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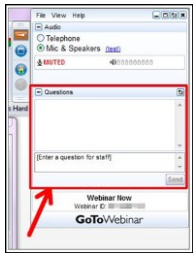

Type them into questions box!

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The American Chemical Society Fellows Program was created by the ACS Board of Directors in December 2008 to recognize members of ACS for outstanding achievements in and contributions to science, the profession, and the Society.

Nominations for 2017 ACS Fellows:
February 1, 2017 through April 6, 2017

Detailed guidelines and instructions for submitting nominations

www.acs.org/fellows

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Thursday, February 9, 2017

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Rich Hartel, Professor of Food Engineering, University of Wisconsin-Madison
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David Constable, *Science Director, ACS Green Chemistry Institute*

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Learn how to nominate your industrial colleagues at www.acs.org/heroes

The Honeywell UOP team behind its green jet fuel was celebrated as 2016 Heroes of Chemistry. ***Do you know an industry chemist or team that deserves the same honor?***

The Honeywell UOP team

Chad Cavan, Ralph Davis, Donald Eizenga, Daniel Ellig, Stanley Frey, Tom Kalnes, Michael McCall, Hieu (Sunny) Nguyen, James Wexler, and Randall Williams

Credit: Peter Cutts Photography

Deadline for submissions is March 1, 2017

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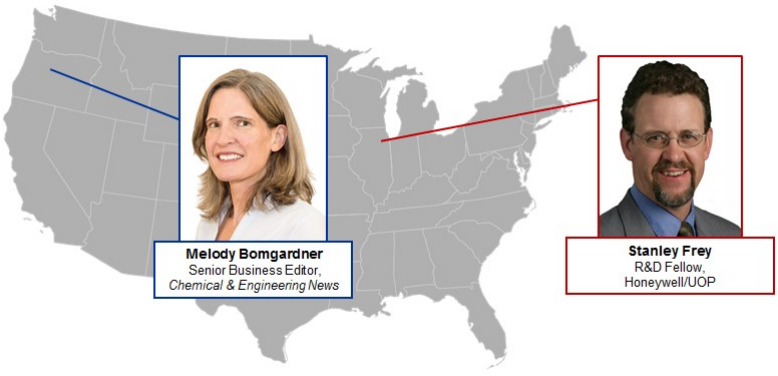
*"**The Future of Flight:** Advanced Renewable Jet Fuels"*
Session 1 of the 2017 Industry Science Series



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Stanley J Frey
R&D Fellow
Honeywell/UOP

February 2, 2017

The Future of Flight: Advanced Renewable Jet Fuels

ACS Webinar

Honeywell UOP

UOP 7200-13

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What we will talk about…

- What is a Honeywell/UOP?
- UOP's green fuel technologies for renewable transportation fuels
- Renewable Jet Fuel certification and specifications
- Ecofining and UOP Renewable Jet process and chemistry
- Commercial application status of the technology
- Feedstock expansion supported by Life Cycle Analysis

Honeywell UOP

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What is Honeywell

$38.5B
2015 sales

55%
sales outside U.S.

- 1,300 sites, 70 countries
- 132,000 employees
- Morristown, NJ headquarters
- Fortune 100

Aerospace
$15.2 billion sales

Automation and Control Solutions
$14.1 billion sales

Performance Materials and Technologies
$9.2 billion sales

Honeywell UOP

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UOP creates knowledge for the oil and gas industry

UOP technology makes more than 60% of the world's gasoline, 70% of its polyester and 90% of biodegradable detergents, and processes more than 40% of its LNG

Better Economics
UOP technologies offer a high return on investment

Continuous Innovation
Continuous technology improvement allows customer operations to remain cutting edge

Reliability
UOP technologies are among the most widely proven in the world

Expertise
UOP has a century-long record leading technology development for the oil and gas industry

- **Process Technology**
- **Catalysts**
- **Adsorbents**
- **Equipment**
- **Services**

2,500 Engineers and scientists

200 with **PhDs**

31 out of **36** refining technologies in use today were developed by **UOP**

Largest process licensing organization in the world

3,000+ Active patents

800+ R&D employees

Honeywell UOP

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UOP- A Century of Innovation

1914: Dubbs Cracking Process – *manufactured gasoline made driving affordable*

1938: High Octane Aviation Gasoline – *high-power fuels helped win the battles in World War II*

1949: Platforming™ Process – *dramatically improved yields*

1953: Synthetic Zeolites – *opened new avenues for petroleum chemistry*

1957: Zeolites for Catalytic Cracking – *another revolution in yield improvement*

1960: Unleaded Gasoline – *improved air quality*

1968: Biodegradable Detergents – *improved water quality*

1970: Automotive Catalytic Converter – *improved air quality*

1970: Parex™ Process – *efficiently produces paraxylene for polyester, resins and films*

1990: Oleflex™ Process – *building blocks of gasoline and plastic from propane and isobutane*

2006: Green Diesel Technology – *clean fuels made from inedible plants and waste oils*

2008: Green Jet Fuel Technology **and Methanol to Olefins, Uniflex™** – *Green Jet fuel from renewable sources, plastics from coal, bottom-of-barrel upgrading and*

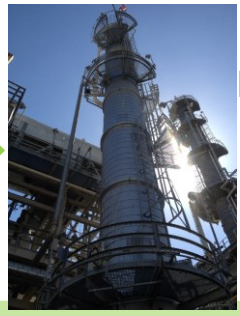
2012: Acquired Thomas Russell and Callidus Technologies – *End to End gas processing solutions and combustion equipment*

2014: UOP celebrated its 100th anniversary and licenses more than 70 processes and more than 300 catalysts to support refineries and chemical plants around the world

Continuing Innovation in Clean Fuels in the Renewable Era

Drop-in Renewable Fuels from Honeywell UOP

Plant-derived Oils
Animal Fats & Grease
Used Cooking Oil
Algal Oil



Ecofining™ Process or UOP Renewable Jet Fuel Process

Honeywell Green Diesel™

Honeywell Green Jet Fuel™ (HEFA SPK)

TheDigest 2015 Advanced Bioeconomy Awards — Process of the Year: Honeywell's UOP Green Fuels Technology

PLATTS GLOBAL ENERGY AWARDS — Industry Leader Award Biofuels

ACS Chemistry for Life® — HEROES of CHEMISTRY

Honeywell Green Jet Fuel™ 2016 Heroes of Chemistry Award

Honeywell UOP

Proven Technologies for Feedstock Flexible Drop-in Fuels

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

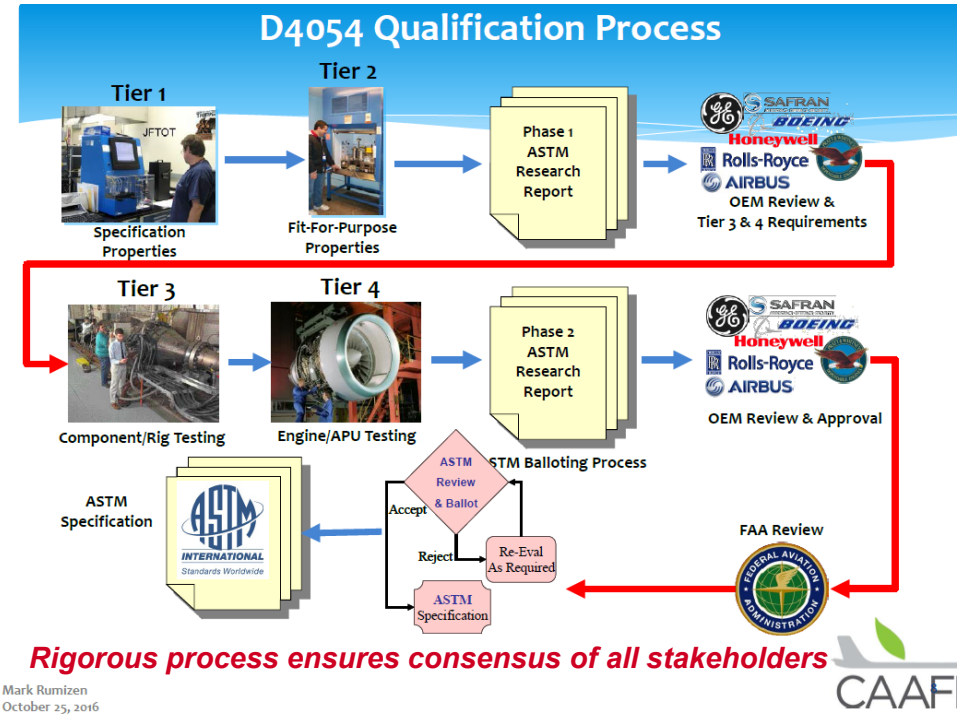
What is the best description of the typical hydrocarbon mix that constitutes turbine aviation fuel?

A) Iso-paraffins that boil between n-decane and n-heptadecane

B) Heptane to decane N-Paraffins with hydrazine and methanol combustion additives

C) Iso-paraffins, cycloparaffins and aromatics that boil between n-decane and n-heptadecane

D) Heptane to decane n-Paraffins blended with similar boiling range aromatics



Product Quality from the Ecofining and UOP Renewable Jet Fuel Processes

Honeywell Green Diesel™ also known as

- Renewable Diesel
- HVO (hydrotreated vegetable oil)
- HRD (hydrotreated renewable diesel)
- BHD (bio-hydrogenated diesel)

Properties	ULSD	FAME Biodiesel	Green Diesel
Oxygen, %	0	11	0
Cetane	40-55	50-65	75-90
Energy Density, MJ/kg	43	38	44
Specific Gravity	0.84	0.88	0.78
Sulfur, ppm	<10	< 2	< 2
Cold Flow	Baseline	Poor	Excellent
Oxidative Stability	Baseline	Poor	Excellent

Honeywell Green Jet Fuel™ also known as

- Renewable Jet
- SPK, or Bio-SPK (synthetic paraffinic kerosene)
- HRJ (hydrotreated renewable jet)
- HEFA-SPK (hydroprocessed esters and fatty acids)

Properties	Jet A-1 Spec.	50/50 Blend	Green Jet
Flash Point, °C	38 min	46	45
Freeze Point, °C	-47 max	-57	-57
Energy Density, MJ/kg	42.8 min	43.6	43.9
Density @15°C, kg/m3	Min 775 Max 840	778	761
Thermal Stability	Baseline	Excellent	Excellent
Aromatics	8 min 25 max	8.5	Nil

Drop-in Alternative Fuels, High Quality Products

Honeywell UOP

HEFA SPK unique as biofuel approved for aviation

- There are **four types** of biofuels produced today in large commercial volumes but only one that is currently approved for aviation fuel
  - **Ethanol** (not suitable for aviation)
  - **FAME** Biodiesel (not suitable for aviation)
  - **HEFA** Renewable Diesel (potentially suitable for aviation)
  - **HEFA SPK** Renewable Jet (approved for aviation)
- Honeywell UOP technology for producing HEFA SPK has been commercialized and costs of production have been reduced as expected
  - Ground transportation fuels currently offer greater incentives for producers and this must be overcome to expand the supply of renewable aviation fuels (ICAO CORSIA)
- New types of feedstocks will emerge as the demand for HEFA continues to increase
  - Must be economically competitive and sustainable

Honeywell UOP

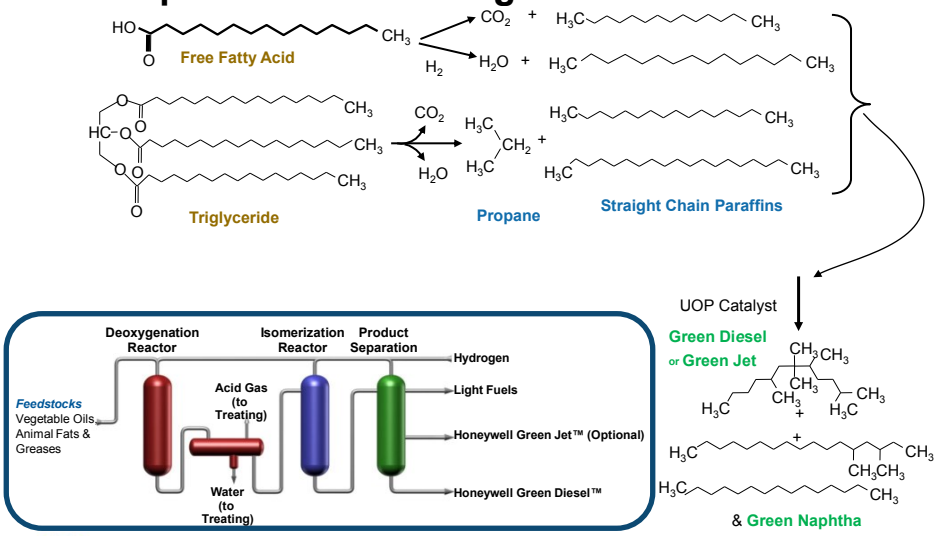
Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

How many airlines currently fly regular commercial routes with renewable jet fuel?

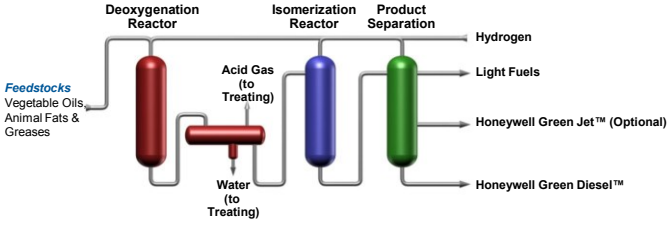
- 0
- 1
- 4
- 9
- 19

Ecofining Chemistry & Simplified Process Diagram



Honeywell UOP

Ecofining™ Process



Green Diesel Product Description

- A '**drop-in' hydrocarbon biofuel**
- **Meets ASTM D975, blends meet EN590**
- **Adjustable cold flow properties,** independent of feedstock type
- **50-90% GHG Savings relative to fossil diesel** depending upon feed source
- **Low density, high cetane** allows blending of heavier, low cetane diesel components
- **Ultra low sulfur, low NOx emissions**

Benefits

- **Reduce costs and risks of compliance** by making biofuels instead of buying them
- **Higher Margins**– utilize lower cost feeds, while producing higher value product with high yeilds
- **Optional capability to produce renewable jet**
- Strong interest from airlines to **reduce greenhouse gas emissions**
- Options to **integrate/revamp** in refineries to minimize capital costs

Commercial Scale, Proven Technology

Honeywell UOP

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Why Two Stages?

- Need to isomerize *n*-paraffins to improve cold flow properties:
  - Jet: Freeze Point (D2386)
  - Diesel: Cloud, Cold Filter Plugging Point (D2500, D6371)

	Melting Point			
	Normal Paraffins		Iso-Paraffins	
	°C	°F	°C	°F
C_9	-54	-65	-80	-113

Iso-paraffins have better cold flow properties than normal paraffins

Honeywell UOP

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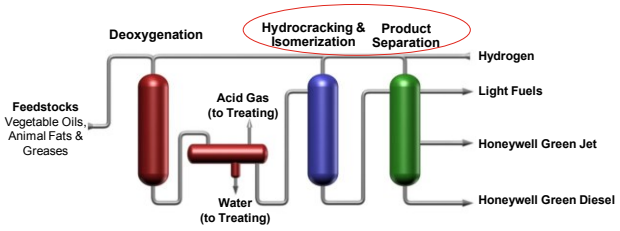
UOP Renewable Jet Fuel Process™



Green Jet Product Description

- A '**drop-in' hydrocarbon biofuel for aviation**; meets key requirements for flight
- **Certified for use in commercial aviation** via **ASTM D7566** and meets **ASTM D1655** in blends up to 50% with fossil jet
- **50-90% GHG Savings relative to fossil diesel** depending upon feed source
- **Higher energy content** compared to fossil jet fuel

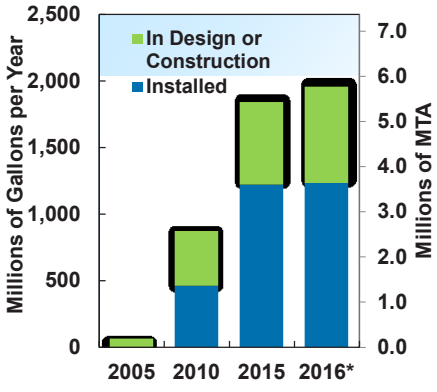
Benefits

- **Reduce costs and risks of compliance** by making biofuels instead of buying them
- **Higher Margins**– utilize lower cost feeds, while producing higher value product
- **Ability to produce jet or diesel, on demand, responding to market demands and prices**
- Strong interest from airlines to **reduce greenhouse gas emissions**
- Options to **integrate/revamp** in Refineries to minimize capita costs

Commercial Scale, Proven Technology

Progress Producing Renewable Fuels

Worldwide Capacity for HEFA type Renewable Diesel/Jet



* as of October 2016

- HEFA SPK is being commercially produced using Honeywell UOP technology and is in use in regular commercial flights
- Commercial offtake agreements
- Substantial capacity has been installed for HEFA type fuels
  - 3.7% of global biofuels demand
  - 0.2% of global diesel & jet fuel demand
  - Predominantly diesel
  - Additional capacity under design or construction
- Five aviation biofuels currently approved by ASTM International
- Additional aviation biofuels are being tested under ASTM
  - Includes testing by Honeywell of expanded HEFA

Growing supply but more capacity is needed

Honeywell UOP

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

How much more would you be willing to pay for a flight using fuel that has greater than 30% reduction (after blending with 50% petroleum jet fuel) **in GHG emissions versus pure petroleum?**

- $0
- $0 - $1 per 1000 miles
- $1 - $5 per 1000 miles
- $5 - $10 per 1000 miles
- $10 - $20 per 1000 miles

Operating Plants using UOP's Renewable Technology

Multiple Feedstock Options

- **Diamond Green Diesel**
  - Ecofining Unit at Norco, Louisiana
  - 450,000 MTA Green Diesel
  - Major expansion in progress
- **ENI**
  - Ecofining Unit at Venice, Italy
  - 400,000 MTA Green Diesel
  - 2nd project in progress
- **AltAir**
  - UOP Renewable Jet Fuel Unit at Paramount, California
  - 100,000 MTA Green Diesel and Green Jet

Commercial Production of Green Fuels Since 2013

Life Cycle Analysis

Expanding Feedstocks for Renewable Diesel/Jet Fuel Production

UOP participation in Feedstock Programs:

- USDA
  - Redesigned Oilseed Feedstocks for HEFA SPK
- Collaborations on developing and testing of new feedstock pathways
  - Algal oils
  - Cellulosic
- Biofuel Producers, Project Developers, & Feedstock Suppliers:
  - Support for oilseed crop commercialization
  - Approval of new feedstocks

Focus on expanded utilization of sustainable & economic feedstocks

Honeywell UOP

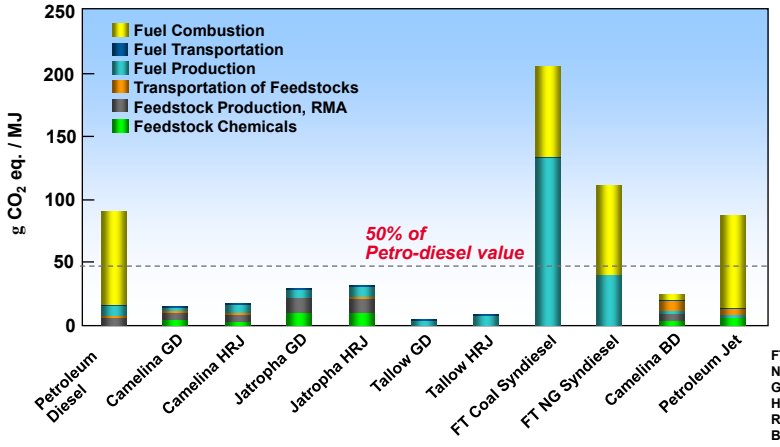
Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

What best describes your opinion of the use of biofuels as related to the environment

- It is an untapped resource that can be utilized with less environmental impact than petroleum.
- I am undecided or not informed well enough to have an opinion.
- I believe that biofuels are inherently more detrimental to the environment than petroleum.
- Biofuels have less environmental impact than petroleum use in only a few systems that have been proposed.
- Biofuels have less environmental impact than petroleum use in many systems that have been proposed.

A Common Goal- Reduce CO_2 Emissions



FT = Fischer Tropsch
NG = Natural Gas
GD = Green Diesel
HRJ = Hydrotreated Renewable Jet
BD = Biodiesel (FAME)

Source: Michigan Technological University

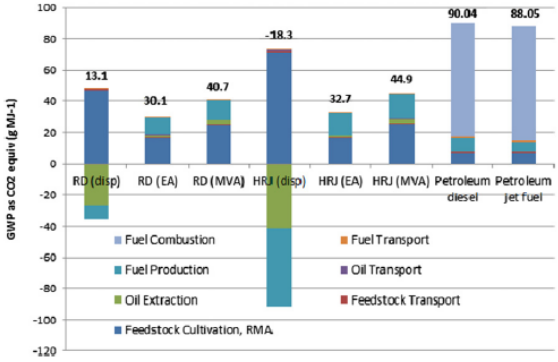
Honeywell UOP

All renewable fuel programs goals are to reduce CO2 emissions

Pennycress Life Cycle Analysis (LCA)

- Green Jet Fuel (Bio-SPK) has equal or higher energy intensity as fossil jet fuel
- No significant land use changes (LUC)
  - Pennycress displaces fallow weeds in crop rotation with corn, soybeans
  - No food production is displaced by pennycress seed cultivation
- SPK from pennycress oil yields 62% savings in GHG emissions

Greenhouse Gas (GHG) Intensity



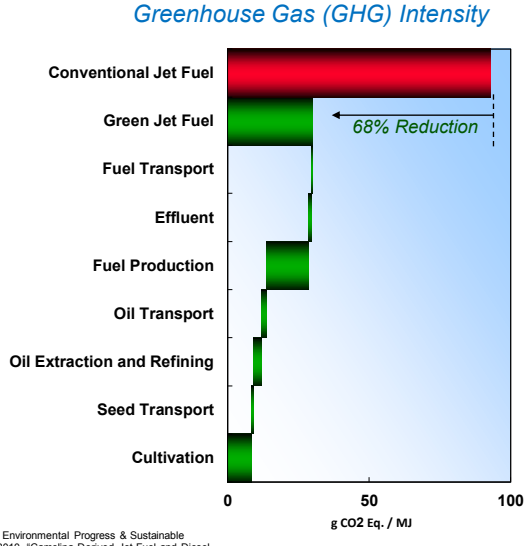
Data Source: Biomass & Bioenergy- 2013, "A life cycle assessment of pennycress (Thlaspi arvense L.)- derived jet fuel and diesel"

RD = Renewable Diesel
HRJ- Honeywell Renewable Jet

Honeywell UOP

Camelina Life Cycle Analysis (LCA)

- Green Jet Fuel (Bio-SPK) has equal or higher energy intensity as fossil jet fuel
- No significant land use changes (LUC)
  - Camelina displaces fallow weeds in crop rotation with wheat
  - No food production is displaced by camelina seed cultivation
- SPK from camelina oil yields 68% savings in GHG emissions



Data Source: Environmental Progress & Sustainable Energy- Oct 2010, "Camelina-Derived Jet Fuel and Diesel-Sustainable Advanced Biofuels"

Commercial Renewable Aviation Biofuels… Now a Reality

United Airlines is first commercial airline in U.S. to use renewable jet fuel on regular scheduled flights (started March 2016 at LAX)

Fuel provided by AltAir Fuels in first dedicated commercial production of HEFA SPK renewable jet fuel using UOP Renewable Jet Fuel Process

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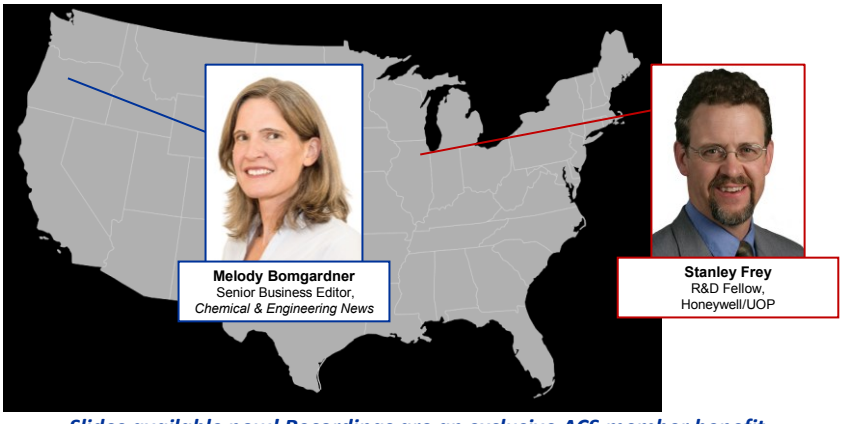

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HEROES of CHEMISTRY

The Honeywell UOP team

Chad Cavan, Ralph Davis, Donald Eizenga, Daniel Ellig, Stanley Frey, Tom Kalnes, Michael McCall, Hieu (Sunny) Nguyen, James Wexler, and Randall Williams

Credit: Peter Cutts Photography

Deadline for submissions is March 1, 2017

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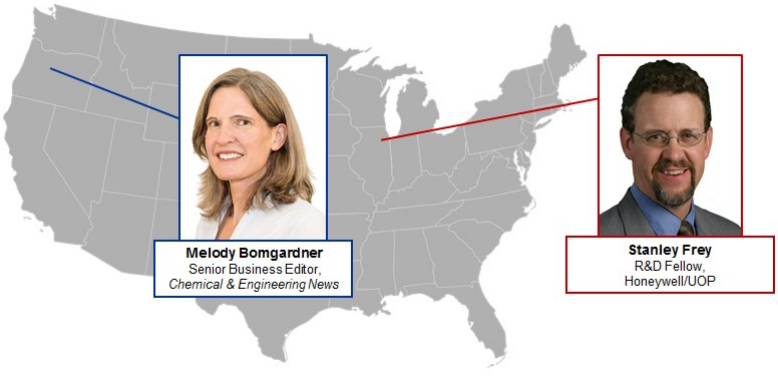

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