Bio Aviation Fuel

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- Leading supplier and licensor of process technology, catalysts, adsorbents, process plants, and technical services to the petroleum refining, petrochemical, and gas processing industries
- UOP technology furnishes 60% of the world's gasoline, 85% of the world's biodegradable detergents, and 60% of the world's para-xylene
- Strong relationships with leading refining and petrochemical customers worldwide
- UOP's innovations enabled lead removal from gasoline, biodegradable detergents, and the first commercial catalytic converter for automobiles

2003 National Medal of Technology Recipient

Biofuels: Next in a Series of Sustainable Solutions

What is an Alternative Fuel?

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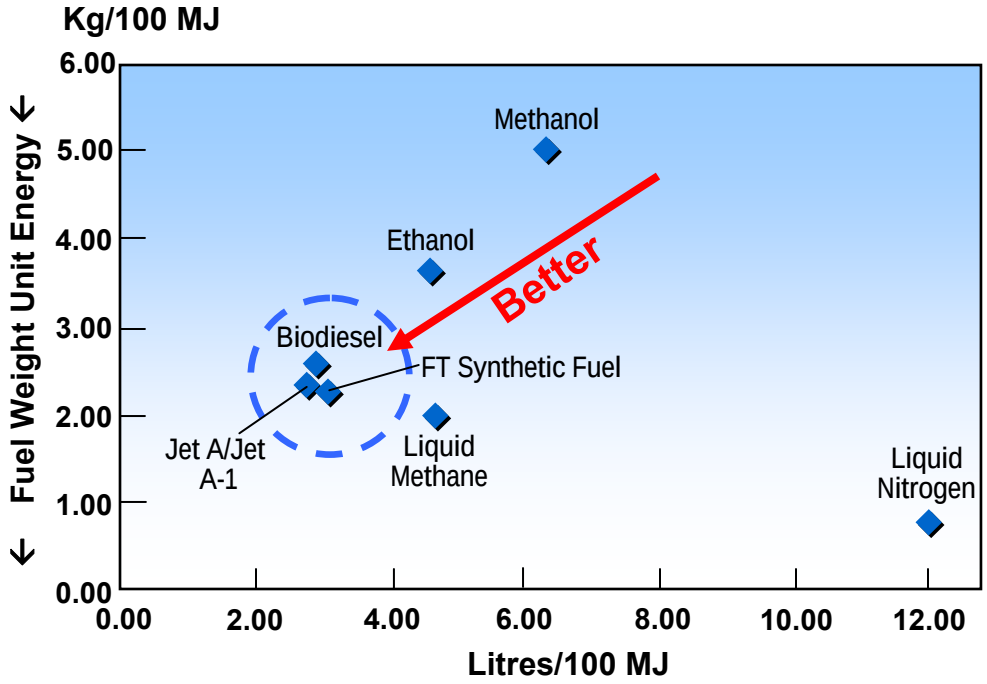
Conventional Fuel (Per fuel specification)

- **Aviation turbine fuel shall consist of refined hydrocarbons derived from conventional sources including: crude oil, natural gas liquid condensates, heavy oil, shale oil, oil sands**

Alternative Fuels

- **Derived from all other sources: biomass, natural gas, coal**



Source: Chevron

UOP Strategy

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Fuel Additives / Blends

- Ethanol
- Biodiesel

Fuels

- Diesel
- Jet
- Gasoline

UOP's Bio-Fuels Technology Goals

Identify and utilize processing, composition, and infrastructure synergies to lower capital investment, minimize value chain disruptions, and reduce investment risk.

Inedible Oils: Jatropha

Generation 1

- Vegetable oils, greases to diesel, gasoline and jet fuel

Generation 2

- Lignocellulosic biomass to fuels
- Algal oils to fuels

Production of Jet Fuel

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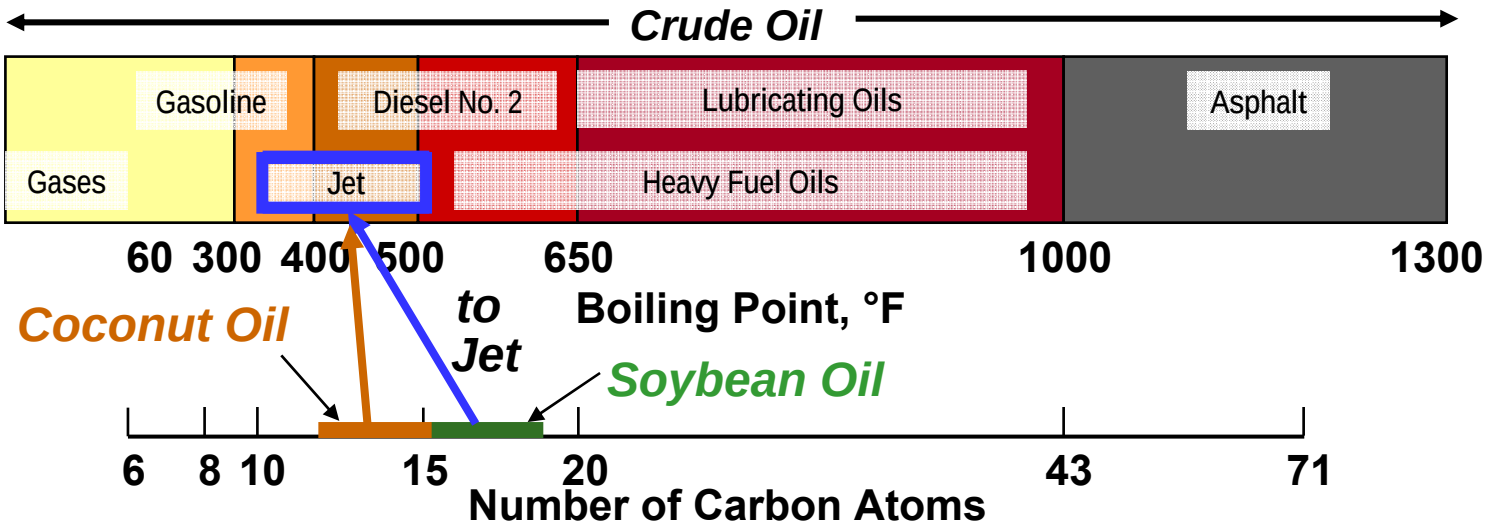
UOP/ENI Ecofining™

New Bio-Oil to Jet Process Based on Ecofining



Properties of UOP's Bio-Based JP-8

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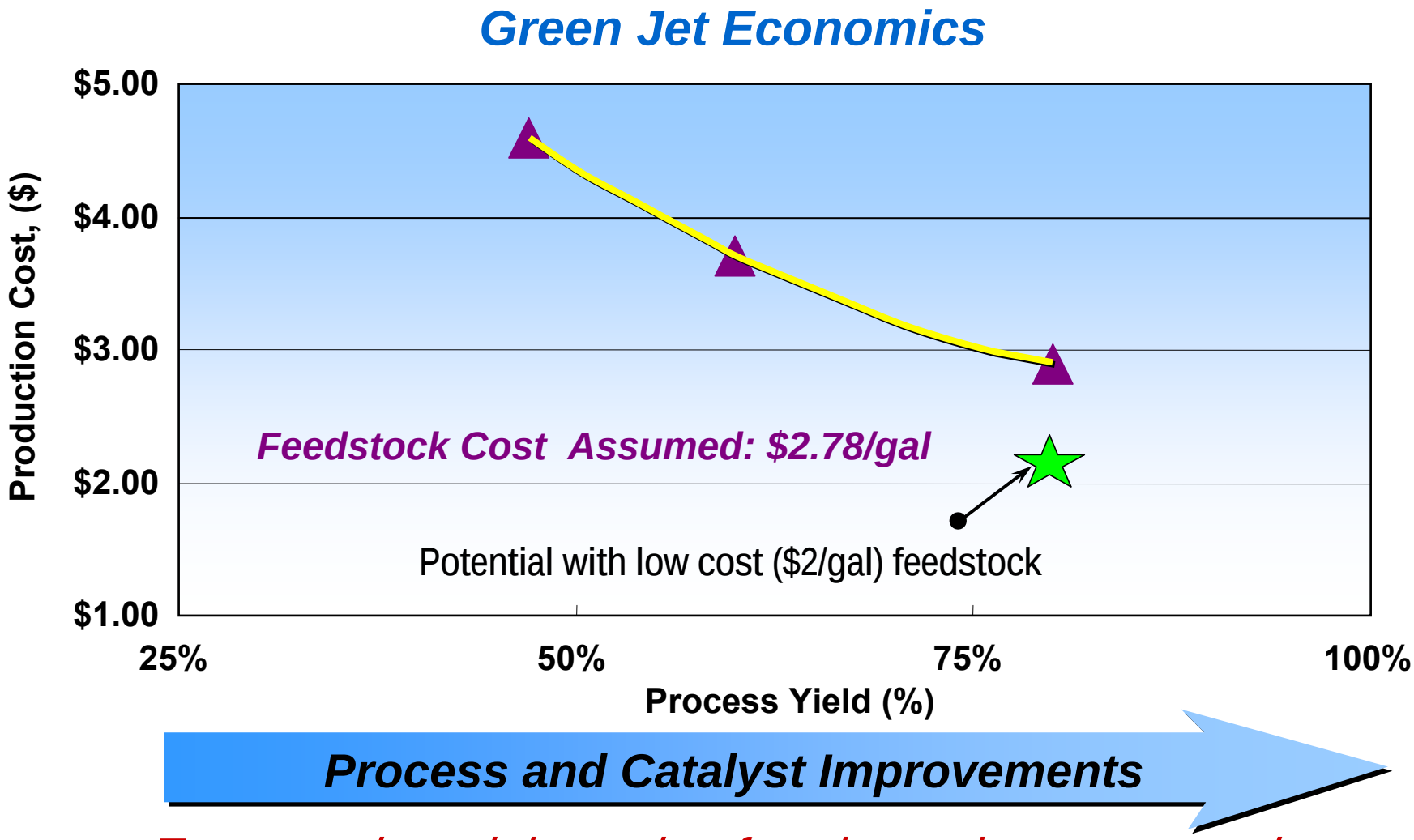
	JP-8 Spec	*Soybean oil derived JP-8*	*Coconut oil derived JP-8*	*Petroleum JP-8*
% aromatic (*added)	max 25 vol %	15%	22%	18.8
Freeze Point, °C	-47	-50	-62	-50
Flash Point, °C	38	54	56	51
Specific Gravity @ 15°C	.775-.84	0.779	0.780	0.804
Heat of combustion (Btu/lb)	18400 min	18600	18655	18600
IBP, °C (D86)		165	169	159
10% (D86)	157-205	176	177	182
20% (D86)		180	179	189
50% (D86)	168-229	199	188	208
90% (D86)	183-262	268	226	244
FBP, °C (D86)	300	279	262	265

Feedstock Flexibility Demonstrated

Green Jet Economics



Economics driven by feedstock costs and process efficiency

Enablers for a Sustainable Biomass Infrastructure

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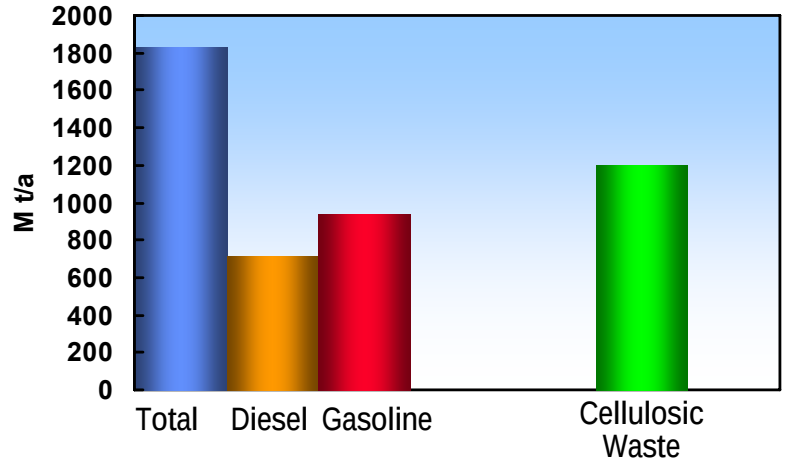
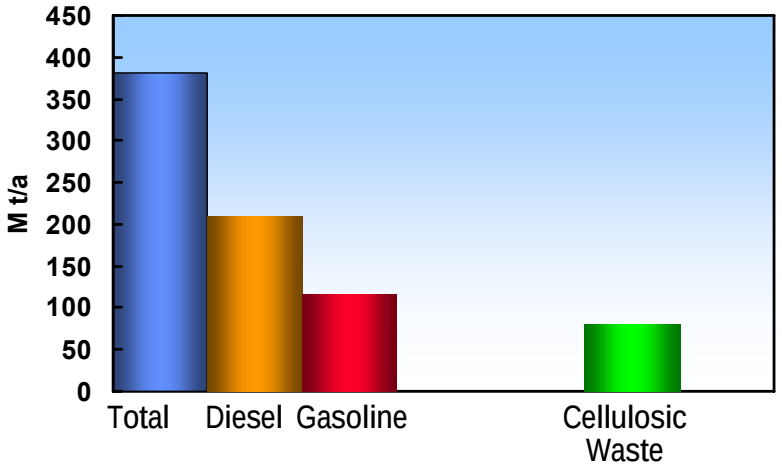
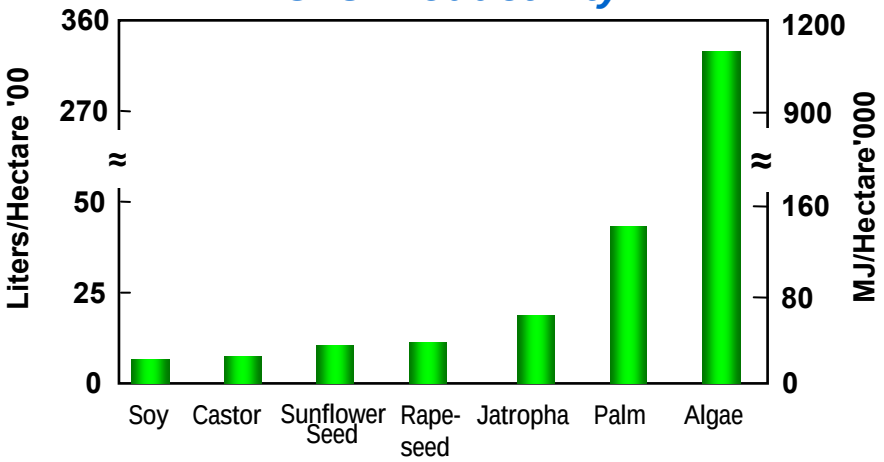
Global Transport Fuels



European Transport Fuels



Oils Productivity



- **Cellulosic waste could make a significant contribution to liquid transportation pool.**
- **Algal Oils could enable oils route to biodiesel, green diesel and jet fuel.**

Increases Availability, Reduces Feedstock Cost
Technology Breakthroughs Required

Source: Transportation fuels are from Purvin & Gertz Tables II-3 and II-4, 2007 Consumption, Europe

Lignocellulosic Biomass to Fuels Via Pyrolysis

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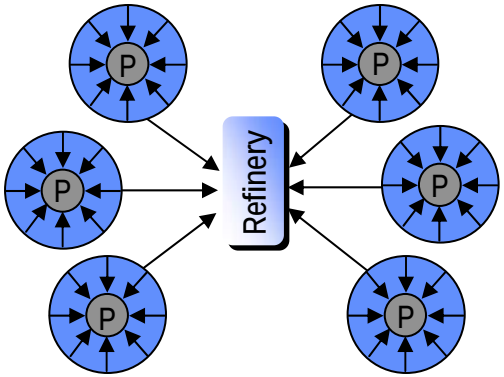
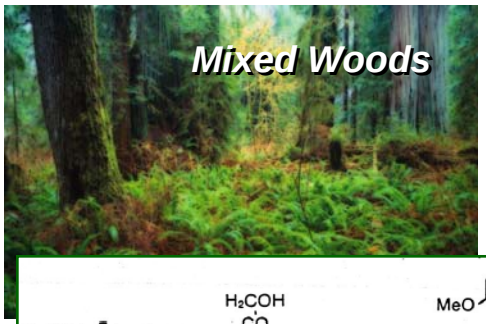
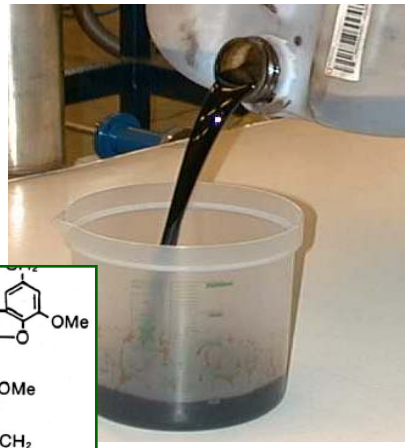
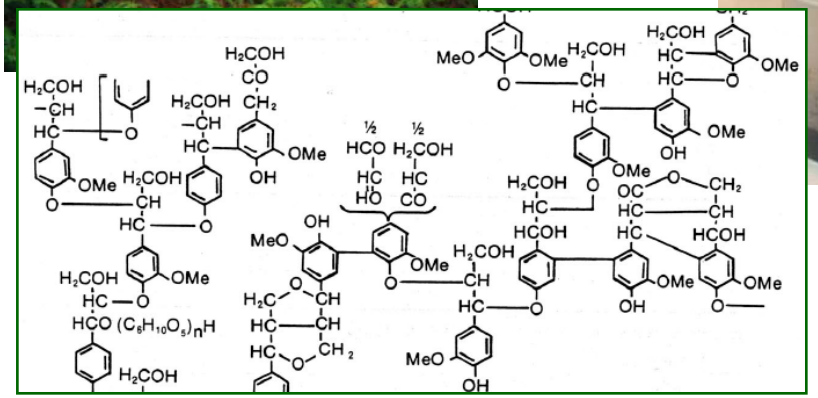


Biomass → Pyrolysis → Stabilization → Biocrude → Deoxygenate / Other Refinery Processes → Gasoline, Diesel, Jet, Chemicals







Collaboration with DOE, NREL, PNNL

2nd Generation Renewable Jet Fuel from Oils and Biomass

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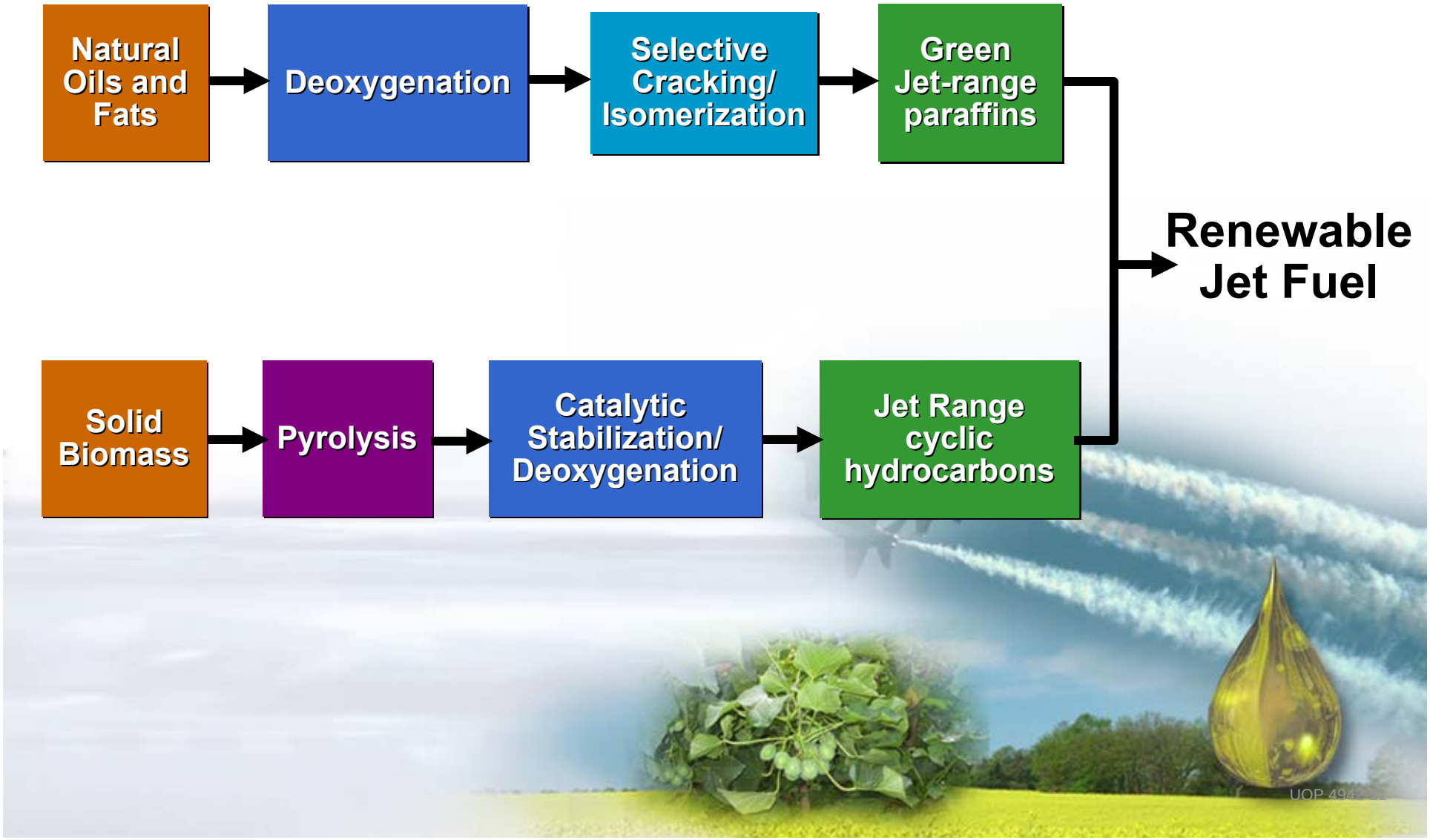

Properties Bio JP-8: Renewable Aromatics

	JP-8 Spec	*Starting Bio Paraffin*	*Corn Stover Pyrolysis Oil*	*Woody Pyrolysis Oil*
Freeze Point (°C)	**-47**	**-53**	**-56**	**-54**
Flash Point (°C)	**39**	**53**	**49**	**54**
Density (g/mL)	**0.775**	**0.759**	**0.790**	**0.782**

100% Bio-derived JP-8 successfully prepared

Integrated Algal Processing for Jet Fuel Production

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CO_2

Oil

Green Jet (paraffin-rich)

Biomass

Green Jet (rich in cyclic hydrocarbons)

2nd Generation On-spec Renewable Jet Fuel

Biofuel Fuel: Key Issues for Aviation

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Technical Risks

- Thermal stability – fuel system component coking
- Storage stability – biological growth
- Low temperature performance
- Combustion properties
- Material compatibility – fuel system and hot section
- Trace contamination (metals, micronutrients)
- Low Density - aircraft range

Quality Risks

- Inconsistent product (source dependent)
- Lack of robust control
- Fragmented industry

Extensive Certification Process

Synthetic Fuel Introduction: Key Challenges

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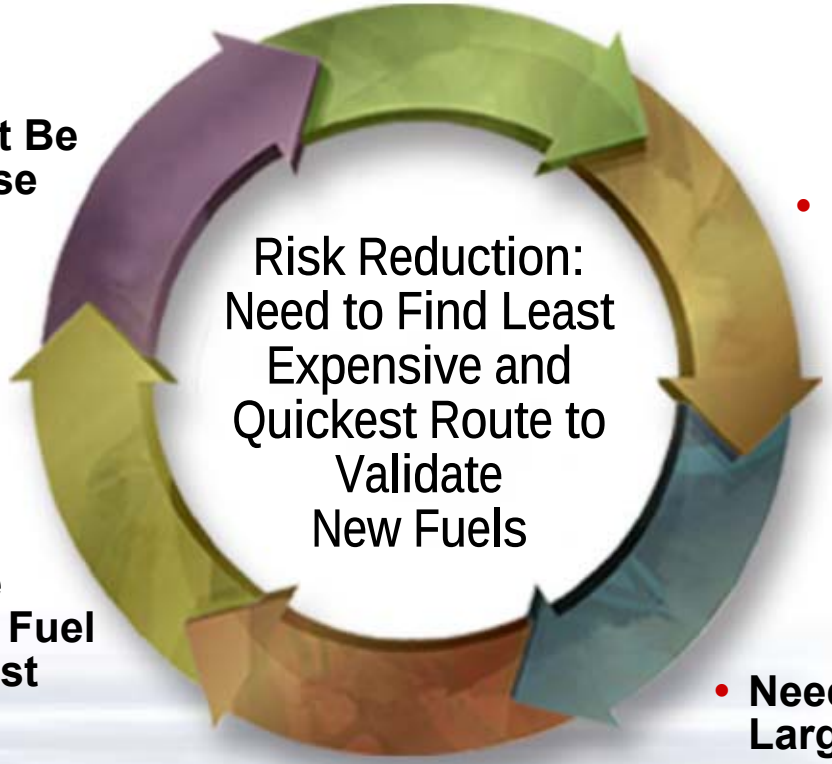
- Plant Investment Risk Deters Investment
- Plant Is Very Expensive
- Need Plant to Make Large Quantity of Fuel
- Need Large Quantity of Fuel to Flight Test
- New Fuels Must Be Validated for Use



Need to Get Early Assessment of Fuel Suitability to Justify Government and Industry Investment

Commercial Alternative Fuel Activity

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- CAAFI (Commercial Aviation Alternative Fuels Initiative)
  - Euro CAAFI forming
- IATA Alternative Fuels Project
  - IATA 2007 Report on Alternative Fuels released Feb 2008
- ASTM Emerging Fuels Task Force
- CRC Emerging Fuels Group
- Oil company initiatives (Shell, AirBP, Chevron, etc.)
- Boeing & Airbus Alternative Fuel Initiatives
- Engine manufacturer initiatives

Achieving Sustainability

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- Renewables are going to make up an increasing share of the future fuels pool
  - Multitude of bioprocessing approaches possible
  - Fungible biofuels are here
- First generation biofuels, though raw material limited, are an important first step to creating a biofuels infrastructure.
- Second generation feedstocks, cellulosic waste and algal oils, have the potential to make significant contributions.
- Jet fuel certification presents unique challenges to rapid adoption
  - Must work with standard setting agencies and OEMs to create a robust but rapid process
- Important to promote technology neutral and performance based standards and directives to avoid standardization on old technology.

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Nodan mamomamo

Teşekkür ederim

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Danke schön

Obrigado

Спасибо

Thank You

Kiitos

جزاكم الله خيراً

Gum xia

धन्यवाद

Merci

Tawdi

Terima kasih

Sha sha

Gracias

Ang kêun

Maulanenga

Efcharisto

Añachaykin

Hvala

Ookini

謝謝

Dekoju

Danyavad

Grazie

Spasibo

Ngiyabonga

Xie xie

どうもありがとう。

Arigato

Giittus

Shukran

Eso

Dhannvaad

Gum xia

Qujanaq

Köszönöm

תרס mersi

Wiyarrparlunpaju-yungu

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Q&A

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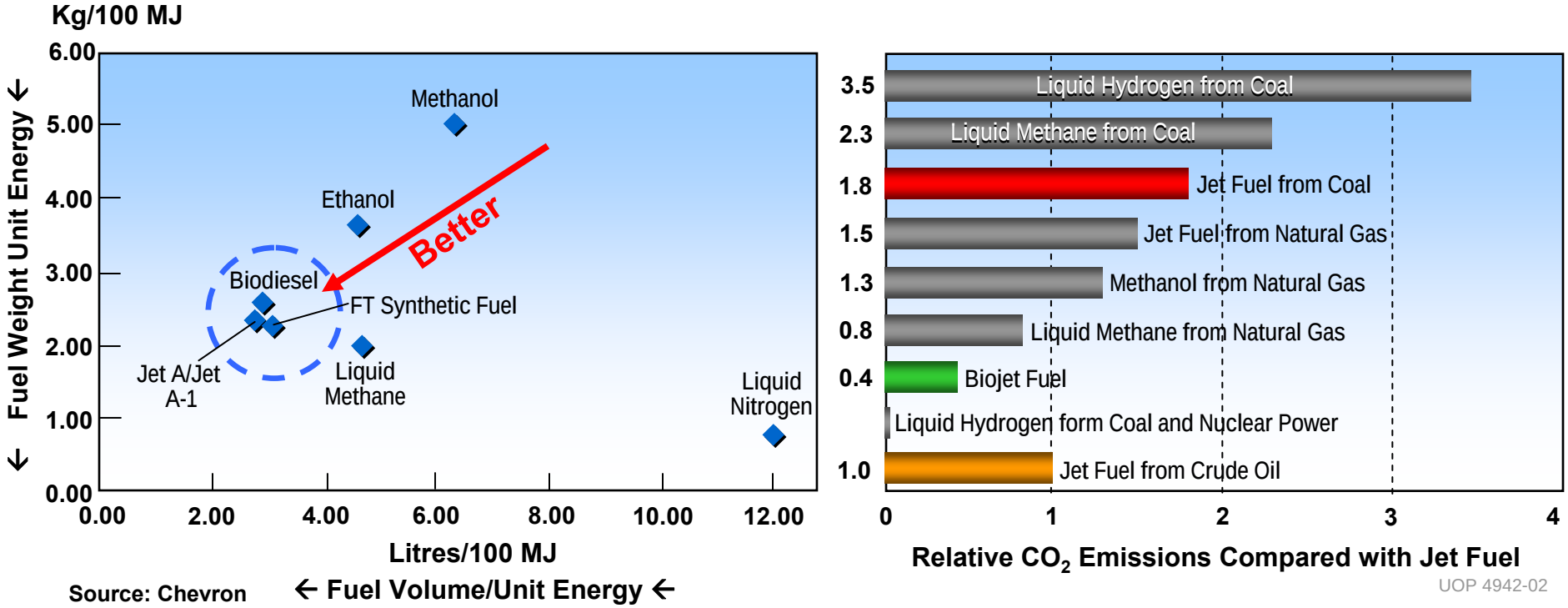
- **Derived from all other sources: biomass, natural gas, coal**



Current/Future Aircraft Need Better Fuel

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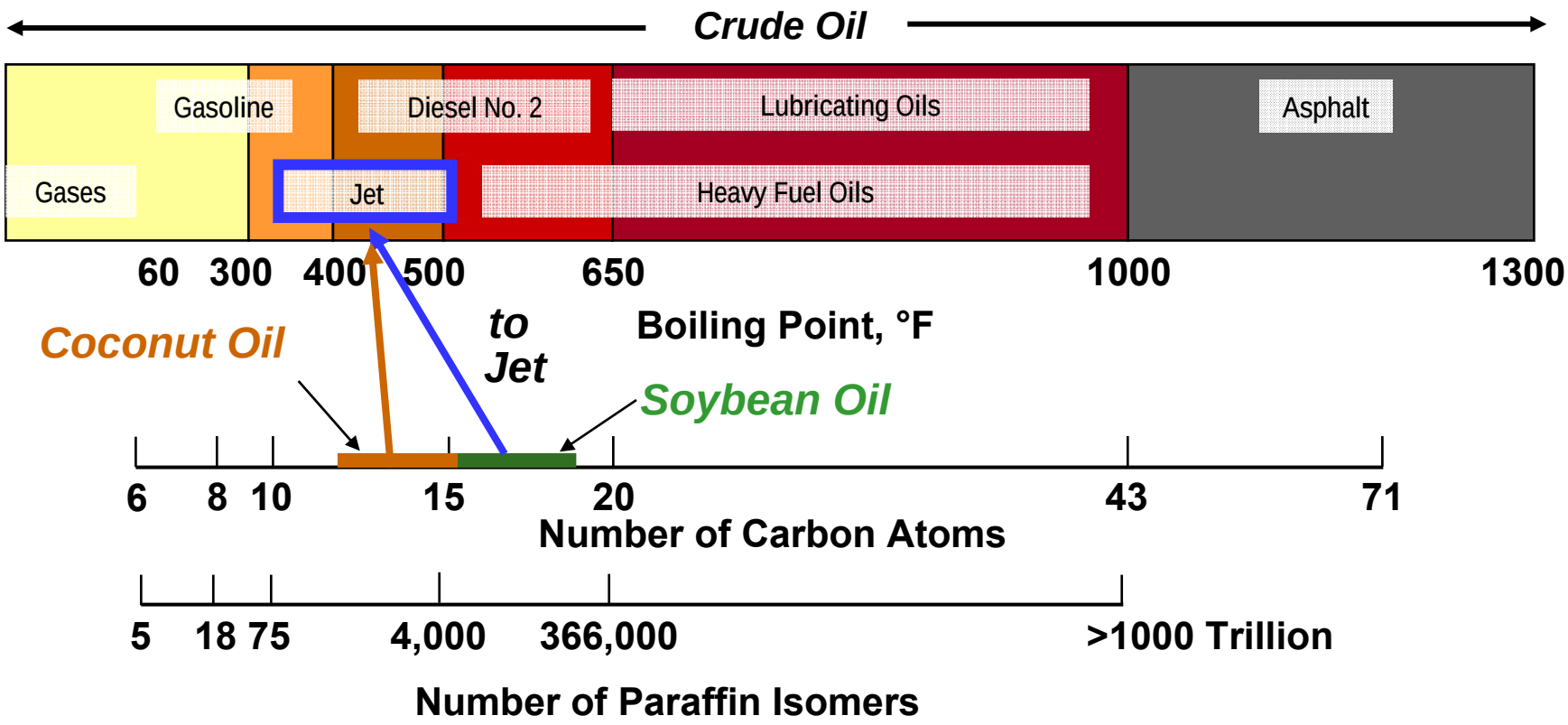
- **Commercial drivers**
  - Improved engine efficiency
  - Improved emissions
  - More electric aircraft (increased heat load)
- **Military drivers**
  - Improved engine efficiency and thrust/weight ratio
  - Long range/High altitude/High Mach aircraft
  - Increased heat load into fuel
- **Place increased demand on aviation fuel**
  - Increased thermal stability
  - Lower freeze point
  - Cleaner fuel (no sulfur, low aromatics, low GHG)

- **Alternate fuels need to look similar to current fuel near team ("drop in fuel")**
- **Engines & components need to be designed for future fuels**
  - Tolerant of future fuels (low lubricity, low aromatics)
- **Faster fuel approval process**
  - True material specification
  - Generic fuel approval - not refinery/feed stock dependent
  - Replace rig/engine testing with bench/lab tests

Bio-Jet Fuel



DARPA

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Honeywell

Cargill

ASU Arizona State University

Southwest Research Institute

Sandia National Laboratories

Production of Jet Fuel

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UOP/ENI Ecofining™

New Bio-Oil to Jet Process Based on Ecofining

Sample	*Freeze Point, °C*	*Flash Point, °C*	*Density, g/cc*
JP-8 Spec	-47	38	0.775
UOP JP-8 range paraffins	-52.6	53	0.759†

†Aromatic additives required to make JP-8 specification; also true for synthetic jet fuel

Integrated Biofuels Production

Meeting JP-8 Specifications: Aromatics to Meet Density Specs

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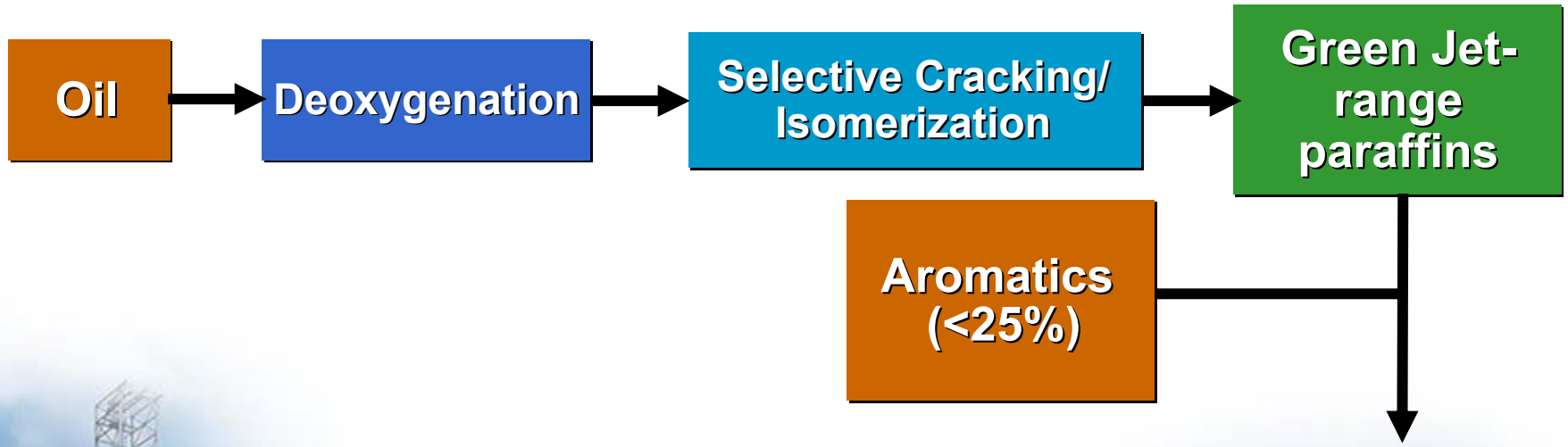

Sources of Aromatics

- Fossil sources
- Renewable sources

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