Biomass Conversion Technologies

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Jackson, MS

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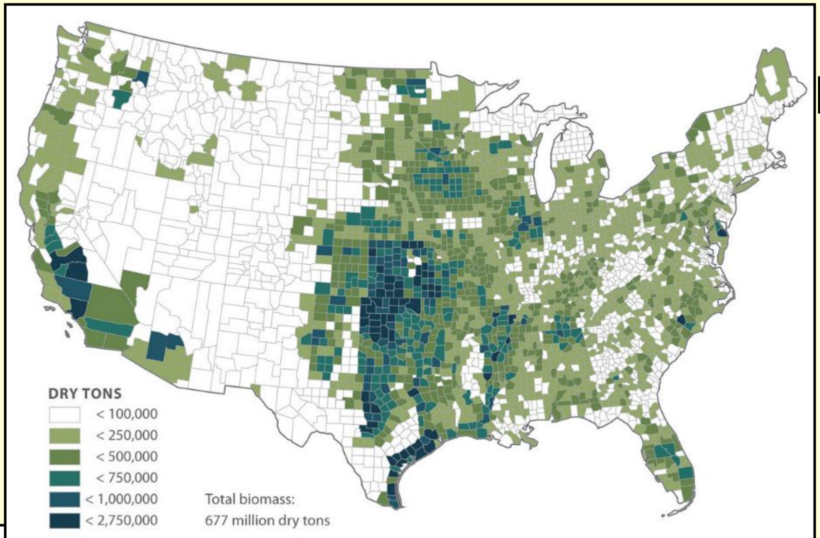
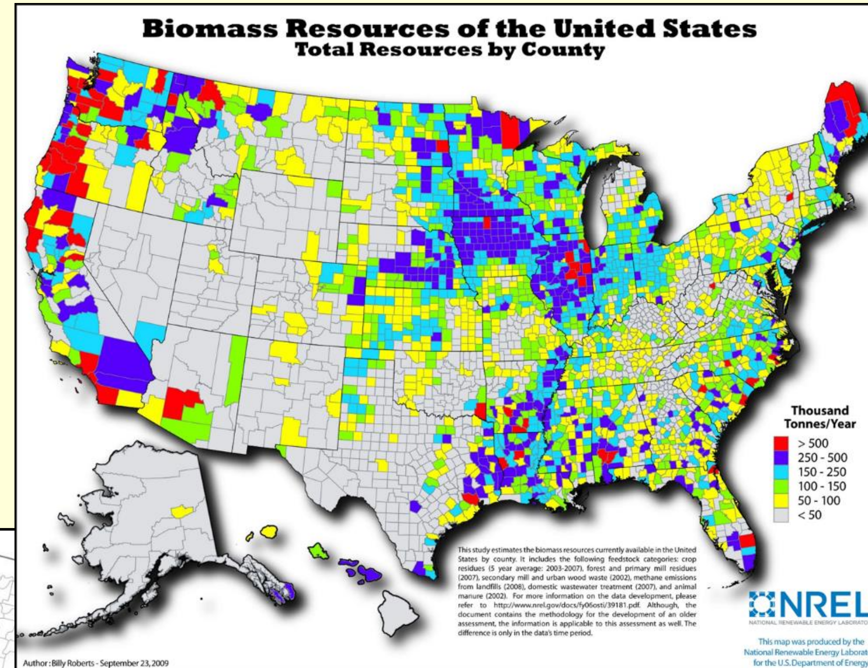
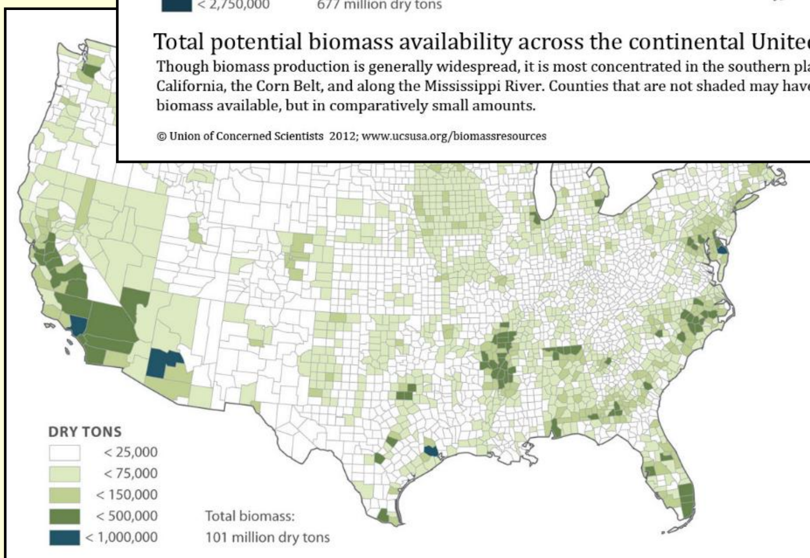
BIOMASS AVAILABILITY IN THE U.S.



Total potential biomass availability across the continental United States

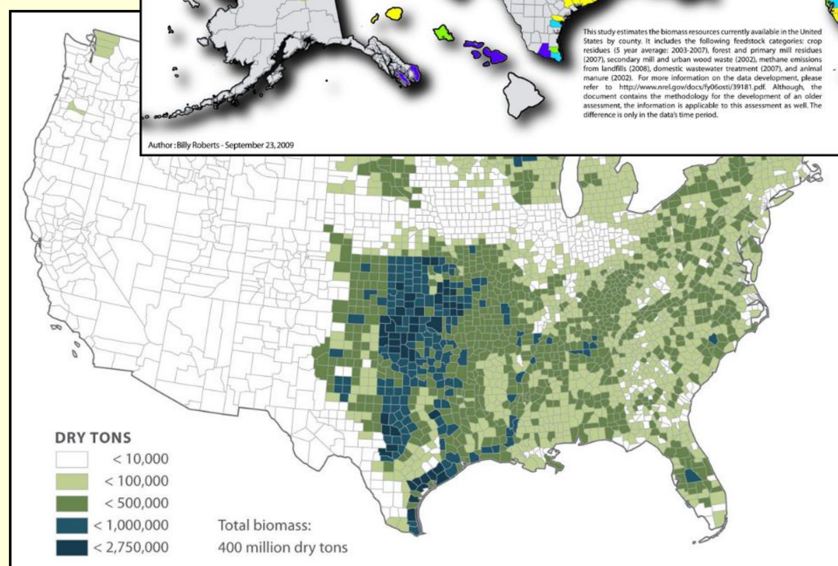
Though biomass production is generally widespread, it is most concentrated in the southern plains, California, the Corn Belt, and along the Mississippi River. Counties that are not shaded may have biomass available, but in comparatively small amounts.





Potential Biomass Resources from Waste Materials

Evident from this map is the concentration of resources in urban centers and certain rural areas where animal agriculture is prevalent

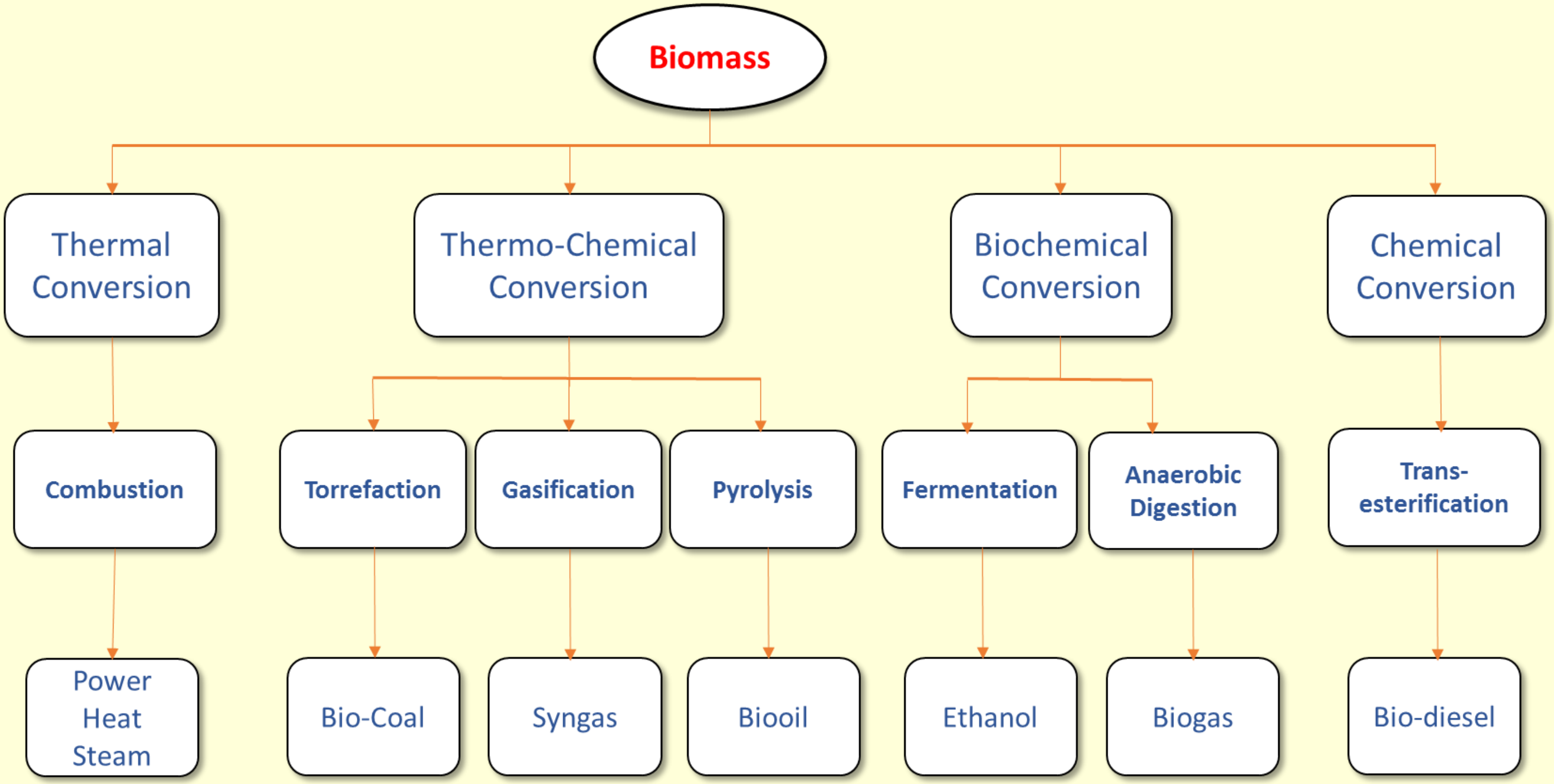


Potential Biomass Resources from Energy Crops

Energy crops could be the largest source of biomass, but time and significant changes in agricultural practices will be needed to produce these crops on the scale shown here.

Potential to produce 732 Billion Kwh
(Appx. 20% of U.S. Power Consumption)

Biomass Conversion Pathways



Chemical/Biochemical Conversion Routes

Transesterification

- Fats/Oils/Grease
- Transesterification of fatty acids in the presence of Catalyst/Alcohol
- Fatty Acid Esters (Biodiesel)/Glycerol

Anaerobic Digestion

- Complex Organic Matter
- Absence of Oxygen, Microbes
- Hydrolysis/Acido-Acetogenesis/Methanogenesis
- Products: Biogas (CH_4 & CO_2)

Fermentation

- Lignocellulosic/Complex Matter
- Enzymatic Hydrolysis/Biological Conversion/Chemical Conversion of sugars
- Products: Ethanol/Fuels

Characteristics of Thermal Conversion Routes

Combustion

- Oxidizing Medium: Air
- Excess than Stoichiometric
- Products: Heat and CO_2

Gasification

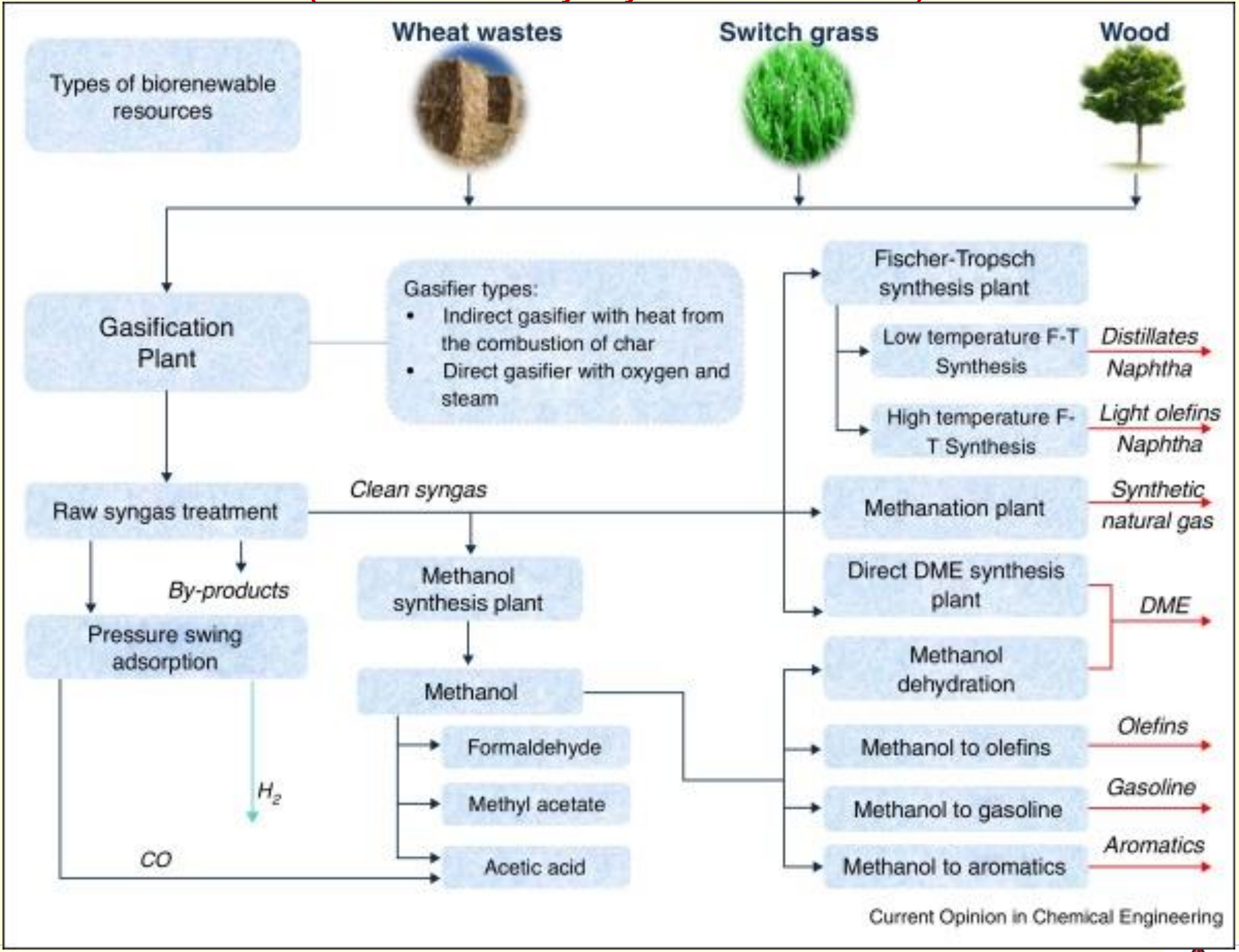
- Oxidizing Medium: Air/Oxygen
- Equivalence Ratio: 0.3
- Products: Syngas and Heat (CO, H_2), CO_2

Pyrolysis

- Oxidizing Medium: None
- Inert Environment
- Products: Bio-oil, Biochar, Torrefied Biomass

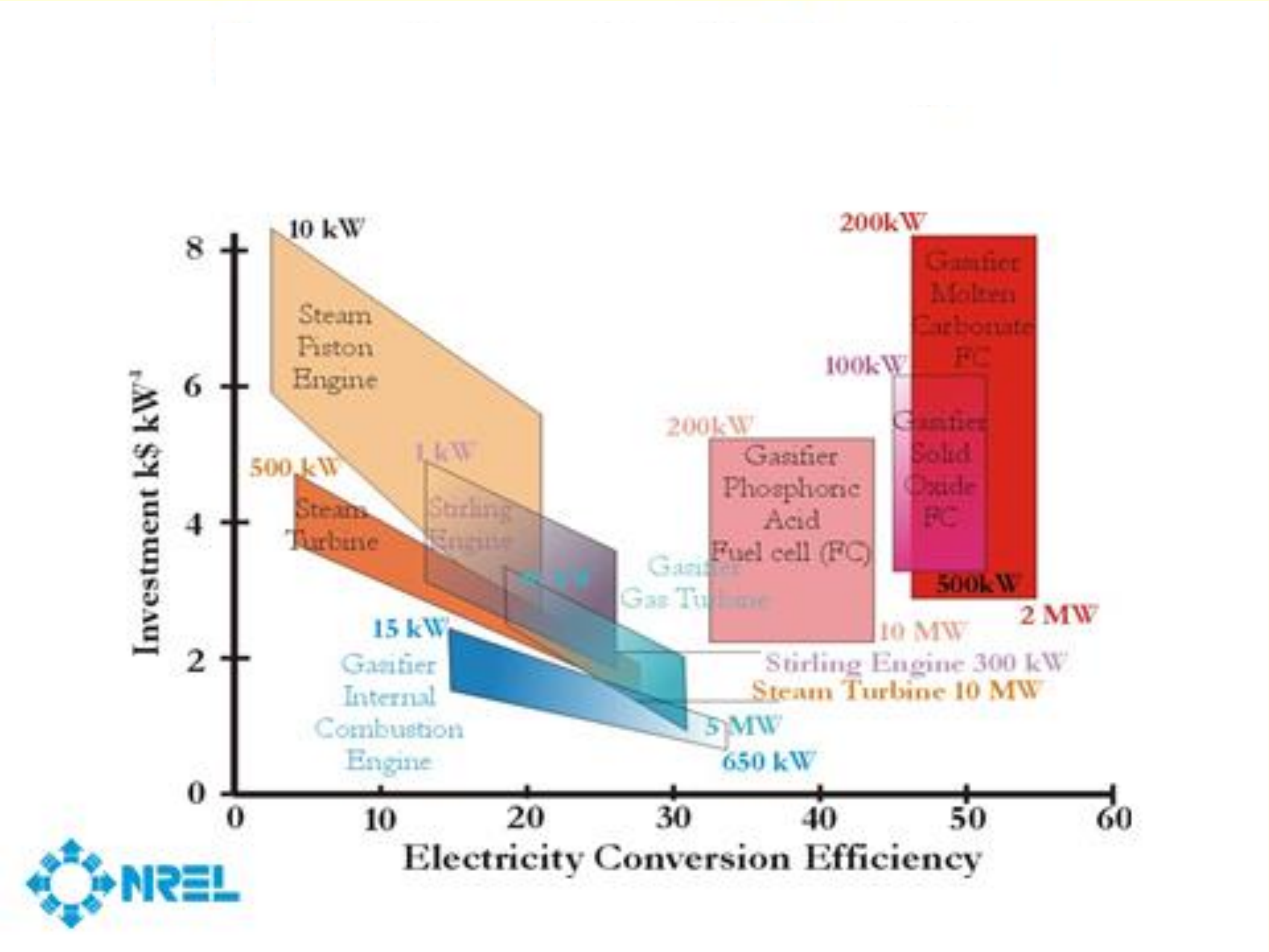
Chemicals and Fuels

(Gasification/Pyrolysis/Biochemical)



*Recent advances in optimal design of thermochemical conversion of biomass to chemicals and liquid fuels, 2105

Power Generation Technologies



Biomass Gasification

Biomass $\rightarrow$ ***CO, CO_2, CH_4, C_2H_4, H_2O, C, Tars***

Oxidation:	$C + O_2 \rightarrow CO_2$	-393 kJ/mol
Partial Oxidation:	$C + 0.5\ O_2 \rightarrow CO$	-123 kJ/mol
Boudard Rxn.:	$C + CO_2 \rightarrow 2\ CO$	+159 kJ/mol
Water Gas:	$C + H_2O \rightarrow CO + H_2$	+118 kJ/mol
Methane Form.:	$C + 2\ H_2 \rightarrow CH_4$	-87 kJ/mol
Methane Ref.:	$CH_4 + H_2O \rightarrow CO + 3\ H_2$	+206 kJ/mol
Water Gas Shift:	$CO + H_2O \rightarrow CO_2 + H_2$	-40 kJ/mol
Dry Reforming:	$CH_4 + CO_2 \rightarrow 2\ CO + 2\ H_2$	+247 kJ/mol

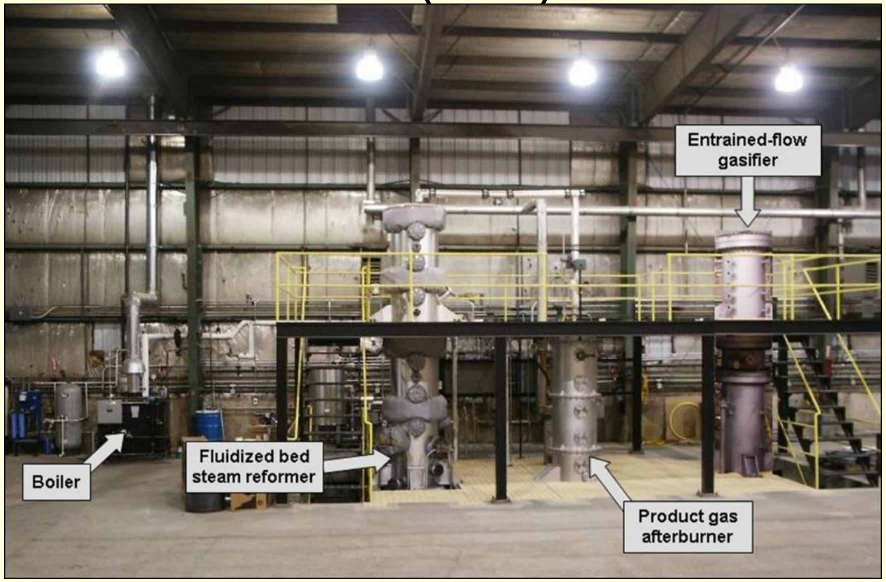
Gasifier Rxn Zones

- Drying
- Pyrolysis
- Oxidation
- Reduction

Syngas HHV (Btu/scf): 80 - 300

Natural Gas (Btu/scf): 950 - 1000

70 lb/hr Biomass Downdraft Entrained Flow Gasifier (Utah)



Gasifier Type (Selection):

- Acceptable feedstock type and size
- Moisture Sensitivity
- Capacity/Scale (Kw-Mw)
- Syngas Quality and Composition
- End Use
- Carbon Conversion and Efficiency

5 MWt Woodchip Bubbling Fluidized Bed Gasifier (Vermont)

1 tpd Downdraft Wood Chip Gasifier (Mississippi)

Cleco/UL Lafayette Gasification System

Gasifier Type	• Bubbling Fluidized Bed • Atmospheric • 250 lb/hr.
Features	• Semi-Portable • Air/Oxygen/Steam • Dual Feed Zones (Wide Feedstock)
Products	• Producer Gas/Syngas • Power • Liquid Fuels/Chemicals

Cleco/UL Gasification System




Air Gasification of Pine Chips

Feedstock evaluated till date include mixed hardwood, pine, oriental stranded board, banding board chips.

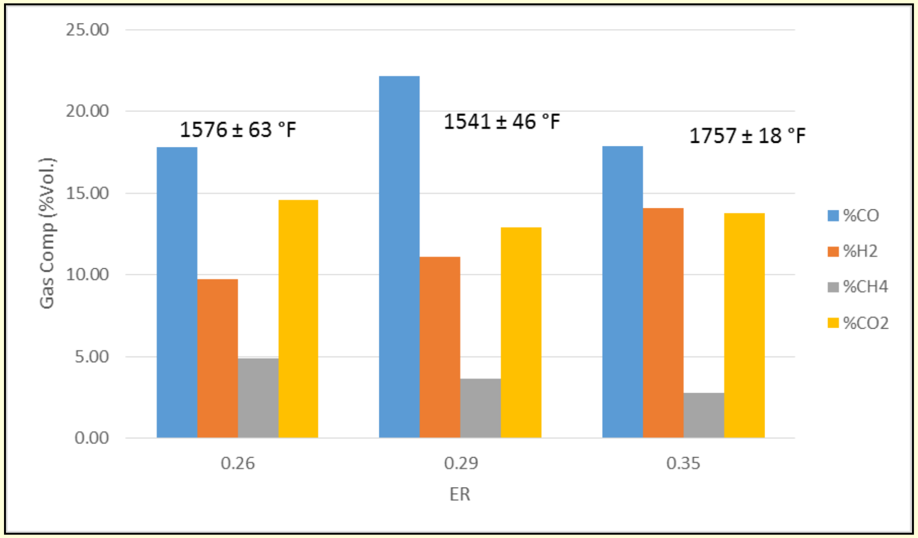
Feedstock Properties

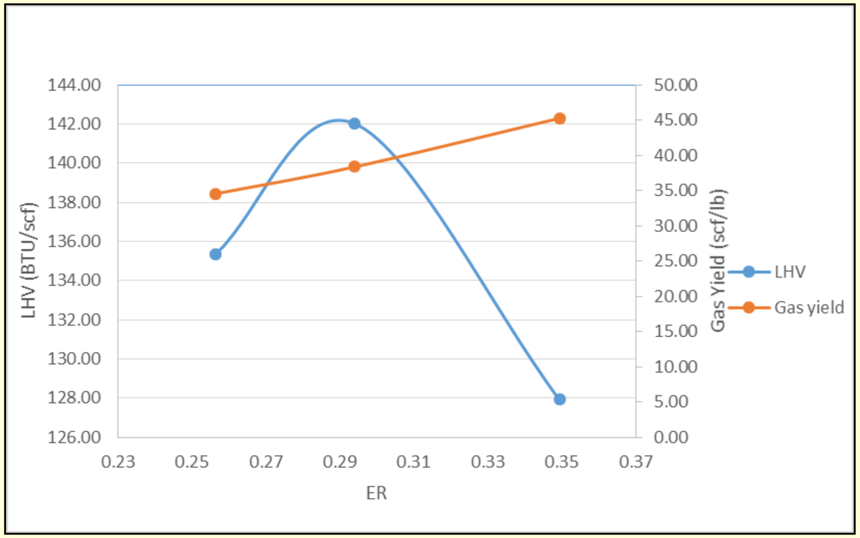
Proximate Analysis		Ultimate Analysis,	
%Moisture Content	10 - 13	% Carbon, $_{daf}$	51.21
% Ash, $_{db}$	0.45	% Hydrogen, $_{daf}$	7.27
% Volatile Matter, $_{db}$	82.40	% Oxygen, $_{daf}$	41.92
% Fixed Carbon, $_{db}$	17.15	% Sulfur, $_{daf}$	0.06
		% Nitrogen, $_{daf}$	0.04
		HHV, $_{daf}$ (MJ/kg)	20.12

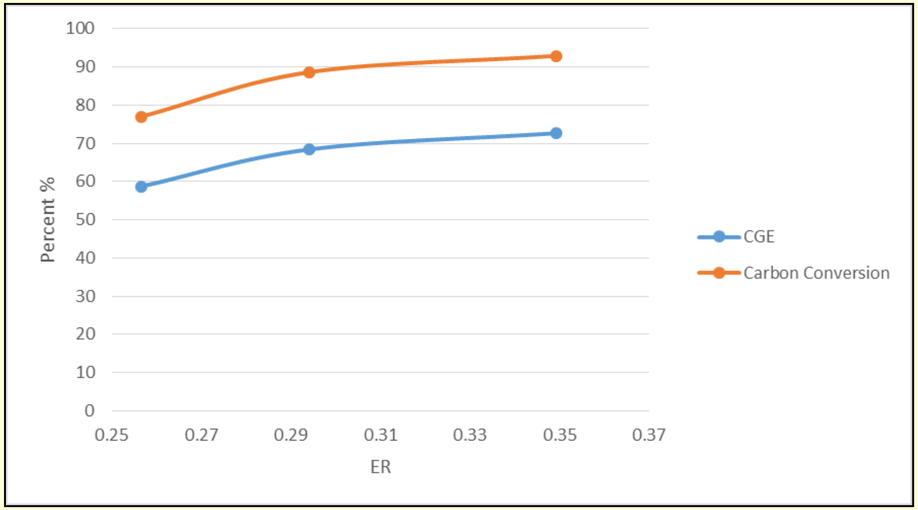
Operating Conditions

Feed Rate	94.0 – 131.8 lb/hr
Moisture Content	11 – 25 %
Equivalence Ratio	0.26 – 0.35
Bed Temperature	1413 - 1770°F
Free Board Temperature	1287 - 1392°F
Bed Velocity	1.2 – 1.5 ft/s
Bed Pressure, psig	0.32 – 2.10 psig
Syngas Production	66 – 79 scfm

Air Gasification of Pine Chips (Representative Data)







Issues with Cofiring Biomass with Coal

- Heterogeneous (Size & Shape)
- Fibrous (Grindability)
- Hydrophilic
- Low Energy Density
- Biodegradable
- High Alkali Metals

Biomass Torrefaction (Mild Pyrolysis)

250-300°C
15-90 mins.

Inert
Atmosphere

Hemicellulose
Decomposition

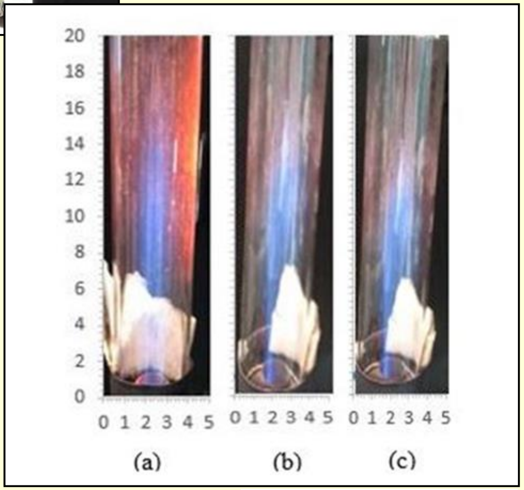
+ Water
Volatiles,
Gases

Untreated Biomass

Torrefied Biomass

Untreated Biomass	Torrefied Biomass
Fibrous	Less Fibrous
Hydrophilic	Hydrophobic
Heterogeneous	Homogenous
6,000-9,000 Btu/lb	9,000-12,000 Btu/lb

0.25 ton/day Indirectly Heated Rotary Torrefaction Reactor



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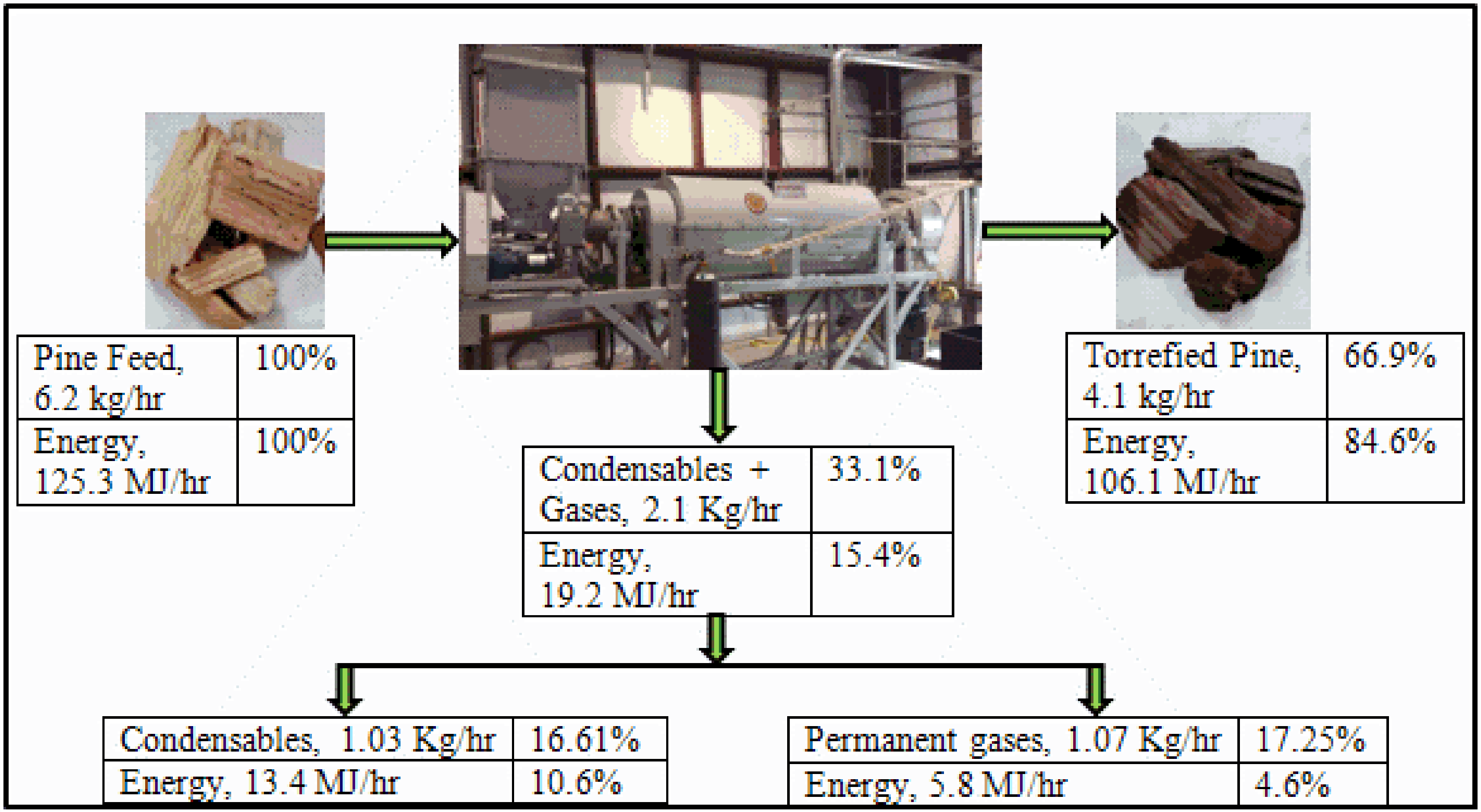
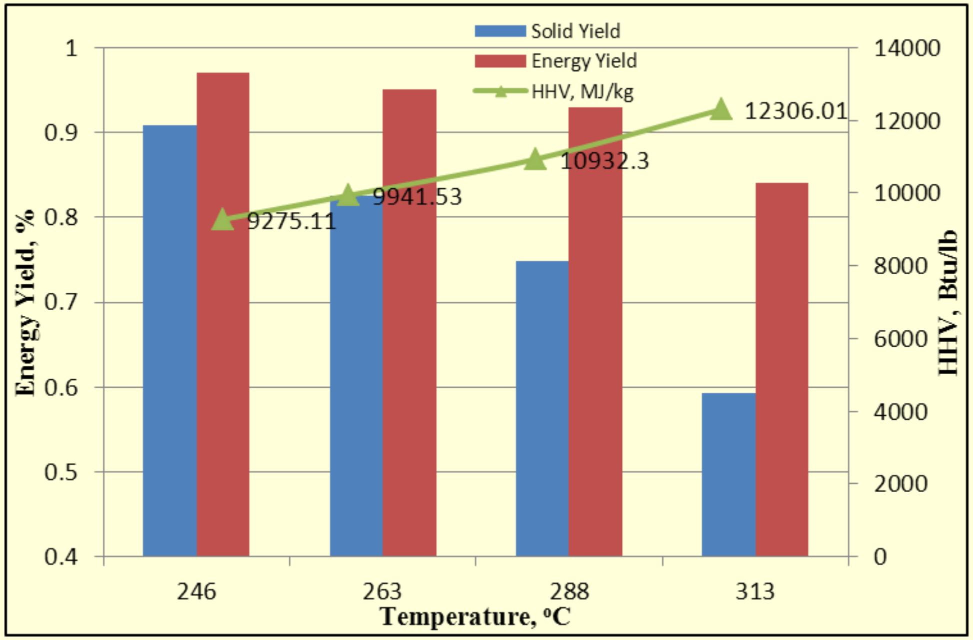
Mass and Energy Balance of Pine on Pilot Scale System



Experimental Conditions - T: 313 °C (308-318 °C), RT: 30 minutes, N_2 – 5 l/min.

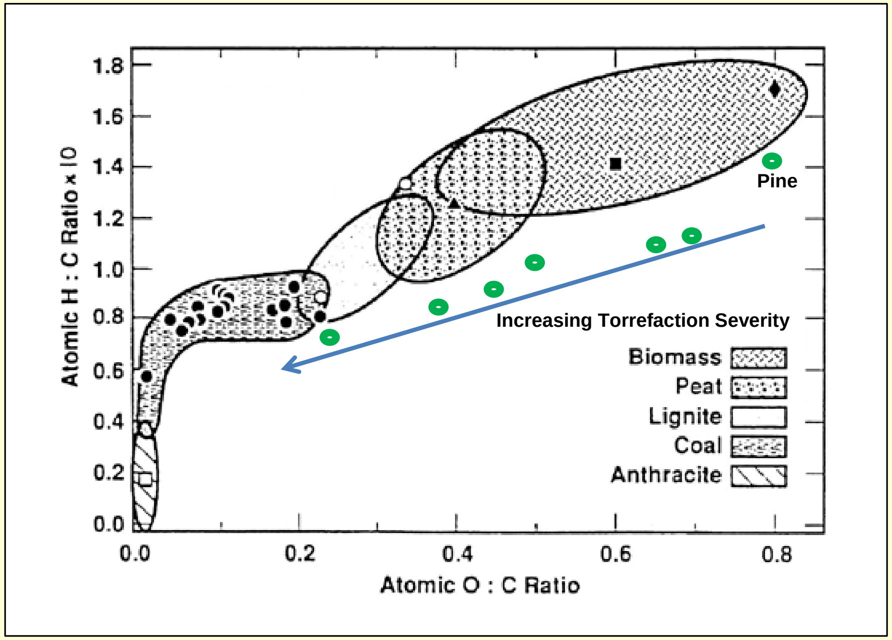
Solid, Energy Yields and HHV of Torrefied Pine

(Variation with increasing temperature, Pine: (8,926 Btu/lb)



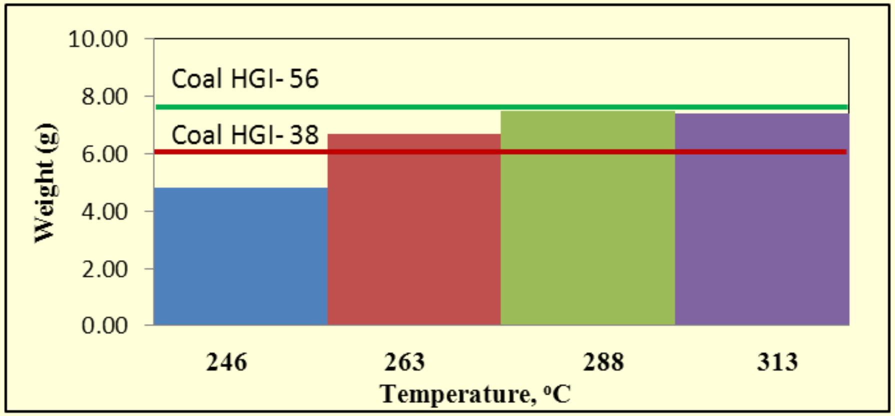
Modified Van Krevelen Diagram

Torrefied Pine (Variation with increasing severity)

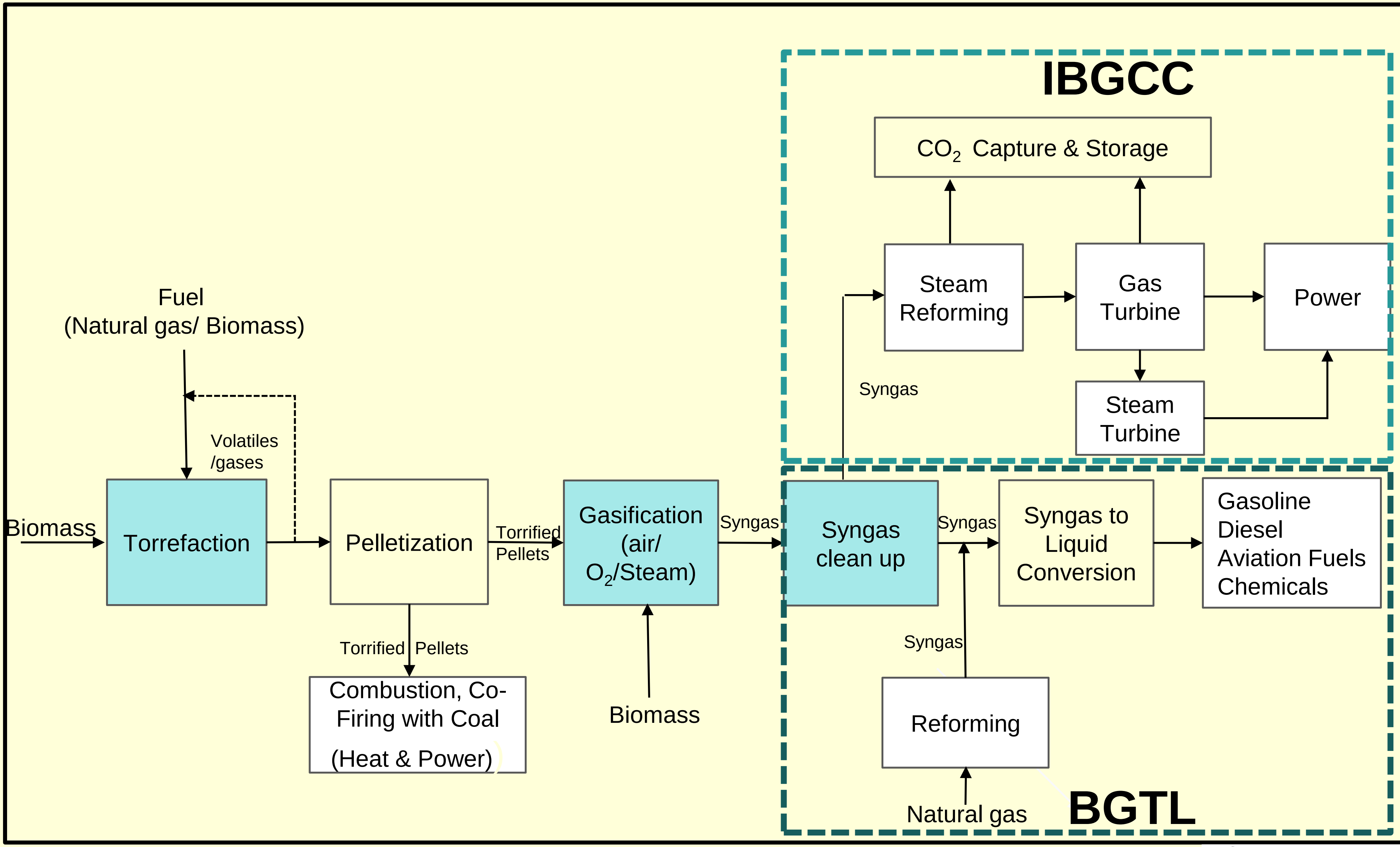


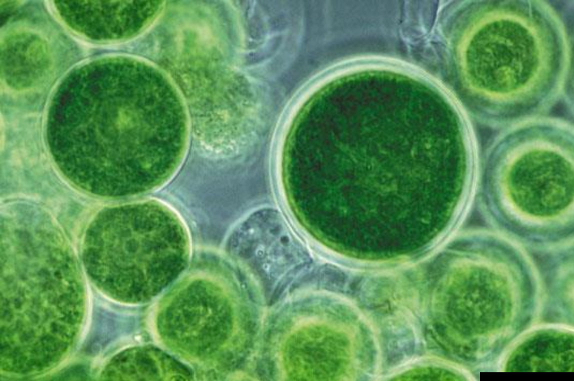
Grindability

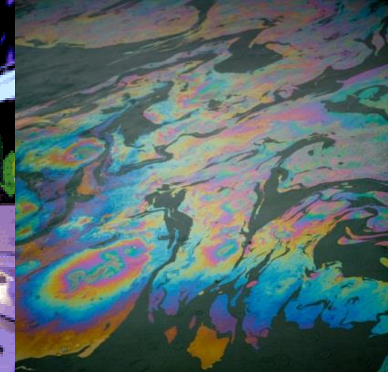
Torrefied Pine (Variation with increasing temperature)



Research Plans/Strategies





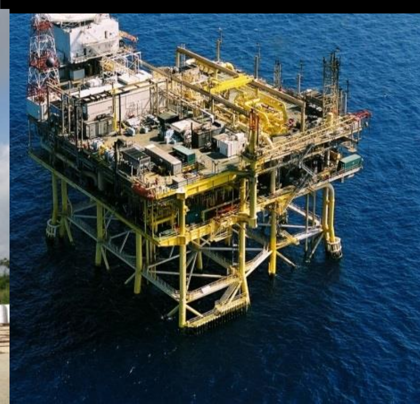


An Introduction to the

ENERGY INSTITUTE OF LOUISIANA

The University of Louisiana
Lafayette, Louisiana, USA





Organizational Structure

Executive Director: Dr. Mark E. Zappi

Associate Director: Dr. Rafael Hernandez

The Energy Institute Of Louisiana

Director: Dr. Boyun Guo

Center for Optimization of Petroleum Systems

OIL & GAS INDUSTRY

Director: Dr. Terry Chambers

Center for Energy Efficiency & Sustainable Energy

POWER PRODUCTION & CONSERVATION

Director: Dr. Rafael Hernandez

Chemicals and Fuels Development Center

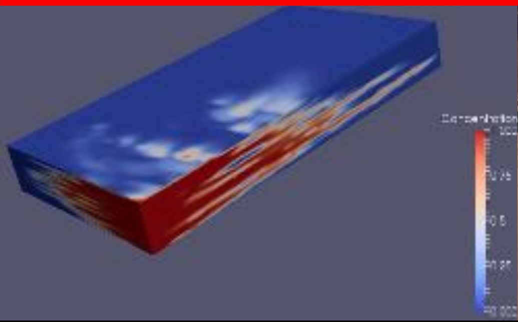
TRADITIONAL & GREEN CHEMICALS AND FUELS

Director: Dr. Mark E. Zappi

Center for Environmental Protection

ECOLOGICAL STEWARDSHIP

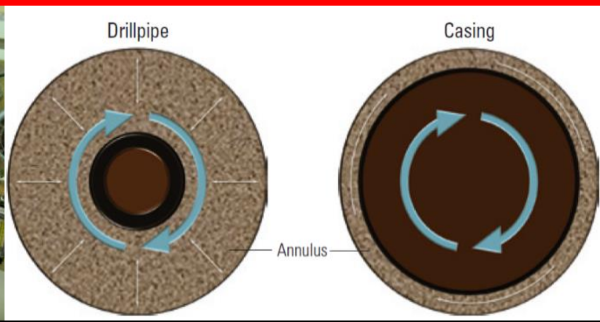
ENERGY RESOURCE DEVELOPMENT



Reservoir Development

Enhanced Oil Recovery

GTL Chemicals



Novel Drilling Methods

Example R&D Interest Areas

Microalgae Biofuels

Green Chemicals

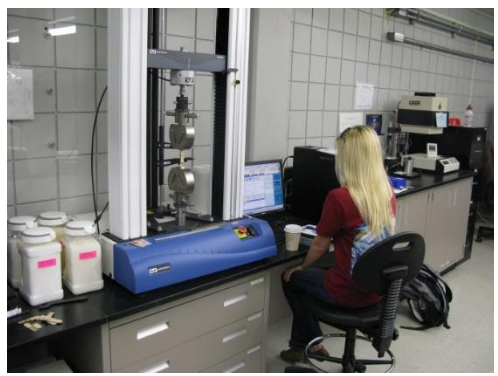
Biocoal

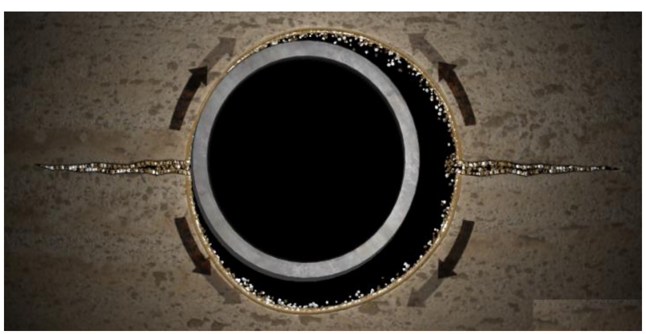
Ethanol

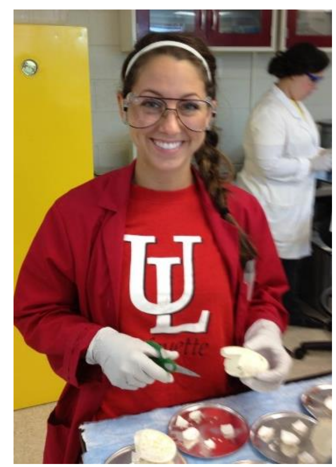
Waste to Watts Processes

TREMENDOUS ON-CAMPUS R&D FACILITY ASSETS

Significant R&D Space & Equipment is On-Campus (over 50,000 sf of R&D laboratories present at UL)

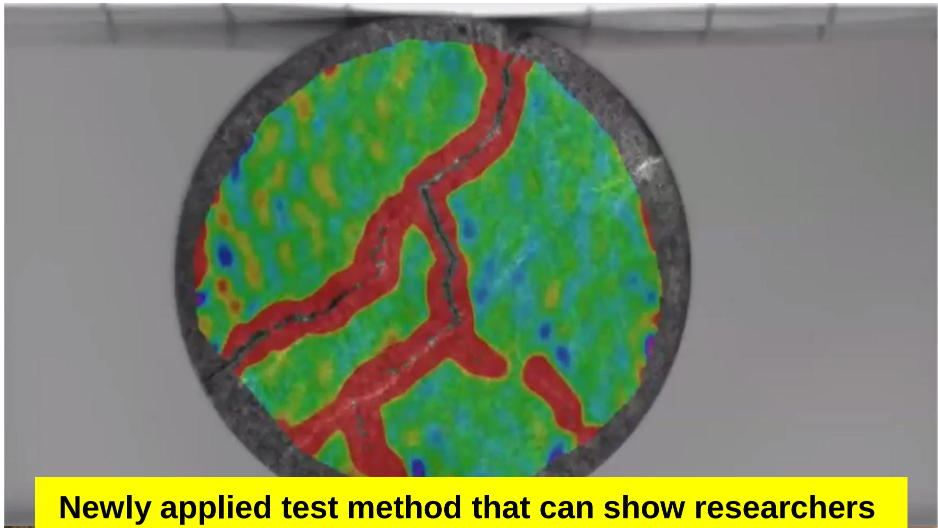






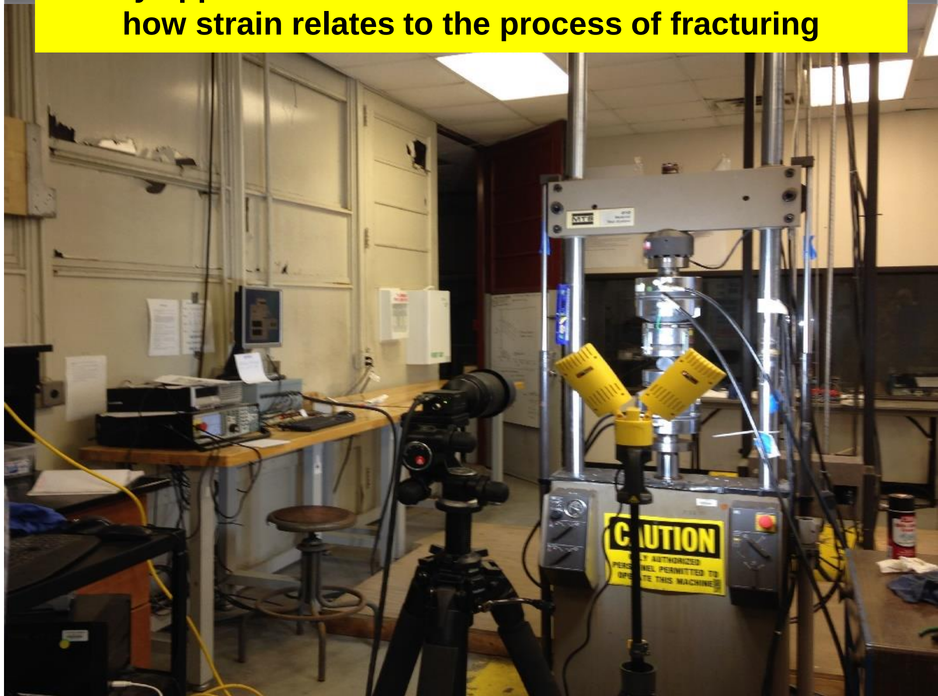
Fracking Research: Performance Optimization Efforts

Optimizing Frack Formations



Newly applied test method that can show researchers how strain relates to the process of fracturing

Test System



Cleco Alternative Energy Center

CLECO

UNIVERSITY LOUISIANA

Large-Scale Testbed at UL for Process Development at the Pilot Scale

- 5 acres R&D facility focusing on pilot-scale evaluation of alternative energy processes
- Over $12M of capital investment (opened in 2012)
- To date, over $5M of R&D projects performed in support of industry and government
- Fully equipped analytical laboratory

PHOTOVOLTAIC APPLIED RESEARCH AND TESTING LAB
$4.5M Grant from NRG
Lead: Dr. T. Chambers (UL Mechanical Engr.)

UNIVERSITY of LOUISIANA LAFAYETTE

PHOTOVOLTAIC
APPLIED RESEARCH AND TESTING
(PART) LAB

PROJECT MANAGERS & DESIGN CONSULTANTS

FENSTERMAKER

Cleco Alternative Energy Center

MOBILE DIGESTION PILOT SYSTEM

(biosolids to lipids & other products)