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solutions that transform

Cool GTL[SM] for the Conversion of Biogas to Jet Fuel

Soheil Hussain, Terry Marker, Pedro Ortiz-Toral

tcbiomass | 09/11/2024

Cool GTL

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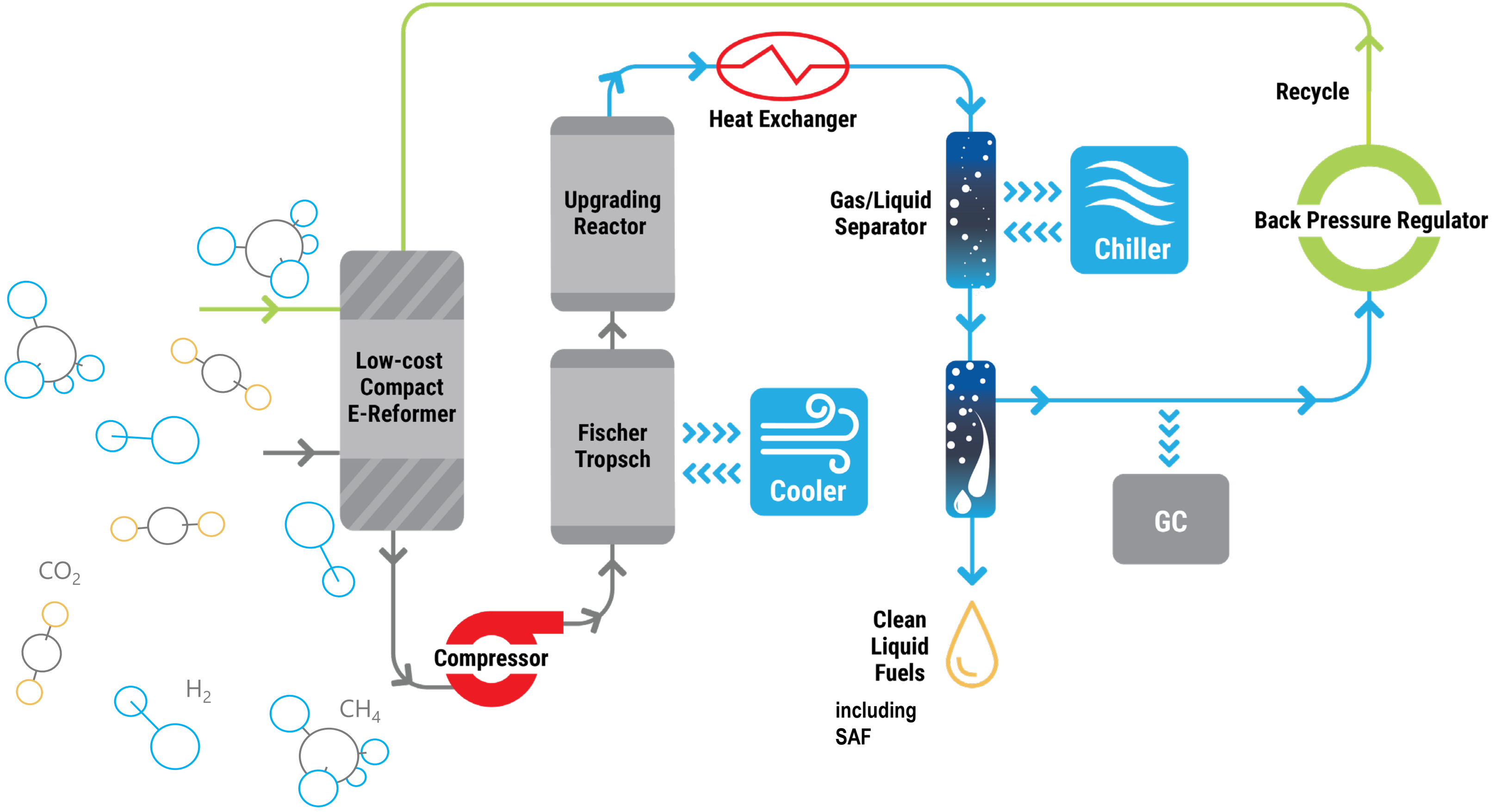
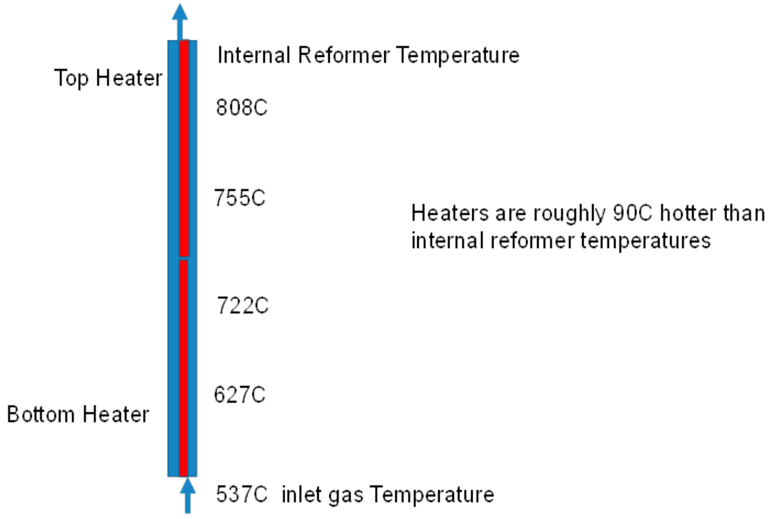


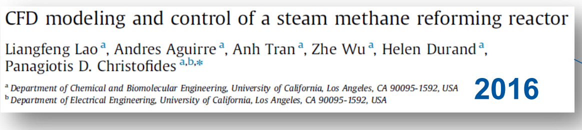
- Integrated, modular skid mounted system
- Converts CO2-rich hydrocarbon streams into high quality fuels
- Low CAPEX and compact electric reformer to produce syngas
- FT reactor followed directly by an upgrading reactor allows for all wax to be eliminated
- Unique catalysts used in all stages of process

E-Reformer Design

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

E-Reformer Temperature Profile




CFD modeling and control of a steam methane reforming reactor

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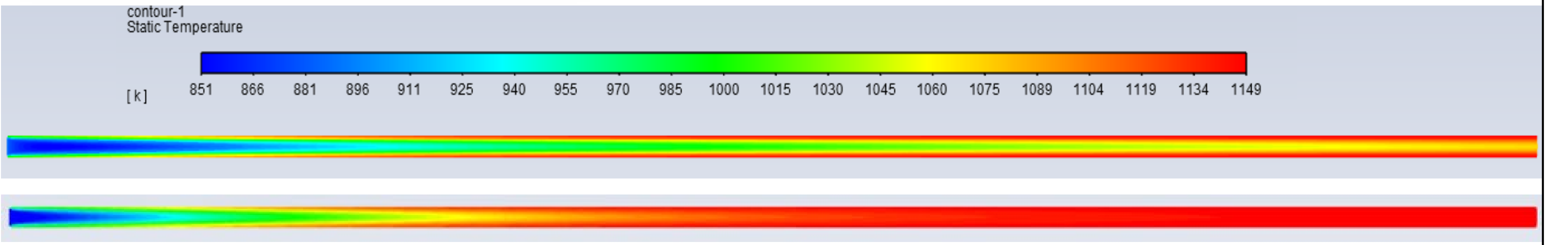
2016

CFD model validation with an industrial SMR

Case			Gas outlet **mole fraction**				
	deltaP(Pa)	Outlet T(K)	CH_4	H_2	CO	CO_2	H_2O
Lao	2.1283E+05	1110	0.0426	0.4645	0.0873	0.0588	0.3467
Current CFD	1.9400E+05	1105	0.0443	0.4701	0.0772	0.0679	0.3405



Validated with an industrial SMR: Upper contour with reaction, lower contour without reaction as a reference

Reformer Performance – Biogas Feed

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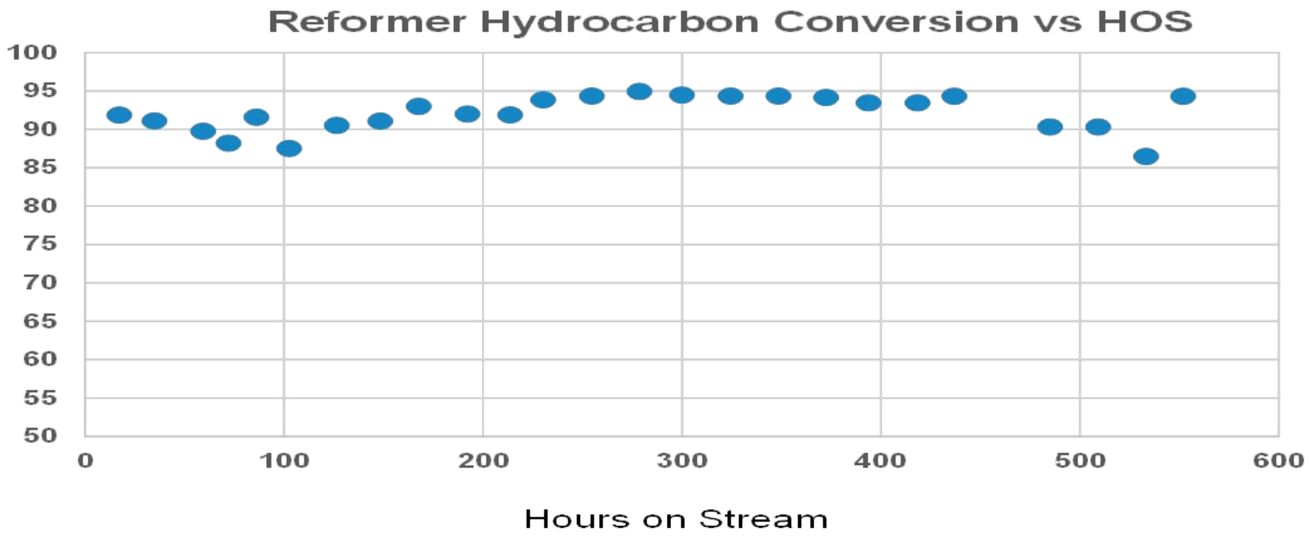
- First 500 hours used bottled biogas feed which simulated GTI Energy's IH2 process offgas
- Hydrocarbon conversion was between 90-95%

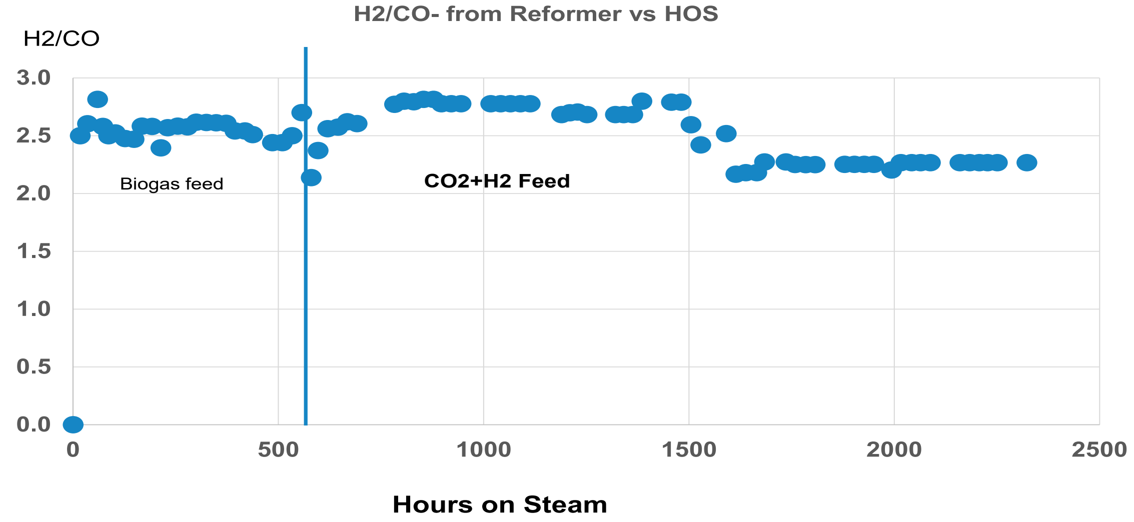


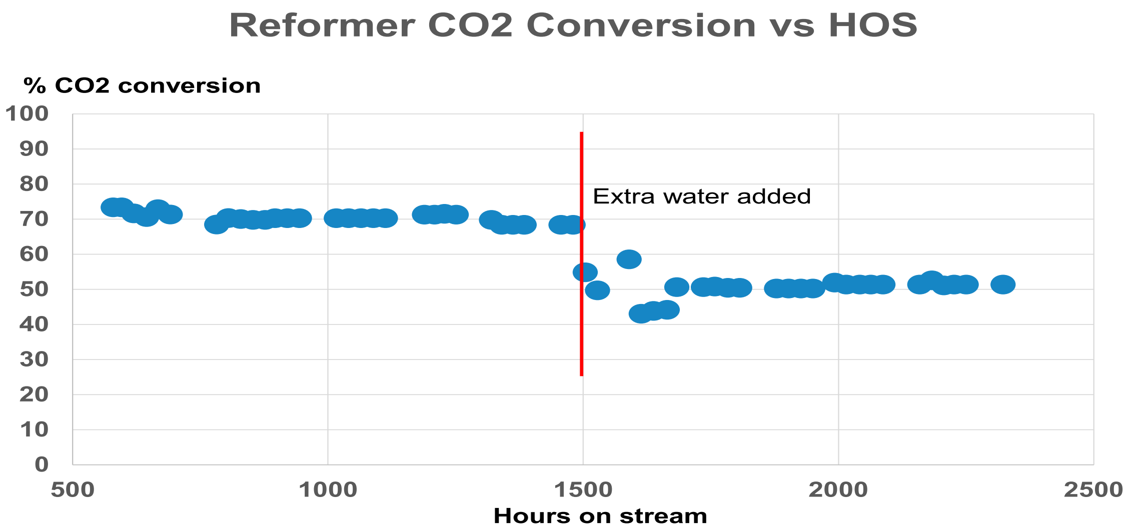
Reformer Feed Comparison

	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 – CO_2 and H_2 Feed

- 1700 hours of testing with CO_2 and H_2 as feed
- Electric reformer produces syngas with H_2/CO ratio ranging between 2.1 and 2.4
- CO_2 conversion around 50% under the CO_2/H_2 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 2^{nd} stage reactor via unique cracking and hydro-isomerization catalysts
- Upgrading allows for:
  – Higher yields
  – Elimination of wax
  – High quality fuels

Upgrading Continued

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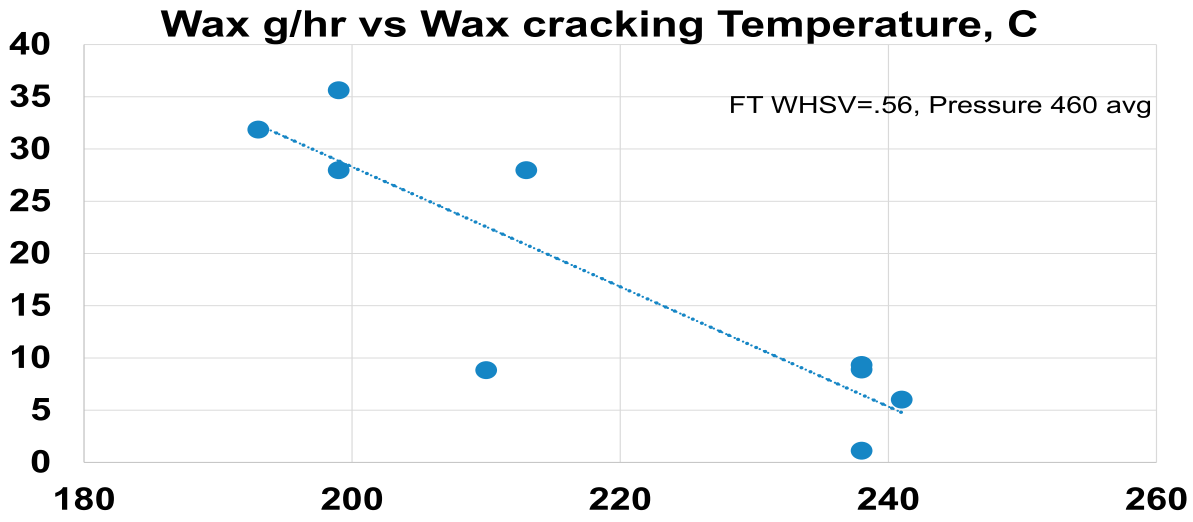
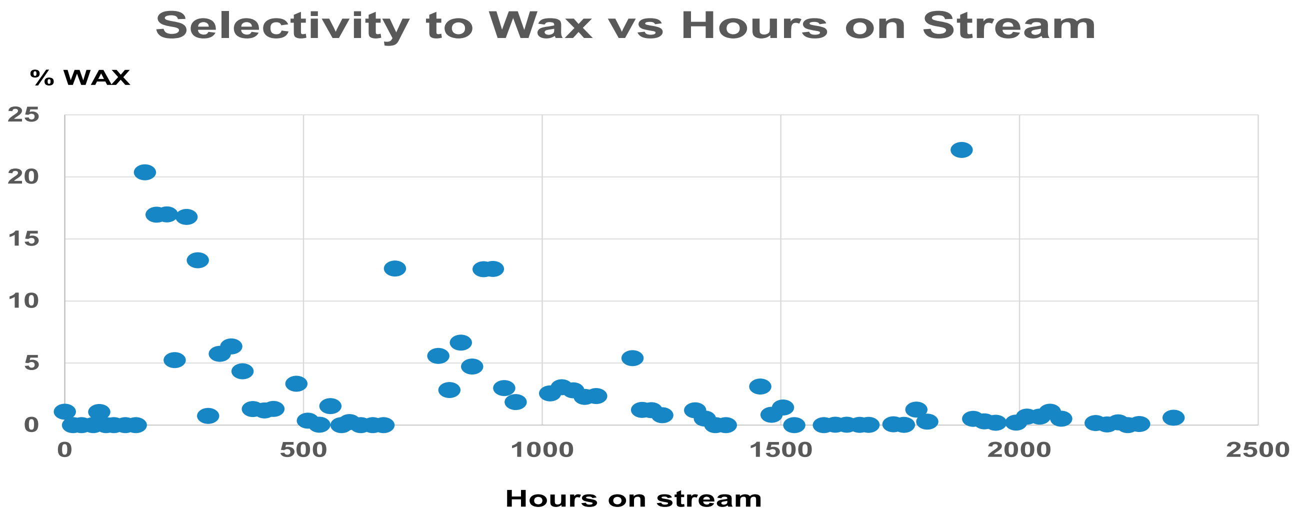
- Low selectivity to wax – less than 1 %
- Upgrading reactor operated at 235 to 240C to ensure all wax was cracked
- FT Liquid product selectivity ranging between 60 and 70%



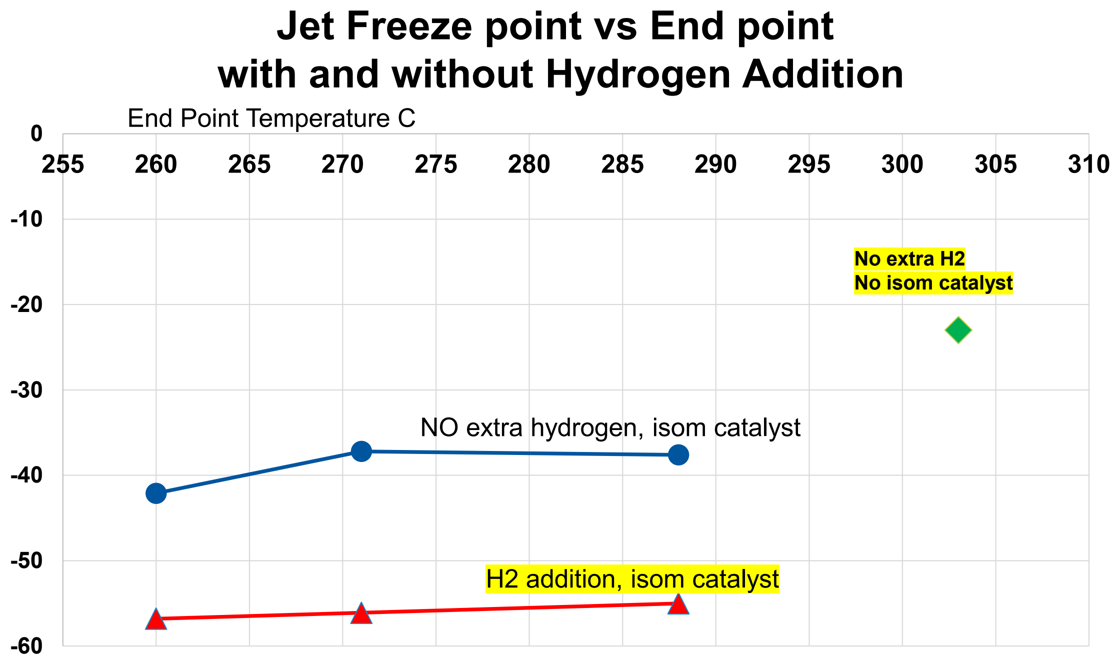


Jet Product Analysis

- Focus on trying to meet Jet A specs, specifically freeze point
- Addition of H_2 aided in the reduction of freeze point.
- Lower H_2 flows can be used if CO concentration to the upgrading reactor is reduced
- Changing endpoint only slightly increases the jet yield

% 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

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	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,mm2/s	2.86	8max	8max		D445	yes

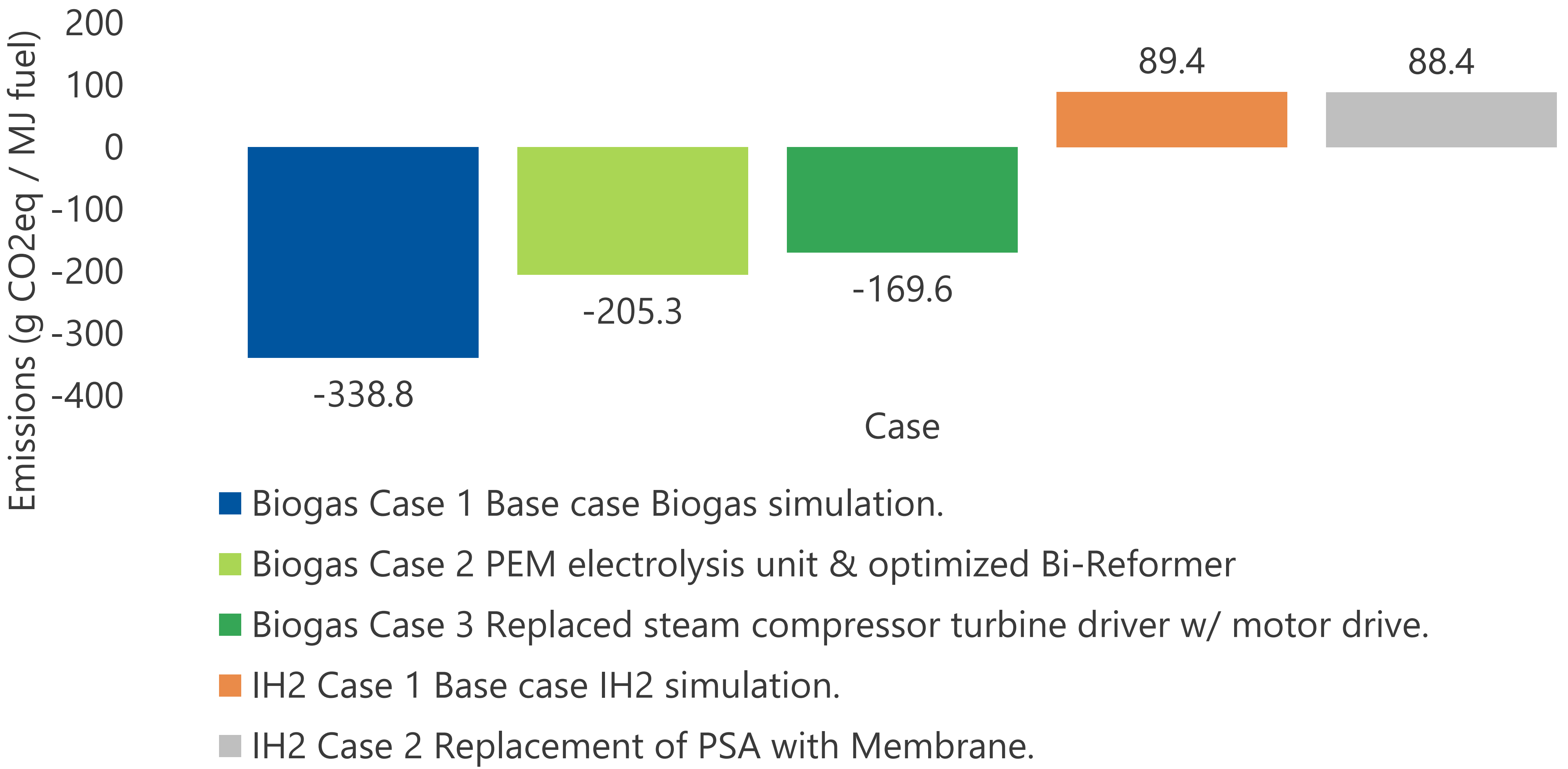
TEA

- 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, CO2,CO,H2	Methane, CO2
Size Million ft3/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


Emissions (g CO2eq / MJ fuel)
200
100
0
-100
-200
-300
-400
89.4
88.4
-338.8
-205.3
-169.6
Case
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.

GTI Energy - Aether Fuels

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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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Questions

Contact Information

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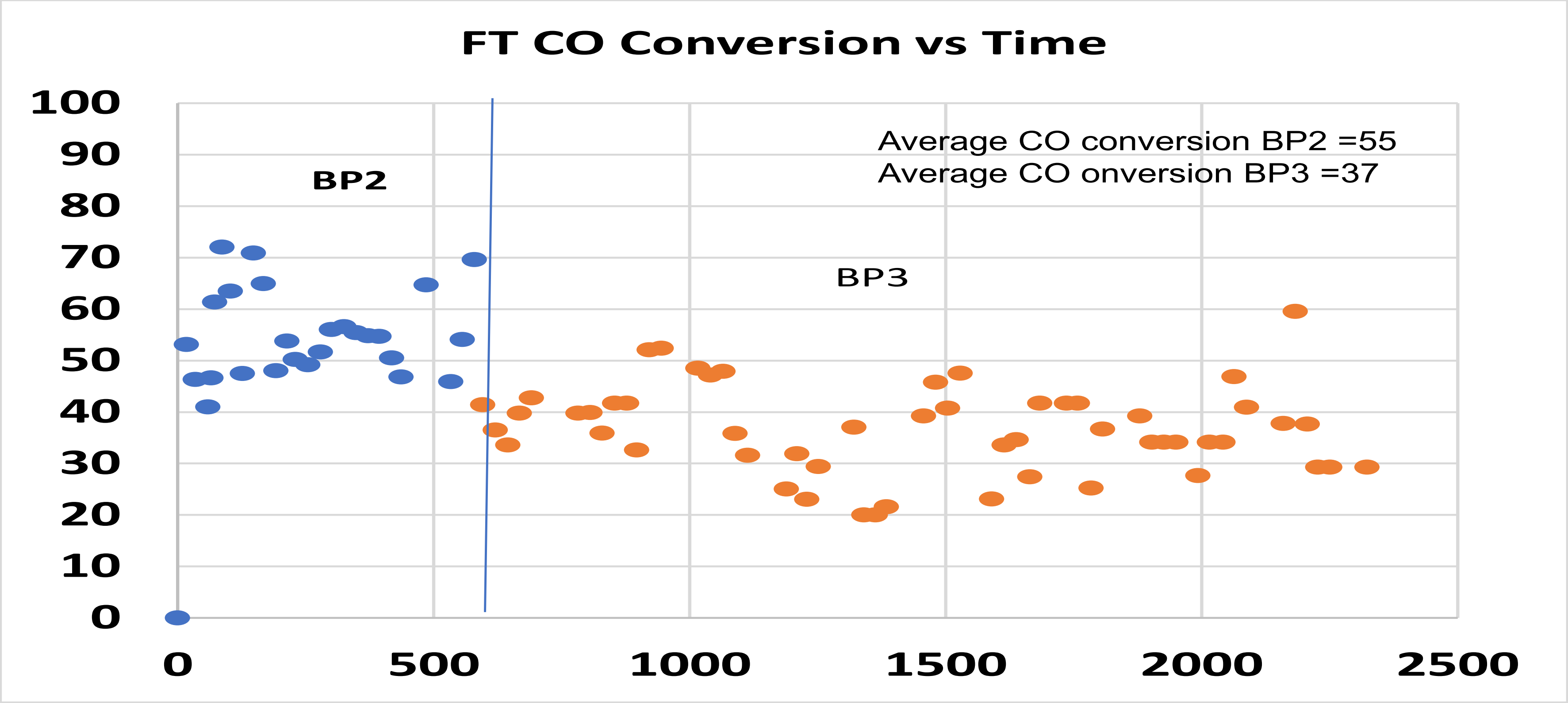
FT CO Conversion vs HOS



Selectivity to Liquid Products

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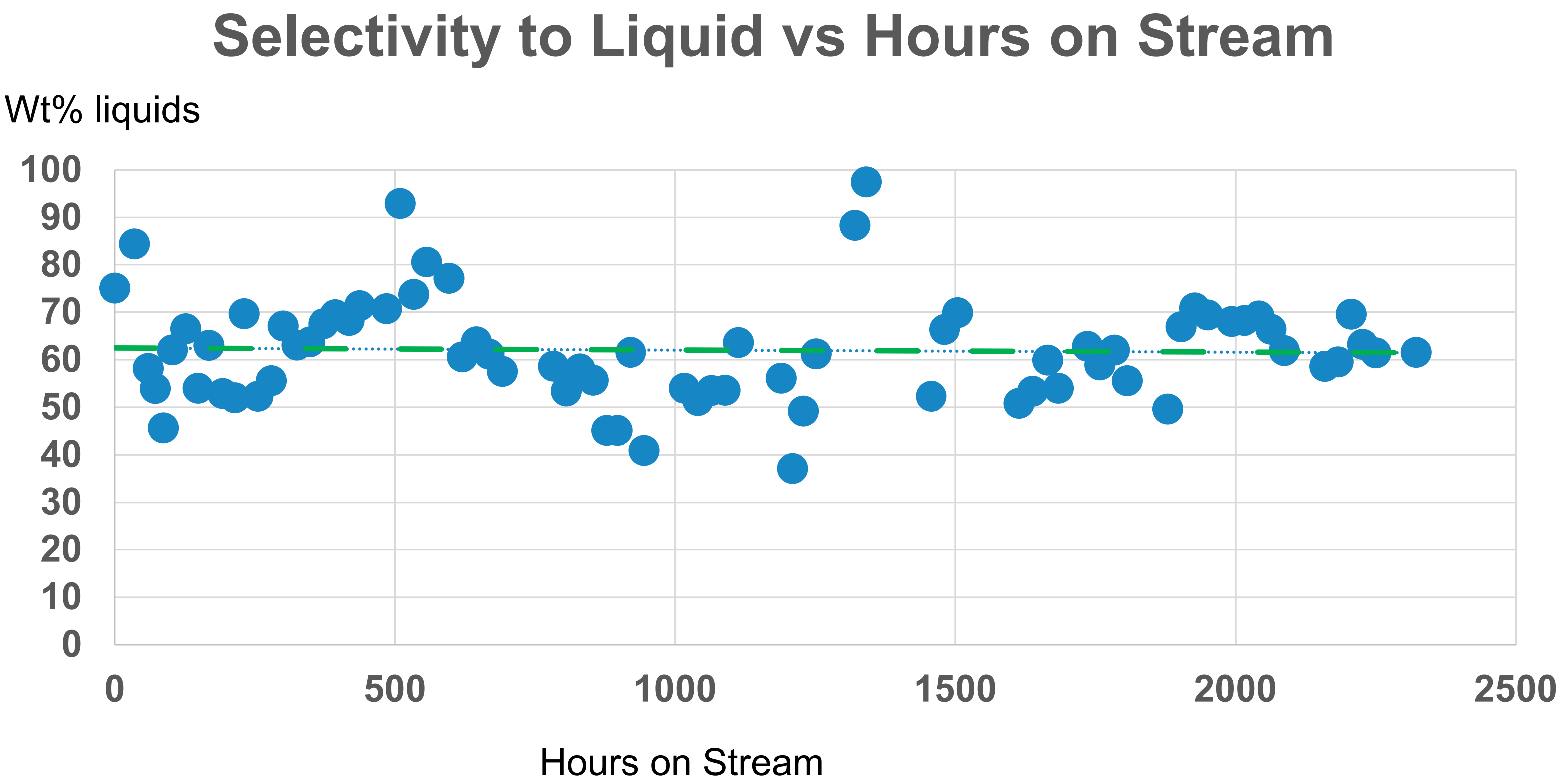

%CO Present in Upgrading Reactor vs Freeze Point