Sustainable Alternative Fuel Use in the Military and Commercial Aviation

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-- Adjunct Professor, QUT

Sustainable Alternative Fuel Use Agenda

- Definitions
- Great Green Fleet 2012 and 2016
- From the Great Green Fleet to the New Normal
- Commercial Aviation Industry
- Cost Competitiveness
- International Interoperability
- Future of Sustainable Alternative Fuels
- Roles for You and Notre Dame
- EYA

SAJF Sustainable Alternative Jet Fuel
a.k.a. aviation biofuel, biojet, alternative aviation fuel

Alternative: Creating synthetic jet fuel by starting with a different set of hydrocarbons than petroleum … a synthetic comprised of molecules essentially identical to petroleum-based jet (in whole or in part) – enables drop-in approach – no changes to infrastructure or equipment

Sustainable: Doing so while taking Social, Economic, and Environmental progress into account

Jet Fuel: Delivering the properties of ASTM D1655

Net LCA GHG reduction: Benefit comes from leaving carbon molecules in the ground; Instead, utilizing the carbon already in the biosphere via recycling or dual use

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U.S. DEPARTMENT OF THE NAVY
POWER.
PRESENCE.
GREAT GREEN FLEET

2012 GGF DEMONSTRATION

USS Princeton (CG 59) refuels from oiler USNS Henry J. Kaiser (T-AO 187) in the Pacific Ocean

Royal Australian Navy S-70B Sea Hawk helicopter

SECNAV and CNO aboard USS Chafee

USS Princeton (CG 59) ,USS Nimitz (CVN 68)

Great Green Fleet Launches

January 2016


U.S. Navy oiler delivering alternative fuel to a Japanese ship
February 2016

Italian oiler delivers alternative fuel to the U.S. Navy


CAPABLE - ADAPTIVE - PARTNERS
RIMPAC
2016
25th
25th
July 2016
11+ million gallons to 9 countries

August 2016 – Great Green Fleet arrives in Sydney Harbor

ROYAL AUSTRALIAN NAVY
NAVY

DEPARTMENT OF THE NAVY
UNITED STATES OF AMERICA

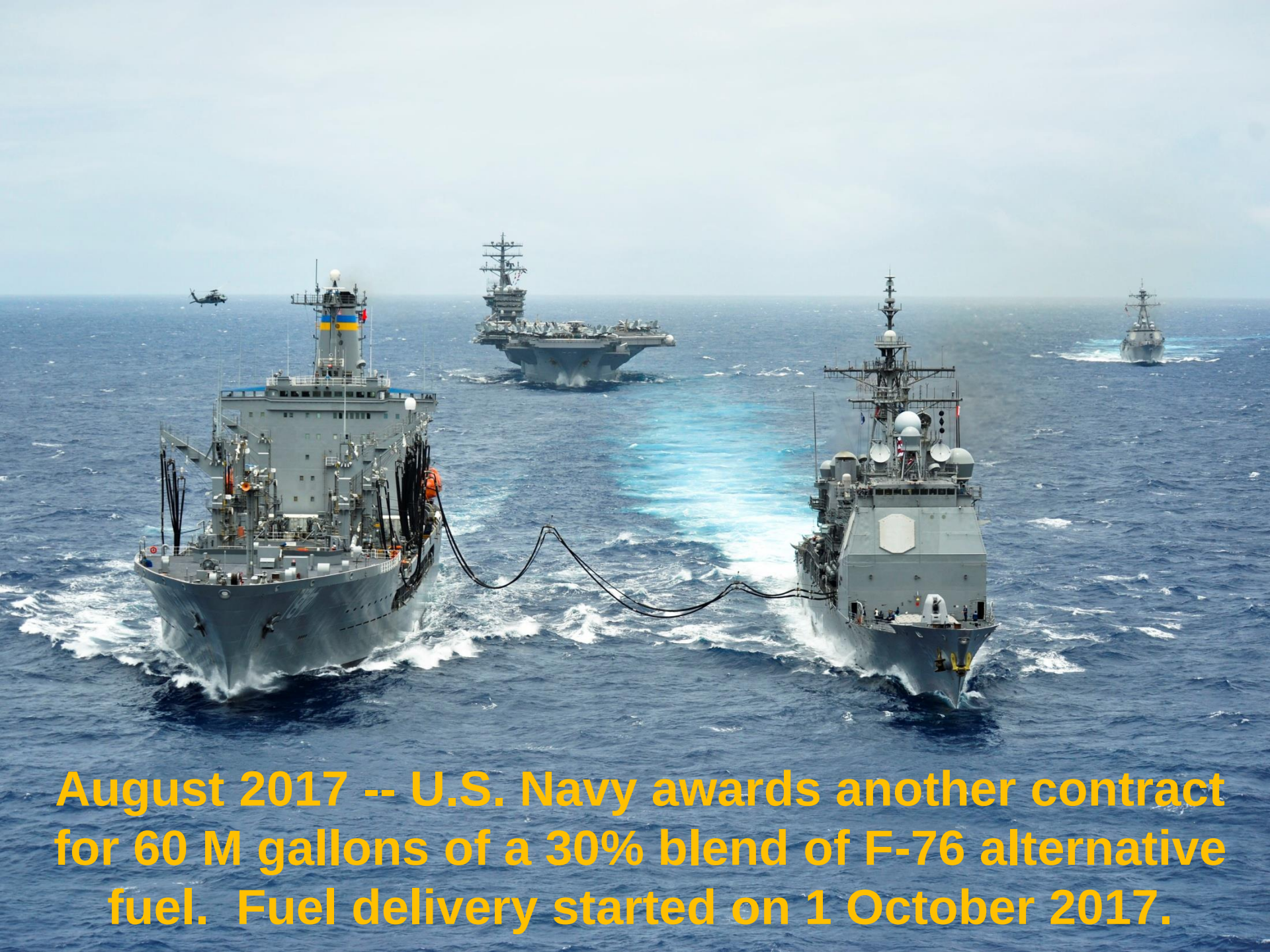
Energy Conservation Measures and Operational Procedures

- **Energy Conservation Measures installed to extend the range of the Fleet and keep ships on station longer in between refuelings at sea**
  - **Stern Flaps**
  - **Bow Bulbs**
  - **Propeller Coatings**
  - **LED Lights**
  - **Others**

- **Operational Procedures are conscious energy behaviors to increase our mission capability. Some examples:**
  - **Steady State Transit**
  - **Trail Shaft**
  - **Auto Pilot**
  - **Low Power Radar Operations**
  - **Drift Operations**

From the Great Green Fleet to the New Normal

- 2016 Energy Efficiency Efforts had measurable results
- Real mission capability was demonstrated through the Fleet-wide employment of energy conservation measures and synthetic fuels.
  - 18,000 Operating Hours' worth of fuel saved
  - Fuel for 5 ships for a year
- **Sustainable alternative fuels are essential to maintain international interoperability**
- **Strategic flexibility and fuel security result from diversity of global energy supplies**



August 2017 -- U.S. Navy awards another contract for 60 M gallons of a 30% blend of F-76 alternative fuel. Fuel delivery started on 1 October 2017.

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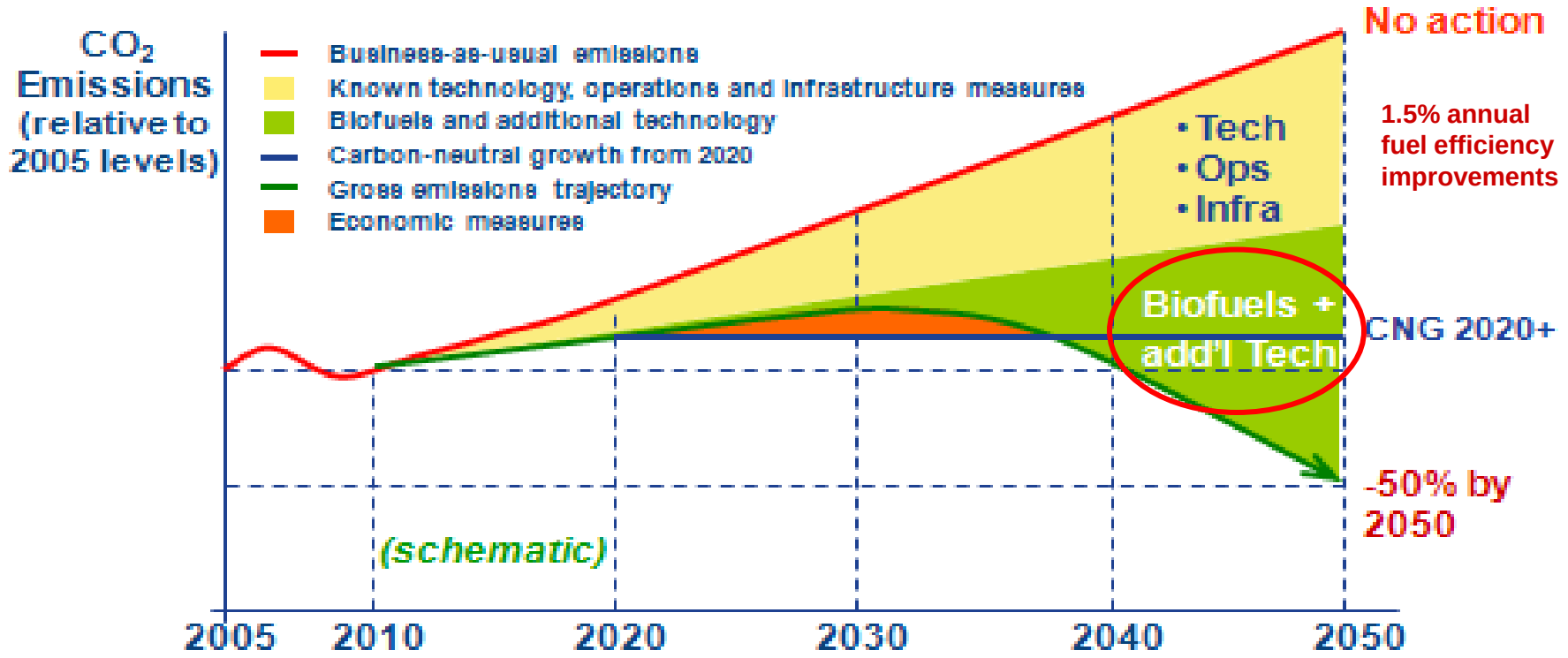
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

First flight from continuous commercial production of SAJF, 10 Mar 2016
Fuel from AltAir Fuels, Paramount, CA (HEFA-SPK 30/70 Blend)
Now being delivered to LAX fuel farm for everyone's upload

Commercial Aviation's CO_2 Commitments
Decouple carbon growth from demand growth

Biofuels a key component of GHG containment strategy



Overall Industry Summary:
Sustainable Alternative Jet Fuel (SAJF) Activity

- SAJF are key for meeting industry's commitments
  - Aviation enterprise aligned; SAJF delivers net GHG reductions
  - Segment knows how to make it; Activities from FRL 1 to 9
  - Commercial agreements being pursued
  - Pathway identified for fully synthetic (50% max blend today)
- CAAFI originally put in place to work a full range of Public-Private Partnership activities to break down barriers and lower risk: foster, catalyze, enable, facilitate, participate
- Making progress, but still significant challenges – only modest production – focus on enabling commercial viability
- Potential for acceleration a function of engagement & success replication

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CAAFI - Public/Private Partnership

A reflection of the 22+B usg U.S. Jet "market pull"

An aviation industry coalition established to facilitate and promote the introduction of alternative aviation fuel

Goal is development of non-petroleum, drop-in, jet fuel production with:

- *Equivalent safety & performance*
- *Comparable cost*
- *Environmental improvement*
- *Security of energy supply for aviation*

Synthetic jet fuels, primarily from renewable sources

Enables its diverse stakeholders to build relationships, share and collect data, identify resources, and direct research, development and deployment of alternative jet fuels

CAAFI Sponsors

AIA Aerospace Industries Association

Federal Aviation Administration

ACI North America Airports Council International

Airlines for America™ We Connect the World

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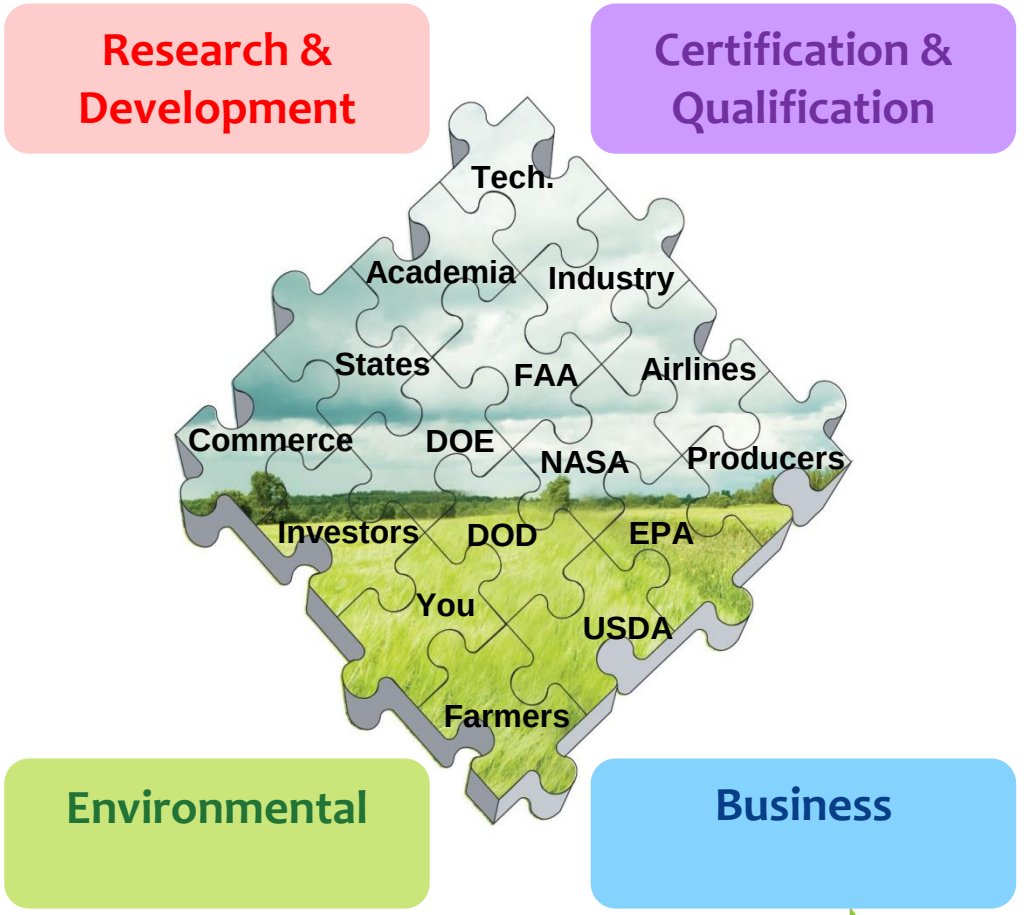
Where CAAFI is working

Facilitation – broad and deep

- Feedstock Development
- Pathway Development
- Sustainability
- Price Point
- Risk Reduction
- Institutional Alignment
- Analysis / Tools
- Regional Engagement
- International Engagement



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… via cooperative R&D efforts

Directly and through several PPPs







Feedstock Production	Feedstock Logistics	Fuel Conversion	Conversion Process Scale-up/Integration	Fuel Testing/Approval: Fuel Performance / Environment Assmt	Enable Production	End User/ Buyer

USDA: BCAP & CIP, Feedstock Development Center Grants, AFRI/NIFA Caps

DOE: FS&L, BRCs
ARPA-E: PETRO, TERRA, pheno-

DOE & DOD: R&D grants

USDA & DOE: R&D grants, IBR

FAA & DOD: C/Q Fuel testing

FAA, DOD, & NASA: Enviro Analysis

USDA, USN, & DOE: Defense Production Act and Biorefinery Program

EPA: Renewable Fuel Standard

DOD/DLA & Airlines: fuel purchase

FAA: Guidance for Airports

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SAJF offtake agreements

Beyond numerous demonstration programs

neat quantities

AltAir Fuels	+ UNITED	=	5 M gpy from 2016
	+ World Fuel Services / Gulfstream	=	3 yr agreement 30/70 blend
	+ Sky NRG / KLM	=	3 yr agreement Enabling LAX flts
Fulcrum BIOENERGY	+ Cathay Pacific	=	375M usg
	+ UNITED	=	90-180 M gpy Over 10 yrs
	+ air bp	=	50 M gpy Over 10 yrs
RED ROCK BIOFUELS	+ Southwest / FedEx	=	3 M gpy each going into Bay Area, CA

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SAJF offtake agreements

Beyond numerous demonstration programs

neat quantities

TOTAL | AMYRIS	+	CATHAY PACIFIC	= 48 A350 deliveries 10% blend
SG Preston	+	jetBlue	= 10M gpy, 10 yrs
gevo	+	Lufthansa	= Up to 40M gal Over 5 yrs (MOU)
NESTE	+	SkyNRG NORDIC; OSLO AIRPORT; Lufthansa Group KLM; SAS	= (Bioport on demand)
	+	BRITISH AIRWAYS	= Focus on new engagement
	+	Alaska Airlines	= Focus on new engagement

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SAJF approved production pathways
Annexes to ASTM D7566: D1655 fuel following blending

Approved

Syngas FT (FT-SPK)	50% max blend
Hydroprocessed lipids (HEFA-SPK)	50% max blend
Biochem sugars (HFS-SIP)	10% max blend
Syngas FT w/ aromatic alkylation (FT-SPK/A)	50% max blend
Isobutanol conversion (ATJ-SPK)	30% max blend

* Commercialization for each in development, in some cases by multiple parties who would use licensing
* Entities may not achieve commercialization for several years following approval

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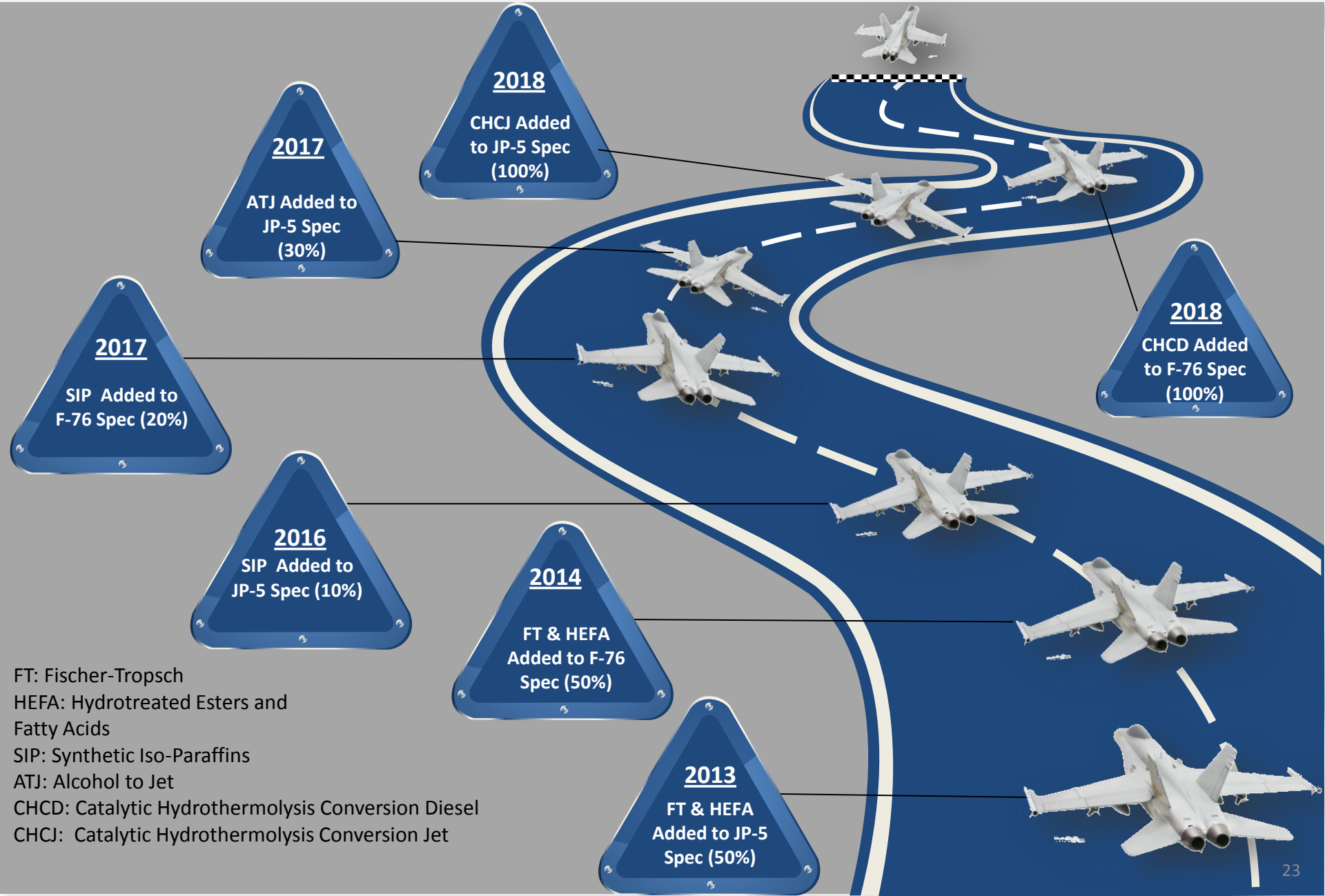
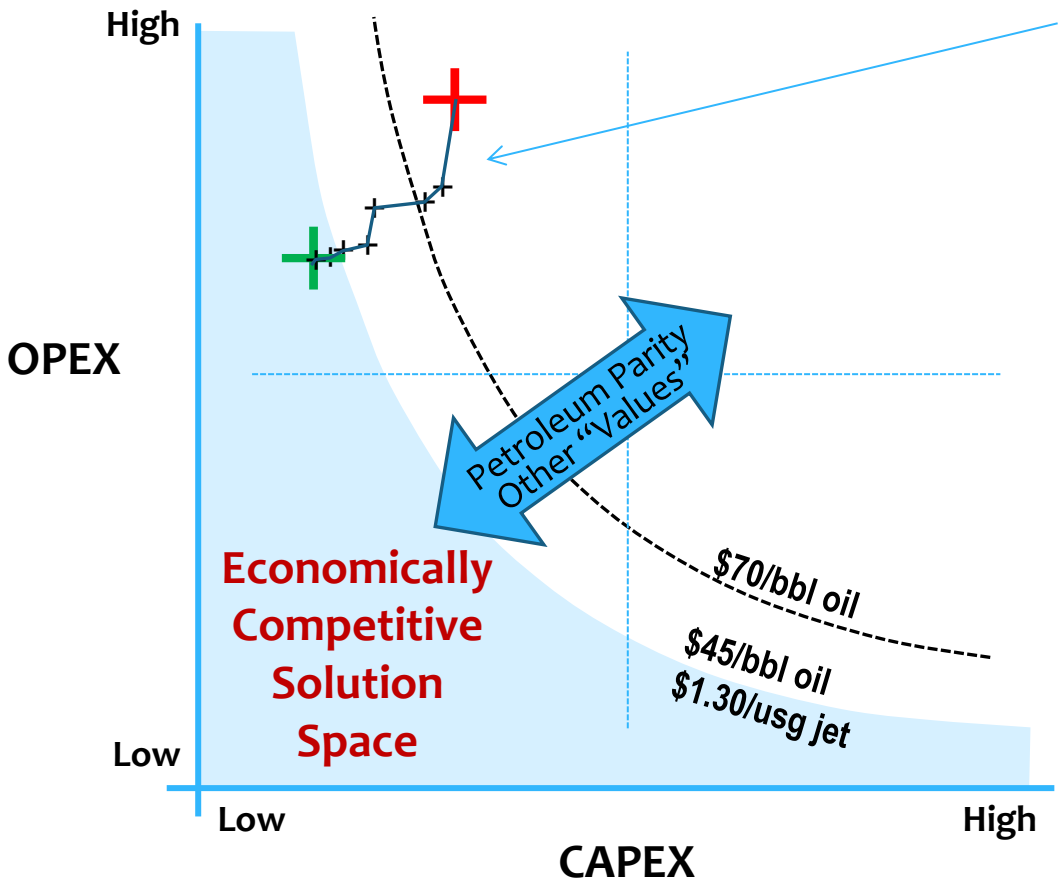
Navy Synthetic Fuel Specification Status



FT: Fischer-Tropsch
HEFA: Hydrotreated Esters and Fatty Acids
SIP: Synthetic Iso-Paraffins
ATJ: Alcohol to Jet
CHCD: Catalytic Hydrothermolysis Conversion Diesel
CHCJ: Catalytic Hydrothermolysis Conversion Jet

Achieving Cost Competitiveness



Enabled by:

* R&D
* D&D Support
* Policy
* Commercialization learning-curve progression
* Build-out – Scale
* Competitive uses
* Valued co-products
* …

Enabling approaches informed by analytics

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Qantas Flight – LAX to MEL 28 Jan 2018

Maintain Interoperability

CATHAY PACIFIC

jetBlue

UNITED

Alaska AIRLINES

NAVAL AIR SYSTEMS COMMAND

RIMPAC 2016

Southwest

BOEING

Lufthansa
Official Airline

26

Sustainable Alternative Fuels in Aviation

2010: 50%

Sustainable Alternative Fuels in Aviation

2016: 100%

Sustainable Alternative Energy in Ships

1775: 100%


Thank You

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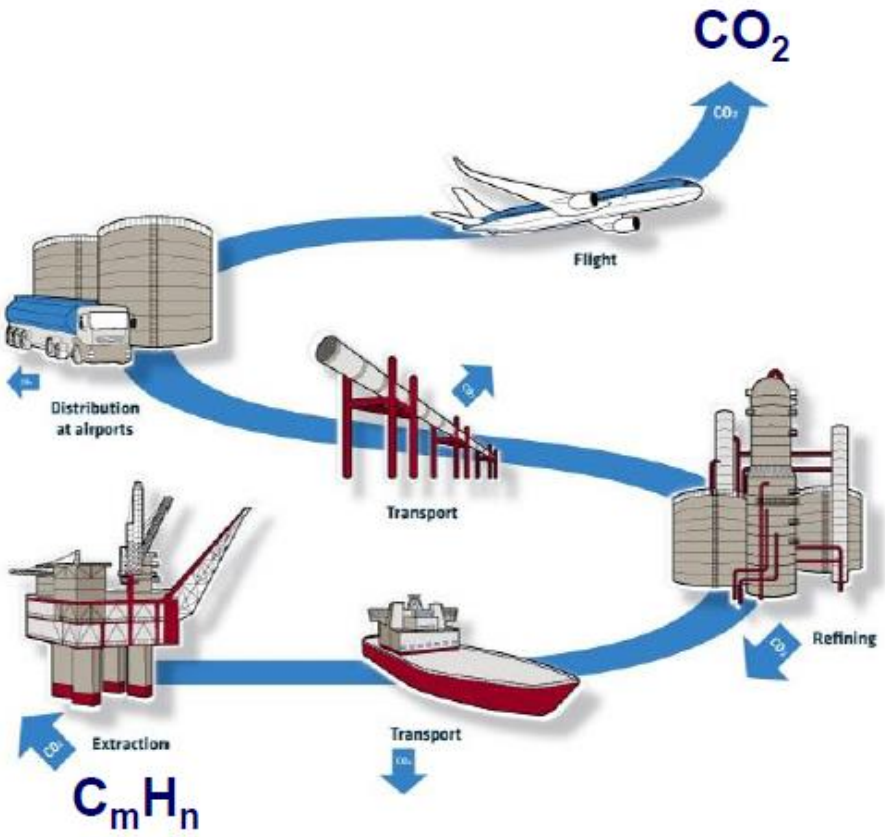
Achieving net LCA GHG reduction

Reduction in carbon being introduced to biosphere



Petroleum based Jet

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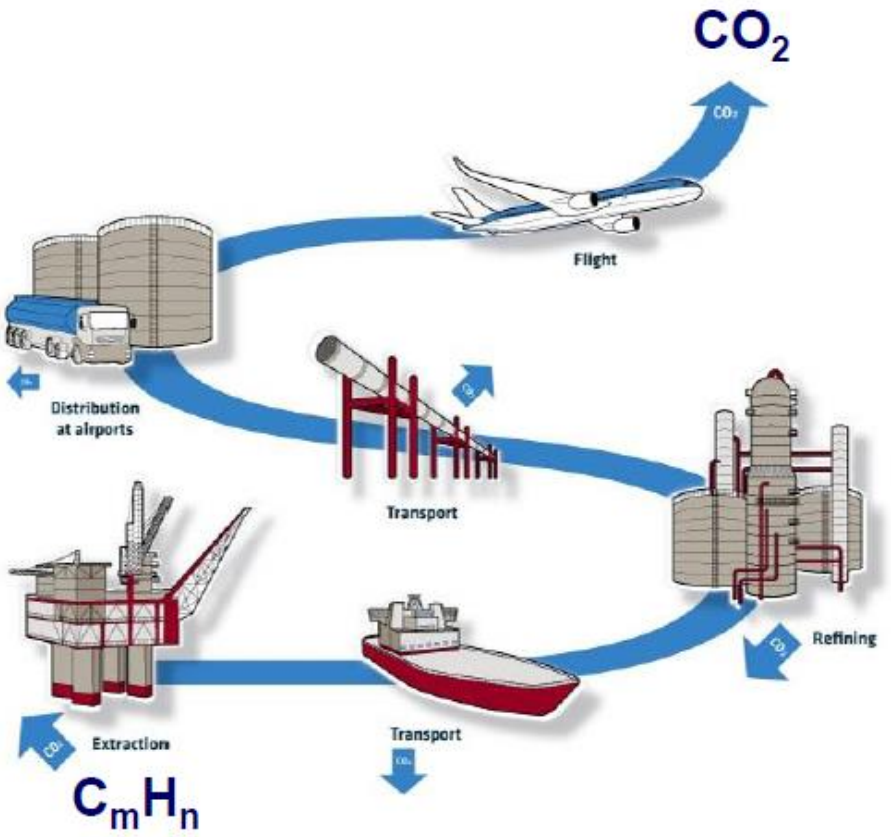
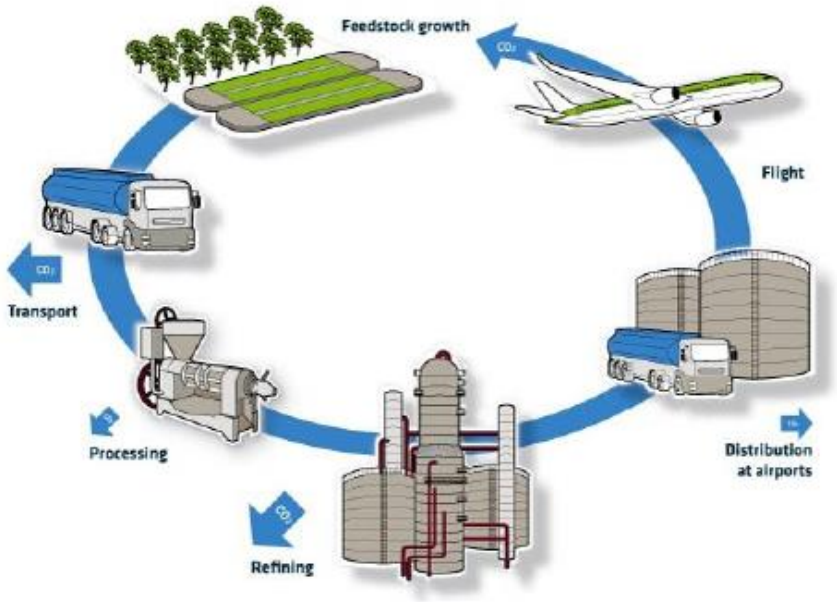
Achieving net LCA GHG reduction

Reduction in carbon being introduced to biosphere



Petroleum based Jet



Sustainable Alternative Jet Fuel

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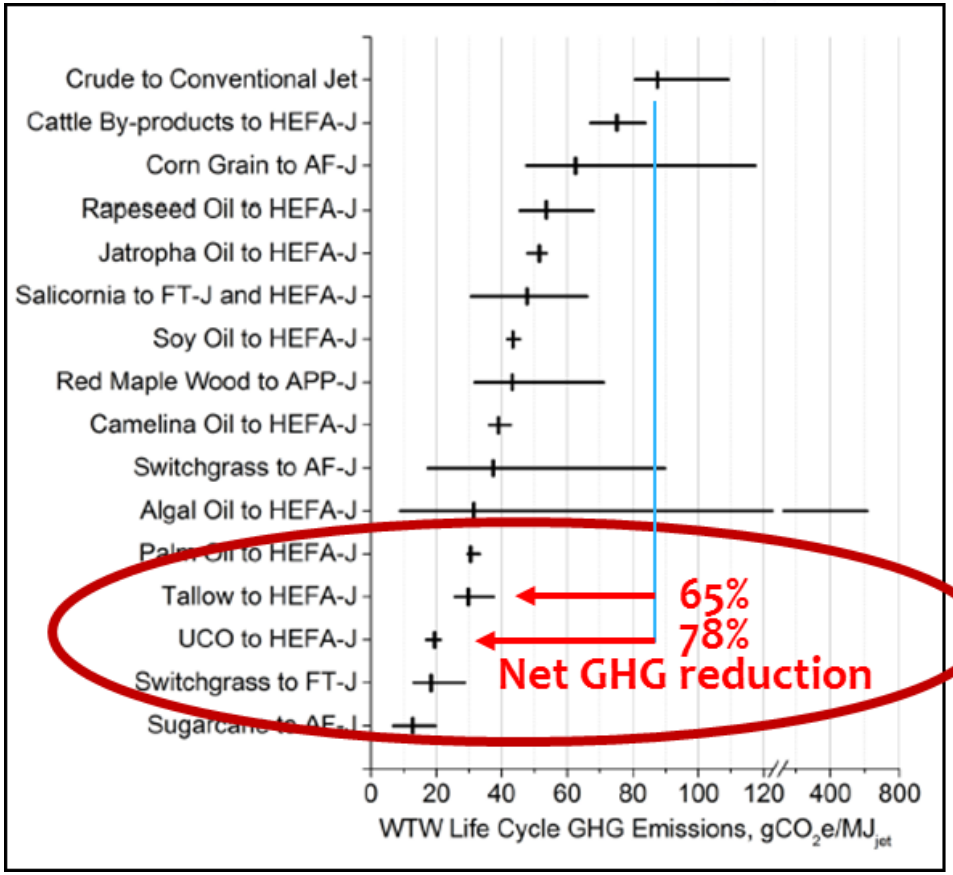
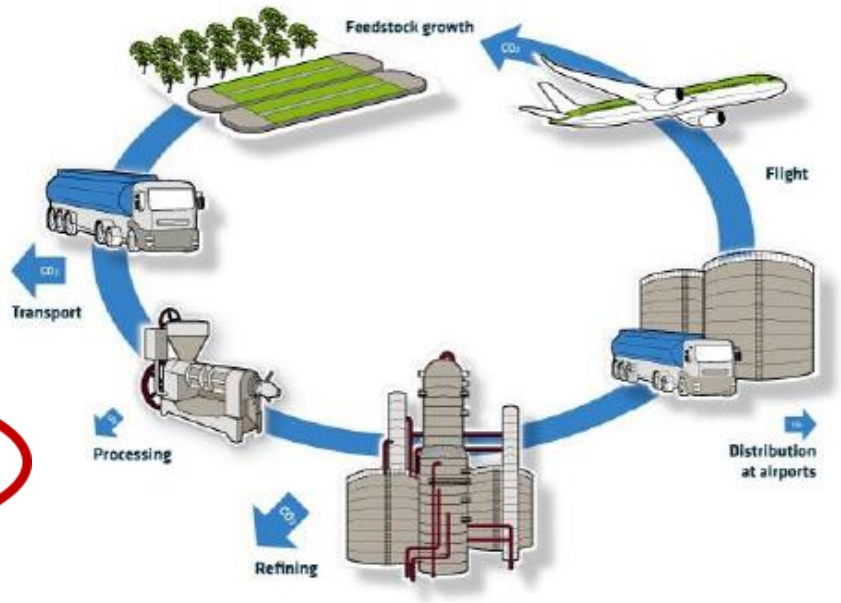
Achieving net LCA GHG reduction

Reduction in carbon being introduced to biosphere





Sustainable Alternative Jet Fuel

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Why Aviation cares about SAJF

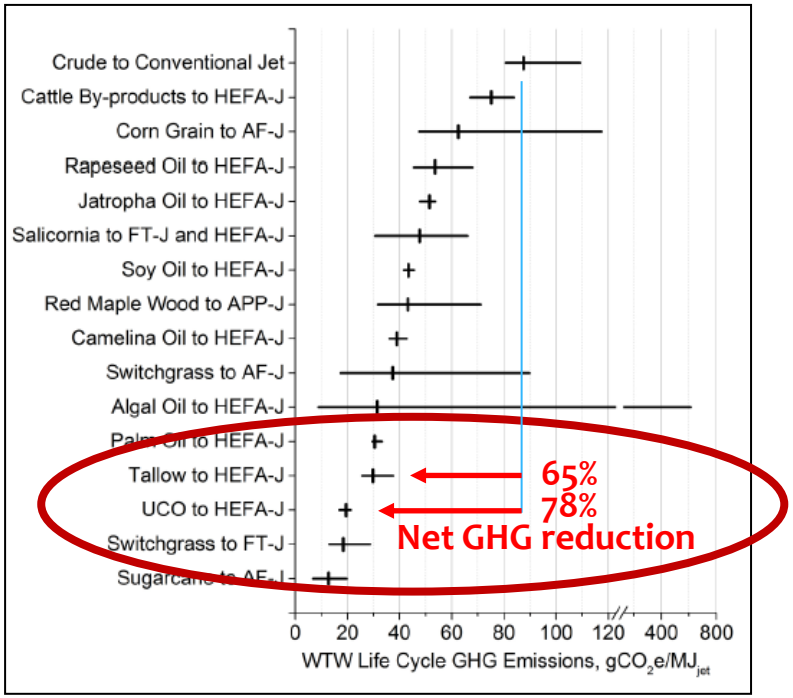
Sustainable Alternative Jet Fuel, a.k.a. biofuel, biojet

Aviation commitments

* Decouple carbon growth
* No other viable options !

Industry alignment on SAJF value proposition

* Net carbon relief !
* Supply surety, Price stability
* Energy security
* Lower "criteria pollutants"
* Improved energy mass density
* Minimal infrastructure impact
* Economic development



SAJF works! Challenges, yes … but abundant options!

* Multiple feedstocks, conversion technologies, entrepreneurs

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