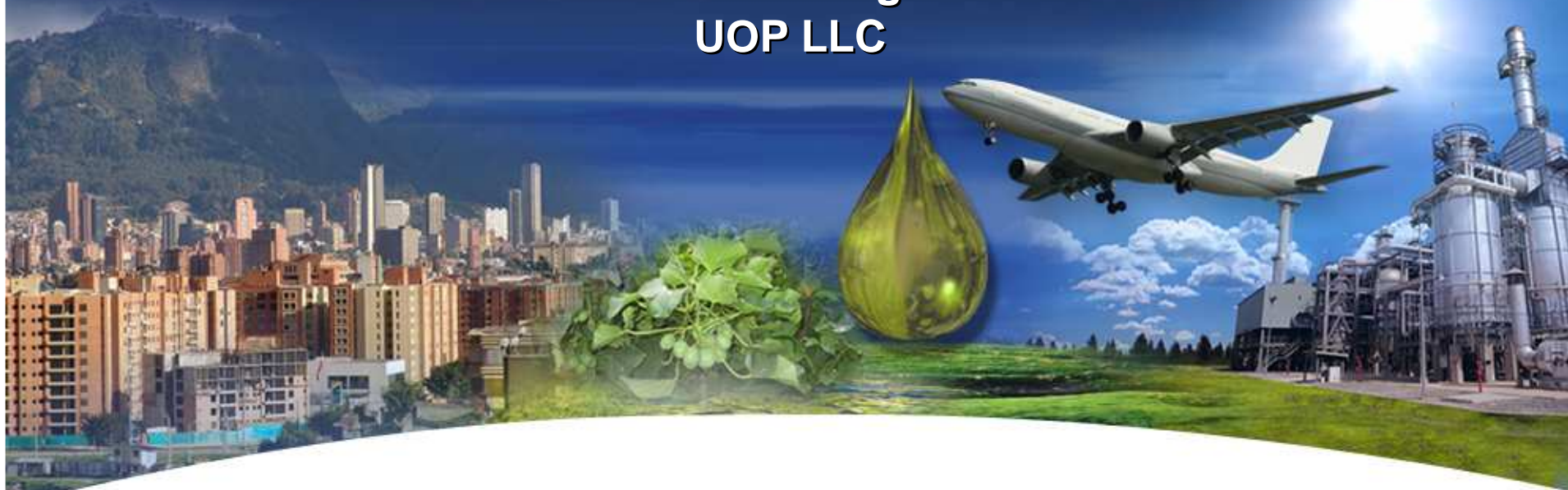


# Conversion of Biofeedstocks to Green Fuels and Power

**Mr. Claudio Bertelli**  
**Sales Manager**  
**UOP LLC**



**BIO2009 IV Seminario Latinoamericano y del  
Caribe de Biocombustibles  
April 28-30, 2009  
Cali, Colombia**



# Agenda

- Introduction & Context
- UOP/ENI Ecofining™ Process:
  - Process
  - Life Cycle Analysis
- Aviation Fuels:
  - Green Jet Process
  - Test Flight
- 2<sup>nd</sup> Generation Feedstocks
  - UOP/Ensyn JV
  - Algal Biorefinery



# UOP Overview

- **Leading supplier and licensor of processing 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; 60% of the world's *para*-xylene.**
- **3400 employees worldwide.**
- **2008 Financials: \$1.9 billion in sales.**
- **Strong relationships with leading refining and petrochemical customers worldwide.**
- **UOP's innovations enabled lead removal from gasoline, the production of biodegradable detergents, the first commercial catalytic converter for automobiles.**



*2003 National Medal of Technology Recipient*



***Biofuels: Next in a Series of Sustainable Solutions***

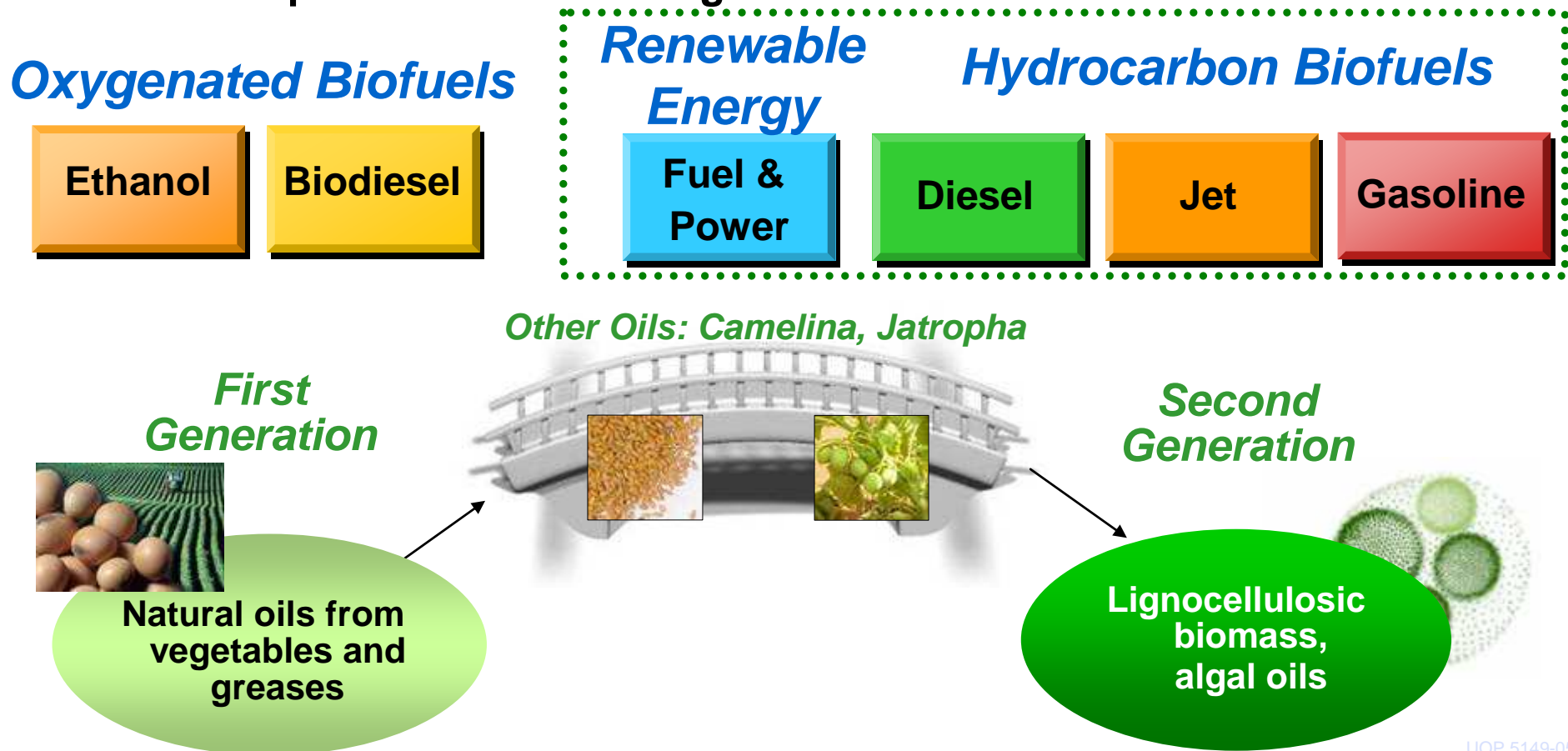
# Biofuels: A Quickly Changing Landscape

2007	2008	UOP Position
<ul style="list-style-type: none"> <li>• All biofuels are good</li> <li>• More, faster</li> <li>• No criteria to measure impact of adopting biofuels</li> <li>• Availability of “inexpensive” bio feedstocks</li> <li>• Government mandates and incentives favor ethanol and biodiesel</li> </ul>	<ul style="list-style-type: none"> <li>• Not all biofuels are good</li> <li>• Measured biofuel adoption</li> <li>• Utilization of LCA analysis to “qualify”: link to GHG, energy, sustainability</li> <li>• Bio feedstocks tracking energy prices</li> <li>• Government mandates and incentives increasingly technology neutral</li> <li>• Emphasis on “real” biofuels</li> </ul>	<ul style="list-style-type: none"> <li>• Emphasis on life cycle analysis as a way of measuring “sustainability”</li> <li>• Ensure technology is feedstock flexible</li> <li>• Focus on 2<sup>nd</sup> generation technologies</li> <li>• Create partnerships between feedstock suppliers and fuel producers</li> </ul>

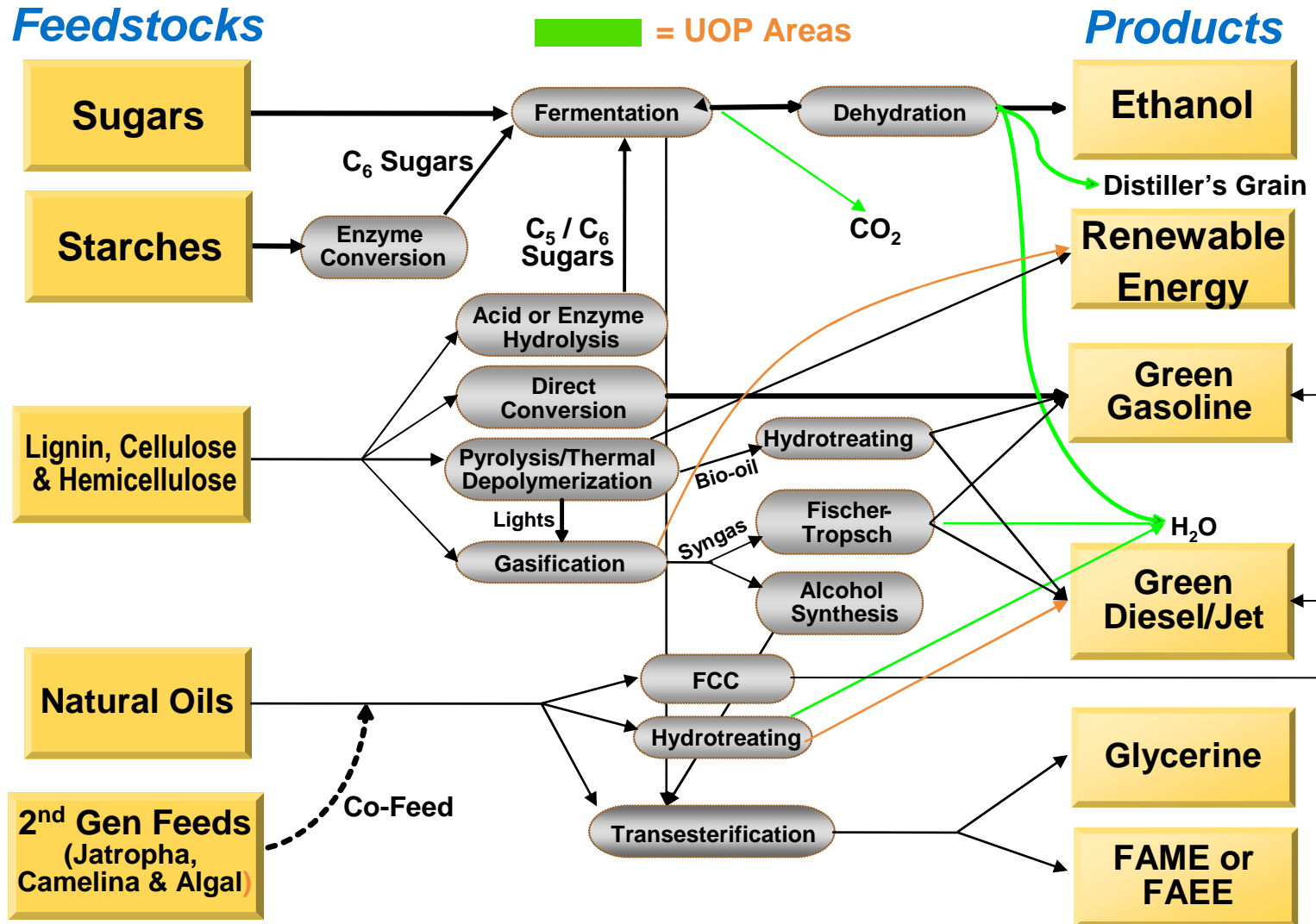
***Increasing Awareness of Impact***

# UOP Renewables Vision

- Building on UOP technology and expertise
- Produce real fuels instead of fuel additives/blends
- Leverage existing refining, transportation, energy, biomass handling infrastructure to lower capital costs, minimize value chain disruptions, and reduce investment risk.
- Focus on path toward second generation feedstocks & chemicals



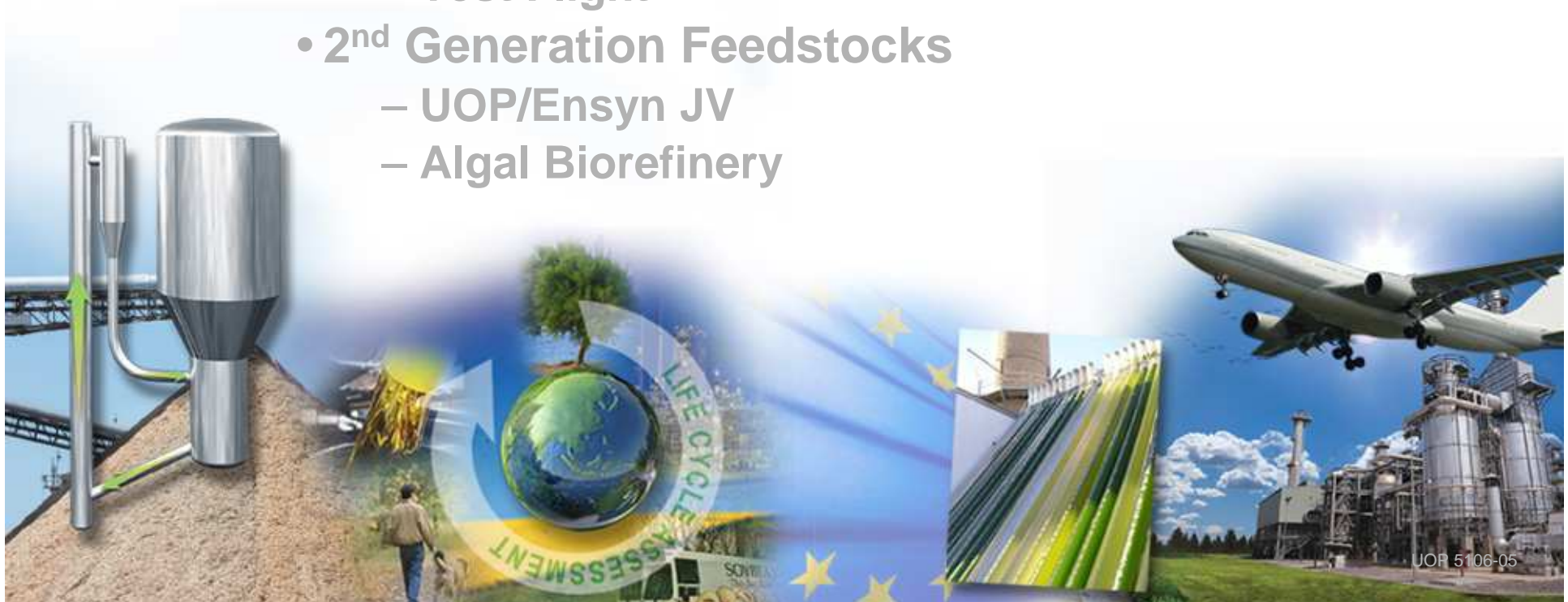
# Biofuels Overview: Technology Pathways



**Current biofuel market based on sugars & oils. Use bridging feedstocks to get to 2<sup>nd</sup> Gen feeds – Algae & Lignocellulosics**

# Agenda

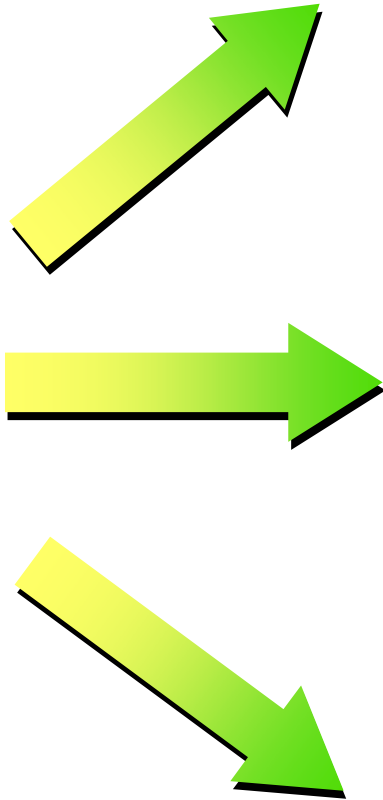
- Context
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  - Process
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# Renewable Diesel Options

## Feedstocks

- Palm Oil
- Rapeseed
- Soybean
- Tallow
- Algal Oils
- Jatropha



**Biodiesel  
(FAME)**



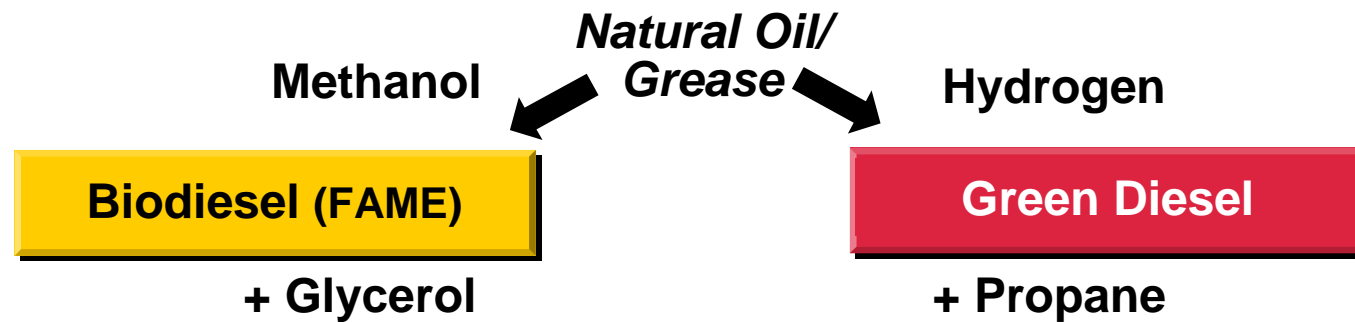
**Ecofining  
(Stand-alone  
Hydroprocessing/  
Isomerization)**



**Co-Processed  
Hydroprocessing**

**3 Options Currently Available**

# Green Diesel vs. Biodiesel (FAME)

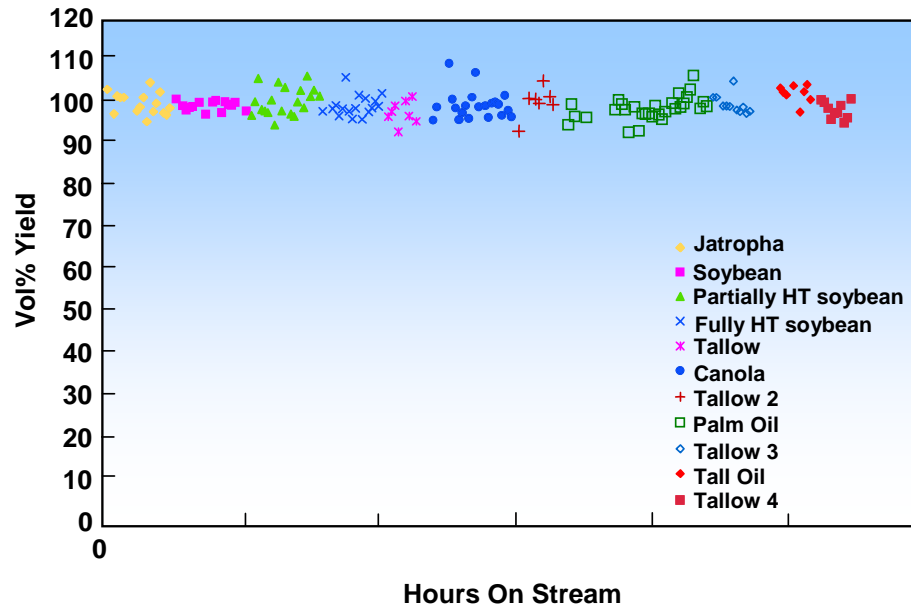


	<i>Petroleum ULSD</i>	<i>Biodiesel (FAME)</i>	<i>Green Diesel</i>
Oxygen Content, %	0	11	0
Specific Gravity	0.84	0.88	0.78
Sulfur content, ppm	<10	<1	<1
Heating Value MJ/kg	43	38	44
Cloud Point, °C	-5	-5 to +15	-30 to -10
Cetane	40	50-65	70-90
Lubricity	Baseline	Good	Baseline
Stability	Baseline	Good/Poor	Baseline

***UOP/ENI Ecofining™ Process to Produce Green Diesel  
Preferred Bio Derived Diesel of ACEA***

# Ecofining Feed Source Options

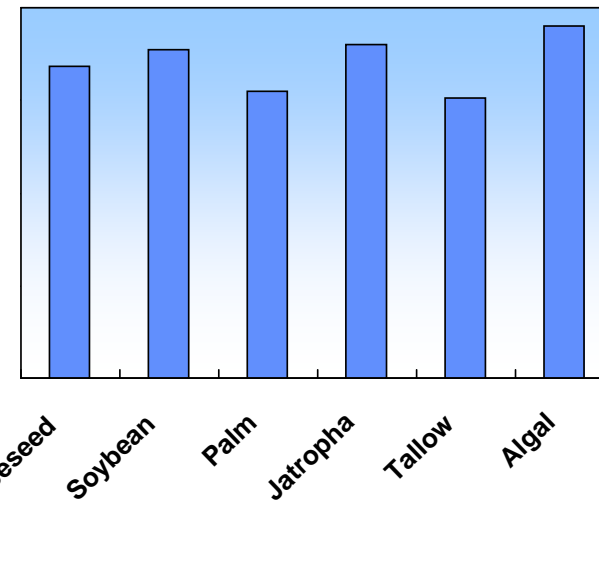
*Vol% 1st Stage Straight Chain Paraffin Yields*



## Flexibility

- Ecofining is applicable to a wide variety of feed-stocks (vegetable & animal)
- Works with 2<sup>nd</sup> generation feed-stocks such as algae and inedible oils such as jatropha

## Relative Hydrogen Consumption

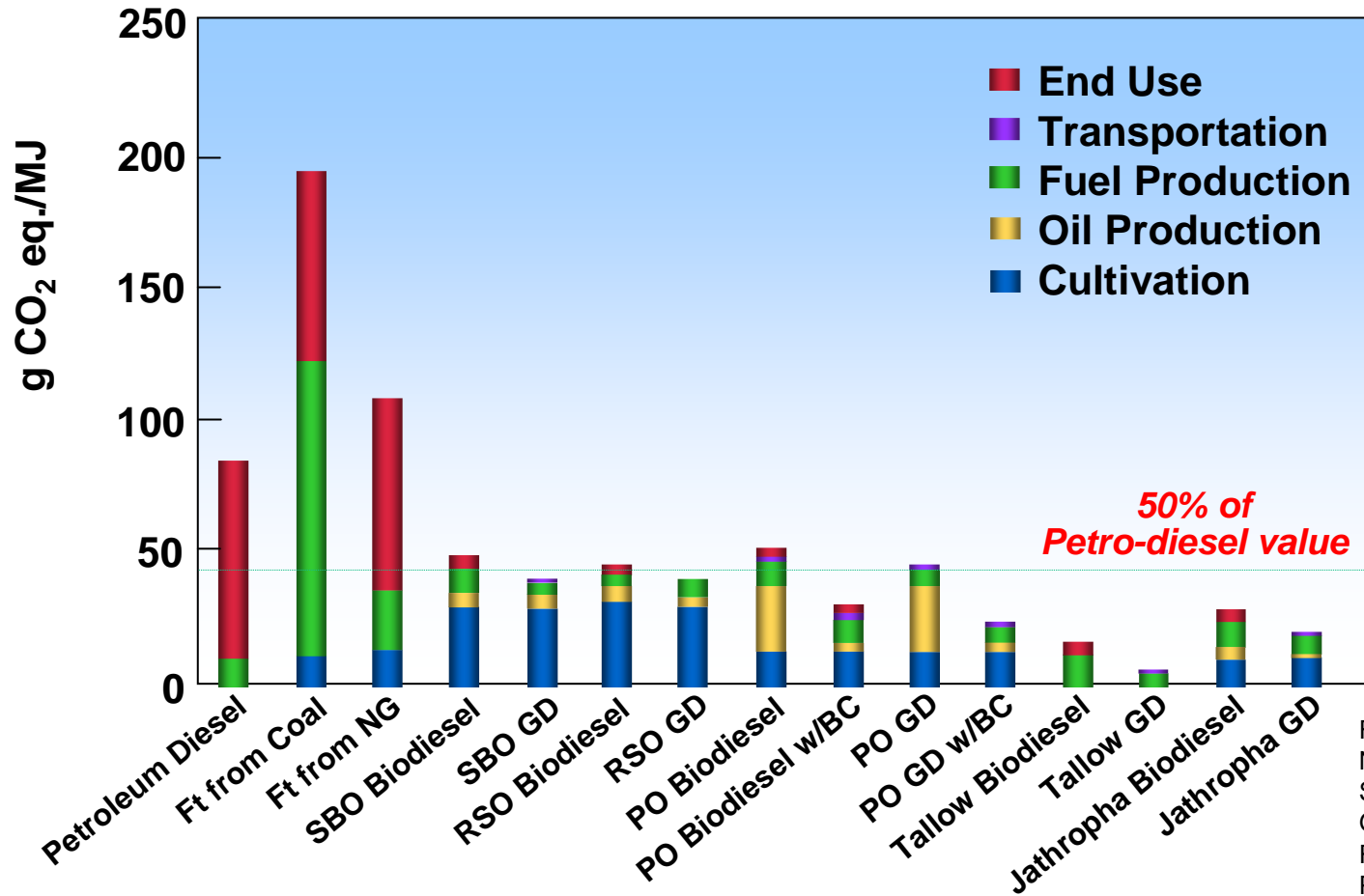


## Processability

- More saturated feed-stocks improve economics
- Green diesel product properties are almost independent of feed-stock source

**Feedstock Flexibility Enhances Profitability**

# Green Diesel Life Cycle Analysis – CO<sub>2</sub> Emissions



DOE Methodology

FT = Fischer Tropsch  
 NG = Natural Gas  
 SBO = Soybean Oil  
 GD = Green Diesel  
 RSO = Rapeseed Oil  
 PO = Palm Oil  
 BC = Biogas Capture

**Green diesel is a sustainable option for biofuels.  
 Greater than 50% GHG reduction saving is possible**

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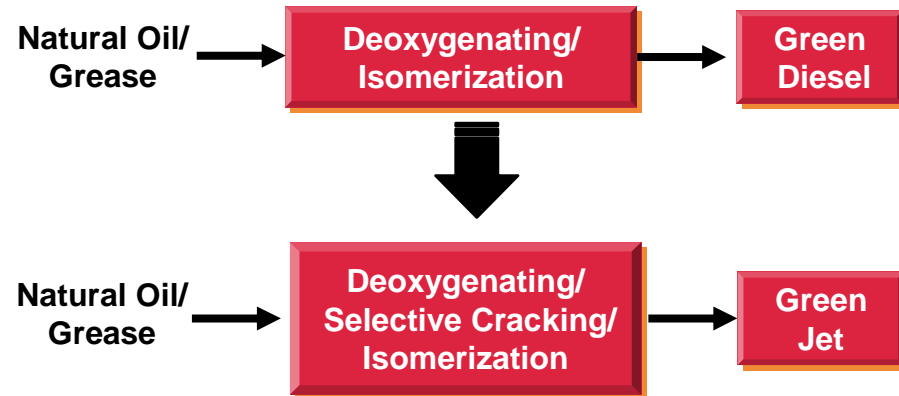


# UOP Green Jet Fuel Program

- U.S. government-funded project to develop process technology to produce military jet fuel (JP-8) from renewable sources
- Process is feedstock flexible and second-generation feedstock “ready”
- Fuel meets stringent requirements for flash point, cold temperature performance, etc.
- Extend to commercial aircraft in partnership with flight demonstration partners
  - Generate sufficient data to enable certification
  - Demonstrate process scalability
  - Fast track commercialization

**Target Commercialization  
by mid 2009**

## Built on Ecofining Technology



## DARPA Project Partners



**Honeywell**

# Completed Flight Demonstrations



**Feedstock:**  
*Jatropha oil*

- Successful ANZ Flight Demo



**Feedstock:**  
*Jatropha and algal oil*

- Successful CAL Flight Demo Date: Jan. 7 2009



**Feedstock:** *Camelina, Jatropha and algal oil*

- Successful JAL Flight Demo Date: Jan. 30 2009



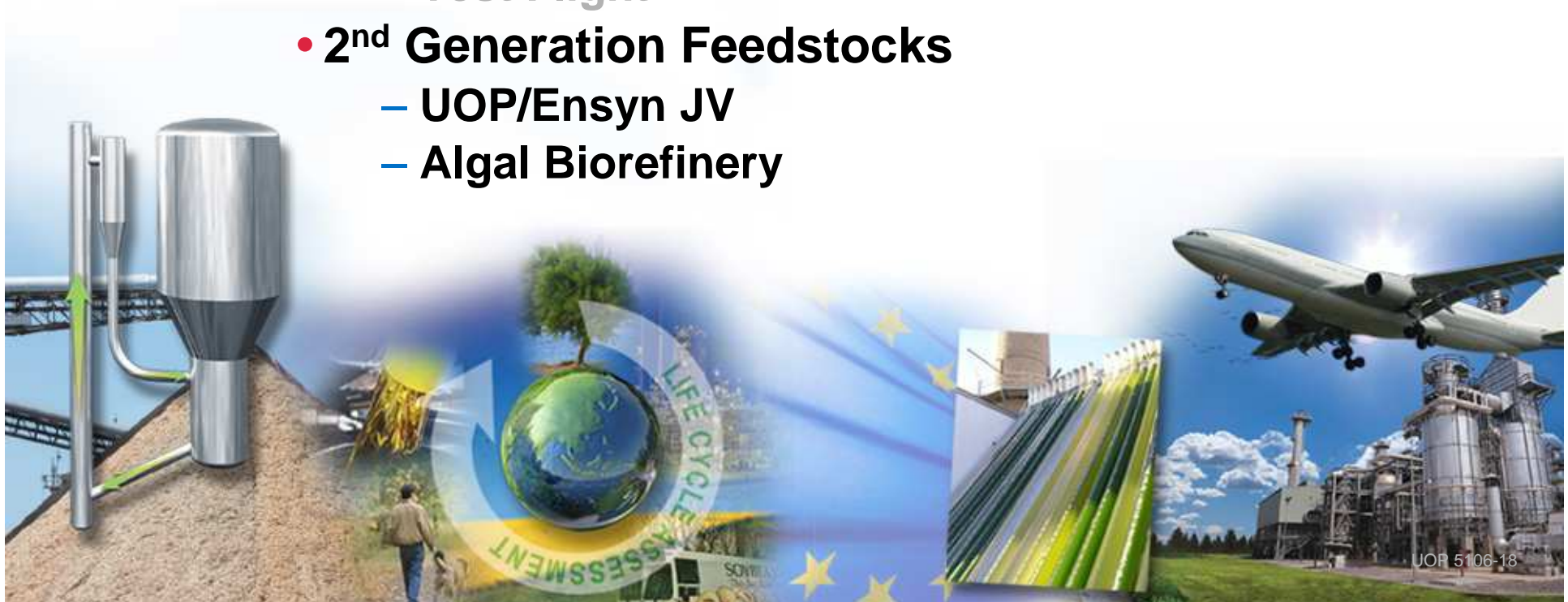
# Key Properties of Green Jet

	Jet A-1 Specs	Jatropha Derived SPK	Camelina Derived SPK	Jatropha/Algae Derived SPK
<b>Description</b>				
Flash Point, TCC, °C	Min 38	46.5	42.0	41.0
Freezing Point, °C	Max -47	-57.0	-63.5	-54.5
JFTOT@300°C				
Filter dP, mmHg	max 25	0.0	0.0	0.2
Tube Deposit Less Than	< 3	1.0	<1	1.0
Net heat of combustion, MJ/kg	min 42.8	44.3	44.0	44.2
Viscosity, -20 deg C, mm <sup>2</sup> /sec	max 8.0	3.66	3.33	3.51
Sulfur, ppm	max 15	<0.0	<0.0	<0.0

***Production Viability Demonstrated  
Fuel Samples from Different Sources Meet  
Key Properties***

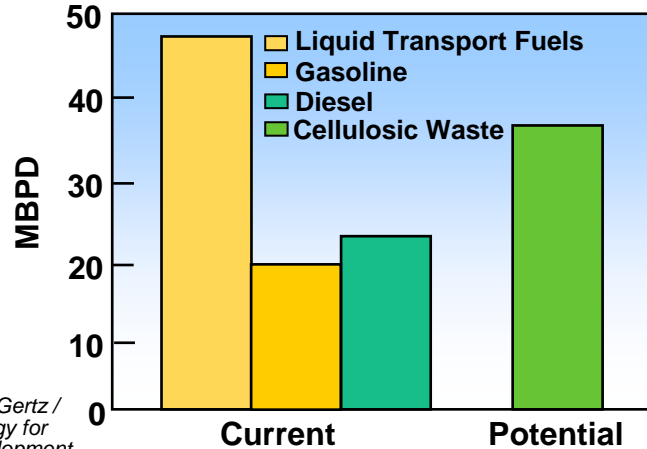
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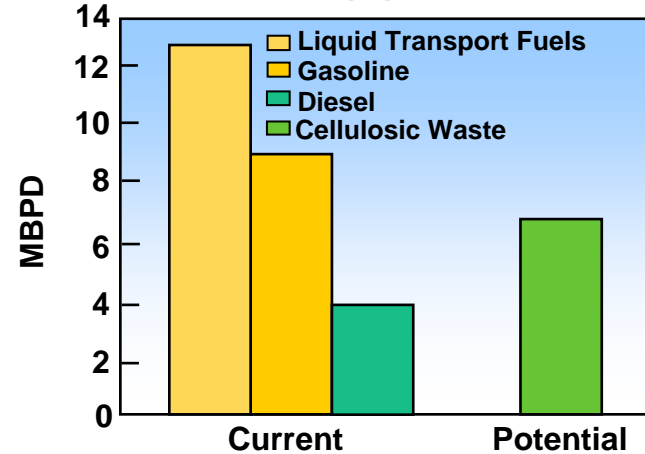
# Enablers for a Sustainable Biomass Infrastructure

## Global

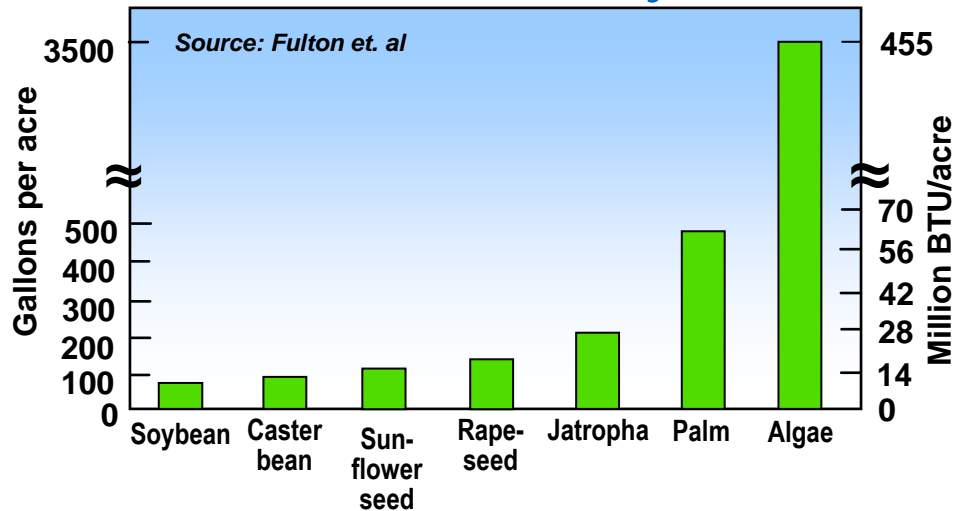


Source: Purvin & Gertz / Eric Larsen: Energy for Sustainable Development, 2000

## US



## Oils Productivity



Source: Fulton et. al

- Cellulosic waste could make a significant contribution to liquid transportation pool.
- Algal Oils could enable oils route to biodiesel, Green Diesel and Green Jet.

**Increases Availability, Reduces Feedstock Cost  
Technology Breakthroughs Required**

# UOP / Ensyn Joint Venture



- Announced September 2008
- Pyrolysis Oil technology for fuel oil substitution & electricity generation now available
- JV becomes channel for UOP R&D results on upgrading pyrolysis oil to transport fuels



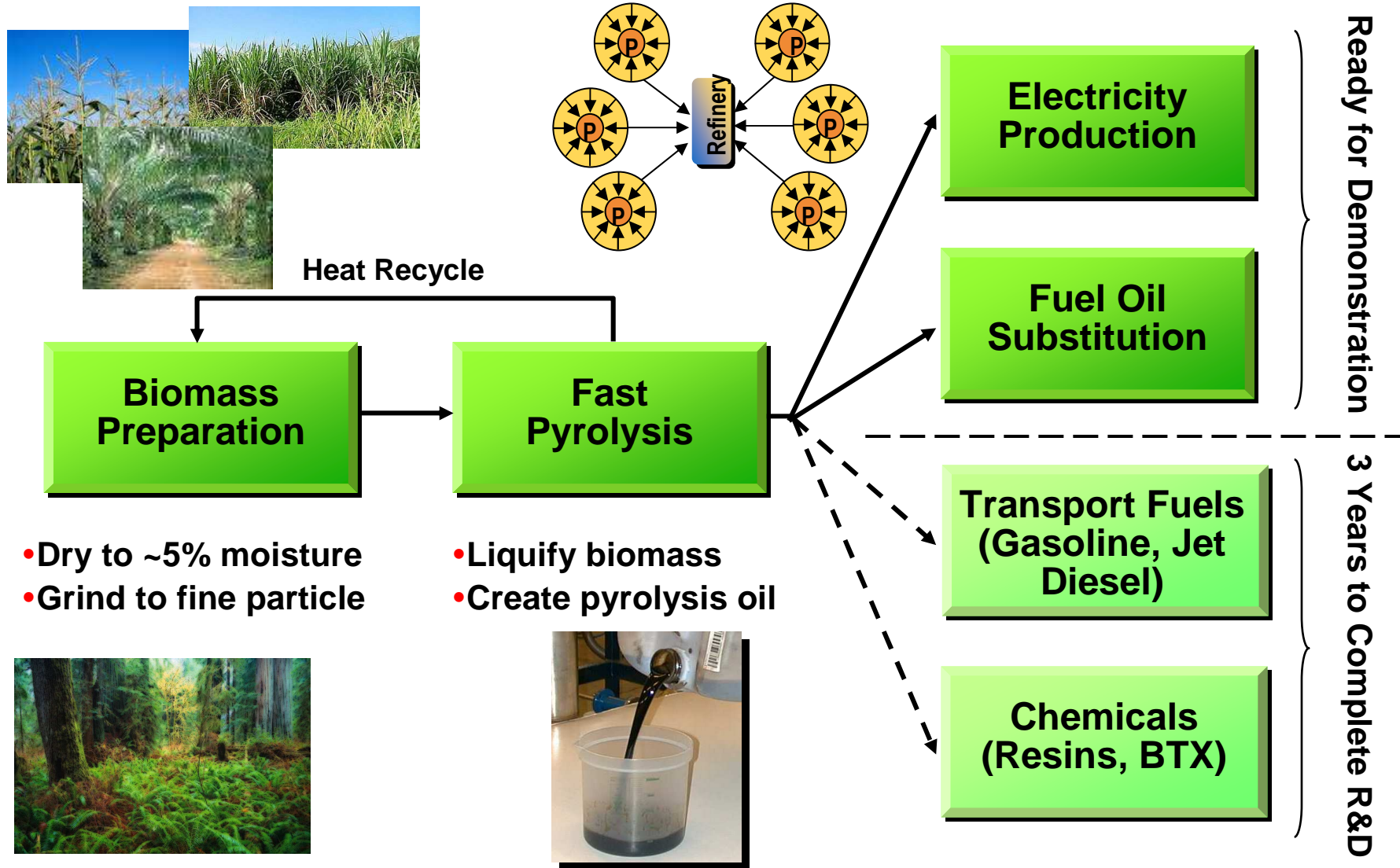
- Core competence in engineering and technology scale-up
- Co-inventor of Fluidised Catalytic Cracking (FCC) technology
- Modular process unit supplier
- Leader in fundamental catalyst and process development (Upgrading)



- ~20 years of commercial fast pyrolysis operating experience in food industry
- Developers of innovative RTP fast pyrolysis process
- 8 commercial RTP units designed for food application
- Now applying technology to fuel oil and energy

***2<sup>nd</sup> Gen Renewable Energy Company – Global Reach***

# Pyrolysis Oil to Fuels



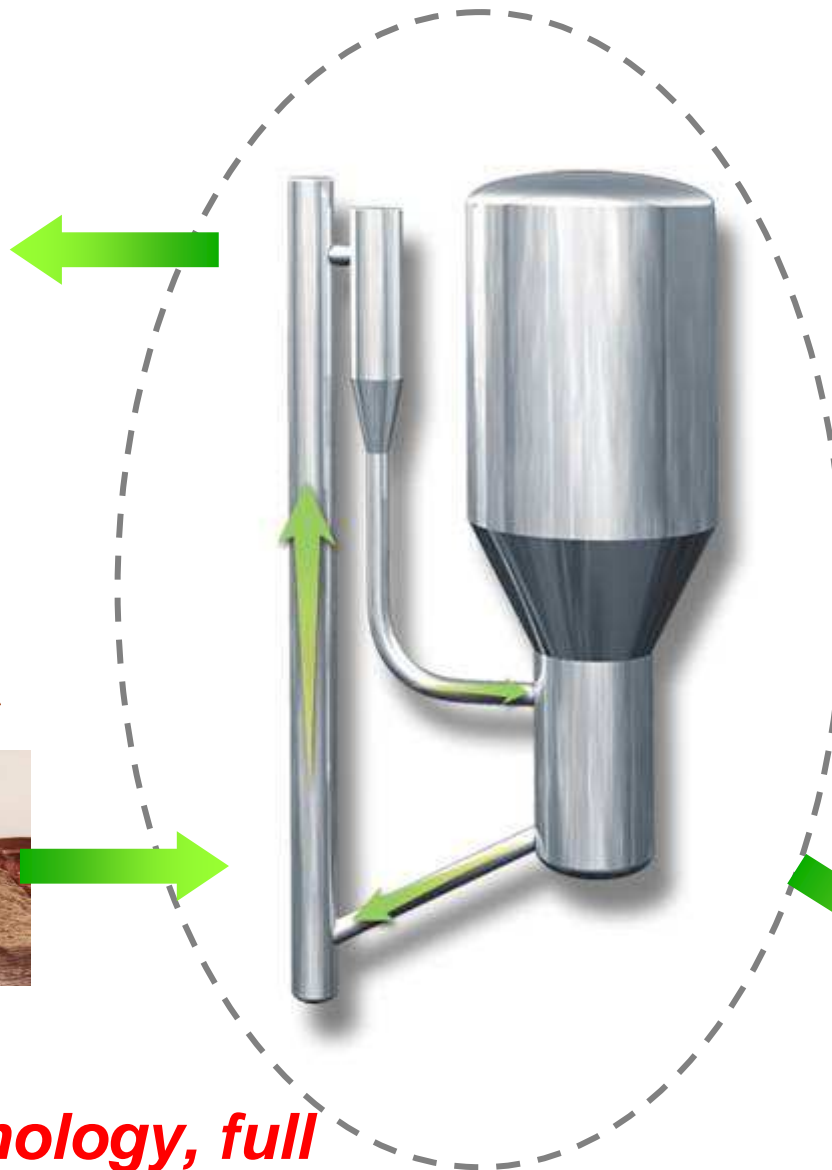
**Phased Demonstration & Commercialization**

# Rapid Thermal Process (RTP™) Technology

## Pyrolysis Oil



## Solid Biomass

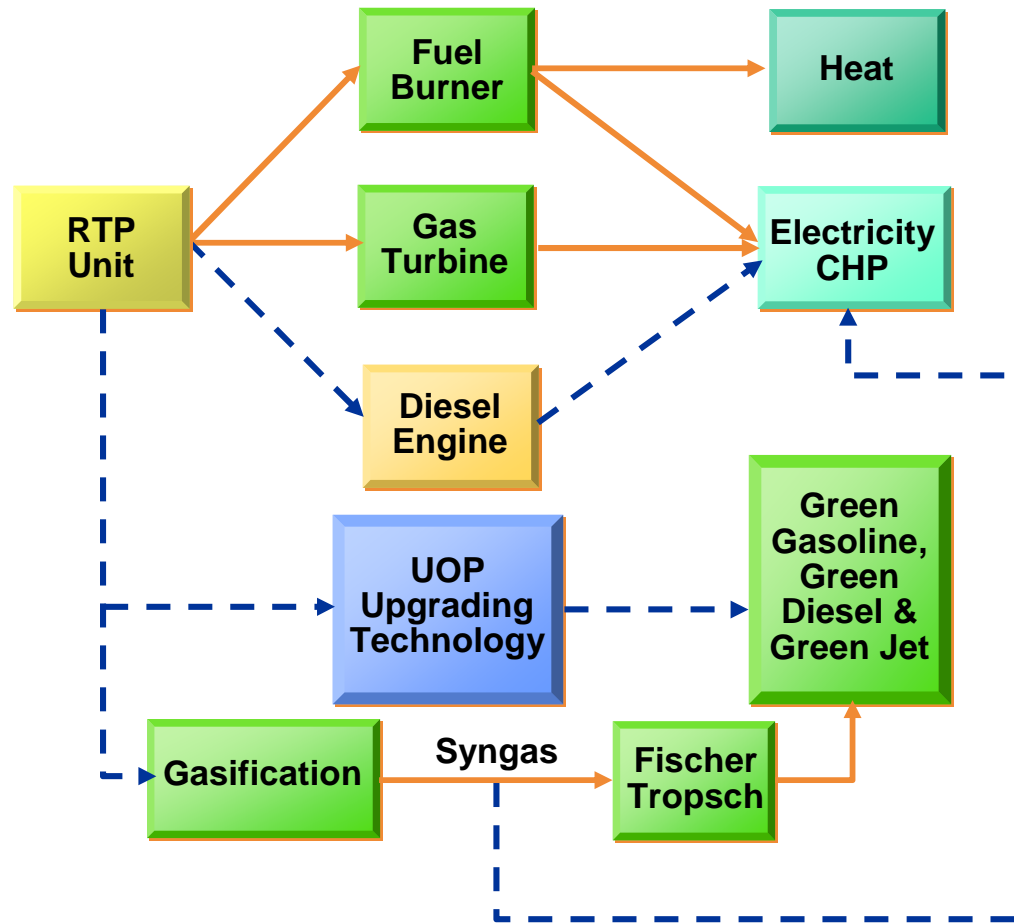


- 510°C, <2 secs
- Biomass converted to liquid pyrolysis oil
- Fast fluidized bed, sand as heat carrier
- High yields; >70 wt% liquid on woody biomass
- Light gas and char by-product provide heat to dry feed and operate unit



**Proven Technology, full scale designs available**

# Pyrolysis Oil Applications



- Current Applications →
- Emerging Applications - ->



***Early Applications Proven. A GHG Emission Reduction Solution for Industrial Sites***

# Renewable Fuels from Algae

- High cellular oil content (~50% of dry weight)
- High photosynthetic efficiency (10~20%)
- Excellent CO<sub>2</sub> capture and sequestration capability
- Water requirement: less than 1/40 of land plants and thrive in saline/brackish/waste water
- Land requirement: desert and arid lands



Source:  
Q. Hu, **ASU**

## Raw Algal Samples

Property	Palm Oil	Soybean Oil	Algae Oil #1	Algae Oil #2	Algae Oil #3
Density	.915	.92	0.9169	pending	0.9383
TAN	1.2	.04	0.31	1.8	181.5
% oxygen	11.2	11.3	11.0	11.0	18
Water,ppm	500	150	482	499	4%
Metals (Na+Ca+K+Mg+Al),ppm	2	<1	<1	1.7	59
Sulfur,ppm	3	<1	3	47	pending
Nitrogen	2	11	16 ppm	<0.1%	1.2 %
Chloride,ppm	2	<.1	2	pending	91

## Deoxygenated Samples

Component	Typical Product (mass %)	Algal Oil #1 Product (Mass %)	Algal Oil #2 Product (Mass %)
<C <sub>15</sub>	0.9	1.3	2.1
C <sub>15</sub> iso	<0.1	<0.1	1.1
C <sub>15</sub> n	3.2	3.3	12.3
C <sub>16</sub> iso	0.1	<0.1	1.7
C <sub>16</sub> n	6.6	4.4	12.8
C <sub>17</sub> iso	1.0	0.3	2.1
C <sub>17</sub> n	29.2	39.8	30.0
C <sub>18</sub> iso	2.2	0.5	2.3
C <sub>18</sub> n	54.7	48.4	29.8
>C <sub>18</sub>	2.1	1.9	5.7

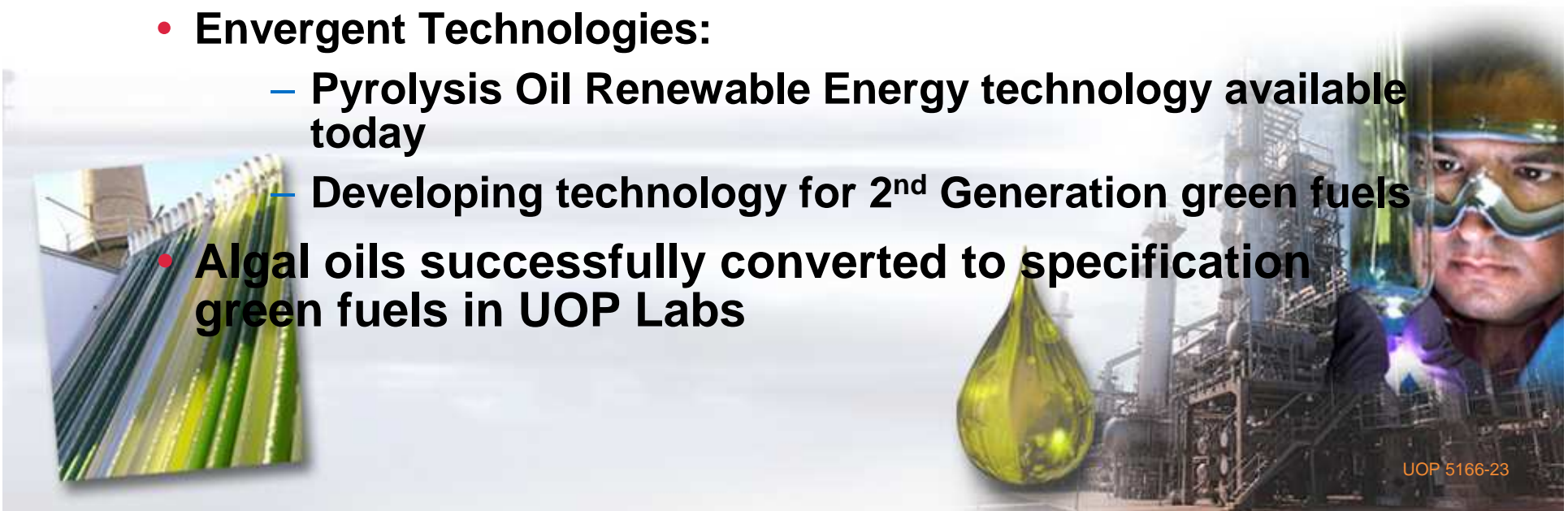
- 3 samples of varying quality analyzed
- Sample 3 highly contaminated
- Processing:
  - Deoxygenation *followed by*
  - Isomerization *and/or*
  - Cracking



- 100% DeOxygenation achieved
- Substantially similar composition to deoxygenated natural oils
- Comparable DeOxy yields to palm
- Readily isomerizable to Green Diesel

# Summary

- **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**
- **Envergent Technologies:**
  - **Pyrolysis Oil Renewable Energy technology available today**
  - **Developing technology for 2<sup>nd</sup> Generation green fuels**
- **Algal oils successfully converted to specification green fuels in UOP Labs**



Q & A

**MUCHAS GRACIAS**

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