2019 AIRPORTS @ WORK

Sustainable Aviation Fuel (SAF) – Is Your Infrastructure Ready?

Grand Ballroom A

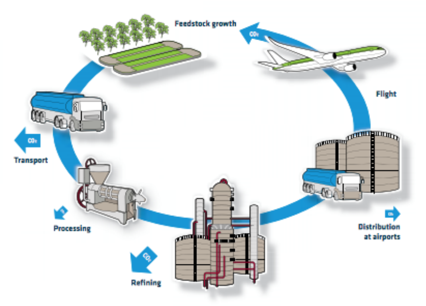
ACI NORTH AMERICA
AIRPORTS COUNCIL INTERNATIONAL

Today's Focus –
Assessing & Readying Your Infrastructure

Zone out if seeking details on SAF benefits, carbon life cycle, production processes, etc…

…or refer to other resources like the ATAG Beginners Guide to SAF

Carbon lifecycle diagram: Sustainable aviation fuel



Carbon dioxide will be reabsorbed as the next generation of feedstock is grown.
Note: *the diagram above does not demonstrate the lifecycle process of SAF derived from municipal waste.*

Key advantages of SAF for aviation

- **Environmental benefits:** sustainably produced alternative jet fuel results in up to an 80% reduction in CO_2 emissions across their lifecycle.
- **Diversified supply:** SAF offers a viable alternative to conventional fuel and can substitute traditional jet fuel with a more diverse geographical fuel supply through non-food crop sources.
- **Economic and social benefits:** SAF provides a solution to the price fluctuations related to fuel cost volatility facing aviation. SAF can provide economic benefits to parts of the world, especially developing nations, that have land that is unviable for food crops, but that is suitable for SAF feedstock growth. Refining infrastructure is often installed close to feedstock sources, generating additional jobs and economic activity.

https://www.atag.org/our-activities/sustainable-aviation-fuels.html

Speakers

Moderator: Carly Shannon, Managing Planner & Sustainability Leader, C&S Companies

Speakers:

- Emily Newes, Resources and Sustainability Group Manager, National Renewable Energy Laboratory
- Kristi Moriarty, Senior Engineer, National Renewable Energy Laboratory
- Erin Cooke, Director, Sustainability & Environmental Policy, San Francisco International Airport
- Stephanie Meyn, Climate Protection Program Manager, Seattle-Tacoma International Airport

Broad Overview of Sustainable Aviation Fuel and Infrastructure

Emily Newes and Kristi Moriarty

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NREL/PR-6A20-73576

The Aviation Industry Has Adopted CORSIA

CORSIA

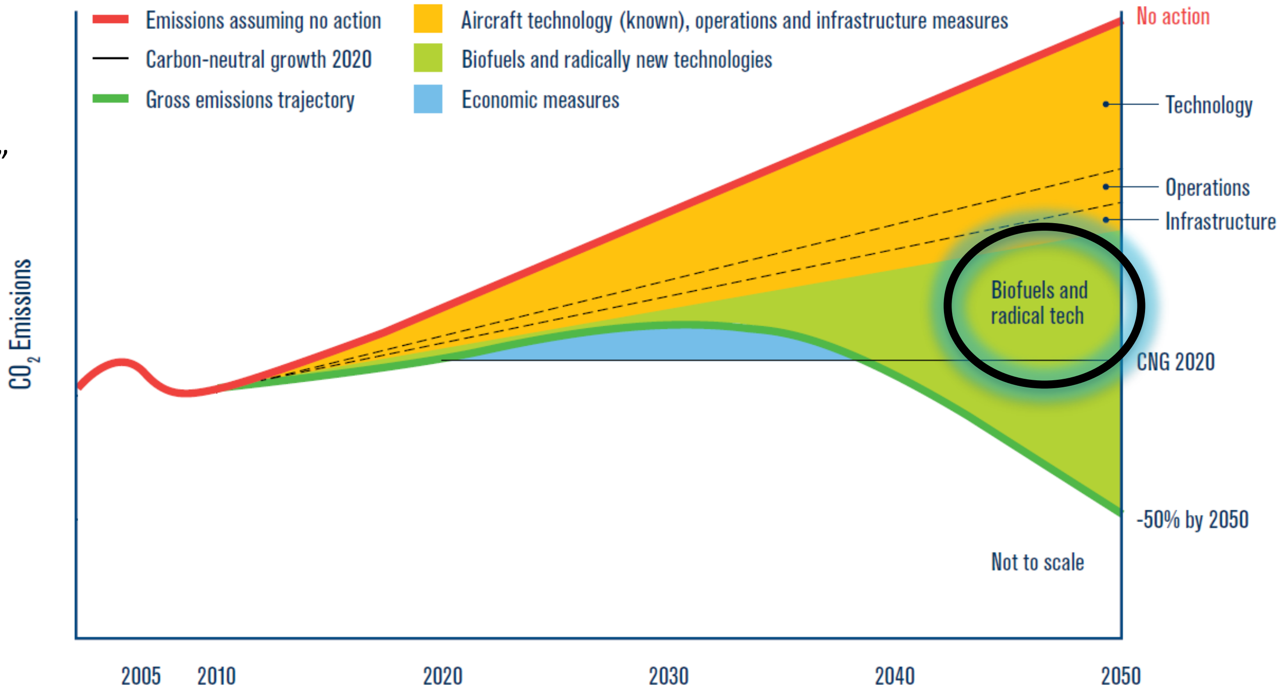
"In 2016, the International Civil Aviation Organization adopted the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to address CO_2 emissions from international aviation."

"CORSIA aims to stabilize net CO_2 emissions from international civil aviation at 2020 levels."

- "From 2021 until 2026, only flights between states that volunteer to participate in the pilot and/or first phase will be subject to offsetting requirements.
- From 2027, all international flights will be subject to offsetting requirements."

Source: IATA, CORSIA Fact Sheet, December 2018

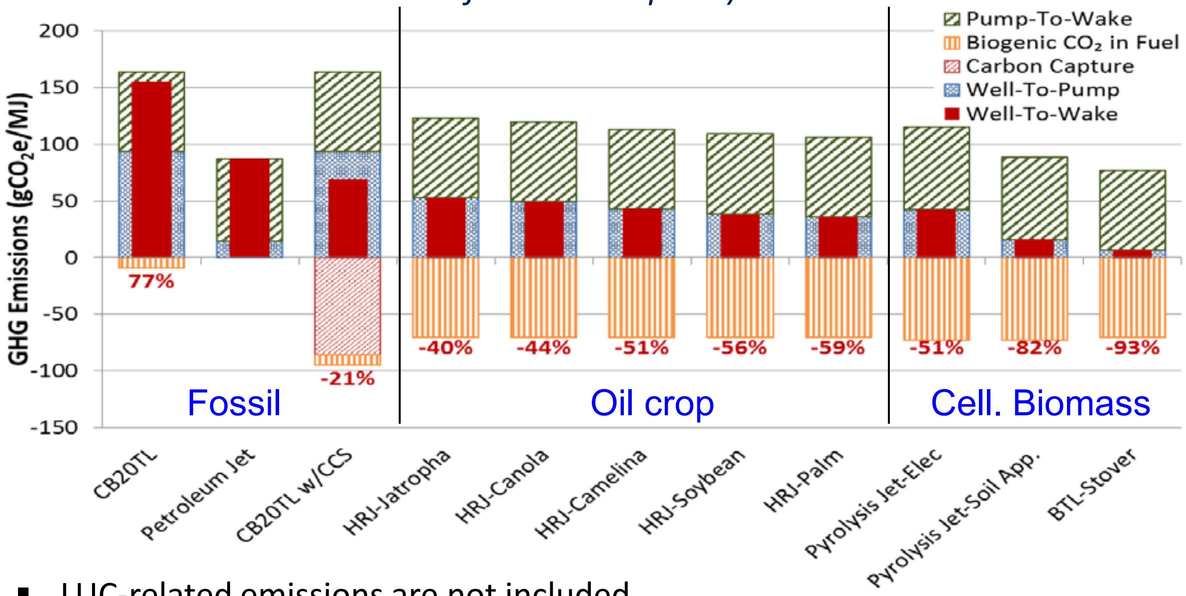
Emissions Reduction Roadmap for Air Travel



Source: International Air Transport Association, Technology Roadmap, June 2013

Alternative Jet Fuel Could Decrease GHG Emissions

WTWa GHG emissions of alternative jet fuels (per MJ of fuel consumption)



Please visit

http://greet.es.anl.gov for:

- *GREET models*
- *GREET documents*
- *LCA publications*
- *GREET-based tools and calculators*

- LUC-related emissions are not included
- Other key factors: Technology readiness level (TRL), production costs, resource availability and fuel types

Source: simulation results with GREET2016 by Argonne National Laboratory

Alternative Jet Fuel Could Decrease Air Pollutant Emissions

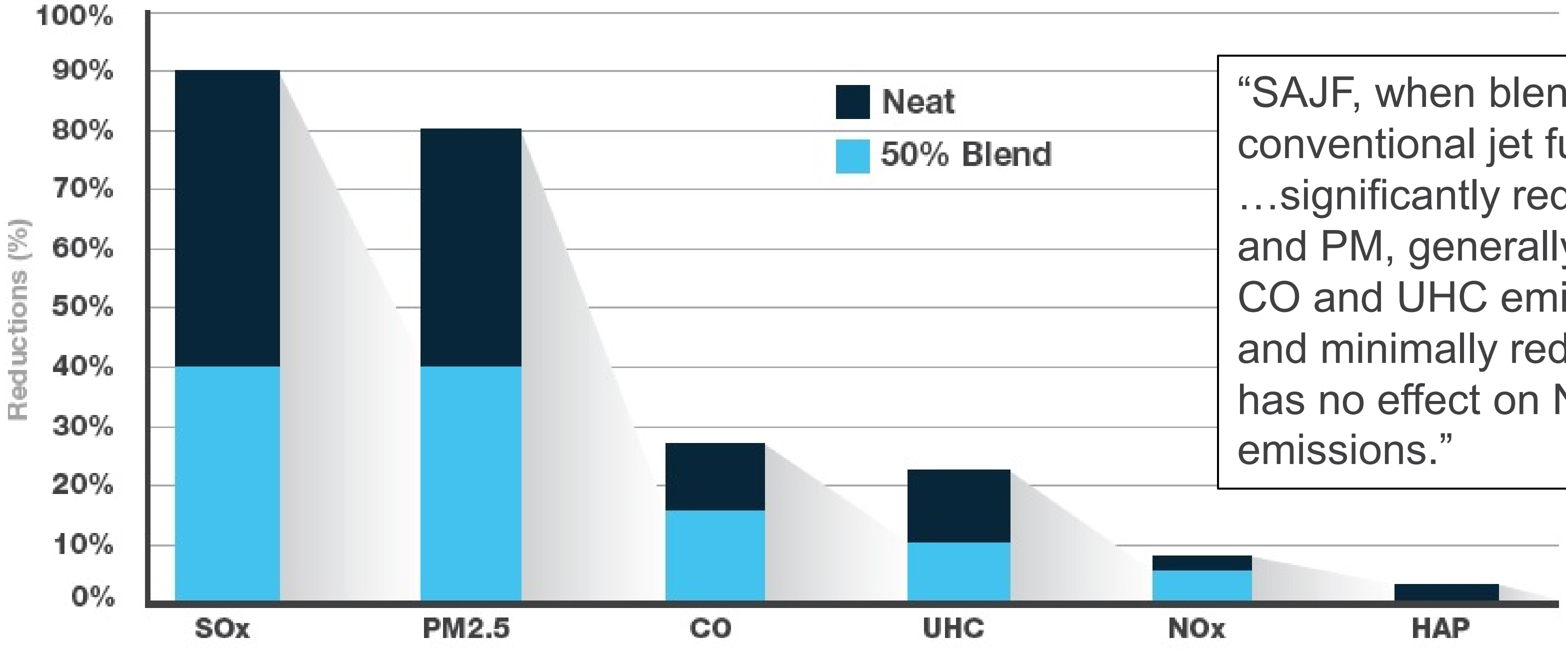


Figure ES-2: Representative Air Pollutant Emission Reductions from the Use of SAJF

"SAJF, when blended with conventional jet fuel …significantly reduces SO_x and PM, generally reduces CO and UHC emissions, and minimally reduces or has no effect on NO_x emissions."

SOx: sulfur oxides ; PM2.5: particulate matter; CO: carbon monoxide; UHC: unburned hydrocarbon; HAP: hazardous air pollutants

Source: State of the Industry Report on Air Quality Emissions from Sustainable Alternative Jet Fuels (February 2018)

Airlines Continue to Sign Offtakes Agreements

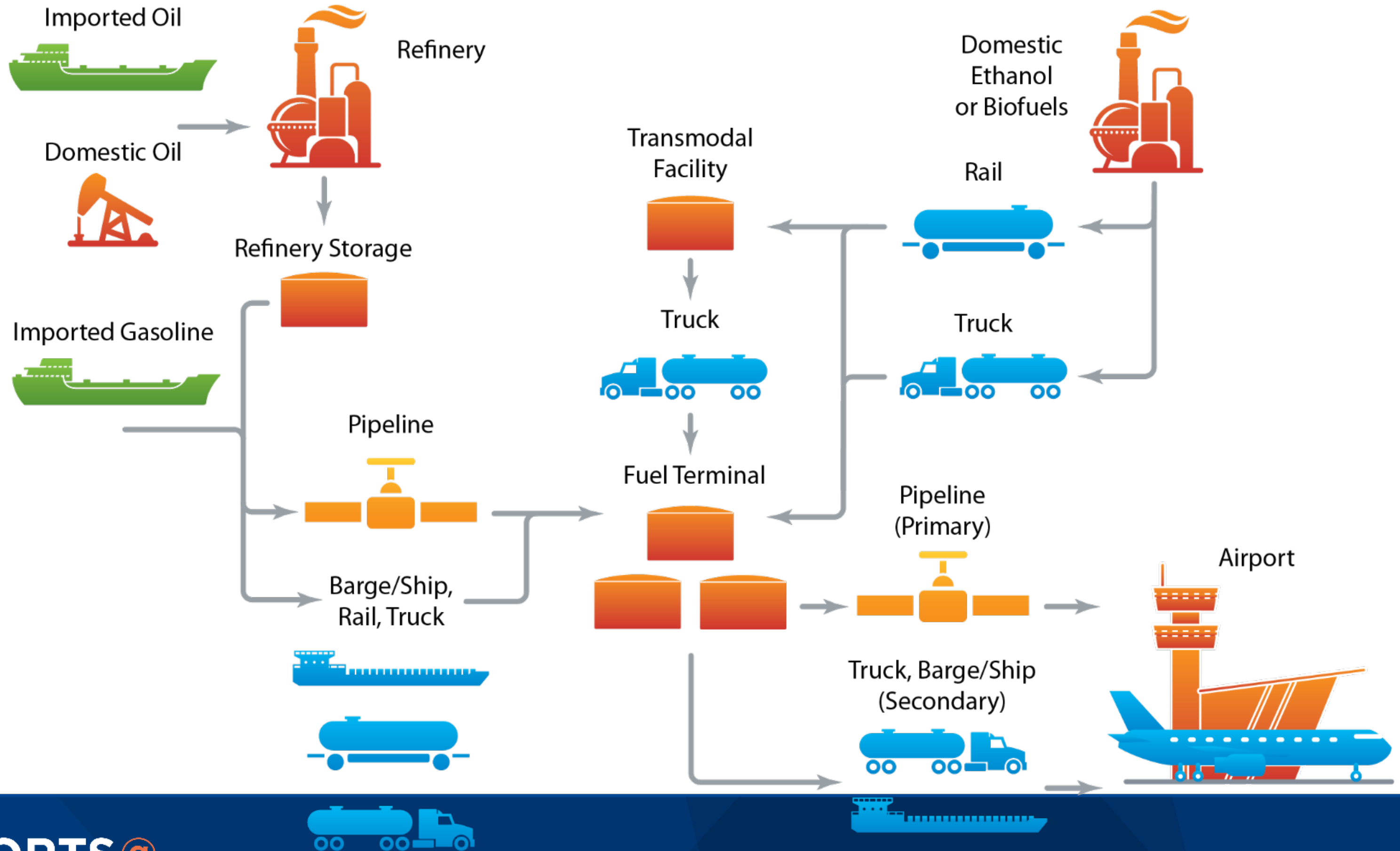
Producer	+	Airline / Partner	=	Agreement
RED ROCK BIOFUELS	+	Southwest	=	3 M gpy each, 7 yrs (Bay Area, CA)
	+	FedEx	=	
TOTAL | AMYRIS	+	CATHAY PACIFIC, CHINA AIRLINES	=	A350 deliveries 10% blend (ex-TLS)
SG Preston	+	jetBlue	=	10M gpy, 10 yrs (JFK
	+	QANTAS	=	4M gpy, 10 yrs (LAX
gevo	+	AVFUEL	=	Up to 1M gpy, 5 yrs-
	+	Virgin australia	=	Brisbane Supply Demonstration
DG Energy	+	GE Aviation	=	0.5M gpy, 10 yrs
Multiple Producers, TBA	+	World Fuel Services	=	Full production slate offtakes
preem Gothenburg Refinery	+	SAS	=	Long-term supply negotiation (from 202
LanzaTech capturing carbon fueling growth	+	virgin atlantic	=	UK DfT F4C Funding: A Development; Demo flight MCO-LG
TBA	+	FINNAIR	=	Customer funding of S purchase from 2019
Multiple Producers & Suppliers	+	Airports and Airline Tenants, Port of Seattle (Seattle-Tacoma International Airport), SFO	=	Exploration of Greater ambition

Producer	+	Airline / Partner	=	Agreement
VELOCYS	+	BRITISH AIRWAYS, Shell	=	MSW-based FT-SPK evaluations
	+	In negotiation	=	BTL #1, Natchez, MS 1,400 bpd
NESTE	+	American Airlines, DFW Dallas Fort Worth International Airport	=	SAJF Supply exploration
	+	Alaska	=	MOU to design & implement adoption
	+	air bp	=	Collaboration on supply expansion
AGRISOMA, SkyNRG Nordic	+	QANTAS	=	Carinata supply development
	+	Shell	=	SAJF Supply collaboration
world energy Paramount *	+	UNITED	=	Up to 5 M gpy from 2016 (LAX)
	+	World Fuel Services, Gulfstream	=	3 yr agreement 30/70 blend
	+	KLM	=	3 yr agreement Enabling LAX flts
	+	SkyNRG Nordic, air bp, OSLO AIRPORT, SAS, Lufthansa Group	=	Bioports on demand, et al. (Halmstad, Arlanda, Bromma, Goteborg, Leeuwarden)
Fulcrum BIOENERGY	+	CATHAY PACIFIC	=	37.5M gpy
	+	UNITED	=	90-180 M gpy
	+	air bp	=	50 M gpy
	+	JAPAN AIRLINES, JOIN, Marubeni	=	Project Development, License, and Offtake

10 yr agreements

Source: Commercial Aviation and Alternative Fuels Initiative, 10/2018

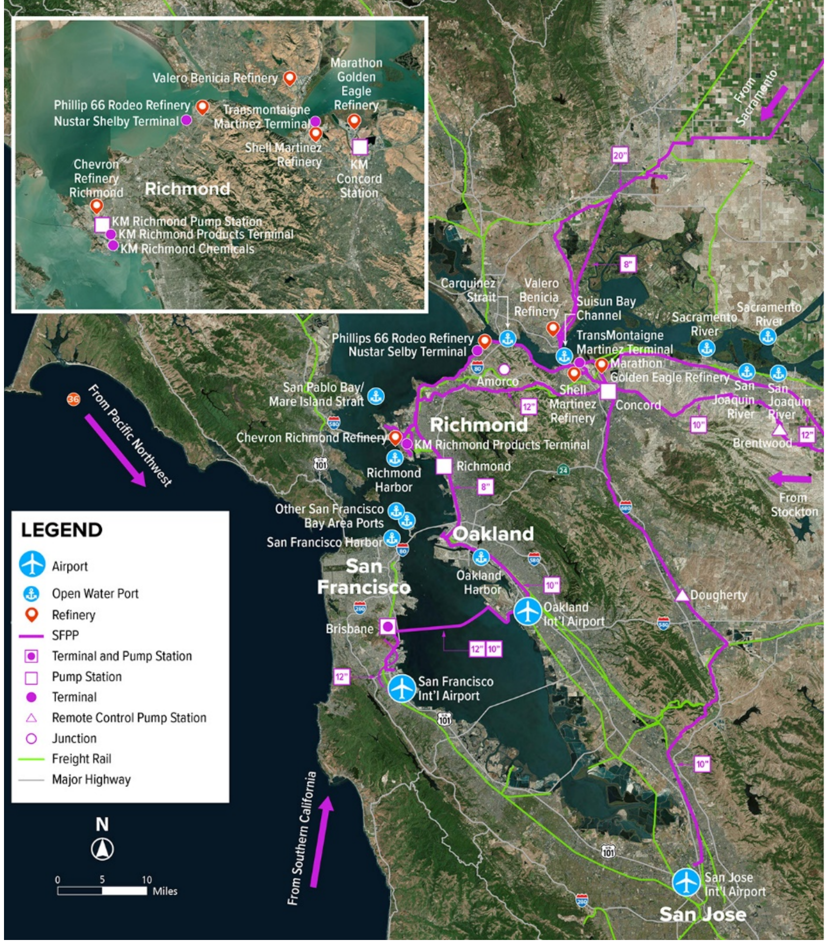
Typical Fuel Supply Chain



SFO Snapshot

SAF @ SFO

- SFO Fuel Farm
- Shell Storage Facility
- KM Brisbane Terminal



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Sea-Tac Snapshot

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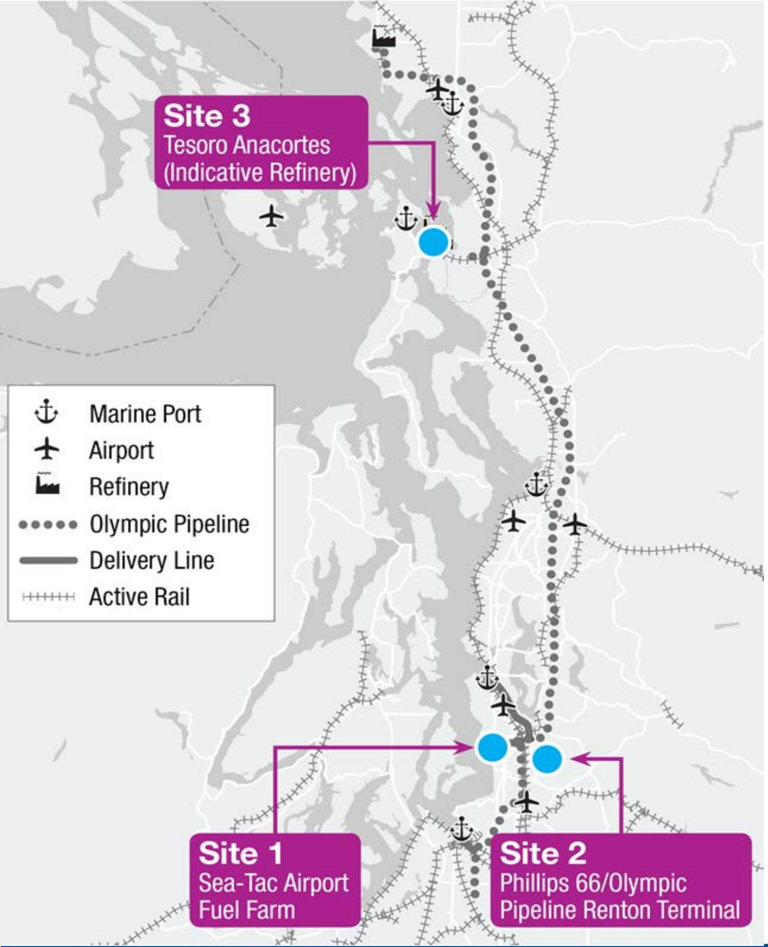

Key Findings

- Limited property options for long term (50+ million gallons).
- Short term option (5 million gallons) at airport could be established sooner, lower costs*.
- Refineries have best access to modes of delivery
  - Olympic Pipeline
  - Rail
  - Barge or vessel
  - Truck
- Supply integration with the SEA Fuel Facility.

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Backup Slides

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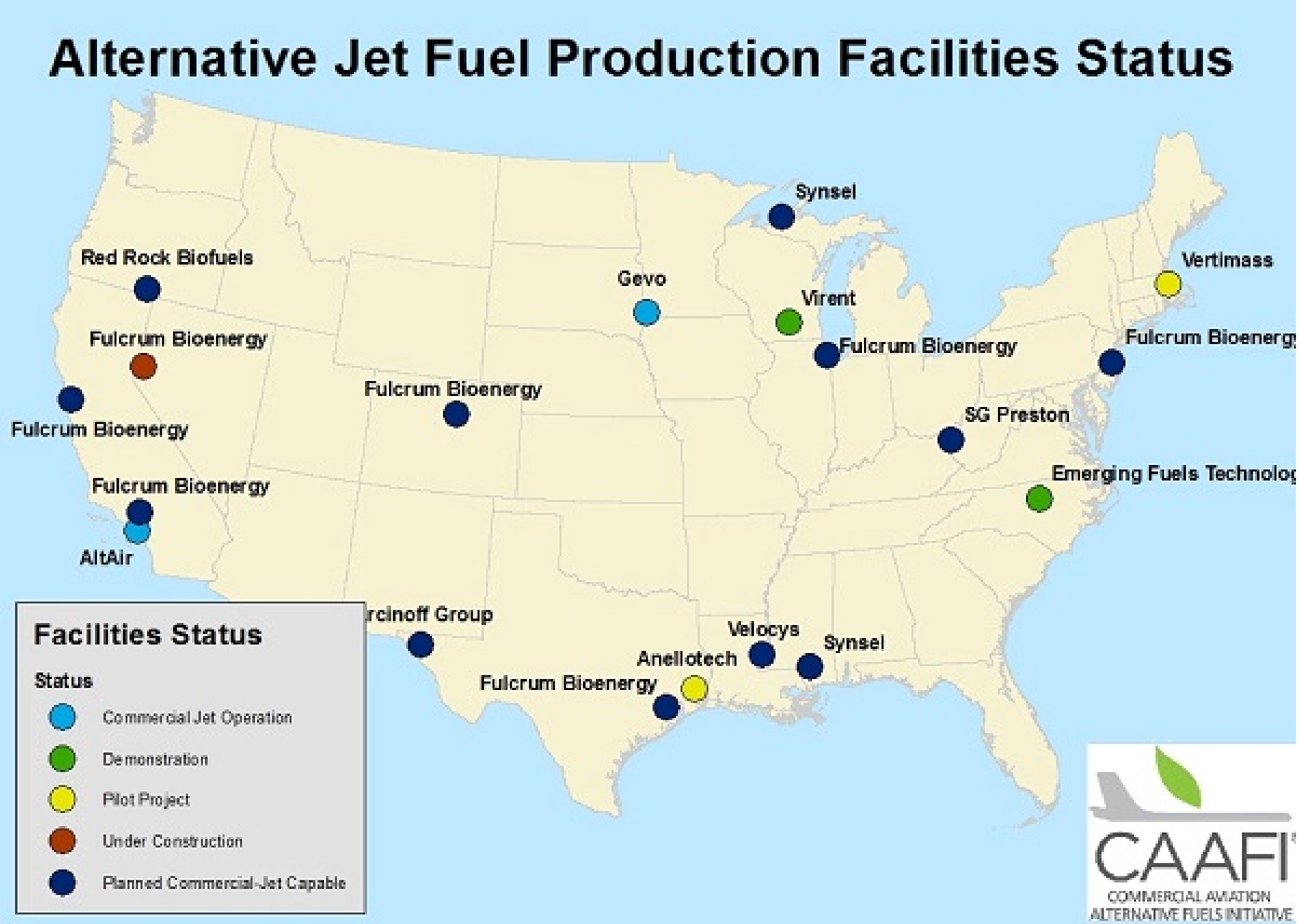


CAAFI

Source: http://www.caafi.org/focus_areas/deployment.html

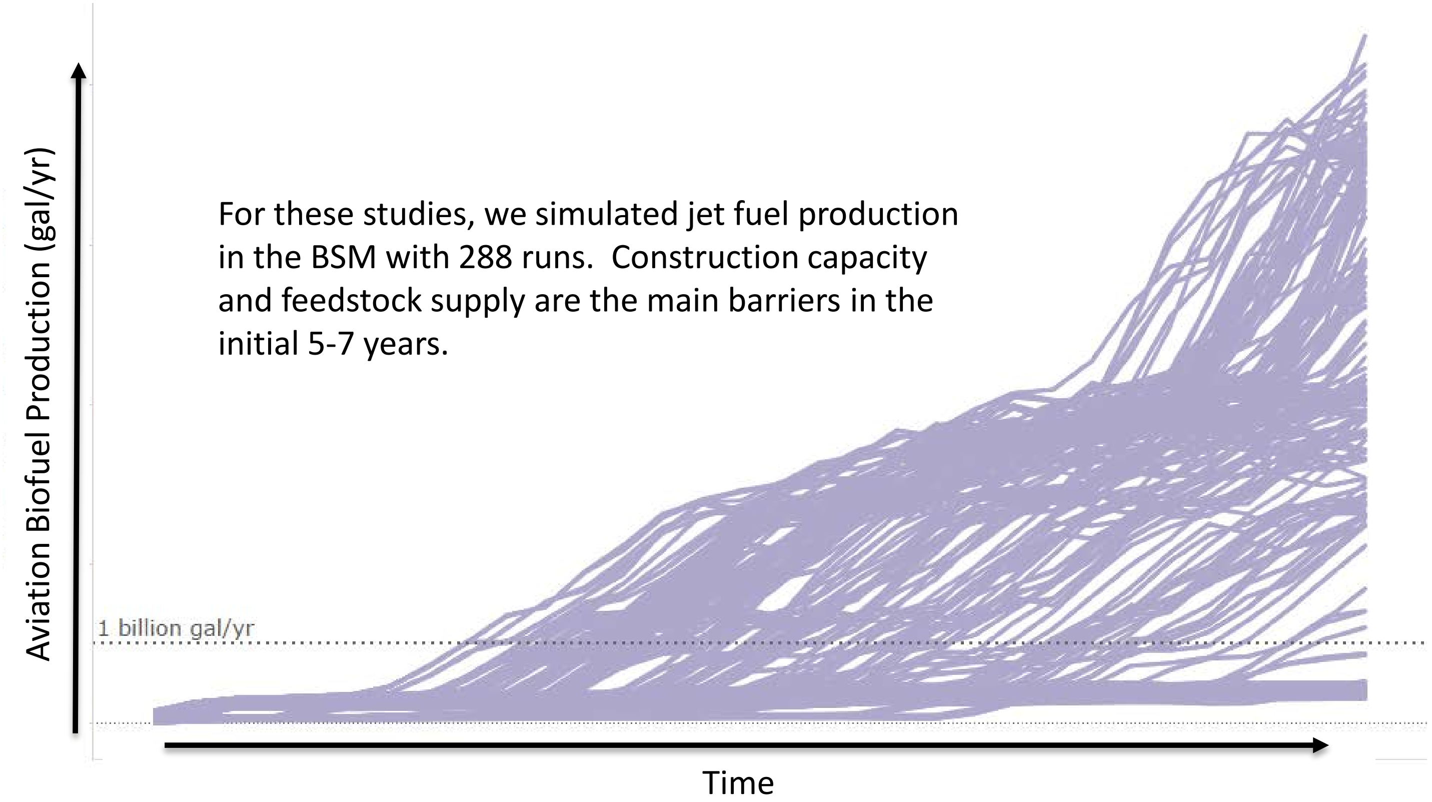
ICAO Environment News & Activities

Source: https://www.icao.int/environmental-protection/GFAAF/Lists/SAAFA/SAAFA.aspx

Transporting SAF

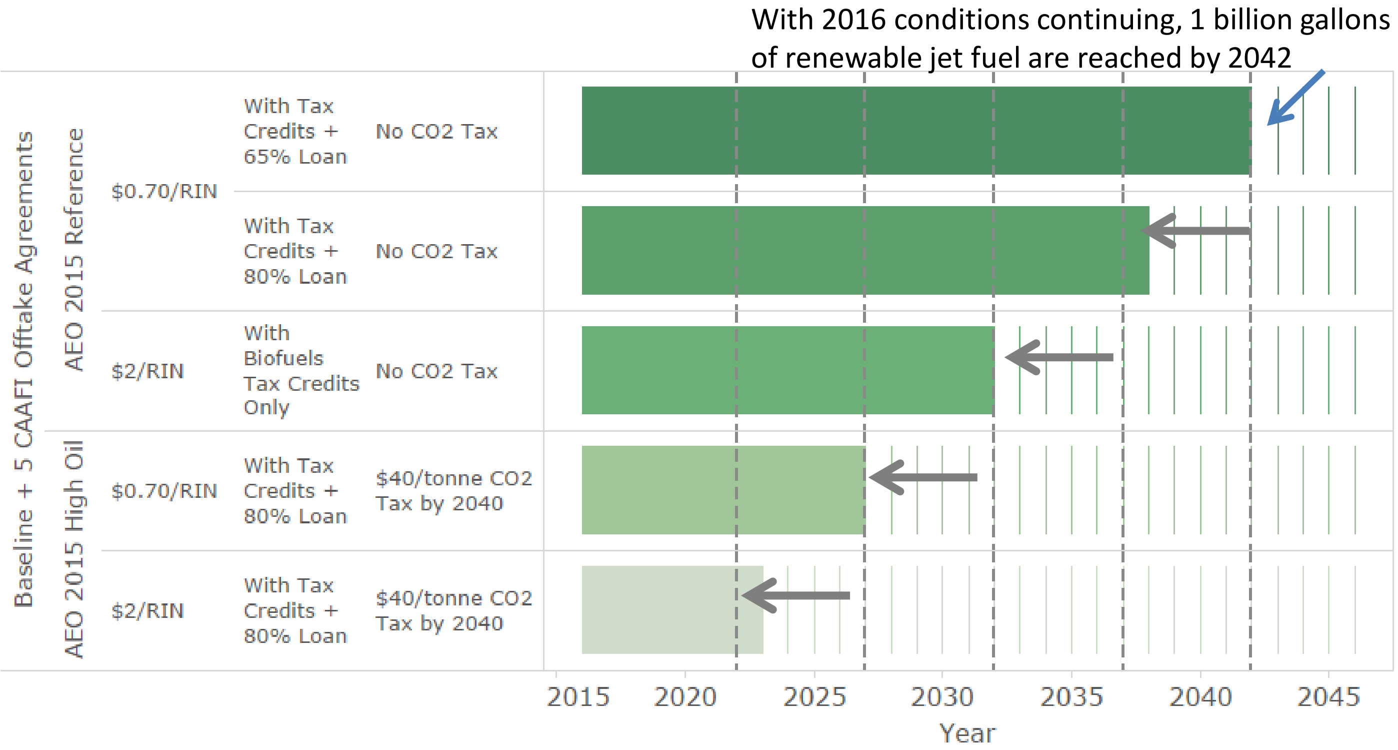
- SAF is transported in the same infrastructure as petroleum-based jet fuel
- SAF and petroleum jet fuel are not generally produced at the same location
  - The quantities of SAF production at this time are small and it most likely travels via truck or rail to reach its end user
  - There is the potential to co-process SAF at an oil refinery
- Fuels are stored in separate tanks at refineries and terminals; they are not co-mingled
- The same tanks that store petroleum jet fuel can store SAF
  - It is a best practice to clean a tank prior to storing a different fuel
- In many instances, airports receive fuel by pipeline
  - Pipelines are owned by oil/refinery companies (who own the fuel), pipeline or terminal companies (who own the infrastructure but not the fuel), and other entities
  - Each airport will need to discuss the potential to move SAF with the pipeline owners supplying the airport

Wide Range of Jet Fuel Production Trajectories



Source = Lewis et al. (Accepted 2018)

Necessary Assumptions for One Billion Gallons by ____ Year

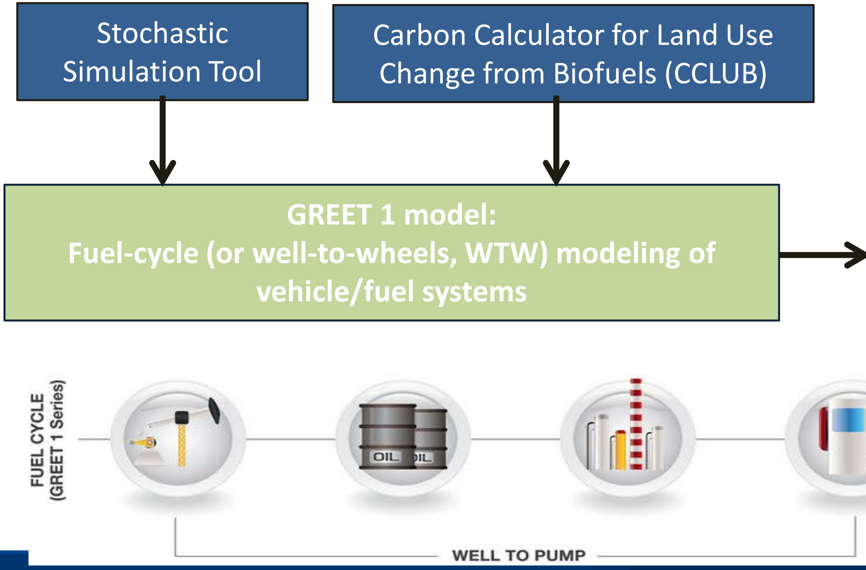


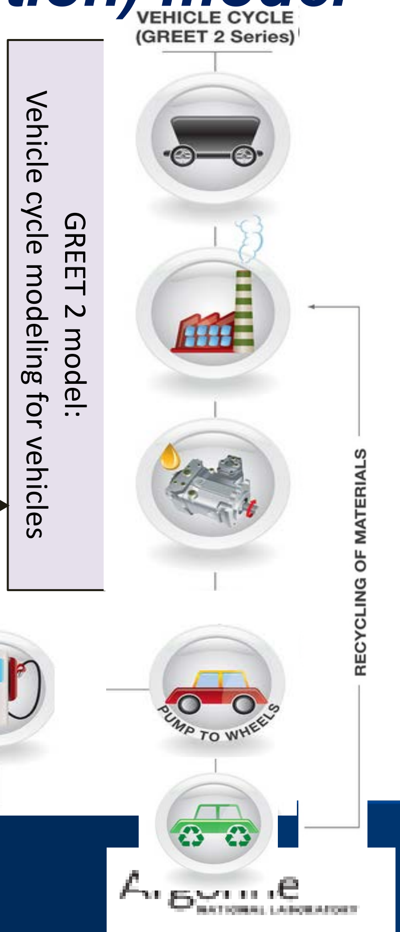
Source = Lewis et al. (Accepted 2018)

This figure shows possible scenarios that would accelerate reaching 1 billion gallons of renewable jet fuel production by 5, 10, 15, or 20 years.

The GREET® (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model

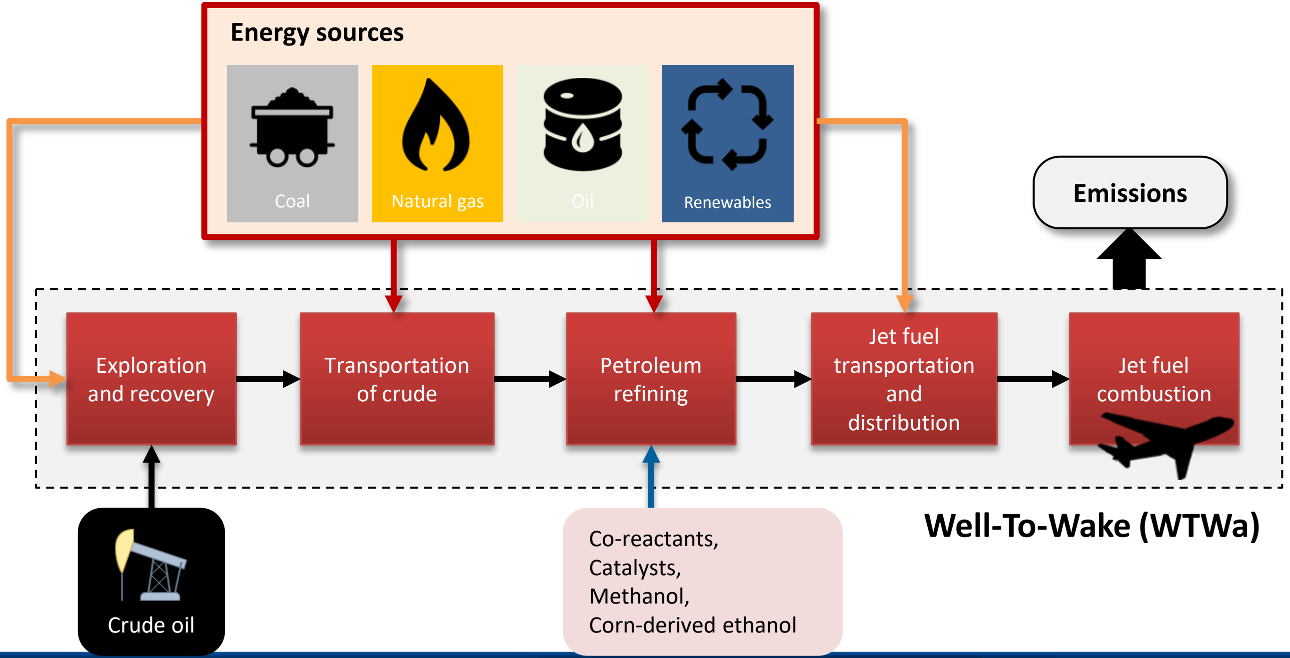
- Argonne has been developing the GREET LCA model since 1995 with annual updates and expansions
- It is available at greet.es.anl.gov





Life cycle analysis of petroleum aviation fuels

- Well-To-Wake (WTWa) analysis: Specific to aviation fuels
- WTWa analysis takes into account the direct fuel use and its upstream energy use and associated emissions



Aviation fuel and aircraft options in GREET

Fuels and Feedstocks

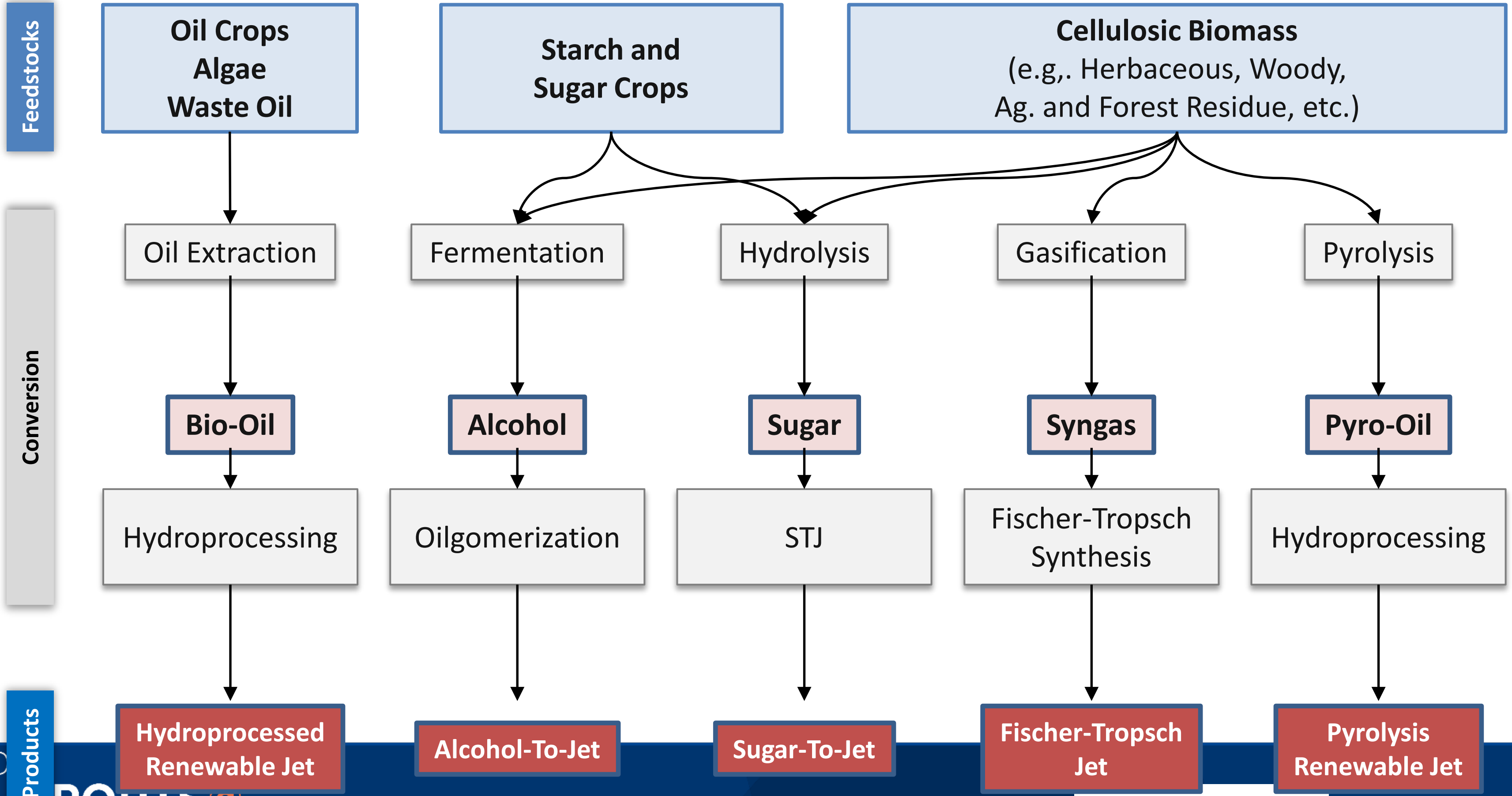
- **Petroleum Jet Fuel**
  - Conventional Crude
  - Oil Sand
- **Pyrolysis Oil Jet Fuel**
  - Crop Residues
  - Forest Residues
  - Dedicated Energy Crops
- **Hydrotreated Renewable Jet Fuel (HRJ)**
  - Soybeans
  - Palm Oil
  - Rapeseeds
  - Jatropha
  - Camelina
  - Algae
- **Ethanol-To-Jet (ETJ)**
  - Corn
  - Crop Residues
  - Forest Residues
  - Dedicated Energy Crops
- **Sugar-To-Jet (STJ)**
  - Crop Residues
  - Forest Residues
  - Dedicated Energy Crops
- **Fischer-Tropsch Jet Fuel (FTJ)**
  - North American Natural Gas
  - Non-North American Natural Gas
  - Renewable Natural Gas
  - Shale Gas
  - Biomass via Gasification
  - Coal via Gasification
  - Coal/Biomass via Gasification
  - Natural Gas/Biomass via Gasification

Aircraft Types

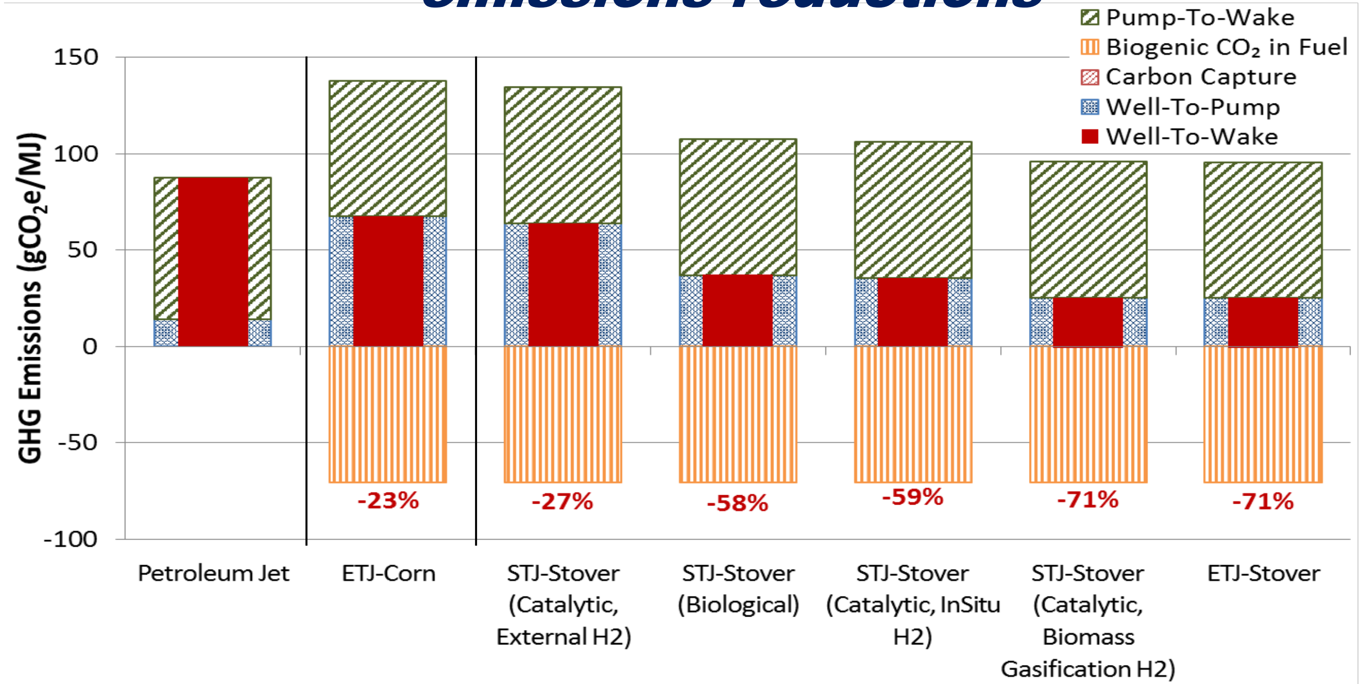
- **Passenger Aircraft**
  - Single Aisle
  - Small Twin Aisle
  - Large Twin Aisle
  - Large Quad
  - Regional Jet
  - Business Jet
- **Freight Aircraft**
  - Single Aisle
  - Small Twin Aisle
  - Large Twin Aisle
  - Large Quad

- **LCA Functional Units**
  - Per MJ of fuel
  - Per kg-km
  - Per passenger-km

Bio-aviation fuel pathways by feedstock



Ethanol-to-jet (ETJ) and sugar-to-jet (STJ) shows promising GHG emissions reductions



- Corn-ethanol-based ETJ reduces GHG emissions by 23%, cellulosic by 71% compared to petroleum jet
- Stover-based STJ reduces GHG emissions by 27 – 71% depending on conversion process and hydrogen source
- Note: LUC-related emissions are not included; ETJ-corn could have LUC GHG of 8 grams/MJ; stover pathways do not presumably cause LUC.

ASCENT Analyses

FAA Center of Excellence (COE) for Alternative Jet Fuel and the Environment, known as the Aviation Sustainability Center or ASCENT

– the COE for the Office of Environment and Energy charged with creating science-based solutions for many of the aviation industry's challenging problems

ASCENT
AVIATION SUSTAINABILITY CENTER

Alternative Fuels Supply Chain Analysis (Project 01)

- **Environmental Services**: Analysis of ecosystem service valuation, law and policy drivers, and potential policy design of water quality, soil and biodiversity improvements associated with perennial grasses and winter cover crops. [Dr. Tom Richard, Katherine Zipp, Lara Fowler, Gabrielle Gilbeau , Pennsylvania State University]
- **Emission Reduction-Life Cycle Analysis-**Support US participation in the International Civil Aviation Organization Committee for Aviation Environmental Protection Alternative Fuels Task Force (ICAO CAEP AFTF) to develop a methodology for appropriate accounting of alternative jet fuel (AJF) life cycle greenhouse gas (GHG) emissions under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [Dr. Mark Staples, Massachusetts Institute of Technology]

Source: https://ascent.aero/project/alternative-jet-fuel-supply-chain-analysis/