Sustainable Alternative Jet Fuel Development & Commercialization

TRACK: Bio-Based Opportunities
The BIO-Economy: Fuels, Jobs and Power

Steve Csonka
Executive Director, CAAFI

First flight from continuous commercial production of SAJF, 10Mar'16.
Fuel from AltAir Fuels, Paramount, CA (HEFA-SPK 30/70 Blend)
Now being delivered to LAX fuel farm for everyone's upload

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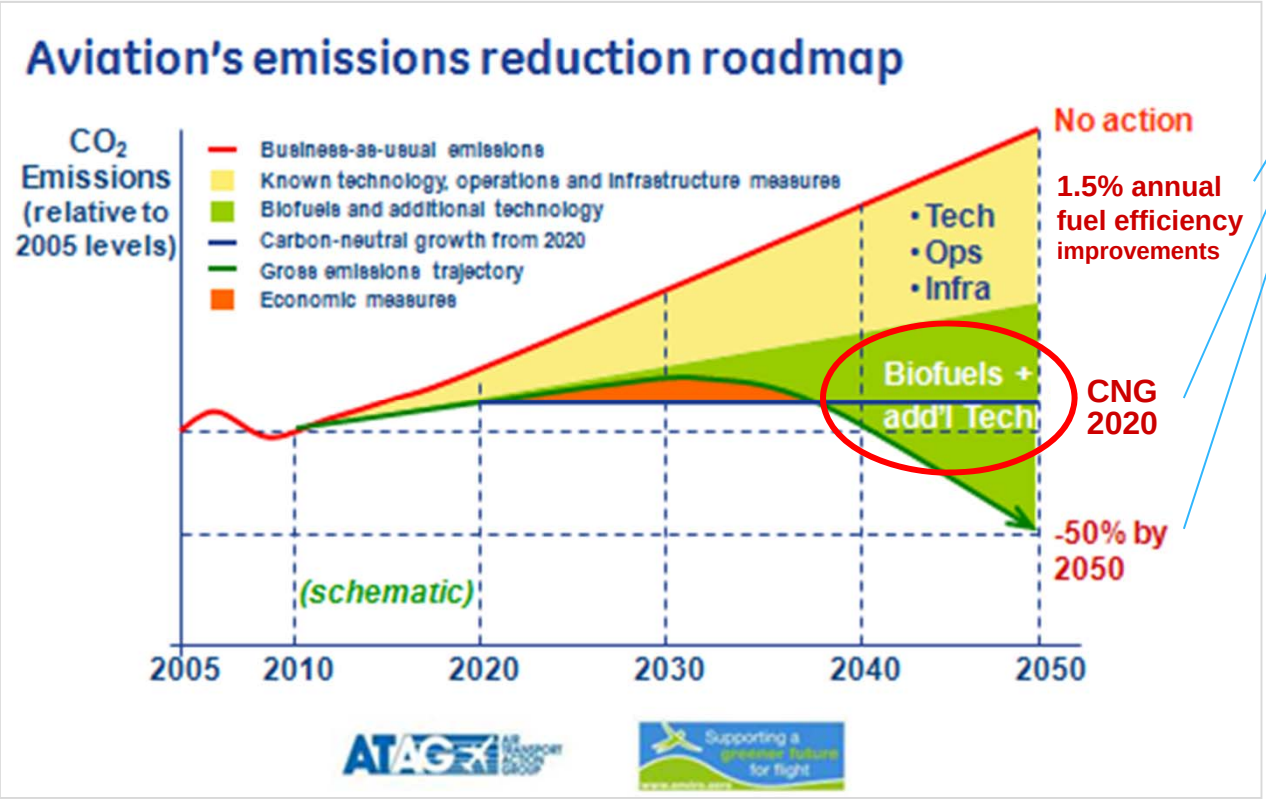
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

Feb 2017

Commercial Aviation's CO_2 commitments
To decouple carbon growth from traffic increases

Biofuels a key component of GHG containment strategy



These 3 industry commitments are currently being converted into regulation through an ICAO/CAEP "basket of measures":

- CO_2 Standards
- MBMs – will monetize carbon

Similar commitment from BizAv & DOD

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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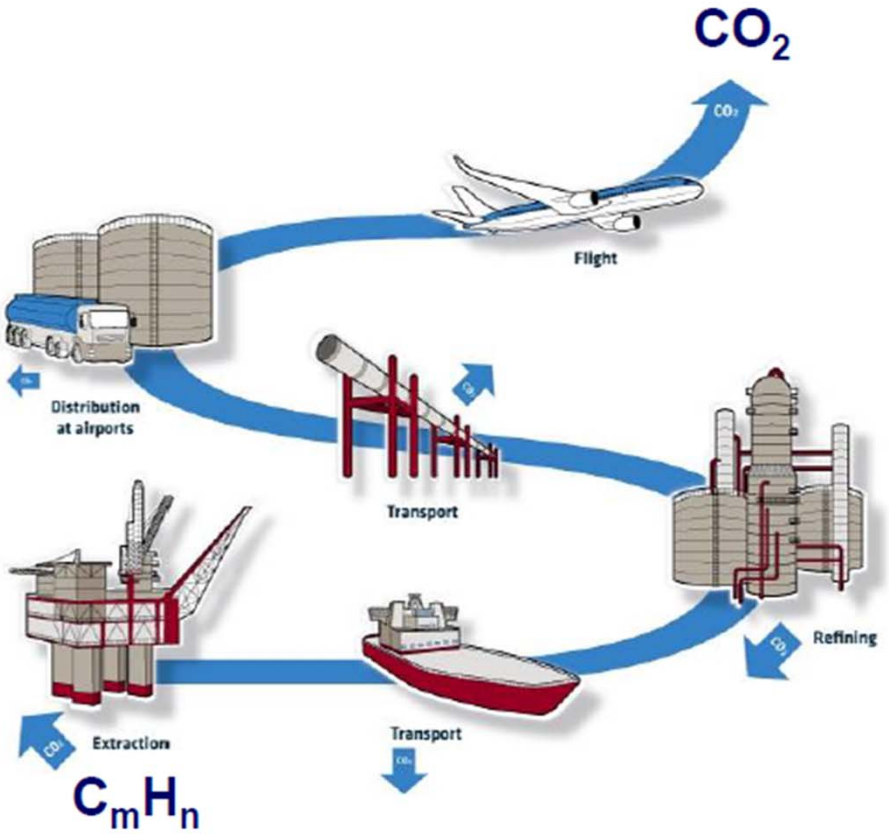
Achieving net LCA GHG reduction

Reduction in carbon being introduced to biosphere



Petroleum based Jet

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Achieving net LCA GHG reduction

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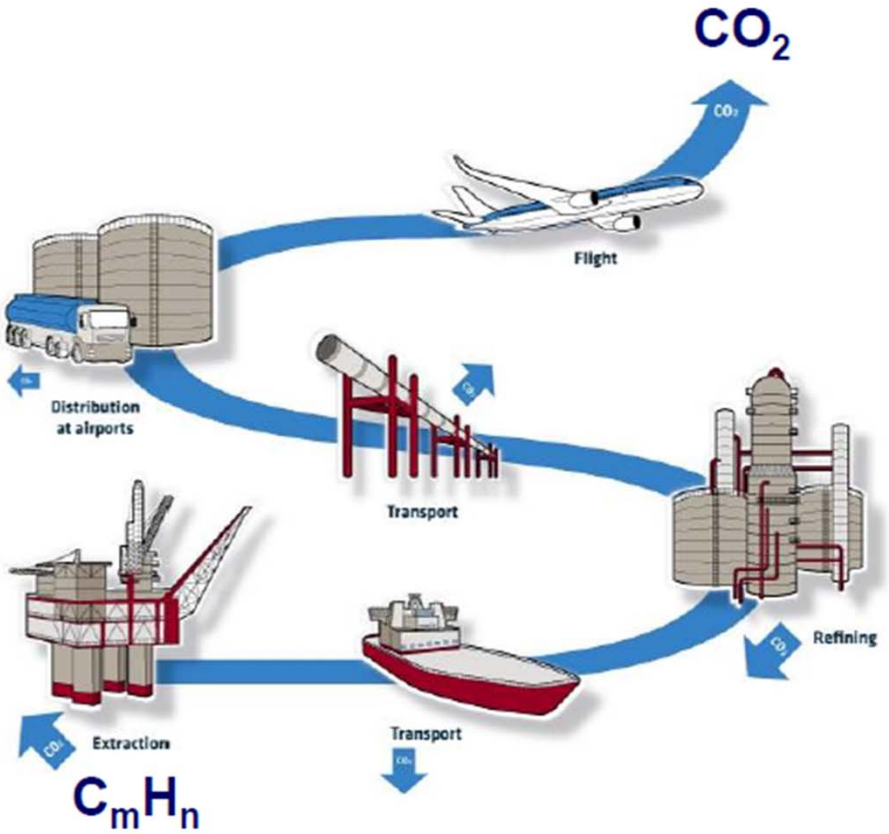

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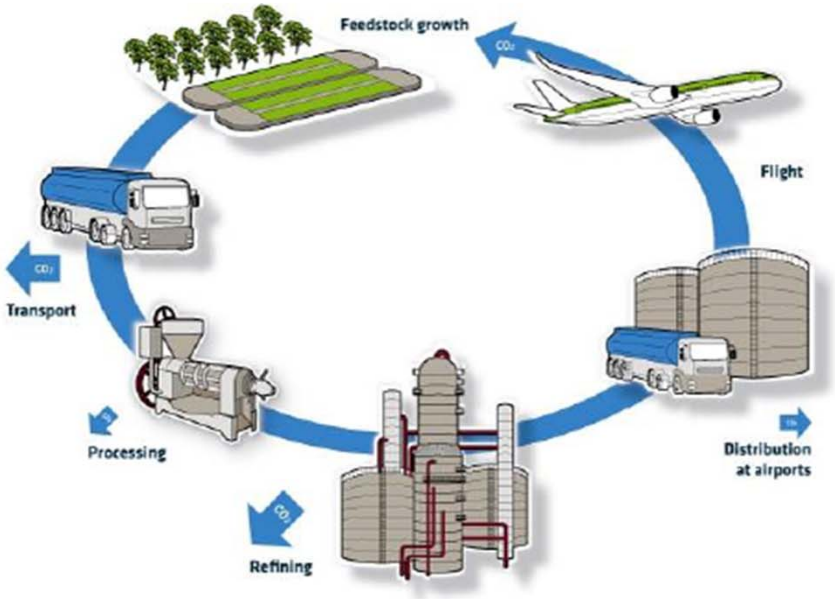

Sustainable Alternative Jet Fuel

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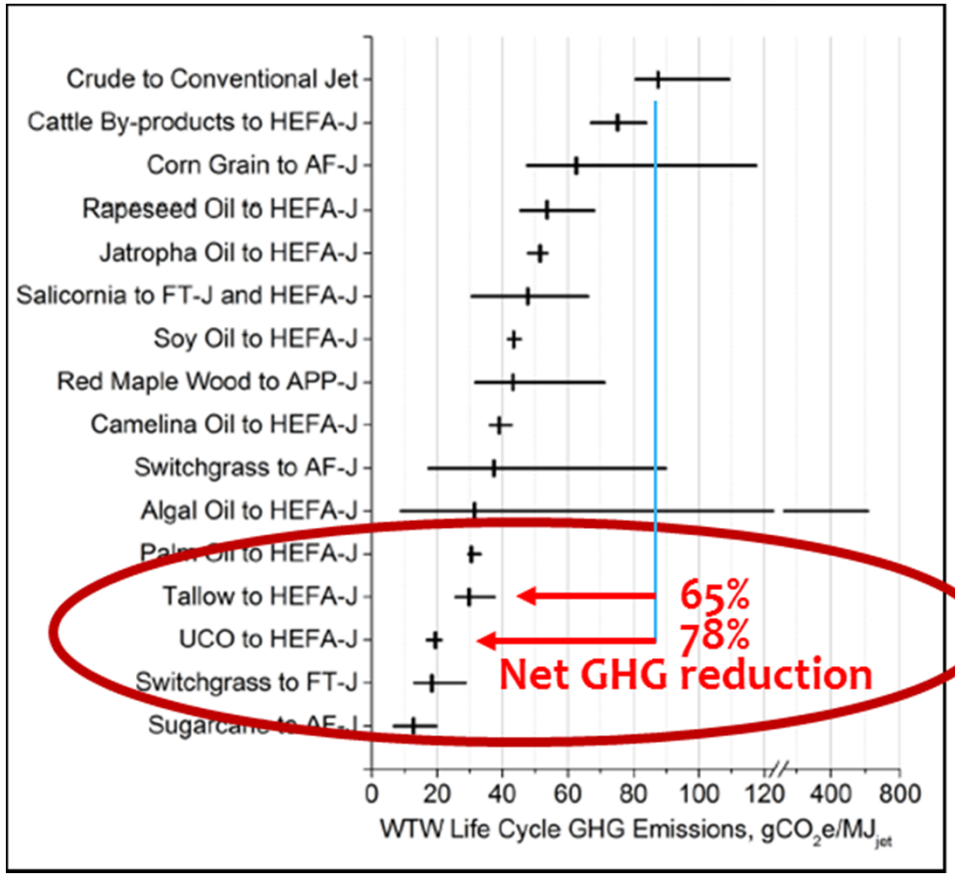

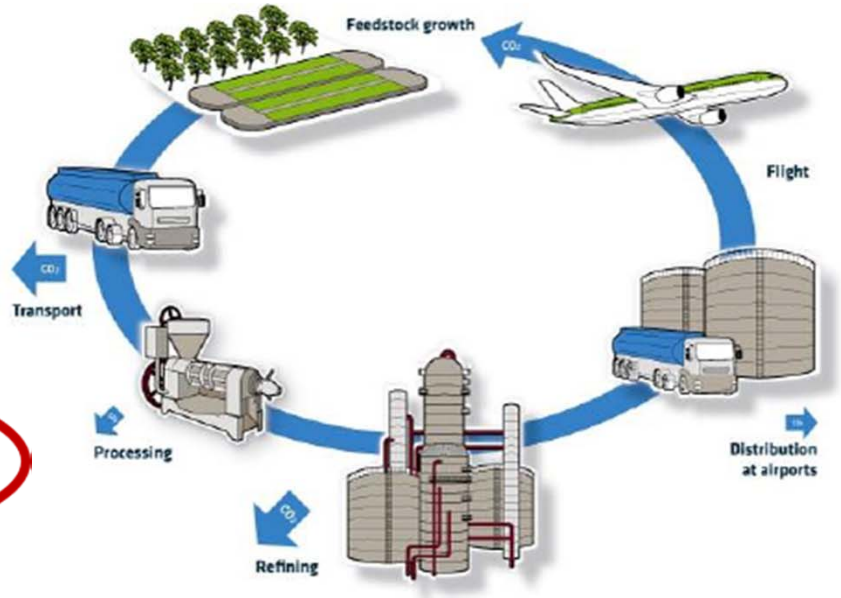

Sustainable Alternative Jet Fuel

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Why Aviation cares about SAJF

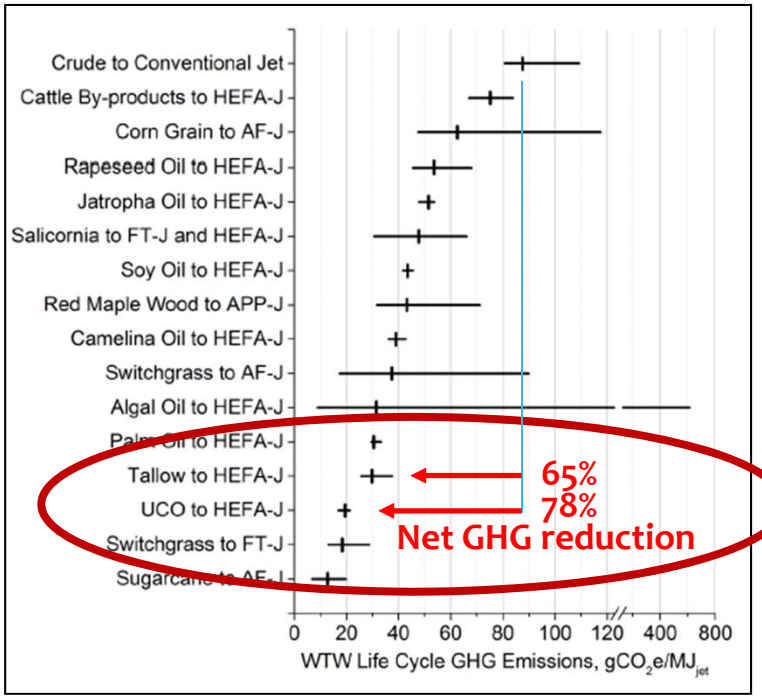
Sustainable Alternative Jet Fuel, a.k.a. biofuel, biojet

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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SAJF offtake agreements

Beyond numerous demonstration programs

neat quantities

AltAir Fuels + UNITED = 5 M gpy from 2016

AltAir Fuels + World Fuel Services / Gulfstream = 3 yr agreement 30/70 blend

AltAir Fuels + Sky NRG / KLM = 3 yr agreement Enabling LAX flts

Fulcrum BIOENERGY + CATHAY PACIFIC = 375M usg

Fulcrum BIOENERGY + UNITED = 90-180 M gpy Over 10 yrs

Fulcrum BIOENERGY + 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	= (Salvage MSW work?)
	+	Alaska Airlines	= (HBE defunct, focus on new engagement)

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SAJF conversion processes

Start with hydrocarbon / organic building-blocks

Deconstruct & remove extraneous molecules

Process to workable intermediates

Reformulate to appropriate C_8-C_{16} molecules

Utilize standard refinery "finishing" processes

D7566 - SAJF Blending Components

D1655 – from petroleum and D7566 fuel blends

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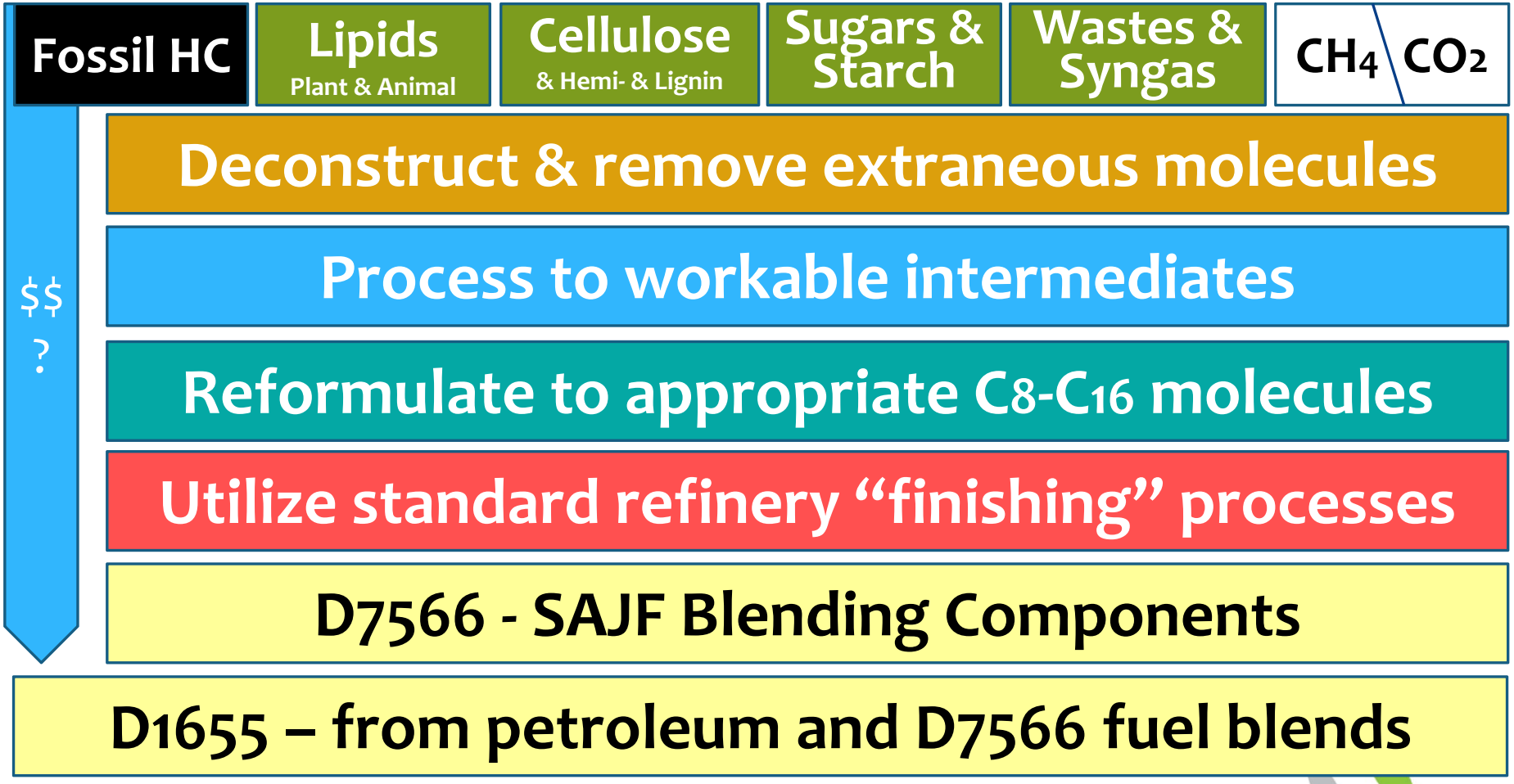
What are these feedstock sources?



What are these feedstock sources?

Lipids Plant & Animal	Cellulose & Hemi- & Lignin	Sugars & Starch	Wastes & Syngas	CH_4 \ CO_2
Brassicaceae	Ag. Residues	Agave	Black liquor	
Canola/Rape	Bagasse	Cassava	Brewery Waste	
Camelina	Grasses	Corn	Coffee waste	
Carinata	Wood products	Sugar Beet	Comm/Ind. bio	
Mustards	- coppiced	Sugar Cane	Food waste	
Pennycress	- short rotation	Sweet Sorghum	Manure	
Corn (DGO)	- slash, trim	Sweet Tubers	MSW	
Castor	Other	Hydrolyzed	Non-recyc plastics	
Cull edibles			Sludge	
Cuphea			Syngas	
Euphorbia			Waste carbon gases	
Hemp seeds			Wood processing residues	
Jatropha				
Jojoba				
Lesquerella				
Lupine				
Moringa				
Pongamia				
Animal processing fats				

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First refinery online!
AltAir Fuels in Paramount, CA

- First dedicated US production facility for HEFA-SPK and HDRD fuels with ongoing production
- Repurposing of Alon refinery
- Tallow feedstock initially

* 40M gpy nameplate capacity in "Phase 1"
* SAJF being delivered to airlines and suppliers
  * United (LAX), WFS (Gulfstream), SkyNRG (KLM)
* HDRD (F76) delivered to Navy under DLA FY'16 contract
* Ownership evaluating expansion in next 2-3 years

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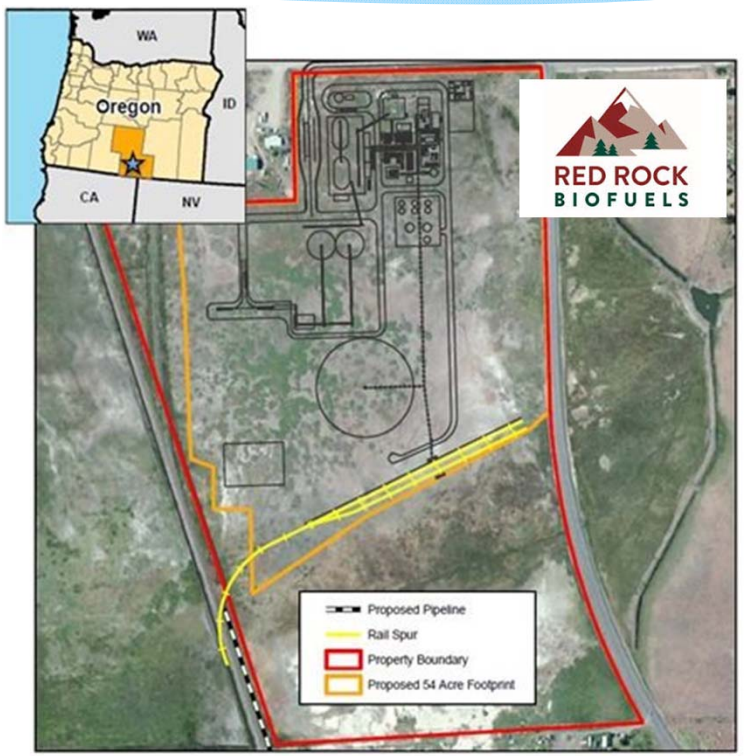
DPA Recipient: Red Rock Biofuels

- 16 M gpy of renewable, liquid transportation fuels – FT process
  - From 175,000 tpy of woody biomass
  - 3M gpy SAJF offtake agreement from each of Southwest Airlines and FedEx
  - $70 million DPA Title III award for ~$200 million refinery
- Replicable approach targeting 10 additional sites
  - E.g. - working with CAAFI in southeast F2F2 State Initiative



TCG Global gasifier
Velocys FT reactors
Haldor Topsoe / Valero upgrading

Courtesy Biofuels Digest

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DPA Recipient: Fulcrum Bioenergy

* 10-11 M gpy syncrude production plus power – FT process
  * From 200,000 tons of post-recycled waste
* Subsequent plants at 3-6X size; targeting 8 plants by 2022 delivering 300 M gpy middle distillates

TRI Gasifier, EFT FT unit
Waste agreements comprising ~4% of US total landfill volume

WM WASTE MANAGEMENT

WASTE CONNECTIONS INC.
Connect with the Future®

* Replication approach ➔

Courtesy Fulcrum-Bioenergy
http://www.fulcrum-bioenergy.com/index.html

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DPA Recipient: Emerald Biofuels

* *Emerald One*: 88 M gpy HDRD capacity from conversion of lipids
* Development program to achieve >500M gpy portfolio

Non-edible oil feedstocks
Honeywell UOP Green Diesel/Jet Technology
Gulf Coast

Courtesy Beaumont Enterprise, photo by Jake Daniels
https://emeraldonellc-public.sharepoint.com/

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DPA Title III Project, Round 2 FOA
USDA/DOE/DON Advanced Drop-In Biofuels Initiative

* The proposed IBPE must bring online at least 10 M gpy of capacity with the capability to produce MILSPEC compatible biofuel.
* Potential for $55M project assistance, with the requirement of a 50/50 or greater cost share from the private sector.
* … To create a new Green-Field facility, or expand/modify an existing Brown-Field facility comprised of partners within the complete value chain.
* Industry Roundtable next week
  * DATE: Wednesday, March 1, 2017
  * TIME: Arrival: 7:30 a.m., Program runs: 8:00 a – 11:00 a
  * LOCATION: USDA Jefferson Auditorium, USDA South Building, 14th and Independence, Washington DC 20250

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Production in development

* Existing DPA Awardees
  * Red Rock, Fulcrum, Emerald, and their build-out plans
* AltAir Build out (~5X)
* SG Preston (5 facilities in first tranche)
* ARA licensing and build-out
* Neste, REG, UPM pivots

Necessitates serious engagement with purpose grown oilseed & FOG development / expansion

* Unlocking of renewable diesel and refinery co-processing
* Initiating activities of Amyris/Total, Gevo, and LanzaTech, et al.
* Other commercial-scale technology demos to occur in next 12 months that should prove to be enabling

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Ex: Lipid pathway applicability
Conversion of fats, oils & greases

SAJF Pathways

Approved

- FT-SPK, FT-SPK/A
- HEFA-SPK
- HFS-SIP
- ATJ-SPK

→ HW UOP: Ecofining / GreenJet
→ Neste: NEXBTL
→ UPM:

SAJF Intentions (first facilities)

AltAir Fuels	40 M gpy (30% jet)
Emerald Biofuels	88 M gpy
SG Preston	120 M gpy (77% jet)

In- Process & Pipeline

- Hydrotherm oils (CH) → ARA - unique value prop. => 100% drop-in
- Renewable Diesel → Unlock existing 1 B+ gpy HDRD production
- Refinery Co-processing
  - Front-end: Blend with crude
  - Mid: FCC, HC, Coker ?
  - Back-end: Hydroprocessing ✓
- SBI → Unlock existing biodiesel production
- Forge, Tyton, … → Toward improved affordability

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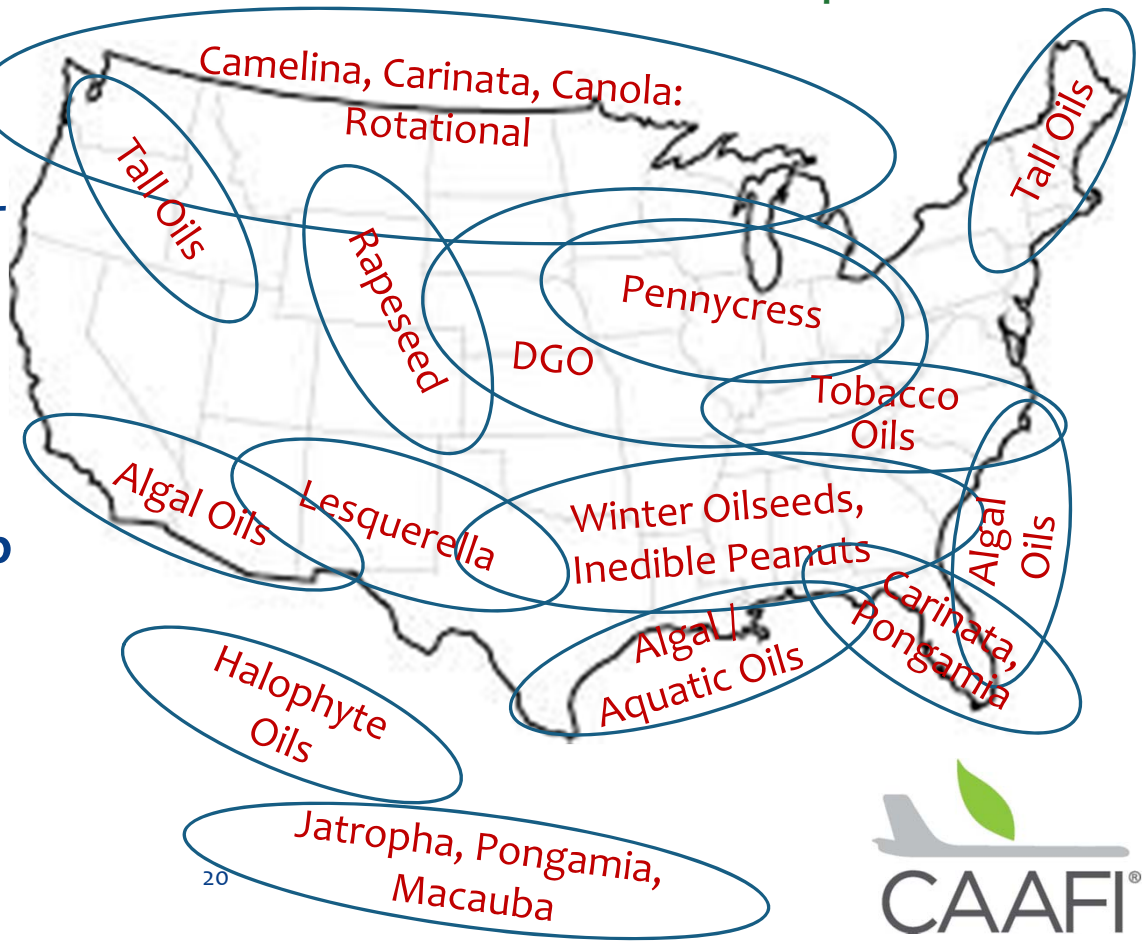
Lipid feedstocks
Potentially enabling of significant production …

- Multiple conversion processes
- Multiple feedstock developers
- Multiple producers
- Multiple low LUC/ILUC agri-based feedstocks, **plus:**
  - White Grease, Chicken Fat, Tallow
  - UCO / Yellow Grease
  - Brown Grease, Biosolids
- Easier supply chain scale-up leveraging biodiesel and RD production capacity
- Lowered H2 cost & availability helps

Targeting most sustainable solutions:
Low, or Zero, impact LUC/ILUC & F-v-F solutions; Environmental Services a plus.



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