Advantages of Computer Modeling in Biofuel Production and Utilization Processes

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Challenges in Biofuel Production and Utilization

- Understanding the Biofuel Production Process
- Optimizing System and Equipment Design
- Scaling up the Design
- Understanding the Impact of Biofuel Utilization
- Optimizing the Utilization Process and Design

Fundamentals of the Biofuel Processes

- Fluid Flow: Single or Multi-phase
- Heat Transfer: Conduction, Convection, Radiation
- Chemical Reactions: Heterogeneous or Homogeneous, Endothermic or Exothermic, Catalytic or Non-catalytic
- Conservation: Momentum, Mass, and Energy
- Mathematical Modeling

Advantages of Computer Modeling

- Model application gives a deep understanding of the process.
- Parametric studies can be conducted efficiently and effectively.
- System and equipment design can be optimized and scaled up easily.
- Feasibility studies reduce risks of utilizing biofuel.
- Process and equipment of biofuel utilization can also be optimized.

Modeling Applications

- Biomass gasification in a fixed bed gasifier
- Biomass gasification in a fluidized bed gasifier
- Black liquor gasification in an entrained flow reactor
- Direct firing of wood syngas in lime kilns
- Direct firing of bark and lignin in lime kilns
- Direct firing of wood syngas in combustors
- Direct firing of wood syngas in boilers
- Direct firing of wood syngas in drying kilns
- Direct firing of wood syngas in HVAC applications

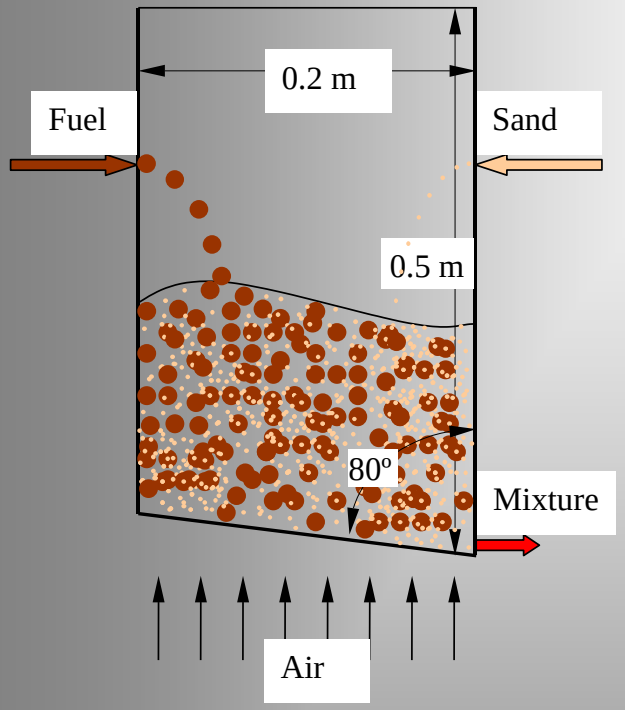
Modeling a Fixed Bed Gasifier

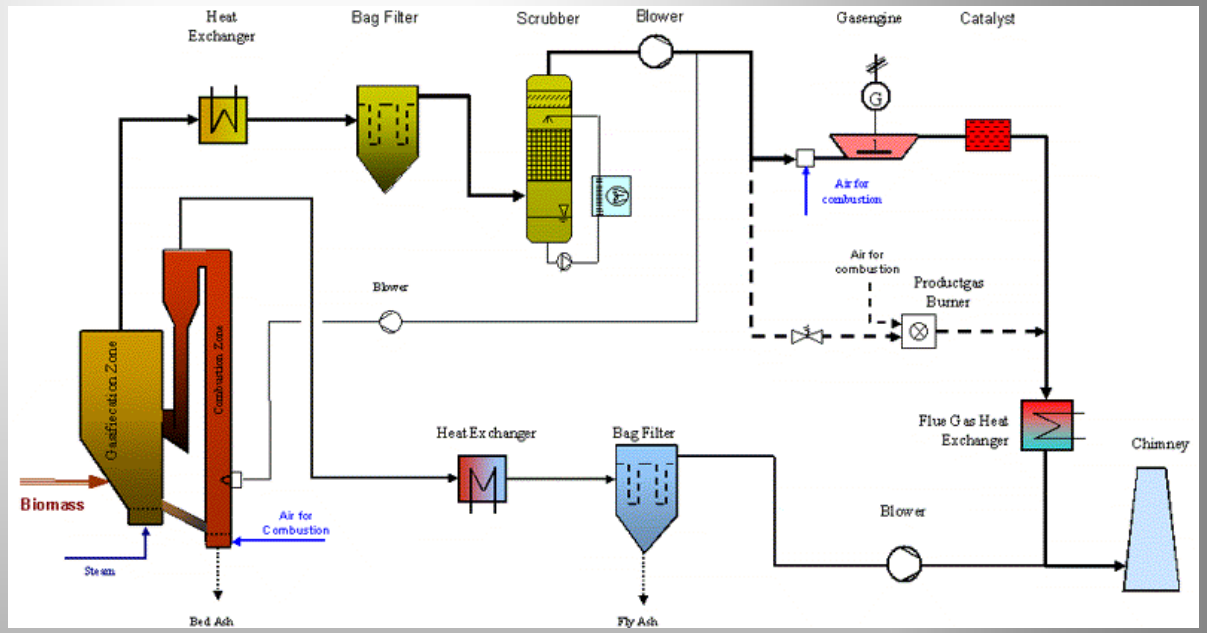
- Nexterra gasification technology: fixed bed gasifier
- Biomass gasification: drying, pyrolysis, char gasification
- Blast air flow inside porous bed and syngas flow in freeboard
- Optimization of freeboard design for carryover reduction
- Capable of optimizing gasifier design and scaling up

Modeling Predictions and Validation

- Modeling outputs include three-dimensional distributions of fuel and gas temperature, gas velocity, gas species concentration, the fuel feed rate, and the syngas composition.
- The model predictions of fuel feed rate, fuel temperature, and syngas composition are reasonably consistent with the measurements in a pilot gasifier.
- The modeling has been applied to a commercial gasifier design and provided reasonably good results.

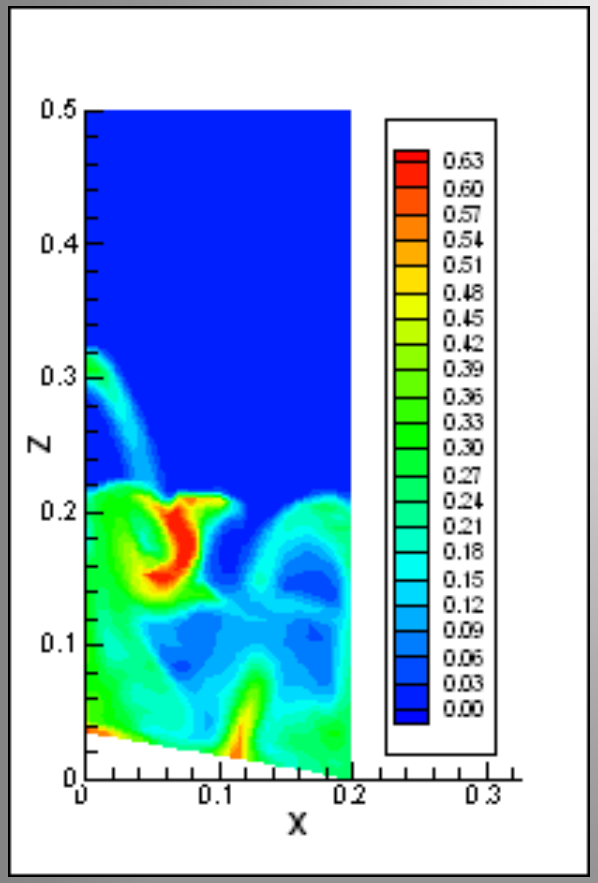
Modeling Multi-Phase Flow in Fluidized-Bed Gasifier



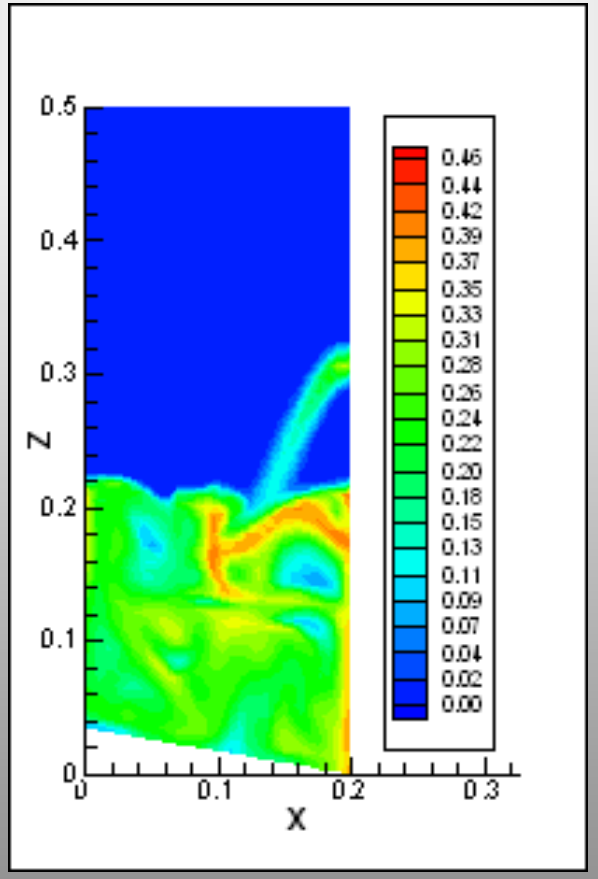


- RENET gasification process (Rauch et al, 2004): fluidized-bed gasifier and combustor are separated
- Mixing and heat transfer between fuel and hot sand in gasifier
- Complete combustion of char and heat transfer to sand in combustor
- Multi-phase flow characteristics playing a critical role

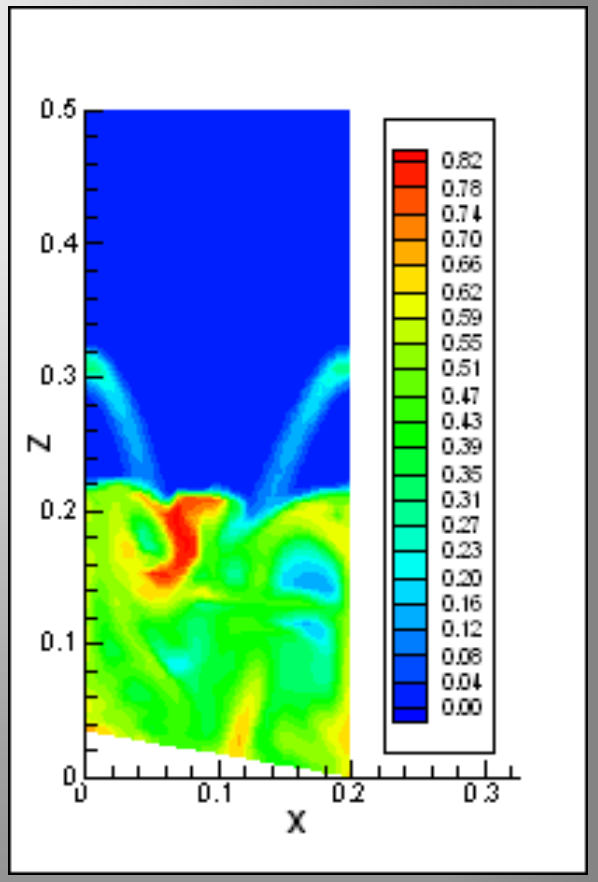
Prediction of Fuel and Sand Flow



Fuel

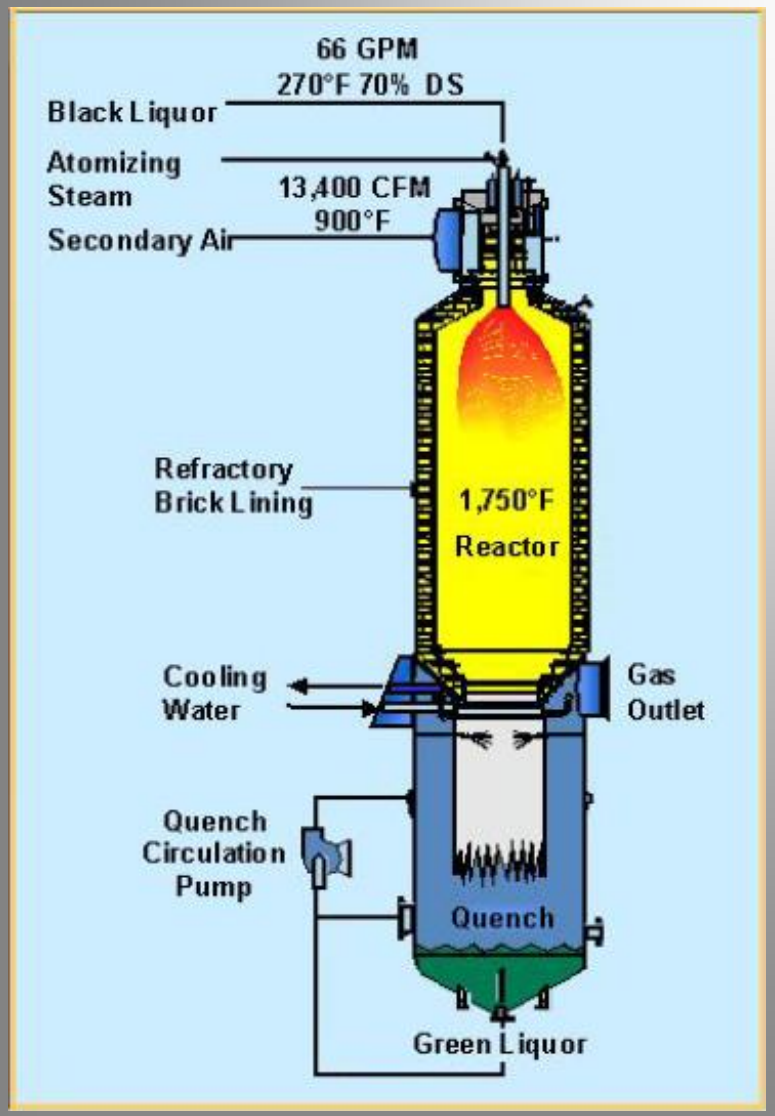


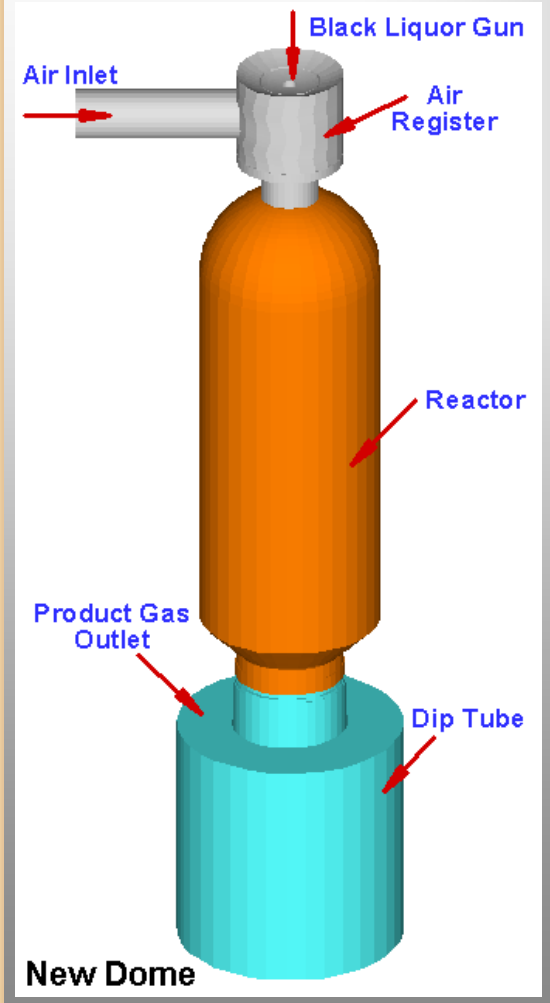
Sand



Fuel & Sand

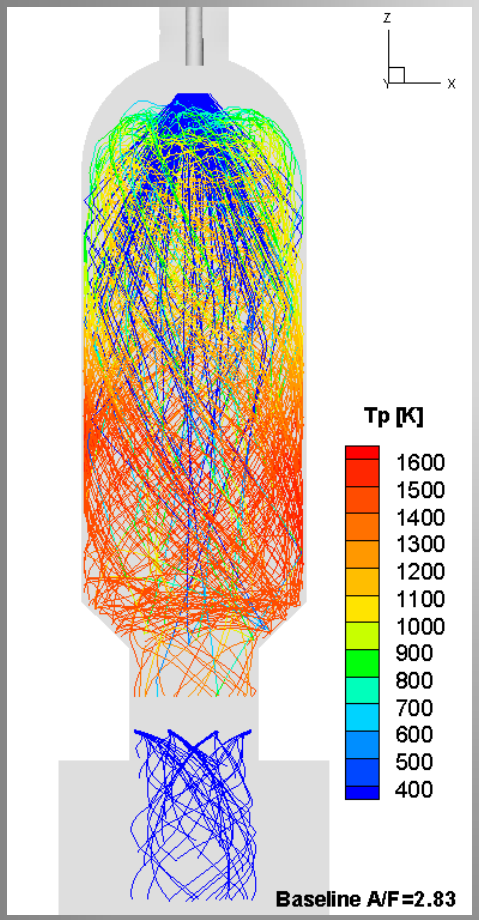
Modeling a Black Liquor Gasifier

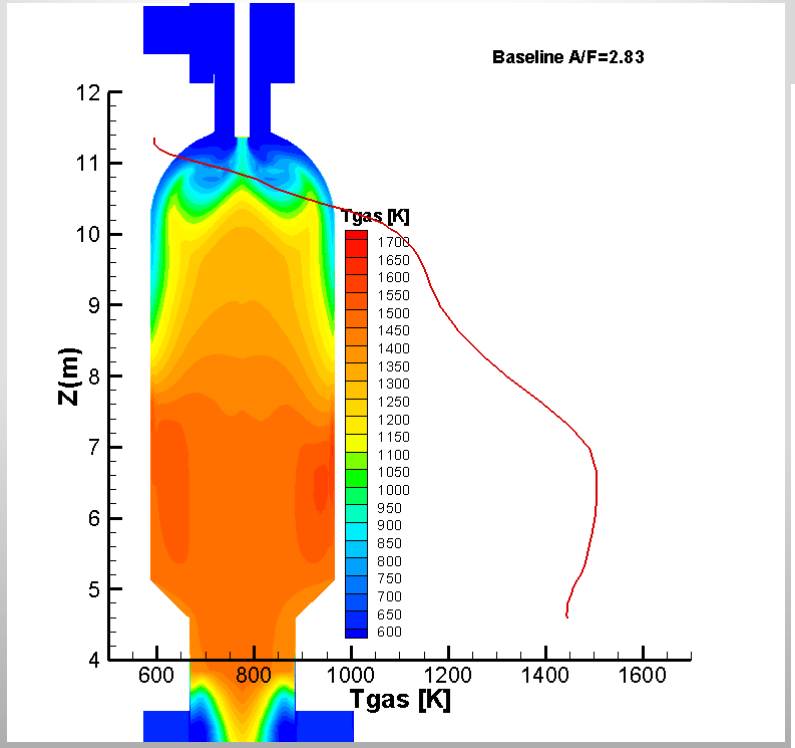


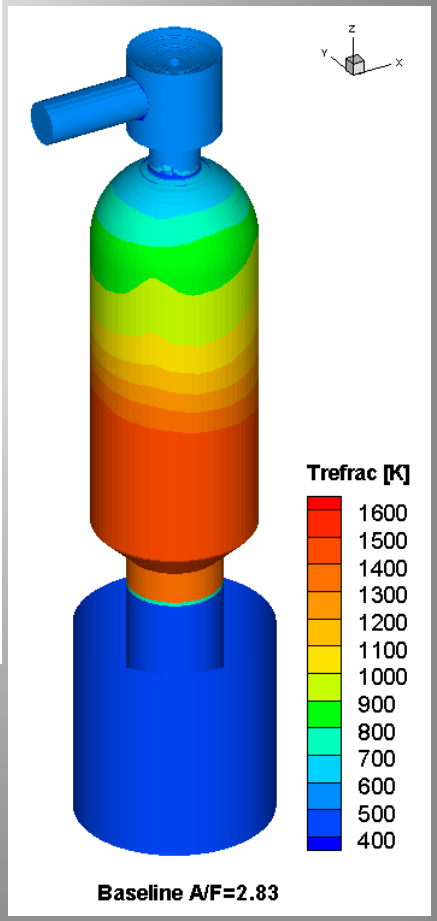


- High temperature and corrosive environment in the reactor
- Degrading of refractory lining and cracking of metallic supports and shell
- High temperature zone and liquor trajectory being helpful information

Temperatures and Liquor Trajectory



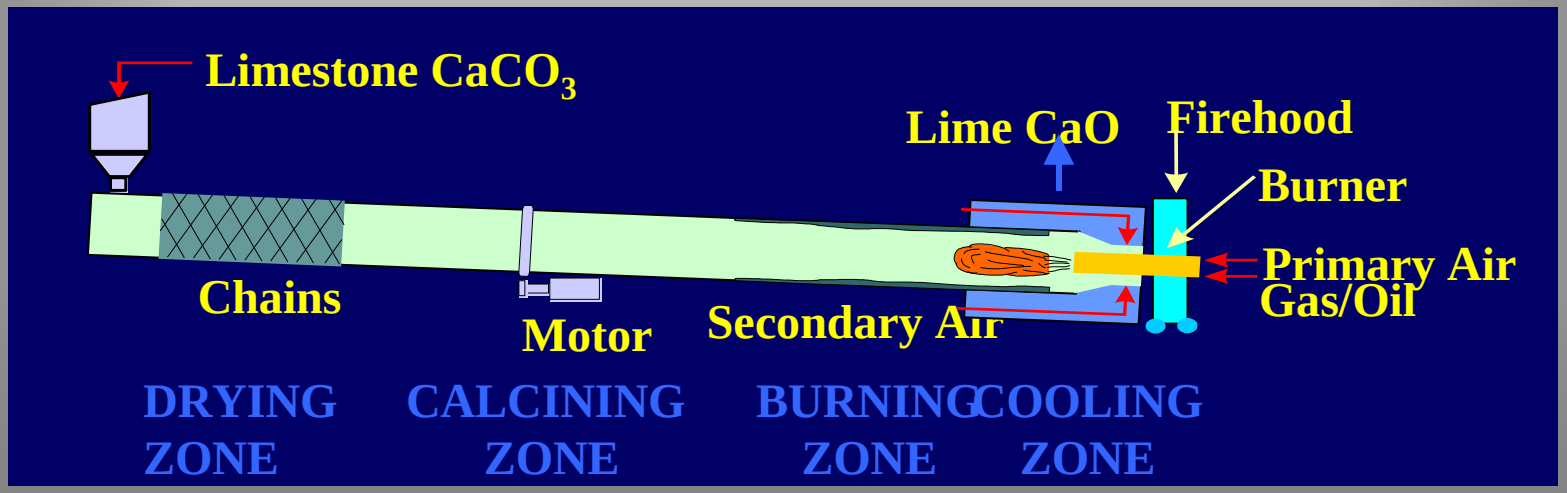




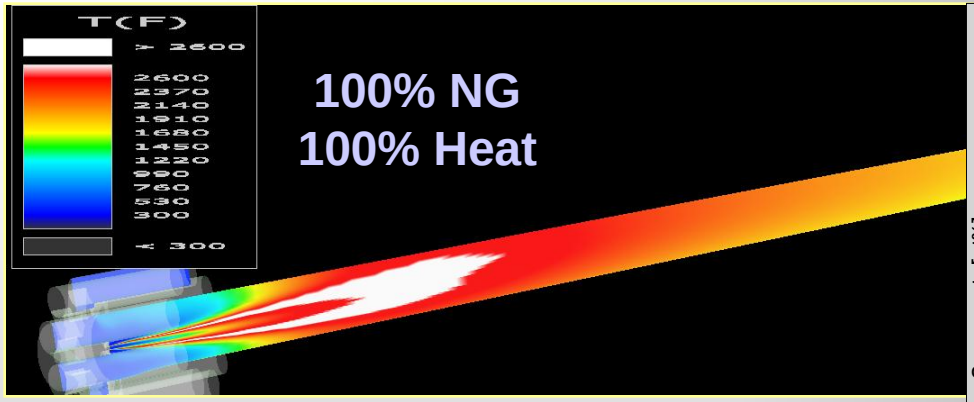
Model predictions		New Baseline (A/F=2.83)
Gas temperature at reactor exit	K	1446
	F	2143
Product gas CO	% dry, vol	2.88%
Product gas CO_2	% dry, vol	20.47%
Product gas CH_4	% dry, vol	0.48%
Product gas H_2	% dry, vol	7.13%
Product gas H_2S	% dry, vol	0.24%
LHV of product gas	kJ/Nm^3Dry	1298
Flow rate of green liquor	kg/s	1.135
Unburned combustible in green liquor	kg/s	0.068
	% of GL	5.98%
Maximum gas temperature in reactor	K	1622
	F	2460
Maximum refractory temperature	K	1492
	F	2226

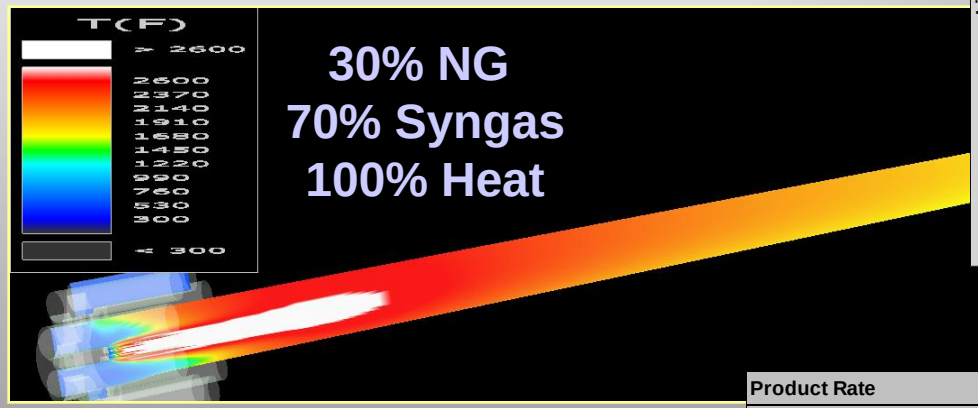
Firing Wood Syngas in Lime Kilns

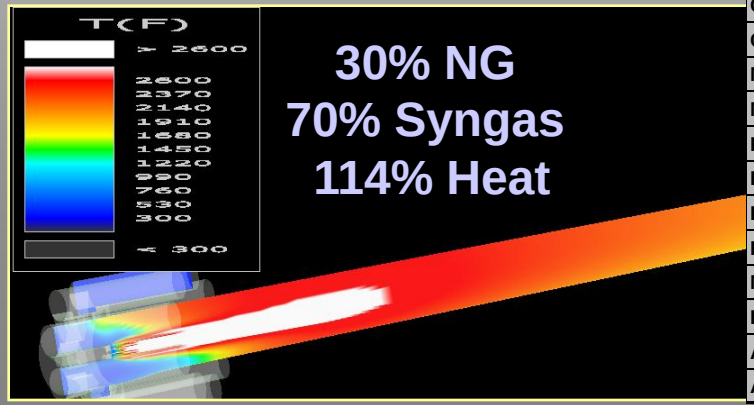
- Alternative fuels for natural gas and heavy oil
- Not a simple replacement of energy.
- Requirements for flame temperature and shape, volumetric flow of flue gas.
- Feasibility study, replacement ratio, burner design

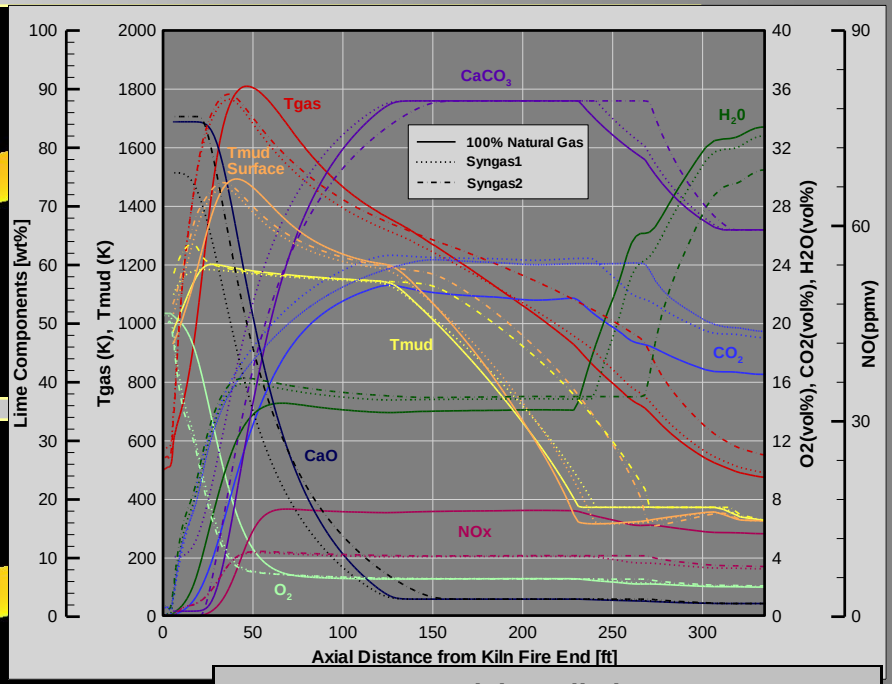


Flame Temperature vs. Kiln Performance





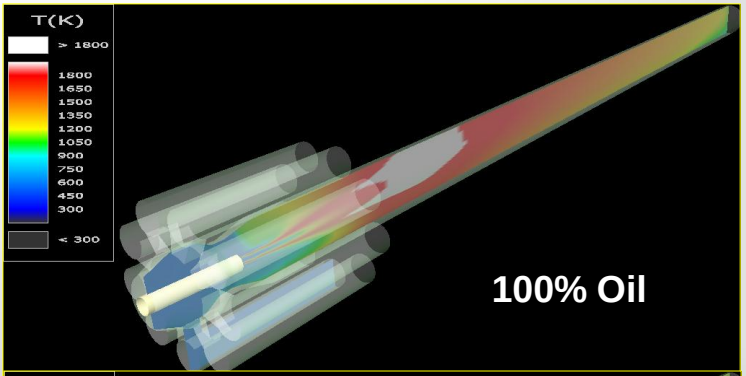


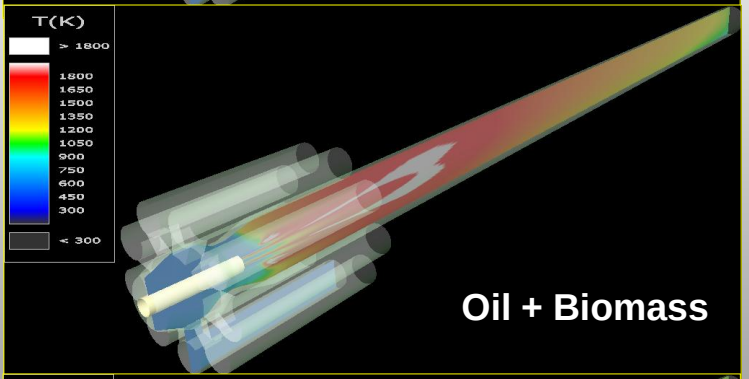


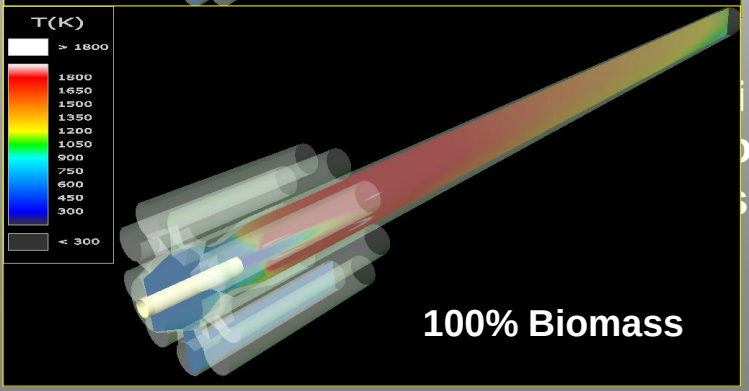
Model Predictions			
	100% Natural Gas	Syngas1	Syngas2
Product Rate	469.9 TPD	490.0 TPD	469.9 TPD
CaCO3 in Product (% mass)	1.04 %	10.33 %	0.01 %
CaO in Product (% mass)	84.3 %	75.7 %	85.2 %
Maximum Mud Temperature	1,706 deg F	1,672 deg F	1,828 deg F
Maximum Mud Surface Temperature	2,230 deg F	2,172 deg F	2,206 deg F
Product Temperature Into Coolers	1,288 deg F	1,505 deg F	1,628 deg F
Flue Gas Temperature	397 deg F	426 deg F	534 deg F
Flue Gas O2 (% vol)	2.0 %	2.0 %	2.0 %
Flue Gas Volumetric Flow Rate	30,496 SCFM*	31,768 SCFM*	35,104 SCFM*
Maximum Axial Average Gas Temperature	2,798 deg F	2,719 deg F	2,750 deg F
Kiln Shell Heat Loss	16.0 MMBtu/hr	16.6 MMBtu/hr	18.4 MMBtu/hr
Average Refractory Temperature	1,457 deg F	1,482 deg F	1,598 deg F
Average Shell Temperature	467 deg F	478 deg F	508 deg F

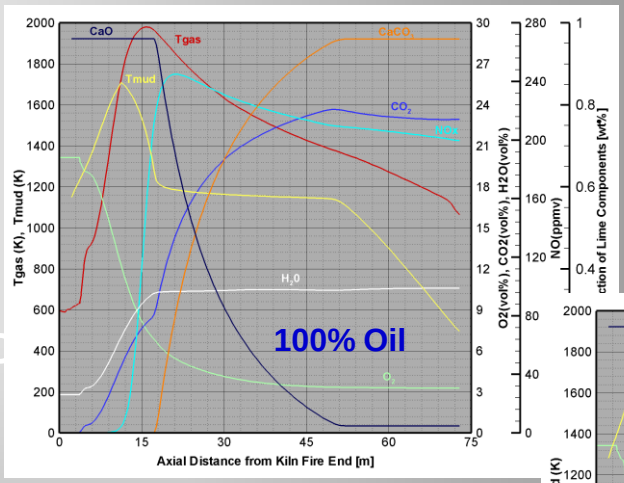
*Standard Conditions: 0 degC and 101325 Pa

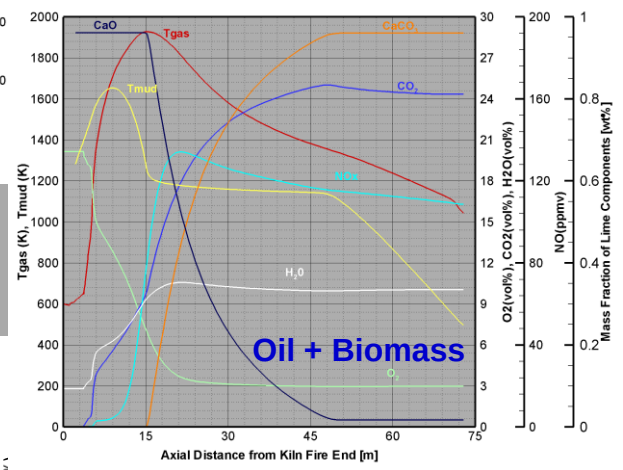
Direct Firing Bark & Lignin in Lime Kilns

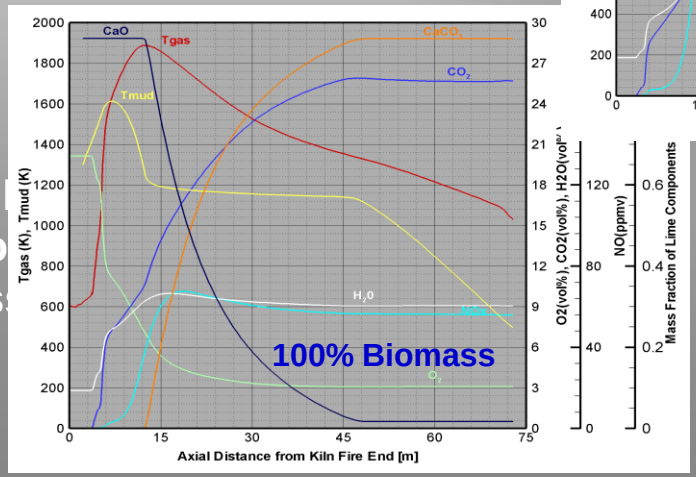












Optimizing Designs for Biofuel Firing

- Dual burner for co-firing wood syngas with gas/oil in kilns
- Dual burner for co-firing solid biofuel with gas/oil in kilns
- Igniter for firing wood syngas in boilers
- Concerned issues: mixing, flame shape and temperature, flexibility for firing rate variation, instability, emissions, etc.

Conclusions

- **Computer modeling provides an effective tool in biofuel research and development.**
- **We expect to work with biofuel producers in their process optimization and scaling up design.**
- **We expect to help biofuel users evaluate the utilization process and optimize the designs.**
- **PSL/UBC look forward to working with you in any kind of ways to make the world greener.**