Johnson Matthey
Inspiring science, enhancing life

VIRENT

BioForming® S2A technology: Success in fuels and fabrics

World BioMarkets | May 2023

Virent and Johnson Matthey – A powerful collaboration

Virent—a subsidiary of Marathon Petroleum Corporation—developed its BioForming® technology to create the fuels and chemicals the world demands from a wide range of

naturally occurring, renewable resources

Johnson Matthey (JM) is a global leader in science that enables

a cleaner and healthier world

and has developed a portfolio of process technologies and catalysts for licensing and sale throughout the world

Virent and JM have combined their skills and expertise to further develop and bring to market Virent's proprietary technology for the production of BioFormate®, enabling production of

bio-gasoline, sustainable aviation fuel (SAF), and bio-aromatic chemicals

Johnson Matthey and Virent will license the BioForming® technology

at capacities greater than 8000 bbl/day

to meet their customer's needs and transfer the technology via an engineering package

BioForming® S2A process

The BioForming process can work with a range of sugar feedstocks and produces products which can be blended with existing refinery streams

Corn sugars

Sugar cane

Sugar beet

Cellulosic sugars from biomass deconstruction

BioForming® plant

Hydrogen

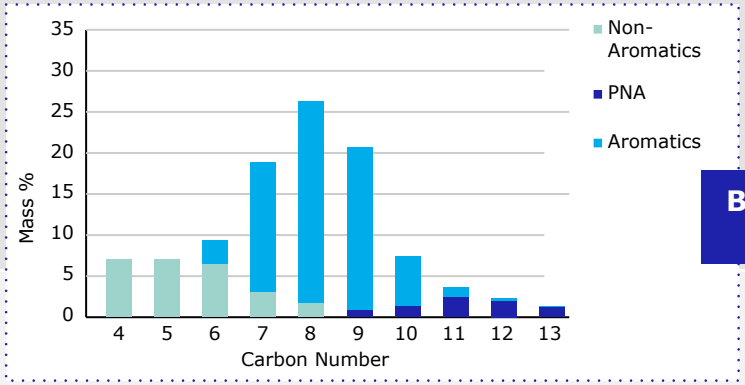
Feedstock clean-up → Hydrogenation → HDO → Acid condensation

Removes catalyst poisons

Stabilizes sugars

Lowers oxygen content

Makes the aromatic mixture



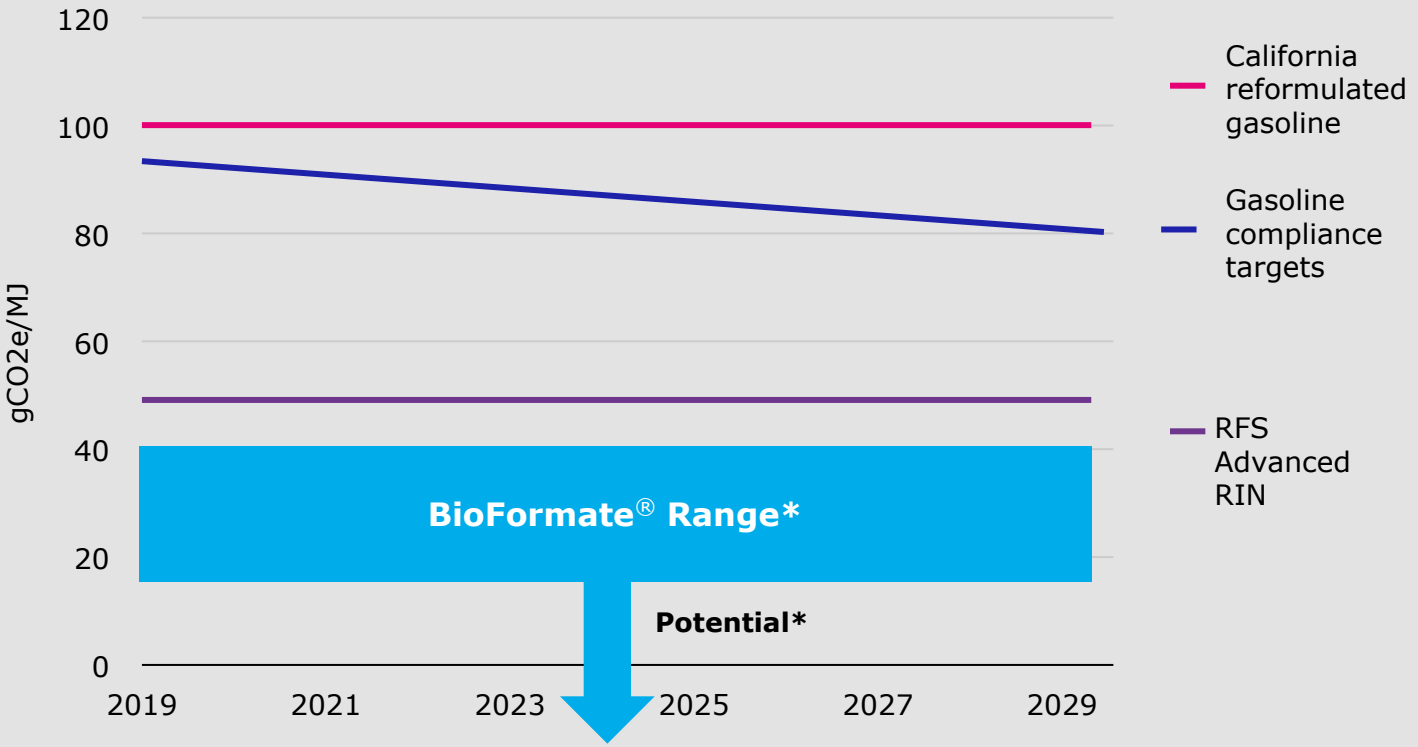
BioFormate® product

Aromatic chemicals option

Bio-fuels

- BioForm® Gasoline
- BioForm® SAK Jet Fuel
- BioForm® Distillate

BioFormate® delivers a high-quality, low-CI gasoline and SAF blendstock



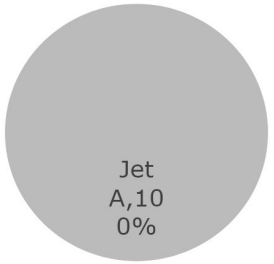
*BioFormate CI will be determined by choice of utilities and deployment strategy.
Examples: Grid electricity vs renewable electricity, renewable natural gas (RNG) use

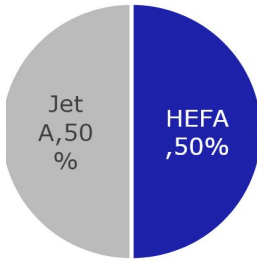
Successful 12-vehicle no-harms testing

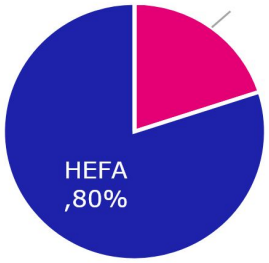
EPA part 79 registered up to 45% BioForm® Gasoline

Synthesized aromatic kerosene (SAK)

Enables 100% drop-in SAF with lower particulate matter emissions than conventional jet A







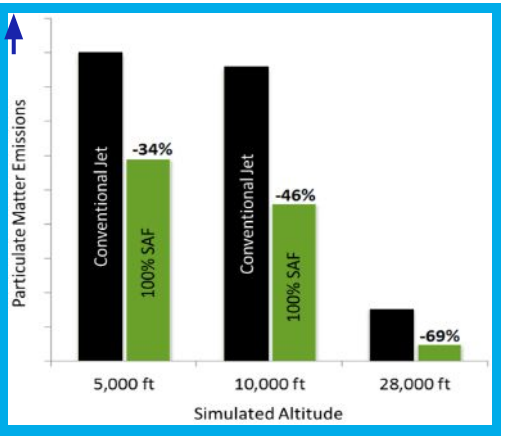
Drop-in	✓	✓	✓
Lower PM		✓	✓
100% SAF			✓
Comment		Max blend allowed by HEFA Annex and spec limits	Unique **100% drop-in SAF**: meets all jet specs

>50% blends needed to meet long-term airline industry sustainability targets

Test	Units	D1655 Limit	HEFA	SAK	20% SAK + HEFA
Aromatics	Vol %	8 – 25	**0**	**98.0**	19.6
Naphthalenes	Vol %	< 3	0	0.1	0.02
Density	kg/m3	775 – 840	**750**	**875**	775
Freeze Point	°C	< -40	< -40	< -77	<< -40

High density, low freeze point SAK + low density, high freeze point HEFA

2015: small jet test flight on 100% SAF matched Jet A engine performance with lower PM emissions



Progressing through Phase 2 of the ASTM approval process

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BioForm® SAK jet fuel
Ready for takeoff

United Airlines
December 2021

Gulfstream G650
December 2022

Emirates 777
January 2023

Bell Helicopter
February 2023

Enabling **100% SAF** demonstration flights

100% drop-in SAF using BioForm® SAK that meets **all ASTM D7566** requirements

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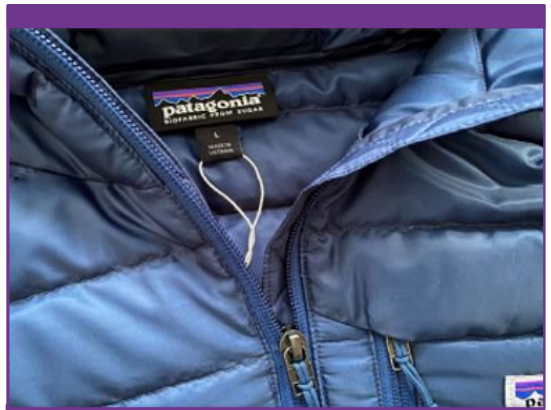
BioFormate®

Creating new market opportunities for renewable chemicals

Coca-Cola
November 2021

Paris Fashion Week with Issey Mayake
February 2022

Headrest Covers on ANA Green Jet
October 2022



Patagonia SugarDown Hoody
November 2022

Expanding the market for 100% bio-based plastics, fibers and films

100% bio-PET using BioForm PX®

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BioForming® S2A: Ready for commercialisation

Designed to provide real-world impact

Proven, commercially driven technology solutions that meet the world's growing demand for renewable fuels and chemicals

Proven performance

- **Fully integrated "Eagle" demo plant** currently running with all recycles included
- Currently producing **1 barrel of BioFormate® product per day**
- **Over 25,000 hours of operation** on Eagle to date
- **Commercial scale catalysts loaded** and performing as expected while **achieving established targets**
- Current focus is optimisation

Ready and demonstrated

- Over **35,000 gallons of BioFormate® produced**
- Over **3,000 gallons of SAK** produced for **100% SAF**
- Over **14 tonnes** of BioForm® PX produced
- Renewable gasoline fleet trials and EPA certification demonstrated acceptability for commercial use
- SAF test flight in 2015 **demonstrated equivalent performance** and **35-70% lower particulate emissions**
- SAF demonstration flight in 2021 **validated readiness for commercialisation**
- Commercial and test products made from BioFormate® sourced paraxylene

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Contact or Visit Us at MS06 to Learn More

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