NATIONAL ENERGY TECHNOLOGY LABORATORY

Kinetics of Coal/Biomass Co-gasification

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U.S. DEPARTMENT OF ENERGY

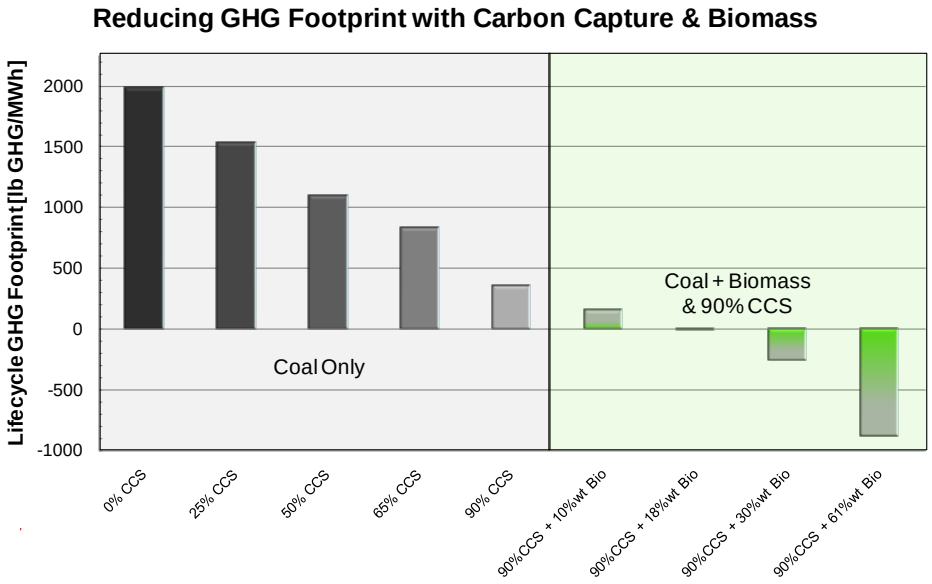
Background

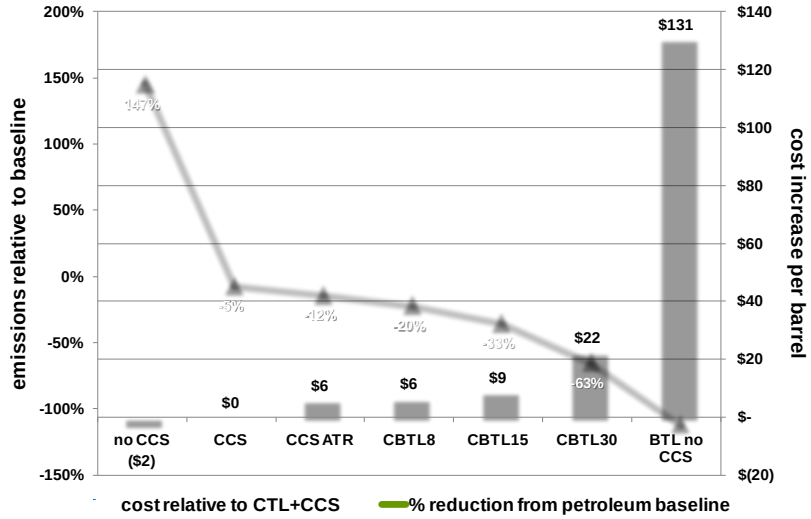
Coal

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

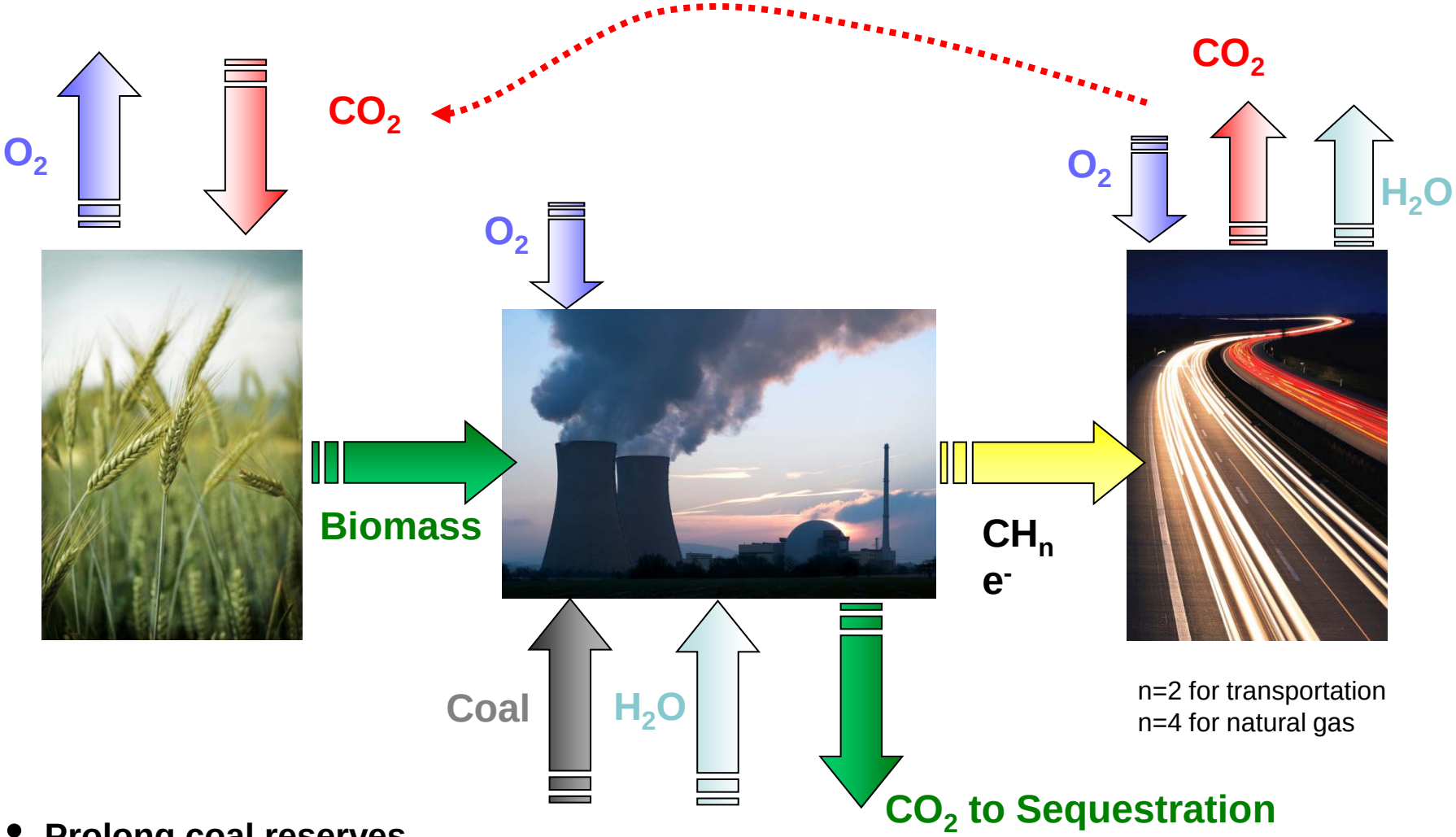
Biomass

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



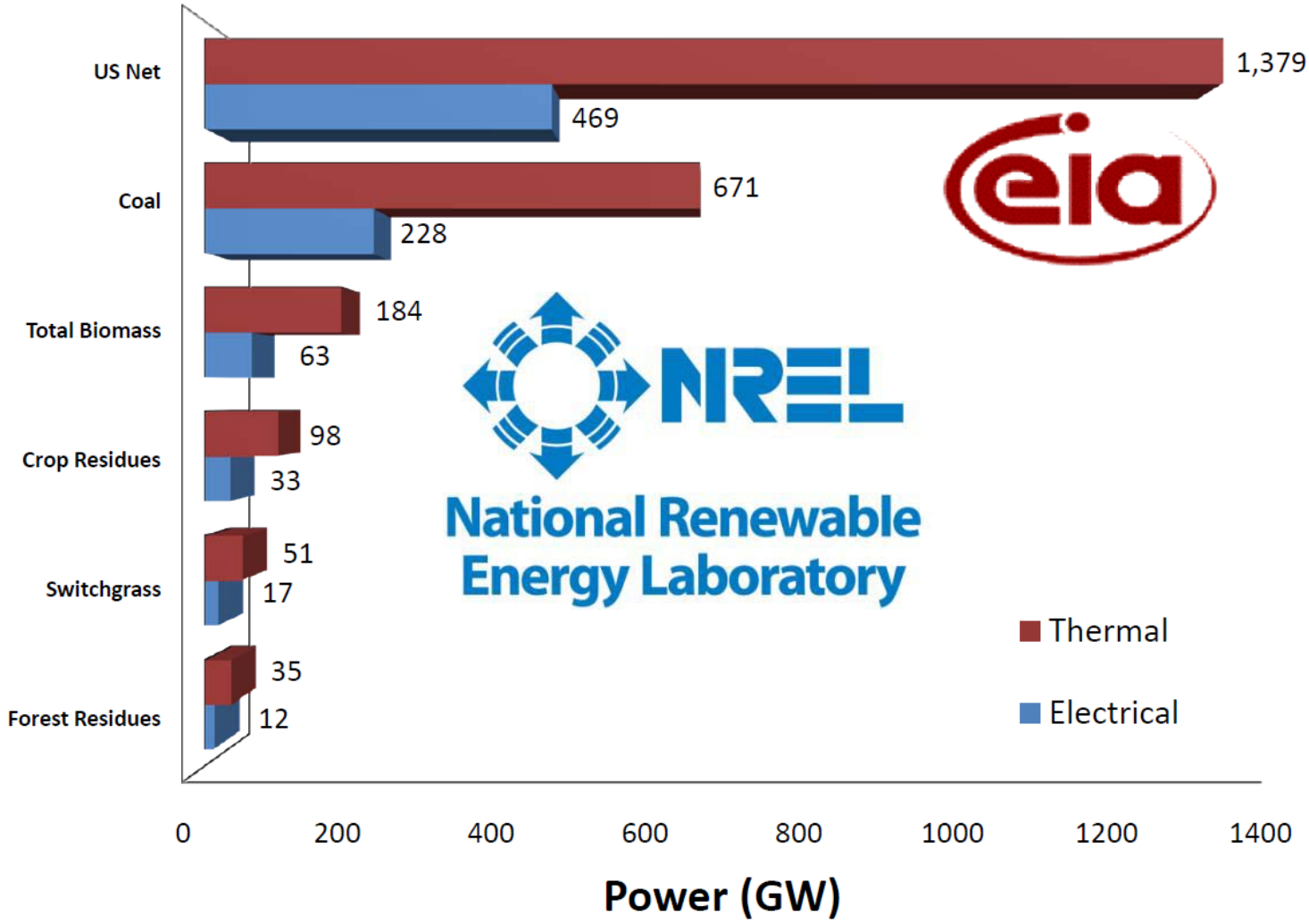


Influence of Biomass Addition



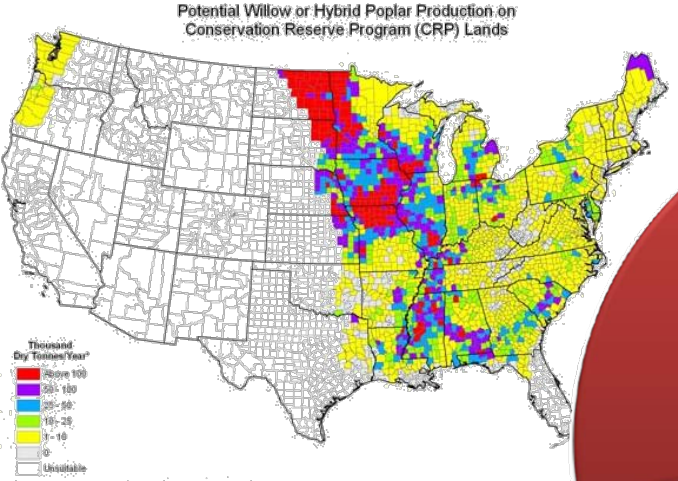
- **Prolong coal reserves**
- **Reduce carbon foot print of gasification process**

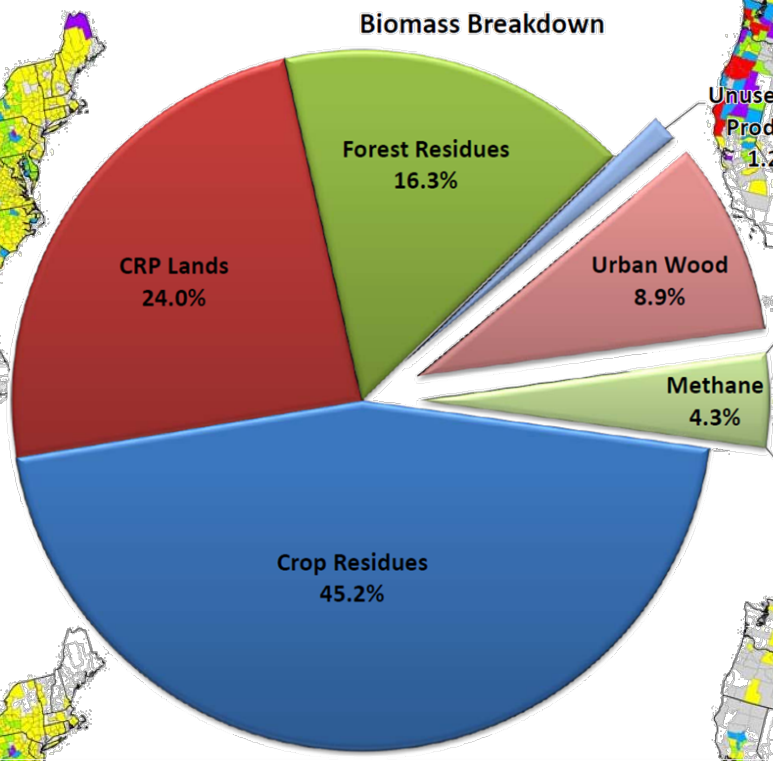
How Significant of a Resource is Biomass?

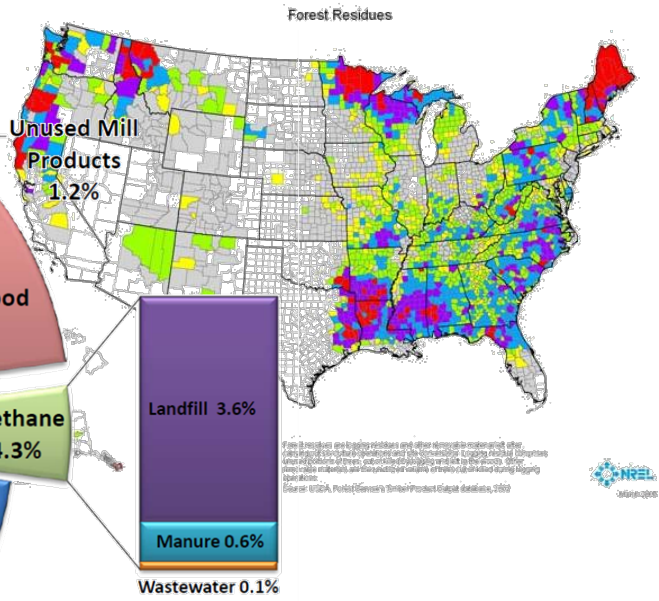


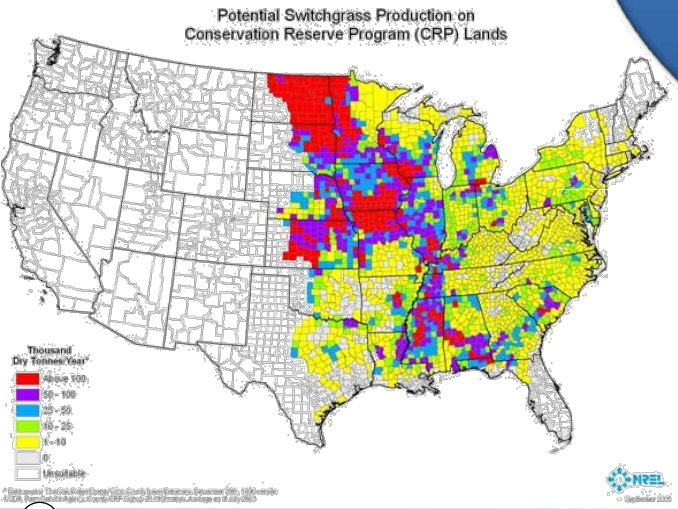
Mbrandt, A., A Geographic Perspective on the Current Biomass Resource Availability in the United States. 2005, National Renewable Energy Laboratory: Golden CO.
Net Generation by Energy Source: Total (All Sectors). : http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html

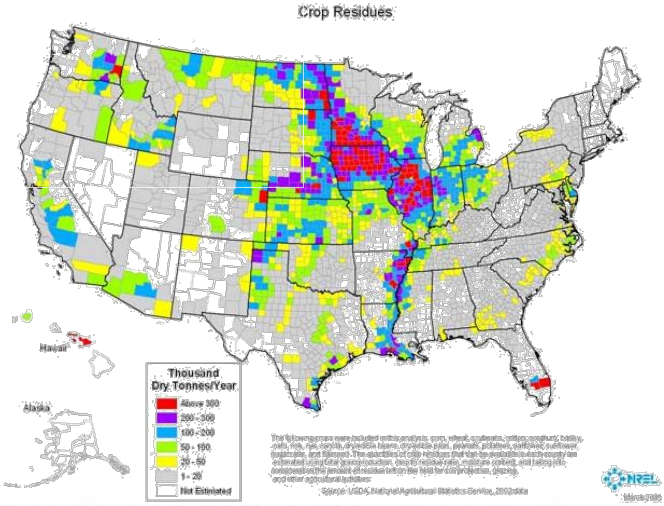
Where is Biomass Located in the US?











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

Goals

Programmatic Goal

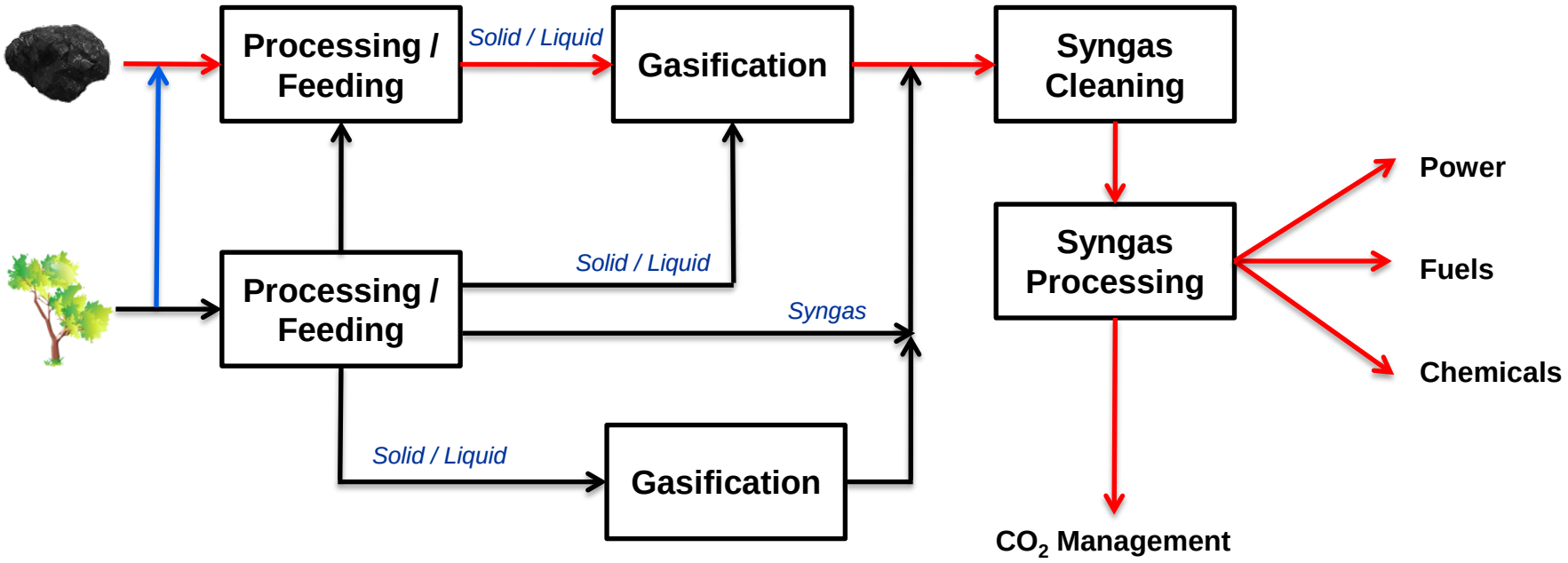
- **<u>Coal & Power Systems:</u> Sequester 90% of the carbon from coal with minimal impact to the cost of power, fuels and chemicals**
- **<u>Advanced Gasification</u>: Develop innovative gasification technologies that provides a clean, stable, secure and affordable energy supply to meet the nations growing demand**

Project Goal

- **Promote the utilization of biomass in coal gasification processes for the production of power, fuels and chemicals by applying computational and experimental approaches ranging from fundamental through demonstration scales**

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

Gasification Process



	Operating T (°C)	Biomass waste	Coal	Gas	Petcoke	Petroleum
Entrained	1400-1600	0	41	22	9	60
Fluidized bed	900-1050	10	3			
Moving bed	425-650	3	7			

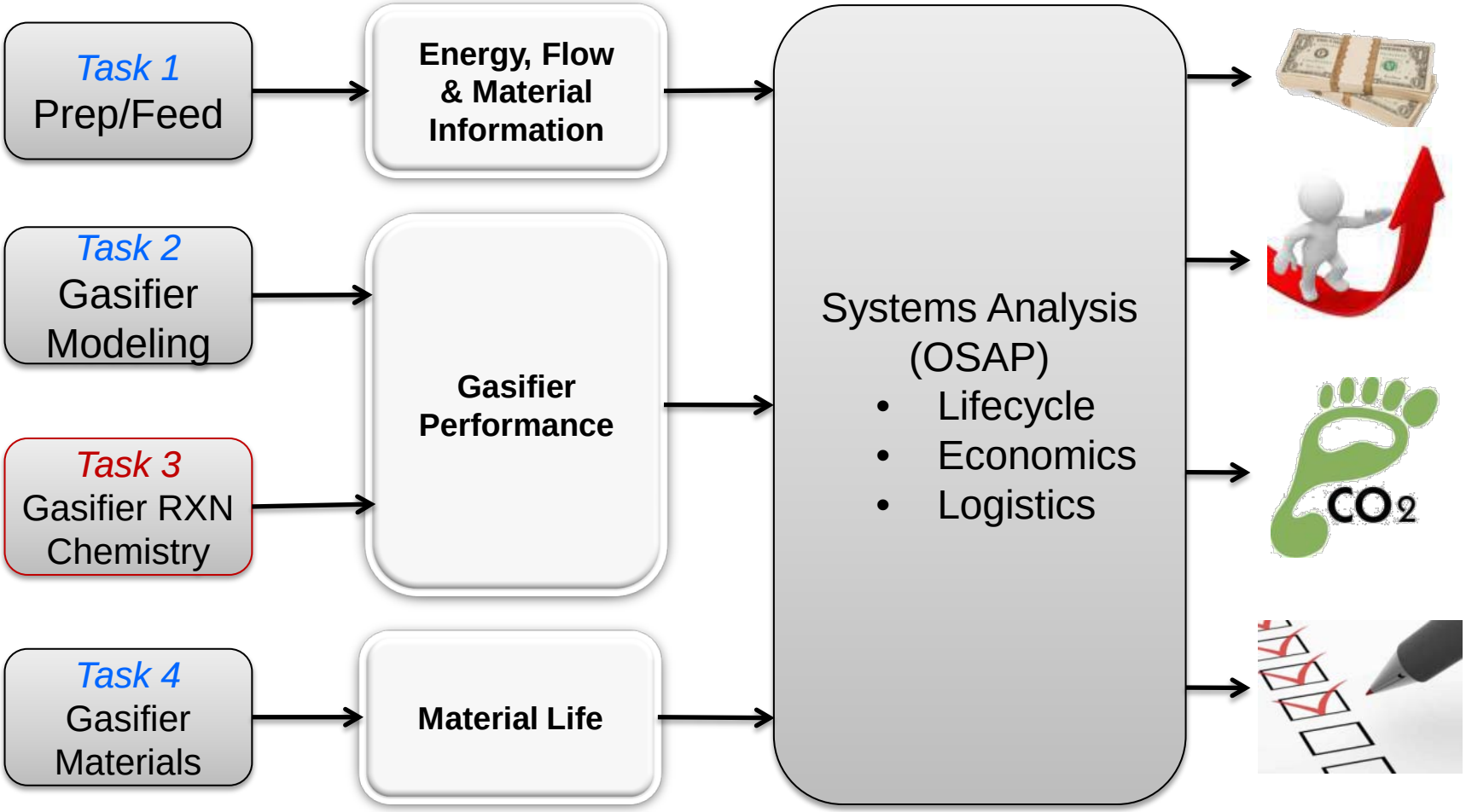
**Feed class by plant*

Brown et al., Assessment of Technologies for Co-converting Coal and Biomass to a Clean Syngas, NETL Task Report
Ciferno et al., Benchmarking Biomass Gasification Technologies for Fuels, Chemicals and Hydrogen Production, NETL Task Report

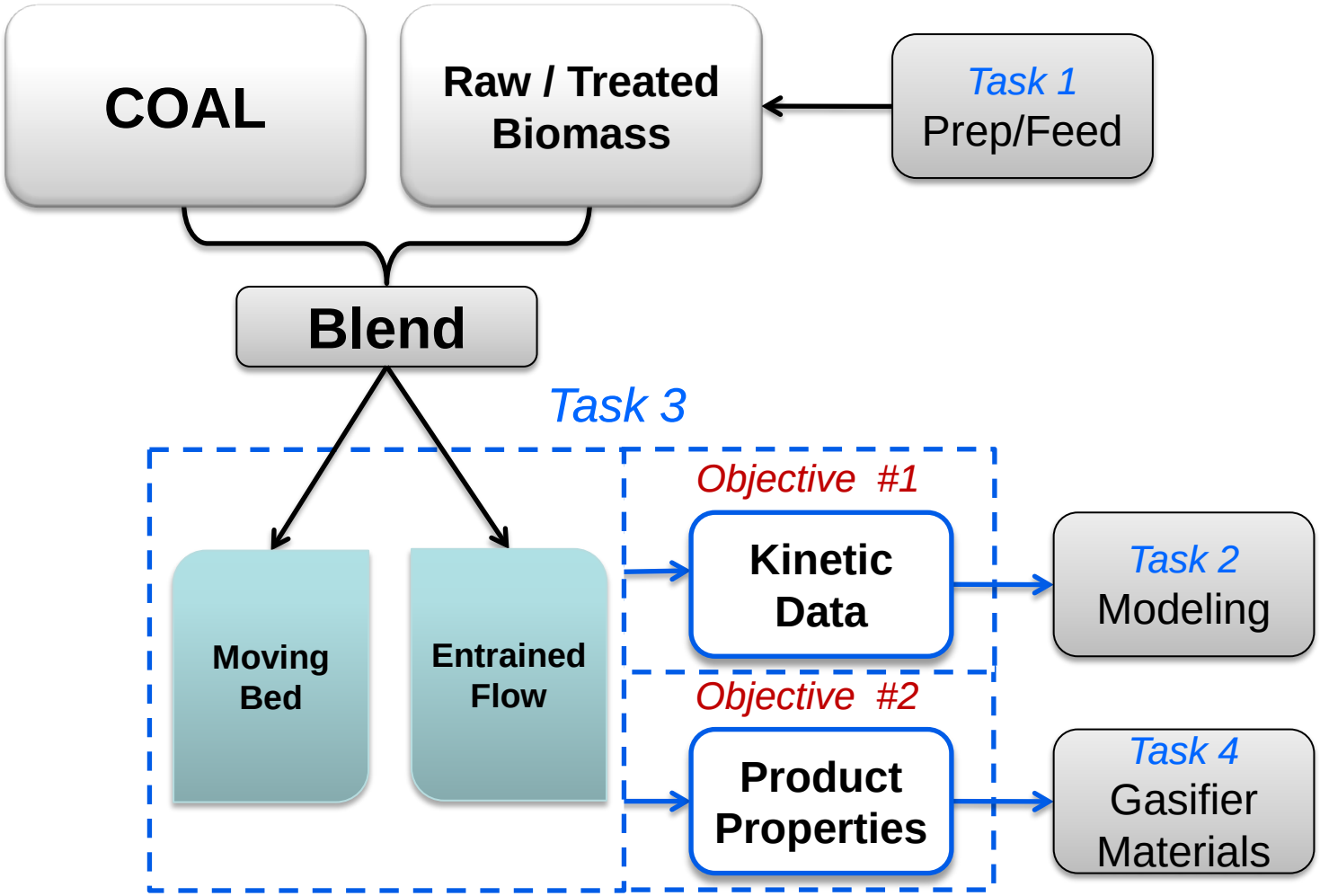
Co-Gasification Technical Uncertainties

- **Raw Biomass**
  - Material Variability (season, location, etc)
  - Transportation (Energy Density)
  - Storage (Degradation)
  - Biomass Structure and Mechanical Properties
  - Grindability
- **Pressurized Dry Feed**
  - Technology is not mature
  - Particle Size & Shape factors critical for specific feeder types
- **Gasifier Performance**
  - Reaction Kinetics
  - Material Interactions
  - Product Effects
  - Models not Developed/Validated
- **Process Optimization**

Co-gasification Program Strategy

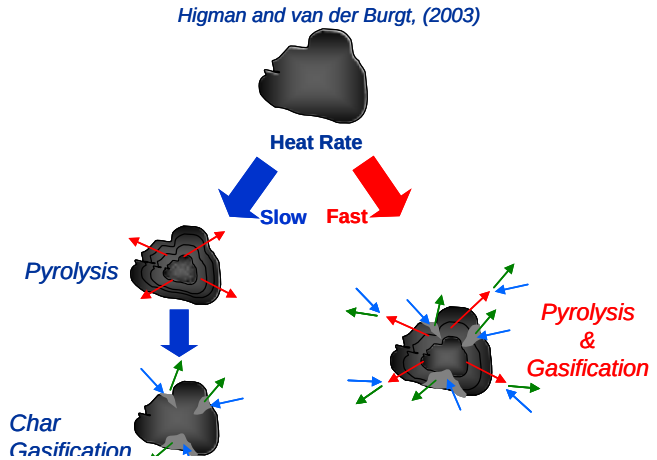


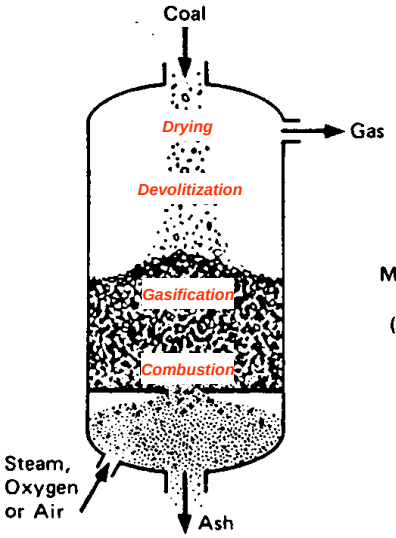
Task 3. Gasifier Reaction Chemistry Approach

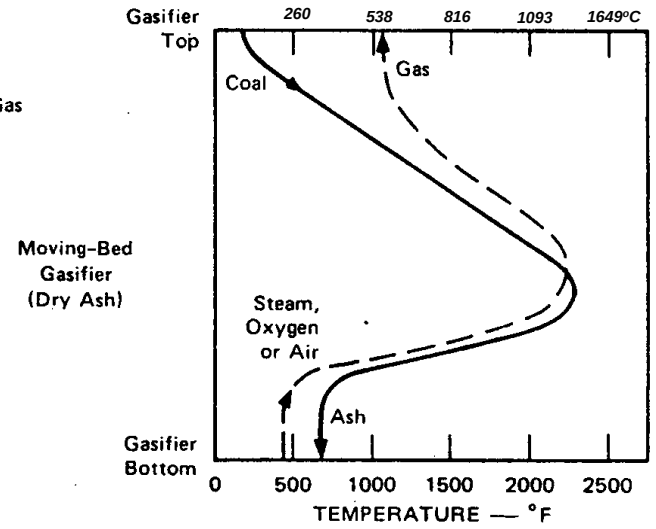


Gasifier Reaction Chemistry

- **Objective #1**
  - Identify the influence of co-feeding coal-biomass mixtures on kinetics
    - Heat rate and pressure
    - Feed mixtures
    - Feed preparation method
    - Particle size
  - Conditions consistent with Sasol gasification
    - Moving bed
    - 1000°C
    - Pyrolytic conditions
- **Feedstock Selection**
  - **Coal types**: Illinois #6, Wyodak, Powder River Basin, North Dakota Lignite
  - **Biomass types**: Mixed hardwood, wheat straw, corn stover, switchgrass DDG, algae

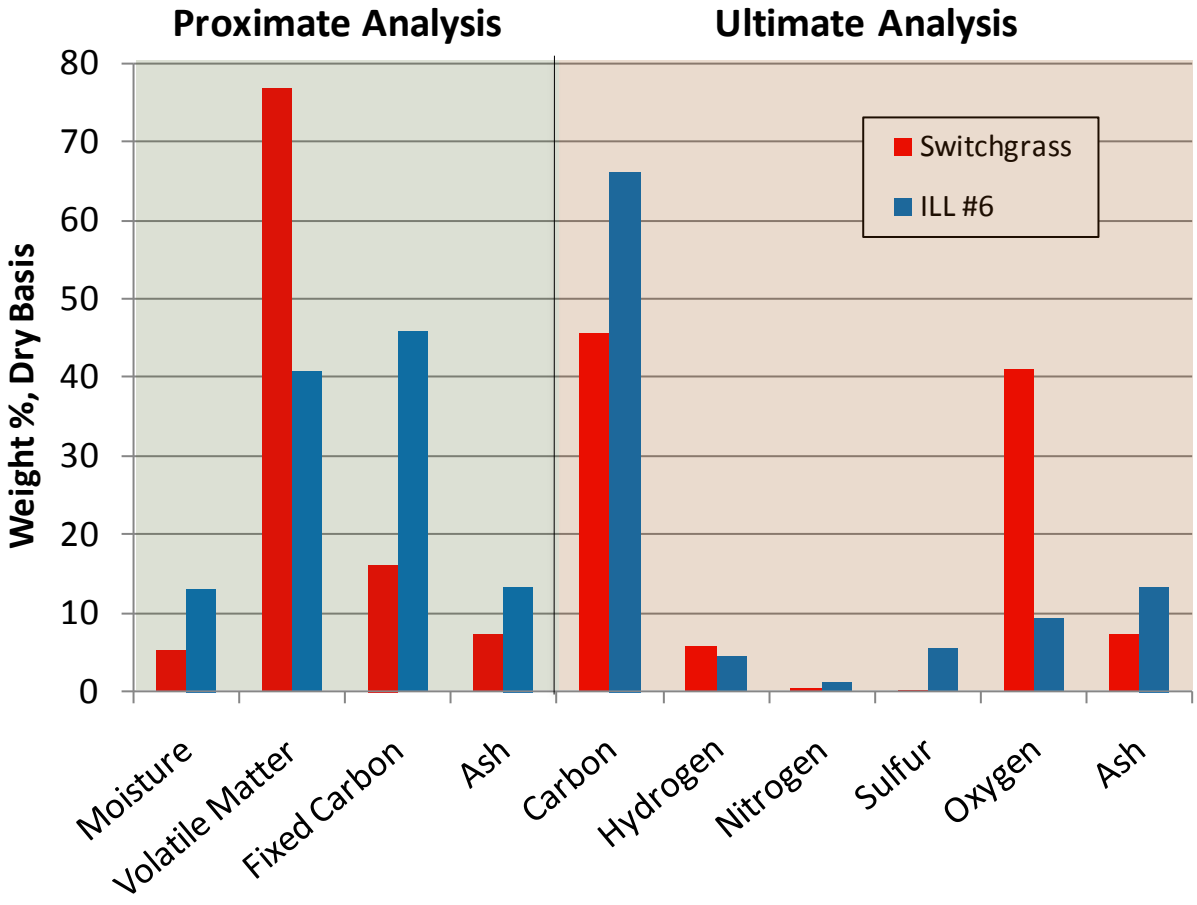




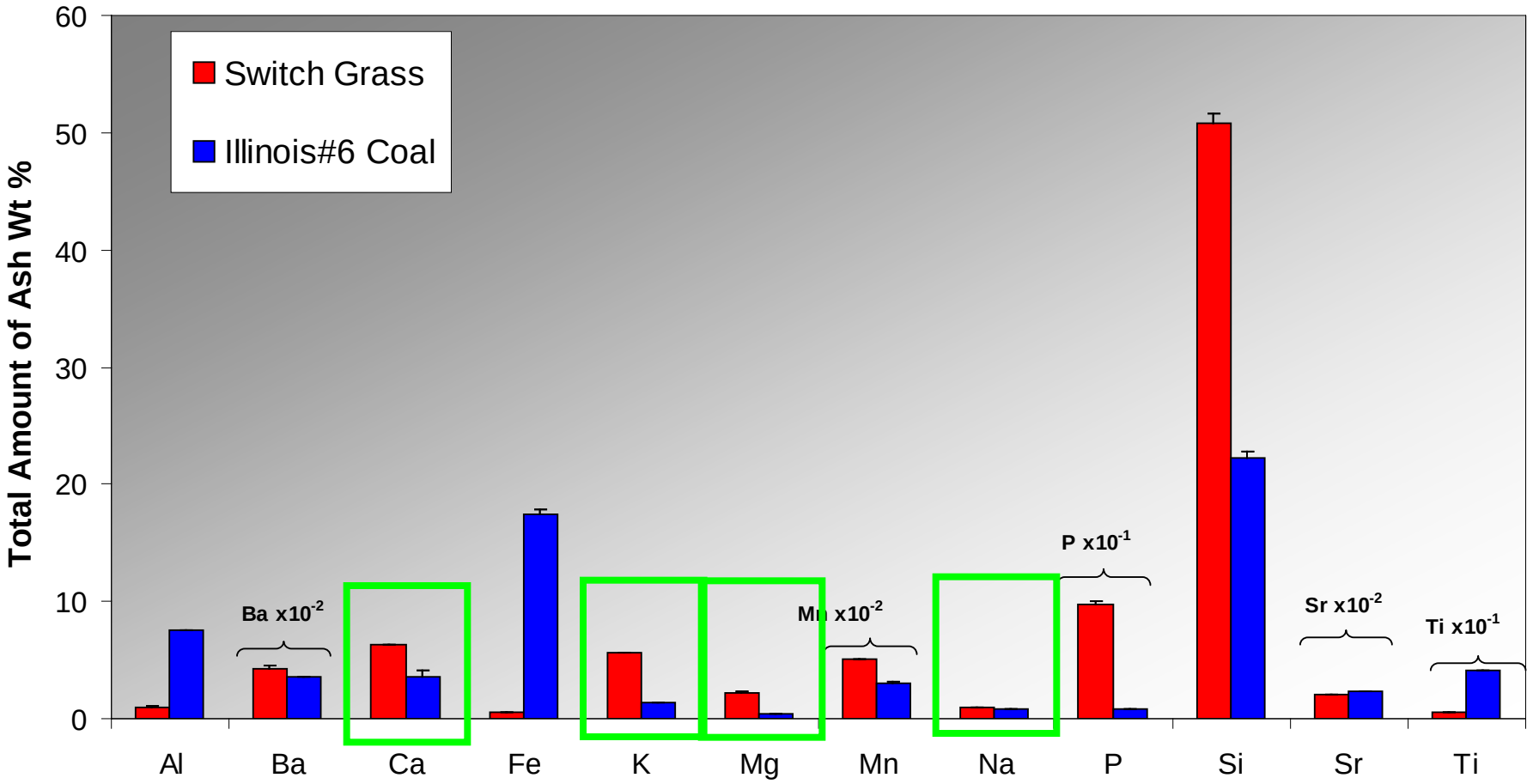


Sample Specifications

- **Illinois #6**
  - Ground & sieved
    - -18 +50 mesh
    - 279 to 1000μm
- **Switchgrass**
  - Pelletized
  - Ground & sieved
    - -16 +50 mesh
    - 279 to 1190μm

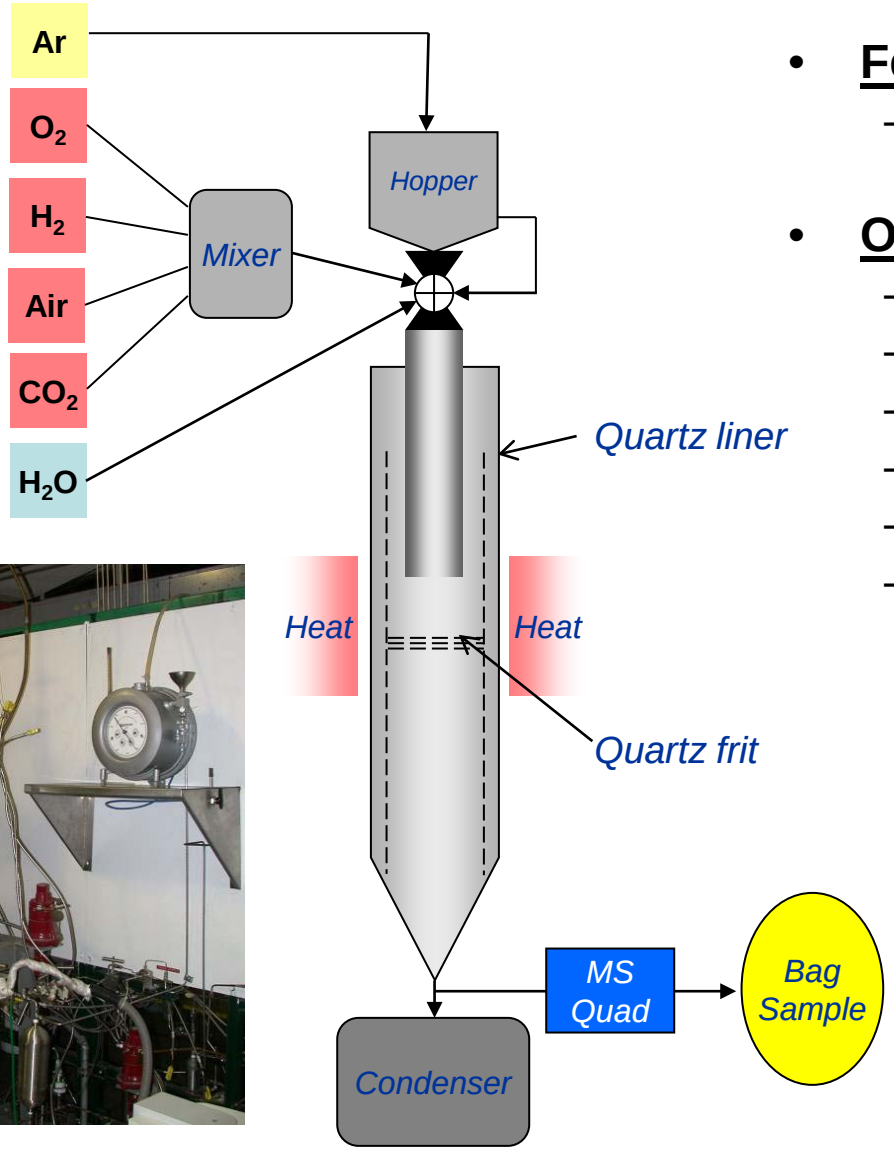


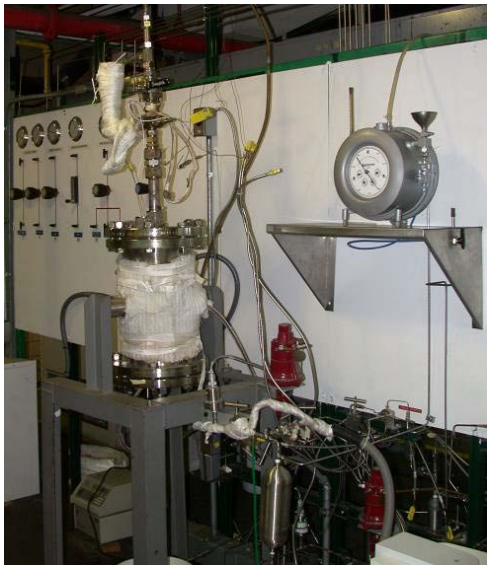
Coal / Biomass Feed Stock Ash Analysis



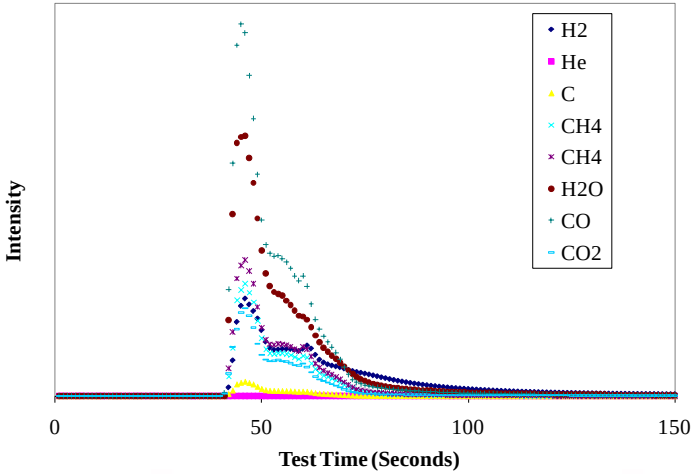
- Analysis done by ICP OES
- Ash analysis of raw, as received samples

Experimental Setup



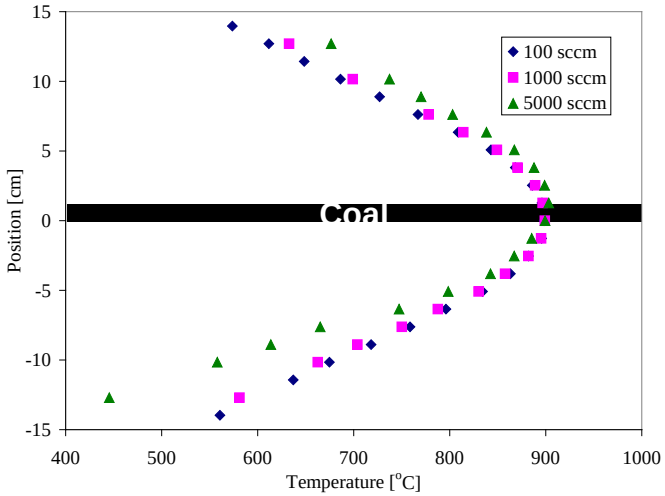


- **Feed mixtures**
  - 100, 85, 70, 50, 0 (wt% coal)
- **Operations**
  - Semi-batch
  - 1 gram loading
  - T to 1000°C
  - P to 1000 psi
  - On-line MS-Quad gas analysis
  - Ex-situ tar, char and gas analysis

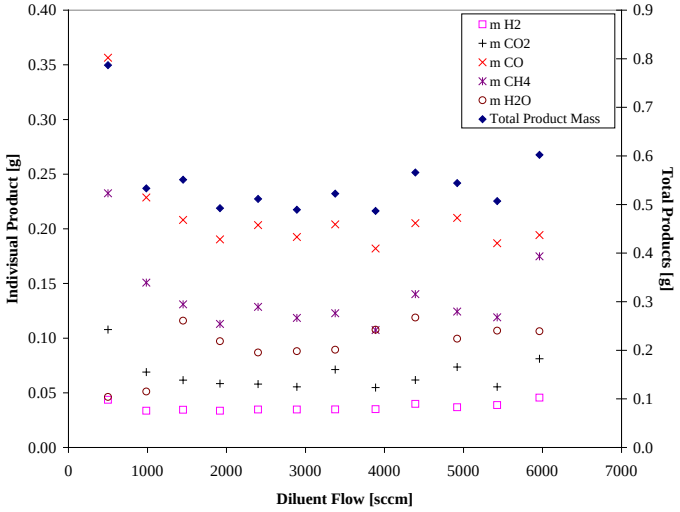


Gasifier Process Development

- **Reactor Temperature**
  - –~1 cm isothermal zone, +/- 2 C
  - –Independent of flow
  - –Initial 10 C drop in temperature at drop time

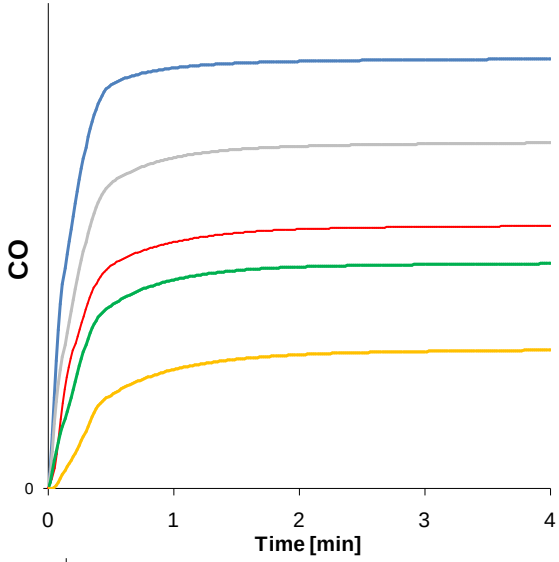


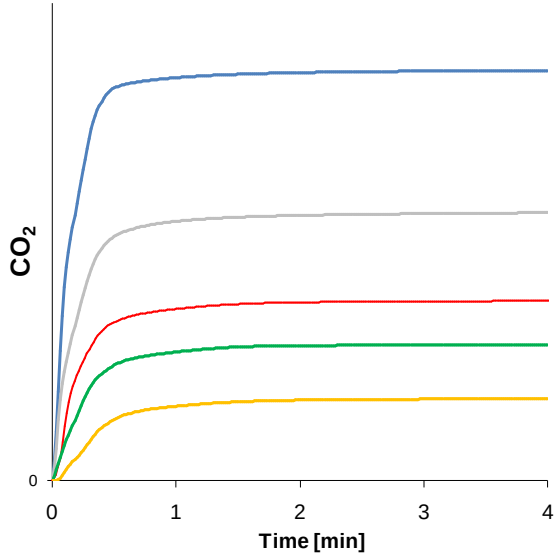
- **Reactor Flow**
  - –Minimize side reactions
  - –Maximize gas sampling sensitivity
  - –Optimal reactor flow is greater than ~1.5slpm for pure coal and biomass

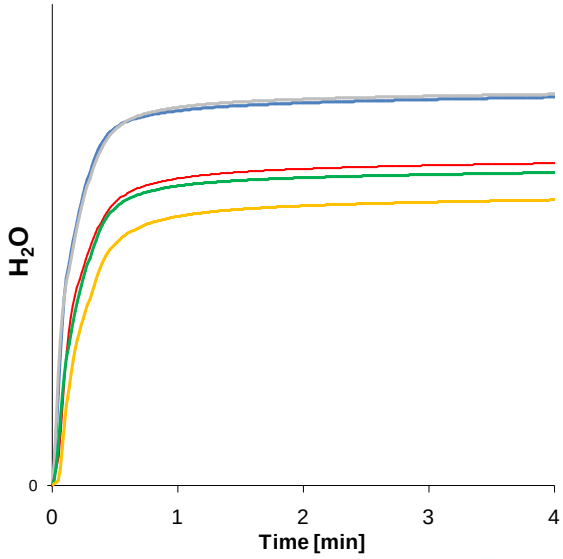


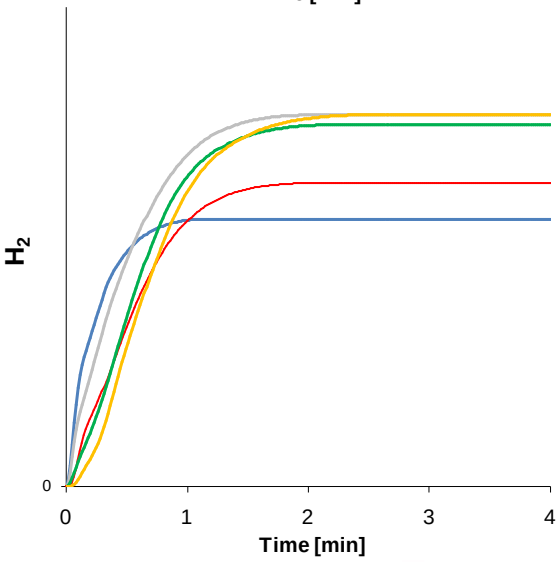
Influence of Co-Feeding on Gaseous Products

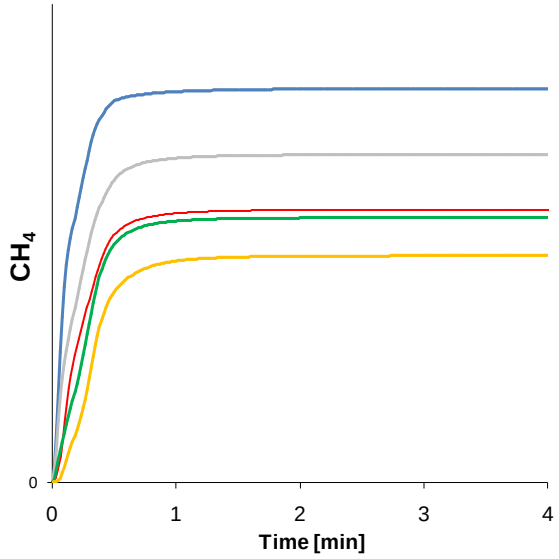
- Switch Grass
- 50wt% SG/ILL
- 30wt% SG/ILL
- 15wt% SG/ILL
- Illionis#6 Coal



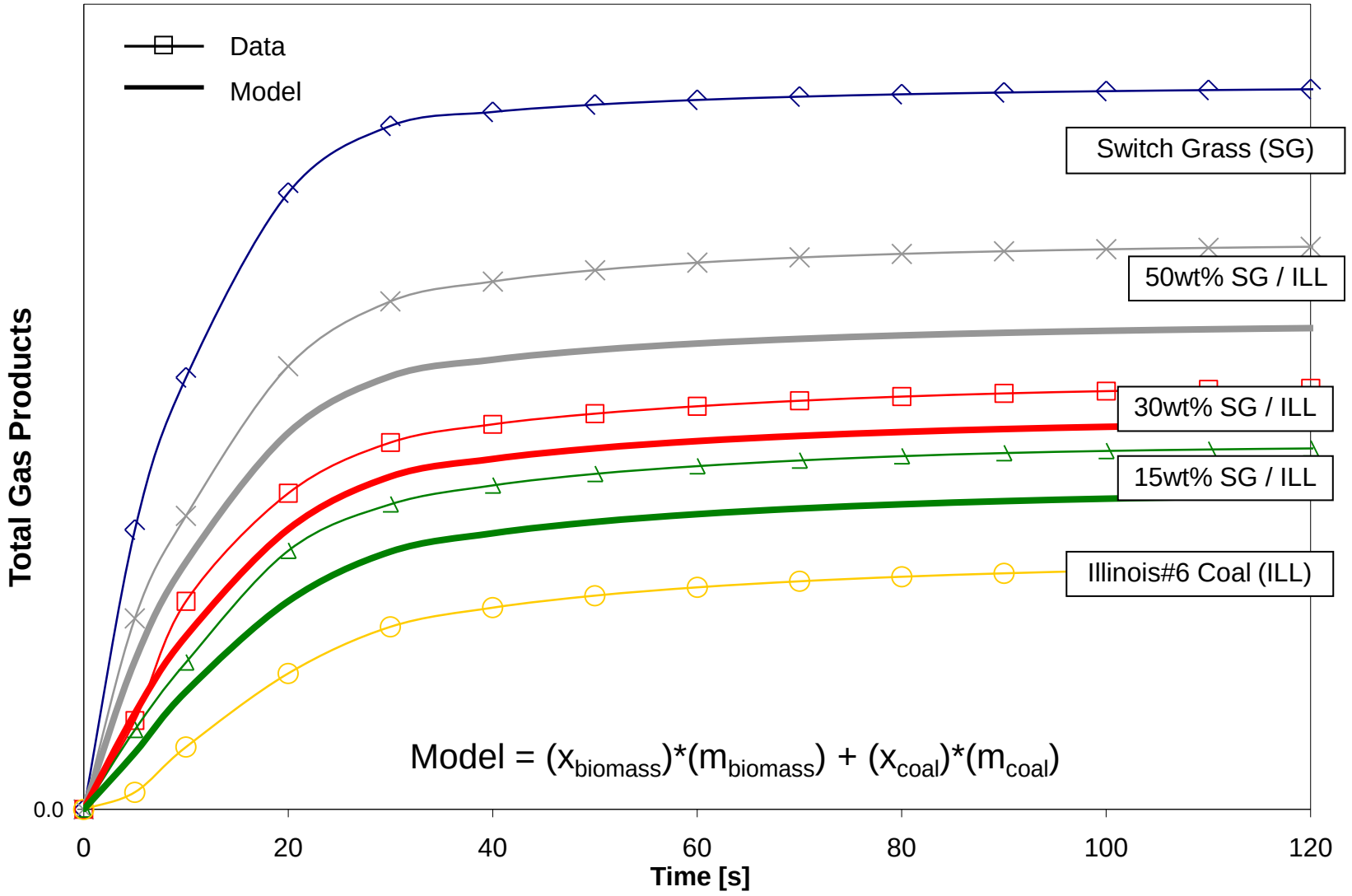




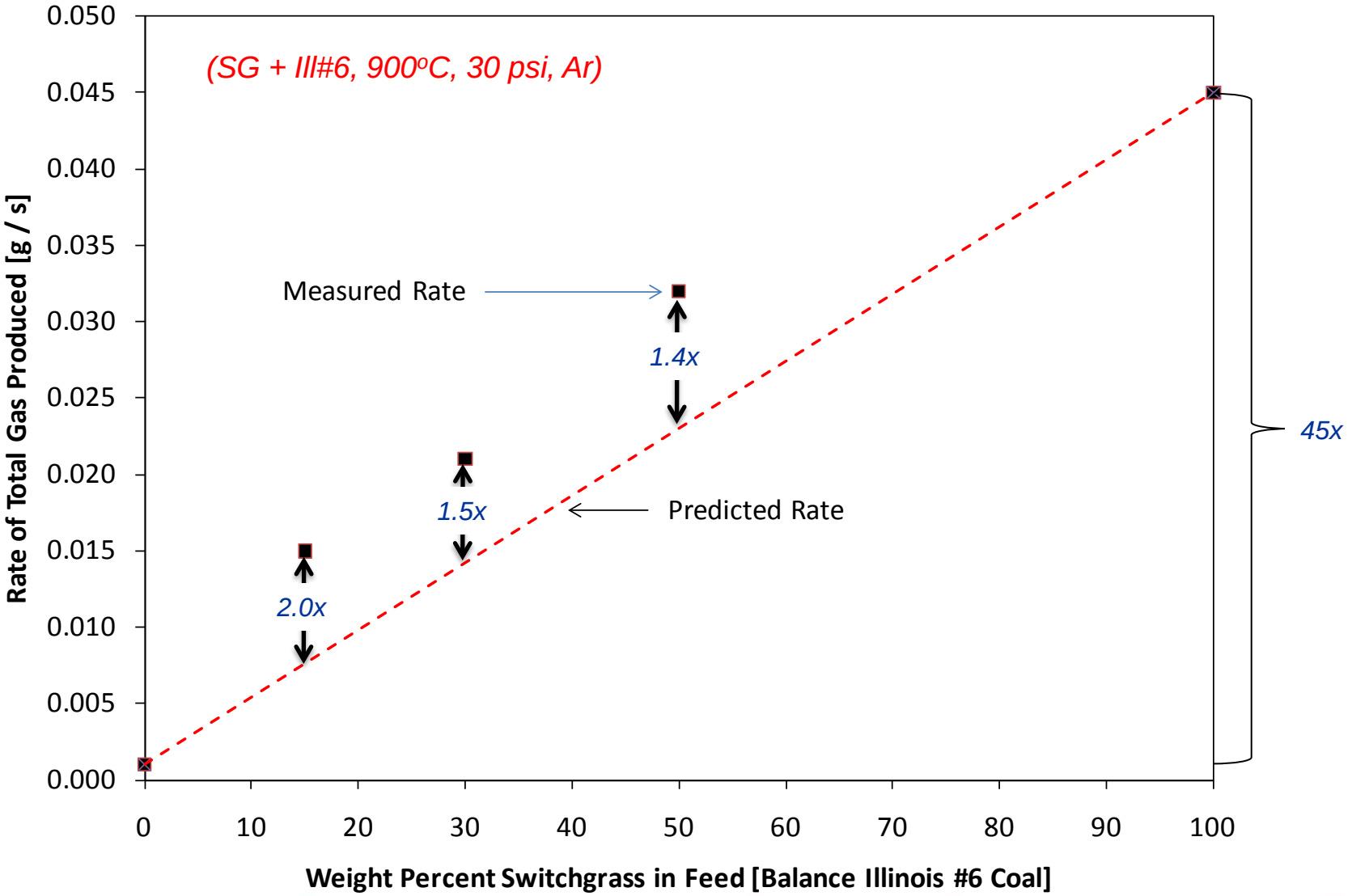




Influence of Co-Feeding on Gaseous Products

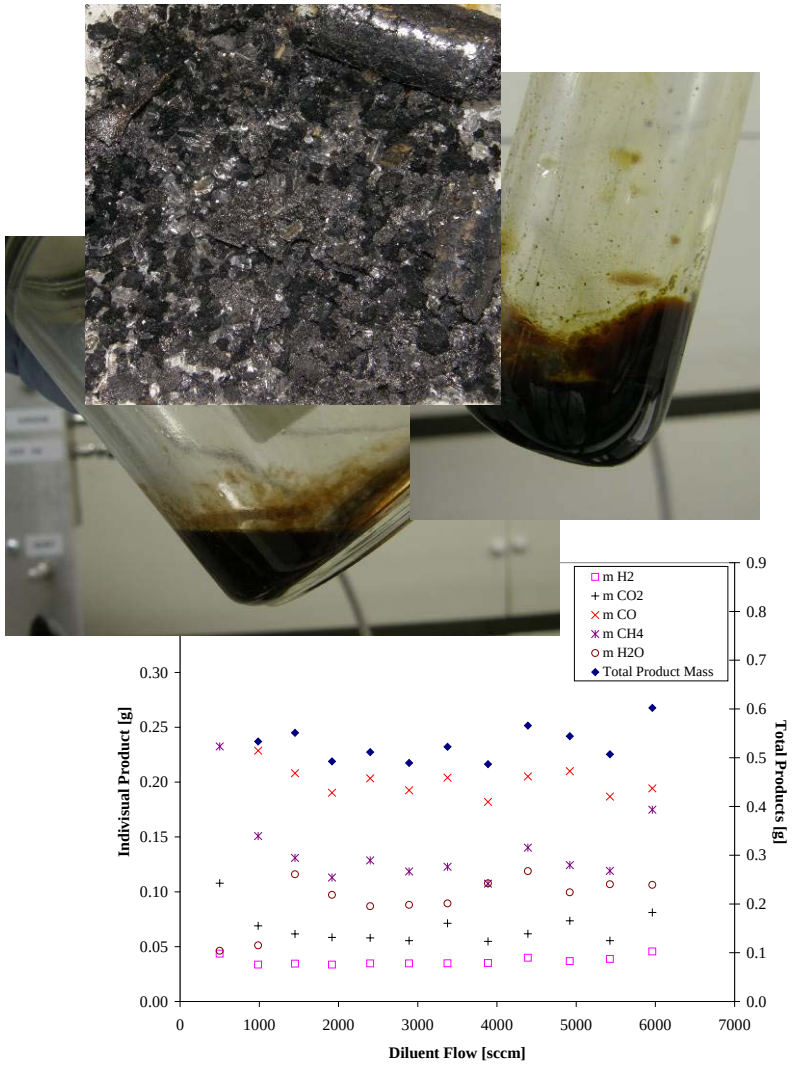


Influence of Co-Feeding on Gaseous Products

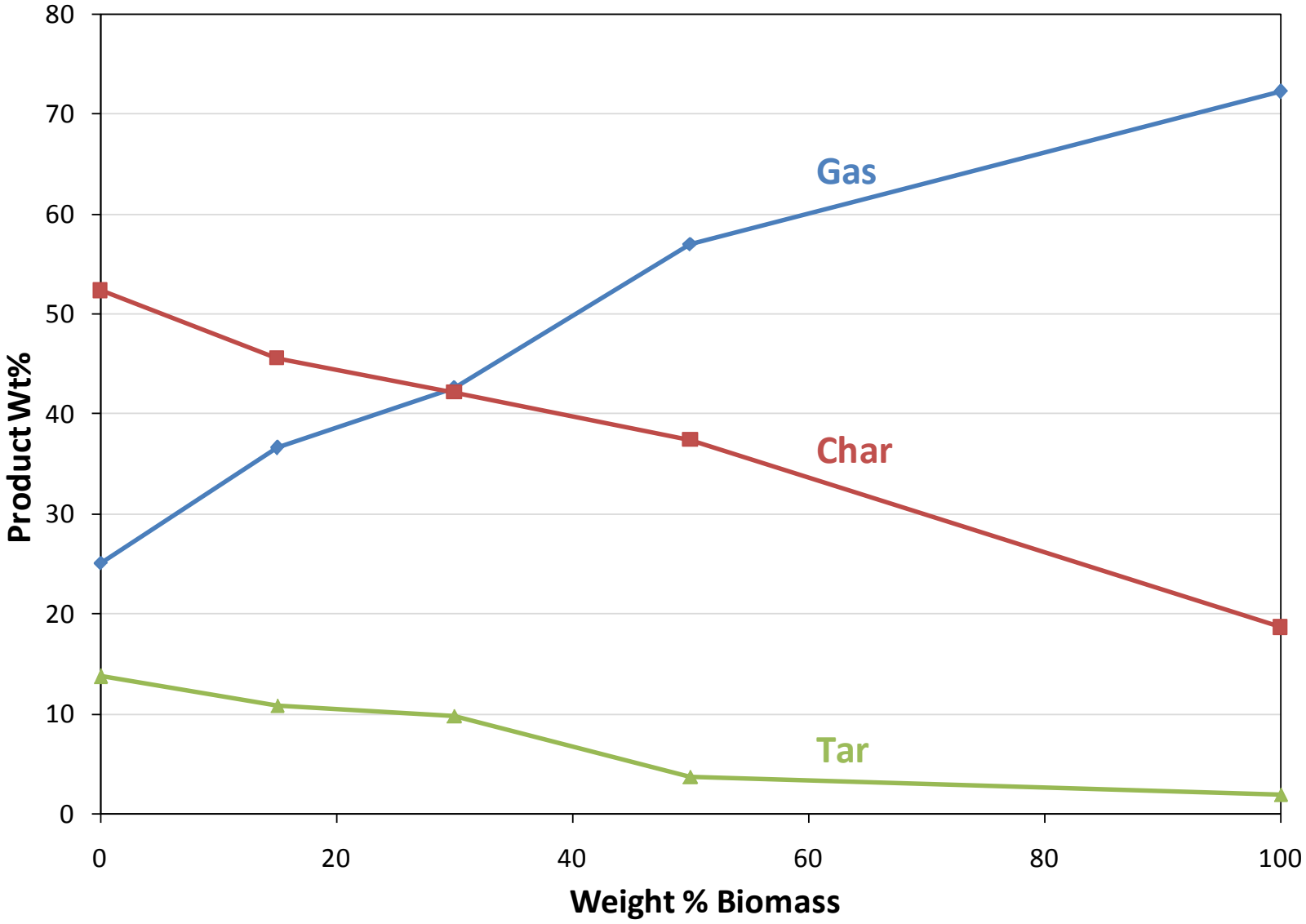


Co-Gasification Product Characterization

- **Objective #2**
  - Identify the influence of co-feeding coal-biomass mixtures on solid, liquid and gaseous products
    - Syngas composition
    - Catalytic effects
    - Alkaline biomass ash effects on syngas cleanup
- **Conditions consistent with Sasol gasification technology**
  - Fixed bed, Lurgi gasifier
  - 1000^{o}C
  - Pyrolytic conditions
- **Same feedstocks**
  - Illinios #6 Coal
  - Ground, Pelletized Switchgrass

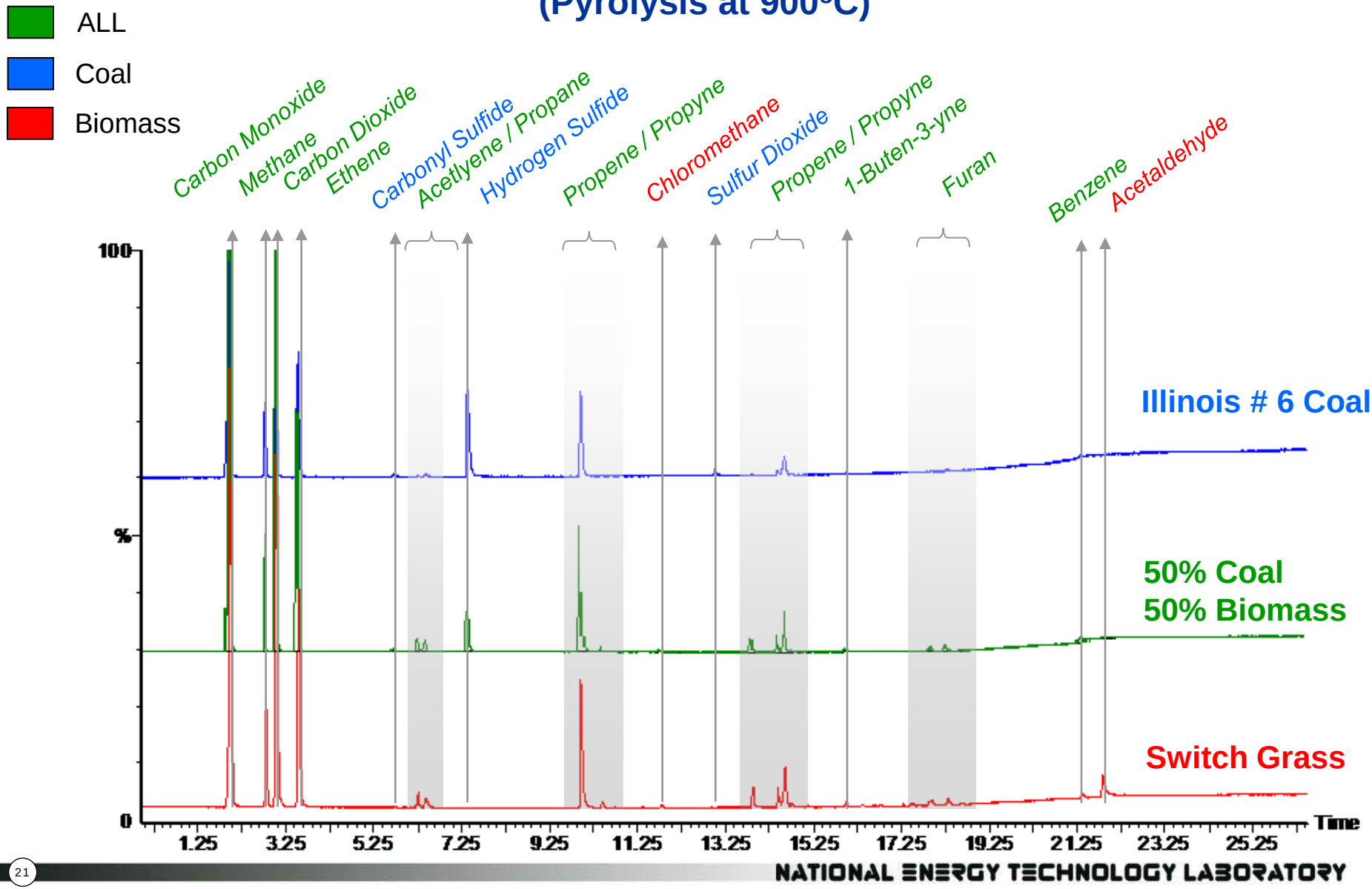


Qualitative Product Distribution Trends



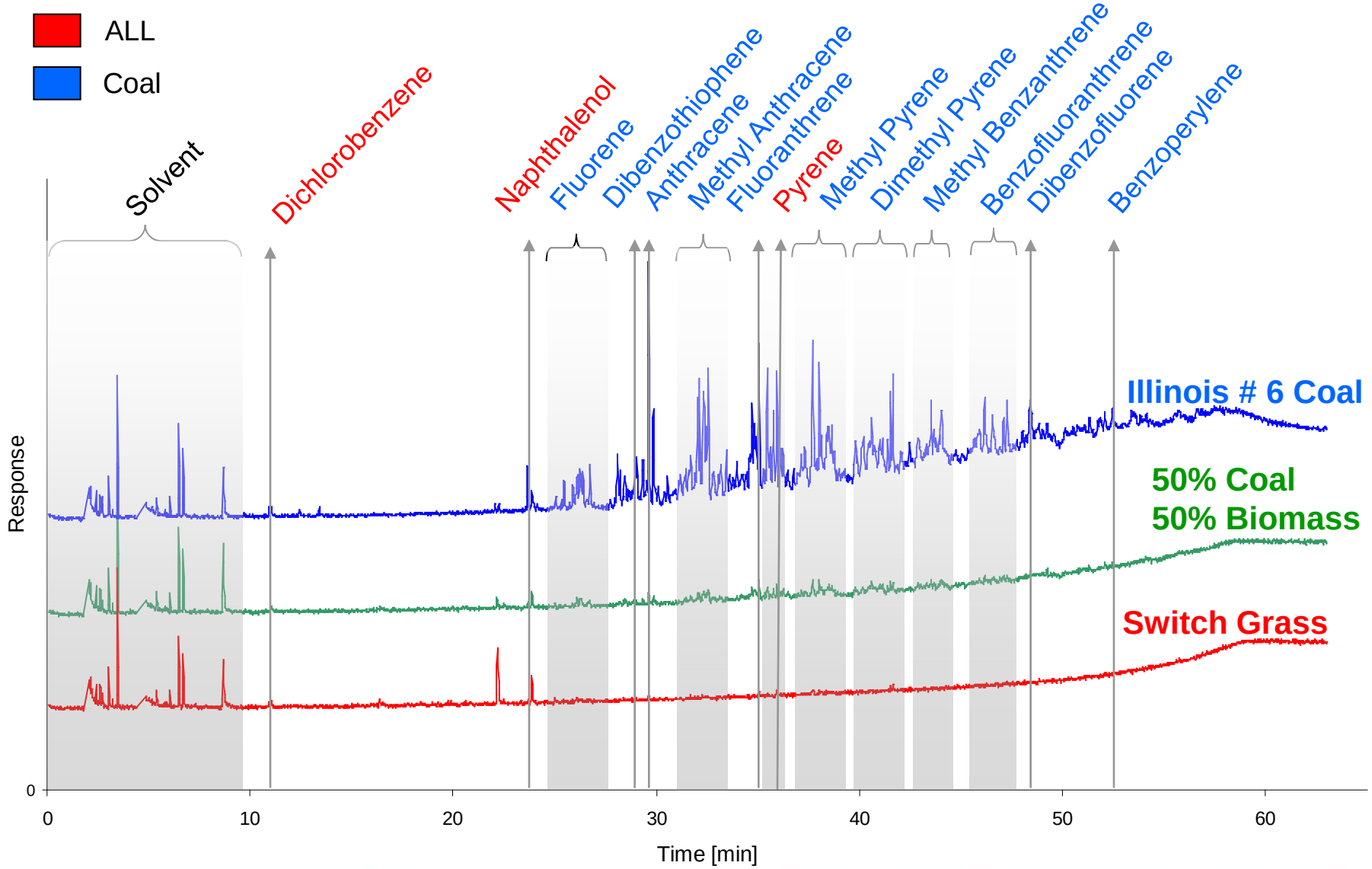
Influence of Co-Feed on Gas Composition

(Pyrolysis at 900ºC)

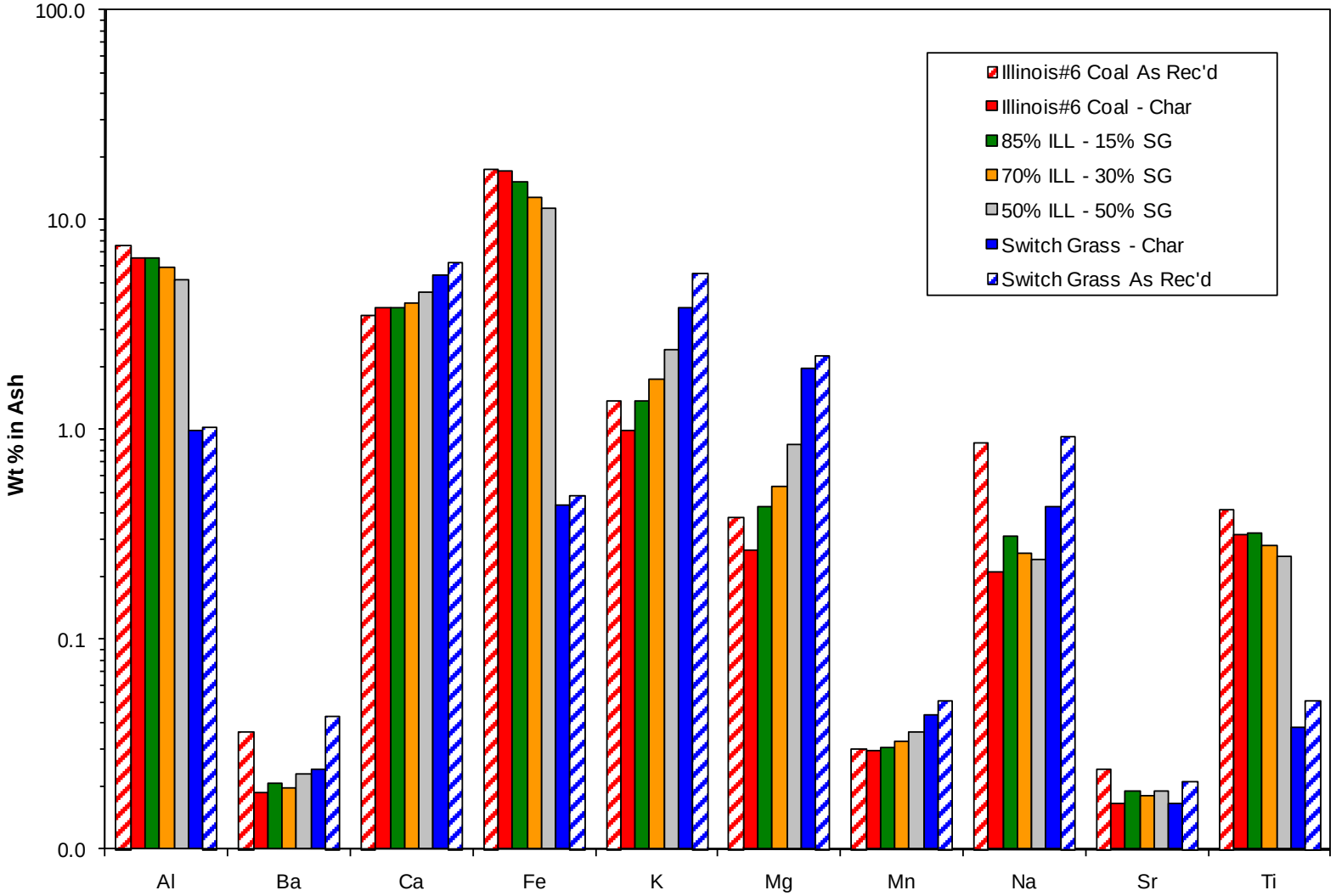


Influence of Co-Feed on Tar Composition

(Pyrolysis at 900ºC)



Influence of Co-Feed on Char Composition



Summary

- **Established a test protocol for quantifying the influence of biomass on coal gasification reactions**
- **Preliminary results suggests that co-feeding Ill#6 and SG has**
  - Minimal deviation from production trend
    - More coal yields more ash and tar, less syngas
  - Reaction rates appear to deviate from pure samples
    - Not simply release of volatile gases
      - Coal - biomass char interactions (possibly catalytic)
      - Coal - volatile gas product interactions
  - Gas and liquids products:
    - Coal rich feeds had more aromatics and S-containing compounds
    - Biomass rich feeds had O-containing compounds, chlorinated HC's, and low HC's
  - Solid Products
    - Ill#6 had higher transition metal content (Fe, Al, Ti)
    - SG had higher alkali content (K, Ca, Mg)
    - Biomass char – coal interactions (catalytic effect)
    - Some mineral species volatilizing from ash (K, Mg, Na)

Future Work

- **Relocating and upgrading reactor**
- **Develop kinetic devolitization model**
  - Varying temperature & pressure
  - Species, feed ratio, particle size
  - Investigate catalytic effect
- **Complete devolitization evaluation of 2nd coal-biomass combination**
- **Investigate effects of biomass feed preparation methods**
- **Initiate testing protocol with mixed feed gases (gasification)**
  - H_2O, O_2, CO_2

- **Coal types**
  - Illinois #6
  - Wyodak
  - Powder River Basin
  - North Dakota Lignite
- **Biomass types**
  - Mixed hardwood
  - Wheat straw
  - Corn stover
  - Switchgrass
  - DDG with corn fiber
  - Algae

Anticipated Benefits

- **Provide fundamental gasification reaction chemistry required to address co-gasification uncertainties as well as optimize co-gasification models**
- **Develop a thorough understanding of gas, liquid and solid products developed from co-gasification reactions which will enable the development and optimization of construction materials and downstream processing**

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