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Techno-economic Analysis of Biofuel Production via Catalytic Upgrading of Carbohydrates in Paper Sludge

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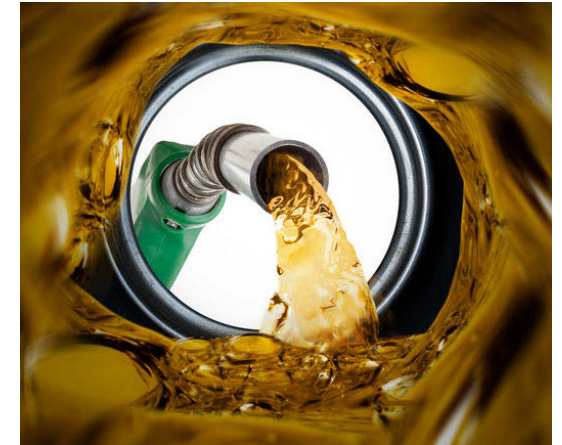
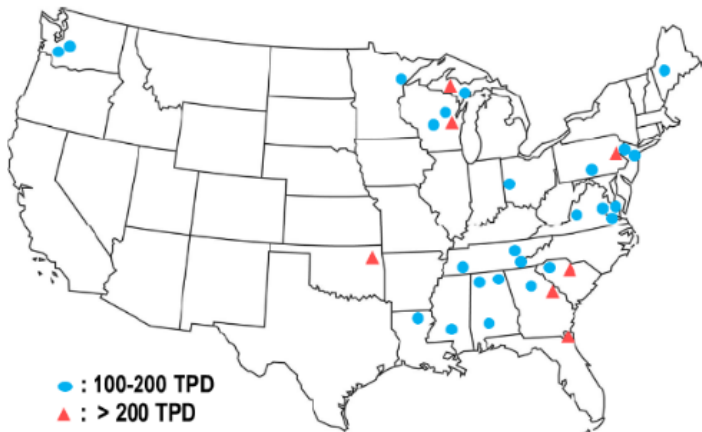
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Paper Sludge as Feedstock for Liquid Fuel Production



+8MM wet tonne/year (50% MC) [1].
 Trucking & landfilling ~USD\$ 60/dry tonne.
 Cost ~USD\$240MM/year.

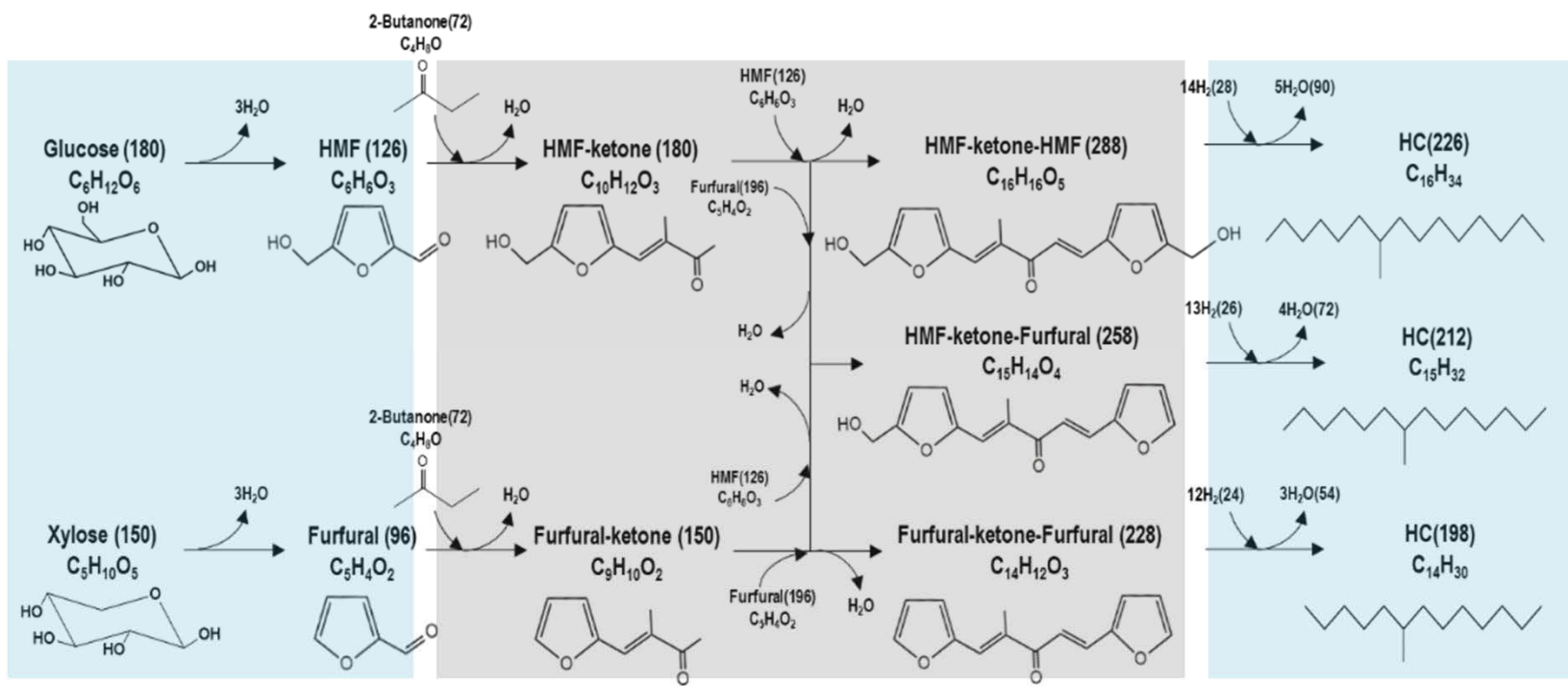
Carbohy.	Ash	Lignin
53.2% ± 0.7	43.1% ± 0.9	3.7% ± 0.5

Glucan	Xylan	Mannan
75.8% ± 1.1	13.2% ± 0.2	3.4% ± 0.8

US Diesel Fuel Consumption (2019)
 1.74MM barrels diesel per day [2].

[1] FisherSolve™ - Pulp and Paper Industry Database.
 [2] U.S. Energy Information Administration (2019).

Proposed Catalytic Conversion Pathway

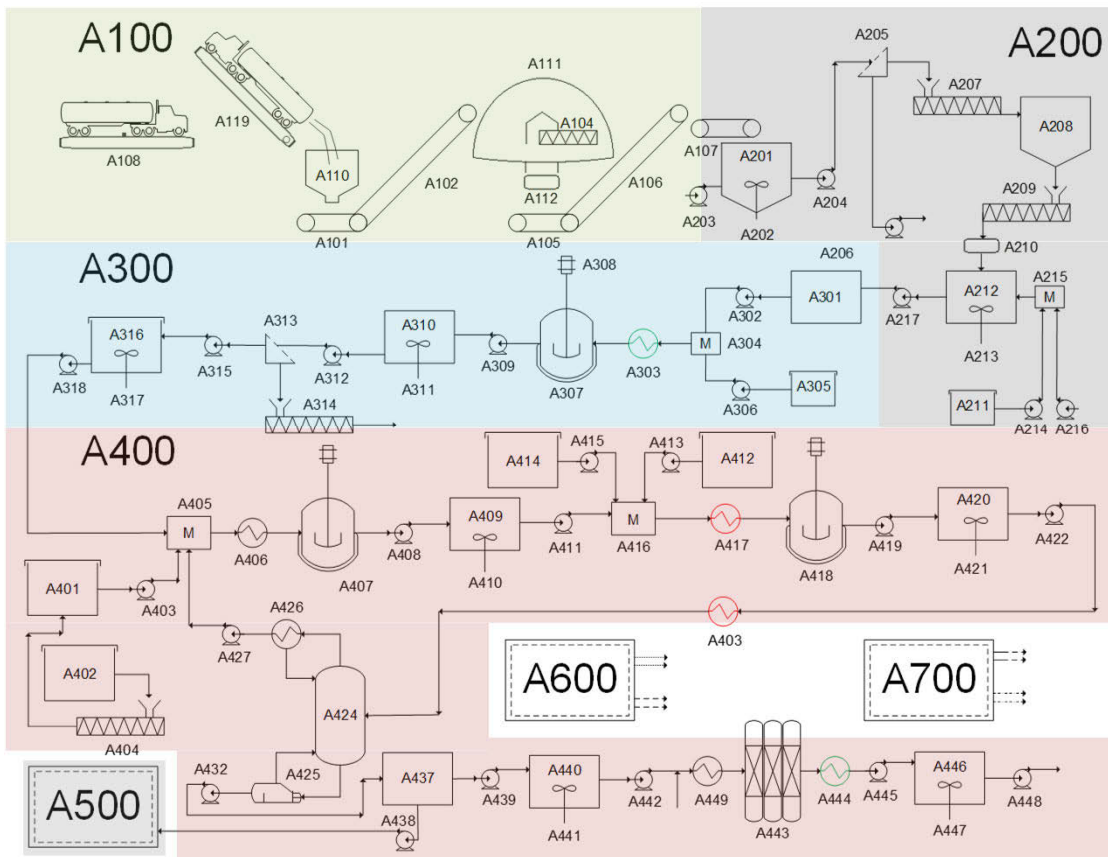


Dehydration Reaction	
Catalyst	AlCl ₃
Temperature	195°C

Aldol Condensation Reaction	
Catalyst	NaOH
Temperature	40°C

Hydro Deoxygenation	
Catalyst	Pt/Al ₂ O ₃ -SiO ₂
Temperature	300°C

Chemical Processes & Unit Operations in Base Case



A100 – Feedstock & Handling

Paper Sludge	750 dry tonne/day	NCSU
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A200 – Pretreatment

Carbohydrates Ret.	68.7% ± 1.8	NCSU
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Ash Removal	99.9% ± 0.0	NCSU
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A300 – Enzymatic Hydrolysis

Hydrolysis Temp	50°C	NCSU
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Glucose Conv.	97.5% ± 1.8	NCSU
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A400 – Catalytic Upgrading

1,4-Dioxane : Water	2 : 1 (v/v)	NREL
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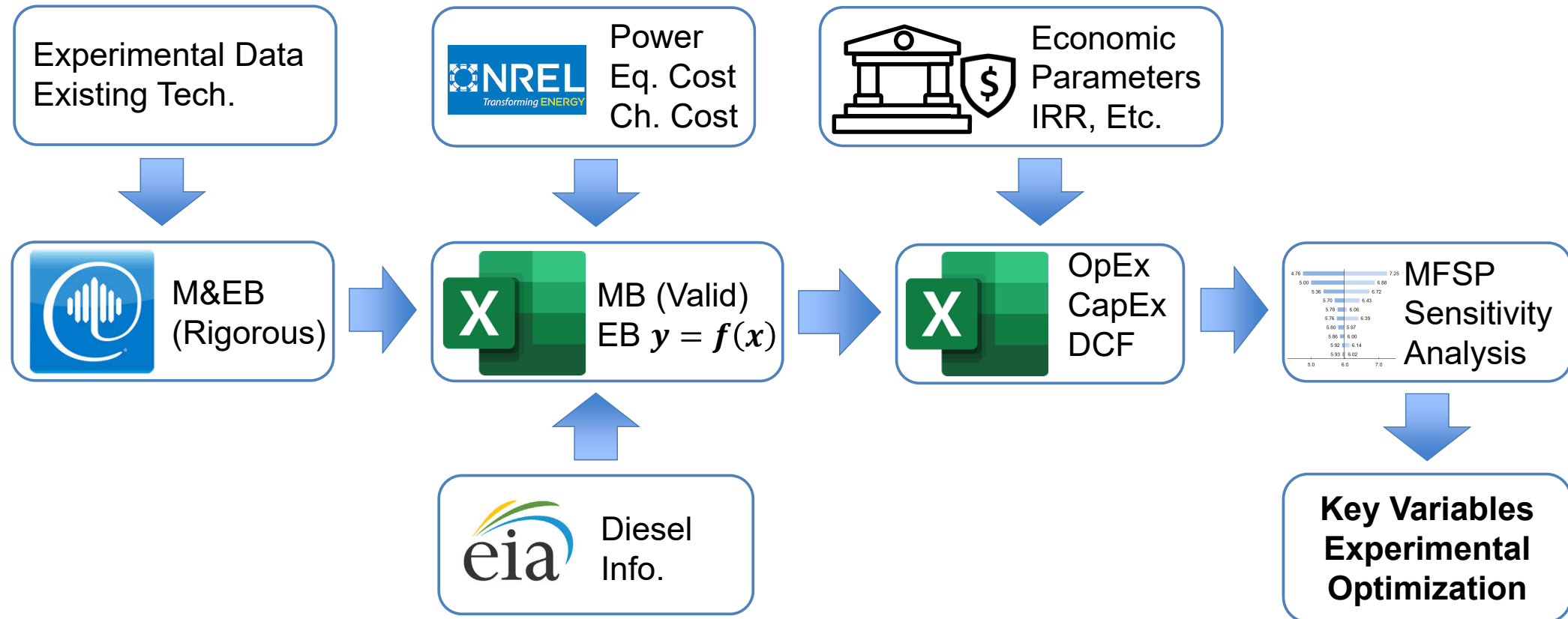
Dioxane/Water Az.	88°C & 81%Diox.	Aspen
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A500 – Waste Water Treatment

A600 – Heat & Power

A700 – Utilities

How Information Flows for MFSP & SA



MFSP, Cost Breakdown & Sensitivity Analysis

Minimum Fuel Selling Price 2020's\$

USD\$ 5.97 / GGE

Production Results

14.2 MM GGE / year

95.2 GGE / tonne Carbohydrates

86.4 GGE / tonne Carbohyd. & ketone

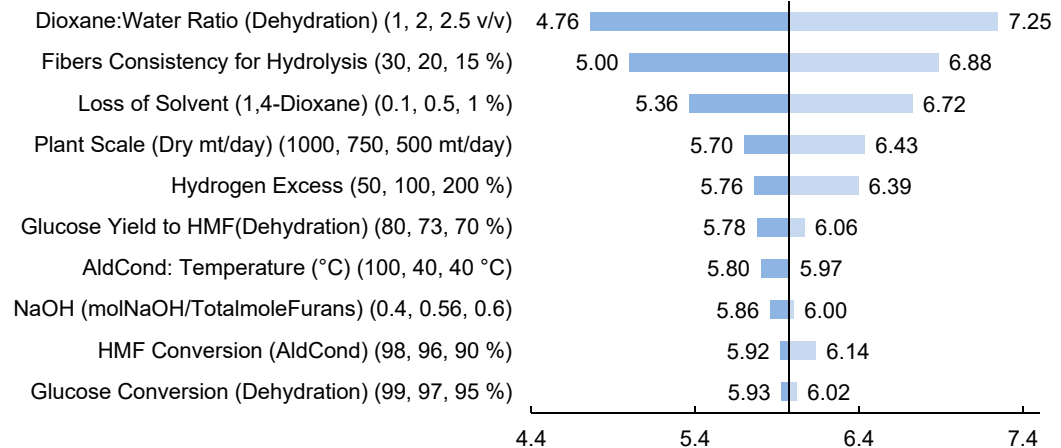
57.7 GGE / tonne Paper Sludge (dry)

Costs

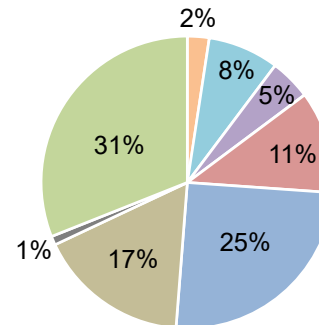
Total Equipment Cost	108,400,000
Total Direct Cost	120,000,000
Total Indirect Cost	96,000,000
Fixed Capital Investment	216,000,000
Total Capital Investment	228,700,000

Manufacturing Cost (cents\$/GGE)

Feedstock and handling	0.0
Ketone (MEK)	158
Hydrogen	94
Solvent (Dioxane)	76
Natural gas	58
Ald. Cond. Catalyst (NaOH)	39
Enzyme	37
Waste Water Treatment	0.0
Process makeup water	5.2
Dehydration Catalyst (AlCl ₃)	1.6
HCl	1.5
HDO Catalyst (Pt/Al ₂ O ₃ -SiO ₂)	0.3
Other raw materials	0.1
Solid waste disposal	0.0
Sludge disposal credits	-106
Net Electricity (Surplus)	-8.8
Fixed Operating Costs	41
Capital Depreciation	51
Average Income Tax	15
Average Return on Investment	134



Total Power Generated 7.4 MW

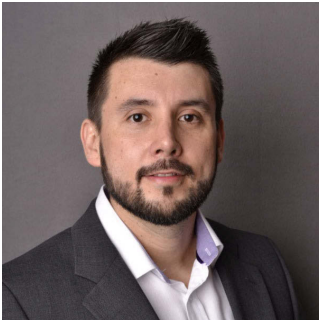


Minimum Fuel Selling Price (USD\$/GGE)

- A100 - Feedstock Handling
- A200 - Pretreatment
- A300 - Enzymatic Hydrolysis
- A400 - Catalytic Conversion and Upgrading
- A500 - Waste Water Treatment
- A600 - Heat and Power
- A700 - Utilities
- Excess Power Generation

Conclusions

- ✓ A **full-plant model** was developed using **correlations from a rigorous mass and energy balance** and **based on experimental results** to determine the **MFSP** and its **Sensitivity Analysis** in the production of a hydrocarbon product from **Paper Sludge**.
- ✓ In this base case a preliminary **MFSP** of **\$5.97/GGE** has been determined. This value is higher than the results reported in recent NREL reports. The difference is explained since much larger capacity plants are considered in those reports, and because we are not considering the production of co-products that bring the fuel costs down.
- ✓ The **obtained model** is being used to **guide the next steps in our laboratory work** since the team is now aware of which are **the more sensitive process parameters** “impacting” the MFSP of the final product.



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