Impact of Fossil Versus Alternative Fuels on Local Air Quality and Climate

Dr. Lourdes Q. Maurice
Federal Aviation Administration
United States

Outline

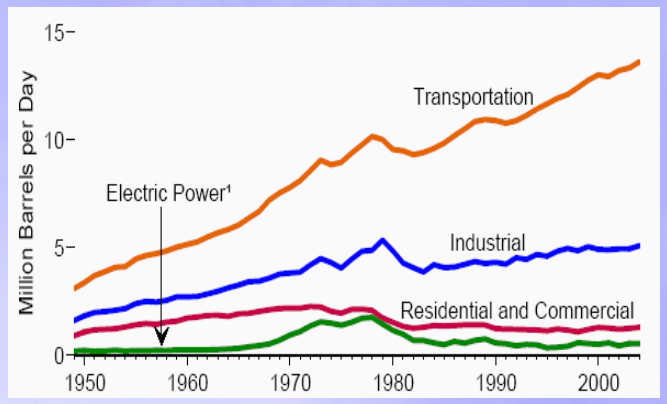
- *The Issues & Drivers*
- Alternative Fuels Basics
- Causes for Caution & Optimism
- The Way Ahead

Issues Within an Environmental Context

Energy Tops the List of Environmental Concerns

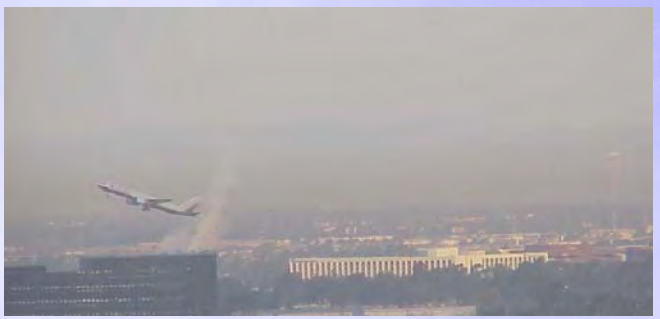
- Increasing demand
- Worries about supply peaks and decline
- Supply interruptions
- Geopolitical instability
- Price Stability
- Government regulation to increase “national” fuels
- Environmental pressures

Drivers for Commercial Alternative Aviation Fuels



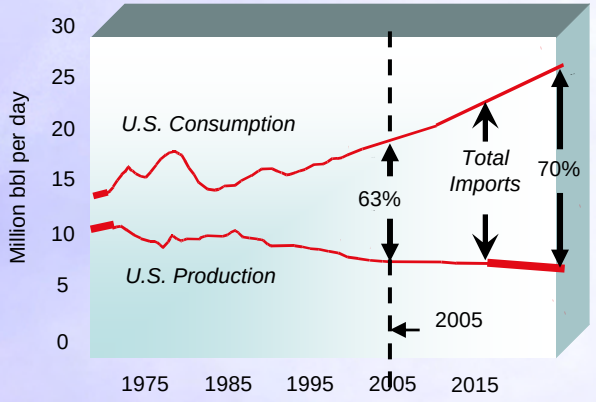
Price

Demand



Supply Stability

Environmental impact



..... And must meet specification for safety

Outline

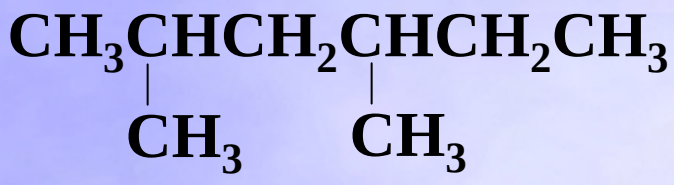
- The Issues & Drivers
- *Alternative Fuels Basics*
- Causes for Caution & Optimism
- The Way Ahead

Jet Fuel Chemistry 101

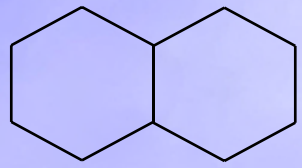
Jet Fuel comprises vast array of compounds

Paraffin – C_nH_{2n+2} $CH_3CH_2CH_2CH_2CH2CH_2CH_2CH_3$

Iso-Paraffin – C_nH_{2n+2}



Naphthene – C_nH_{2n}

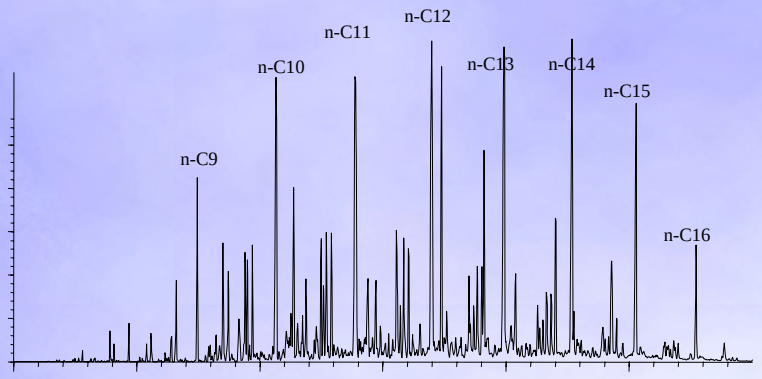


Aromatic – C_nH_{2n-6}

Ringed compounds related to higher particulate matter (PM)

Conventional Jet Fuel

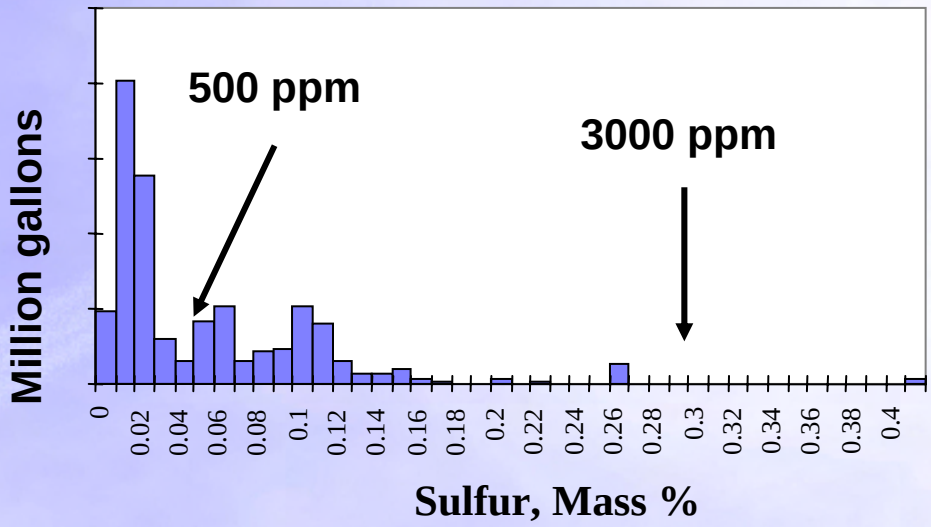
- Broad specifications allow significant variations in composition
- Jet A (Commercial), JP-8 (Military) very similar
- Sulfur spec limit 3000 ppm; avg~500 ppm



$C_{11}H_{21}$

Average Composition	
Paraffins	60%
Naphthenes	20%
Aromatics	20%
Sulfur	500 ppm

Sulfur Content, JP-8 1997 Buys



Edwards, Harrison & Maurice, AIAA-2001-0498

Potential Alternative Aviation Fuels

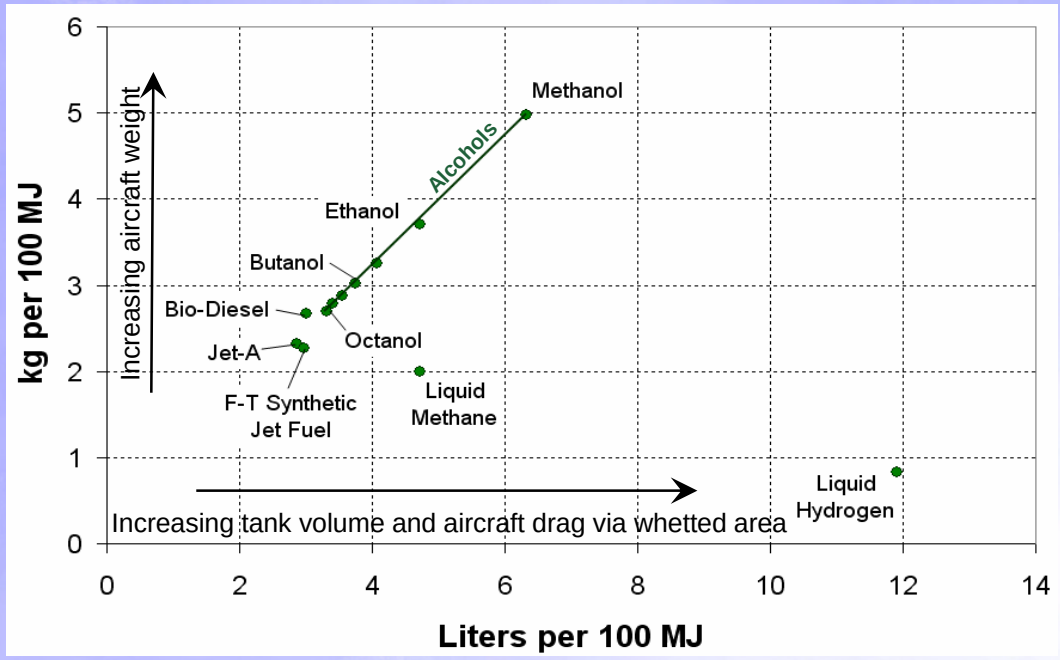
Drop-in replacements

1. *Low Sulfur Jet-A*

   Note: Jet-A or Low Sulfur Jet-A can be derived from conventional oil, tar sands, extra heavy oil, or oil shale

2. *Fischer-Tropsch (F-T) Fuels*

   Synthetic jet fuel created from coal, natural gas, or biomass



Truly Alternative Liquid Fuels (NOT a drop-in replacement)

3. *Bio-Fuels* - infinite variety (grass to algae), reusable, low feedstock yield

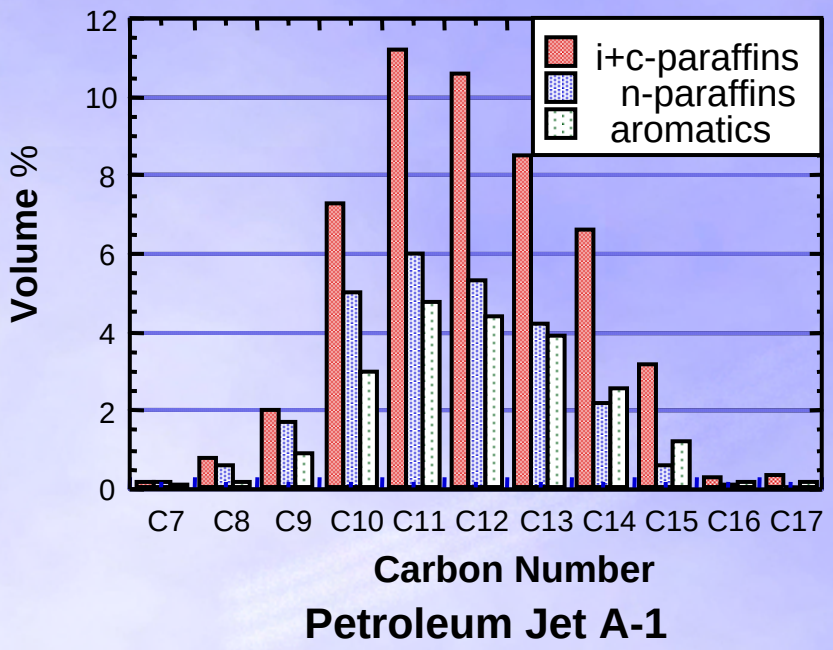
4. *Cryogenic Fuels (Hydrogen, methane)*

Alternative Fuels Composition and Combustion Products

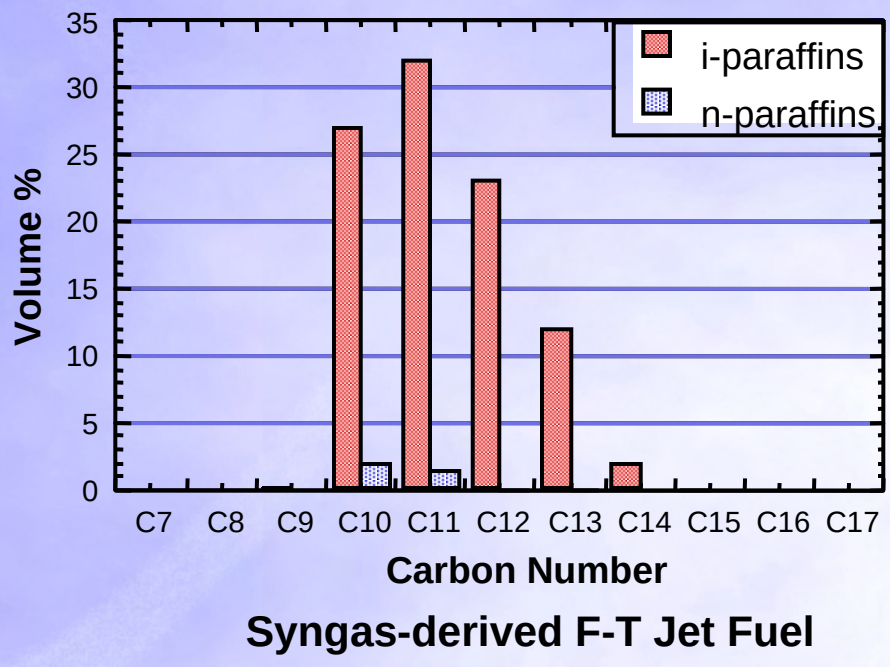
- Fuel + x1 O_2 → x2 H_2O + x3 CO_2 (complete combustion)
- Assume sulfur in fuel is fully converted to SO_2

Fuel	Chemical Composition	Carbon Mass Fraction	CO2 EI g/kg	H2O EI g/kg	SOx EI g/kg
Jet-A	CmHn	86.2	3157	1237	0.80
Low S Jet-A	CmHn	86.2	3157	1237	0.03
F-T Synfuel	CmHn	84.9	3111	1349	-
BioDiesel, B100	CmHnO2CH3	77.6	2726	942	-
Methanol	CH3OH	37.5	1374	1125	-
Ethanol	C2H5OH	52.1	1911	1173	-
Butanol	C4H9OH	64.8	2375	1215	-
Octanol	C8H17OH	73.8	2703	1215	-

Conventional versus F-T Aviation Fuels Composition



Petroleum Jet A-1



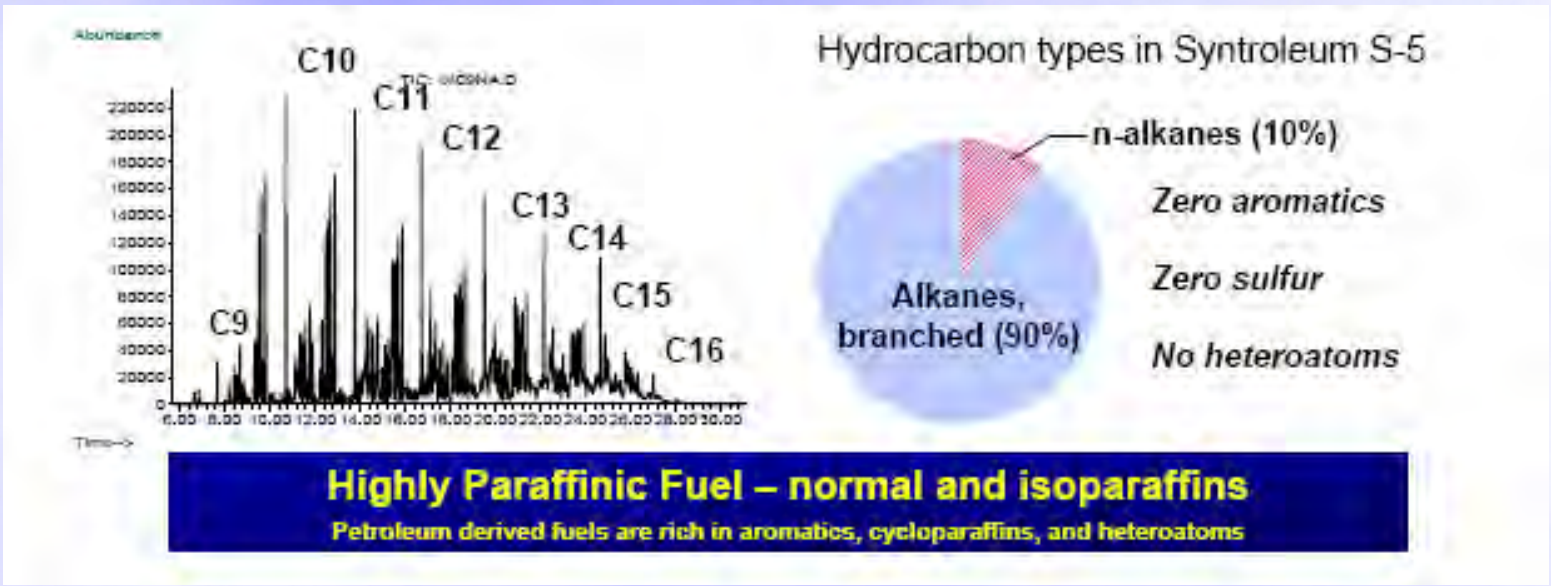
Syngas-derived F-T Jet Fuel

Moses et al., SwRI-8531, 1997

Fischer-Tropsch Fuels Environmental Implications

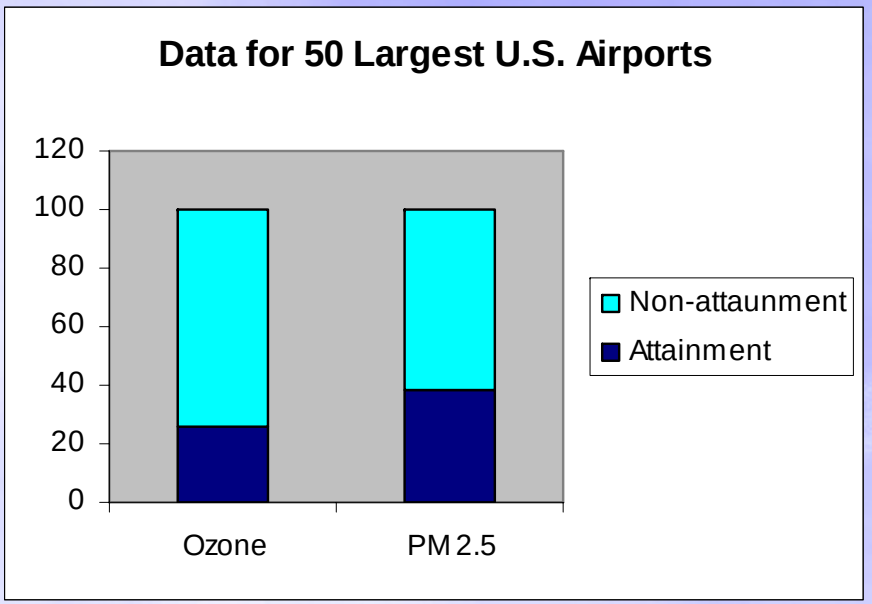
Less Emissions

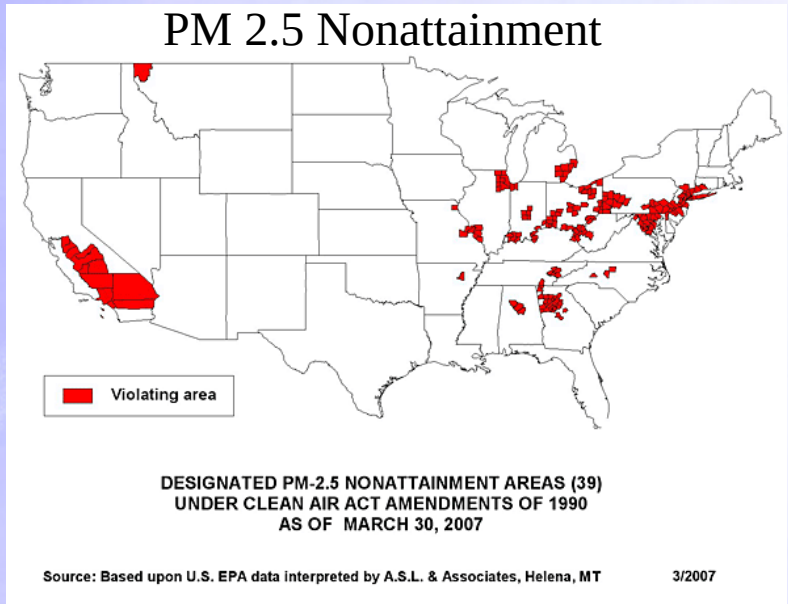
- ~ 1.6% less CO_2 created during fuel combustion
- 50% to 90% less particulate matter (PM) (measured)
- 100% reduction in SOx
- ~ 1% less fuel burn (increased gravimetric energy density)



PM is a Growing Concern for Aviation

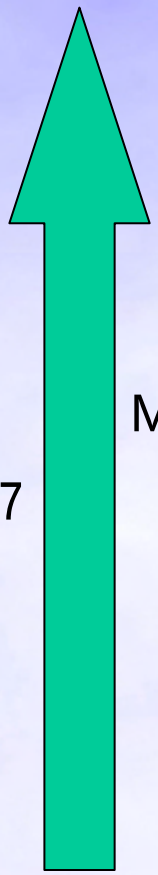
- Particulate matter (PM) impacts health and welfare and contributes to visibility degradation
- Many U.S. airports in areas that are not compliant with national air quality standards for PM
- PM also a concern because of potential climate impacts



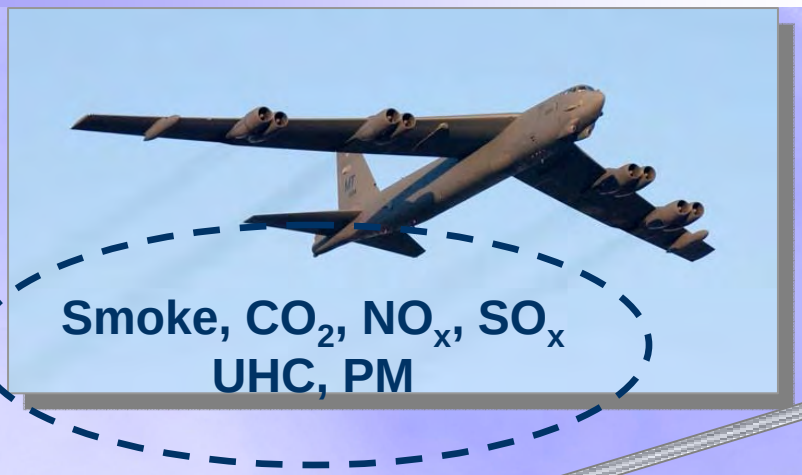


Alternative Aviation Fuels Development Maturity

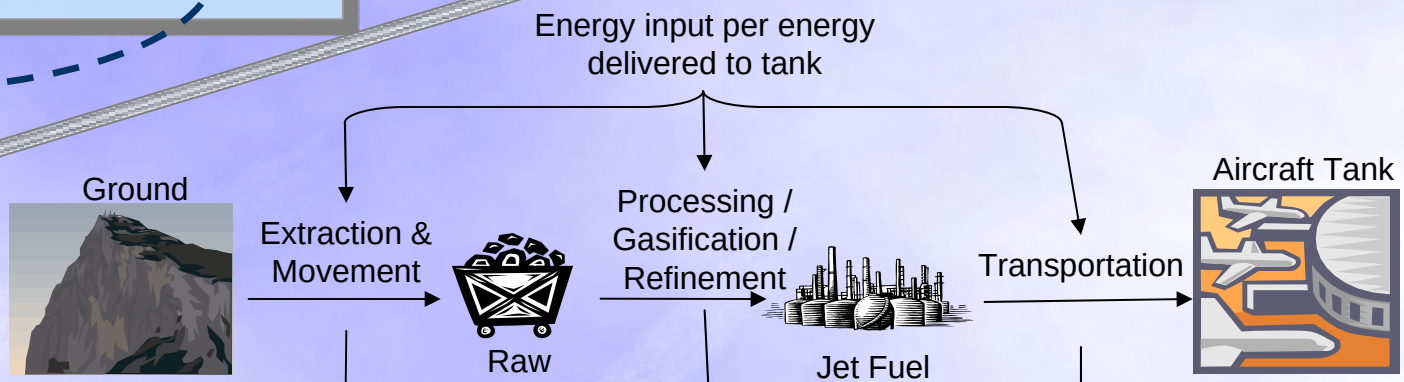
Fuel Type	Status
➢ 100% SASOL F-T (substitute for Jet A (Coal-to-Liquid -CTL))	➢ Single source approval ➢ All tests complete ➢ OEM* approvals 1st quarter 2007 *Original Equipment Manufacturer
➢ 50% syntroleum F-T (substitute for JP-8 (Gas-to-Liquid- GTL))	➢ Second source ➢ Final tests funded ➢ Results targeted by mid-year 2007
➢ Iso Pariffinic Kerosene	➢ 2008 target 50/50 F-T blend ➢ 2009 target 100% F-T
➢ Bio (Renewable) fuels	➢ Boeing/Virgin ➢ DoD/NASA projects in progress ➢ Challenges with freeze point, growing feedstocks



Why We Also Need to Focus on Fuel Production

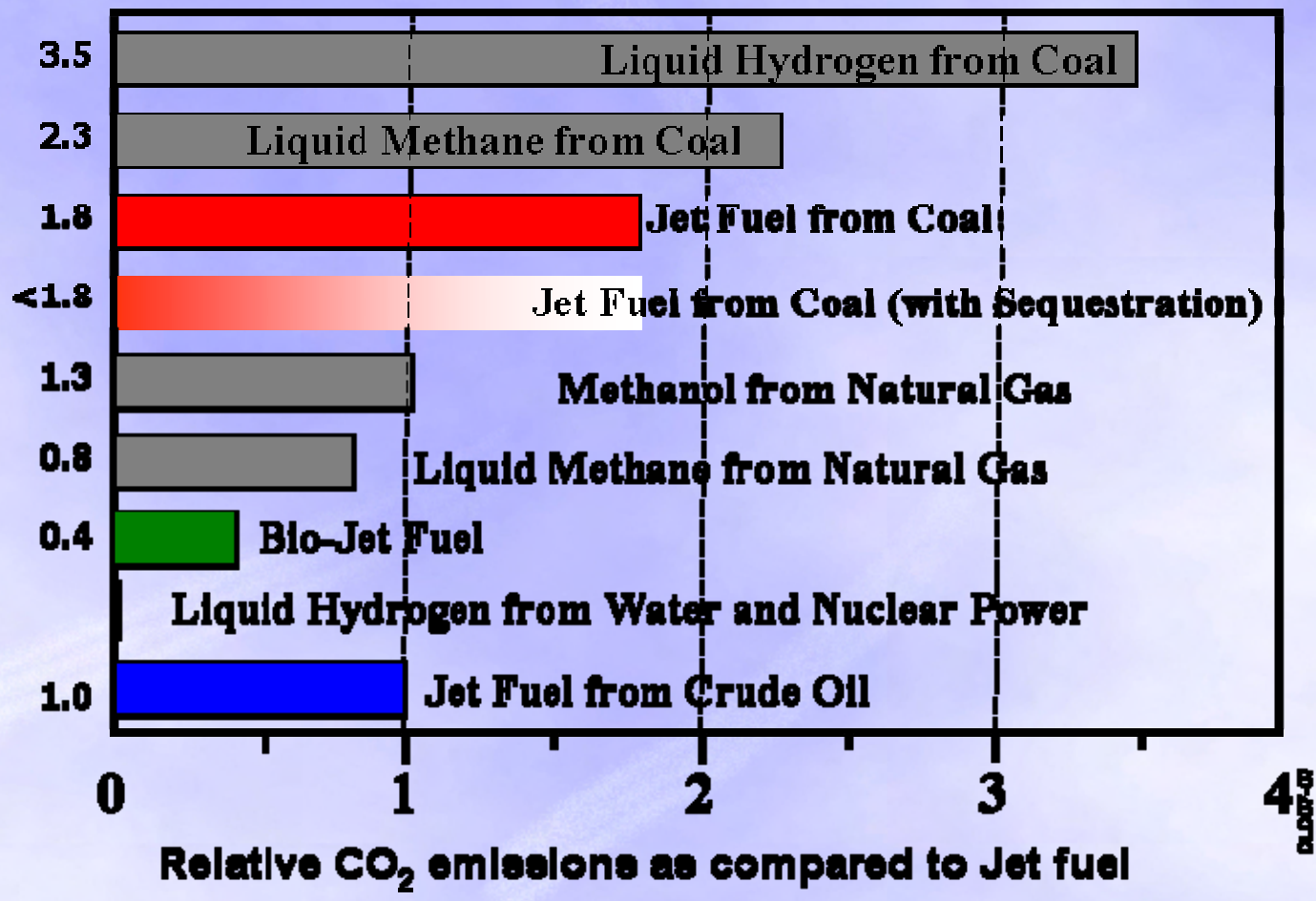


Tank to wake



Ground to tank

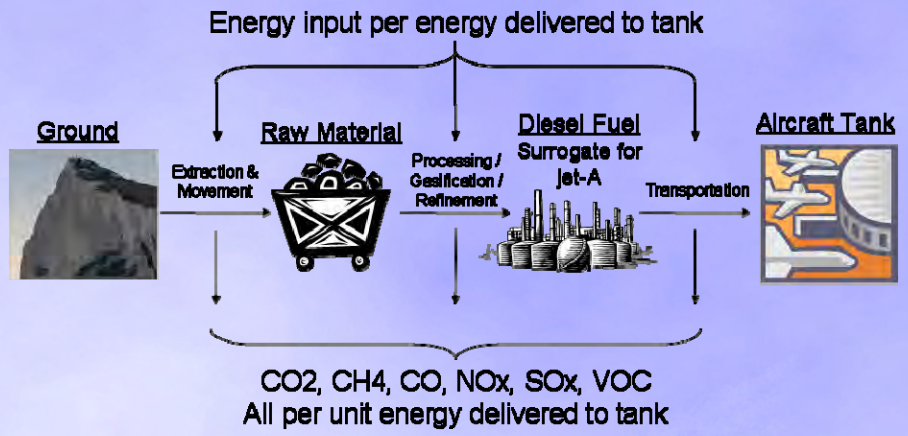
Relative CO_2 Emissions for Various Alternatives



Dagget et al., SAE-07ATC-15, 2007

Next Steps: Life-Cycle Analysis

Source-to-Tank Analysis



Analysis examines each part of the fuel production cycle using accepted databases such as the Argonne GREET model

Tank-to-Wake Analysis

Use existing data to estimate:

- Greenhouse gas emissions
- Emissions affecting local air quality
- Aircraft noise (weight impacts)

Focus is on estimating environmental impacts versus aviation economics

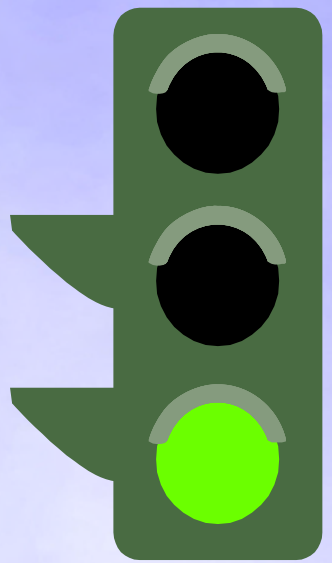
Analysis to use FAA-developed tools *(Ref. Panel 2, Prof. Waitz)*

Analyses combined to determine impacts on costs, energy use, climate, local air quality, and noise resulting from alternative aviation fuel use.

Outline

- The Issues & Drivers
- Alternative Fuels Basics
- *Causes for Caution & Optimism*
- The Way Ahead

Alternative Aviation Fuels – Reasons for Optimism



- Alternative Fuels may be Environmentally Friendly
- Helps Manage Interdependencies
- Enhances Energy Security
- Aviation's May Have Potential as Early Adapter
- Sustained High Costs Keep Synthetics Viable

Alternative Aviation Fuels – Reasons for Caution

- Do not Underestimate Technical Difficulty
- Cannot compromise safety
- Easier Transition on the Ground
- Difficulty of Predicting Energy Markets
- Production environmental drawbacks

Outline

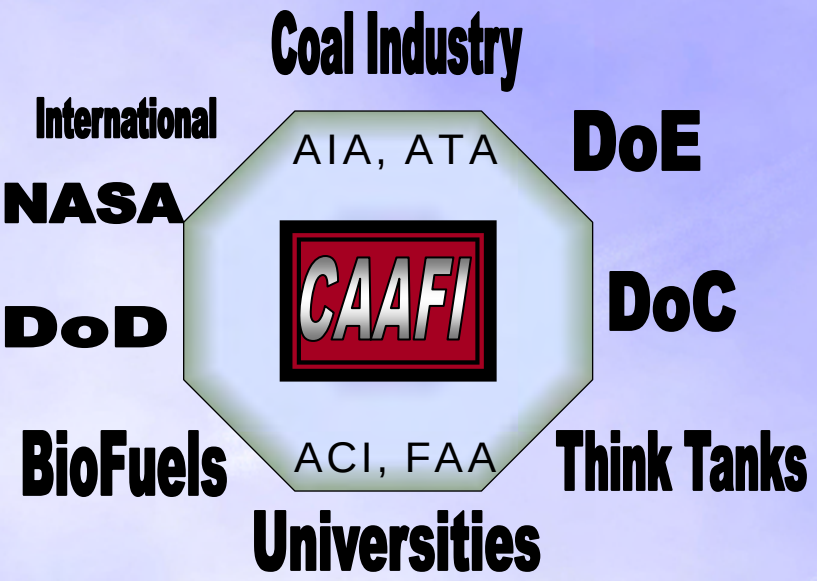
- The Issues & Drivers
- Alternative Fuels Basics
- Causes for Caution & Optimism
- *The Way Ahead*

Next Steps

- Establish whether we can and should pursue alternative aviation fuels
- Establish the net environmental benefits – taking into account potential environmental costs – that would arise from such fuels; and
- Identify the framework and policies required to facilitate adoption of alternative fuels

Commercial Aviation Alternative Fuels Initiative

Commercial Aviation Industry Consortium Formed to work with DoD/DOE/NASA to pursue alternative fuels for the purpose of:



- Securing a stable fuel supply
- Reducing environmental impacts
- Improving aircraft operations
- Furthering research and analysis

Closing Observations

- Alternative Fuels Not Abstract – In Use Today
- "Drop-In" Synthetic Fuels Feasible Near Term
  - Tank to Wake Emissions Reductions
- Need to Consider Source to Tank Impacts
- Renewable Fuels Offer Longer-Term Potential
  - Source to Wake Emissions Reductions
- Need to Assess Impacts Carefully
- Been on this Road Before – Let's Stay the Course