expanding the realm of POSSIBILITY®

Conversion of Carinata Oil into "Drop-in" Fuels & Chemicals

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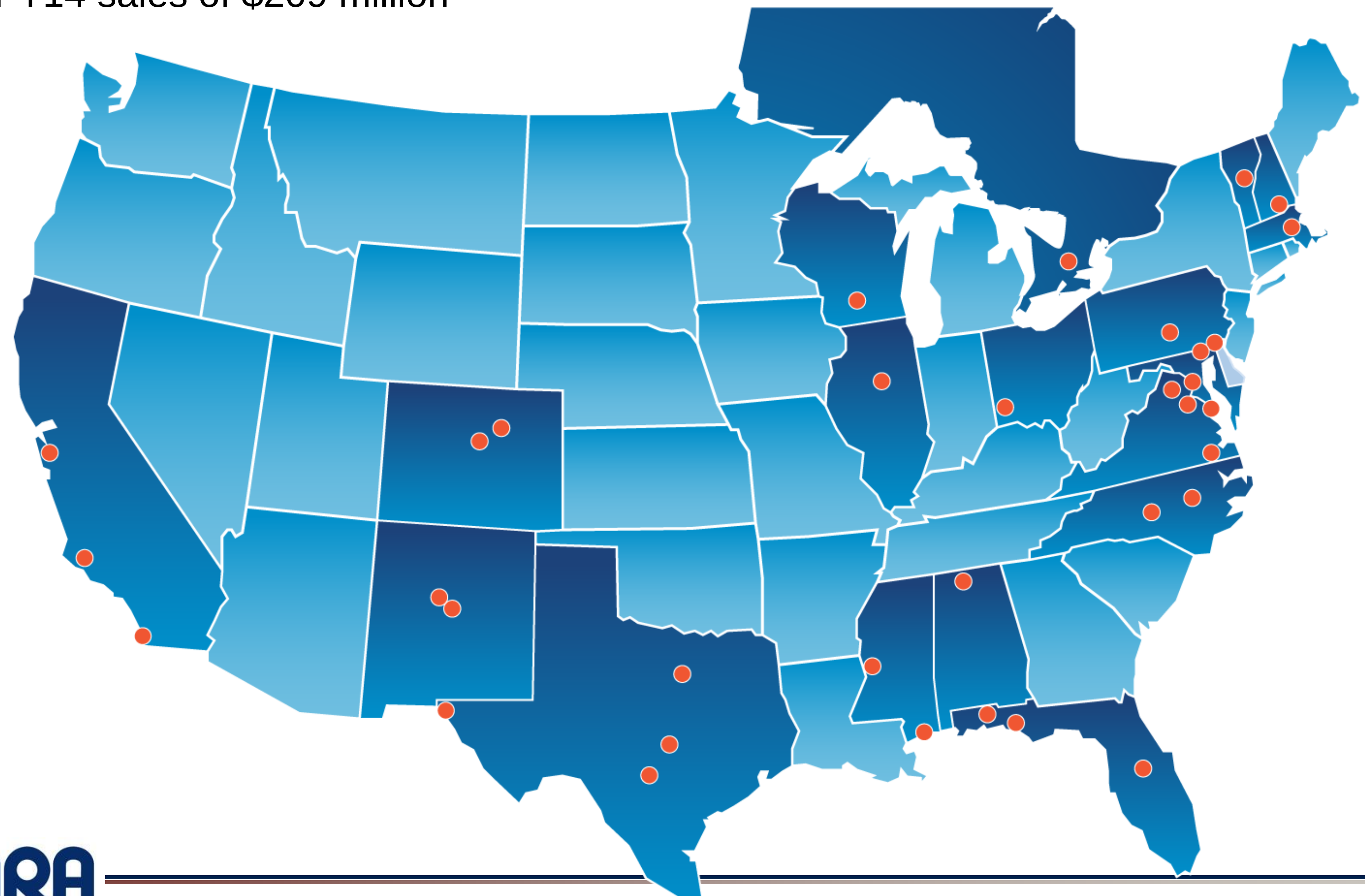
Quincy, Florida
28 April 2015

ReadiJet™
ReadiDiesel™
ARA®

About ARA, Inc.

- Founded 1979, Albuquerque, New Mexico
- 1,086 employee owners at locations in the U.S. and Canada
- FY14 sales of $209 million



Business Areas

National Security

ARA delivers innovative solutions to assess, detect, deter, defeat, and respond to threats facing us at home and abroad.

Infrastructure

ARA leads in technologies and services to improve performance and sustainability of infrastructure for transportation, buildings, and energy systems.

Energy & Environment

ARA provides innovative engineering services and products for alternative fuels, and the power and utility services market.

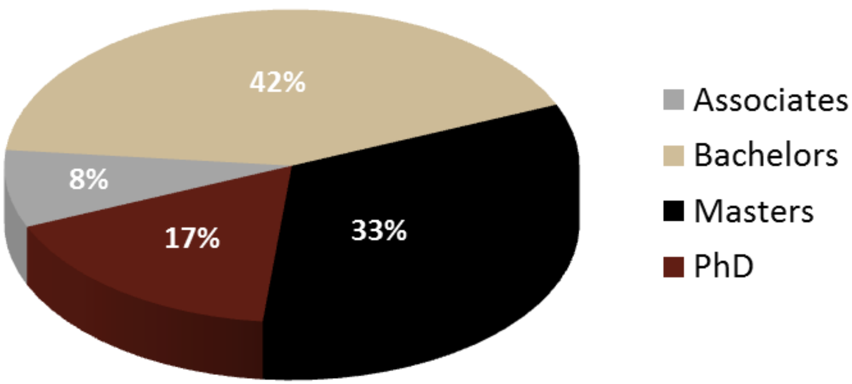
Health Solutions

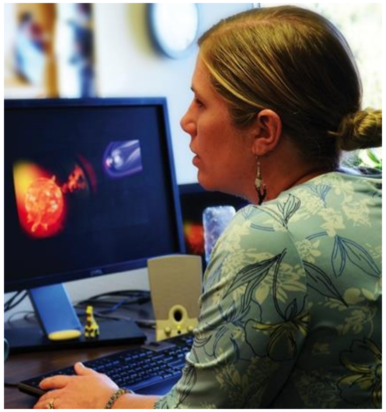
ARA provides specialized research and technology services, testing and product development in health science and engineering.

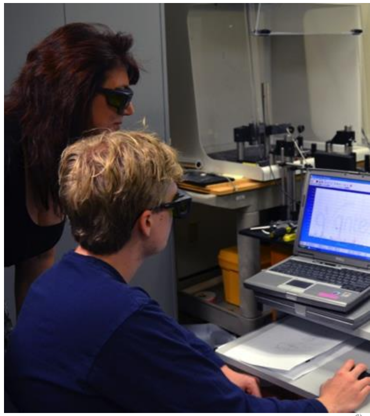
Company Profile

ARA employees have diverse expertise to provide mission-critical solutions

Engineers & Scientists	731	67%
Exec/Management	35	3%
Technicians/Interns	141	13%
Professional Services	106	10%
Administrative	73	7%
Total	**1,086**	

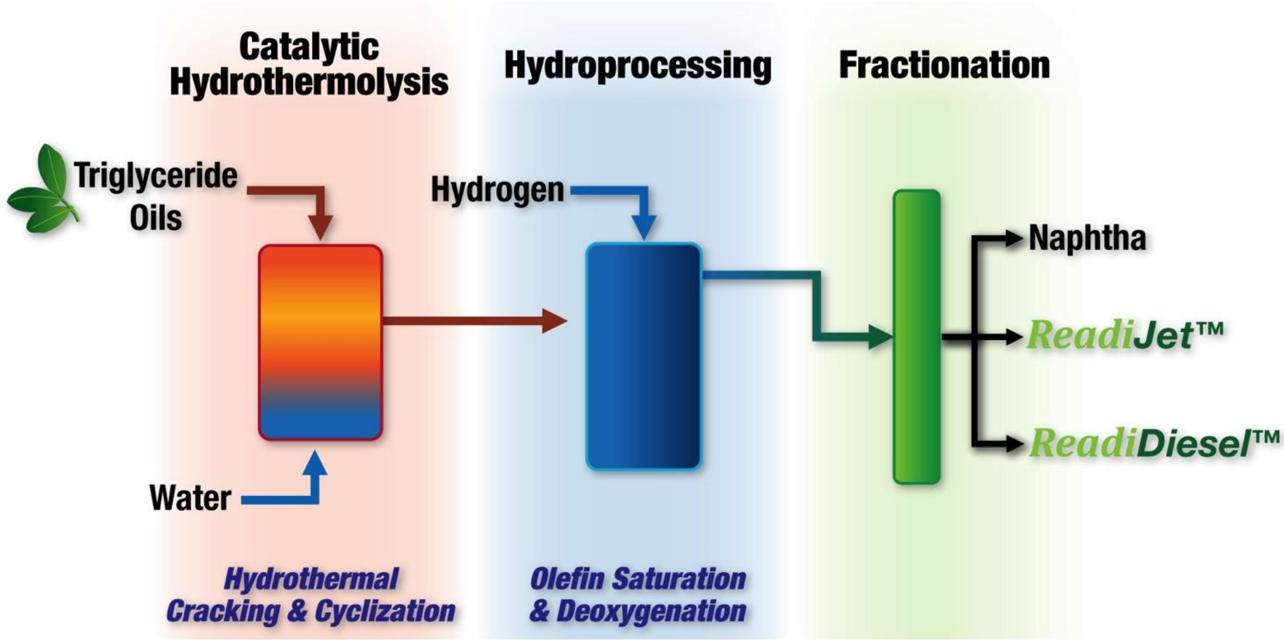






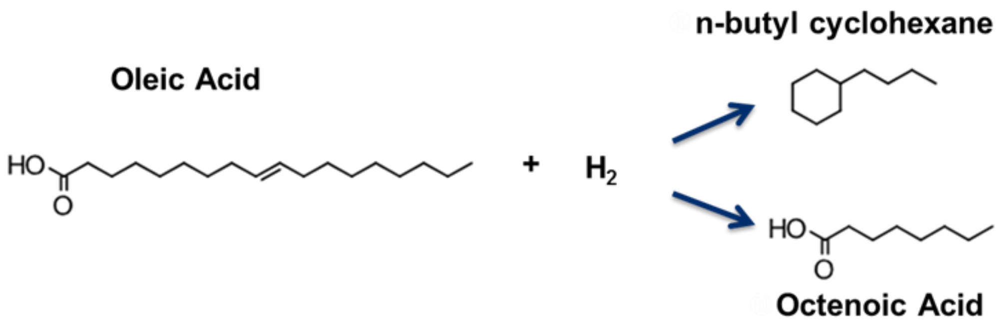
BioFuels ISOCONVERSION (BIC) Process

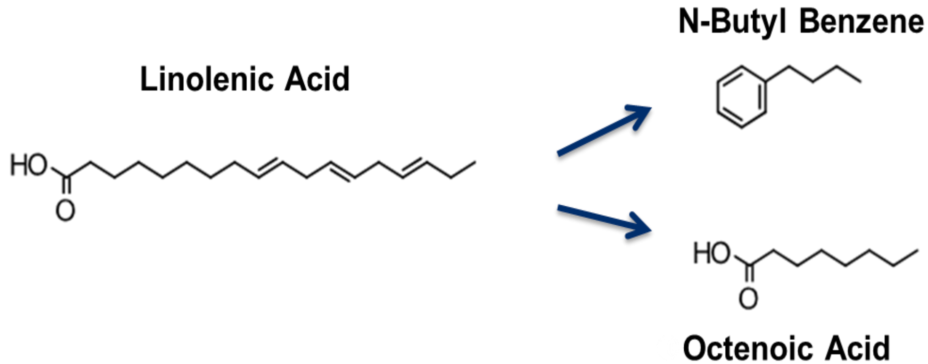
Jointly Developed by ARA and Chevron Lummus Global



- **Catalytic Hydrothermolysis (CH) converts renewable feed stocks directly into cracked and cyclized hydrocarbons**
  - **Same hydrocarbon types as petroleum – distributed over entire boiling range**
- **Hydrotreating saturates residual olefins and removes residual oxygen**
  - **Aromatic and cycloparaffin compounds are preserved**
  - **Hydrogen consumption & GHG generation are much less than HEFA processes**

Characteristic CH Conversion Reactions





- Cycloparaffins and Aromatics are formed
- Entire homologous series of isomers are formed
- Ring structures are conserved during hydrotreating
- Hydrogen is conserved by formation of ring structures

<u>Hydrogen saved vs. IPK reactions</u>

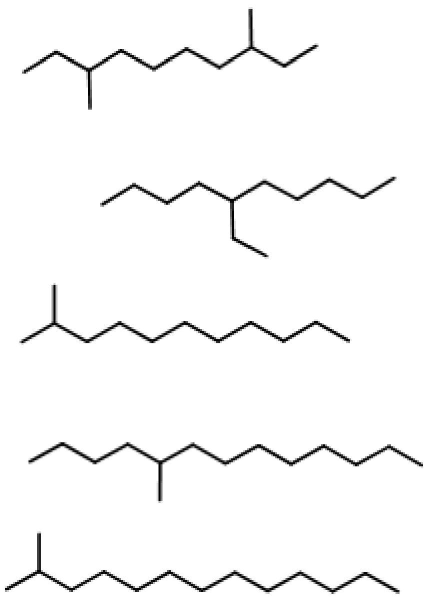
Oleic (18:1) →	cycloparaffin	+ H_2
Linoleic (18:2) →	cycloparaffin	+ H_2
Linoleic (18:2) →	aromatic	+ $3H_2$
Linolenic (18:3) →	aromatic	+ $4H_2$

Typical Alternate Fuel Hydrocarbons

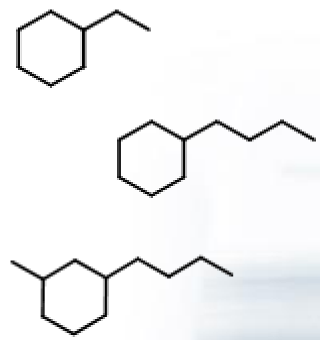
<u>SPK from FT & HEFA</u>

<u>Catalytic Hydrothermolysis (CH)</u>

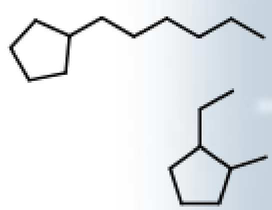
Paraffins



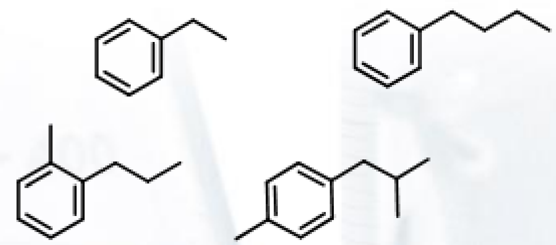
\+ Cyclohexanes



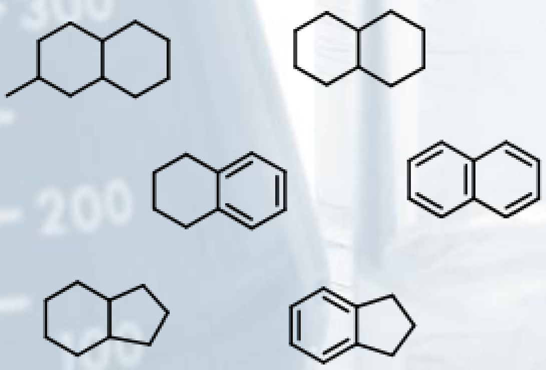
\+ Cyclopentanes



\+ Alkylbenzenes

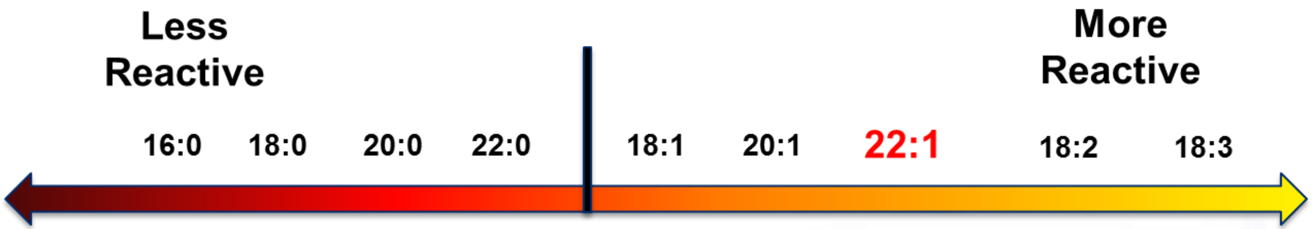


\+ Polycyclics



Conversion of Carinata Oil

- **High concentration of Erucic acid (22:1)**
  - **Low degree of saturation – higher reactivity**



  - **High yield of aromatics & cycloparaffins**
  - **High density and energy content**
  - **Excellent low-temperature properties**
- **Higher molecular weight than Soybean, Canola, Jatropha**
  - **Higher yield of hydrocarbon fuels & chemicals than C18 oils**
  - **Potentially 2 wt% net increase in hydrocarbon yield**
  - **Equates to ~100 bbl/day for a 5000 bbl/day commercial refinery**
  - **Additional net profits up to $10,000/day or $3.4M/yr**

Pilot Testing

- **CH Bench system – operational since 2008**
  - **25 gallon/day treatment capacity**
- **CH Pilot system – operational since 2010**
  - **160 gal/day treatment capacity**
  - **High-rate reactor (~1 min. residence time)**
  - **Thousands of gallons of crude produced**
- **Evaluated many different feed stocks**
  - **Algal, Brown grease, Camelina, Canola, Carinata, Castor, Corn, Jatropha, microbial, Peanut, Pongamia, Shae Butter, Soybean, Tall oil fatty acids, Tallow, Tung, WVO, Yellow grease**
- **In-house capability**
  - **Hydrotreating – 3 L/day, packed-bed**
  - **Fractionating – 12L batch (D2892)**
  - **Specification fuel samples (1-20 liter)**
- **Conducted 4 major pilot campaigns**
  - **Chevron – Hydrotreated in Richmond, CA**
  - **Air Force Research Lab – WPAFB, OH**

Pilot Production Campaigns

- Hundreds of gallons of jet fuel produce during each campaign
- Primary source of the data for the ASTM Research Report
- Successfully converted different feed stocks and used different facilities

Pilot Production Campaigns		Specification, Rig, FFP, Engine, & Flight Testing		
Feed Stocks	Hydrotreating	Organization	Fuels	Testing
Carinata & waste vegetable oil	Chevron Richmond, CA	AFRL	JP-8	Spec & limited FFP
		Rolls-Royce	Jet A-1	Spec & rig
		NRC-IAR Canada	Jet A-1	Ground & flight tests
Canola	AFRL WPAFB, OH AARAF	AFRL	Jet A	Spec & limited FFP
		SwRI	Jet A	FFP suite
		PWC	Jet A	PW615 engine test
Distillers grain corn oil	AFRL WPAFB, OH AARAF Pilot	Honeywell Aerospace	Jet A	APU testing for FAA
		Other TBD	Jet A	Jet testing TBD
Carinata	AFRL WPAFB, OH	DLA - NAVAIR	JP-5	Spec & limited FFP

ARA

Production of Certification Fuels for DLA-Navy

- **Three production campaigns**
  - Initial 100-gallon samples (produced in pilot equipment)
  - FY15 – 35,300 gallons of CHCJ-5 (jet) CHCD-76 (diesel)
  - FY16 (projected) – 45,000 gallons each of CHCJ-5 and CHCD-76
- **Feed stocks**
  - Carinata oil (domestically-grown) – initial 100-gallon campaign & FY16 production
  - Canola oil – FY15 production
- **Fuel production**
  - Crude oil – St Joseph, MO, 100 bbl/day conversion facility
  - Finished fuel hydrotreating and fractionation – Centauri, Pasadena, TX
  - CHCJ-5 and CHCD-76 will be "co-produced"
- **Delivery schedule**
  - FY15 – May-June 2015
  - FY16 – November-January 2016

100 bbl/day Demonstration System

CHCJ-5 Spec Test Results – 100 Gallon Sample

ASTM Method	Property	Min	Max	Result
D6045 - 12	Color, Saybolt	Report		30
D3242 - 11	Total Acid Number (mgKOH/g)		0.015	0.001
D1319 - 14	Aromatics (% vol)		25.0	14.8
D1319 - 14	Olefins (% vol)	Report		0.7
D3227 - 13	Sulfur, Mercaptan, mass percent, max		0.002	0.000
D 5453 - 12	Total Sulfur (% mass)		0.20	0.0001
D86 - 12	Distillation			
	Initial Boiling Point (°C)	Report		182
	10% Recovered (°C)		205	190
	20% Recovered (°C)	Report		192
	50% Recovered (°C)	Report		198
	90% Recovered (°C)	Report		218
	End Point (°C)		300	232
	Residue (% vol)		1.5	1.1
	Loss (% vol)		1.5	0.4
	T50 - T10 (°C)	15		9
	T90 - T10 (°C)	40		28

CHCJ-5 Spec Test Results – 100 Gallon Sample

ASTM Method	Property	Min	Max	Result
D93 - 13e1	Flash point, °C, min	60		64
D4052 - 11	Density, at 15°C (kg/L)	0.788	0.845	0.805
D5972 - 05e1	Freezing Point (°C)		-46	-50
D445 - 14e2	Viscosity @ -20°C (mm^2/s)		8.5	4.5
D 445 - 14e2	Viscosity @ -40°C (cSt)	Report		9
D4809 - 13	Net Heat of Combustion (MJ/kg)	42.6		43.2
D4737 - 10	Cetane Index, Calculated	Report		48
D7171 - 05	Hydrogen Content by NMR (% mass)	13.4		13.9
D1322 - 14	Smoke Point (mm)	19.0		27.0
D130 - 12	Copper Strip Corrosion (2 h @ 100°C)		No. 1	1a
D3241 - 14a	Thermal Stability @ 280°C			
	Tube Deposit Rating		3	1
	Visual Change in Pressure (mmHg)		25	0
D381 – 12	Existent Gum (mg/100 mL)		7	1.0
D5452 - 12	Particulate Matter (mg/L)		1.0	0.7
	Filtration Time (min)		15	4.0
D 7224 - 13	WSIM	80		97.0
D2624 - 09	Conductivity (pS/m)	Report		0
D 5001 - 10	Lubricity Test (BOCLE) Wear Scar (mm)	Report		0.7
D 6304 - 07	Water, Coulometric Karl Fischer Titration (ppmw)	Report		6.9

CHCJ-5 Hydrocarbon Type Results

AFRL/UDRI

ASTM Method	Min	Max	Result
D2425 (mass%)			
Paraffins (normal and iso)	Report		37
Cycloparaffins	Report		48
D6379 (vol%)			
Total Aromatics	8.4	25	14.3
% of Total Aromatics			
Monoaromatics	96.5		>99
Diaromatics		3.0	<0.3
Polyaromatics		0.5	<0.3

Renewable Chemicals

- **ARA Hydrothermal Cleanup (HCU) process (patent pending)**
  - **Rapid hydrolysis – production of glycerin**
  - **Alternative to Chemical degumming**
- **HCU can be employed to concentrate erucic acid**
  - **Multiple direct applications – OBIC Study**
  - **Intermediate for the production of other chemicals/commodities**
- **Other renewable chemicals of interest**
  - **Paraffin wax**
  - **Aromatics**
  - **Carboxylic acids**
  - **Alkylbenzene**

Commercialization Activities

1100 BBL/day – Engineering – Distillers Corn Oil

700 BBL/day – Engineering – Yellow/Brown Grease

7000 BBL/day – Siting/Due Diligence – Georgia and Virginia sites – Yellow/Brown Grease – Soybean and Canola as transitional feedstocks

250 BBL/day – Engineering – Waxy crude oil from recycled plastic

10000 BBL/day – Engineering – Waxy Petroleum Crude

Next Generation Aviation Fuel

ReadiJet™