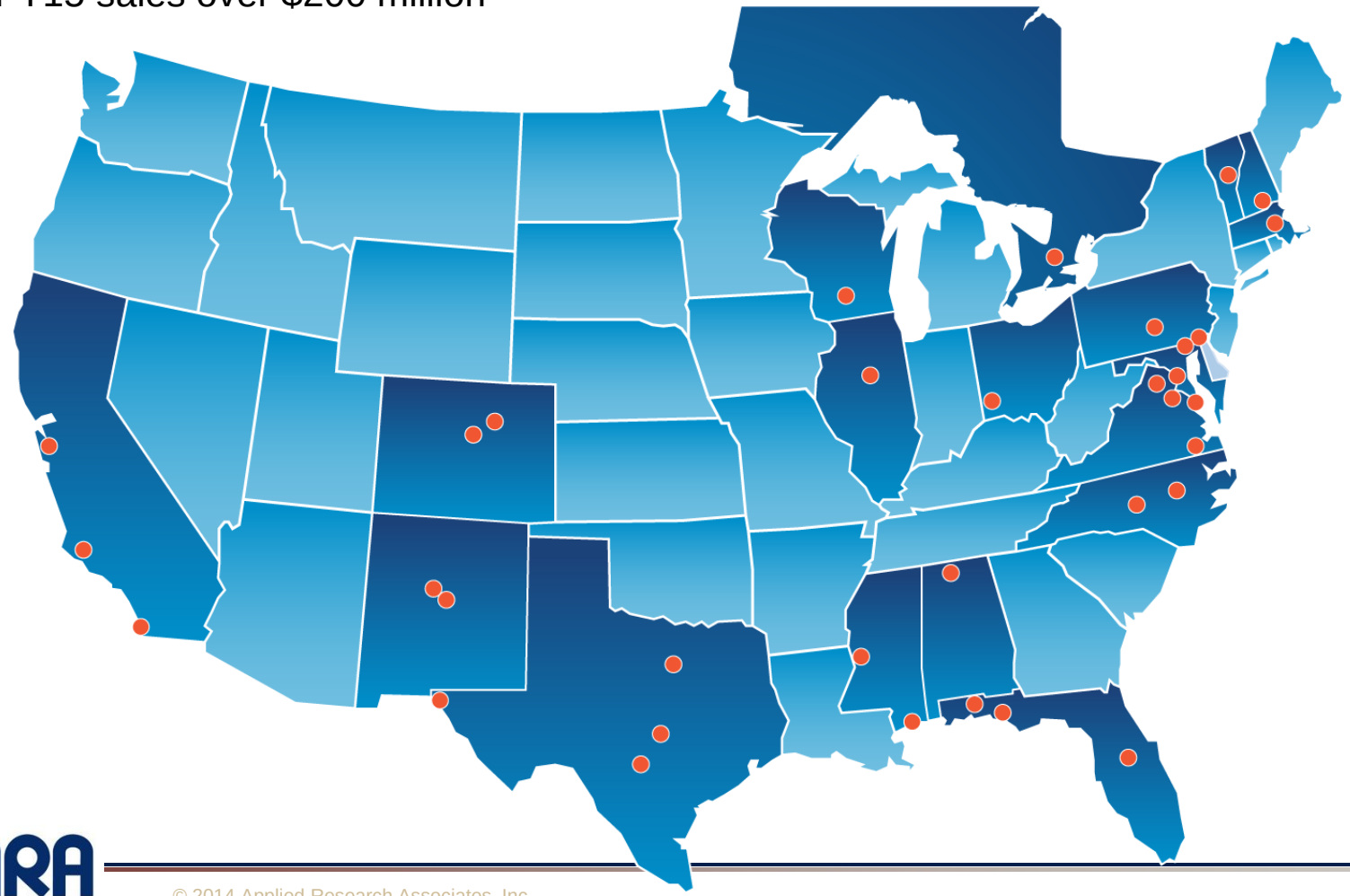
Conversion of Carinata Oil into "Drop-in" Fuels & Chemicals

Carinata Summit
Quincy, Florida
15 March 2016

ReadiJet™
ReadiDiesel™
ARA®

About ARA, Inc.

- Founded 1979, Albuquerque, New Mexico
- 1,086 employee owners at locations in the U.S. and Canada
- FY15 sales over $200 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

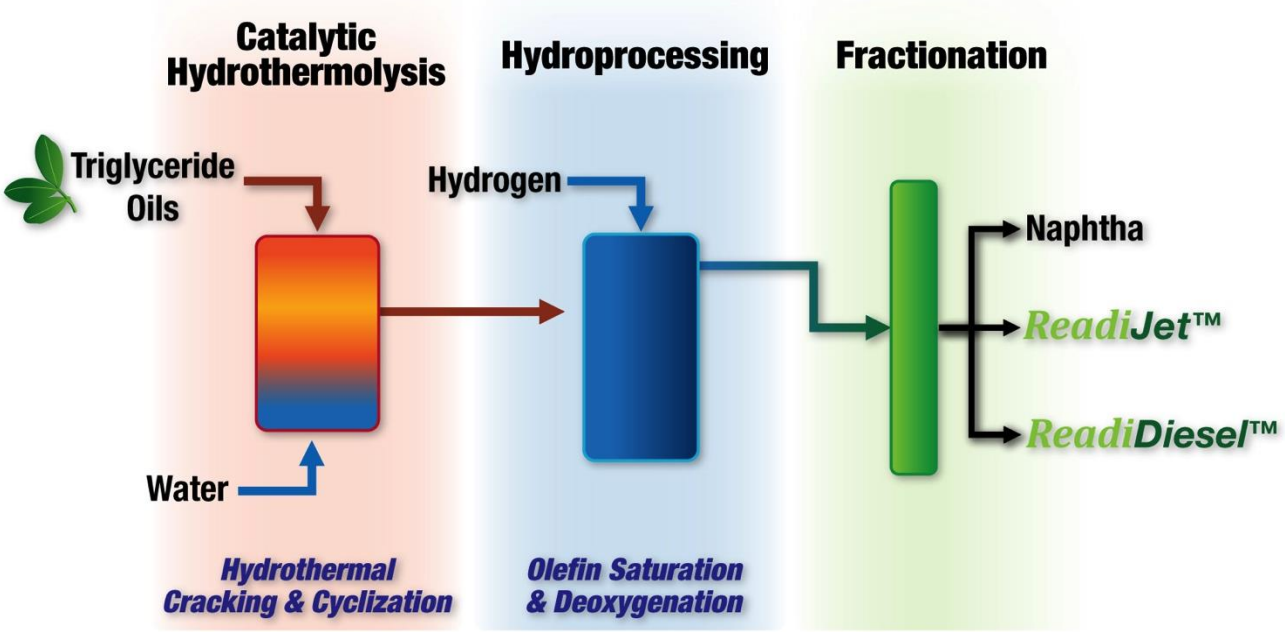
ARA provides innovative engineering services and products for alternative fuels, and the power and utility services market.

Health Solutions

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

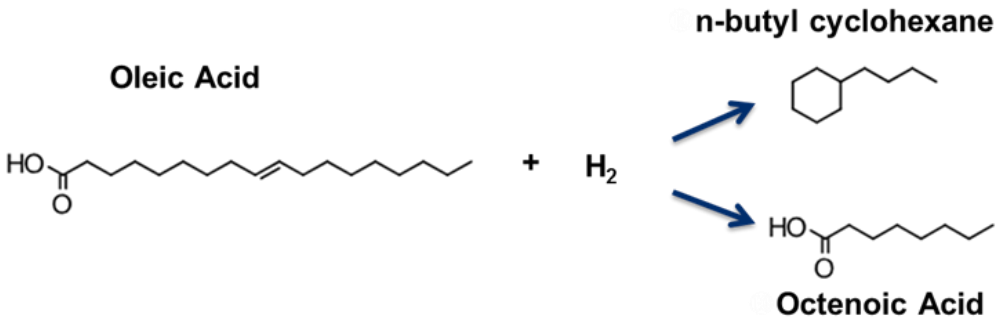
BioFuels ISOCONVERSION (BIC) Process

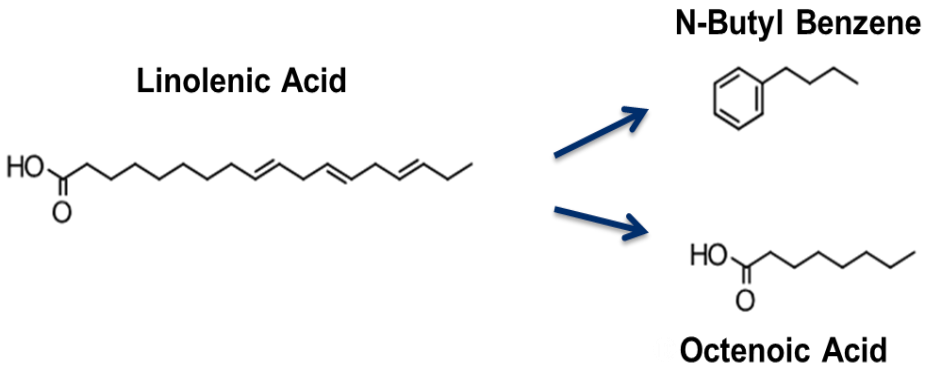
Jointly Developed by ARA and Chevron Lummus Global



- 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

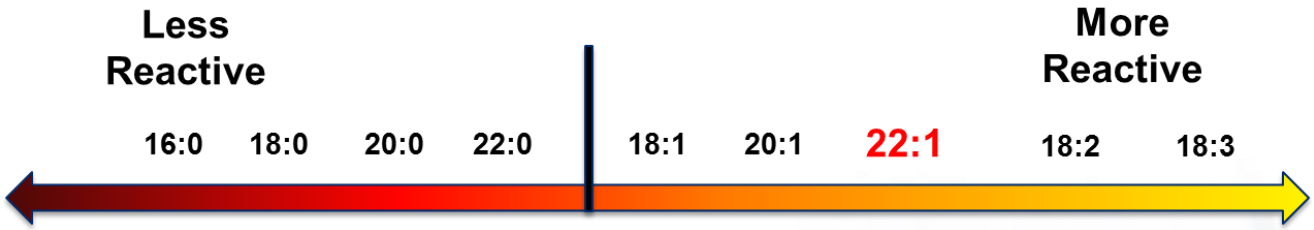




- Cycloparaffins and Aromatics are formed
- Entire homologous series of isomers are formed
- Ring structures are conserved during hydrotreating
- Hydrogen is conserved by formation of ring structures

Conversion of Carinata Oil

- High concentration of Erucic acid (22:1)
  - Unsaturated FFAs are more reactive



  - High yield of cycloparaffins & aromatics
  - 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

Production of Certification Fuels for DLA-Navy

- Three production campaigns
- First campaign:
  - 100-gallon samples (produced in pilot equipment)
  - Carinata oil feed stock
- Second campaign FY15
  - 54,000 gallons of CHCJ-5 (jet) CHCD-76 (diesel) produced for DLA
  - Canola oil feed stock
- Third campaign FY16
  - 97,000 gallons of CHCJ-5 and CHCD-76 produced for DLA
  - Canola and soybean feed stocks
- Fuel production (2nd and 3rd campaigns)
  - Crude oil produced by CH conversion in St Joseph, Missouri
  - Finished fuel hydrotreating and distillation – Centauri – Pasadena, TX

100 bbl/day CH Conversion System – St Joe, MO

Centauri Refinery – Pasadena, Texas

Navy Fuels Certification

100% Drop-in, Unblended

	JP-5 (CHCJ-5) 60°C Flash Jet	F-76 (CHCD-76) 60°C Flash Diesel	Gallons Total
U. S. Navy (DLA)	72,000	79,000	151,000
Other*	9,000		9,000
Total	81,000	79,000	160,000

Commercial Jet A flash point = 38°C
Commercial Diesel #2 flash point = 52°C

***Other recipients – Lufthansa, Air Force, Army, Sweden**

Comparison of Production Campaigns

Specification Test Results (Provided by AFRL & AFPET)

Specification Test	MIL-DTL-83133H Spec Requirement	ReadiJet® Carinata (JP-8) Chevron	ReadiJet® Canola (Jet A) AFRL	Petroleum JP-8 Reference
Total Acid Number, mg KOH/g	≤0.015	0.012	.008	0.003
Aromatics, vol %	≤25	16.8	16.9	18.8
Olefins, vol %	≤5	1.8	1.9	0.8
Heat of Combustion (m), MJ/kg	≥42.8	43.2	43.4	43.3
Hydrogen Content, % mass	≥13.4	13.8	13.9	13.8
Smoke Point, mm	≥19	26	25	22
Thermal Stability @ 260°C:				
Tube Deposit Rating	≤3	1	1	1
Change in Pressure, mm Hg	≤25	0	0	2
Flash point, °C	≥38	46	42	51
Freeze Point, °C	≤-47	-57	-43	-51
Viscosity @ -20°C, cSt	≤8.0	3.5	4.05	4.9
Viscosity @ -40°C, cSt	≤12.0	6.5	7.9	9.9
Density, kg/L @ 15°C	0.775 - 0.840	0.802	0.8036	0.804
Lubricity (BOCLE), wear scar mm	≤0.85	0.57	0.54	0.53

ASTM Certification – Commercial Jet A, Jet A-1

Tier 1

Specification Properties

Tier 2

Fit-For-Purpose Properties

Phase 1 ASTM Research Report

SAFRAN, BOEING, Honeywell, Rolls-Royce, AIRBUS

OEM Review & Tier 3 & 4 Requirements

Tier 3

Component/Rig Testing

Tier 4

Engine/APU Testing

Phase 2 ASTM Research Report

SAFRAN, BOEING, Honeywell, Rolls-Royce, AIRBUS

OEM Review & Approval

FAA Review

ASTM Review & Ballot

Accept

Reject

Re-Eval As Required

ASTM Specification

ASTM Balloting Process

ASTM INTERNATIONAL Standards Worldwide

ASTM Specification

Hydrothermal Cleanup (HCU) Process

Patent Pending

- **Achieves Rapid Hydrolysis**
  - **Production of free fatty acids and glycerin**
  - **Erucic acid (22:1) from Carinata oil**
  - **An effective alternative to chemical degumming/metals reduction**

Unrefined Peanut Oil Example

Metals (ppm)	Peanut oil	HCU FFA	Reduction
Calcium	25.6	4.0	84.4%
Magnesium	28.0	0.9	96.8%
Phosphorus	146.7	2.4	98.4%
Potassium	67.5	2.8	95.9%

Hydrothermal Cleanup (HCU) Process

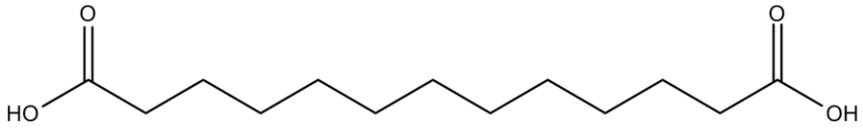
Patent Pending

Super Degummed Carinata Oil Example

Metals (ppm)	Carinata Oil	HCU FFA
Calcium	4.3	1.2
Magnesium	3.0	0.4
Phosphorus	20.1	0.7
Potassium	6.7	2.2

Renewable Chemicals

- Glycerin
- Erucic Acid from Carinata
  - An important derivative is *Brassylic acid* (a 13 carbon di-acid)
  - Chemical intermediate for the synthesis of lubricants and polymers (nylon 1313)



- Other renewable chemicals of interest
  - Paraffin wax (especially from Carinata oil)
  - Normal (straight-chain) paraffins in the kerosene boiling range
    - Linear alkyl benzene (LAB) used in detergent production
  - Cycloparaffin compounds
  - Aromatic compounds
  - Carboxylic acids (short-chain fatty acids)

Commercialization Activities

5000 bbl/day – Engineering Design Package (EDP)

- Southern California

Other Commercial Systems under Evaluation

- Utah – 2500 bbl/day
- Gulf Coast – 2500 bbl/day
- Missouri – 5000 bbl/day
- Northeast – 5000 bbl/day pretreatment

Next Generation Aviation Fuel

ReadiJet™