NATIONAL ENERGY TECHNOLOGY LABORATORY

Fuel Flexible Advanced Energy Systems for the Production of Syngas, Hydrogen and Fuels

Dirk Van Essendelft

U.S. Department of Energy
National Energy Technology Laboratory
Separations and Fuels Processing

McIlvaine Company Hot Topic Hour
August 5, 2010

U.S. DEPARTMENT OF ENERGY

Outline

1. NETL Coal/Biomass Program Objective
2. Technology Concept Overview
3. Technical Challenges in Implementation
4. Program Implementation Strategy
5. Research Summary
6. Program Organization
7. Summary and Future work

Program Objective

"By 2012, complete R&D to integrate this technology with CO2 separation, capture, and sequestration into a "zero" emission configuration(s) that can provide electricity with less than a 10 percent increase in cost."

Project Goal

To identify, evaluate, and address the technical challenges involved in utilizing biomass in conjunction with coal in co-gasification systems

This study supports the expansion of DOE's R&D portfolio with an intent to meet "zero emission" standards

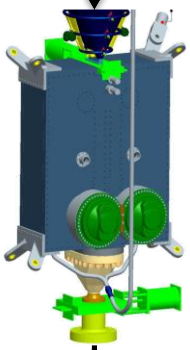
The Concept

Conceptually Simplistic…

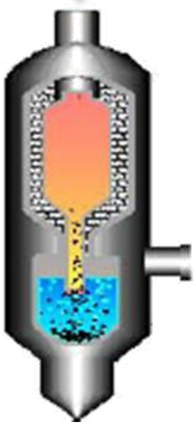
Why not commercialized?

Technical Challenges

Raw Biomass
- *Material Variability (season, location, etc)*
- *Transportation (Energy Density)*
- *Storage (Degradation)*
- *Biomass Structure and Mechanical Properties*
- *Flowability*
- *Grindability*

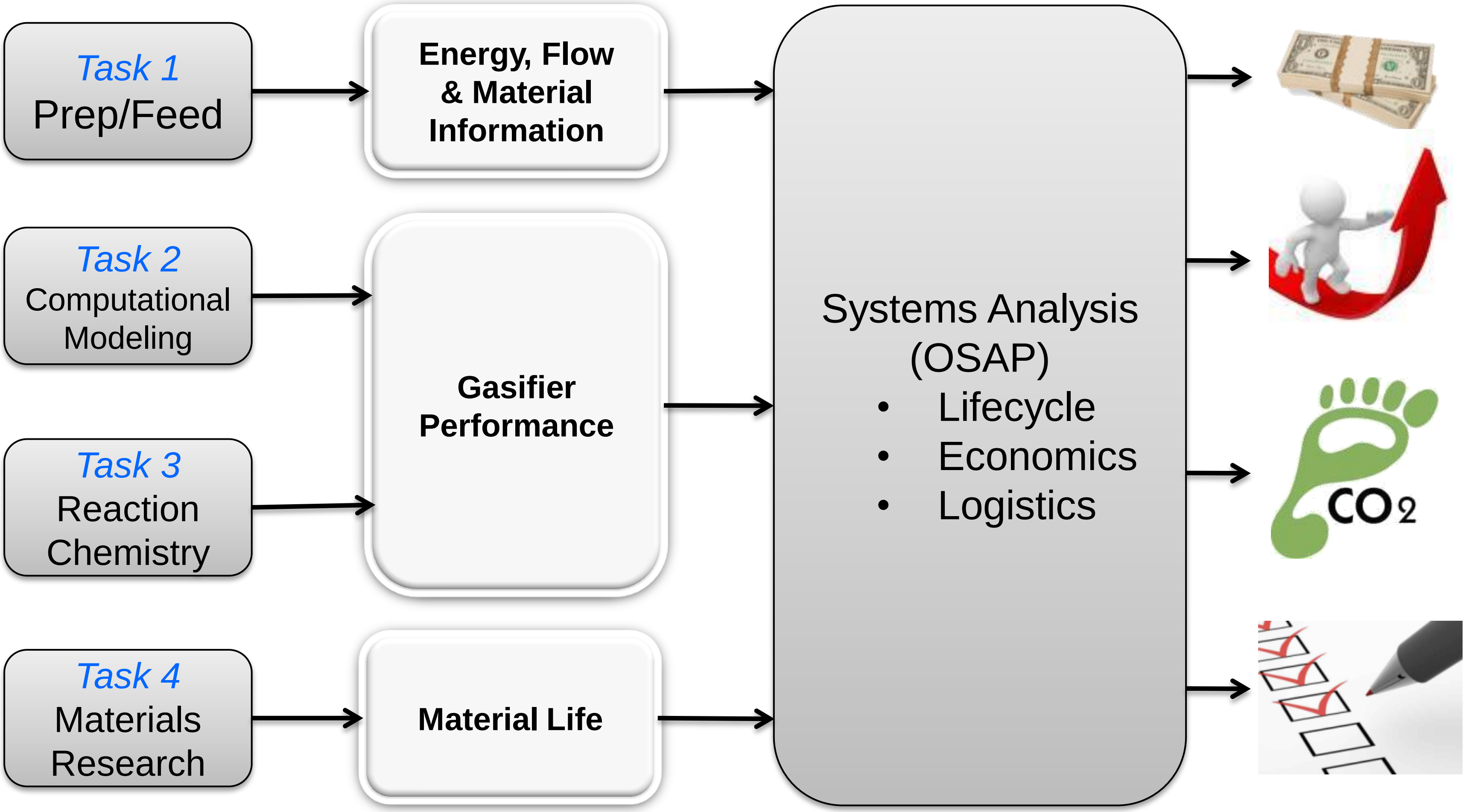


Pressurized Dry Feed
- *Technology is not mature*
- *Particle Size & Shape factors impact feeder performance*



Gasifier Performance
- *Reaction Kinetics*
- *Material Interactions*
- *Product Effects (Ash…)*
- *Models not Developed/Validated*

Program Implementation Strategy



Research Summary

Task 1
Prep/Feed

Focus

- Solve Technical Challenges in Biomass Preparation and Feeding

Active Research

- Chem./Heat Treatments
- Specific Grinding Energy
- Biomass Liquefaction
- HP Dry Feeder

Task 2
Computational Modeling

Focus

- Develop and Apply Computational Methods to Solve Technical Challenges

Active Research

- CFD Model (NETL C3M)
- *Validation Studies*
  - *NRC Canada*
  - *PSDF in Alabama*

Task 3
Reaction Chemistry

Focus

- Measure Chemistry in Real Gasification Environments

Active Research

- Fixed Bed/Lurgy
- Entrained/Drop Tube
- Advanced HP

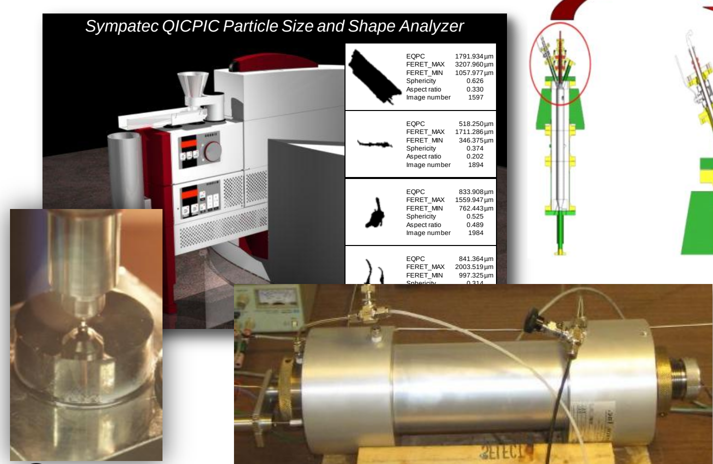
Task 4
Materials Research

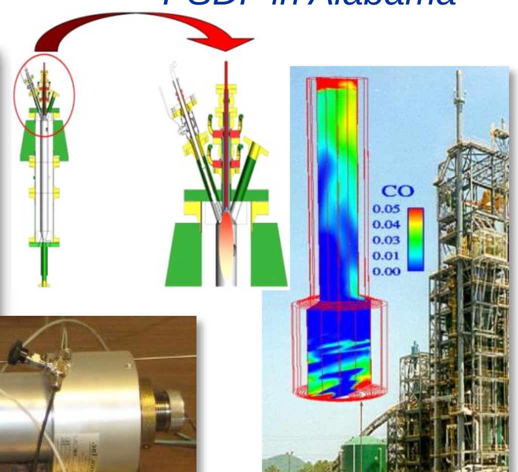
Focus

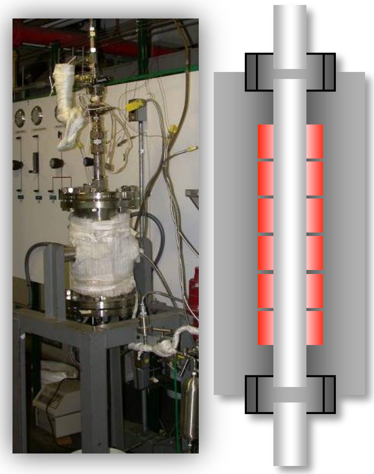
- Develop New Materials that Last Longer in Gasification Environments with Broader Chemical Compatibility

Active Research

- Refractory Materials
- Slag Modeling







Program Organization

NETL Gasification Program

NETL Office of Research & Development

NETL Office of Systems, Planning & Analysis

Biomass Preparation

Geo Richards

Dave Berry
Dirk VanEsselhoft
Ping Wang

Bruce Kang (WVU)
Derrek Elsworth (PSU)

Gasifier Materials

Cindy Powell

James Bennett

Gasification Reaction Chemistry

Geo Richards

Bryan Morreale
Dirk Link

Nick Means (RDS)
Paul Zandhuis (RDS)

Goetz Veser (Pitt)
Nate Weiland (WVU)

Computational Modeling

Madhava Syamlal

Chris Guenther

Summary and Future Work

- NETL has a wide ranging program with the goal of understanding and addressing the technical and logistical hurtles involved in co-utilization of biomass with coal in Gasification

- Always interested in collaboration to develop new research areas and apply technology

- NETL is expanding research and applying knowledge and expertise to other technical areas such as Oxy-Fuel Combustion

Questions

Why High Pressure Dry Feeding?

Table 2 Key results for the computed IGCC cases. A single gas turbine was assumed and the plant gross power was in the 430-480 MW range. The complete power plant system was considered in the energy balance (e.g. the auxiliary power consumption for coal drying and CO_2 compression was accounted for)

Coal ID	Coal 1		Coal 2		Coal 3		Coal 4		Coal 5	
Name	North Dakota lignite		Wyoming Powder River Basin (PRB)		Illinois #6		Upper Freeport, PA		Pocahontas #3, VA	
Capture of CO_2	Without	With	Without	With	Without	With	Without	With	Without	With
Case 1 (Dry feed with syngas heat recovery)										
Coal as-received [kg/s/MW]	0.131	0.171	0.115	0.149	0.089	0.115	0.071	0.091	0.063	0.082
Water removed [kg/s/MW]	0.038	0.049	0.028	0.036	0.003	0.004	0.000	0.000	0.000	0.000
CO_2 captured [kg/kWh]	0.000	0.848	0.000	0.815	0.000	0.767	0.000	0.735	0.000	0.780
Net power [MW]	410	343	412	346	420	353	421	358	419	353
Thermal efficiency (ar, HHV)	44.1 %	33.7 %	44.3 %	34.3 %	44.2 %	34.1 %	45.6 %	35.7 %	45.7 %	35.3 %
Thermal efficiency (ar, LHV)	48.1 %	36.8 %	47.9 %	37.0 %	46.1 %	35.6 %	47.0 %	36.8 %	47.0 %	36.3 %
CO_2 emitted [kg CO_2/ kWh el]	0.762	0.147	0.740	0.143	0.698	0.137	0.679	0.132	0.709	0.138
Case 2 (Slurry feed with full water quench)										
Coal as-received [kg/s/MW]	0.305	0.432	0.199	0.251	0.120	0.140	0.086	0.098	0.076	0.089
CO_2 captured [kg/kWh]	0.000	2.163	0.000	1.377	0.000	0.929	0.000	0.765	0.000	0.815
Net power [MW]	300	220	328	282	357	331	370	351	366	339
Thermal efficiency (ar, HHV)	18.9 %	13.4 %	25.7 %	20.4 %	32.6 %	27.9 %	37.6 %	33.0 %	38.1 %	32.4 %
Thermal efficiency (ar, LHV)	20.6 %	14.6 %	27.7 %	22.0 %	34.0 %	29.1 %	38.7 %	34.0 %	39.1 %	33.3 %
CO_2 emitted [kg CO_2/ kWh el]	1.704	0.253	1.227	0.168	0.907	0.131	0.790	0.136	0.817	0.143

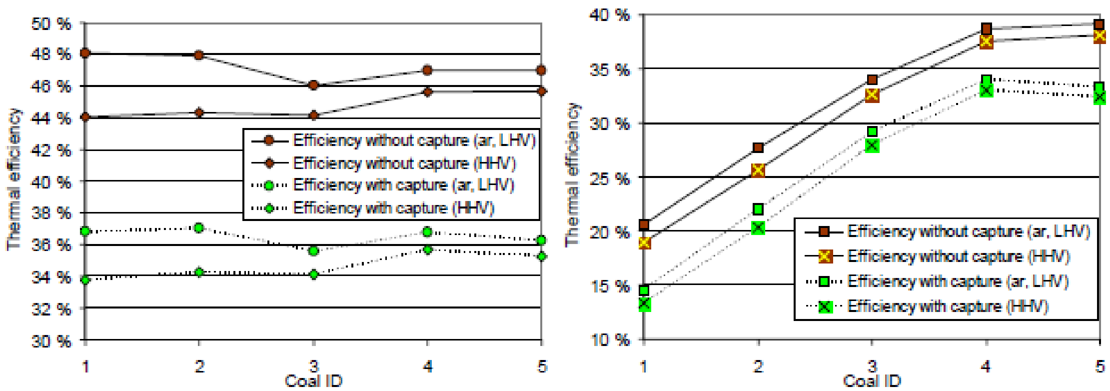


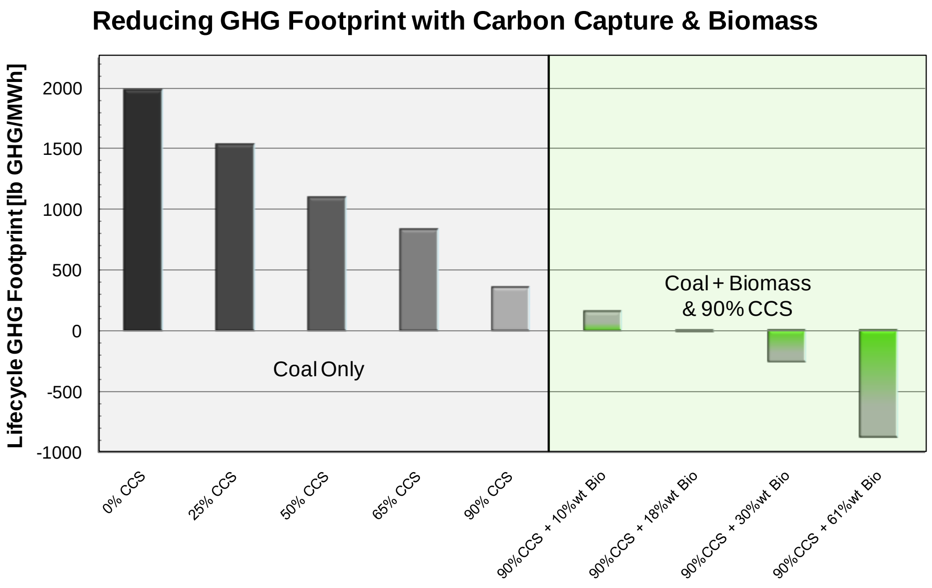
Figure 2 a) Efficiencies for Case 1 (IGCC with dry feed gasifier and heat recovery), b) Efficiencies for Case 2 (IGCC with slurry feed gasifier and water quench)

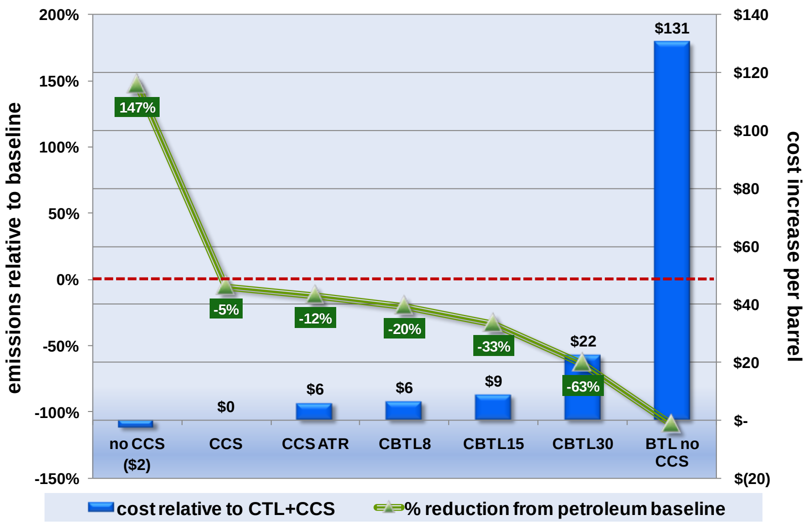
Maurstad, O., H. Herzog, et al. (2006). Impact of Coal Quality and Gasifier Technology on IGCC Performance. 8th International Conference on Greenhous Gas Control Technologies. Trondheim, Norway.

Background

Coal
- **National resource with over 200 years supply**
- **Currently supplies over 50% of US power**
  - Potential to supply transportation fuels

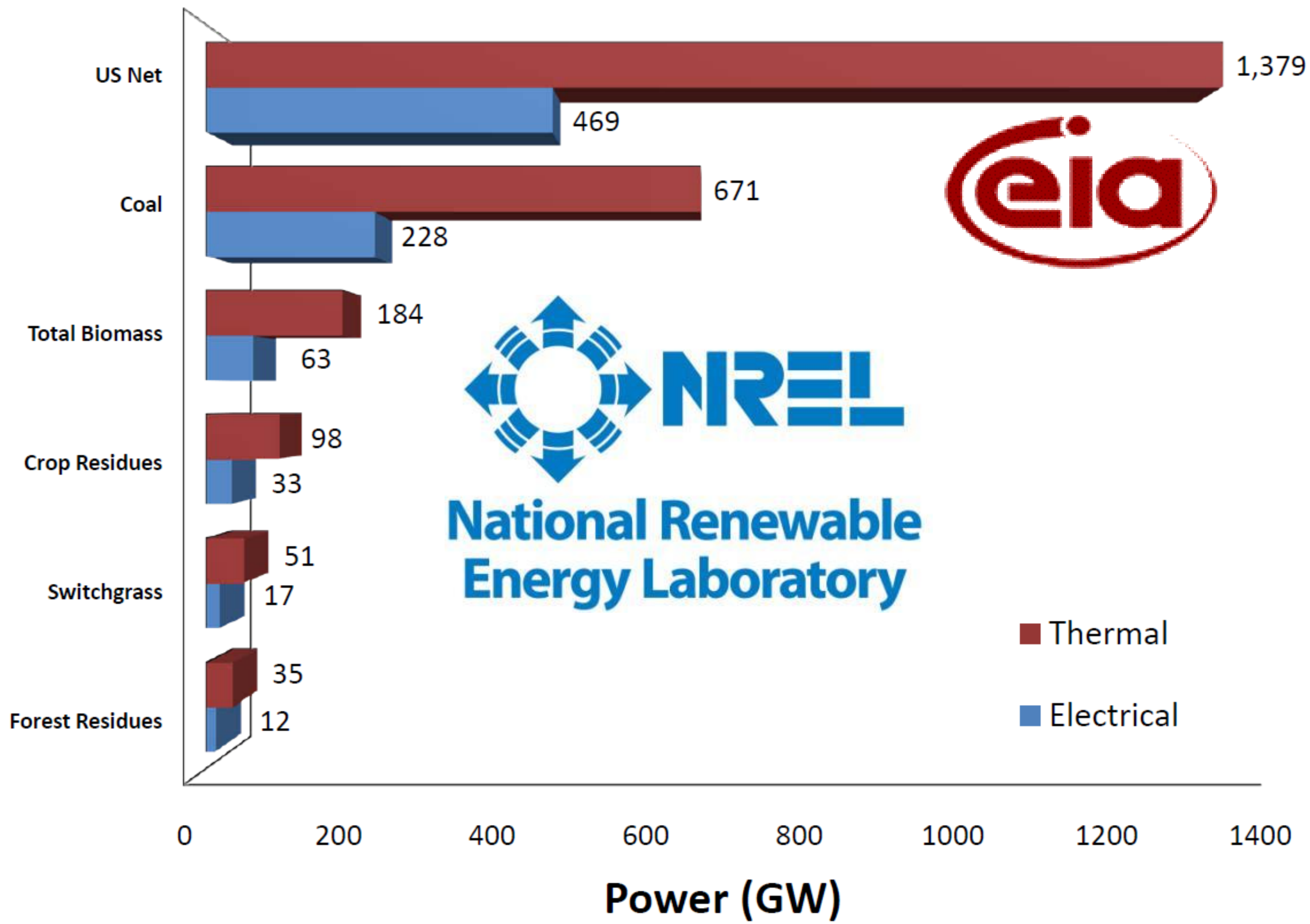
Biomass
- **Carbon neutral**
- **Renewable**





Project Overview

How Significant of a Resource is Biomass?

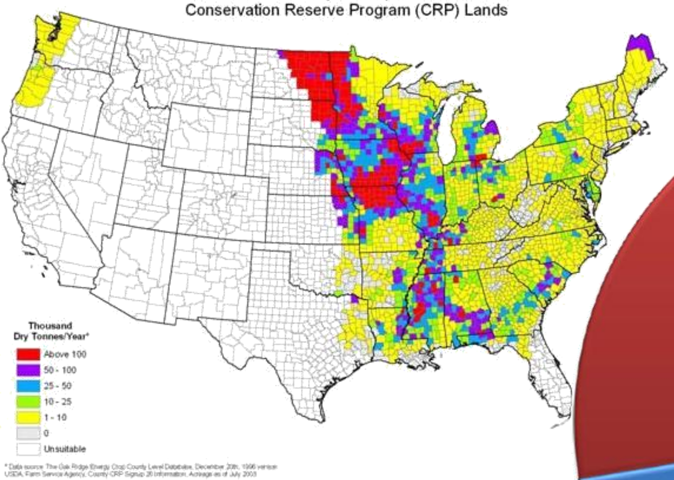


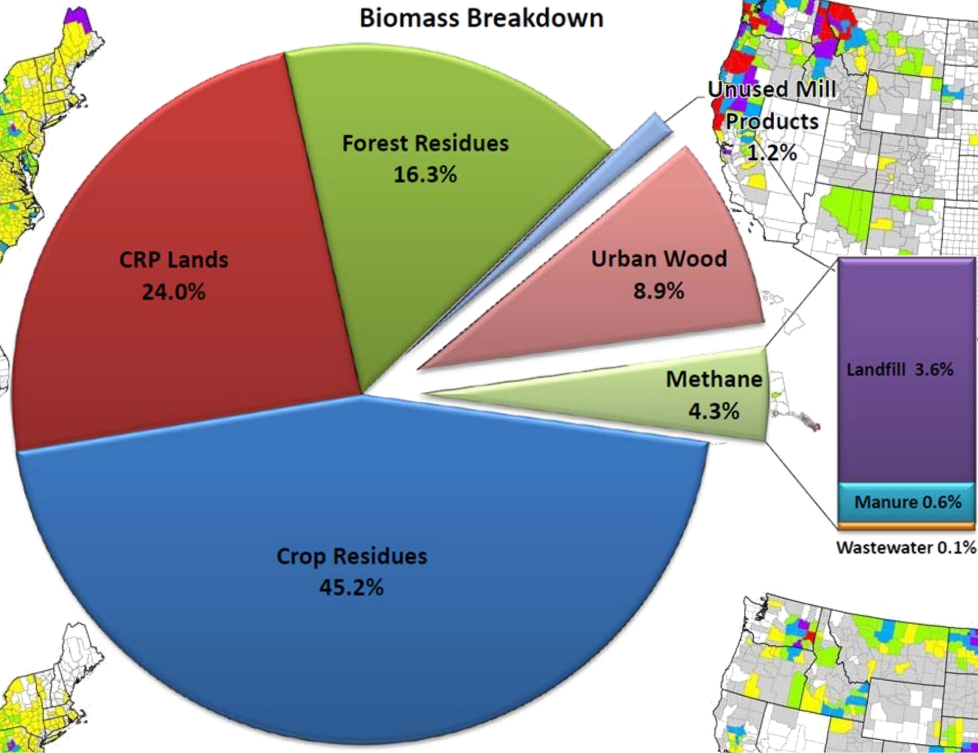
Mbrandt, A., A Geographic Perspective on the Current Biomass Resource Availability in the United States. 2005, National Renewable Energy Laboratory: Golden CO.
Net Generation by Energy Source: Total (All Sectors). : http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html

Project Overview

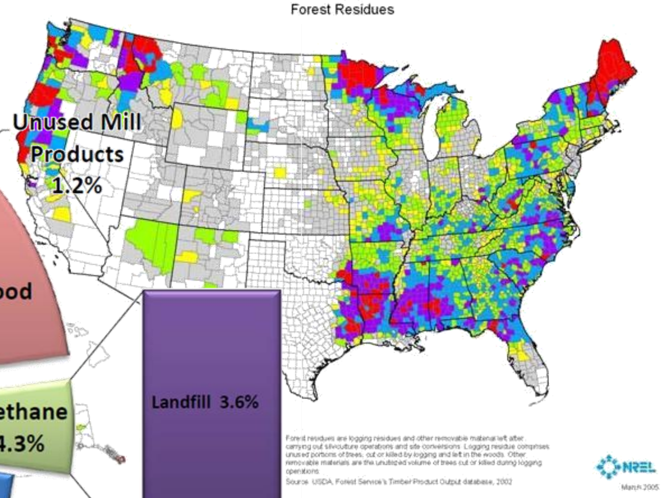
Where is Biomass Located in the US?

Potential Willow or Hybrid Poplar Production on Conservation Reserve Program (CRP) Lands

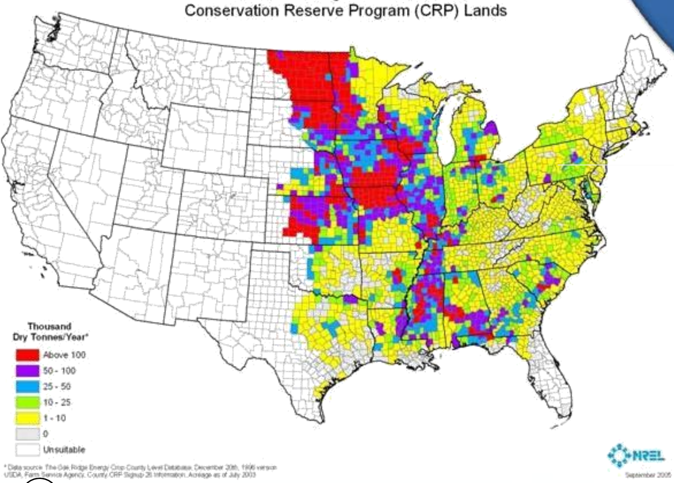




Forest Residues

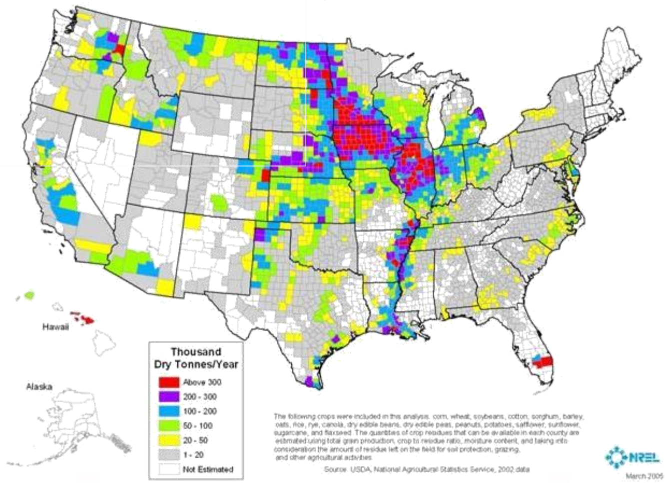


Potential Switchgrass Production on Conservation Reserve Program (CRP) Lands



325-423 MDTA

Crop Residues



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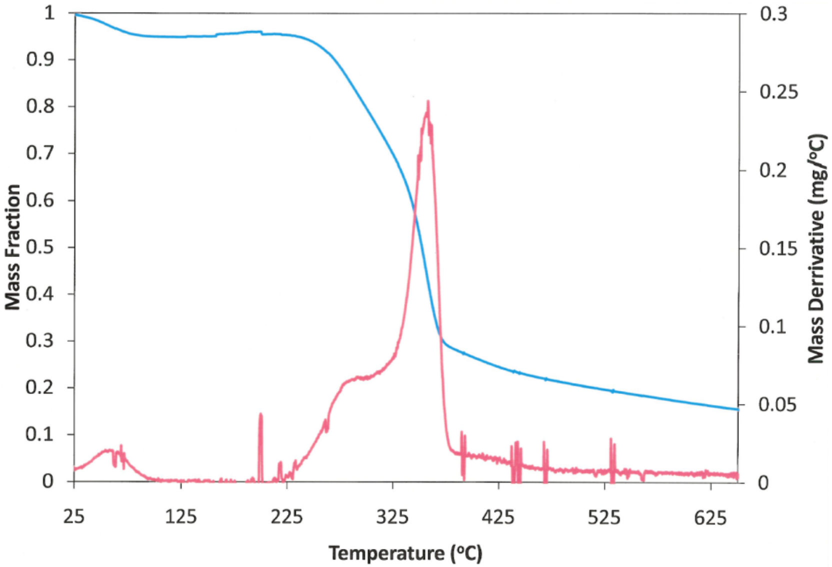
Net Generation by Energy Source: Total (All Sectors). : http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html

Task 1: Biomass Preparation & Feeding

Example of Preprocessing Results: Torrefaction

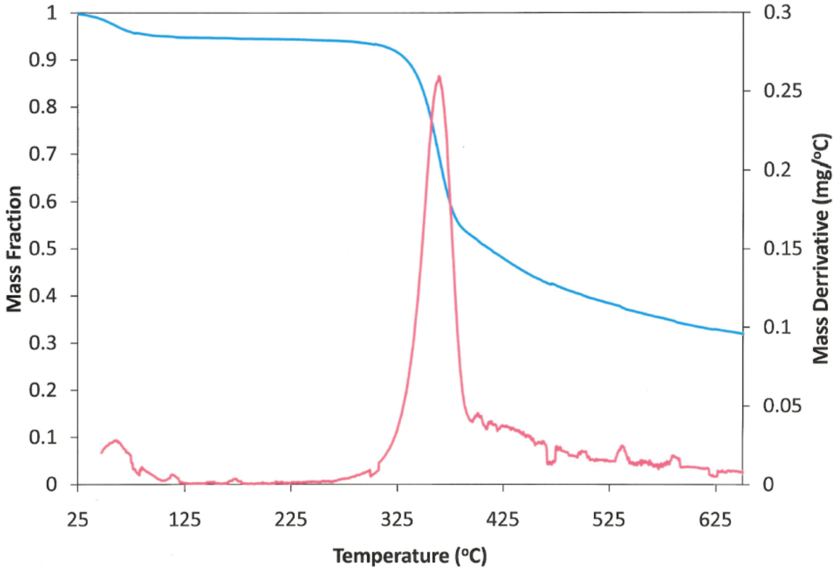
Cherry Wood, 200°C, 1hr

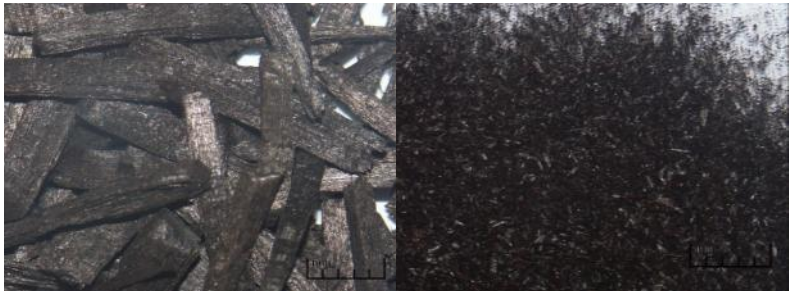


Before and After Grinding for 6 min in a 3" Ball Mill

Young's Modulus = 1.63 +/- 0.26

Cherry Wood, 280°C, 1hr

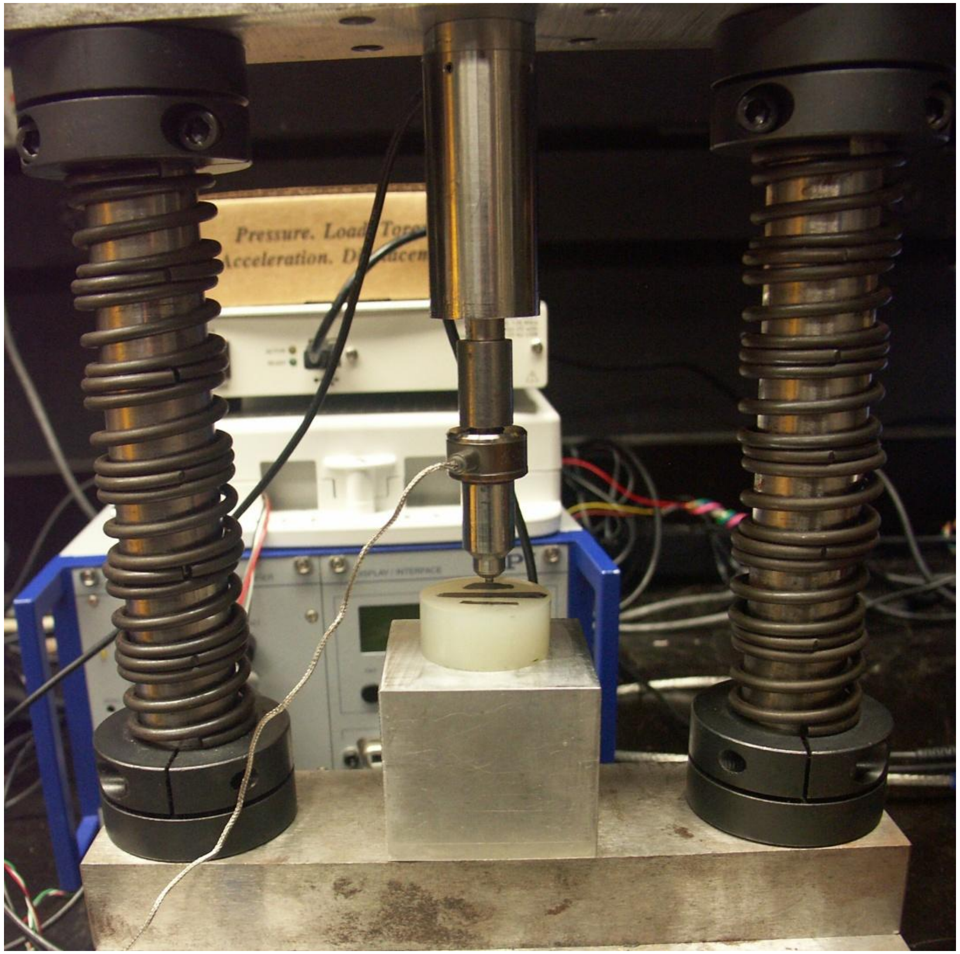




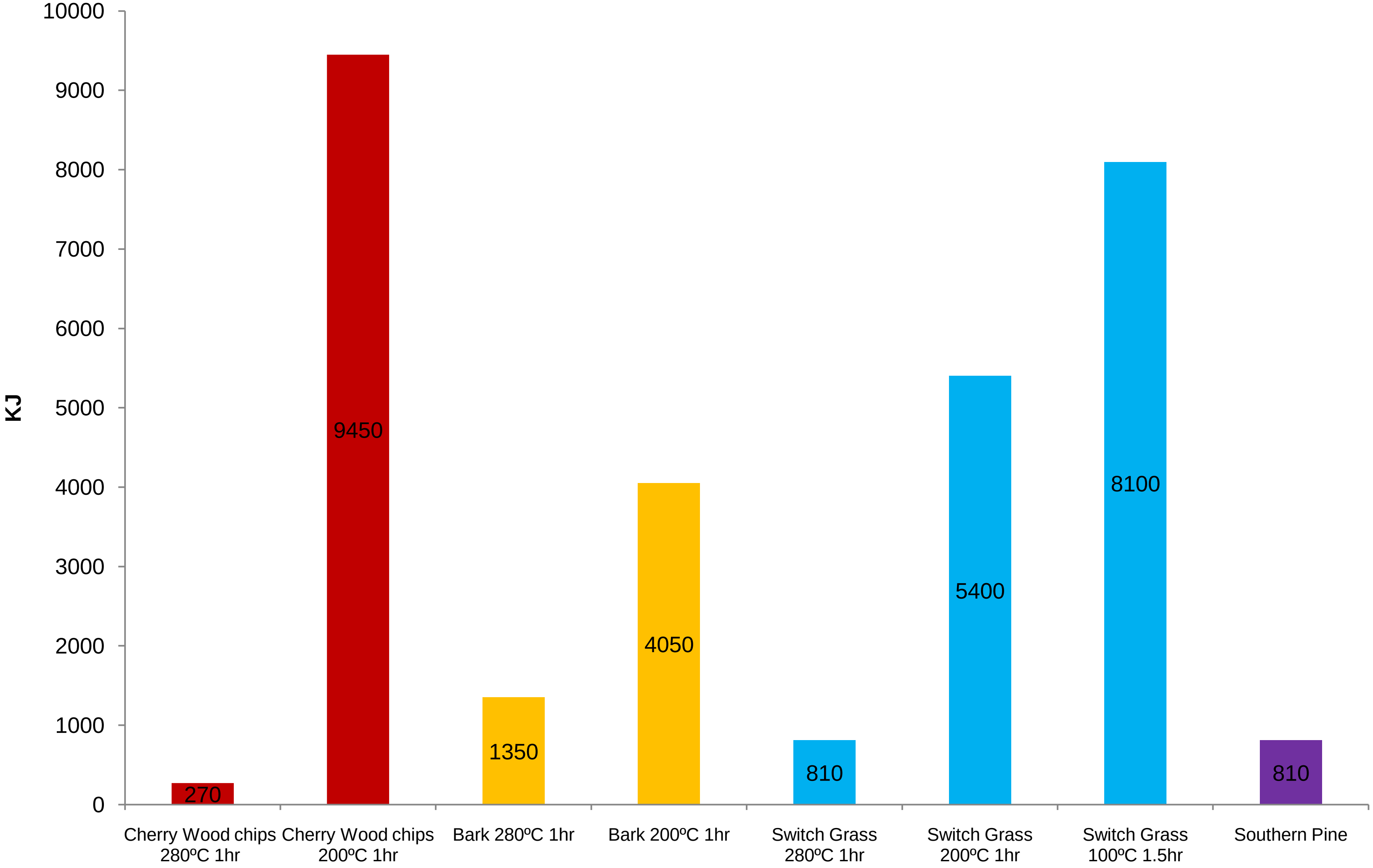
Before and After Grinding for 6 min in a 3" Ball Mill

Young's Modulus = 0.67 +/- 0.21

Young’s Modulus Measurement

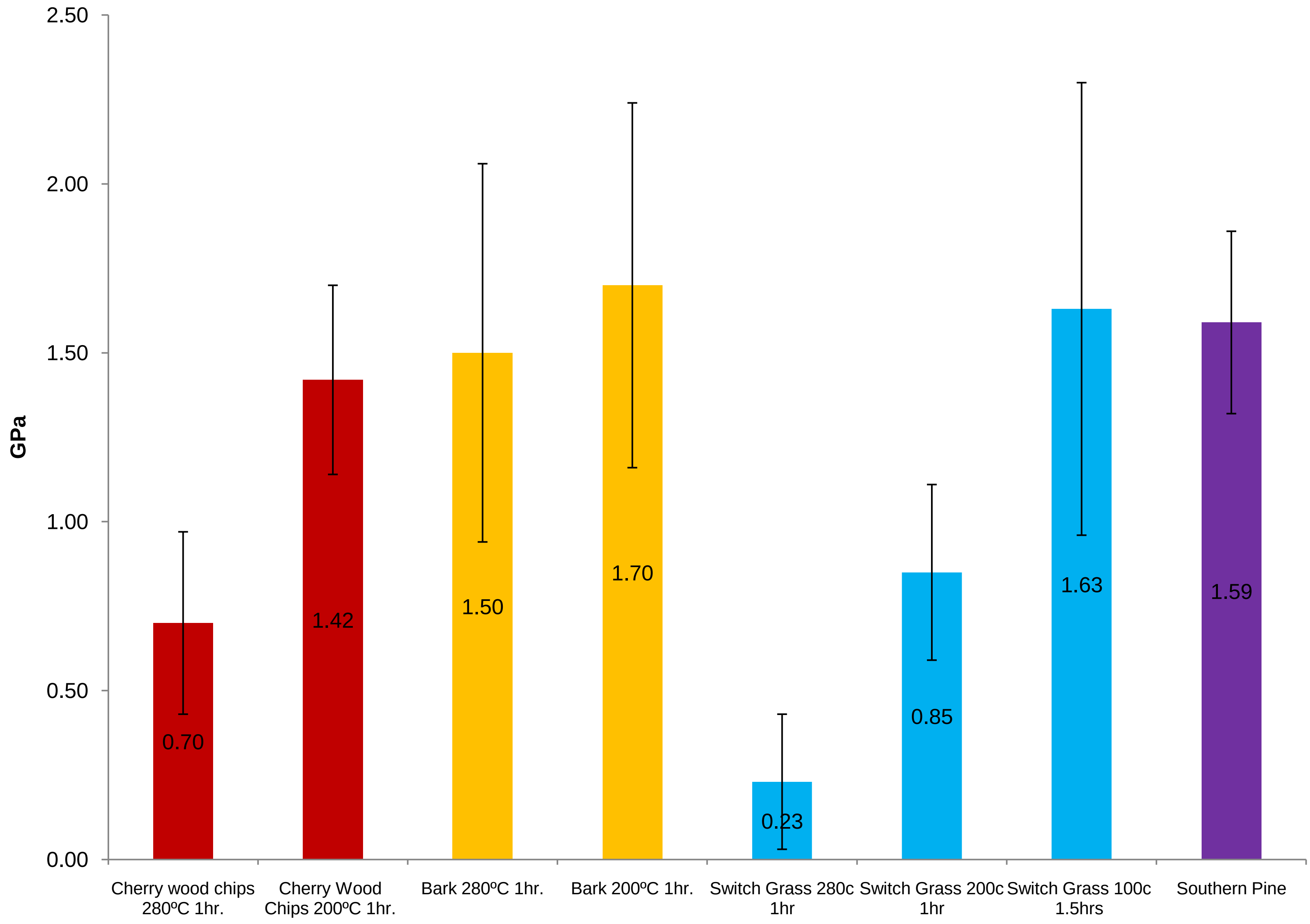


Energy Consumption



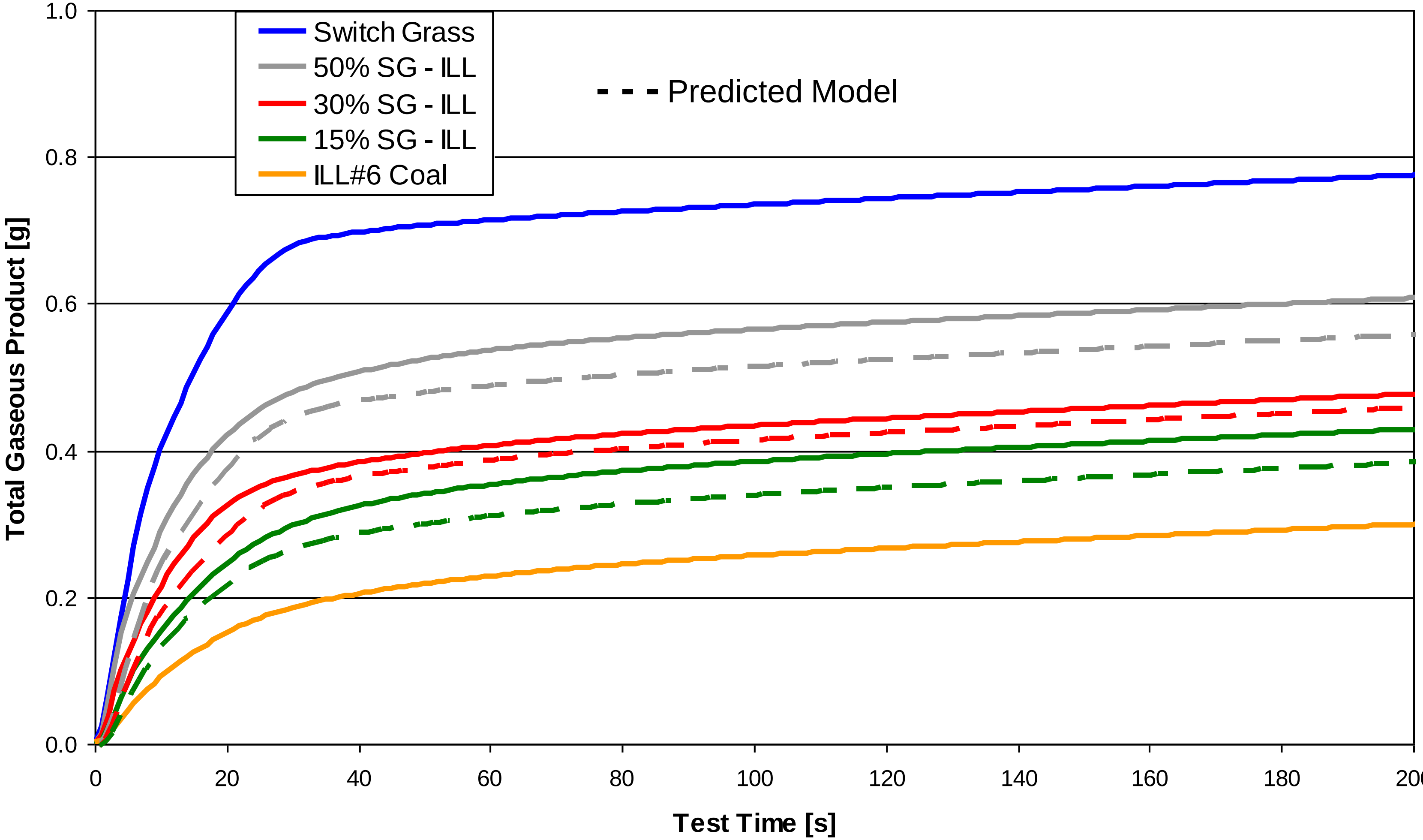
***** Energy consumption of the Ball Mill Instrument, not the actual grinding energy on the biomass materials***

Young's Modulus of Biomass Materials



Task 3. Gasifier Reaction Chemistry

Influence of Co-Feeding on Gaseous Products



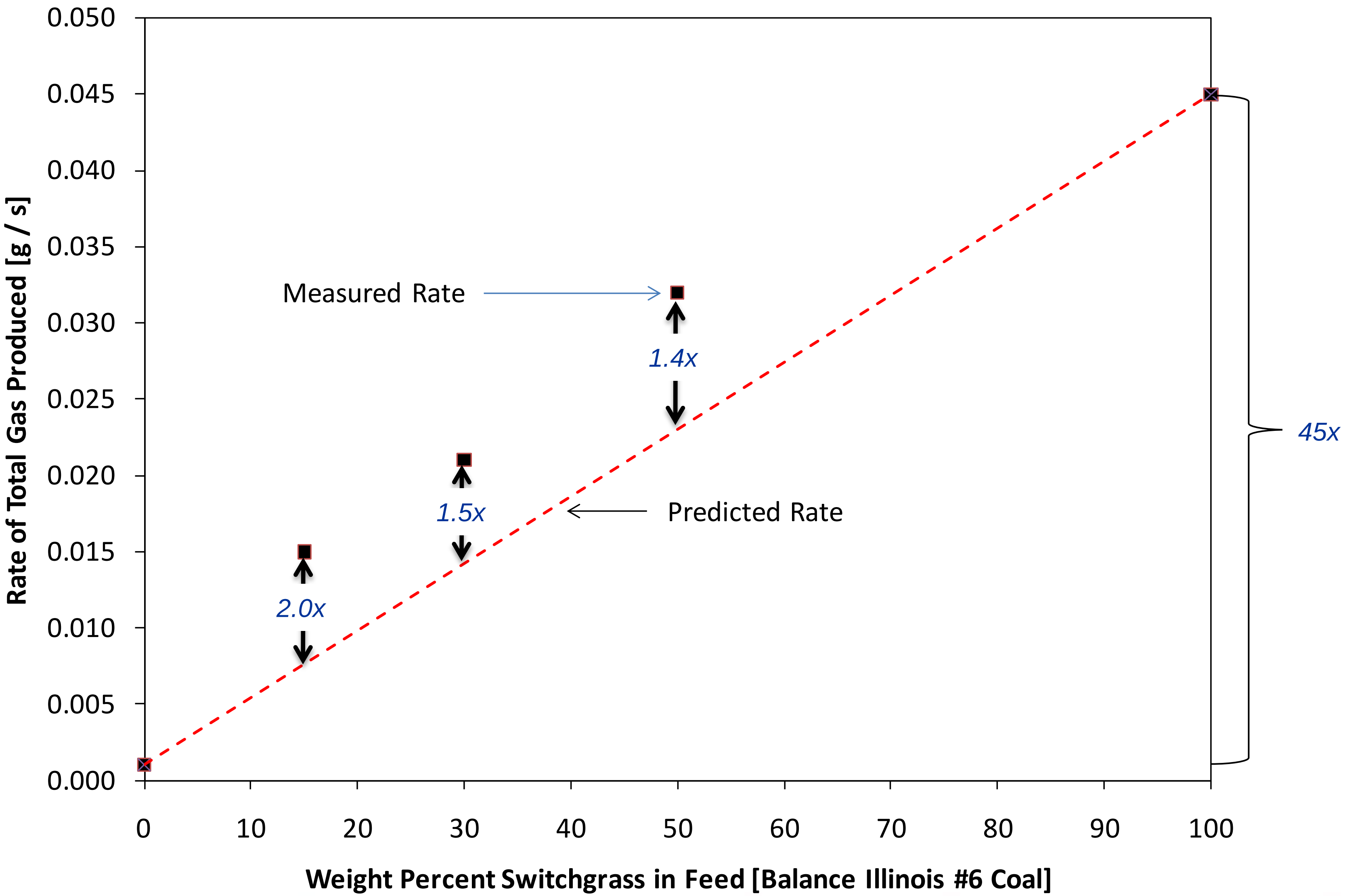
Total feed load of 1g

$$\text{Prediction} = [(x_{biomass})*(m_{biomass})]+[(x_{coal})*(m_{coal})]$$

(SG + Ill#6, 900ºC, 30 psi, Ar)

Task 3. Gasifier Reaction Chemistry

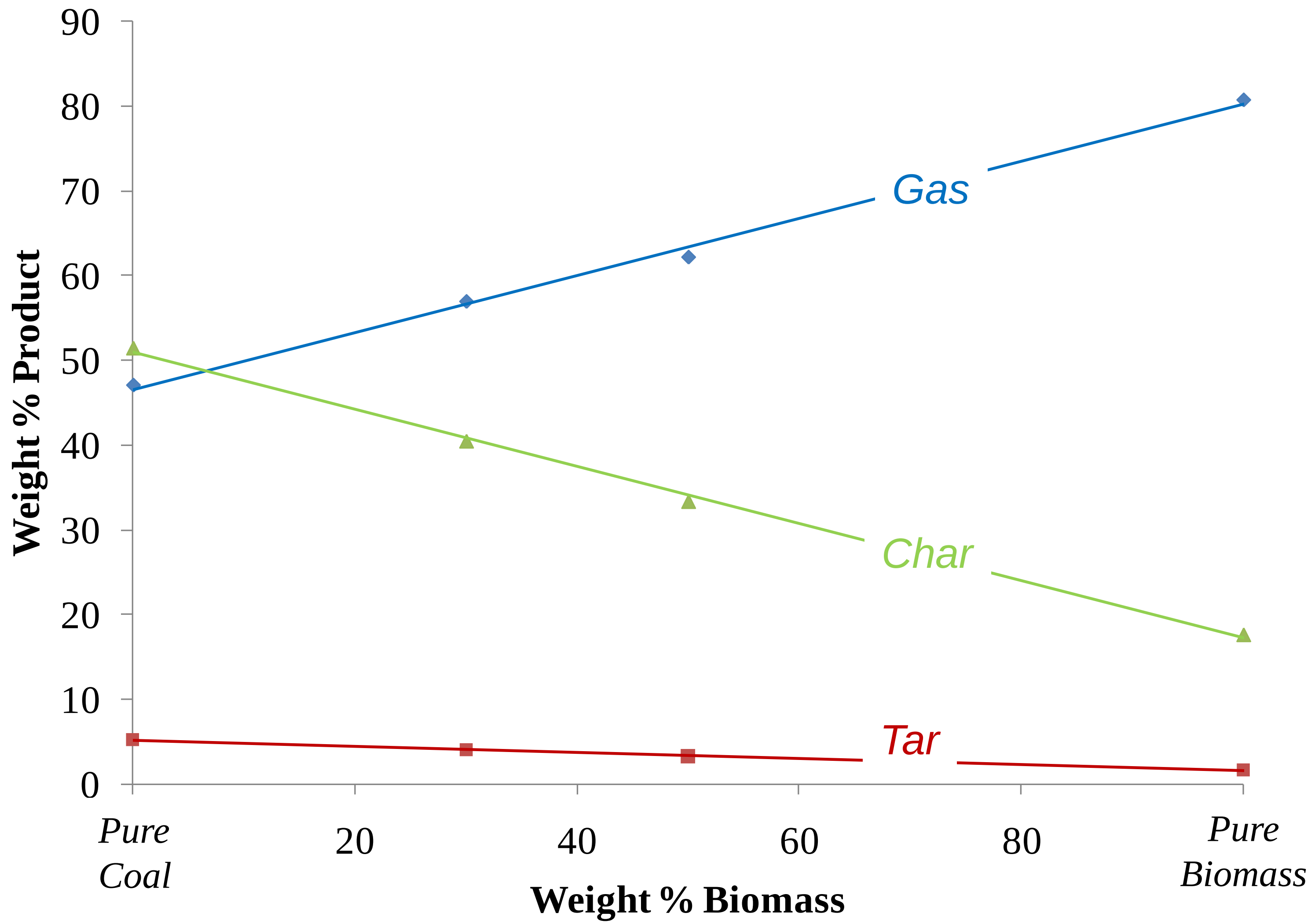
Influence of Co-Feeding on Gaseous Products



(SG + Ill#6, 900°C, 30 psi, Ar)

Task 3. Gasifier Reaction Chemistry

Product Distribution Trends



(SG + Ill#6, 900ºC, 30 psi, Ar)

Task 4: Gasifier Materials

Refractory Material and Slag Testing

Biomass Data
Task 1
Task 3

INPUT

- Ash Data
  - chemistry
  - quantity
  - pct.
- Gasifier Conditions
  - temperature
  - gas environment

COMPUTER MODEL

- Thermodynamic Computations
- Computer Modeling Predictions
- Literature
- Laboratory Test Data

OUTPUT

- Melting point
- Solid Phases Formed
- Slag Viscosity
- Refractory/Slag Interactions
- Additives to Control Slag Viscosity/Corrosion
- Vapor Phases Formed

GOAL: control refractory corrosion and slag flow