Production of Drop-in Transportation Fuels via Combined Biomass Gasification-Fischer-Tropsch Synthesis

Amit Gujar, Jong Baik, Nathaniel Garceau,
Nazim Muradov and Ali T-Raissi

Florida Solar Energy Center
University of Central Florida

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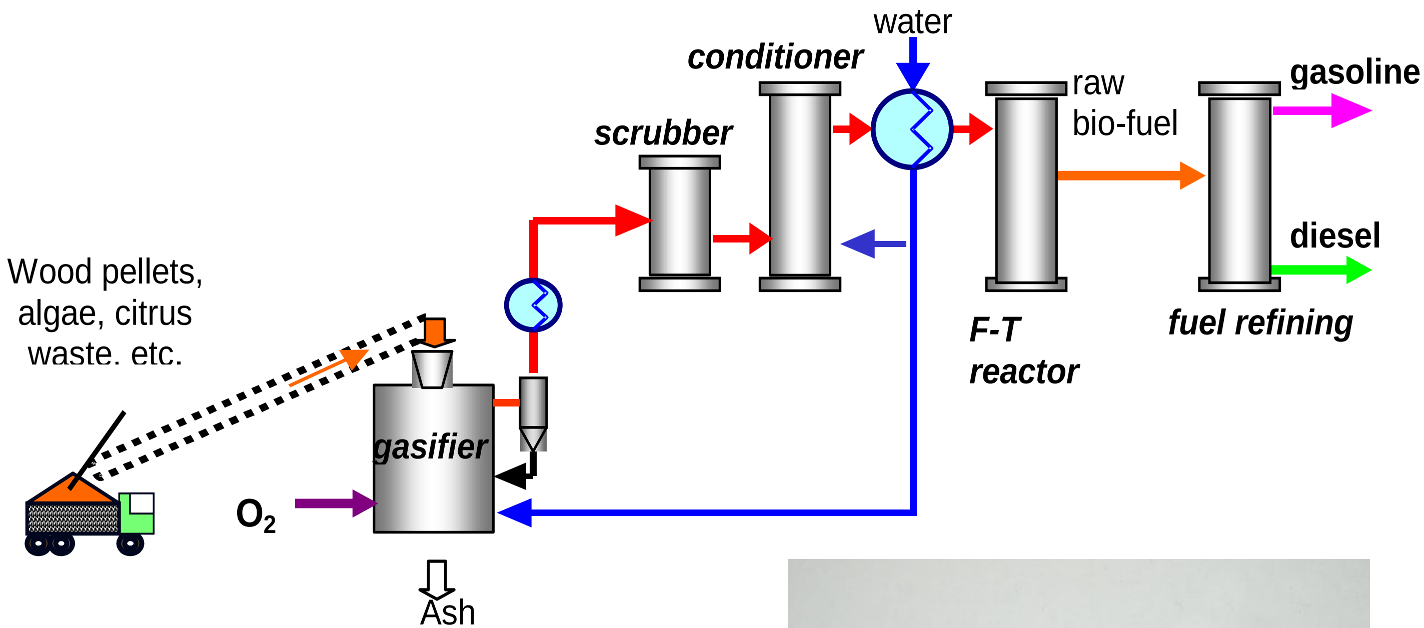
Objectives & Approach

- Demonstrate, at pilot-scale, production of transporatation fuel from biomass feedstock
- Build a PDU-scale oxygen-blown gasifier capable of steady-state operation.
- Fabricate a multi-tube Fischer-Tropsch (FT) reactor capable of yielding 1L/8hr liquid hydrocarbon fuel
- Integrate, operate and optimize integrated combined biomass gasification and FT synthesis reactor.

Introduction



River algae

Duckweed

Citrus pulp pellets

Pine wood pellets

Pine charcoal pellets

Introduction

- Ideal biomass gasification reaction-

  $CH_{1.4}O_{0.6} + 0.4\ O_2 \rightarrow 0.7\ CO + 0.3\ CO_2 + 0.6\ H_2 + 0.1\ H_2O$

- Ideal Fischer-Tropsch (FT) synthesis reaction-

  $CO + 2\ H_2 \rightarrow -CH_2- + H_2O$

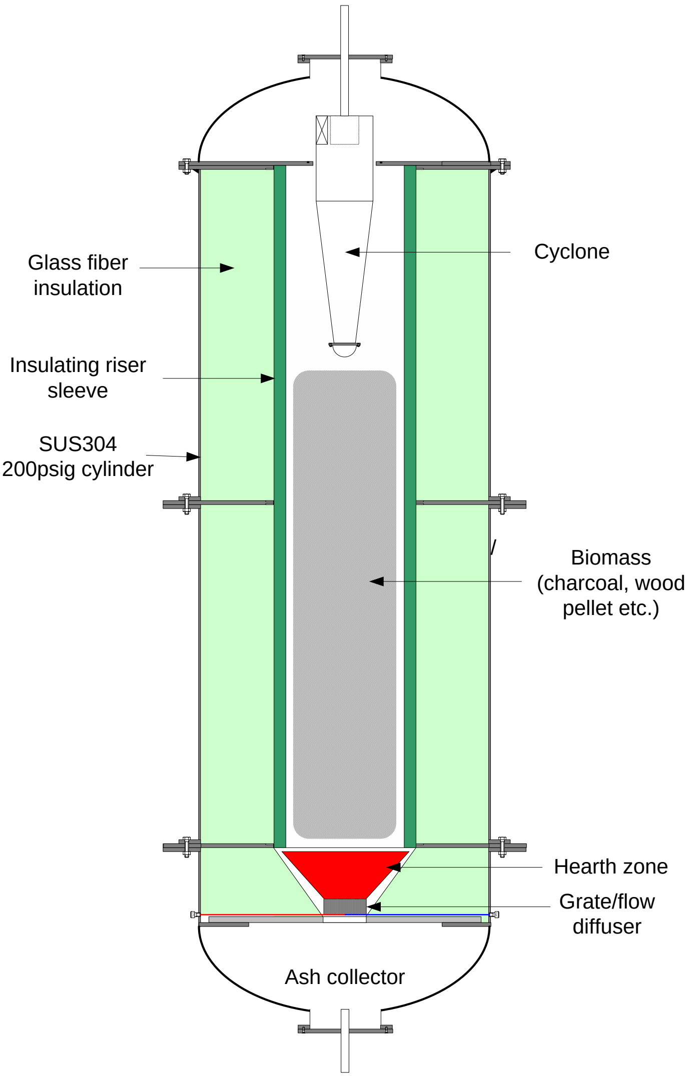
Other reactions

$CO + H_2O \text{------>} CO_2 + H_2$

$C + CO_2 \text{----->} 2CO$

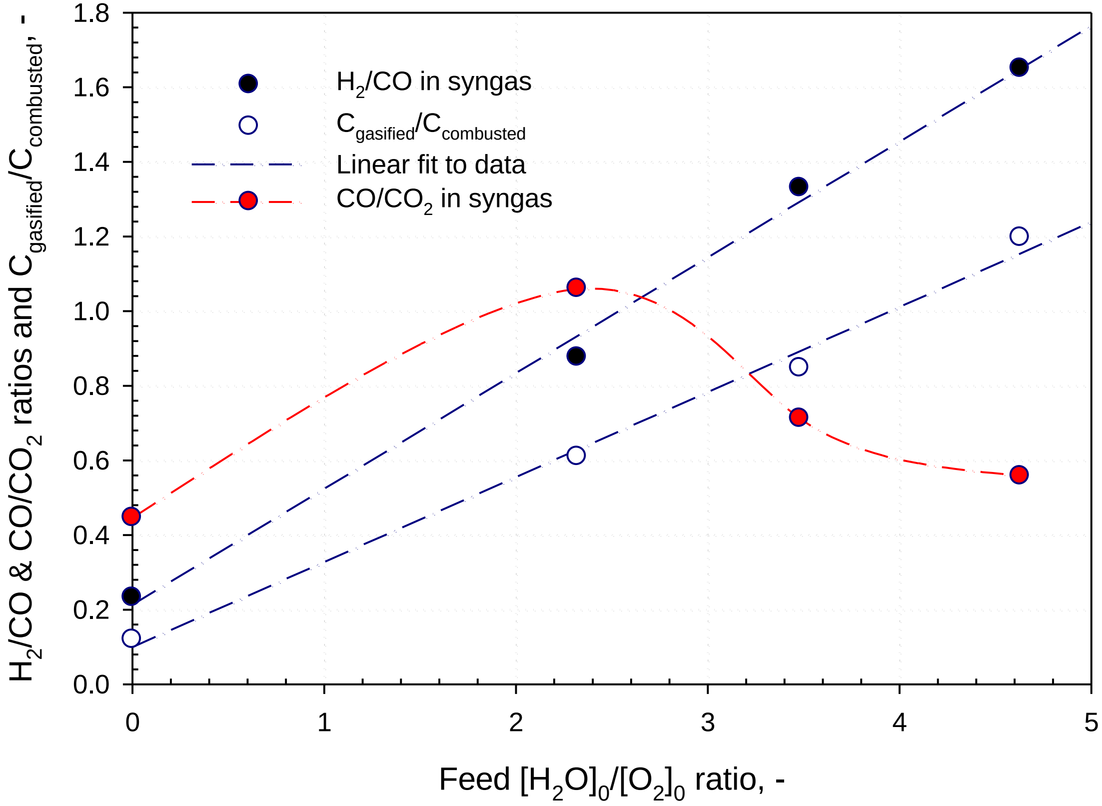
$CO + 3H_2 \text{----->} CH_4 + H_2O$

Gasification Reactor



- 3.25" Hearth dia.
- 9" Internal dia. of the riser sleeve.
- 41 lt of biomass volume capacity.
- 200psig pressure rating.

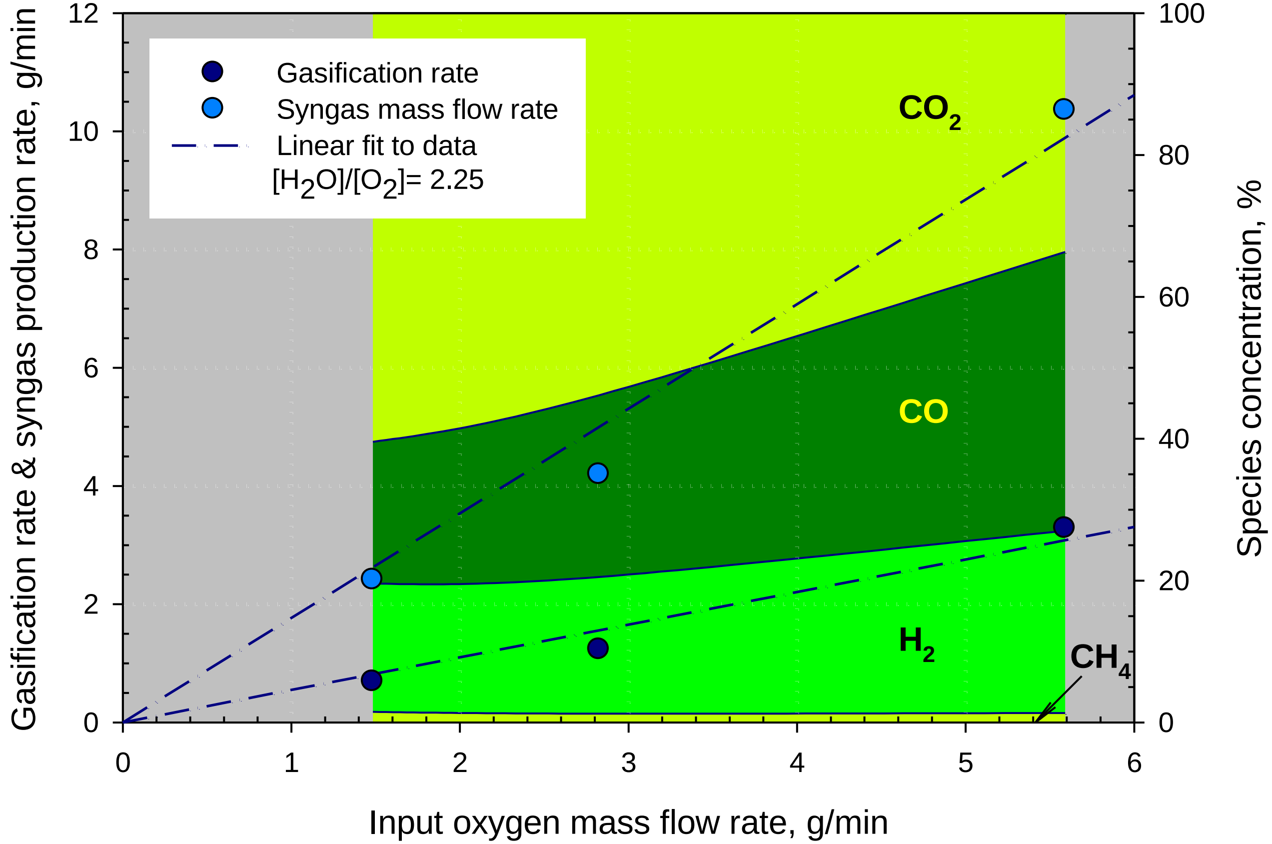
Results – Biomass Gasification (1)



Small gasifier

Optimum $[H_2O]_0/[O_2]_0$ molar feed ratio appears to be in the range of 4-5.

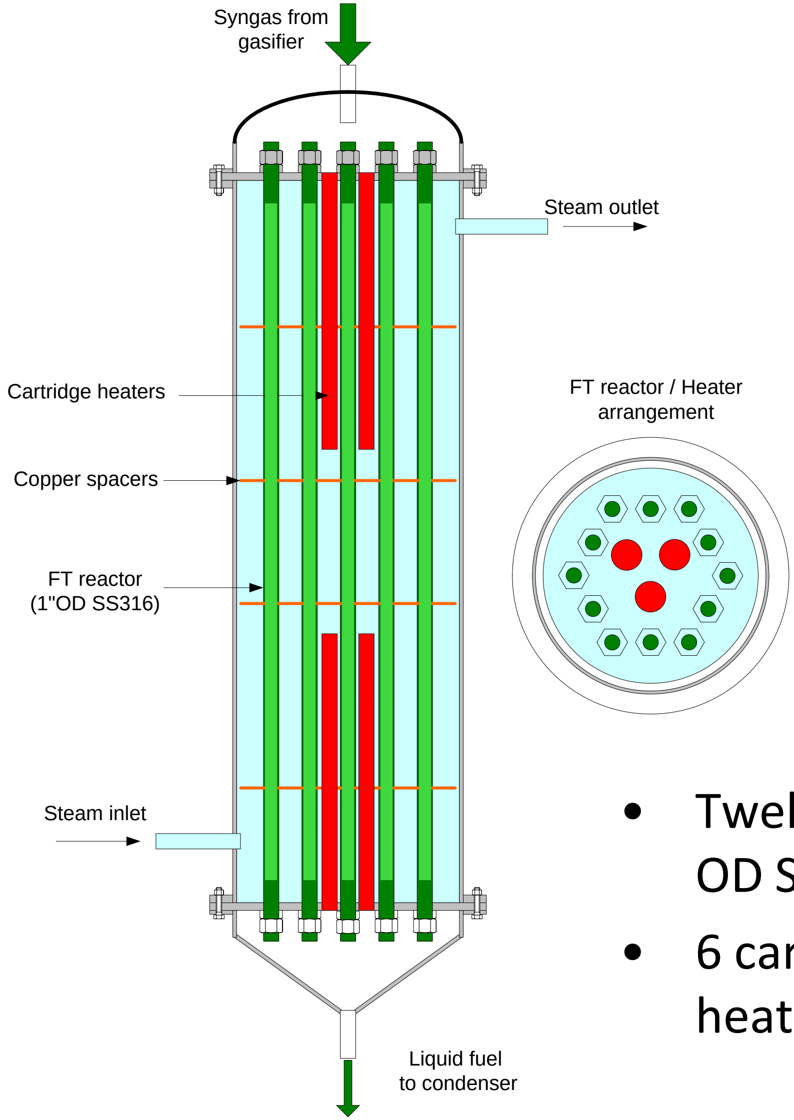
Results – Biomass Gasification (2)



High O_2 mass flow rate leads to higher concentration of H_2 & CO in the syngas as well as higher gasification rates.

Useful data for sizing the gasifier

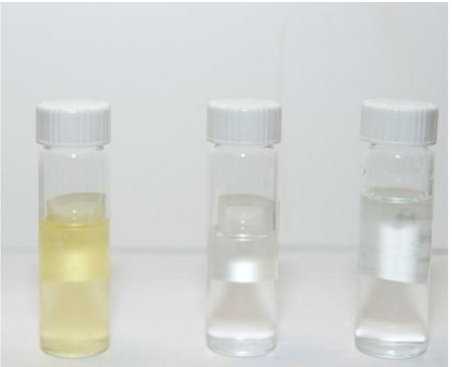
FT Reactor Design



- Twelve (12) 1" OD SS316 tubes
- 6 cartridge heaters

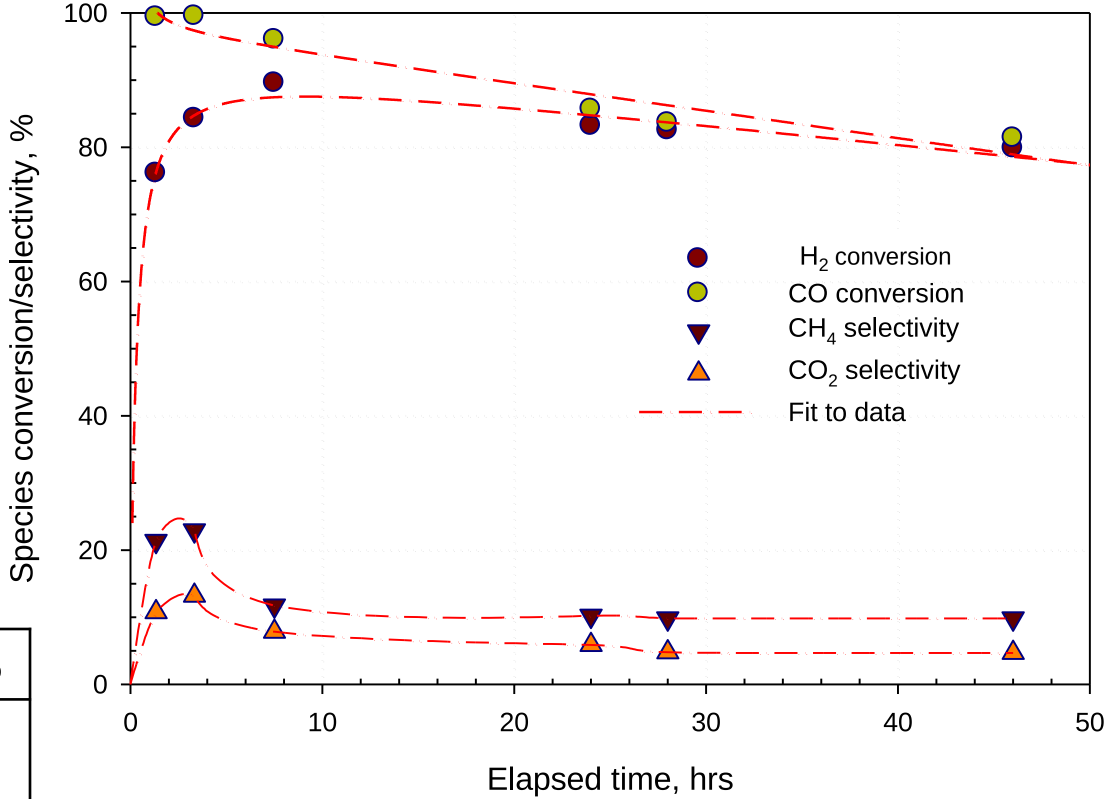
Results – FT Synthesis (1)

- Co catalyst tested at 250°C, 200 psig, 3,106 mL/gcat.hr



Gasoline range (C_5-C_{10})	48.98 wt%
Kerosene/jet fuel range (C_{11}-C_{12})	15.08
Diesel range (C_{13}-C_{16})	21.10
Lube oil and wax range (C_{17}-C_{26})	14.84

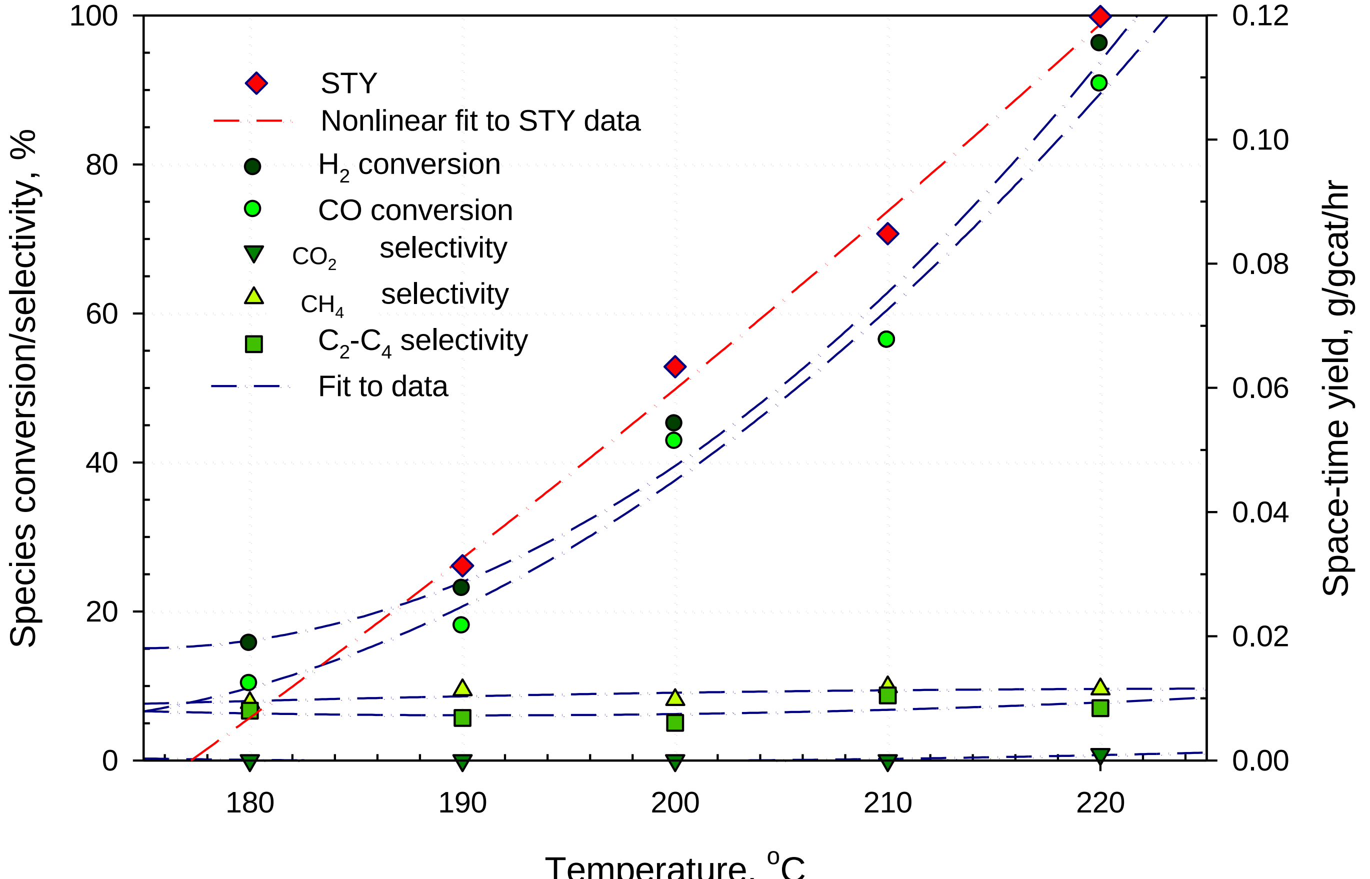
33% CO & balance H_2 over 20% Co-SiO_2



Space-time yield = 0.24 g/gcat.hr

Results – FT Synthesis (2)

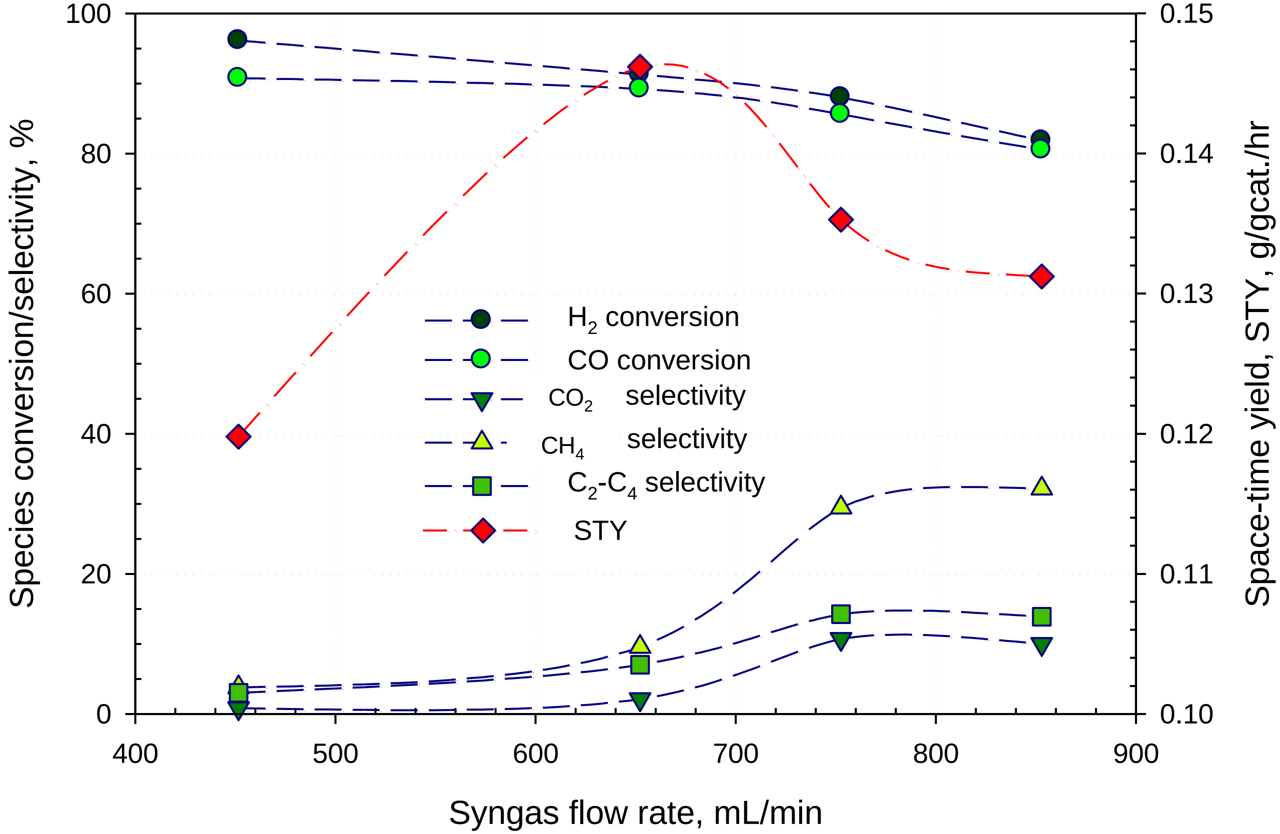
Scale up studies Temperature effect (H_2:CO=2:1 & 450 mL/min flow)



- Increase in temperature leads to increase in conversions and space time yields of liquid product

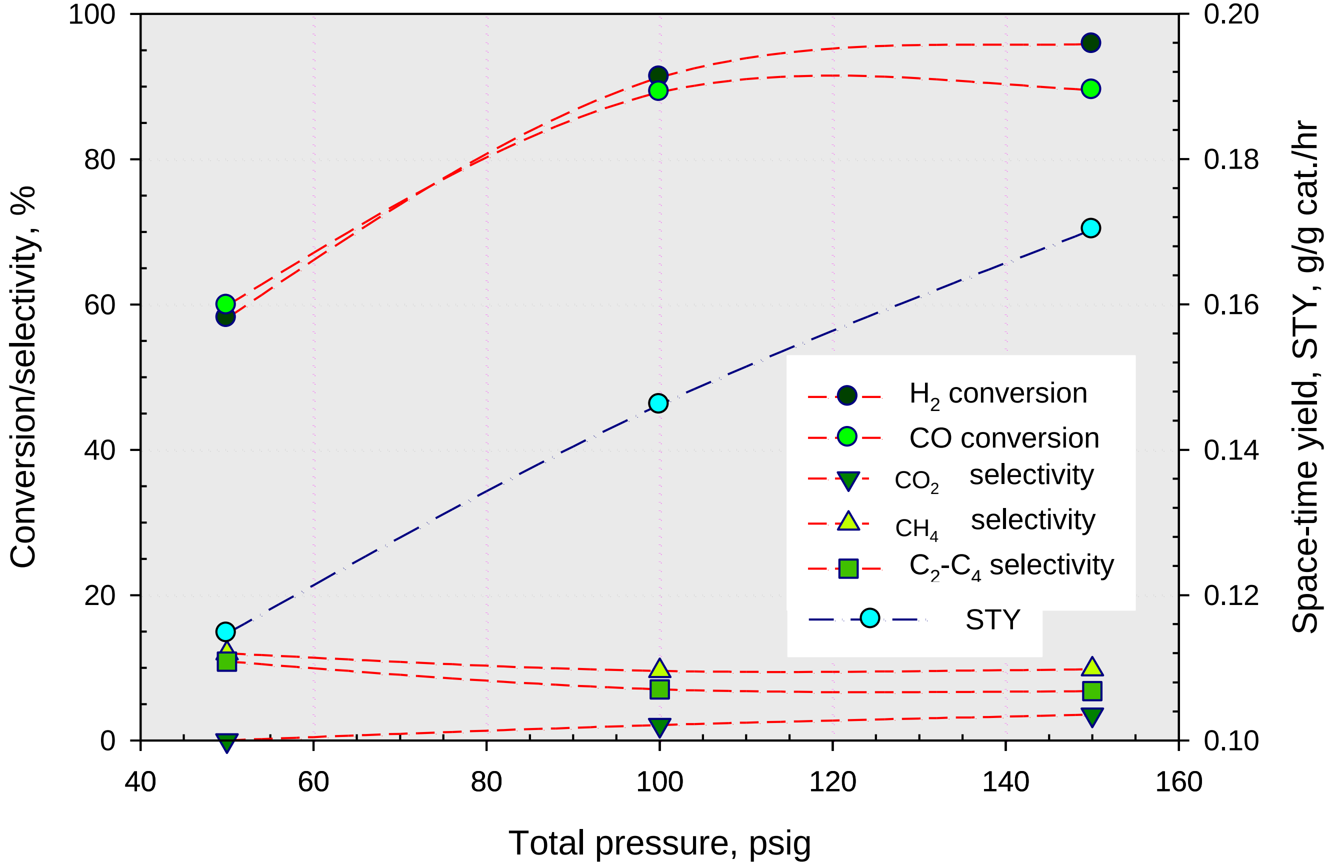
Results – FT Synthesis (3)

Effect of space velocity at 220°C



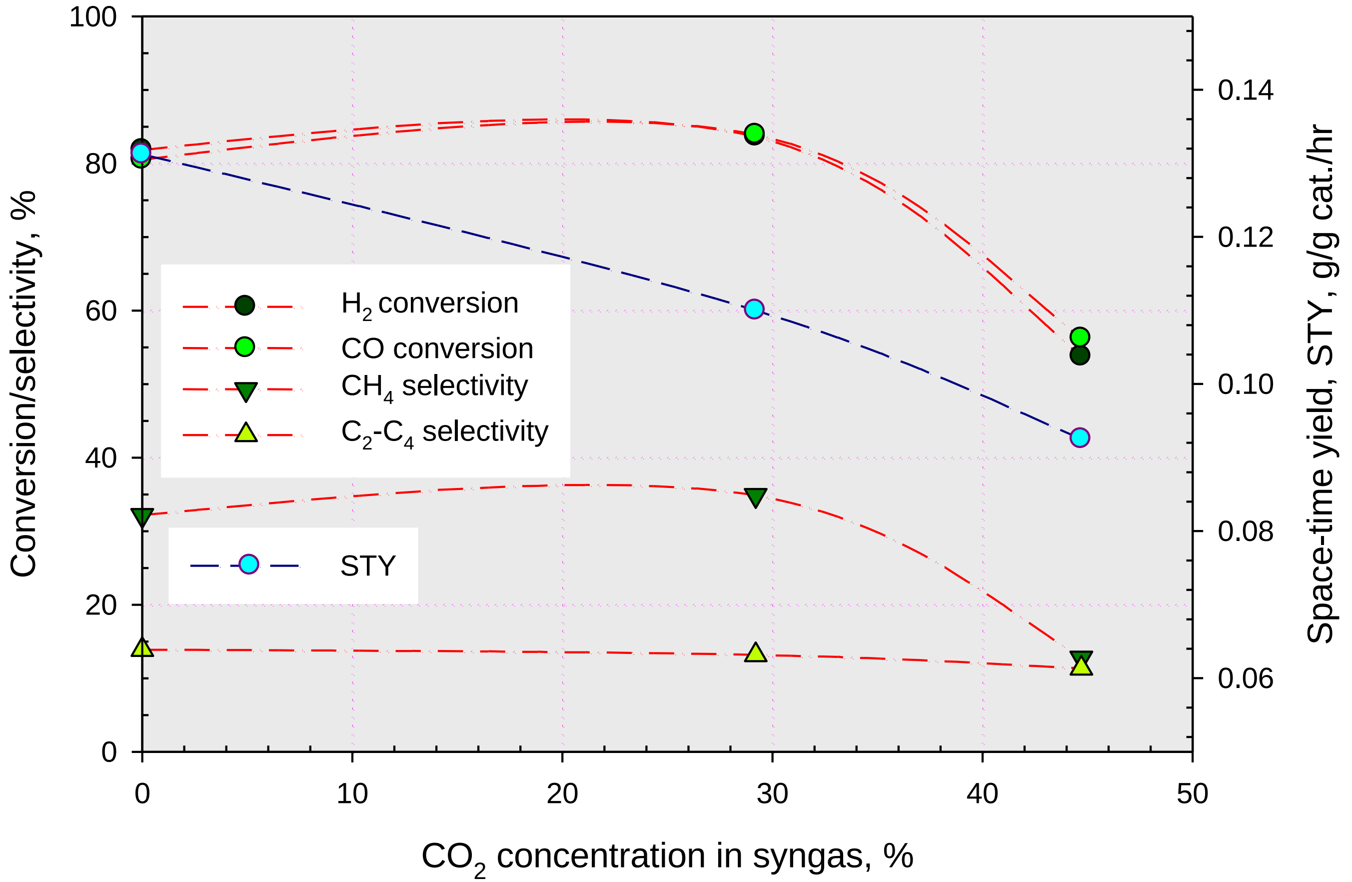
- Increasing the syngas flow rate eventually leads to increase in methane light gas selectivity due to exothermicity of the reaction thus leading to decrease in liquid yields.

Results – FT Synthesis (4)



Increasing pressure helps but reaction does proceed at low pressures, as well (unlike Fe catalyst)

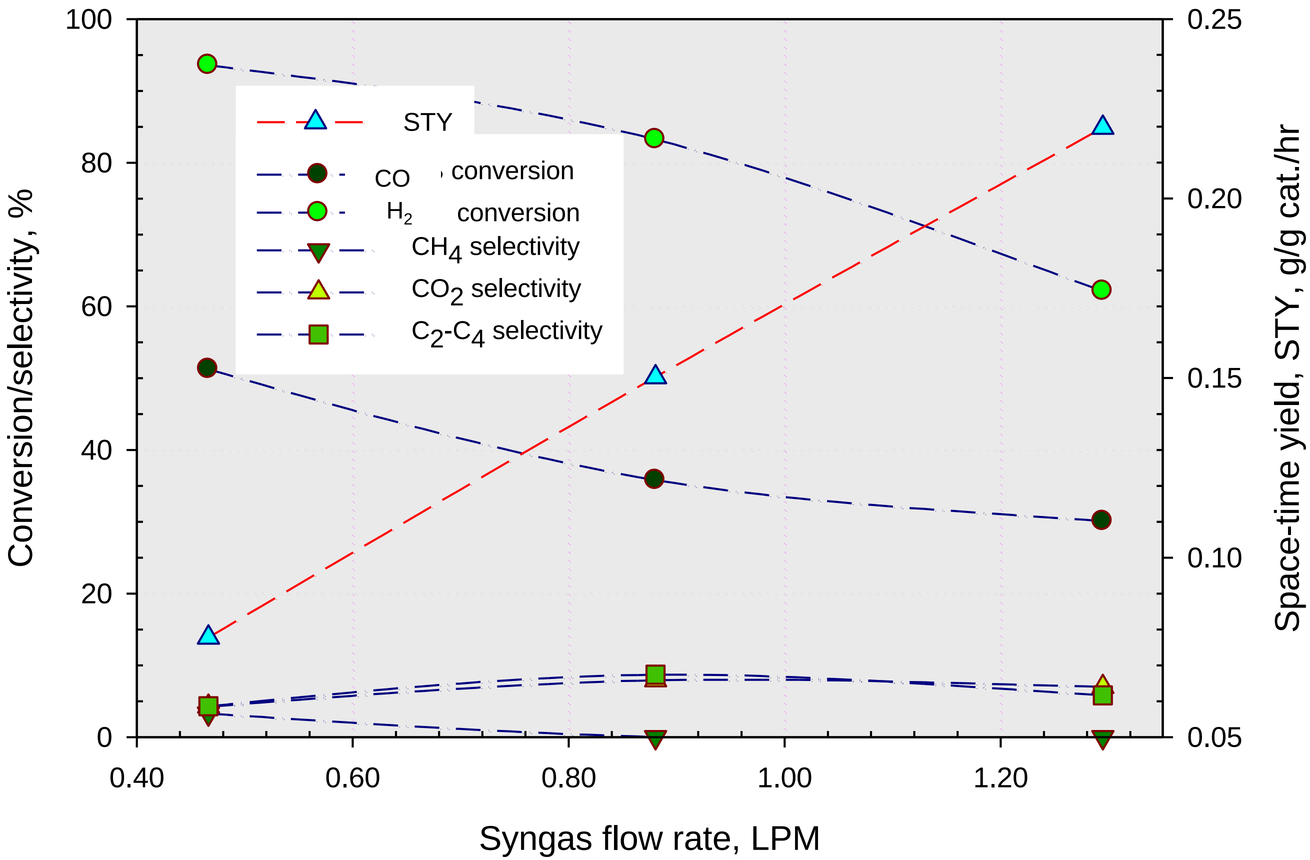
Results – FT Synthesis (5)



Decrease in the CH_4 selectivity as CO_2 concentration in the feed increases

Results – FT Synthesis (6)

Effect of space velocity (230°C & H_2:CO= 1:1)



- Upto 50% more liquid yield per tube when H_2:CO=1:1

Summary of FT Tests

- Using Syngas of H_2:CO=1:1 is preferable if the aim is to get maximum liquids out in a single pass mode.
- The use of syngas of H_2:CO=2:1 is preferable if the aim is to have maximum utilization of the inlet gas.
- Presence of CO_2 is helpfully in controlling the exothermicity of the reaction thus reducing the methane and light gas selectivity.

Acknowledgement

FESC Florida Energy Systems Consortium

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