

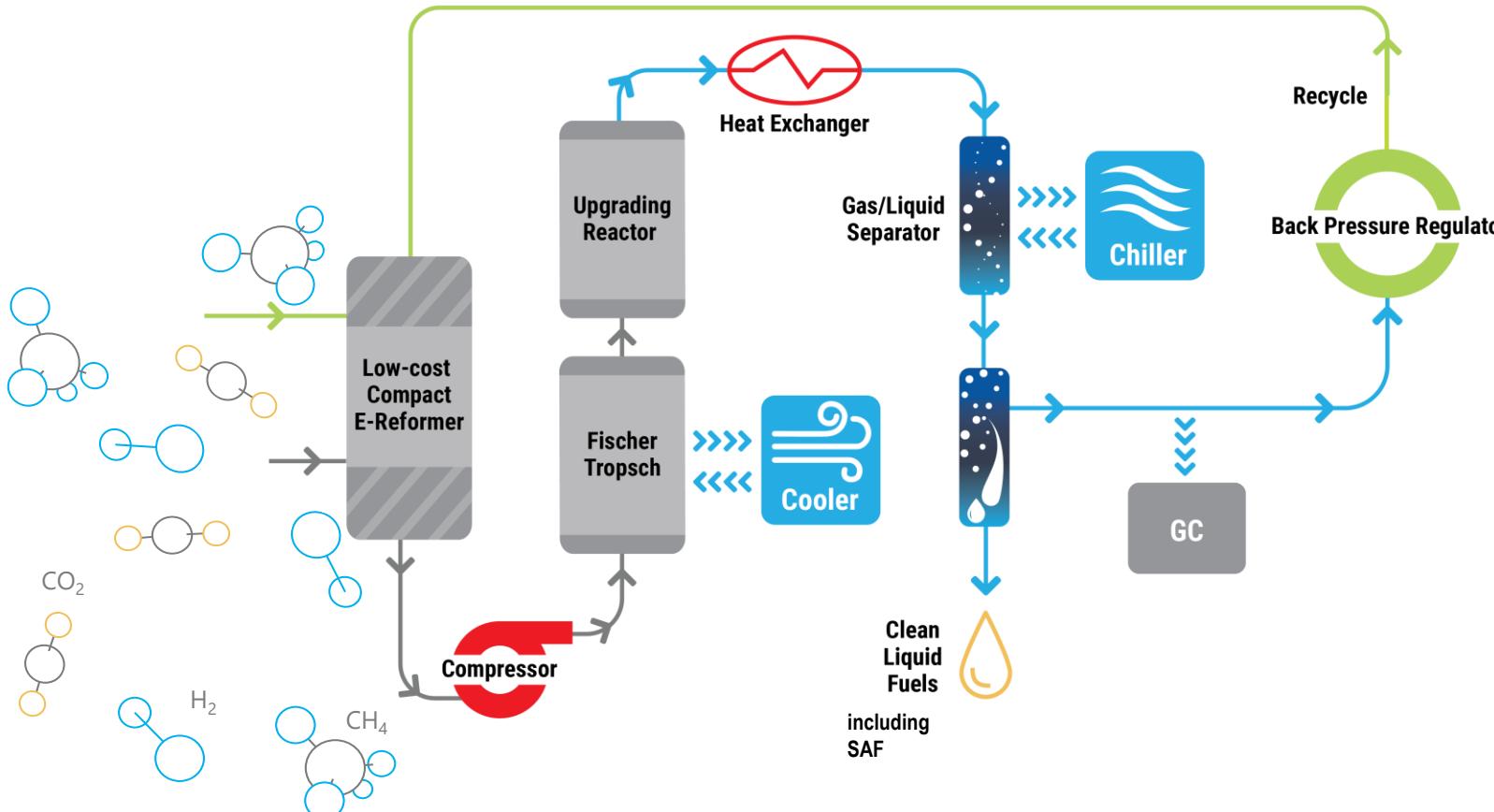


Cool GTLSM for the Conversion of Biogas to Jet Fuel

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Cool GTL

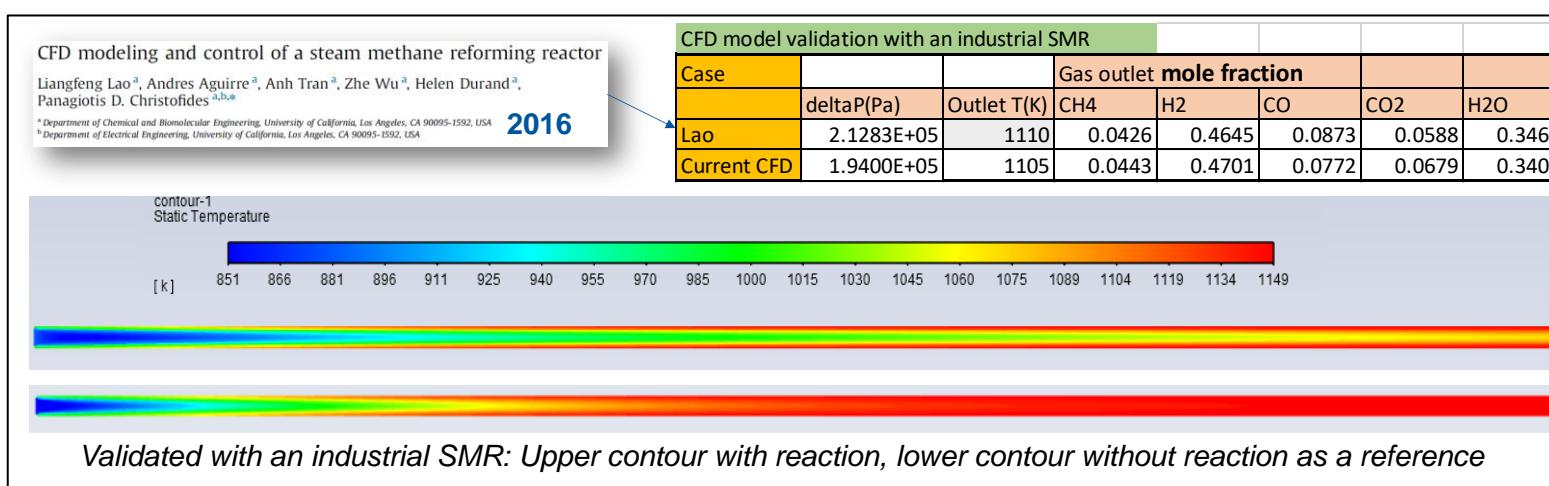
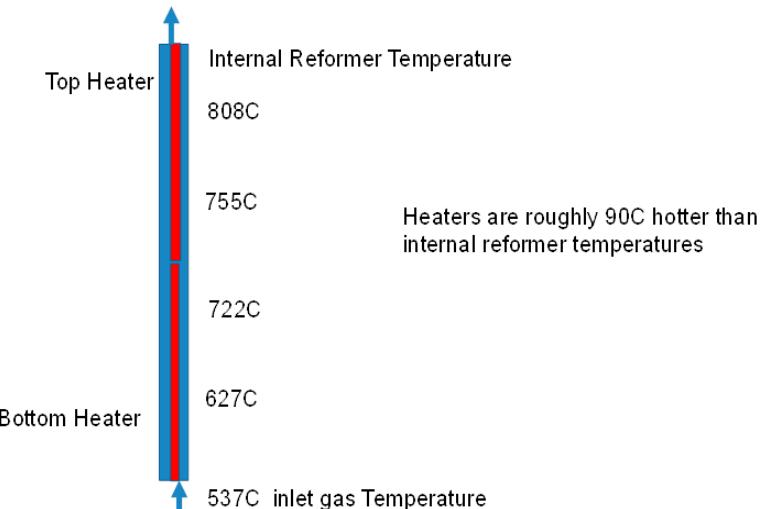


- Integrated, modular skid mounted system
- Converts CO₂-rich hydrocarbon streams into high quality fuels
- Low CAPEX and compact electric reformer to produce syngas
- FT reactor followed directly by an upgrading reactor allows for all wax to be eliminated
- Unique catalysts used in all stages of process

E-Reformer Design

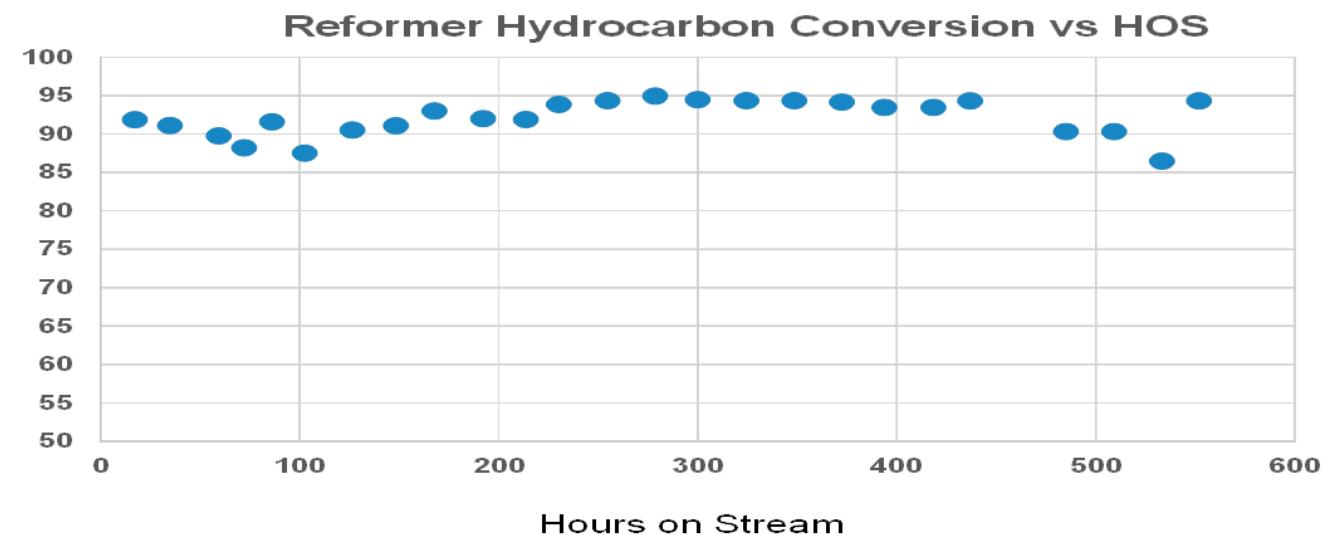
- Up flow reactor design
- Internal heating elements
- Operates at mild conditions

E-Reformer Temperature Profile



Reformer Performance – Biogas Feed

- First 500 hours used bottled biogas feed which simulated GTI Energy's IH2 process offgas
- Hydrocarbon conversion was between 90-95%

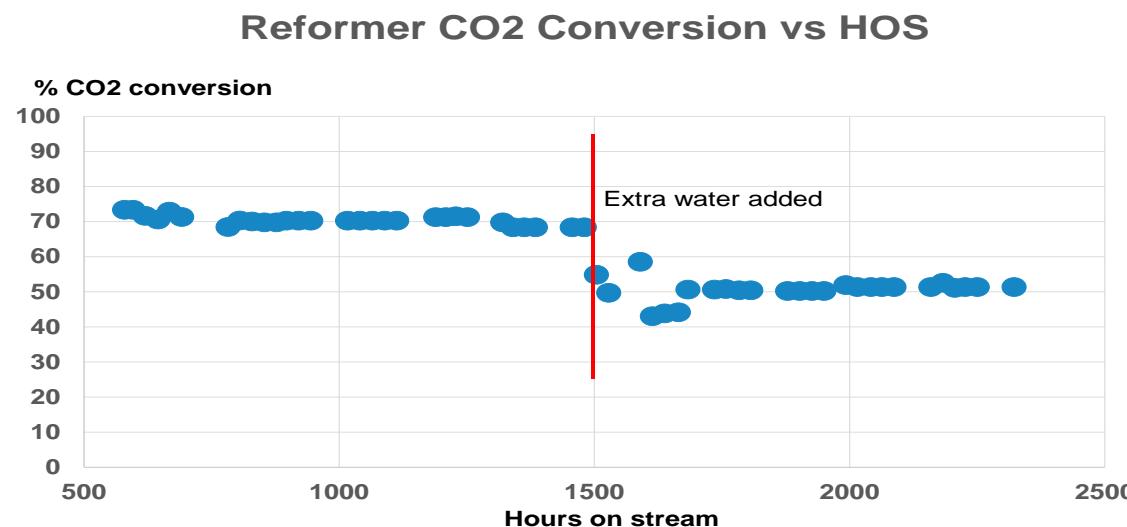
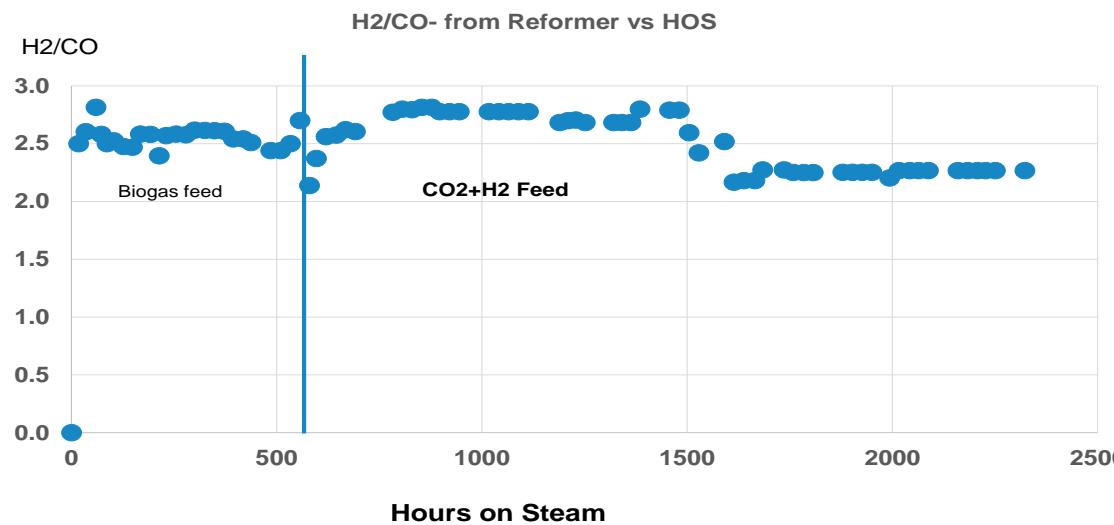


Reformer Feed Comparison

	Typical IH2 feed	Bottled Gas feed
H2 vol	25	24
Methane ,vol %	22	18
Ethane, vol%	18	-
Propane, vol %	7	18
CO ,vol%	23	-
CO2,vol%	5	41
Total vol%	100	100

Reformer Performance – CO2 and H2 Feed

- 1700 hours of testing with CO2 and H2 as feed
- Electric reformer produces syngas with H2/CO ratio ranging between 2.1 and 2.4
- CO2 conversion around 50% under the CO2/H2 feed
- No more sooting noticed with the addition of steam



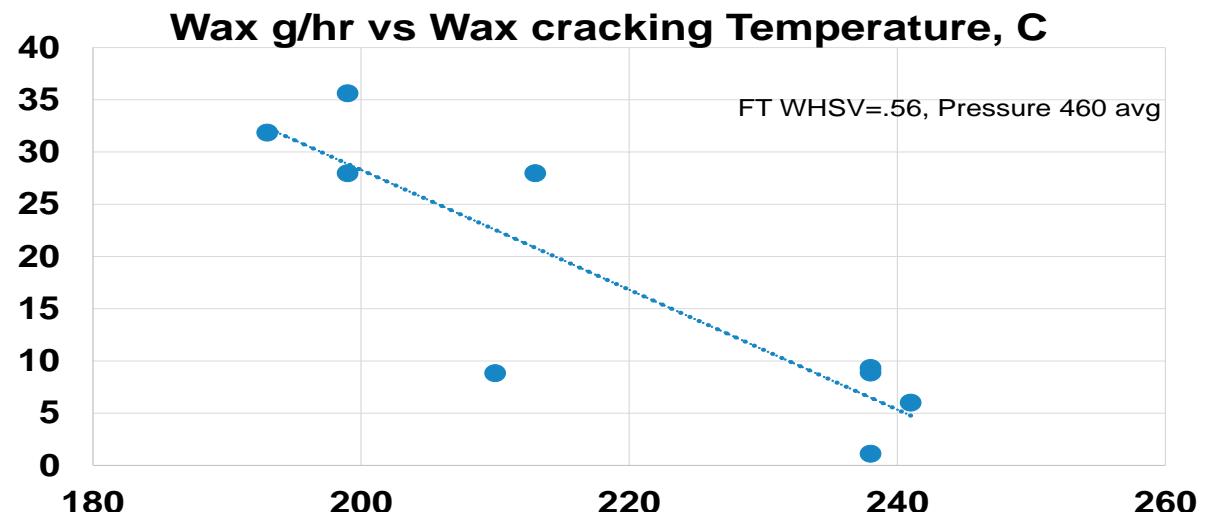
Fischer Tropsch and Upgrading

- High conversion per pass. Have achieved 60% conversion of CO
- Fischer-Tropsch products are directly upgraded in the 2nd stage reactor via unique cracking and hydro-isomerization catalysts
- Upgrading allows for:
 - Higher yields
 - Elimination of wax
 - High quality fuels

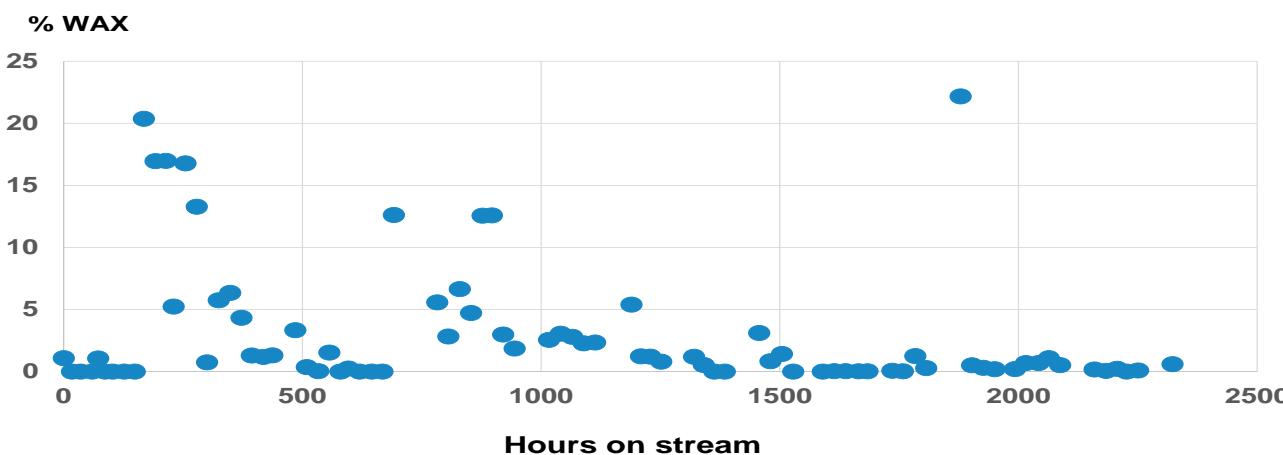


Upgrading Continued

- Low selectivity to wax – less than 1 %
- Upgrading reactor operated at 235 to 240C to ensure all wax was cracked
- FT Liquid product selectivity ranging between 60 and 70%



Selectivity to Wax vs Hours on Stream

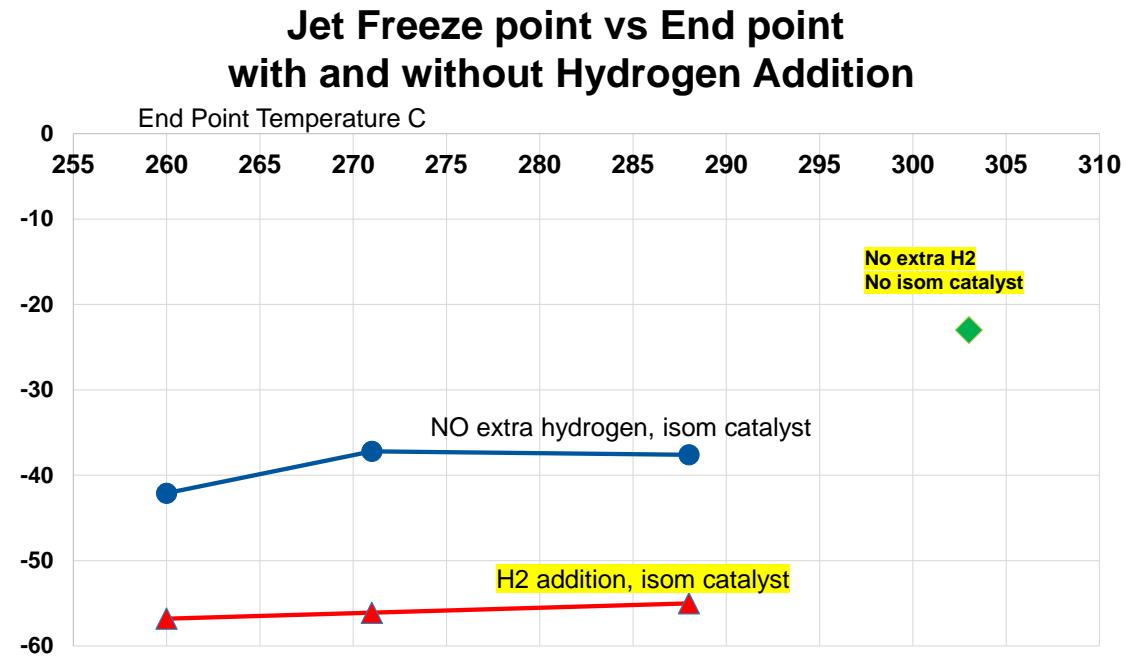


Jet Product Analysis

- Focus on trying to meet Jet A specs, specifically freeze point
- Addition of H₂ aided in the reduction of freeze point.
- Lower H₂ flows can be used if CO concentration to the upgrading reactor is reduced
- Changing endpoint only slightly increases the amount of jet

% Jet in sample vs. Endpoint

Cut Point °C	2/19	2/26	C Number distribution
132-260	-49.5	-50.3	C9-C14
132-271	-51.8	-52.7	C9-C15
132-288	-52.1	-52.9	C9-C16



1/29/2024 Sample Results

	Result	ASTM1655	ASTM 7566	ASTM 4054	Test method	Meets spec
Freeze. C	-54	-40 Jet A -47Jet A1	-40 Jet A -47 Jet A1	-40 Jet A -47Jet A1	D5972	yes
Density,g/cc	.76	.775-.840	.730-.770 (for FT liquids)		D4052	Yes (for FT liquids)
Flash	38	Min 38	Min 38	Max68	D58	yes
Distillation					D86	Yes
10 % recovery C	157	205max	205 max	150-205		Yes
50% recovery C	175			165-229		Yes
90% recovery C	218			190-262		Yes
Final boiling point	275	300max	300 max	300 max		Yes
Distillation Residue	1.1	1.5max	1.5 max			Yes
T90-T10	91	40min	22 min			Yes
T50-T10	32	15min	15 min			Yes
Acidity, acid number mgKOH/g	.59	.1max	<.015			No
Heat of Combustion MJ/kg	46	42.8min	42.8 min		D240	Yes
Copper strip corrosion	1a	1max	1 max		D130	Yes
Kinematic viscosity @ -20C,mm ² /s	2.86	8max	8max		D445	yes

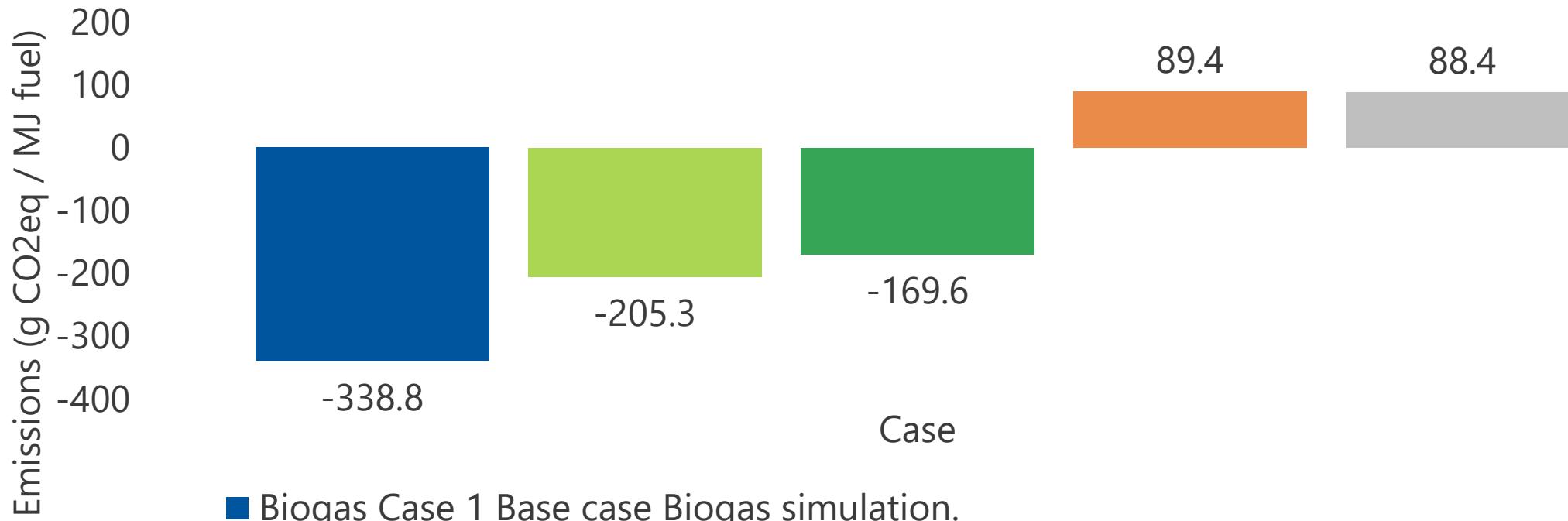
TEA

- Two cases conducted:
 - IH2 biogas (producing 818 b/d)
 - Digestor gas (4.9 b/d)
- Breakeven cost of jet fuel at \$3.2/gal with IH2 case
- Further improvements to help bring costs down even more

	IH2 Biogas	Digestor Biogas
Direct cost	112.7	38.7
Indirect Cost	25.8	11.9
Direct + indirect	138.5	50.6
Contingency (30%)	41.6	15.2
Overall costs	180.1	65.8

	IH2 Biogas	Digestor Biogas
Feed gas composition	Methane, ethane, propane, CO ₂ , CO, H ₂	Methane, CO ₂
Size Million ft ³ /d feed gas	8.4	1.2
Size bbl/d product	818	118
Size Million gal/yr product	11.9	1.7
Total Installed Capital Cost \$Million	180	66
Breakeven \$/gallon (no RINS)	3.2	6.2
Breakeven \$/gallon(with RINS)	2.2	5.2

LCA



- Biogas Case 1 Base case Biogas simulation.
- Biogas Case 2 PEM electrolysis unit & optimized Bi-Reformer
- Biogas Case 3 Replaced steam compressor turbine driver w/ motor drive.
- IH2 Case 1 Base case IH2 simulation.
- IH2 Case 2 Replacement of PSA with Membrane.

Aether Fuels

- Aether Fuels is the exclusive licensor of the Cool GTL technology
- Aether Fuels will be commercializing the technology as the proprietary Aether Aurora solution





Acknowledgements

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Special thanks to Dr. Robert Handler and Prof. David Shonnard for their work on the LCA

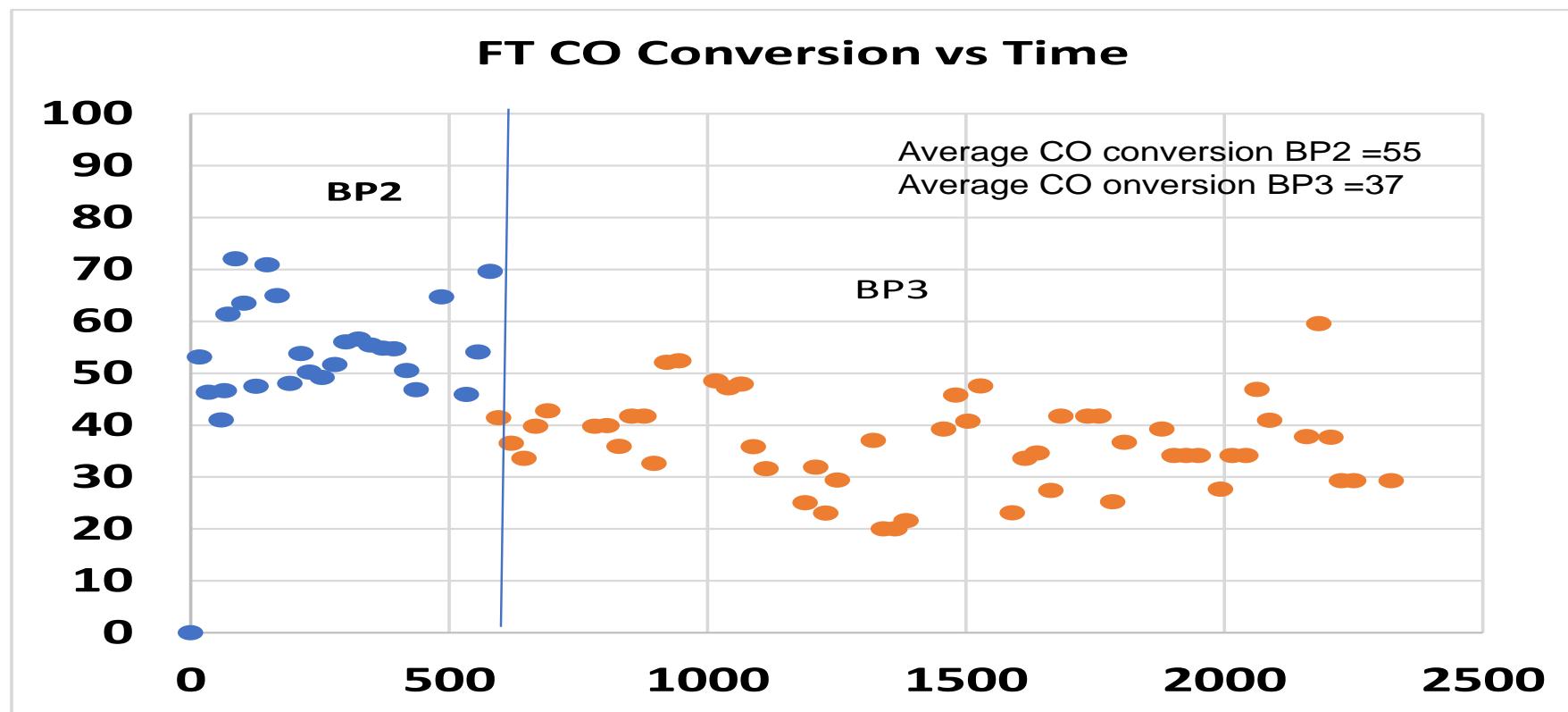


Questions

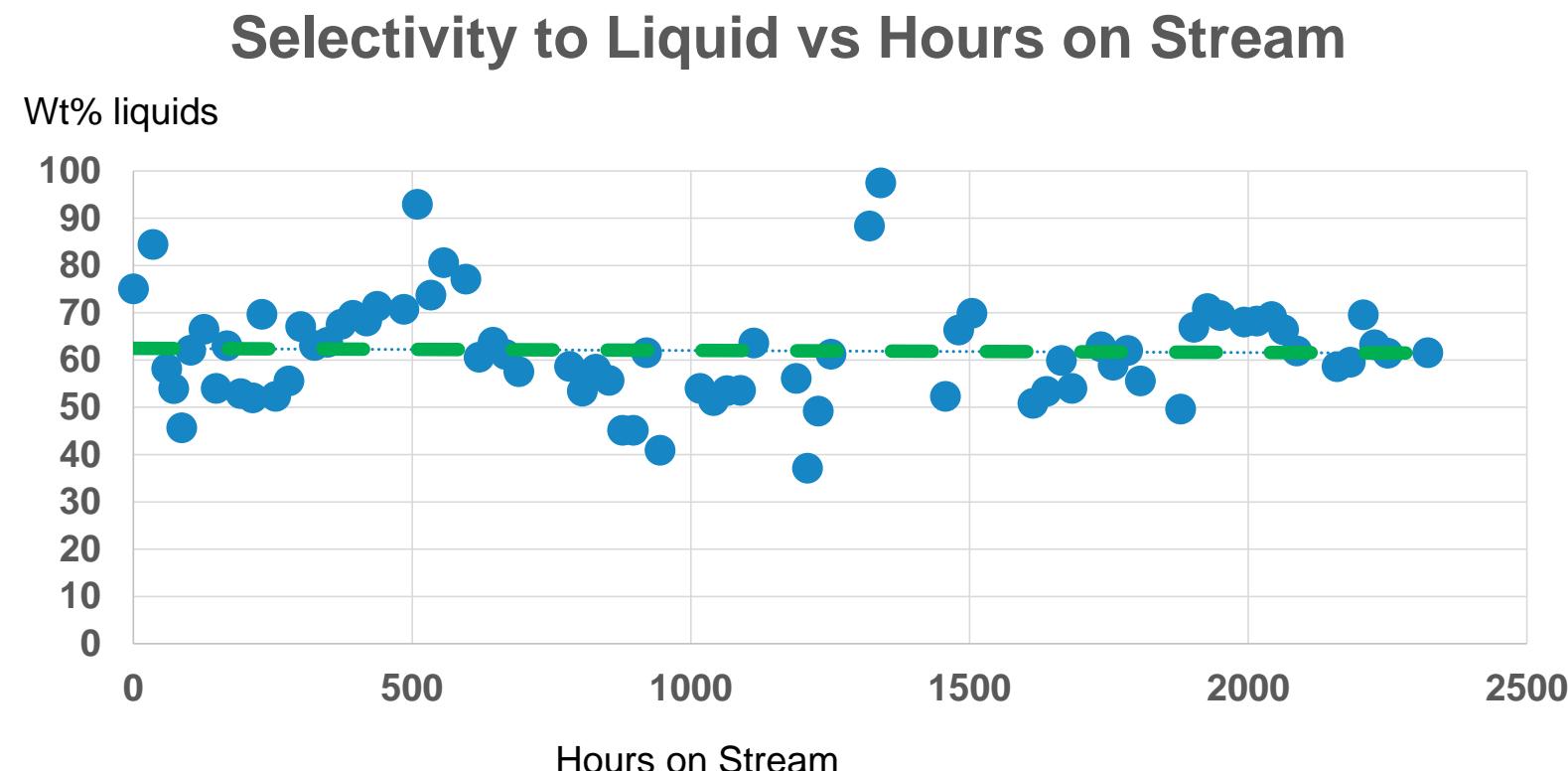
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FT CO Conversion vs HOS



Selectivity to Liquid Products



%CO Present in Upgrading Reactor vs Freeze Point

Jet freeze point Vs % CO in gas feed to Cracking/isomerization reactor

