

Gasification of Agricultural Wastes for the Production of Power and Fuels

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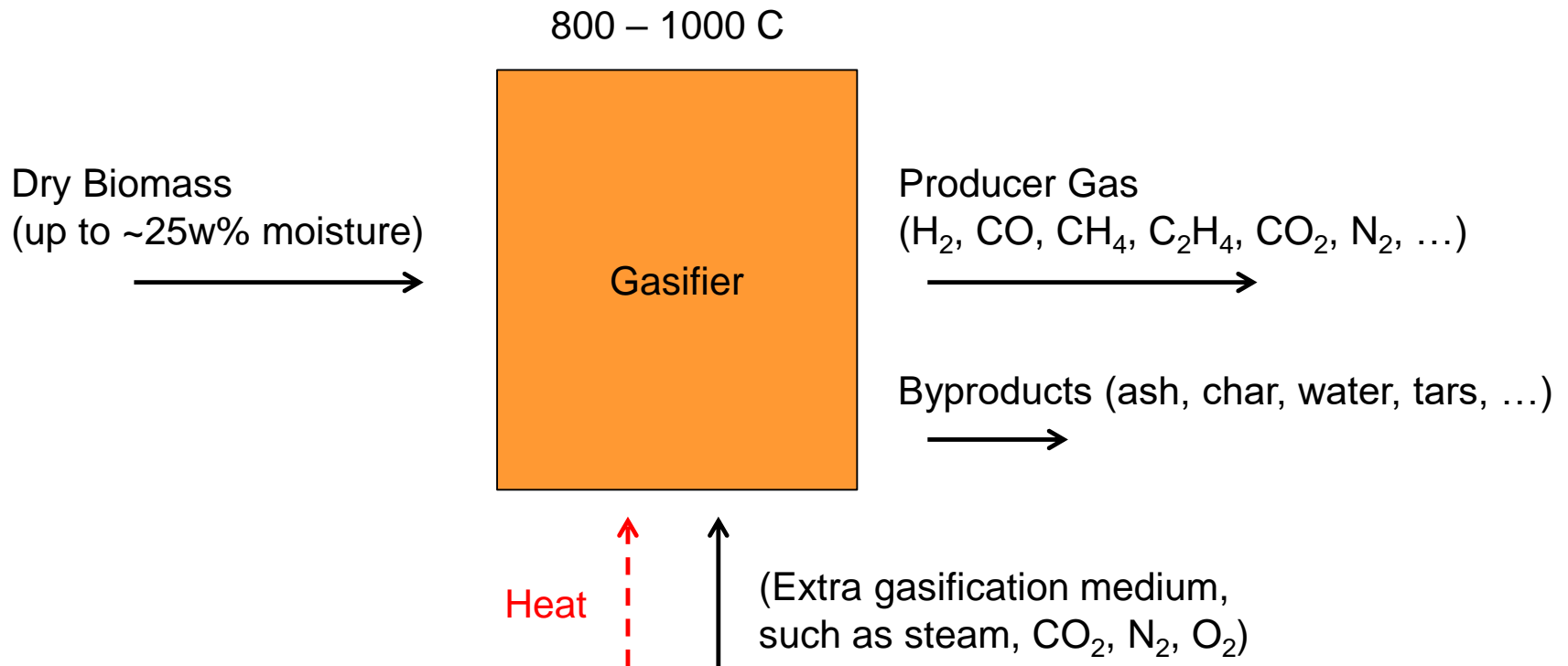
Industrial Ecology Seminar Series

Winter 2018

“The Power of Food and Agricultural Wastes”

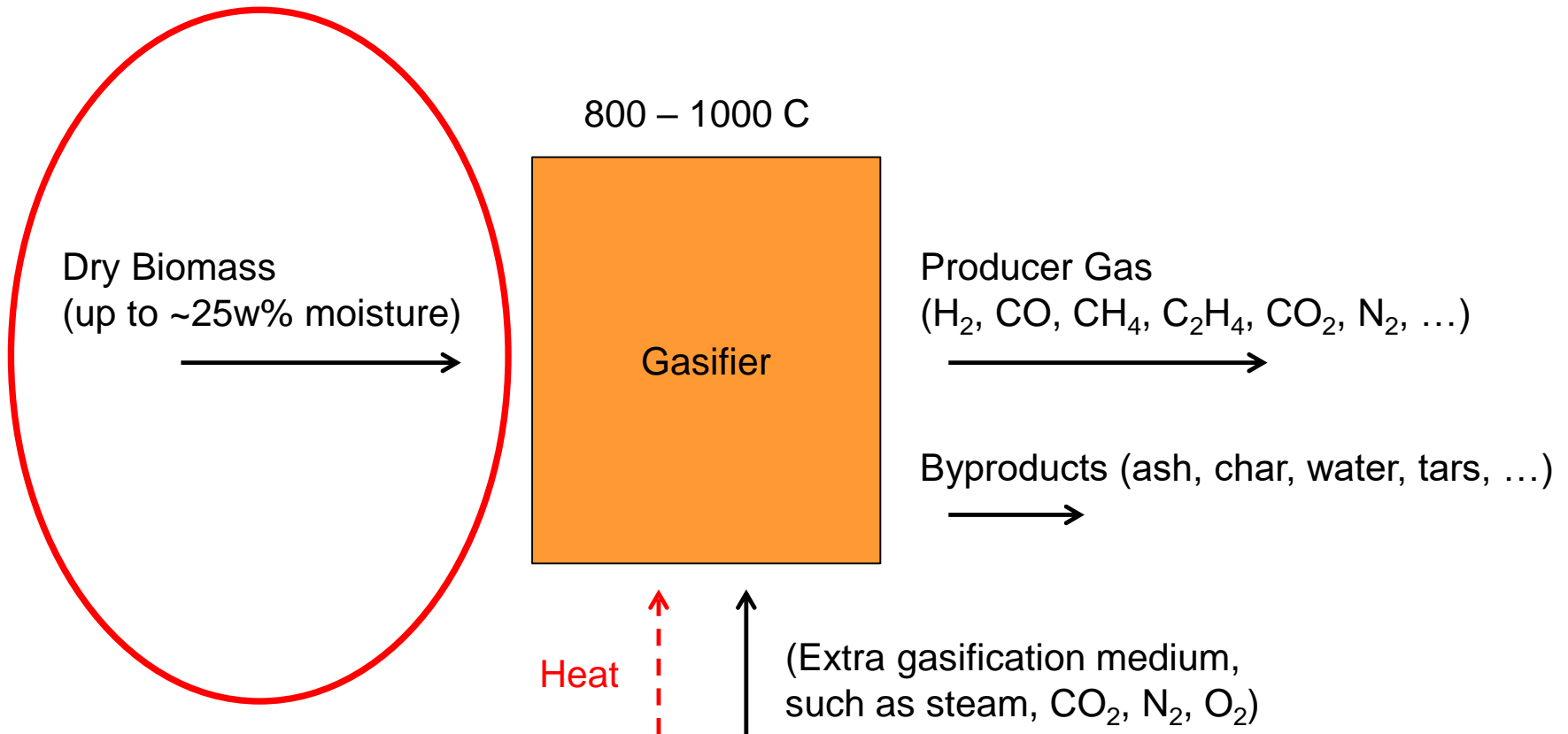
Biomass Gasification

Thermo-chemical conversion process at high temperature to convert biomass to mostly gaseous products.

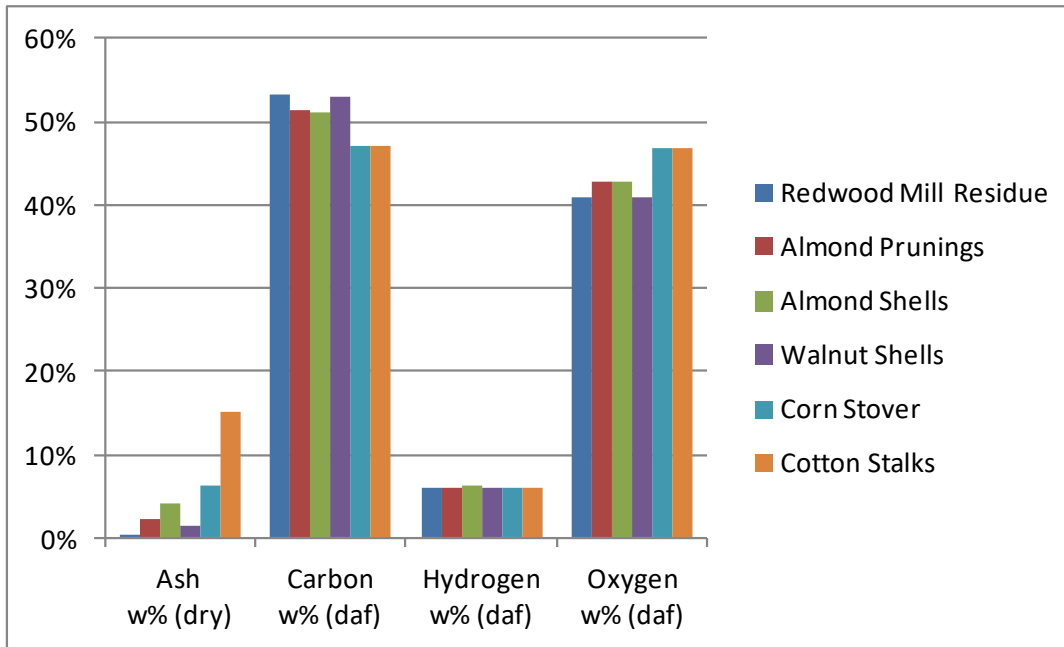


Biomass Gasification

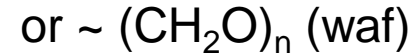
Thermo-chemical conversion process at high temperature to convert biomass to mostly gaseous products.



Composition of Lignocellulosic Biomass



Converted to moles:

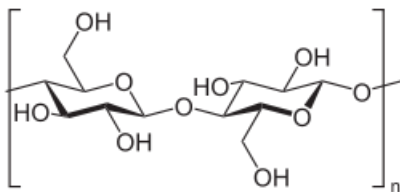


daf...dry and ash free

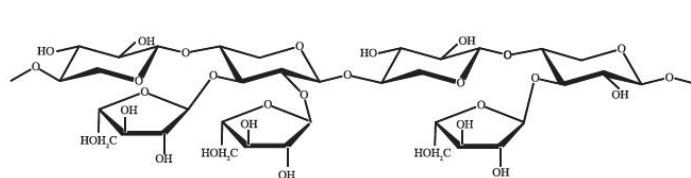
waf...wet and ash free

Ash: Si, K, Na, Ca, Mg, Al, Fe, and other metals.
Inorganics: N, S.

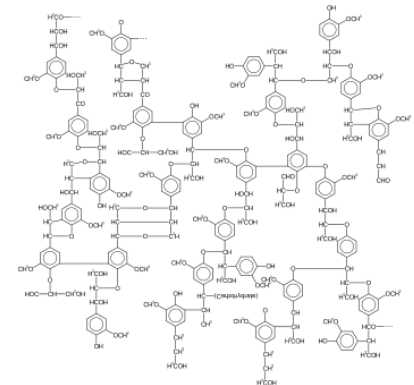
Cellulose ($\text{C}_6\text{H}_{10}\text{O}_5$)_n, 40-50%



Hemicellulose ($\sim\text{C}_5\text{H}_8\text{O}_4$)_n, 20-35%

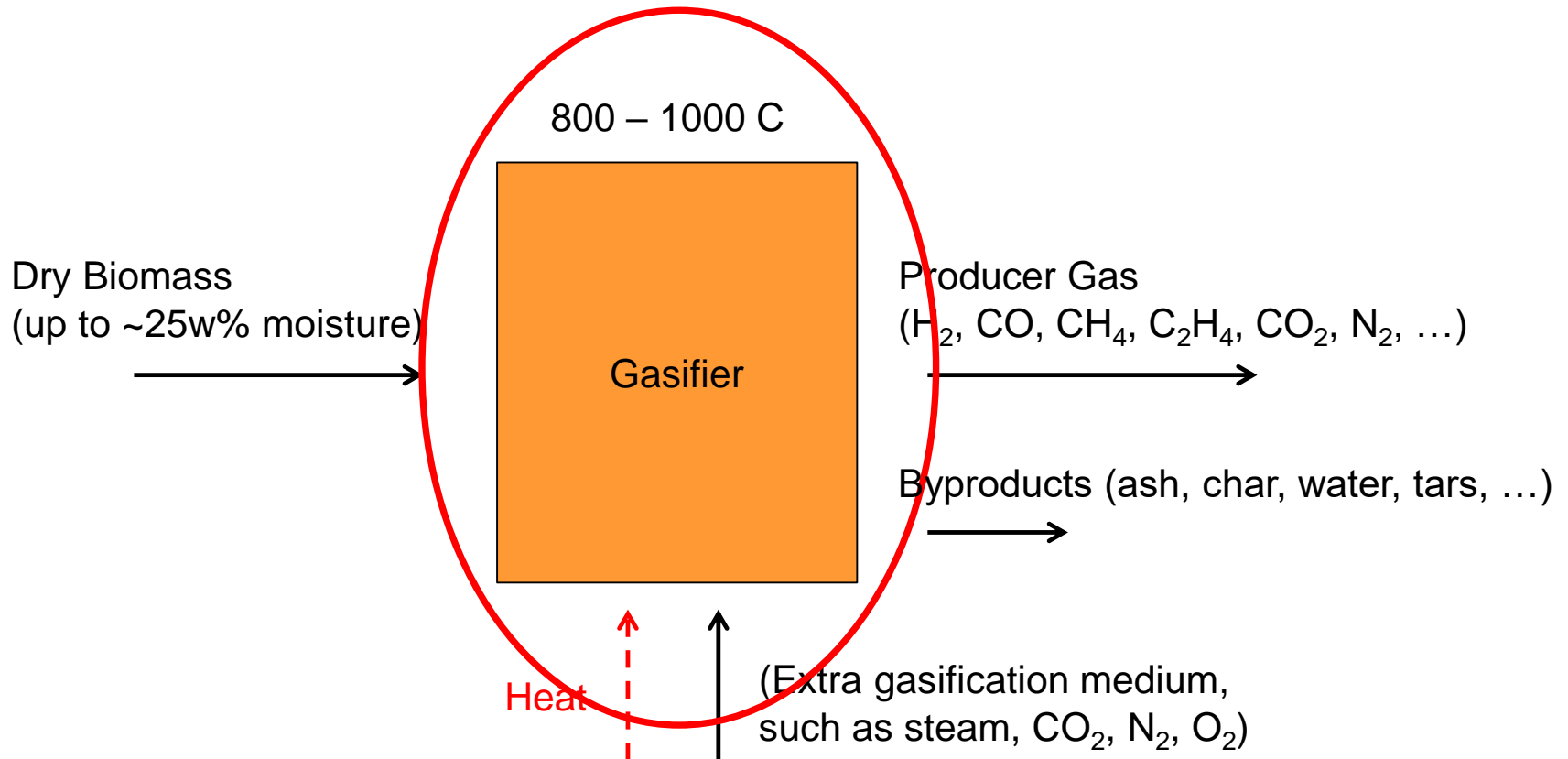


Lignin ($\sim\text{C}_{31}\text{H}_{34}\text{O}_{11}$)_n, 15-35%



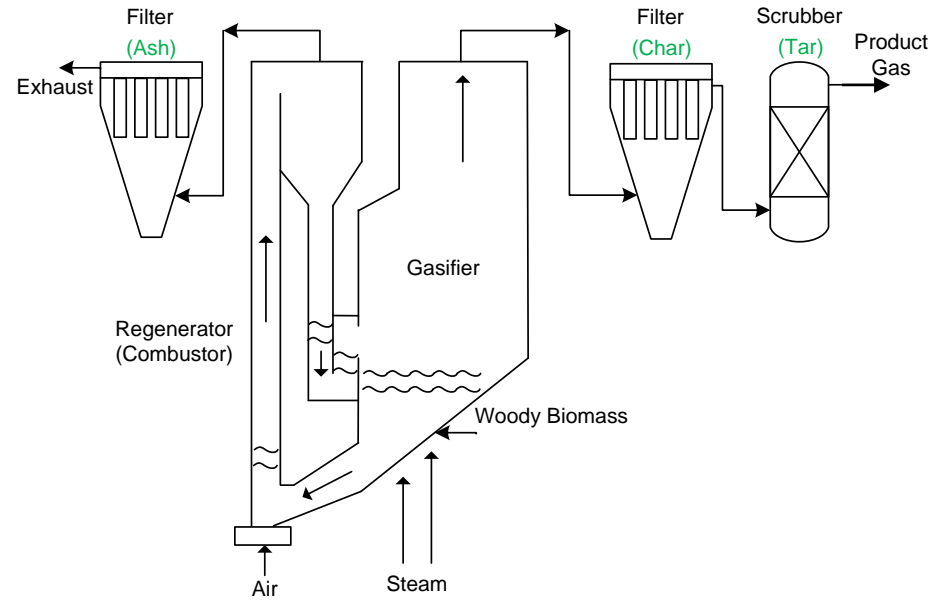
Biomass Gasification

Thermo-chemical conversion process at high temperature to convert biomass to mostly gaseous products.



FICFB Gasifier: Converting Biomass to Producer Gas

- Fast Internally Circulating Fluidized Bed (FICFB)
- Fluidized bed using bed material such as Olivine sand
- Indirectly heated, air-blown, ambient-pressure design.
- Low nitrogen producer-gas, acceptable tar levels.
- Cold-gas efficiency > 70%



Woodland, CA

~1 MW_{fuel}



Research

Burgeis, Italy

~2 MW_{fuel}



CHP

Gussing, Austria

~8 MW_{fuel}



CHP

Senden, Germany

~16 MW_{fuel}



CHP

Gothenburg, Sweden

~32 MW_{fuel}

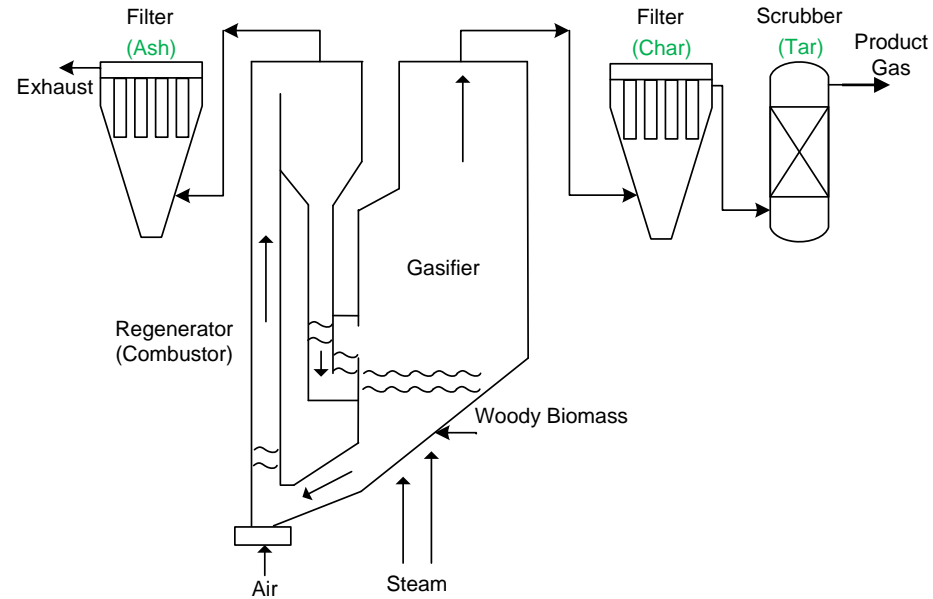


RNG

CHP...Combined Heat and Power, RNG...Renewable Natural Gas

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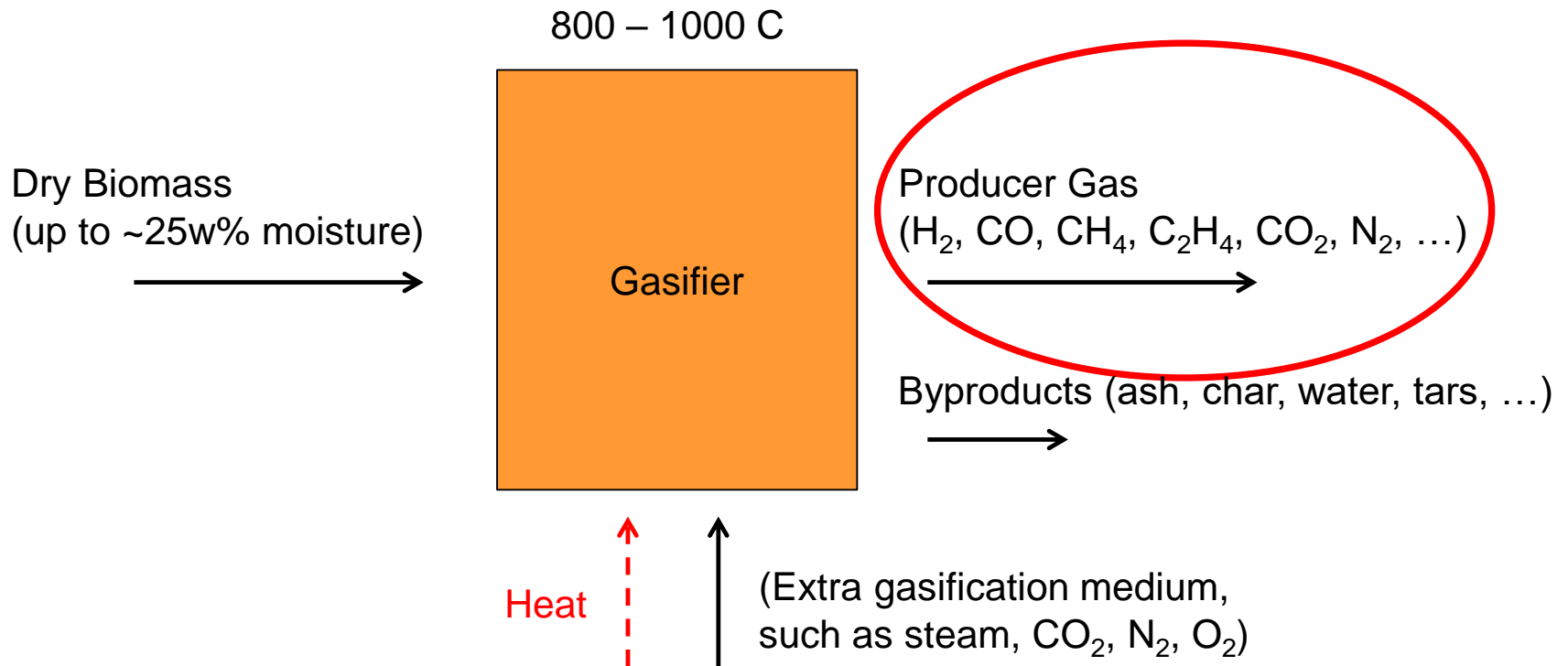
RNG

Currently limited to chipped forest wood and prunings to prevent ash melting

CHP...Combined Heat and Power, RNG...Renewable Natural Gas

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Typical Producer-Gas Composition

(after raw-gas cleanup and cool down, ready for power production in SI-engine)

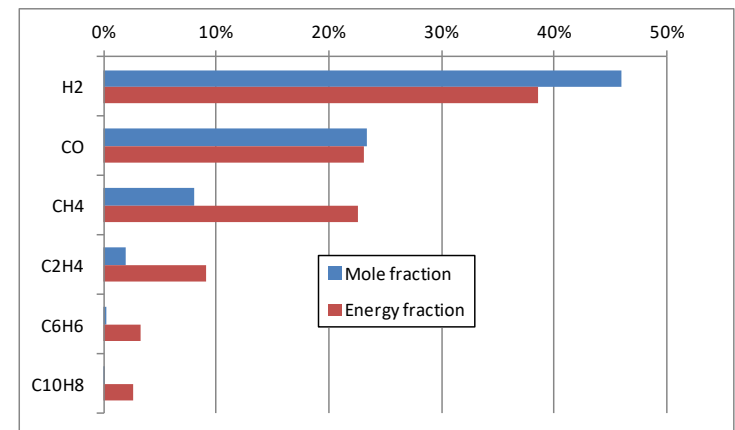
Compound	Chemical Formula	Volume Fraction
Hydrogen	H ₂	0.38
Carbon Monoxide	CO	0.19
Carbon Dioxide	CO ₂	0.22
Methane	CH ₄	0.09
Water	H ₂ O	0.07
Oxygen	O ₂	0.002
Nitrogen	N ₂	0.02
Ethylene	C ₂ H ₄	0.02
Ethane	C ₂ H ₆	0.002
Acetylene	C ₂ H ₂	0.002
Propylene	C ₃ H ₆	100 x 10 ⁻⁶
Benzene	C ₆ H ₆	0.003
Toluene	C ₇ H ₈	100 x 10 ⁻⁶
Naphthalene	C ₁₀ H ₈	0.002
Other Tars		0.001
Ammonia	NH ₃	150 x 10 ⁻⁶
Hydrogen Sulfide	H ₂ S	100 x 10 ⁻⁶
Hydrogen Chloride	HCl	1 x 10 ⁻⁶
Carbonyl Sulfide	COS	3 x 10 ⁻⁶
Thiophene	C ₄ H ₄ S	5 x 10 ⁻⁶
Methyl Mercaptan	CH ₃ SH	50 x 10 ⁻⁹
Carbon Disulfide	CS ₂	30 x 10 ⁻⁹
Benzothiophene	C ₈ H ₆ S	12 x 10 ⁻⁹

Depending on steam (water-gas shift), catalysts, residence time.

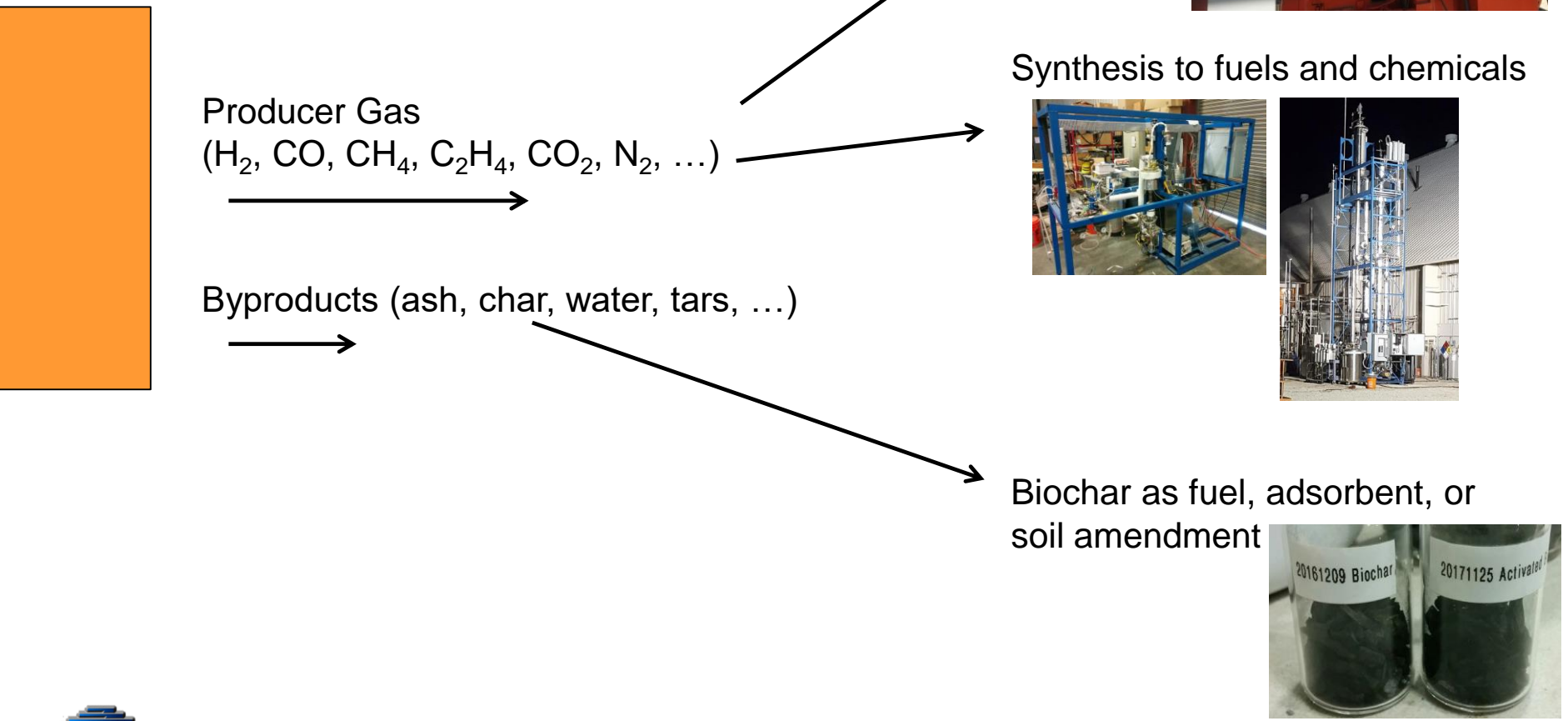
Decrease with increasing temperature, catalysts, residence time

Oxygen-blown or indirectly-heated gasifier for low N₂ content. Nitrogen content of fuel matters.

Depending on biomass composition

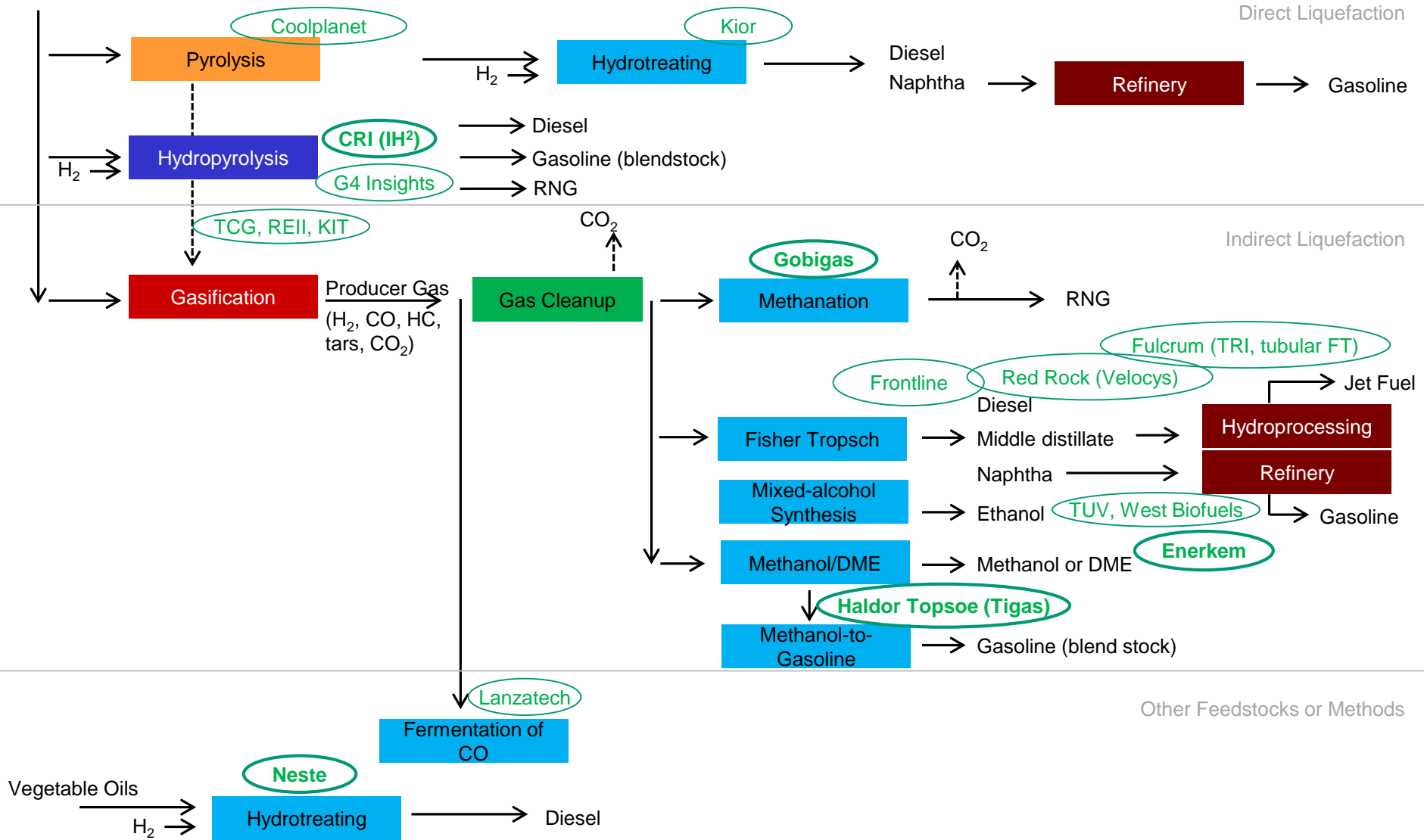


Final Products



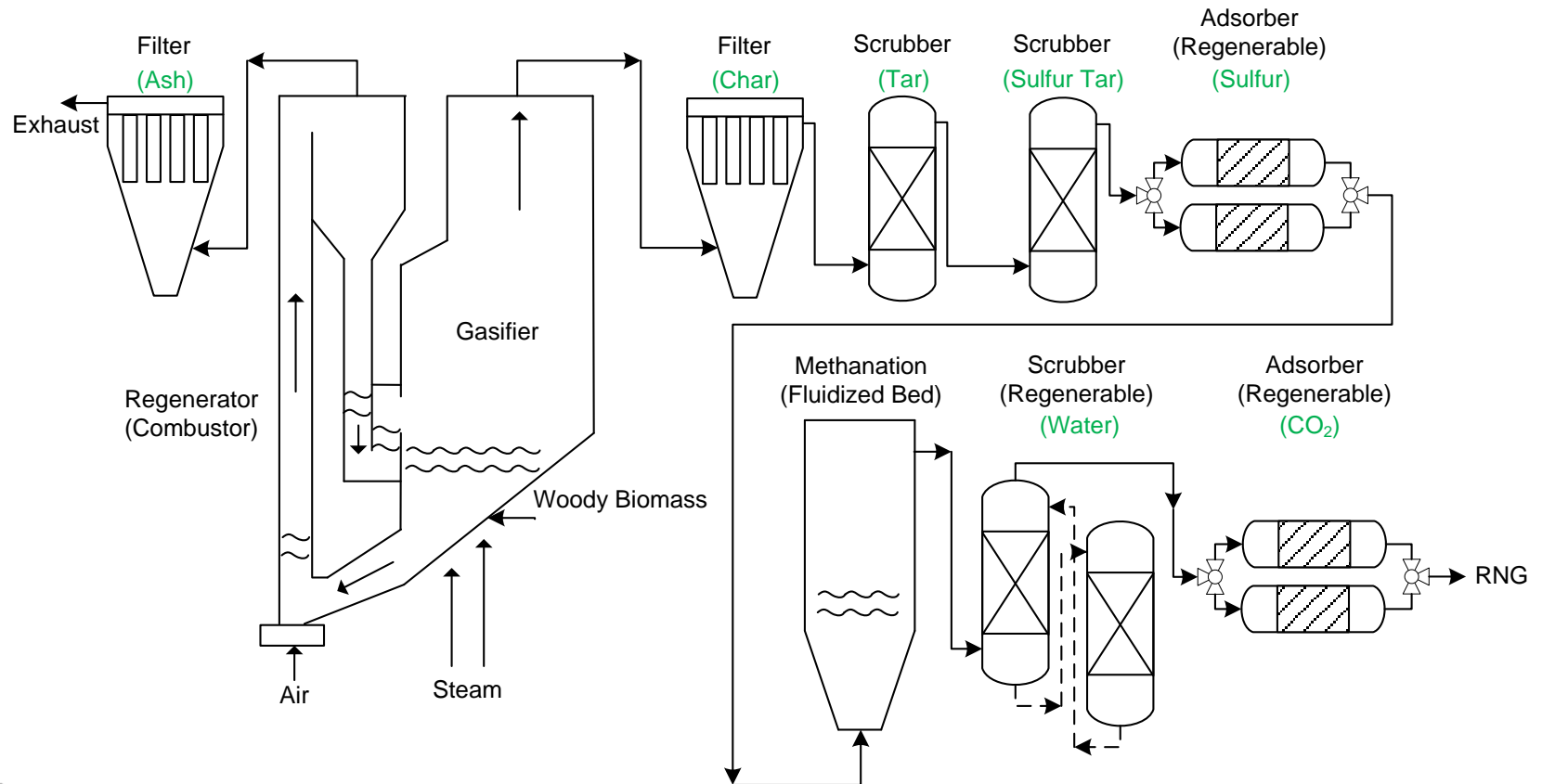
Conversion of Lignocellulosic Biomass to Fuels

Lignocellulosic Biomass

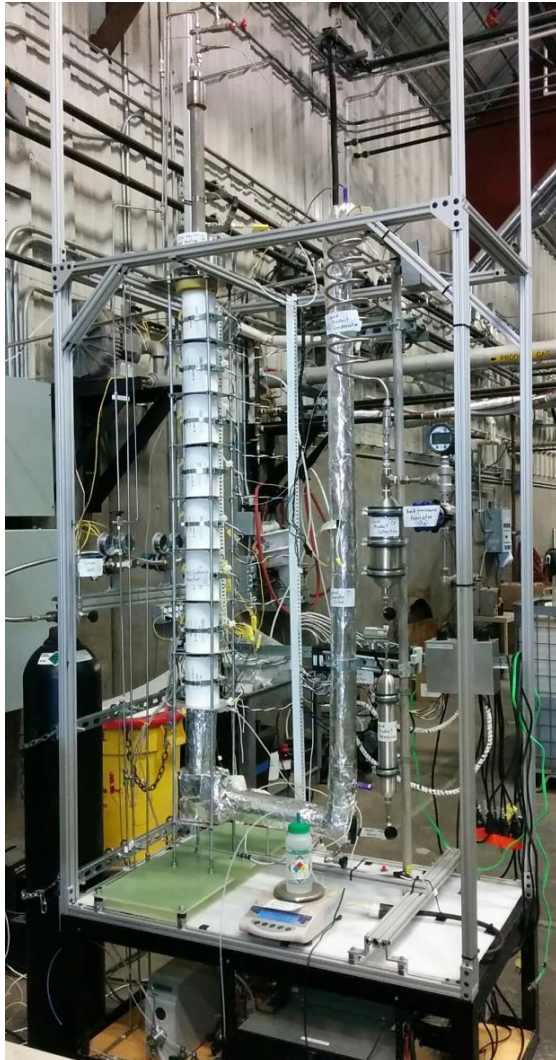


Concept: Fluidized-bed Methanation to Convert Producer Gas to Renewable Natural Gas

- Reducing number of unit operations to a minimum.
- Scrubbing or adsorbing media is either regenerated or sent to the combustor section of the gasifier.
- Fluidized-bed methanation can tolerate olefins and aromatics
- Sulfur removal is necessary and key element

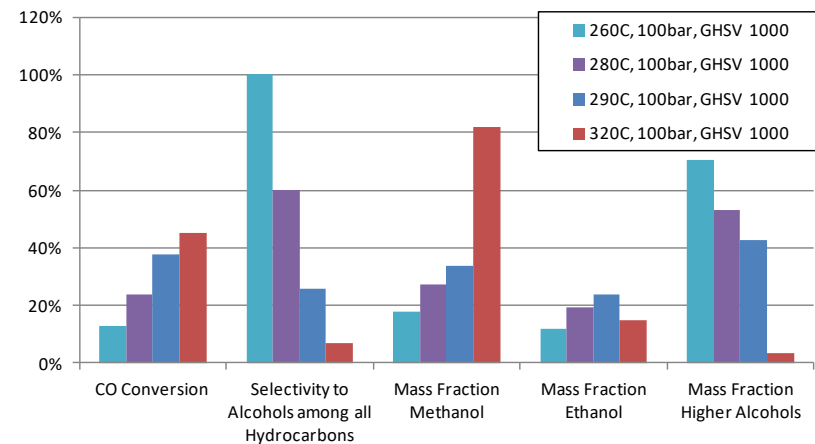


Concept: Mixed-Alcohol Synthesis to Convert Producer Gas to Liquid Product



Bench-scale synthesis reactor at the Woodland Biomass Research Center

- MoS₂ based Catalyst from Albemarle. Similar to “Dow” Catalyst, NREL, Range Fuels.
- Allows for 100ppm of H₂S in the feed gas.
- No further producer-gas cleaning necessary.
- Pressures around 100bar are tested.
- Methanol and tail-gas recycling is investigated.
- Commercially, alcohols and water would be separated by distillation.
- Benchscale, laboratory-scale, and pilot-scale unit.
- Collaboration between UCSD, bioenergy2020+ (Austria), and West Biofuels.



Acknowledgments / Partners



CALIFORNIA
ENERGY COMMISSION



bioenergy2020+

