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Synthetic Fuels from Hydrogen and Captured Carbon Dioxide

PEP Report 285D

Gajendra Kumar, **Director, Process Economics Program**

Tanushri Sood, **Research Analyst, Process Economics Program**

Table of contents

Tables

Figures

Appendix C Figures

Glossary

AMP	2-amino-2-methyl-1-propanol
atm	Atmospheres
ATR	Autothermal reactor/reformer
BCM	Billion cubic meters
b/d	Barrels per day
BFD	Block flow diagram
BLI	Battery limits investment
Btu	British thermal units
CC	Carbon capture
CCS	Carbon capture and storage/sequestration
CCU	Carbon capture utilization
CCUS	Carbon capture utilization and/or sequestration
cm^2	square centimeter
¢	US cents
cP	Centipoise
$	US dollars
FOB	Freight on board
F-T	Fischer-Tropsch
ft^3	Cubic feet
g	Grams
gal	Gallons
Gt	Billion metric tons
GTL	Gas-to-liquids
GW	Gigawatt
h	Hours
HP	High pressure
HSS	Heat-stable salts
kg	Kilograms
kJ	Kilojoules
kPa	Kilopascals
kWh	Kilowatt hour
lb	Pounds
LHSV	Liquid hourly space velocity
LFP	Liquid fuel production
LP	Low pressure
LPG	Liquid petroleum gas
m	Meters
m^2	square meters
M	Thousand
Mgal	Thousand gallons
Mlb	Thousand pounds
MM	Million
mm	Millimeters
MP	Medium pressure
MMt	Million metric tons
MOF	Metal-organic frameworks
mol%	Molar percent
mPa	Megapascals
MtG	Methanol-to-gasoline
Mt/y	Metric tons per year
MW	Megawatt
N	Normal
Nm^3/h	normal cubic meters per hour
NZE	Net Zero Emissions
OSC	Oxygen storage capacity

PEM	Proton exchange membrane
PEP	Process Economics Program
PFD	Process flow diagram
ppb	Parts per billion
ppm	Parts per million
PSA	pressure swing adsorption
psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
PZ	piperazine
ROI	Return on investment
RWGSR	Reverse water gas shift reaction
s	Second(s)
scf	Standard cubic feet
SCM	Standard cubic meter
SMR	Steam methane reforming
SOEC	Solid oxide electrolyzer cell
t	Metric tons
TFC	Total fixed capital
USGC	Unites States Gulf Coast
V	Volts
vol%	Volume percent
wt%	Weight percent
w/w	Weight for weight

Abstract

The world's growing energy demand, coupled with our current dependence on fossil fuels, has led to increased greenhouse gas emissions, particularly carbon dioxide (CO_2). Among all sectors, the transportation sector is a major cause of significant carbon dioxide emissions. Although smaller vehicles are transitioning from gasoline and diesel to electricity, heavy-duty vehicles and aviation continue to rely on diesel and jet fuel. Hence, the need to reduce the greenhouse gas emissions is driving a shift away from fossil fuels, leading to an increased focus on renewable alternatives, particularly for jet fuel and diesel.

The gas-to-liquids (GTL) industry has played a critical role in monetizing natural gas to produce cleaner diesel and kerosene for transportation fuels. The industry is now exploring a shift from using natural gas as the carbon source to utilizing CO_2. This CO_2 can be obtained from various sources, including direct air capture, biogenic origins or unavoidable CO_2 emissions from the industries.

The conversion of CO_2 and H_2 via Fischer-Tropsch (F-T) synthesis holds great potential as a pathway for producing transportation fuel. Several companies, including Topsoe, Johnson Matthey, Sunfire, Carbon Engineering and Intratec, have developed technologies for converting CO_2 into synthetic fuels.

Synthetic fuels (synfuels) produced from CO_2 offer significant potential for reducing greenhouse gas emissions in the transportation sector. They can be particularly beneficial for applications, such as heavy-duty vehicles, rail locomotives, marine vessels and aviation aircraft that are challenging to electrify directly. These fuels, derived from waste CO_2 streams and green hydrogen generated from electrolysis, have properties similar to the conventional petroleum fuels but with much lower emissions.

This report presents the techno-economic analysis of three commercial processes to produce synthetic fuels. These processes are.

1. G2L™ e-Fuels by Topsoe
2. Synthetic fuels by Johnson Matthey and BP via F-T CANS™
3. Electrofuels by Infinium™

In addition to covering the above three processes, the report will provide an overview of the most recent advancements in technology, such as reactor design, catalyst performance and separations, emphasizing technology readiness.

The production economics assessment in this report is based on a US Gulf Coast (USGC) location. However, an iPEP Navigator module (an Excel-based computer costing model developed by S&P Global will be attached with this report to allow a quick calculation of the process economics for three other major regions: Germany, Japan and mainland China. The module also provides production economics for every process to be reported in English or metric units in each region.

The technological and economic assessment of the processes is Process Economics Program's (PEP) independent interpretation of the companies' commercial processes based on information presented in the open literature, such as patents or technical articles. It may not reflect the actual plant configuration in whole or in part. We believe they are sufficiently representative of the processes and process economics within the range of accuracy necessary for economic evaluations of the conceptual process design.

Contacts

Gajendra Kumar

Director, Process Economics Program
gajendra.kumar@spglobal.com

Tanushri Sood

Research Analyst, Process Economics Program
tanushri.sood@spglobal.com

Richard Charlesworth

Executive Director, Process Economics Program
richard.charlesworth@spglobal.com

CONTACTS

Europe, Middle East, Africa: +44 (0) 203 367 0681
Americas: +1 800 332 6077
Asia-Pacific: +60 4 296 1125

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