Commercial Aviation Alternative Fuels Initiative

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SERVING THE NATION AS A LEADER IN GLOBAL TRANSPORTATION INNOVATION SINCE 1970

CAAFI Goals

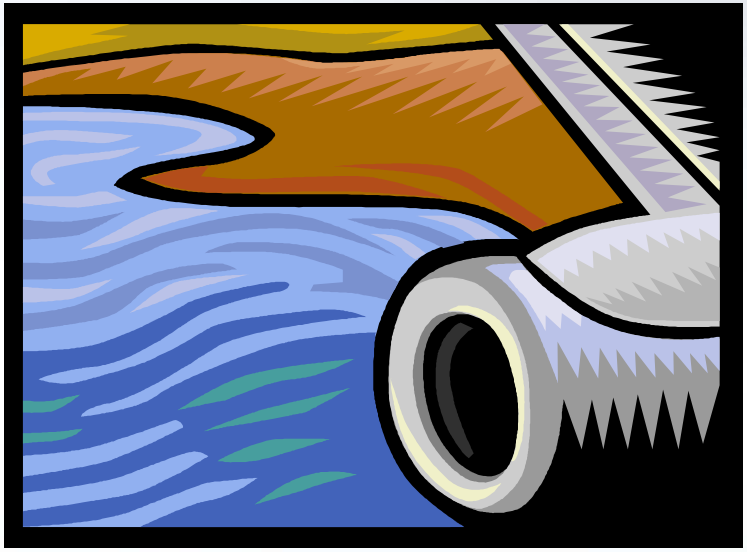
Alternative fuels to enhance:

- Environmental sustainability

  Greenhouse gas (GHG) emissions reduction

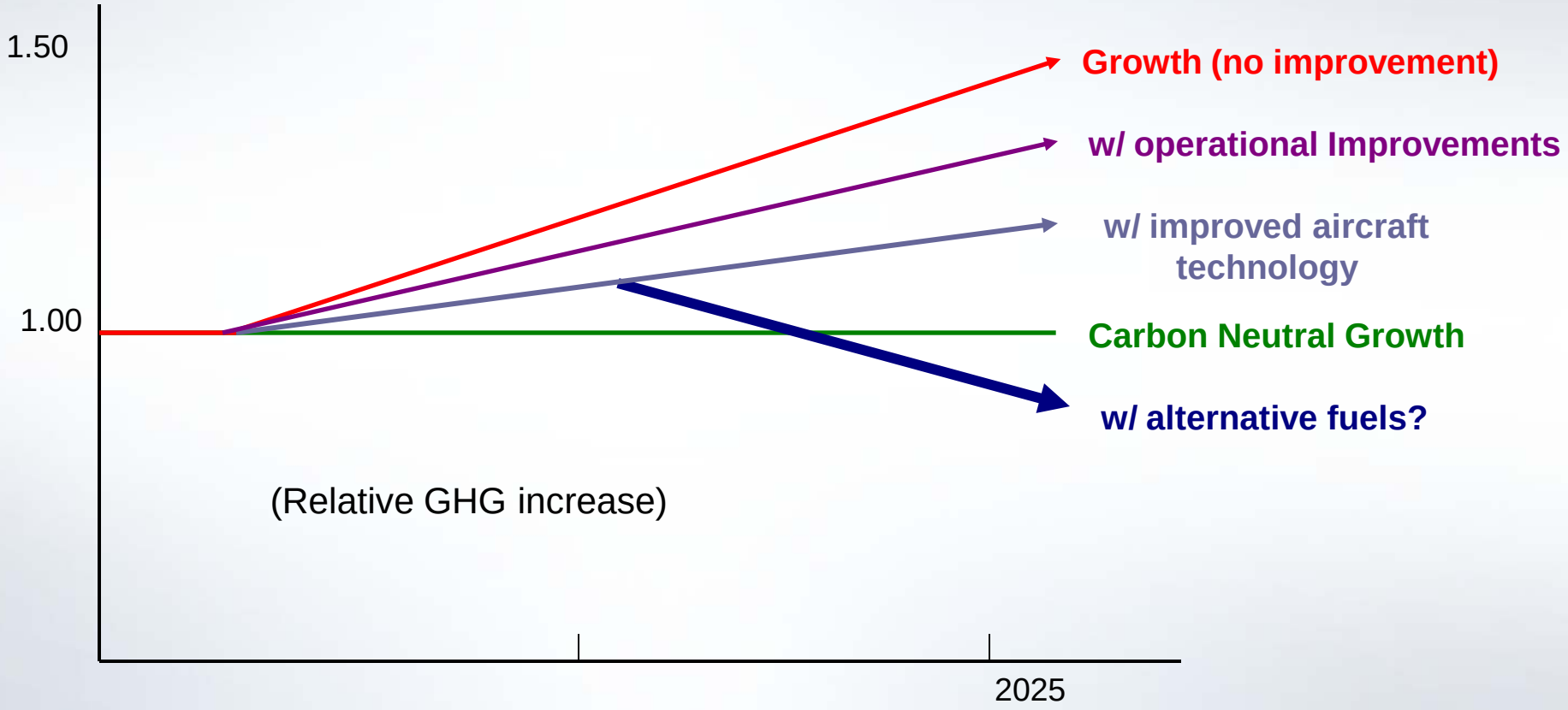
  Air quality benefits (e.g., SOx, PM)

- Fuel supply stability
- Fuel price stability



… without compromising safety or performance.

Alternative Fuels and Carbon Neutral Growth



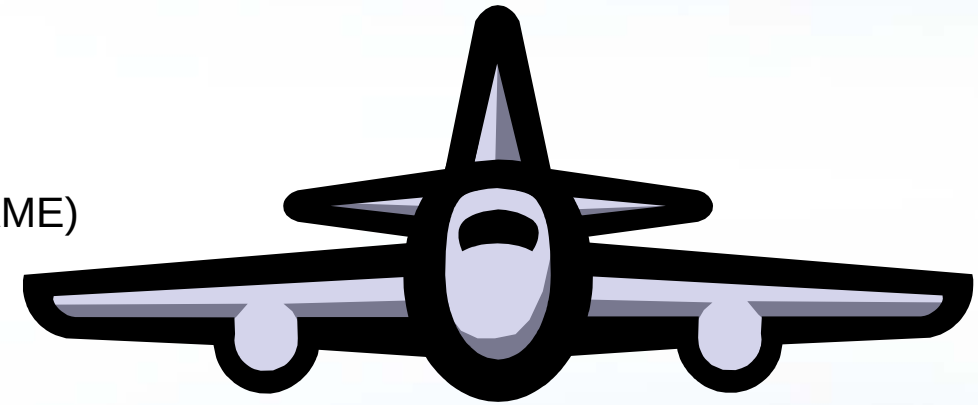
Unique Aspects of Aviation Alternative Fuels

Aviation requires:

- High energy density
- Global deployment and/or compatibility
- Use of existing infrastructure
- Environmental sustainability

Solution: “drop-in fuels”

- e.g., advanced biofuels
  (no ethanol, biodiesel or FAME)
- High energy density
- Suitable lubricity
- Materials compatibility
- Thermal characteristics

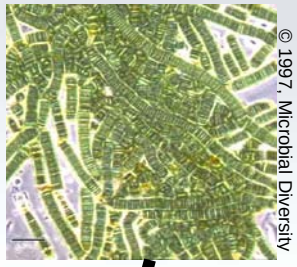


Aviation offers:

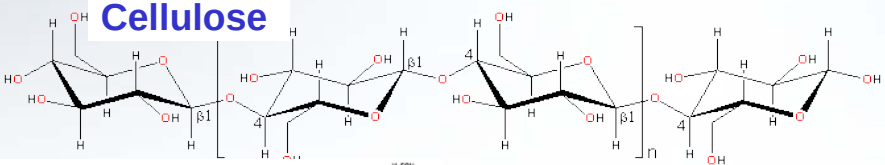
- Concentrated fueling locations (35 airports = 80% of jet fuel in US)
- Limited number of purchasers
- Long-term off-take agreements
- Unified fuel specifications and international regulatory standards (via ICAO)
- Manufacturer, airline and regulator alignment

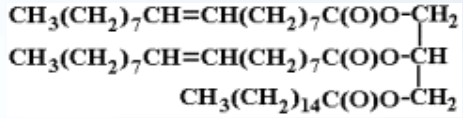
Some ways to make bio-based jet fuel.

GM microorganisms



Cellulose

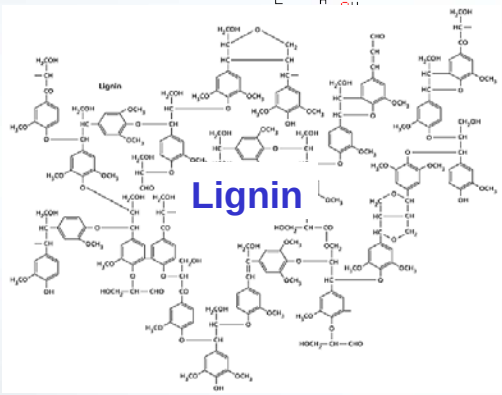




Triglycerides (fats, oils)

C16:1

C18:0



Lignin

pyrolysis

gasification (or co-gasification with coal)

"HRJ"

"Bio SPK"

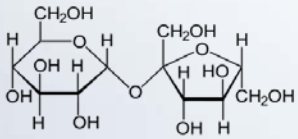
hydroprocessing

$CO + H_2$

"BTL"

cracking

"Synthetic biology"



Sugars

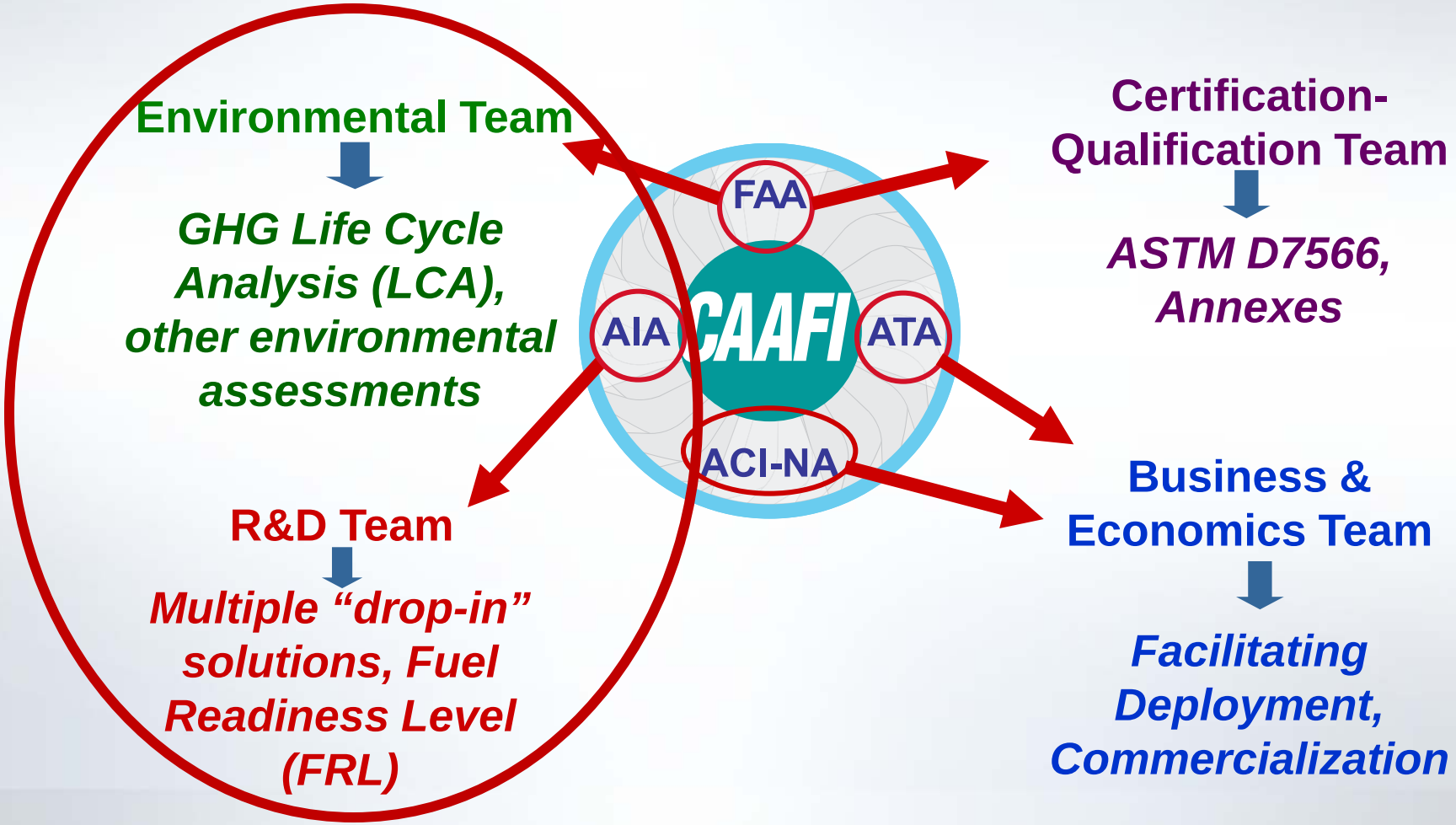
alcohols

catalysis

"advanced/direct fermentation"

jet fuel components

CAAFI Structure



Some Key Biofuels Issues in R&D and Environment

Environmental Issues

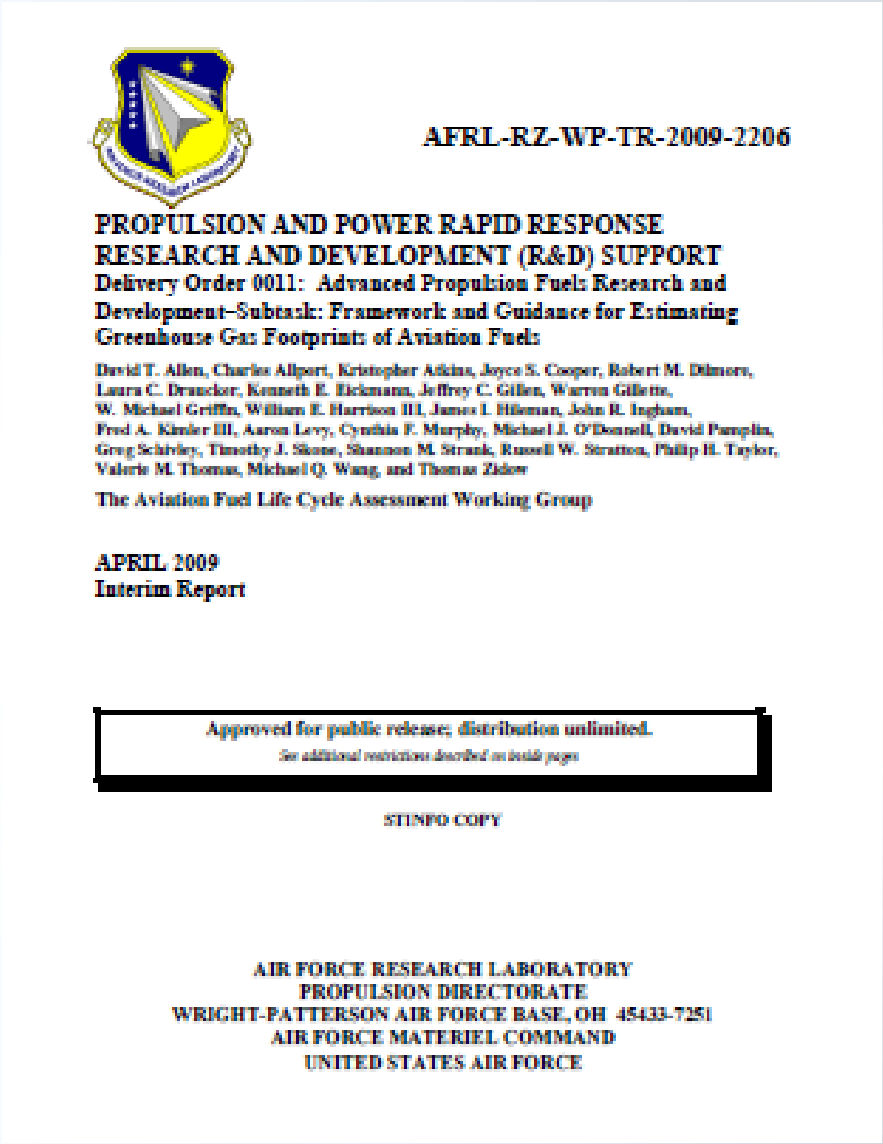
- Greenhouse gas LCA
- Other natural resource issues

R&D Issues

- Feedstock development, production and logistics
- Feedstock conversion efficiency
- Fuel development (proof of concept, scale up, technical suitability)

Aviation Fuel LCA

- IAWG on Aviation Alternative Fuels
  - AFRL-RZ-WP-TR-2009-2206
  - Consistent with ISO, EPA
  - Peer reviewed
  - LCA Case Studies under way
- MIT PARTNER LCAs
  - Based on modified GREET model (originally from M. Wang, Argonne NL)
  - Includes uncertainty boundaries around baseline
  - No indirect land use change



AFRL-RZ-WP-TR-2009-2206

PROPULSION AND POWER RAPID RESPONSE RESEARCH AND DEVELOPMENT (R&D) SUPPORT
Delivery Order 0011: Advanced Propulsion Fuels Research and Development–Subtask: Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels

David T. Allen, Charles Allport, Kristopher Atkins, Joyce S. Cooper, Robert M. Dilmore, Laura C. Drunicker, Kenneth E. Eickmann, Jeffrey C. Gillen, Warren Gillette, W. Michael Griffin, William E. Harrison III, James I. Hileman, John R. Ingham, Fred A. Kimler III, Aaron Levy, Cynthia F. Murphy, Michael J. O'Donnell, David Pamplin, Greg Schivley, Timothy J. Skone, Shannon M. Strank, Russell W. Stratton, Philip H. Taylor, Valerie M. Thomas, Michael Q. Wang, and Thomas Zidow

The Aviation Fuel Life Cycle Assessment Working Group

APRIL 2009
Interim Report

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UNITED STATES AIR FORCE

Other Sustainability Issues

- Food vs. Fuel
- Biodiversity
- Eutrophication
- Acidification
- Other air pollutants
- Water use
- Wetlands
- NEPA requirements
- Invasiveness
- Social sustainability

Possible vehicles

  - RSB Sustainability Scorecard
  - Product Category Rules

Research and Development Activities

R&D Team Foci:

- Tools for evaluating status of alternative aviation fuels (Fuel Readiness Level, or FRL)

FRL Expansion

- Feedstock availability
- Environmental due diligence progression
- Pass/fail criteria

Panicum virgatum – Chhe 2009: http://commons.wikimedia.org

Fuel Readiness Level Scale

FRL	Description	Exit Criteria	
1	Basic Principles	Feedstock / Process Observed / Reported	
2	Concept Formulated	Feedstock / *Complete* Process identified.	
3	Proof of Concept	Basic Fuel Properties Validated at Lab Scale	0.13 US gal. (500 ml)
4.1 4.2	Preliminary Technical Evaluation	System Perf. & Integration Studies Entry Criteria/Specification Properties	10 US gal. (37.8 L)
5	Process Validation	Scaling from Laboratory to Pilot plant	80 US gal. (302.8 L) to 225,000 US gal. (851,718 L)
6	Full-Scale Technical Evaluation	Fuel Properties, Rig and Engine Testing	80 US gal. (302.8 L) to 225,000 US gal. (851,718 L)
7	Fuel Approval	Fuel Class/Type Listed in Int'l Fuel Standards	
8	Commercialization	Commercial Purchase Agreements	
9	Production Capability Established	Full Scale Plant Operational	

Legend:	R & D	Certification/ Qualification	Business & Economics

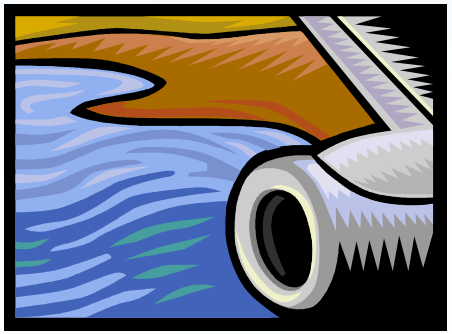
Fuel Readiness Level Implementation

FEEDSTOCK READINESS

Bruno Miller

FRL

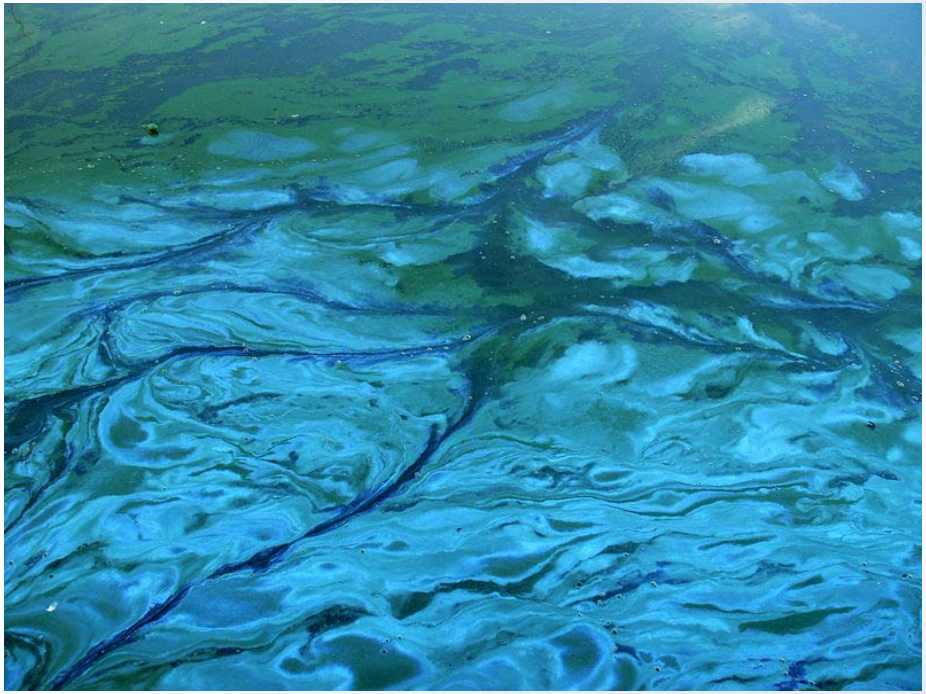
ENVIRONMENTAL ANALYSIS



Opportunity for Feedstock Readiness Level (FeRL)

Goals:

- Clarify risks and barriers to feedstock development and availability
- Provide a risk management tool for evaluating individual feedstocks
- Comparison with FRL to identify R&D gaps



Cyanobacteria – Lamiot, 2007; http://commons.wikimedia.org

Feedstock Readiness – Potential Components

Production Capacity
- Current production
- Geographic distribution
- Geographic potential
- Current yield
- Project yield
- Competing uses for land
- Current land use (idle? marginal?)

Densification/Logistics
- Standard/widely accepted cultivation, harvesting, collection, storage, densification, transport equipment?

Conversion Efficiency
- By conversion type
- First, second, third generation crops

Germplasm Maturity
- Potential for improvement through breeding, and, if necessary, GM
- Identification of optimal strains for local conditions

Coproduct Maturity

Feedstock Readiness – Potential Components

Barriers to Cultivation

- Education
- Extension services
- Credit facilities (acquisition of materials)
- Long-term contracts/agreements for sale at competitive prices

Permitting and Approvals

- Novel crops / organisms
- Special cultivation facility permitting (e.g., algal ponds, halophyte land inundation)
- Wetland / estuarine impacts
- Local and state requirements

Policy Support

- Crop insurance
- Loan guarantees
- Grants
- Payment/incentive programs
  - For production of feedstock
  - Harvest, storage, transportation
  - For fuel itself

Feedstock Readiness Level Progression Draft

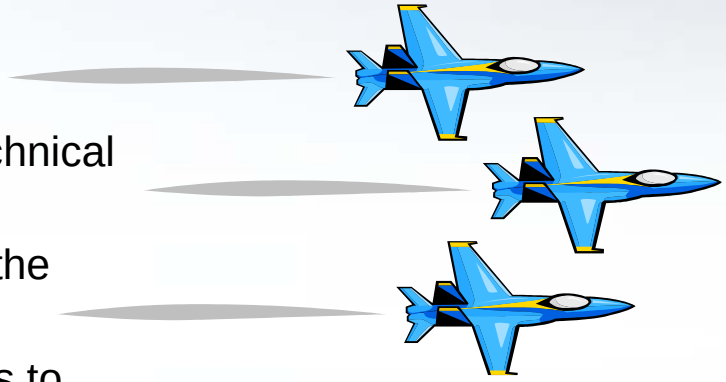
FRL	Description	Feedstock Readiness Progression	
1	**Basic Principles**		
2	**Concept Formulated**	Invasive species assessment. Preliminary NEPA/sustainability evaluation. Water usage studies. Permit feasibility. Barriers to cultivation identified.	
3	**Proof of Concept**	Cultivation and logistics requirements established. Regional variations identified. Plot test and field harvest accomplished. Permit requirements and approvals identified. Coproducts identified, coproduct maturity evaluated.	**0.13 US gal. (500 ml)**
4.1 4.2	**Preliminary Technical Evaluation**	Education and extension. Feedstock trials. Applications for permits/approvals completed. Germplasm maturity established.	**10 US gal. (37.8 L)**
5	**Process Validation**	Wetlands/other specific resource evals. Required permits/approvals accomplished. Barriers to cultivation overcome. Coproduct maturity established. Conversion efficiency established.	**80 US gal. (302.8 L) to 225,000 US gal. (851,718 L)**
6	**Full-Scale Technical Evaluation**	Policy supports for feedstock production implemented. Credit facilities and long-term contract/agreement development.	**80 US gal. (302.8 L) to 225,000 US gal. (851,718 L)**
7	**Fuel Approval**	Cultivation of sufficient feedstock for plant operation	
8	**Commercialization**	General Sustainability Criteria Assessed Feedstock cultivation expanded for regional use.	
9	**Production Capability Established**	Feedstock cultivation on national level (occurs after a facility achieves step 9)	

Discussion

- Questions
- Suggestions
- Critique
- Guidance
- Partnering opportunities
- Potential applications of readiness tool(s)
- Applicable USDA knowledge bases

The aviation community is …

- Looking to alternative fuels to meet GHG goals, improve price and supply stability
- Producing tools to evaluate environmental and technical readiness of aviation fuels
- Coordinating within commercial aviation and with the DoD agencies involved in aviation
- Coordinating with other agencies and stakeholders to develop additional tools (e.g., feedstock readiness)
- Buying fuels and using MOUs to establish relationships with fuel producers
- Beginning to look at other aspects of sustainability beyond GHG LCA



For further information

www.caafi.org

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Aviation fuel MOUs

- 3/10 - ATA / Defense Energy Supply Center (DESC) MOU
  - Acknowledges joint interest in alt fuels and establishes collaborative forum to move developmental and marketing goals forward.
- 12/09 - MOUs signed to negotiate purchase of alternative jet fuels
  - Two suppliers: AltAir Fuels (renewable) and Rentech (synthetic)
  - Fifteen airlines from four countries participated in the MOUs
  - Continued expansion of signatories and interest
- 9/09 – DESC contracts for 600,000 gallons of Camelina-based jet fuel and a small amount of algal-based jet fuel
- 8/09 - Purchase agreement signed in August for renewable synthetic diesel for ground support equipment at LAX
  - Fuel supplied by Rentech through ASIG -1.5 M gal/year starting late 2012
  - Eight airlines

Jatropha curcas – Immersia, 2007: http://commons.wikimedia.org

DoD Recent Test Flights

U.S. Air Force

- March 2010 – Test military flight on biofuels
  - A-10 Thunderbolt II jet
  - 90 minute flight
  - 50/50 blend of camelina oil-derived HRJ and jet fuel

U.S. Navy

- April 2010 – "Green Hornet" flight by Navy
  - Break sound barrier on 50/50 blend
- 2016 circumnavigation of globe by "Great Green Fleet"

http://blog.newsok.com/nerdage/2008/09/22/green-hornet-gets-director/