for Using Biomass

- 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)
- Can generate reliable "firm" power for the grid
- Lowers the overall greenhouse gas emissions from ethanol production

## ASPEN Plus Ethanol Plant Model

- USDA ARS developed model
- 40MMgal/year baseline
  - Scaled up to 50 MMgal/year for this analysis
- Used this model to understand the ethanol process and its energy requirements
- Heat and power generation systems are based upon this model

## Conventional Dry Grind Ethanol




http://www.midmissourienergy.com

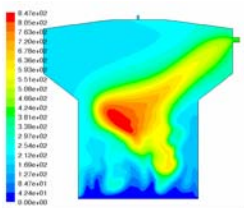
## Biomass Property Data

- Data primarily taken from fuel characterization study (Morey et al. 2006)
  - Samples taken from five ethanol plants

| Fuel | Moisture mass % | HHV MJ/kg Dry basis | Nitrogen mass % Dry basis | Sulfur mass % Dry basis |
|---|---|---|---|---|
| Corn Stover | 13% | 17.9 | 0.7% | 0.04% |
| Syrup | 67% | 19.7 | 2.6% | 1.0% |
| DDGS | 10% | 21.8 | 4.8% | 0.8% |
| DWG | 64% | 22.0 | 5.4% | 0.7% |

## Emissions Modeling

- RMT: Computational Fluid Dynamics
  - Predictive modeling of NOx and SOx emissions
  - The Aspen Plus models were calibrated to these emissions estimates



## Definition of Technology Combinations

- Thermal conversion
  - Fluidized bed combustion
    - Able to handle fuels with high moisture
    - Some flexibility of fuel sizing
  - Fluidized bed gasification
    - Lower reaction temperatures
    - Greater opportunity to control emissions

## Definition of Technology Combinations

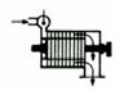
- Co-product Drying
  - Natural gas fired, direct dryers are typical
  - Steam tube, indirect dryers
    - Commonly used for solid fuel systems
    - Lower volume of dryer exhaust

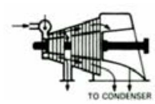
## Definition of Technology Combinations

- Emissions Control
  - Dryer Volatile Organic Compounds (VOC)
    - Route dryer exhaust through combustion unit
  - Particulate Matter
    - Cyclones
    - Baghouse
  - SOx emissions
    - Limestone sorbent bed material
    - Flue Gas Desulfurization (FGD) wet scrubbing
  - NOx emissions
    - Selective Catalytic Reduction (SCR)
    - Selective Non-Catalytic Reduction (SNCR)

## Definition of Technology Combinations

- Electricity Generation
  - Back-Pressure Turbine
    - Constant steam pressure at outlet
    - Should use all outlet steam for process needs
  - Extraction Turbine
    - Extract Steam at constant pressure for process
    - Condense excess steam at low pressure

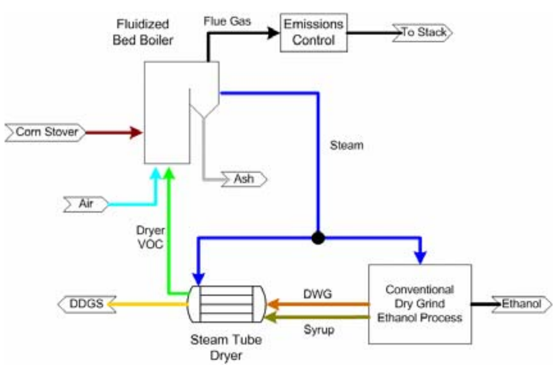




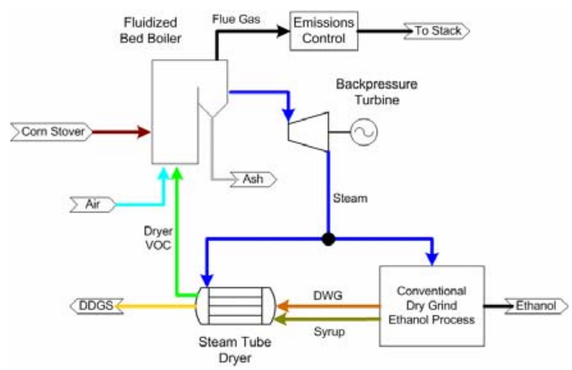

## Definition of Technology Combinations

- Levels of electricity generation
  - Level 1: Process Heat
    - Produce steam for process needs only
    - No electricity generated
  - Level 2: CHP
    - Produce steam to drive a backpressure turbine
    - All turbine exhaust steam is used for process needs
  - Level 3: CHP + Grid
    - Produce steam to drive an extraction turbine
    - Process steam is extracted at medium pressure
    - Excess steam is condensed at low pressure
    - Heat rate is limited by the total fuel energy available in the co-products at the plant

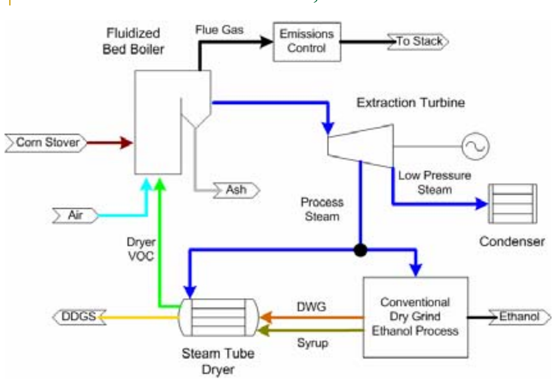
## Combustion of Corn Stover, Level 1: Process Heat



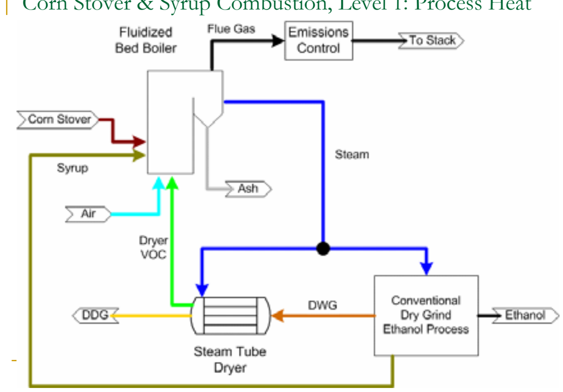

## Combustion of Corn Stover, Level 2: CHP



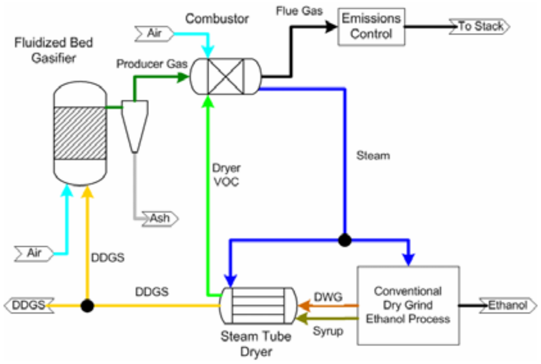

## Combustion of Corn Stover, Level 3: CHP + Grid

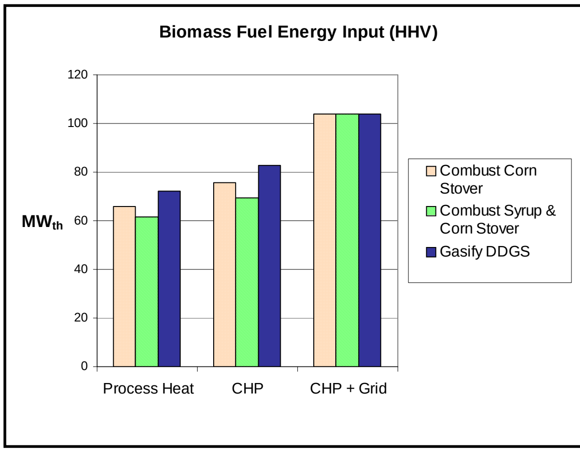


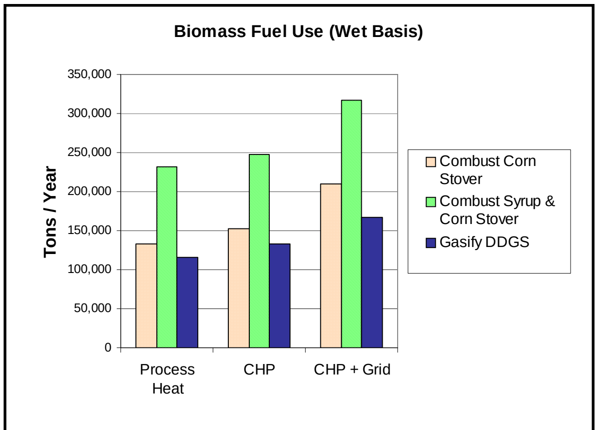

## Corn Stover & Syrup Combustion, Level 1: Process Heat

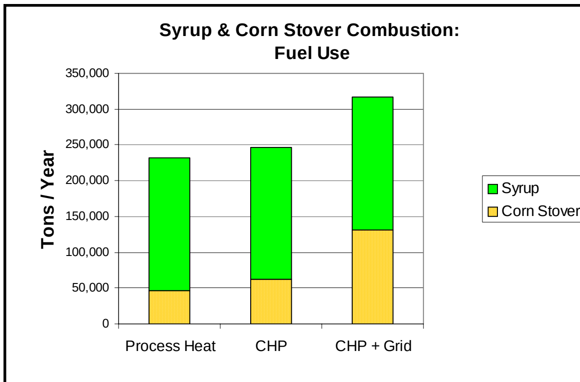


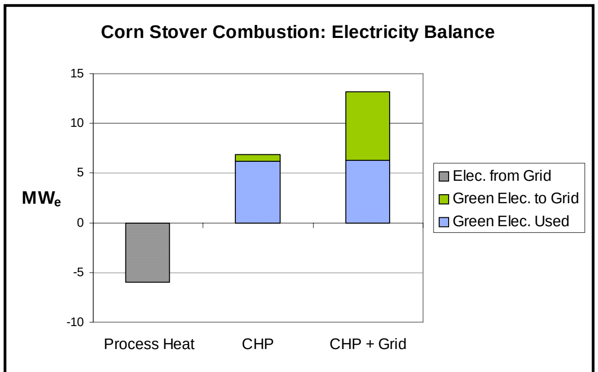
## DDGS Gasification, Level 1: Process Heat

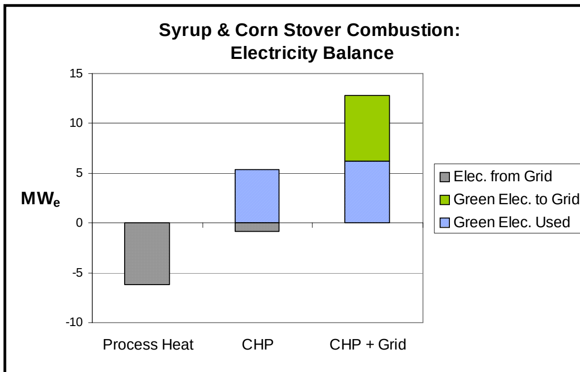


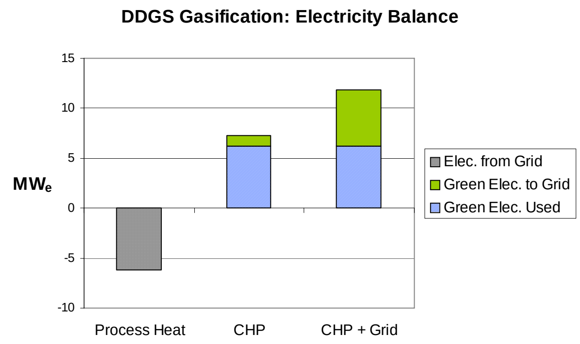






# Results

| Corn Stover Combustion | | | | |
|---|---|---|---|---|
| | | 1. Proc. Heat | 2. CHP | 3. CHP + Grid |
| Fuel Energy Input | MWth | 66 | 76 | 104 |
| Power Gen. (Gross) | MWe | 0 | 6.9 | 13.2 |
| Power to Grid | MWe | (6.0) | 0.7 | 6.9 |
| Power Gen. Efficiency | | - | 9.1% | 12.7% |
| Thermal Efficiency | | 80% | 79% | 63% |

(all valued based on fuel HHV)

# Results

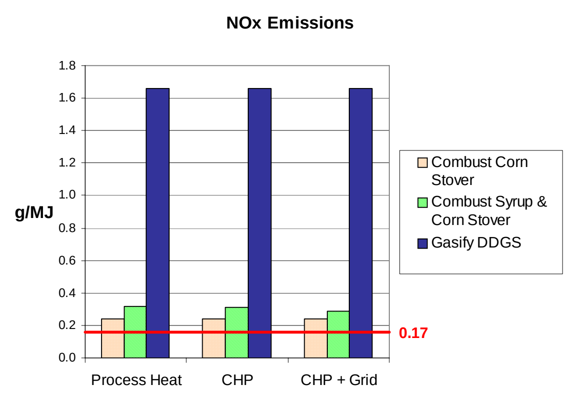
| Syrup & Corn Stover Combustion | | | | |
|---|---|---|---|---|
| | | 1. Proc. Heat | 2. CHP | 3. CHP + Grid |
| Fuel Energy Input | MWth | 62 | 69 | 104 |
| Power Gen. (Gross) | MWe | 0 | 5.3 | 12.8 |
| Power to Grid | MWe | (6.2) | (0.8) | 6.6 |
| Power Gen. Efficiency | | - | 7.7% | 12.3% |
| Thermal Efficiency | | 70% | 70% | 54% |

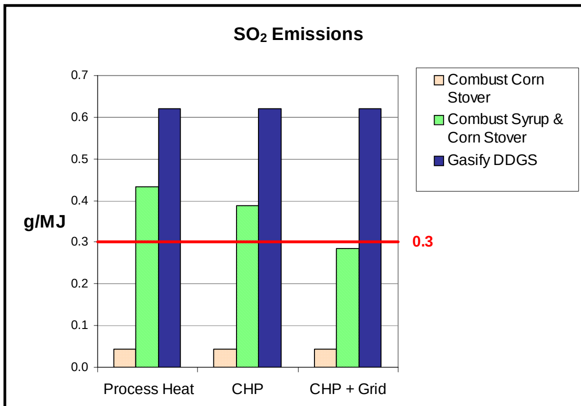
(all valued based on fuel HHV)

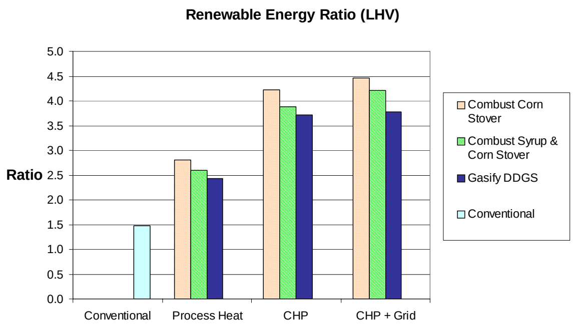
# Results

| DDGS Gasification | | | | |
|---|---|---|---|---|
| | | 1. Proc. Heat | 2. CHP | 3. CHP + Grid |
| Fuel Energy Input | MWth | 72 | 83 | 104 |
| Power Gen. (Gross) | MWe | 0 | 7.2 | 11.9 |
| Power to Grid | MWe | (6.2) | 1.0 | 5.6 |
| Power Gen. Efficiency | | - | 8.8% | 11.4% |
| Thermal Efficiency | | 73% | 72% | 62% |

(all valued based on fuel HHV)






## Conclusions

- Using biomass to fuel ethanol plants can significantly improve the renewable energy balance
- Ethanol plants have more than co-product material to provide all the plant heat and power needs
- Emissions will be an issue, especially with DDGS
- The economics will determine feasibility

## Future Analysis

- Co-product Drying
  - Modify direct heat dryers
    - Utilize flue gas from the boiler
    - Burn producer gas from a gasifier
  - Superheated steam dryers
    - Higher efficiency
    - All dryer exhaust steam is condensed
- Integrated Gasification Combined Cycle

## Questions?