Biomass to Liquid Hydrocarbon Process via Catalytic Conversion on Carbon Encapsulated Iron Nanoparticles

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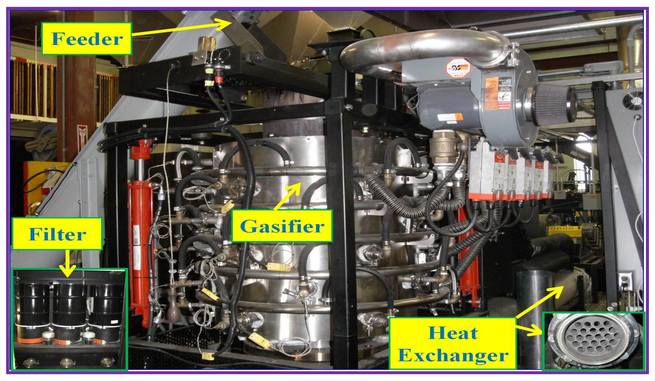
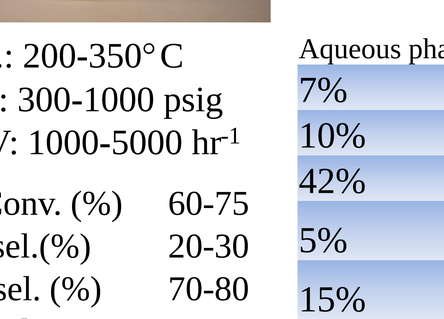
Biomass like wood chips, switchgrass and other plant residues are first converted to syngas through gasification process using air, oxygen or steam. A downdraft gasifier is performed for syngas production in Mississippi State. The syngas from the gasifier contains about 20% H_2, 20% CO, 11% CO_2, and 49% N_2. In addition to the gases listed above, the bio-syngas also contains some tars, ammonia, H_2S, and particulates as impurities. Bio-syngas has to be polished prior to CO hydrogenation to liquid fuels. The purpose of the project is to catalytic upgrade cleaning syngas to higher hydrocarbons and value-added chemicals. A series of catalysts have been developed to produce gasoline, diesel, jet fuels, olefins, higher alcohols and esters. Current work successfully demonstrates the process of biomass to liquid (BTL) fuels via gasification and catalytic conversion.

Biomass Gasification

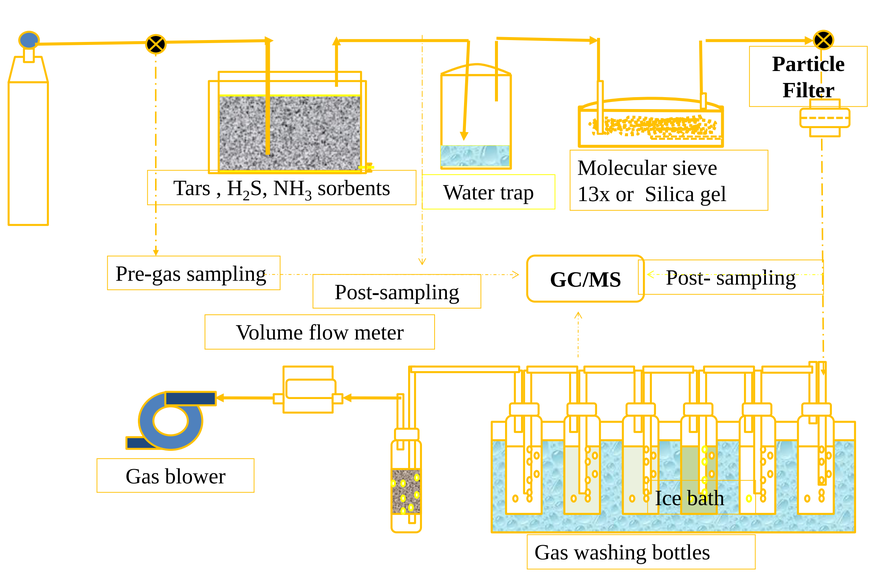


Downdraft Gasifier (BioMax25)
(Capability of 60-120 m^3/hr syngas)



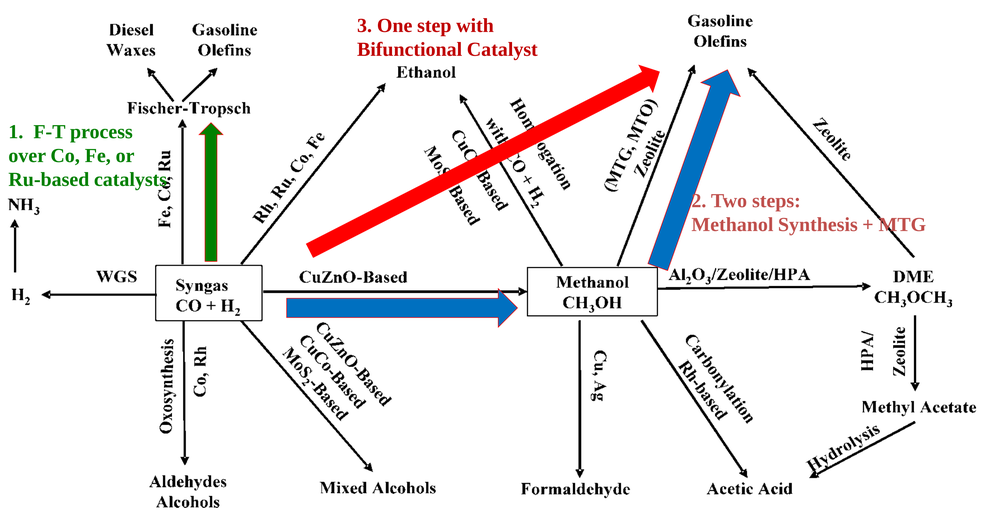
Average Composition of Syngas

Raw Syngas Cleaning



MSU Biosyngas Cleaning System

Catalytic Conversion



Subramani V. and Gangwal S.K. *2008. Energy & Fuels. 22:814–839.*

Catalytic Upgrading Bio-syngas to Liquid Fuels

Gasoline

Temp.: 200-350° C
Press.: 300-1000 psig
GHSV: 1000-5000 hr^{-1}

CO Conv. (%)	60-75
CO_2 sel.(%)	20-30
HCs sel. (%)	70-80
C5+ sel.(%)	40-60

Oil phase components

Olefins	10-15%
Aromatics	30-40%
Paraffins	45-60%

Aqueous phase components

7%	Methanol
10%	Ethanol
42%	Acetone
5%	2-Propanol
15%	2-Butanone

Jet Fuels

Temp.: 200-380° C
Press.: 300-1000 psig
GHSV: 1000-5000 hr^{-1}

CO Conv. (%)	65-85
CO_2 sel.(%)	18-26
HCs sel. (%)	70-80
C5+ sel.(%)	40-60

Oil phase components

Olefins	10-15%
Aromatics	40-50%
Paraffins	35-50%

Aqueous phase components

6%	Methanol
10%	Ethanol
40%	Acetone
6%	1-Propanol
15%	2-Butanone
21%	3-Butyn-1-ol

Diesel

Temp.: 220-400° C
Press.: 200-1000 psig
GHSV: 1000-6000 hr^{-1}

CO Conv. (%)	65-85
CO_2 sel.(%)	18-26
HCs sel. (%)	70-80
C5+ sel.(%)	40-60

Oil phase components

Olefins	1-2%
Aromatics	na
Paraffins	> 96%

Aqueous phase components

5%	Methanol
38%	Ethanol
14%	Acetone
6%	2-Propanol
11%	1-Propanol
9%	propyl ester
4%	2-Butanol
3%	1-Butanol
7%	Pentanone

Olefins

Temp.: 200-350° C
Press.: 200-1000 psig
GHSV: 1000-10000 hr^{-1}

CO Conv. (%)	70-90
CO_2 sel.(%)	15-25
HCs sel. (%)	75-85
C5+ sel.(%)	50-65

Oil phase components

Olefins	30-50%
Aromatics	5-10%
Paraffins	30-50%

Aqueous phase components

12%	Methanol
28%	Ethanol
31%	Acetone
2%	2-Butanol
8%	1-Propanol
4%	2-Butanone
2%	1-Butanol

Oxygenates

Temp.: 200-450° C
Pressure: 200-1000 psig
GHSV: 1000-8000 hr^{-1}

CO Conv. (%)	70-85
CO_2 sel.(%)	10-20
HCs sel. (%)	80-90
C5+ sel.(%)	45-60

Oil phase components

Olefins	10-30%
Aromatics	2-5%
Paraffins	20-70%

Aqueous phase components

7%	Methanol
16%	Ethanol
24%	isopropanol
19%	1-Propanol
2%	Butanal
7%	2-Butanone
2%	Esters
8%	1-Butanol
2%	1-Pentanol
7%	Acetic acid

Conclusions

A series of catalysts have been prepared and evaluated for catalytic converting nitrogen-rich syngas to liquid fuels and oxygenates like gasoline, jet fuels, diesel, olefins, and higher alcohols.
Different liquid products are obtained by tuning the catalyst recipes and operation conditions.