22.033
Biofuels Presentation

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Overview

- Our Goal
- House of Quality
- Comparison of Biomass Sources
- Possible Uses & Processes
- Comparison of Inputs
- Comparison of Outputs
- Conclusion

Our Goal

As a group, we intend to design a biofuels plant which:

1. Maximizes our fuel output
2. Couples with hydrogen production
3. Uses the the resources (electricity, heat, etc.) from the nuclear plant.

House of Quality

Customer Requirements
- Carbon emissions
- Fuel Demand
- Fuel Output (Quantity)
- Competition with Food Suppliers
- Cost of Fuel Produced
- Quality of Fuel Produced (Energy Density)

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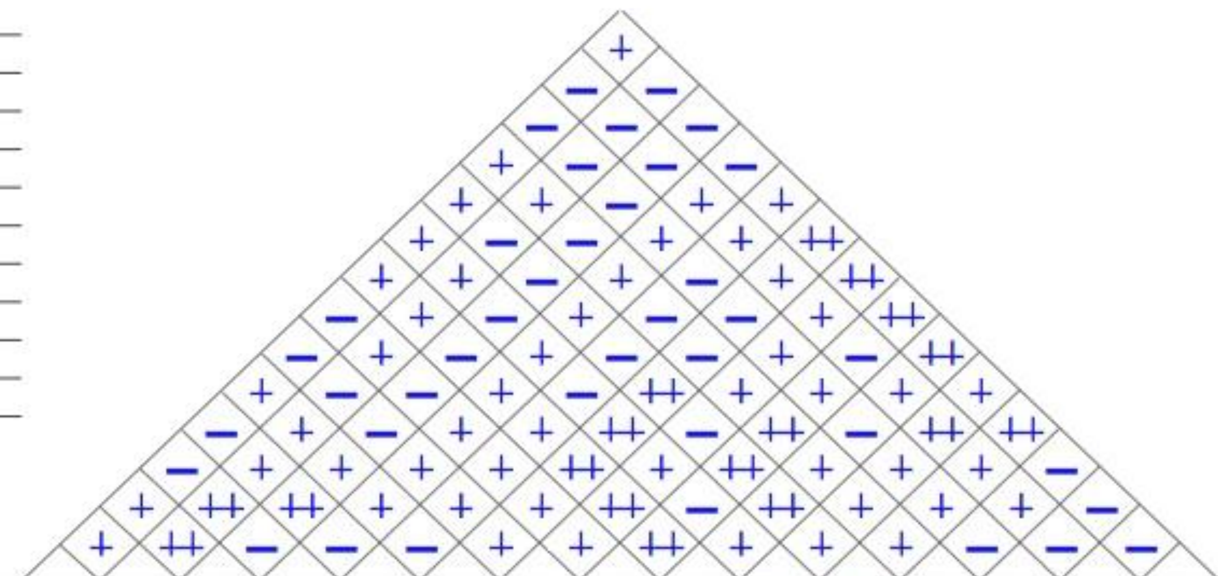
W., Matt C., Kathryn H., Uuganbayar O.



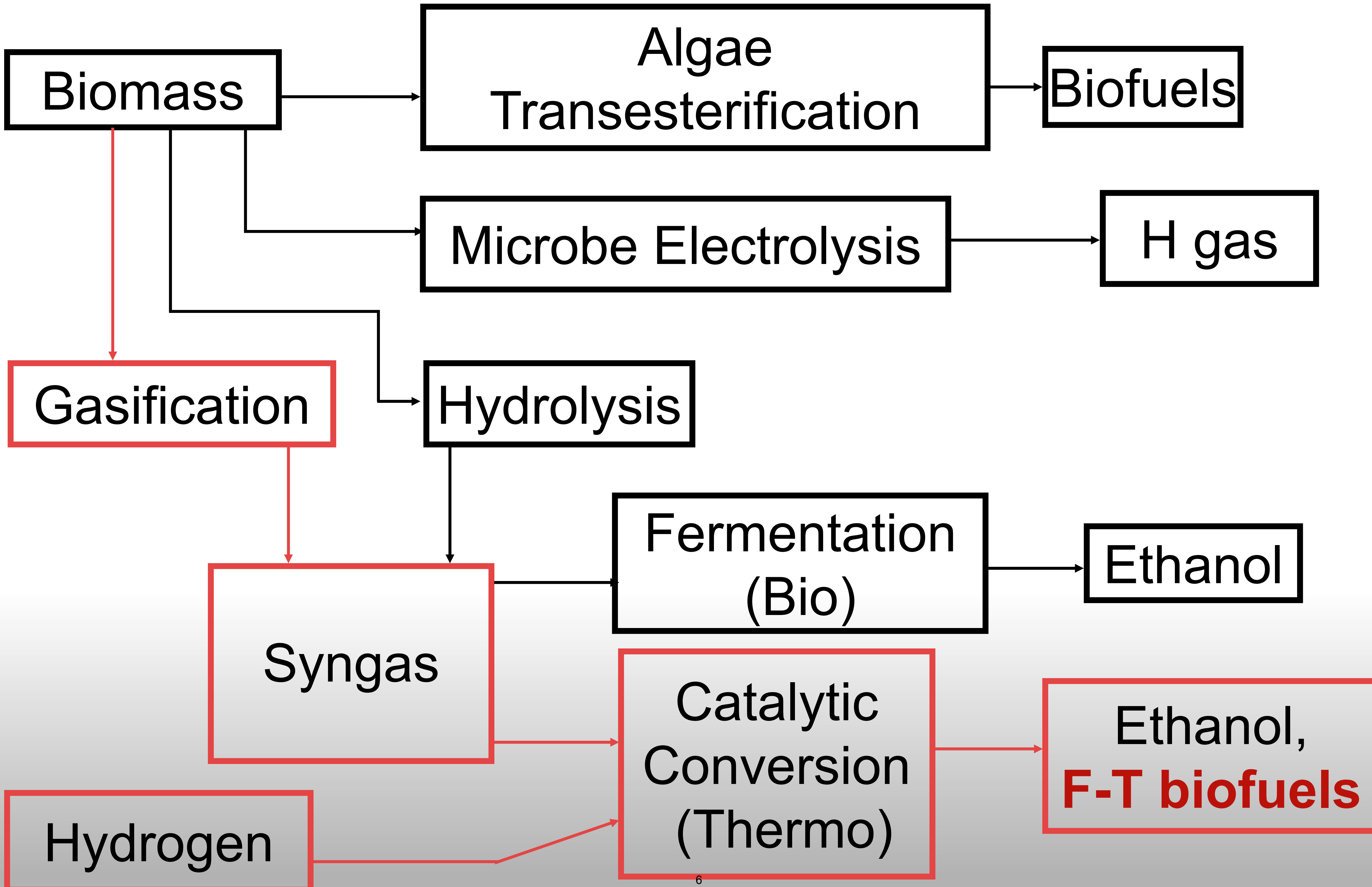
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)																
Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Plant Lifetime	Maintenance	Training	Electricity Input	Licensing	Capital Costs	Useful Byproducts	Waste/Useless Byproducts	Waste Storage	Complexity	Land Requirements	CO2 Emissions	Hydrogen Requirements	Steam/Temperature Requirements	Storage	Our Company: Team 22.033
Carbon Emissions							Θ	Θ	Θ	O		Θ				
Demand of Fuel		O					Θ	▲		O	O		Θ			
Fuel Output/Quantity		O		Θ						O	O		O			
Cost of Electricity				▲		Θ	▲		▲		▲			▲		
Environmental Impact	▲				Θ	▲		Θ	Θ	O	Θ	Θ	▲			
Competition with Food Suppliers					Θ	O	▲				Θ					
Government Subsidizing	▲				Θ	O		Θ	Θ		Θ	Θ				
Cost of Fuel Produced		▲		▲			O			▲			O	▲		
Quality of Fuel/Energy Density (i.e. in relation to fossil fuels, etc.)		O					▲			O			Θ			
Fuel Efficiency																

HoQ template courtesy of QFD Online. Used with permission.

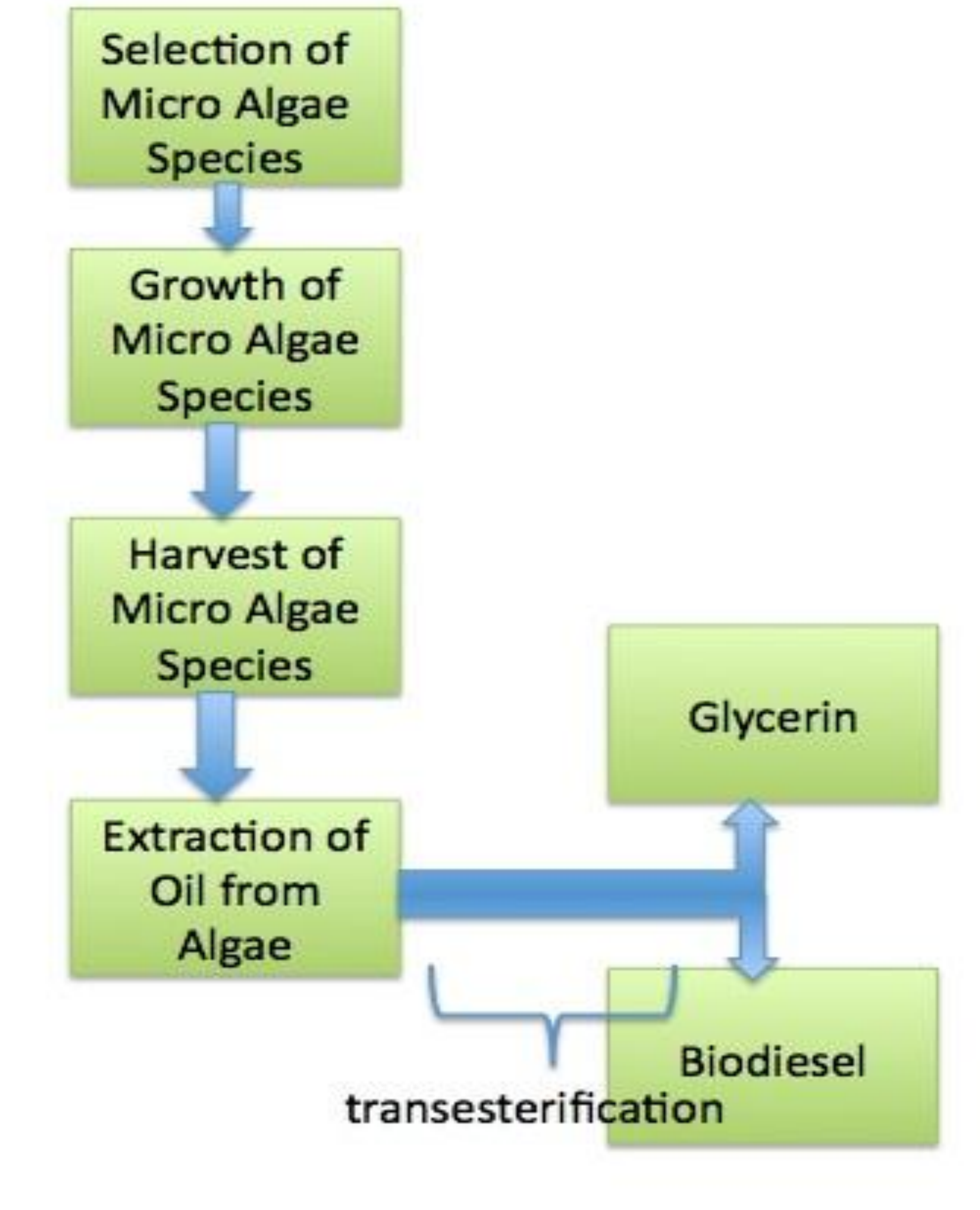
Biomass feedstock comparison

	Cost	Energy density	Agriculture yield	Competition with food source
Switch grass	$60/ton	17 MJ/kg	11.5 ton/acre	no
Sorghum	$40/ton	16.9MJ/kg	20 ton/acre	yes
Energy cane	$34/ton	12.9MJ/kg	30 ton/acre	no
Energy cane	$34/ton	12.9MJ/kg	17 ton/acre	yes
Corn	$40-50/ton	13.4MJ/kg	3.4 ton/acre	yes
Algae			58,700L/ha	no

Biomass feedstock comparison



Algae Transesterification



Pros:

- Requires low temperatures between 20 - 30C
- Produced without the use of high-value arable land

Cons:

- Does not utilize core heat or hydrogen inputs
- Expensive to harvest

***http://www.oilgae.com/algae/oil/biod/tra/tra.html

***Yusuf Chisti (2007) Biodiesel from Microalgae. *Biotechnology Advances* 25:294-306

Electrofuels

Uses power from the core to drive microbial processes that produce hydrogen gas.

1. Microbial Electrolysis Cell (MEC)
   - uses energy to enhance the microbial processing of organic substrates (e.g. cellulose, acetic acid) in a "biobattery" to produce hydrogen gas and oxygen.

2. Microbial Electrosynthesis

Efficiency depends on pH, system temperature, and choice of microbe

Biochemical Ethanol Production

- Dilute acid pre-treatment (glucose etc)
- Simultaneous Saccharification and Fermentation (SSF) (37° C, 7 days)
- Ethanol recovery by distillation
- Waste Water Treatment (WWT) (methane)

Ethanol Inputs and Outputs

<u>Inputs</u>

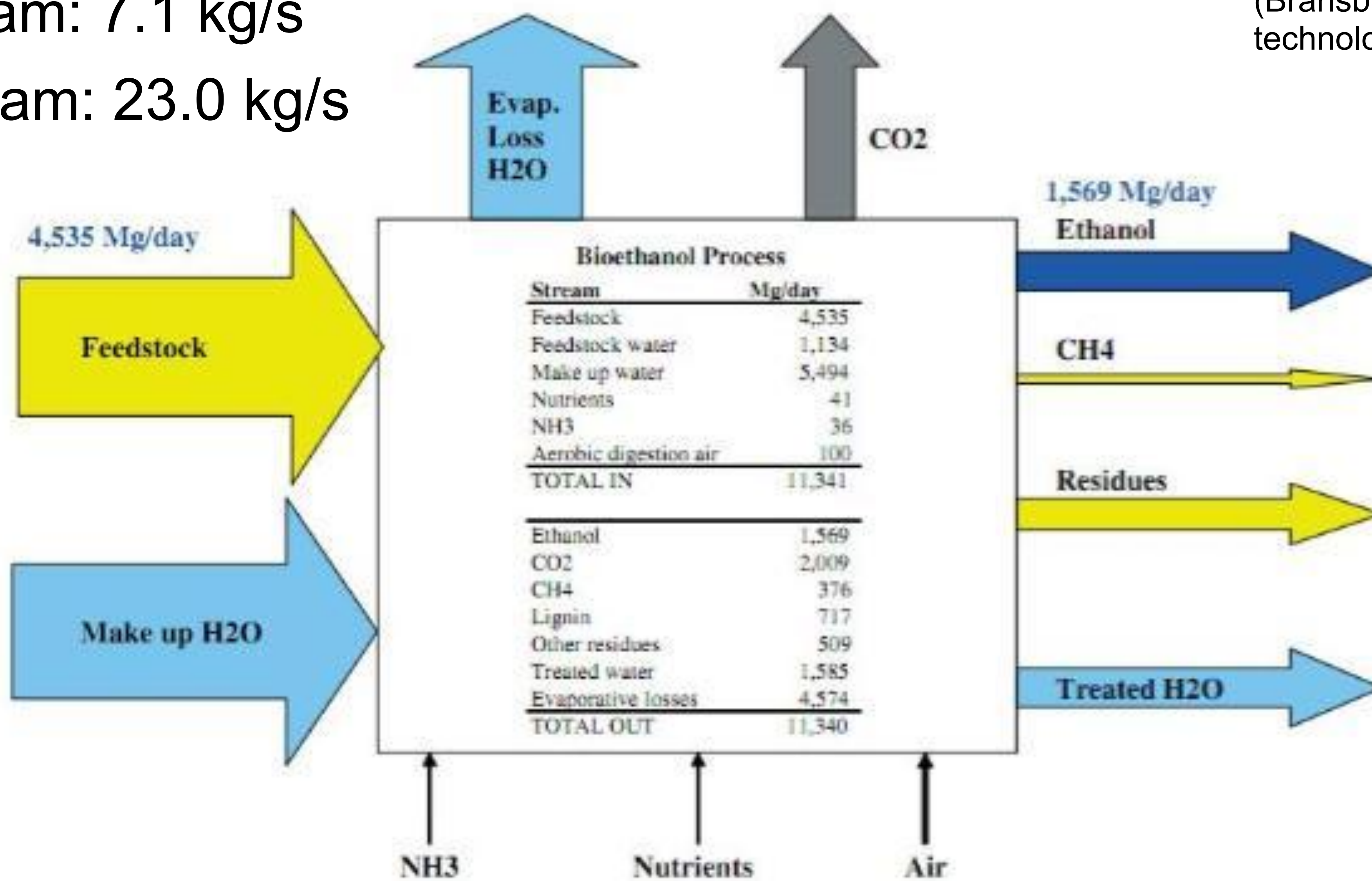
Biomass: 65.6 kg/s

Low P Steam: 7.1 kg/s

High P Steam: 23.0 kg/s

$2/gallon

(Bransby, Cellulosic biofuel technologies)



Stream	Mg/day
Feedstock	4,535
Feedstock water	1,134
Make up water	5,494
Nutrients	41
NH3	36
Aerobic digestion air	100
TOTAL IN	11,341
Ethanol	1,569
CO2	2,009
CH4	376
Lignin	717
Other residues	509
Treated water	1,585
Evaporative losses	4,574
TOTAL OUT	11,340

Thermochemical Biofuel Production

1. Gasification (Syngas production)
2. Syngas conversion (F-T liquid production)
3. F-T liquid refining (gasoline, diesel blend)

F-T Process Overview

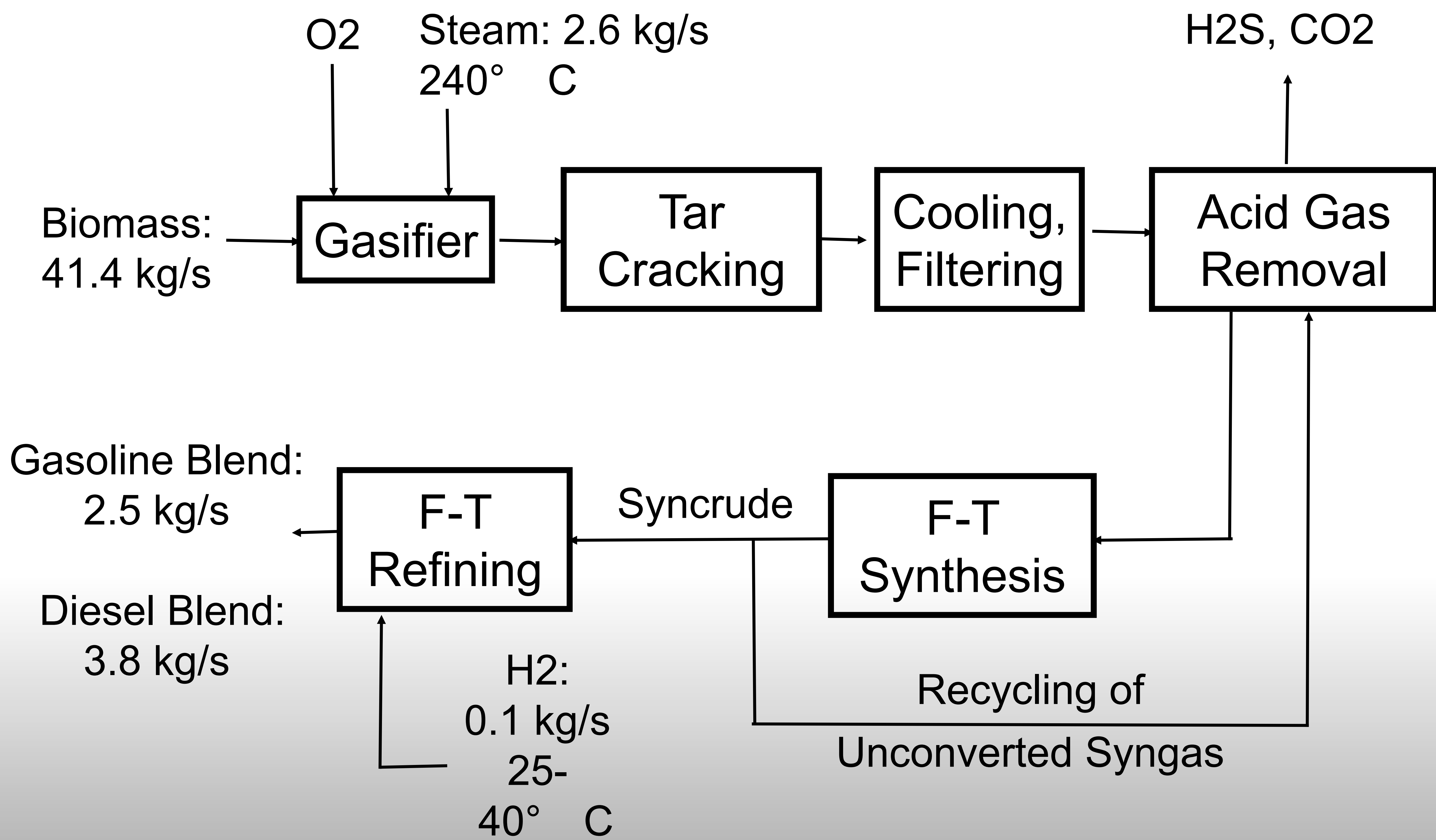
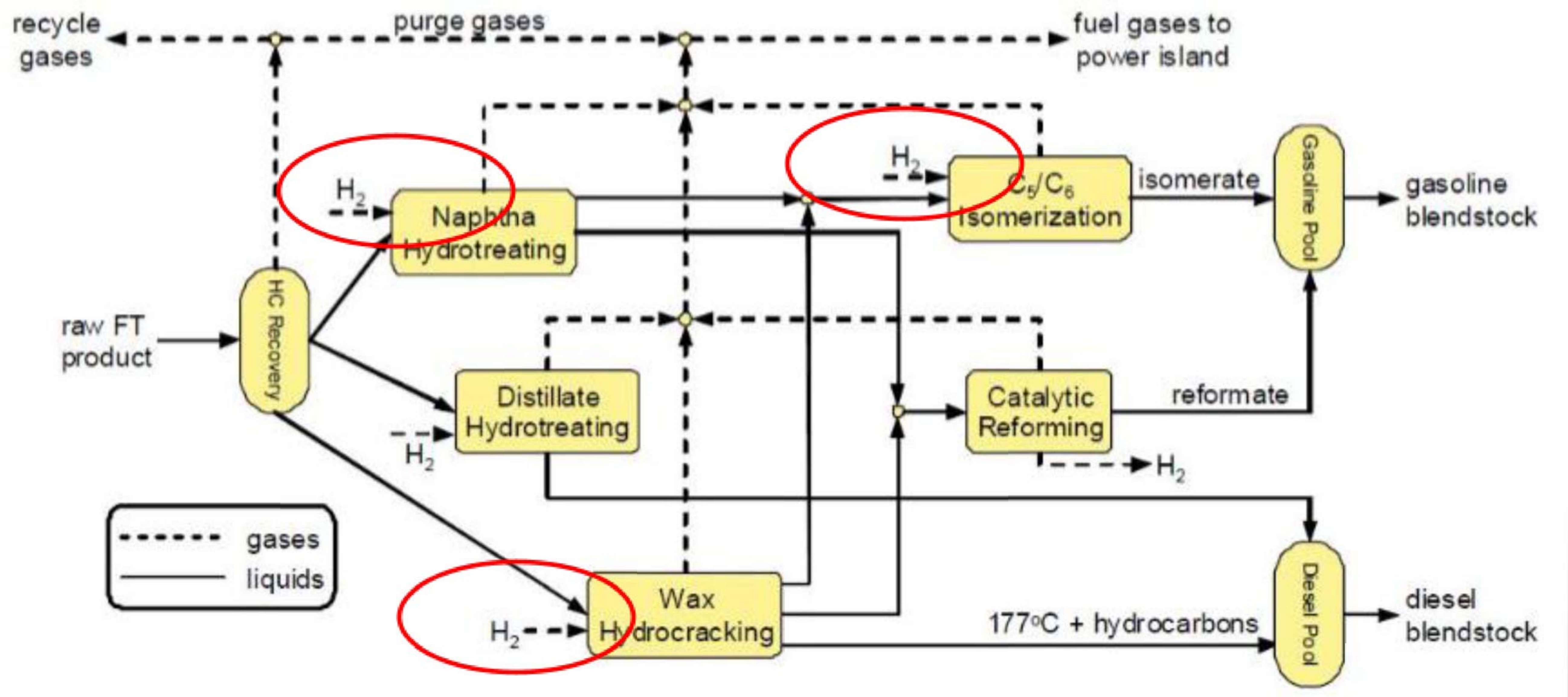


Diagram and numbers adapted from Kreutz, Fisher-Tropsch Fuels from Coal And Biomass, 2008

Hydrogen Use in F-T Refining

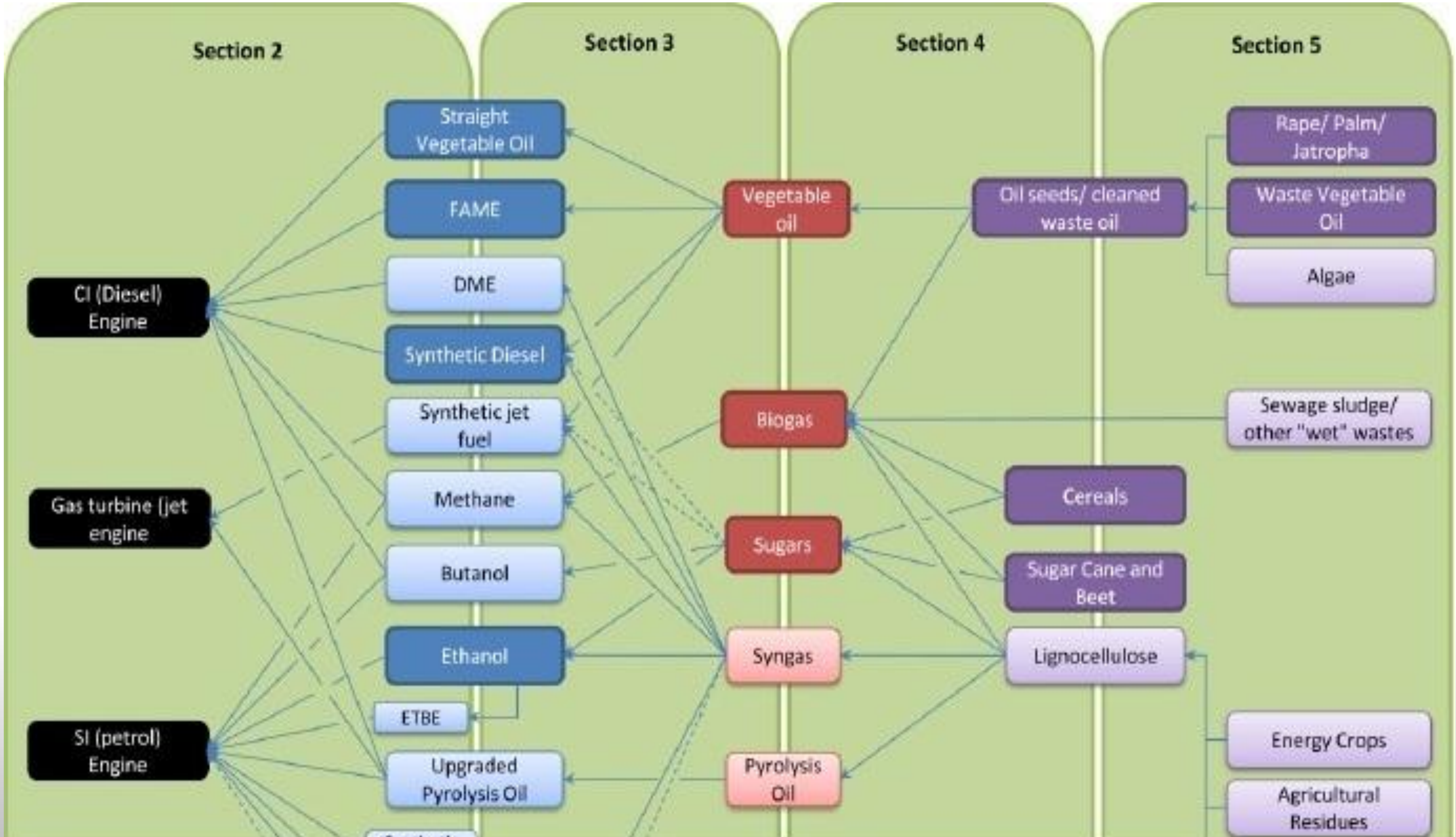


$1/gallon
(Bransby, Cellulosic biofuel technologies)

Comparison of processes

	Temperature of reaction	Hydrogen input	Steam input	Biomass input	Biofuel Output rate	Electricity usage	Capital cost
Electrofuel	25-100C	0	0	7.2 kg cellulose/1 kg H2	1.23 m3 H2/m3 reactor day at optimal voltage	~2.2 kW h/m^3-reactor day	$750,000
Bioconversion	190C	0.41 kg/sec	30 kg/sec (100C and 190C)	65kg/sec (s witch grass)	13.2kg/sec (ethanol)		$346million
Thermochemical biofuel	236	0.1kg/sec (25C, 4bar)	2.6kg/sec,(236 C)	41.4 kg/sec (switch grass)	6.3kg/sec (gasoline blend)	32MW	$541 million
Photosynthetic algae	20-30C	0	0	carbon dioxide, nitrogen, sulfur	226.1 gal/ day	55kW	$821,000-$14million

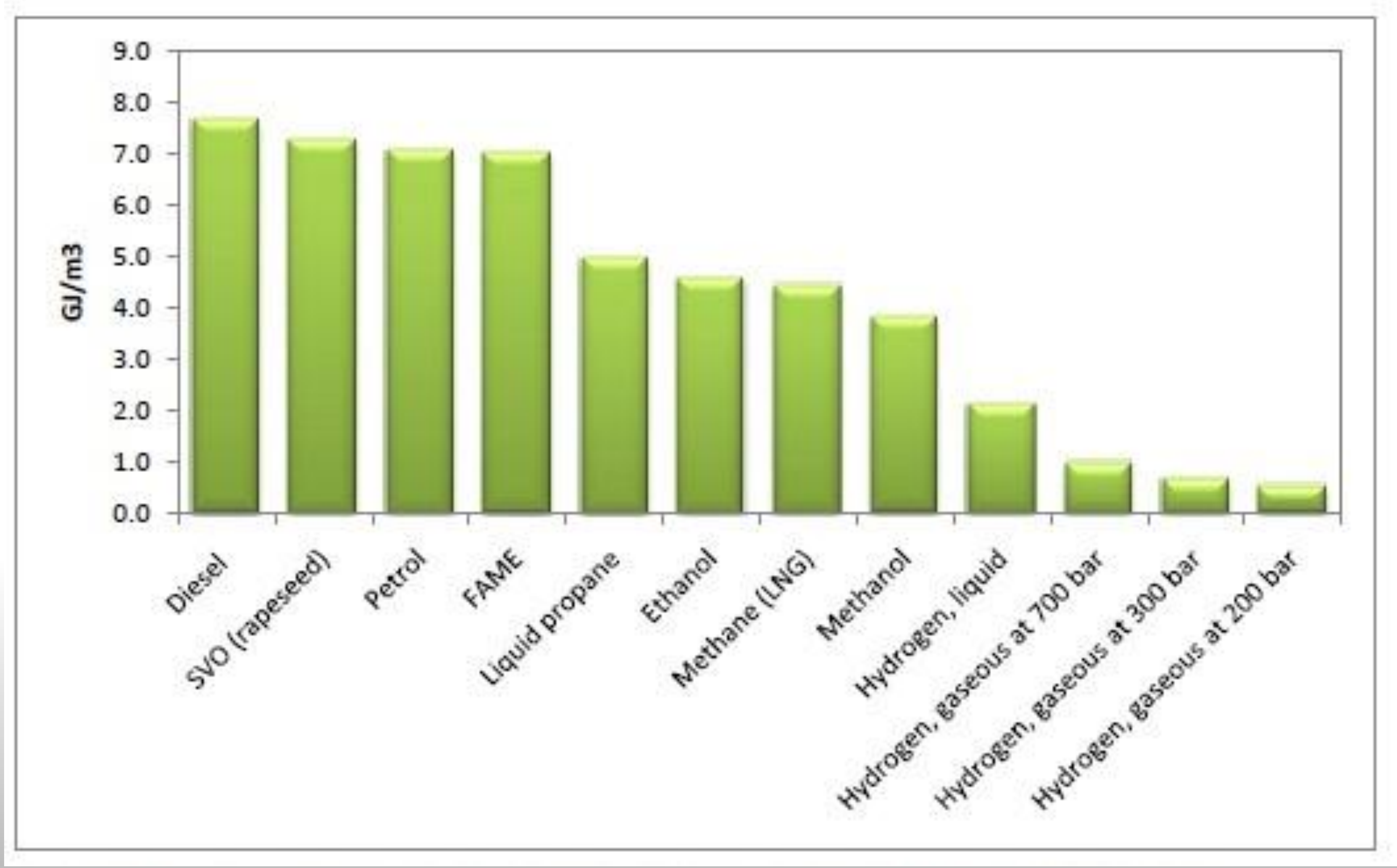
Summary of Products



Energy Density of Biofuels

Energy Density of different possible products from F-T liquids

- Bio-diesel fuel - highest energy to volume ratio



Biofuel Carbon Emissions

Bio-diesel Emissions vs. Conventional Diesel Emissions for:

- 100% bio-diesel fuel
- 20% bio-diesel fuel and 80% conventional diesel fuel

AVERAGE BIODIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL, ACCORDING TO EPA

Emission Type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nox	+10%	+2% to -2%
Non-Regulated		
Sulfates	-100%	-20%*
PAH (Polycyclic Aromatic Hydrocarbons)**	-80%	-13%
nPAH (nitrated PAH's)**	-90%	-50%***
Ozone potential of speciated HC	-50%	-10%

Bio-Fuel Challenges

- Low freezing point at 100% bio-diesel fuel
  - Generally mixed to dispel these qualities
- Does not meet current EN590 vehicle quality standard
  - Can be used in standard cars up to 20% bio-diesel fuel
- Rise in Nitrogen Oxide emissions, responsible for smog
- Decrease in bio-diversity in energy crop harvesting
- DARPA is interested in alternative jet fuels production
  - Have grants for $5M that can help offset capital cost

Conclusion

- Switchgrass
- Gasification-based F-T process
- Steam requirement: (2.6kg/sec , 240C)
- Hydrogen requirement: 0.1kg/sec (25C, 4bar)
- End products: biodiesel and gasoline

22.033 / 22.33 Nuclear Systems Design Project
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