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FLEXIFORMING Process for Sustainable Aviation Fuel

Flexiforming, a trusted technology for mini-refineries, can be used for production of sustainable aviation fuel.

Jet Fuel and aviation gasoline (avgas) are the types of transportation fuels where an alternative to liquid fuels is not available yet. Even in 2021 when travel was restricted by COVID, approximately 500 million barrels of jet fuel have been used in the US alone, generating over 440 billion pounds (~200 million metric tons) of CO_2 emissions.

Flexiforming has been successfully used as a core technology for standalone mini-refineries. It can be used to convert ethanol into sustainable aviation fuel (SAF) and avgas or motor gasoline blendstocks.

Sustainable Aviation Fuel Incentives

Federal tax credits at 125-175 cpg are available for SAF, and state-level LCFS carbon credits add a comparable amount to revenue on the US and Canadian West Coast.

SAF and Avgas by Flexiforming

Using fuel-grade ethanol as feed, Flexiforming can produce:

- SAF blendstock compliant with ASTM D7566,
- Avgas or motor gasoline blendstock.

SAF Blendstock by Flexiforming		Jet Fuel Requirements ASTM D7566
Density, kg/m^3	820	755-840
Freeze point, °C	-50	≤ -40
Net heat of combustion (NHC), MJ/kg	43.7	≥ 42.8
Viscosity @-20 °C, mm^2/s	2.5	≤ 8.0
Boiling curve:		
10%, °C	160	≤ 205
FBP, °C	240	≤ 300
Aromatics, % vol.[1]	up to 25	8 - 25
Total sulfur, % wt.	0	≤ 0.30

Gasoline Blendstock by Flexiforming[2]		100 LL Avgas Requirements ASTM D910	CARBOB[4] Requirements
MON[3]	80-86	≥ 99.6	≥ 82
RVP, psi	5.5-6.5	5.5-7.1	≤ 6.4-7.0
NHC, MJ/kg	43.4-43.8	≥ 43.5	n/a
Boiling curve:			
10%, °C	50-60	< 75	≤ 70
40%, °C	75-80	≥ 75	n/a
50%, °C	88-95	≤ 105	≤ 100
90%, °C	130-150	≤ 135	≤ 152
FBP, °C	140-155	≤ 170	≤ 225
Aromatics, % vol.	25-35	n/a	25
Benzene, % vol.	0.6-1.5	n/a	0.8
Olefins, % vol.	4-10	n/a	6

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Sustainable Aviation Fuel and Gasoline with FLEXIFORMING

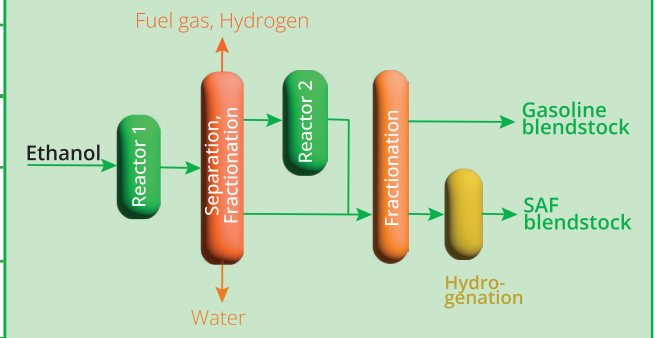
Conversion of ethanol into sustainable aviation fuel is done with Flexiforming technology, commercially proven at small scale.

Molecules of ethanol are dehydrated into ethylene, then oligomerized into isoparafines, aromatized and alkylated into alkyl-aromatics, creating a high octane flexiformate, hydrogen and fuel gas.

After stabilization, the lighter fraction of the flexifomate is ready for blending into avgas or motor gasoline.

The heavier fraction is hydrogenized into SAF blendstock.

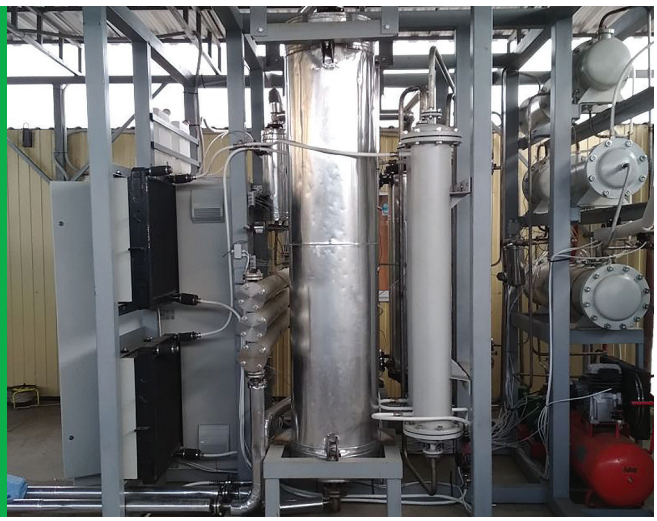
Indicative Material Balance		
In mass units		
In	Ethanol	1 000
	Total inputs	**1 000**
Out	SAF blendstock	332
	Gasoline blend-stock	199
	Fuel gas	78
	Water	391
	Total outputs	**1 000**



Commercial Flexiformers

Four Flexiforming-based mini-refineries, using different generations of our proprietary catalyst, have been in commercial operation since 2015.

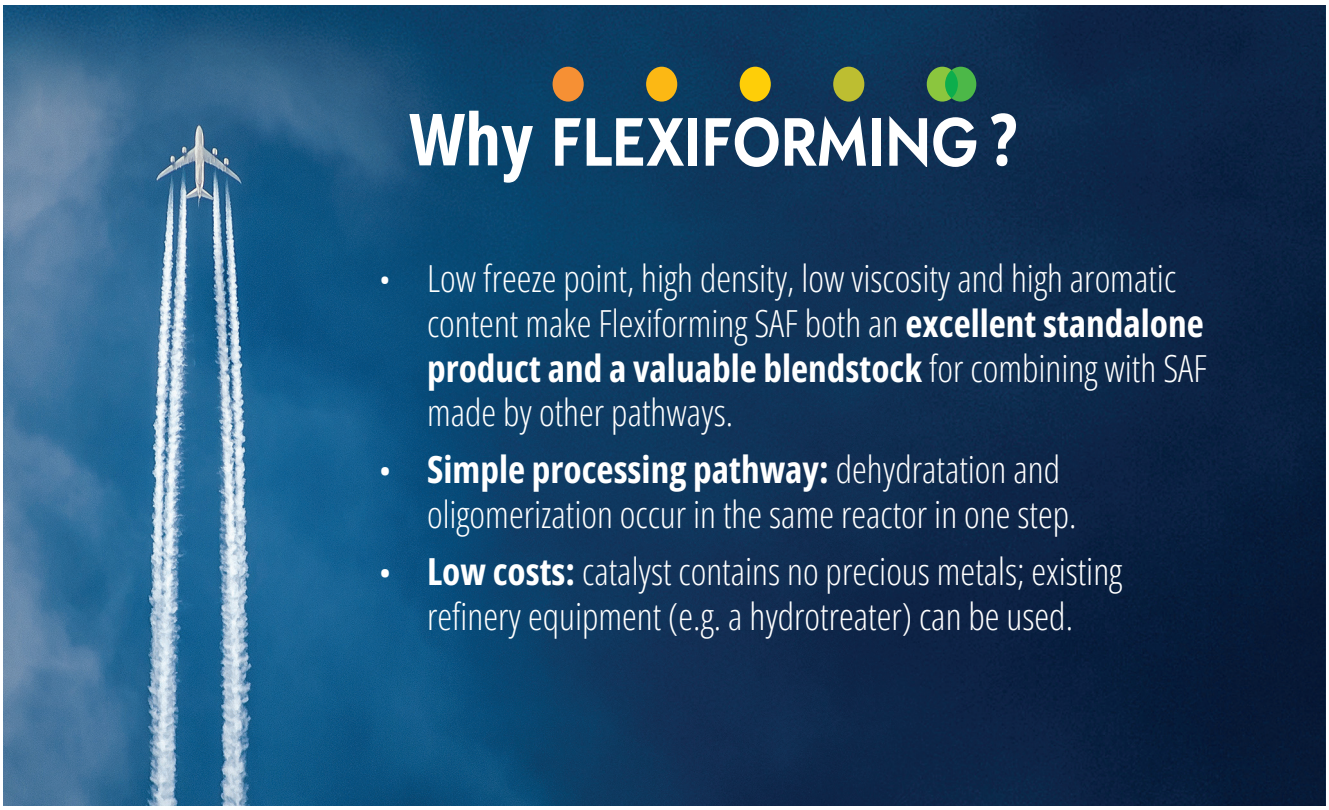
A 500 bpd (~20k tons per year) standalone Flexiformer can profitably produce ASTM-compliant transportation fuels; economic feasibility of smaller scale plants can be assessed if needed.



1 Sustainable aviation fuel is often short on aromatics, which makes the SAF blendstock produced by Flexiforming particularly valuable.
2 Ranges reflect possible process conditions, to be selected by the operator depending on their product and blending preferences.
3 MON of Flexiforming blendstock shown prior to blending. Required MON for avgas and CARBOB shown after blending, per applicable standards.
4 ASTM 4814, California Code of Regulations Title 13 Sections 2250-2273.5, pipeline standards.

Flexiforming technology has the following renewable applications:

- Ethanol to SAF and aviation or motor gasoline (described in this document),
- Ethanol to aviation gasoline,
- Renewable naphtha and a renewable alcohol to SAF and renewable RBOB gasoline,
- Traditional (fossil) naphtha and renewable alcohol to partially renewable RBOB gasoline,
- Renewable naphtha with dry gas from FCC operating on renewable feed to SAF and renewable RBOB gasoline,
- Renewable light olefins to renewable SAF or RBOB gasoline,
- Renewable naphtha with dry and wet gas from FCC operating on renewable feed to SAF and renewable RBOB gasoline.



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