Lessons from Sustainable Aviation Fuel (SAF) Development

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United is the global leader in sustainable aviation fuel

2009	2011	2013	2015	2016	2018	2019
First U.S. test flight	First U.S. commercial flight	First U.S. airline supply agreement (World Energy)	$30M equity investment in Fulcrum BioEnergy	First ongoing use globally (World Energy)	First U.S. airline goal to reduce GHGs (50% by 2050)	Additional $40M collaborative investment

United has the…

- Largest SAF investment
- Largest SAF contract
- First with U.S. GHG reduction goal

Why SAF?

- Batteries are too heavy
- Solar energy is too weak
- No new infrastructure

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United has been flying on SAF produced by world energy

March 2016

United began flying World Energy's SAF from its Los Angeles hub in March 2016.

4 million gallons

United has bought nearly 4 million gallons of SAF through the end of 2019, more than any other airline in the world.

Tallow feedstock

The SAF is made from tallow, an inedible substance made from beef fat.

4,000+ flights

Through the end of 2019, United has flown the equivalent of nearly 4,000 SAF flights.

60% CO_2 reduction

World Energy's SAF provides a greater than 60% reduction in CO_2 emissions on a lifecycle basis when compared to traditional jet fuel.

Dormant refinery

This project created 65 new jobs at the previously idle refinery in Paramount, California.

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In 2015 United invested $30 million in Fulcrum BIOENERGY

$30M invested

United has invested $30M in Fulcrum, the largest airline investment in SAF.

900 million gallons

United can purchase up to 900 million gallons of SAF from Fulcrum over a ten-year period.

Landfill waste

Fulcrum's SAF will be produced from landfill waste, and will also capture recyclables and generate renewable electricity.

20% of waste

20% of U.S. landfill waste could power United's entire aircraft fleet.

80% CO_2 reduction

Fulcrum's SAF will provide a greater than 80% reduction in CO_2 emissions on a lifecycle basis when compared to traditional jet fuel.

Strong partners

Other investors in Fulcrum include important business partners such as BP and Waste Management.

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Alternative fuels have made significant advancements in the last decade

	New feedstock	LCA reduction	Key questions
10 years ago	Crops	10%-20%	*Will it hurt the engines?* *Will it affect aircraft performance?* *How do we certify this?* **Is it safe?**
5 years ago	Waste byproducts	30%-40%	*How does the business case work?* *Why should we be first?* *What policies are needed?* **Is it sustainable?**
Today	Carbon capture	60%-80%	*How do we engage our customers?* *Where is the money to scale up?* **How do we make it affordable?**

SAF must be a drop-in solution, compatible with today's aircraft and airports…

Dollar coin
Re-introduced in 1971, 1979, 2000, 2007

Double-decker bus
Less traffic congestion than articulated buses

Dvorak keyboard
Patented in 1936

**New technology is great—
as long as it fits the existing infrastructure**

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…though today's specifications can originate very far in the past

Solid rocket boosters for the Space Shuttle were built at a factory in Utah, but their width was constrained by a tunnel through the mountains

This tunnel is slightly wider than the U.S. railroad gauge of 4 feet, 8.5 inches

U.S. railroads were designed by British expatriates, who also used the same width

The first British railroads were built by the same workers that built tramways

These workers previously used the same jigs and tools to build wagons

These wagons were built to adhere to the existing rut spacing on old roads

The ruts on these roads were first created by Roman chariots

The Roman chariot width was designed to accommodate two horses

Source: astrodigital.org

Patience and persistence are critical for successful SAF development

AltAir Fuels and 14 airlines sign biofuel MOU

FlightGlobal

December 15, 2009

Fourteen airlines and alternative fuels producer AltAir Fuels have entered a memorandum of understanding to negotiate the purchase of roughly 50 million US gal of bio-derived jet fuel per year. **Participating airlines include…United Airlines.**

AltAir **intends to produce at a new refinery in Anacortes, Washington.** The AltAir facility is **scheduled to begin production in 2012.**

United Airlines and AltAir Fuels to Bring Commercial-Scale, Cost-Competitive Biofuels to Aviation Industry

June 4, 2013

United Airlines today executed a definitive purchase agreement with AltAir Fuels. **AltAir Fuels will retrofit part of an existing petroleum refinery** to become a 30 million gallon, advanced biofuel refinery **near Los Angeles, California.**

AltAir expects to begin delivering five million gallons of renewable jet fuel per year to United **starting in 2014.**

United Airlines is flying on biofuels. Here's why that's a really big deal.

The Washington Post

March 11, 2016

On Friday, United Airlines will launch a new initiative that uses biofuel to help power flights running between Los Angeles and San Francisco, with eventual plans to expand to all flights operating out of LAX. **The renewable fuel used to power United's planes will be coming from a Los Angeles refinery** operated by AltAir Fuels.

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World Energy and Fulcrum are not United's first and second suppliers, but our fifth and sixth

January 9, 2009
Second SAF flight globally
Algae and jatropha

Sapphire Energy™

terasol ENERGY

May 3, 2010
Synthetic fuel test flight
Natural gas

RENTECH

November 7, 2011
First U.S. commercial SAF flight
Algae

solazyme

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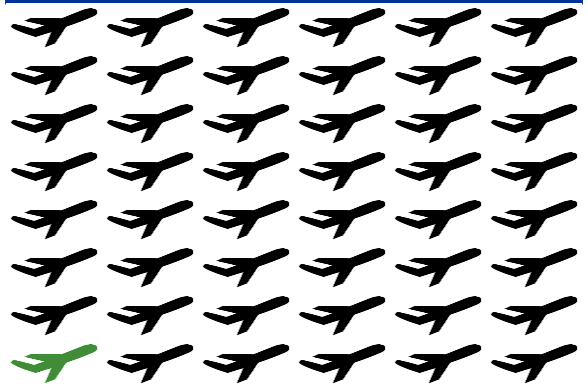
Communicating ideas about SAF is complicated

Naming

Biofuel
Biojet
Renewable jet fuel
SAJF
SAF
Synthetic jet fuel

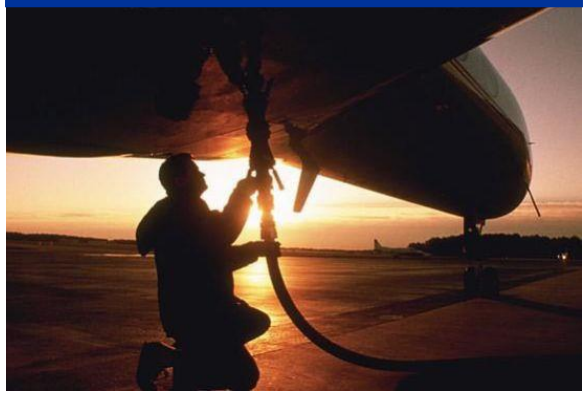
There are many names out there—what should we call it?

Volume



Is 90 million gallons per year a lot or a little?

Blending / shared storage



Sharing too much detail can weaken or distract from the core message

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We flew an eco-flight on World Environment Day 2019—and media focused primarily on cabin waste

- Flight powered by blend of SAF and conventional jet fuel
- Operational fuel efficiency measures
- Offsets for remaining CO_2
- Zero cabin waste: all catering was compostable or recyclable

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We need to do more to make SAF appeal to our customers

Company offers fake vacation photos for your social media accounts

abc NEWS

The Prius as an Oddly-Shaped Status Symbol

The Atlantic

Seven reasons to choose a Dreamliner for your next flight

USA TODAY

"It's just a very pretty plane. The 787 is just a gorgeous craft with its sweptback wings and sleek lines. The forthcoming 787-10 promises to look even more svelte."

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Producers would rather produce renewable diesel—so further incentives are needed

- **Producers can make renewable diesel, which sells for more than jet fuel**
- **SAF production costs are higher**
- **SAF generates fewer RINS and LCFS credits**

$/gallon[1]

		Conventional jet fuel	SAF	Renewable diesel
Profit =		**$0.25**	**($0.50)**	**$0.25**
Revenue	BTC		$1.00	$1.00
	RINs		**$0.50**	**$0.55**
	LCFS		**$1.25**	**$1.45**
	New incentives			
	Customer WTP[2]	**$2.00**	**$2.00**	**$2.25**
– Costs		**$1.75**	**$5.25**	**$5.00**

[1] Figures are approximate and for example purposes
[2] Willingness to pay

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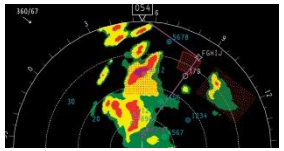
Why is United focusing on sustainability?
Because innovation is a core part of our business

1927-2020
18 new aircraft designs

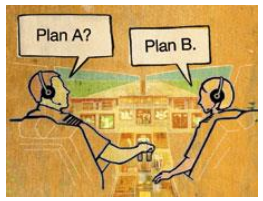
1930
Flight attendants

1936
Onboard meal service

1954
Modern flight simulators



1957
Airborne radar



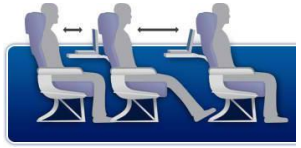
1981
Crew resource management

1994
Electronic tickets

1995
Check-in kiosks

STAR ALLIANCE
THE WAY THE EARTH CONNECTS

1997
Global airline alliances



1999
Economy Plus

2007
Mobile apps

2016
Continuous SAF use

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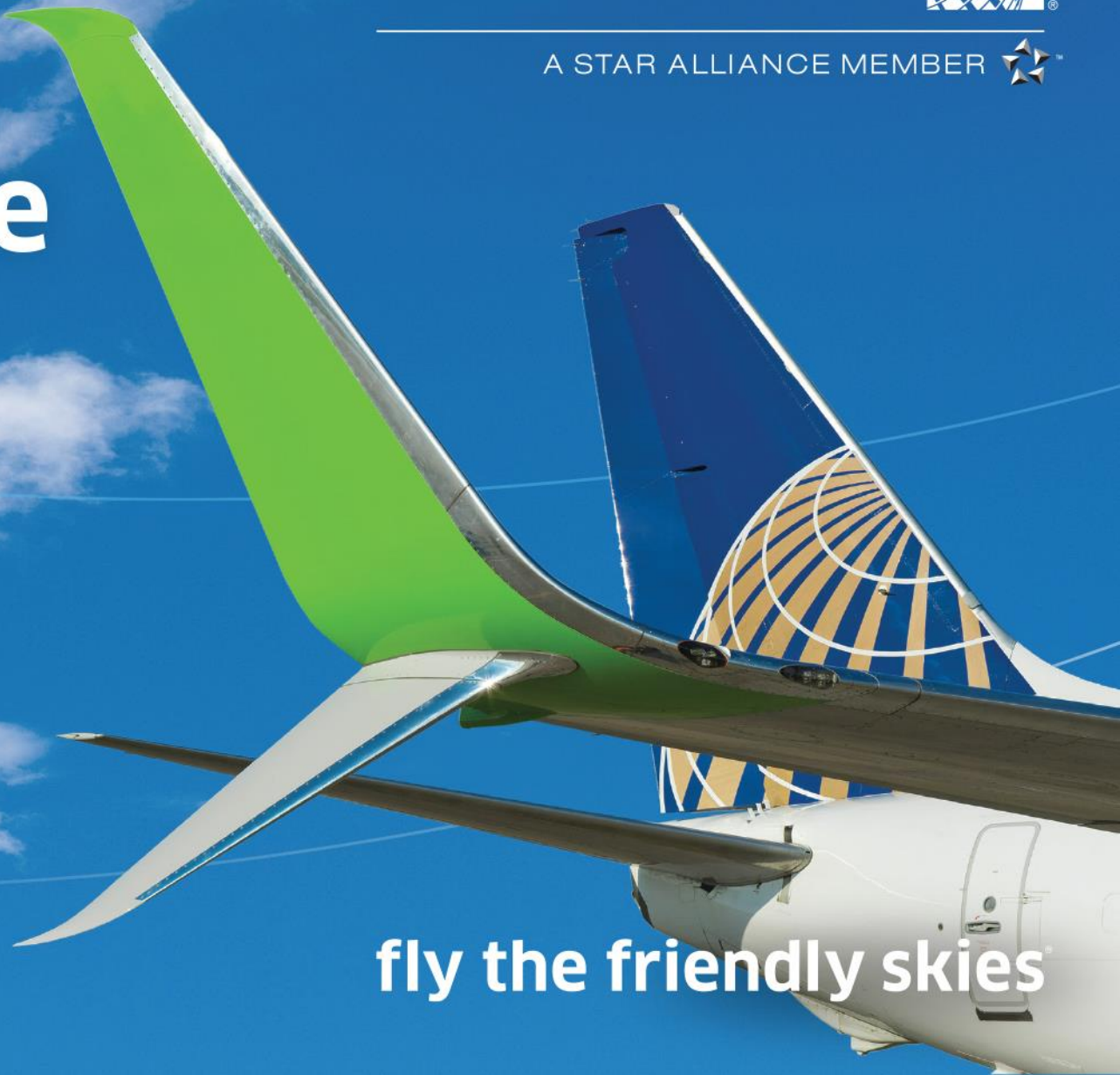
SM

UNITED

A STAR ALLIANCE MEMBER

2017 Eco-Airline of the Year



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2017 ECO-AIRLINE OF THE YEAR AIR TRANSPORT WORLD

fly the friendly skies®