



# IH<sup>2</sup>® Technology: Journey to Commercialization

CAAFI Meeting  
Washington DC, 26 October 2016

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Integrated Hydrolysis & Hydroconversion  
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# Agenda Points

- Shell Commitment
- What is IH<sup>2</sup>® Technology?
- Product Quality
- Life Cycle Analysis
- Demo Progress
- Certification & Approvals Process



# Shell New Energies

## Future of Transport

A range of factors are changing the transport sector ...



Increasing demand for energy and transport

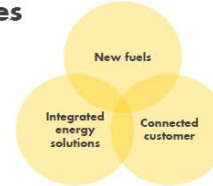
Climate change and air pollution

New technologies available

New transport policies available

## New Energies

Exploring new opportunities



- Winning company in the energy transition
- Established credentials: exploring options



### New fuels

- Cleaner transportation
- Biofuels + hydrogen

### Integrated energy solutions

- NL + USA wind
- Solar for enhanced oil recovery in Oman

### Connected customer

- Connected mobility
- Connected energy

## New Fuels

<http://reports.shell.com/investors-handbook/2015/integrated-gas/new-energies.html>



### GTL

Pioneering Gas to Liquid (GTL) technology



### Biofuels

Conventional & advanced biofuels



### Hydrogen

Active in hydrogen electric



### Electricity

Exploring a role in the charging of EVs

# What is IH<sup>2</sup>® Technology?

Feedstock agnostic  
Flexible process, integrate with refinery, pulp mill, etc  
Continuous catalytic thermochemical process  
Produces hydrocarbon transportation fuels  
Gasoline, Jet and Diesel

# Transformational

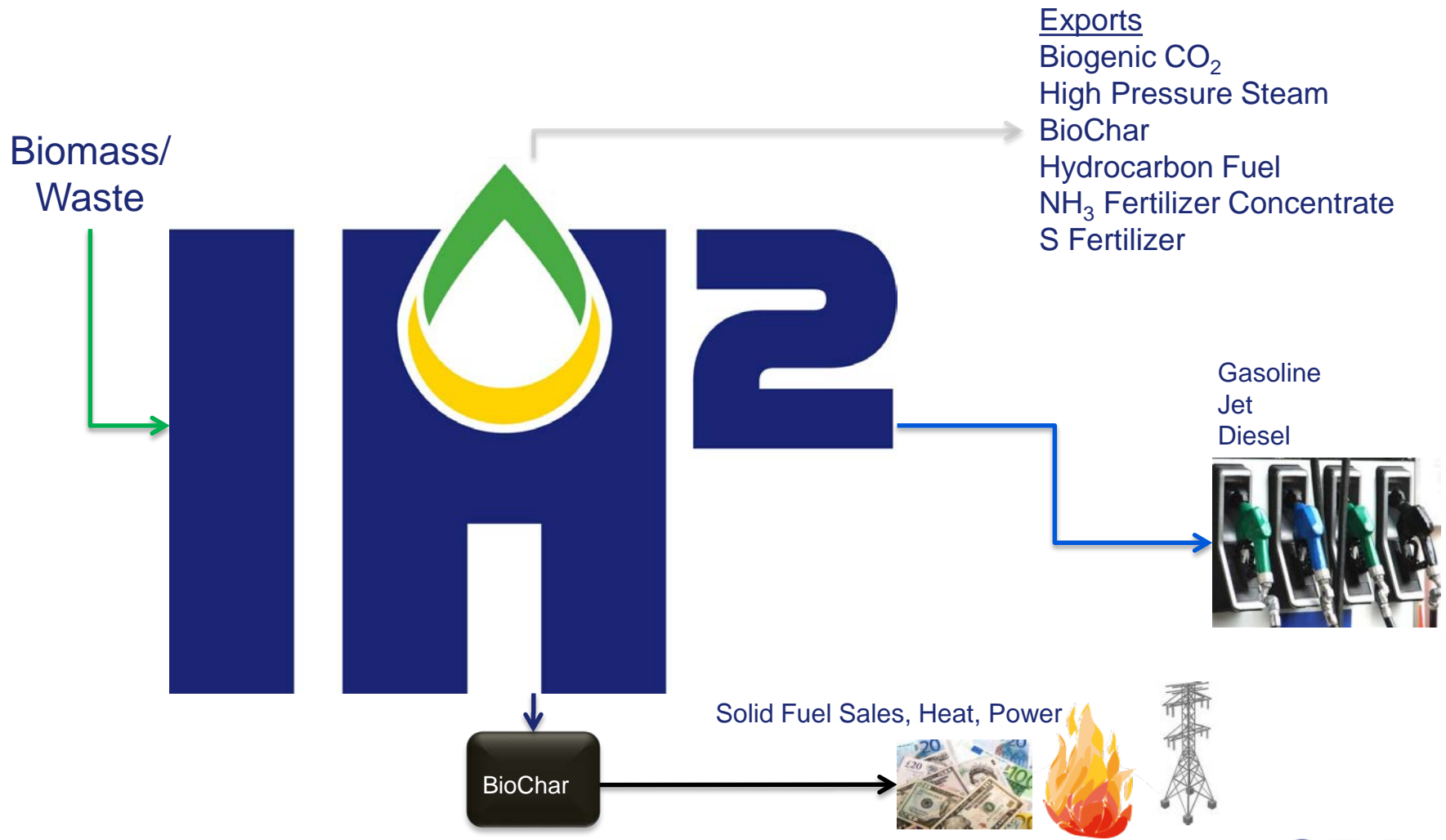
An Overly Simplified View

IH<sup>2</sup><sup>®</sup> technology takes only minutes to achieve what Nature requires millions of years to

But it does her one better by providing *refined* fuel



# At 100,000 Feet...



# Product Quality

High quality hydrocarbon transportation fuels  
Gasoline, Jet and Diesel  
Meet ASTM Road Transport Specs  
Meet Jet A/A-1 Specs



# 'Drop In' Replacement Fuels



## US - Gasoline

- **Meets ASTM D4814-16d**
- 86/87 Octane w/ E15
- S < 10-ppm
- Fully renewable (CA)RBOB

## EU – Petrol

- EN 228: Petrol – Jan 2009
- RON 87 vs 95
- S ~10-ppm
- **Blend Stock**

## World-wide Civil Jet Fuel Grade

- **Meets Jet A/A-1 Specs**
- S < 2-ppm
- Freezing Point BDL
- No naphthalenes
- Low aromatics – CPK
- Ability to allow aromatics

## US - Diesel

- **Meets ASTM D975-15c**
- Cetane Number 44
- S < 10-ppm

## EU Diesel

- EN 590:2009+A1:2010
- Cetane Number 48
- S <15-ppm
- **Blend Stock**



# A Picture is Worth...



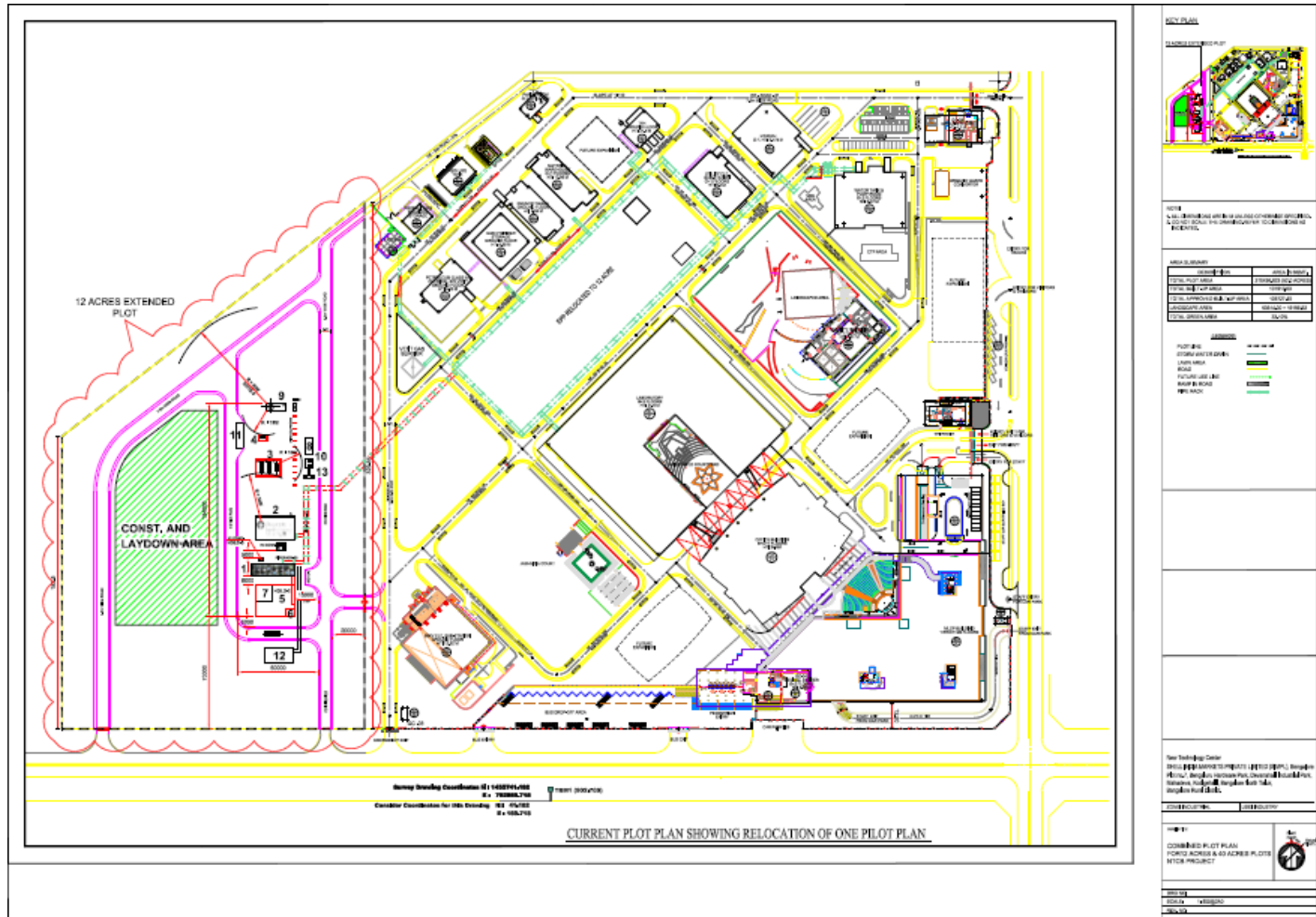
# Life Cycle Analysis

In all cases GHG reduction >60%  
Can be as high as 86.4% processing MSW

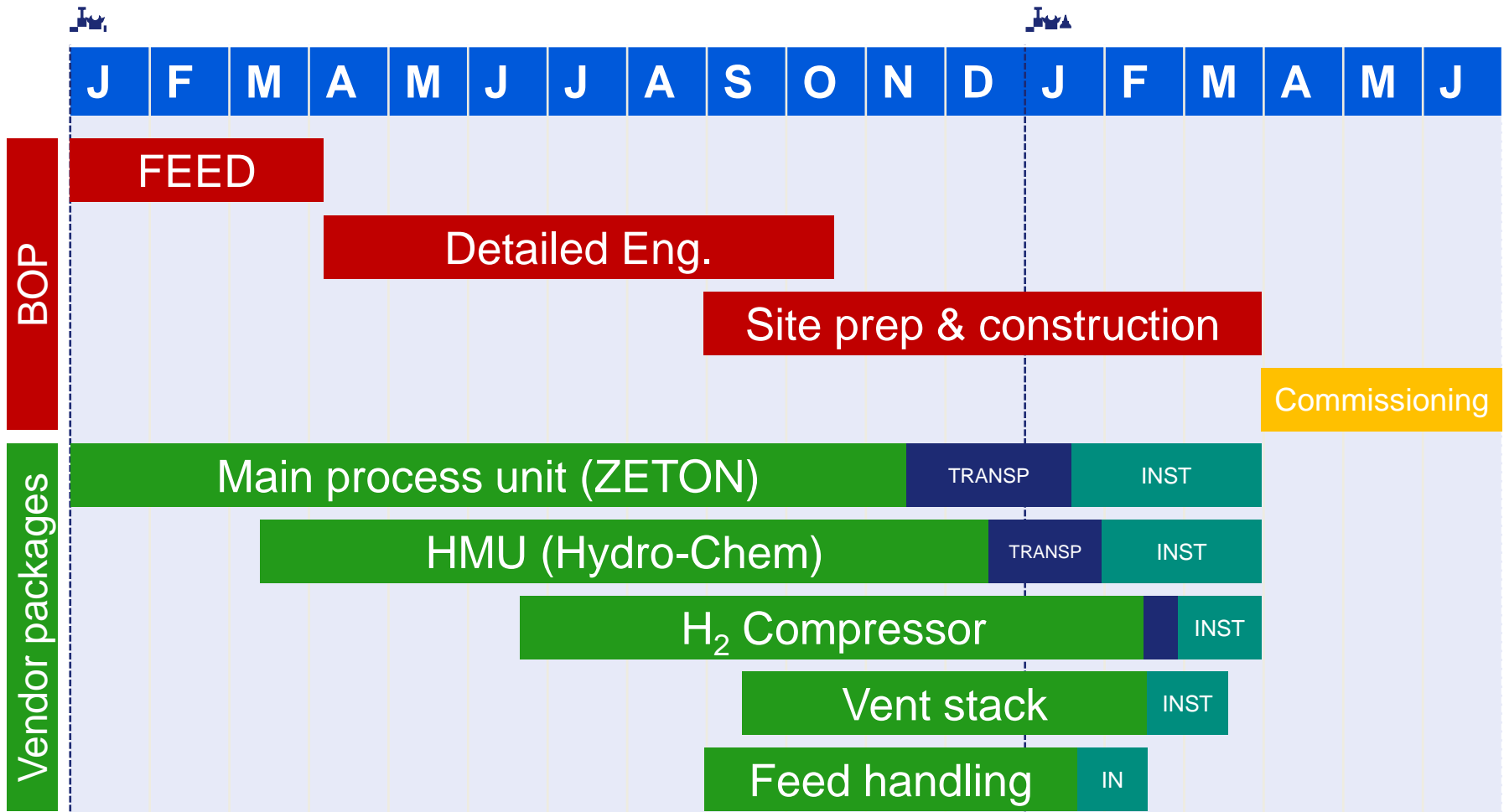
# Demo Progress

Invention by GTI in 2009  
Joint development proceeding with CRI since 2010  
~7000 hours pilot testing since 2012  
Scaled up particle sizes from multi micron to multi mm  
Scaled up process from mL/d to 20L/d  
5 tonne MAF feedstock/day scale (2000L/d)  
On target for commissioning end Q1 2017  
Demonstrates critical process elements  
All equipment commercially proven

# IH<sup>2</sup>-5000 Demo location Shell Bangalore



# IH<sup>2</sup>-5000 current high level timeline



# IH<sup>2</sup>-5000 Zeton Skid (10/19/2016)



# Fuels Certification & Registration

2014-2016 500 gallons of TLP produced at GTI on IH<sup>2</sup>-50 pilot

**1H17** EPA engine screening tests Light & Heavy Duty @ SwRI;  
**Initial jet fuel screening**

3Q17+ IH<sup>2</sup>-5000 demo TLP production

4Q17 Light & Heavy Duty EPA Testing @ SwRI

1H18 Submit SwRI engine test results to EPA

**2H18** **Large volume jet blend for aircraft testing**

2H18+ EPA registration response;  
Continued jet program

Jet approval under ASTM D7566 (50/50 blend)

Petrol approval under ASTM D4814-16d (E10 blend)

Diesel approval under ASTM D975-15c (neat)

EPA Pathway M (gasoline) and L (jet and diesel)

RINs D3 (gasoline) and D7 (jet and diesel) US market sales





# Thank You

*Learn more at*

<http://www.cricatalyst.com/catalysts/renewables.html>

*<http://www.businesswire.com/news/home/20160105005277/en/IH2-Technology-Licensed-Leading-European-Company>*

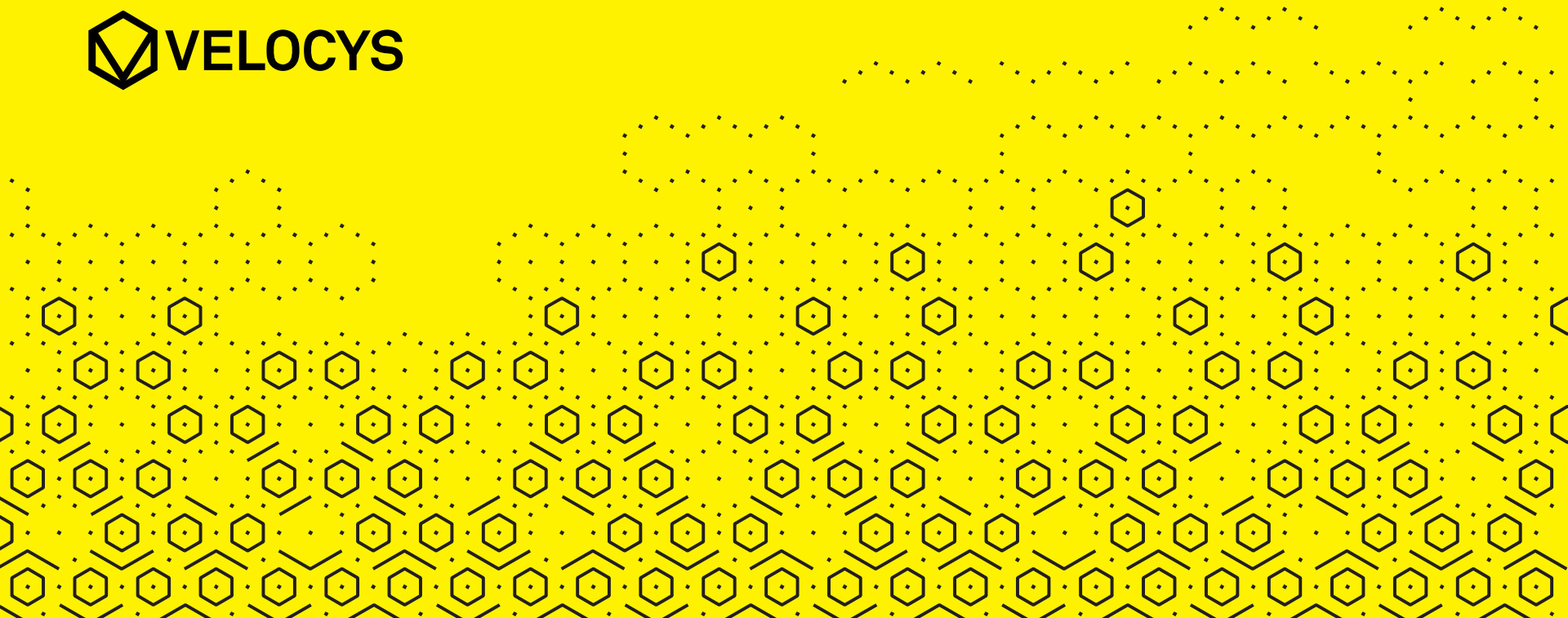
*<http://www.businesswire.com/news/home/20151211005791/en/IH2-Technology-Demonstration-Plant-Built>*

*[http://www.businesswire.com/news/home/20150330006277/en/IH2\\*-Technology-Licensed-Leading-Global-Forest-Products](http://www.businesswire.com/news/home/20150330006277/en/IH2*-Technology-Licensed-Leading-Global-Forest-Products)*

Jeff McDaniel  
CAAFI conference, October 2016

# **Smaller scale gas- and biomass-to-liquids**

A commercially available route for airlines to fulfil renewable fuels commitments



# Velocys

The company at the forefront of smaller scale gas-to-liquids (GTL) and biomass-to-liquids (BTL)

- **Leader** in smaller scale GTL and BTL
  - 15 years and >\$300 million invested in product development
  - Exhaustive and proven patent protection
- First class **partners** offering a **complete solution**
- **Commercial roll-out underway**
- One of the largest dedicated development teams in the industry
  - Commercial center in Houston, Texas; technical centers near Columbus, Ohio and Oxford, UK
  - Permanent pilot plant in Ohio, USA

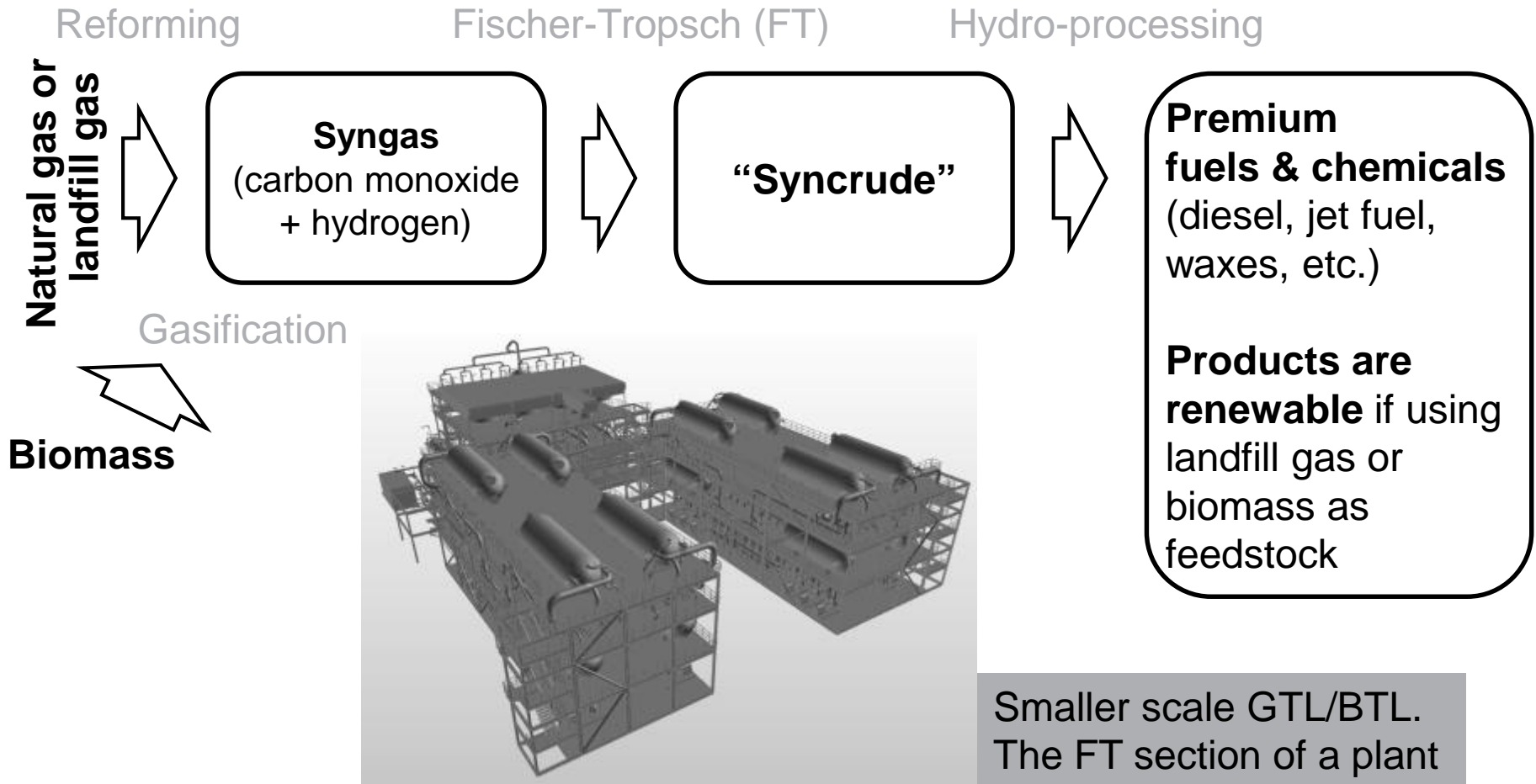


Construction complete at ENVIA Energy's GTL plant



# The GTL / BTL process using Fischer-Tropsch

## For the production of high value products



# Construction complete at ENVIA

## World's first commercial renewable FT facility



# ENVIA Energy Oklahoma City project - status

## Renewable fuel credentials

- **Construction complete**
- Pre-commissioning substantially complete
- **Commissioning underway**
  - Ensure each process system in sequence is working robustly, safely & within specification to best assure successful, safe, uneventful start-up
- **Renewable feedstock (landfill gas) co-fed** with pipeline natural gas
- Portion of fuels produced will generate Renewable Identification Number (**RIN**) **credits**



# ENVIA Energy Oklahoma City project

## Increased involvement for Velocys

- February 2016, Velocys gained
  - **Greater equity stake** in the project
  - **Greater influence** in commissioning, start-up & operations of the plant
- Highly-skilled Velocys managers, engineers & operators on site under secondment agreement with ENVIA
  - **Considerable experience** in GTL plant start-up, commissioning and performance optimisation
  - **From operating commercial large-scale GTL plants** (and VPP)
  - Serving under ENVIA Plant Manager until permanent operations team phased in as planned



Roger Harris, Senior Manager,  
Operations and Technology  
Commercialisation



Johan Malan,  
Commissioning Manager

# Red Rock Biofuels

## US DoD sponsored BTL

- **16 MMGPY** biomass-to-liquids (BTL) plant
- Located in Oregon, USA
- Will use forestry waste as feedstock
- Licensed plant agreement signed with Velocys
- FEED study complete
- **Southwest Airlines & FedEx to each offtake** 3 million gal/yr of jet fuel from the plant
- Supported by US Department of Defense and US Department of Energy
  - \$4.1m phase 1 grant for engineering
  - **\$70m construction grant**
- Targeting **final investment decision in 2016**





# Velocys FT jet fuel versus specification

Supporting delivery of drop in jet fuel – ASTM D7566 for neat synthesized paraffinic kerosene (SPK) component

Physical property	Units	Velocys FT SPK	Specification	Meets spec.
Specific gravity at 15°C	kg/l	0.76	0.73-0.77	✓
Flash point	°C, min	>38	38	✓
Freeze point	°C, max	-47	-40 (Jet A)	✓
Sulphur	% mass, max	<5	15	✓
Carbon & hydrogen	% mass, min	>99.5	99.5	✓
Composition	% max, aromatics	0.5	0.5	✓
	% max, cycloparaffins	<15	15	✓
	% paraffins	90%	Report	✓
Metals	ppm	Nil	0.1 ppm each	✓

# Fuel specifications met by FT jet fuel

- Meets Jet A and Jet A-1 for synthesized paraffinic kerosene (SPK)
  - Must be blended with conventional jet fuel at a maximum of 50%
- **“Drop in” replacement** for petroleum derived fuels, lubricants and other products
- FT route to jet fuel from municipal solid waste **reduces lifecycle greenhouse gas emissions by ~70%**
- Align with airline industries need and desire to tackle CO<sub>2</sub> emissions and sustainability
- United Airways, Cathay Pacific, Southwest Airlines, FedEx all content with the at-wing solution that FT jet fuel can deliver



# Renewable Fischer-Tropsch jet fuel projects

- Velocys and partners are developing renewable FT projects
- **Plentiful, low cost biomass** feedstocks available
  - Landfill gas
  - Woody biomass and agricultural residues
  - Municipal and industrial waste
- FT fuel products **meet all required specifications**
- **Velocys** provides **enabling technology, operational expertise** and other key resources to enable industry growth



# Thank you

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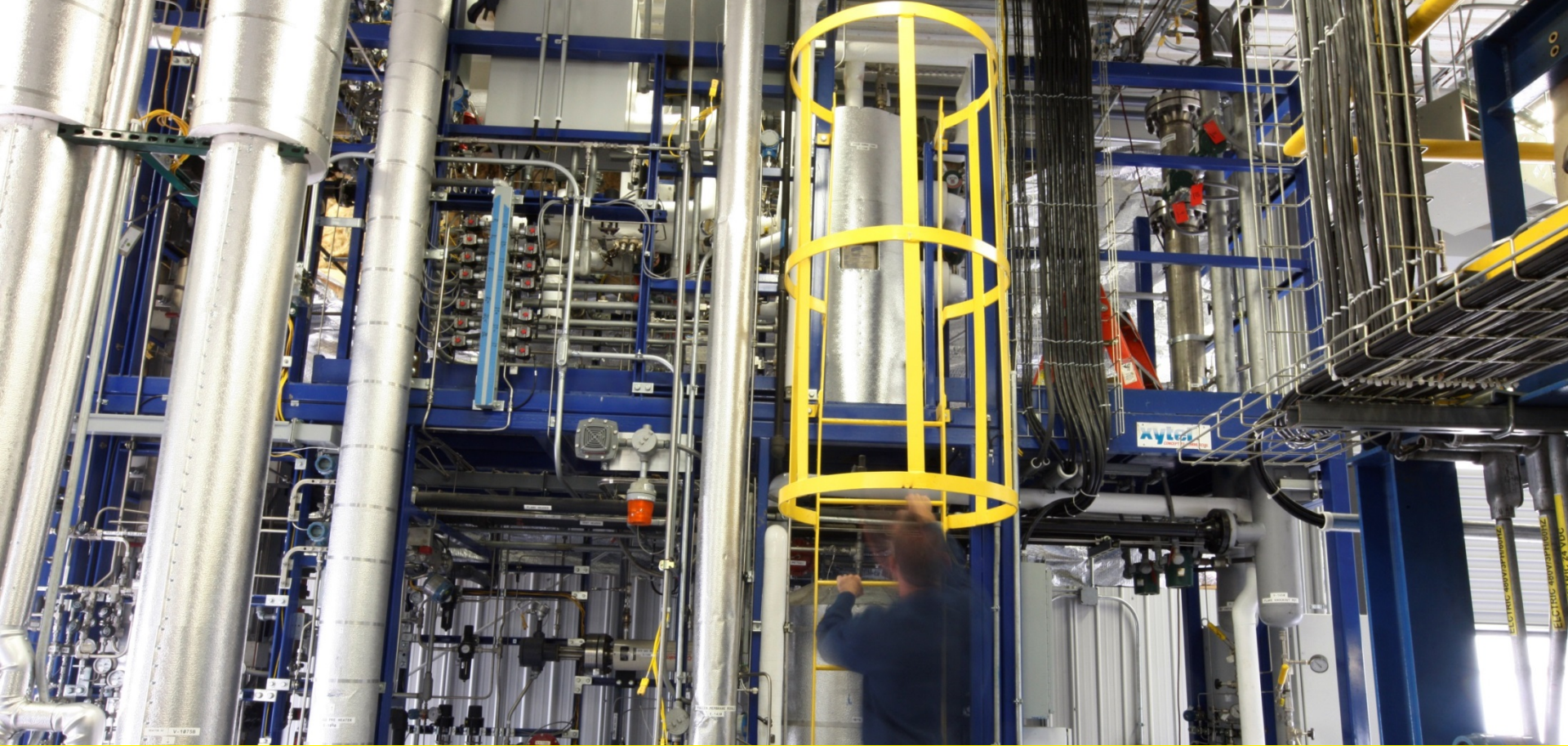
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**Think Smaller**





Dave Cepla  
Jim Andersen

## Commercialization of Aviation Biofuels

CAAFI Biennial General Meeting, Washington DC

October 26, 2016



# 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



Fuel provided by AltAir Fuels in first dedicated commercial production of HEFA SPK renewable jet fuel



**Honeywell UOP Technology Produces First Commercial Volumes of Aviation Biofuel**

# 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**



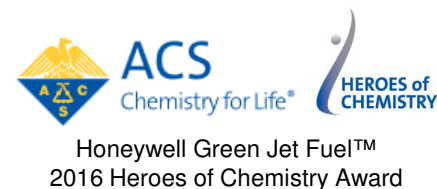
**Honeywell Green Diesel™**



**Honeywell Green Jet Fuel™  
(HEFA SPK)**



Process of the Year:  
Honeywell's UOP Green  
Fuels Technology



Honeywell Green Jet Fuel™  
2016 Heroes of Chemistry Award

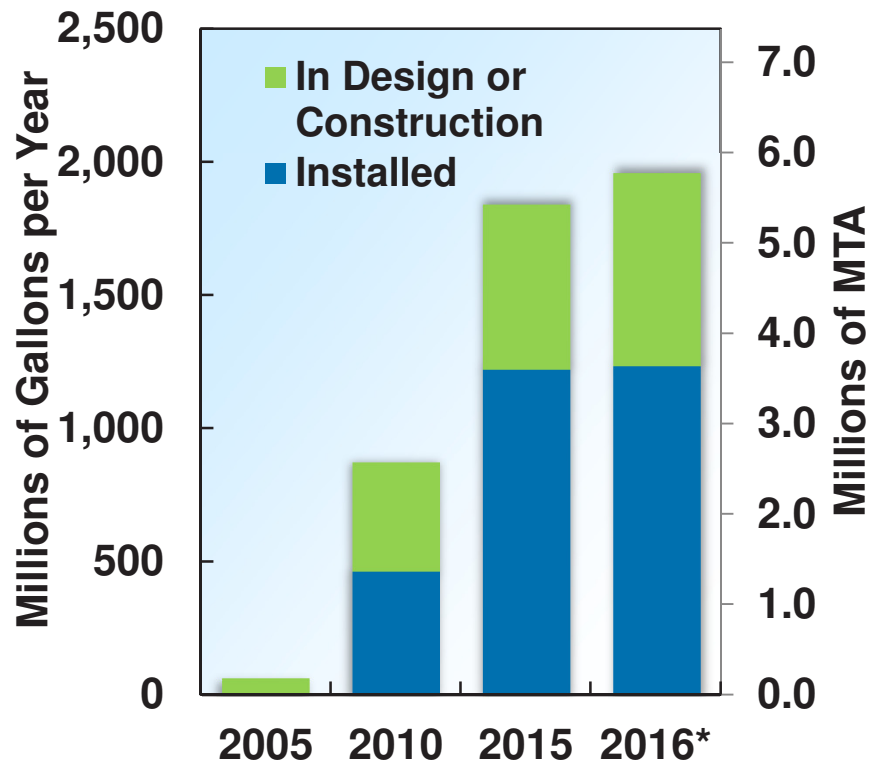
**Proven Technologies for Feedstock Flexible Drop-in Fuels**





# 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**

# 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

# Summary

- 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



**LanzaTech**

**CELEBRATING  
10 YEARS**

**From Mill to Wing: Alcohol to Jet**

**Dave Meyer  
Business Development Manager**

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**LanzaTech**  
capturing carbon. fueling growth.

# The Carbon Imperative

Energy can be  
Carbon free

Wind



Solar



Hydro



Liquid Fuels &  
Chemicals must  
contain



Efficiency  
Recycle C



***Be Carbon Smart!***



# From Waste to Wing



Flight will provide fuel performance data to help accelerate ASTM certification of ATJ production pathway



Dehydration

Oligomerization

Hydrogenation

Fractionation

ATJ-SPK  
Diesel

Ethanol



# Recycling Gases: Environmental, Economic, Social Benefit

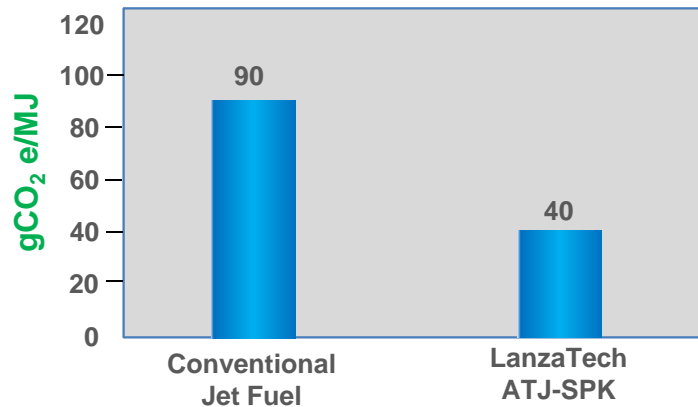
Water  
Recycle



No Land  
Biodiversity



*Life Cycle GHG Emission*



Life Cycle Analyses (LCA) for ethanol and jet fuel performed in cooperation with: Michigan Tech University, Roundtable on Sustainable Biomaterials (RSB), E4Tech, Ecofys and Tsinghua University

**50-70% GHG Reduction over Petroleum Jet Fuel**



Provides new revenue stream from waste materials



Provides energy security from sustainable, regional resources



Provides affordable options to meet growing demand



Provides economic development that creates "green jobs"



# LanzaTech ATJ Production Status



✓ 4000 gallons Jet

✓ 600 gallons Diesel

✓ Properties of neat fuel and 50% blends meet specifications





# Jet Fuel Production Status



- **Demonstrated feedstock flexibility**
  - 1,500 gal from Lanzaol
  - 2,500 gal from Grain Ethanol
- **Technical feasibility established at demo scale**
- **Lanzaol produced in an RSB-certified facility**
  - Shougang-LanzaTech 100,000 gal/yr demonstration plant in China
- **Phase 1 Research Report submitted September 2016**

Increased Run Time and Production Rate

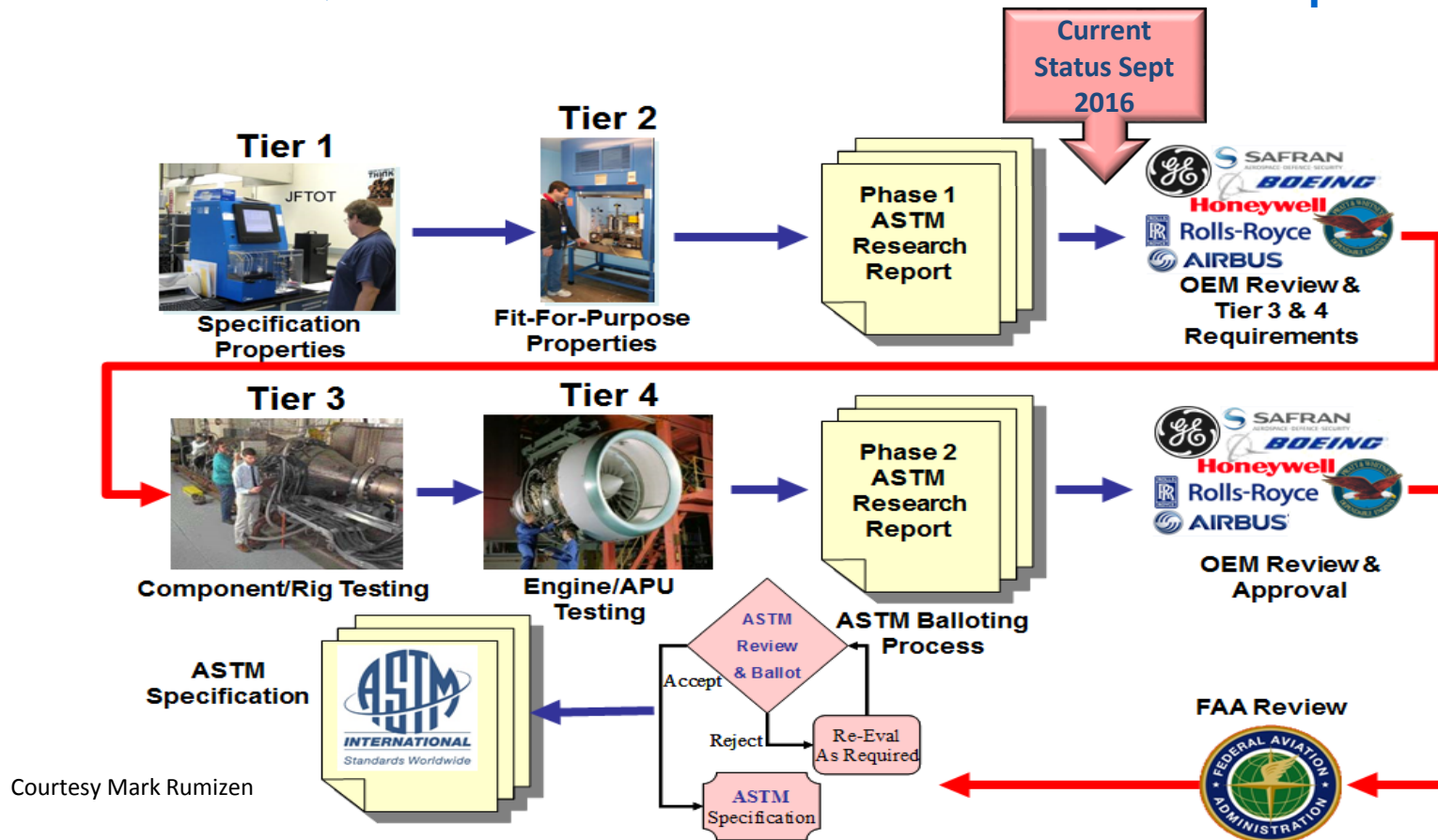
Improved Product Yield

Reduced Operating Cost

**Lower Cost Commercial Product**



# ASTM D4054 Qualification for New Aviation Fuels- Fit for Purpose Testing



Courtesy Mark Rumizen

## FFP Property Testing – Conformance with Conventional Fuels

- ✓ Hydrocarbon #, Type, Distribution
- ✓ Trace Components
- ✓ Bulk Physical, Thermodynamics, Solubility
- ✓ Electrical Properties
- ✓ Ground Handling And Safety
- ✓ Compatibility With Fuels/Additives s, elastomers

## Component And Engine Testing To Ensure No Anomalies

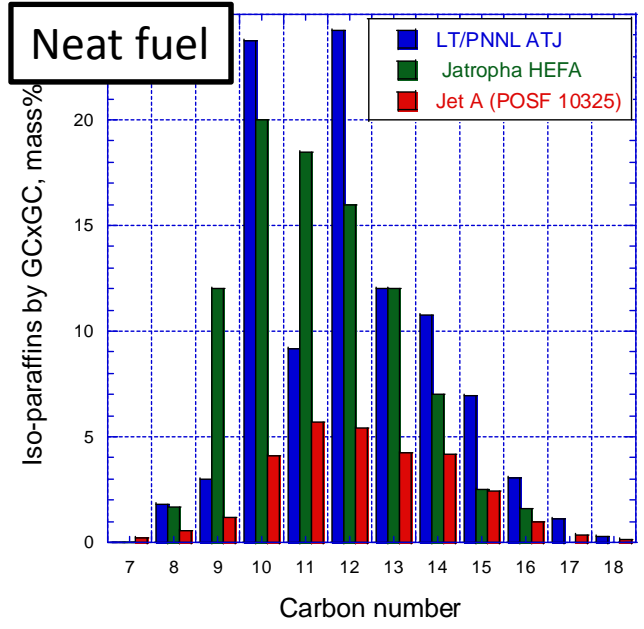
- Turbine Hot Section
- Fuel System, Combustor Rig
- Engine Test At OEM
- Compatibility with Aircraft Parts
- Test Flight

All Future Testing per Guidance from the OEM's

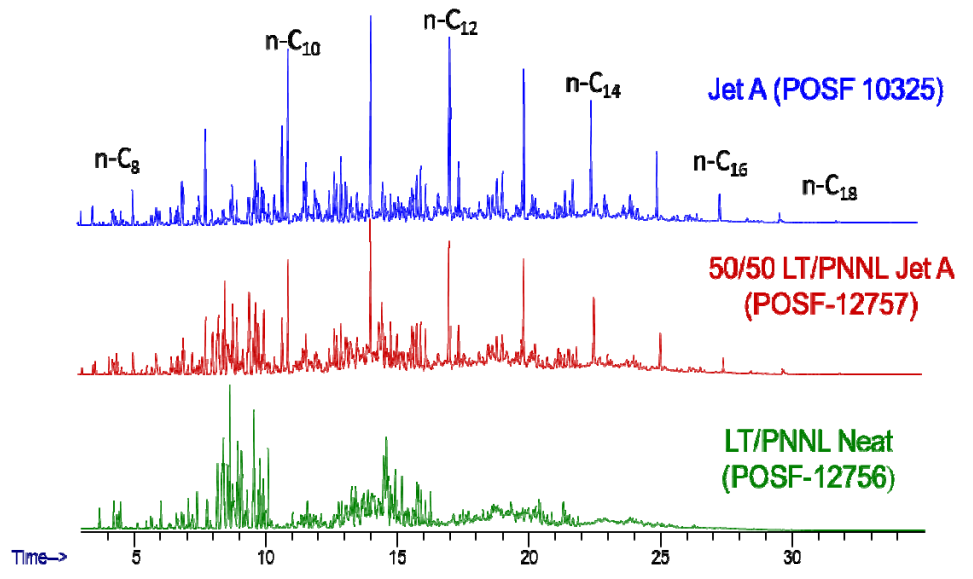
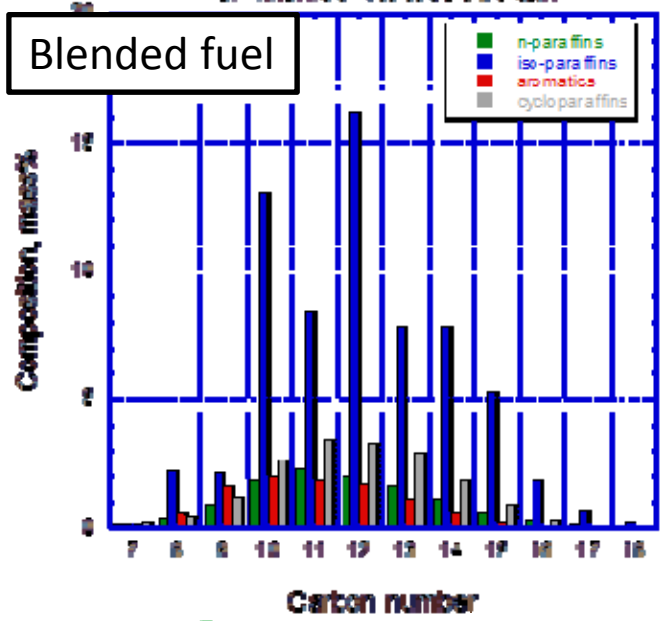


Sept 22, 2016

# Hydrocarbon Class of Lanzatech Jet Fuel Neat and Blended



	D7566 SPK Spec	Neat ATJ Fuel Lab	GRE ATJ	LZ ATJ Demo	Typical Jet A
<b>D2425 (mass %)</b>					
<b>Paraffins(normal + iso)</b>		96	97	97	48
<b>Cycloparaffins</b>	≤15	4	3	3	34
Alkylbenzenes		<0.2	<0.2	<0.2	12
Indans and Tetralins		<0.2	<0.2	<0.2	3.2
Indenes and C <sub>n</sub> H <sub>2n-10</sub>		<0.2	<0.2	<0.2	0
Naphthalene		<0.2	<0.2	<0.2	0.2
Naphthalenes		<0.2	<0.2	<0.2	2
Acenaphthenes		<0.2	<0.2	<0.2	0.2
Acenaphthylenes		<0.2	<0.2	<0.2	<0.2
Tricyclic Aromatics		<0.2	<0.2	<0.2	<0.2
<b>Total Aromatics</b>	≤0.5	<0.2	<0.2	<0.2	18



## ASTM 7566 Table A5.1 Detailed Batch Requirements for Alcohol to Jet (ATJ-SPK)

Property	Limit	ATJ-SPK spec	ATJ Lab	GRE ATJ Demo	LZ ATJ Demo	ASTM Method	
Acidity, KOH mg/g	Max	0.015	0.008	0.001	0.001	D3242	✓
Distillation Temp, °C 10% recovery ,Temp (T10)	Max	205	172	168	162	D86	✓
50 % recovery, Temp(T50)	None	Report	197	185	185	D86	✓
90 % recovery, Temp(T90)	None	Report	239	221	217	D86	✓
Final boiling point, Temp	Max	300	260	257	240	D86	✓
T90-T10, °C	Min	21	67	53	55	D86	✓
Distillation Residue,%	Max	1.5	1.2	1.1	1.1	D86	✓
Distillation Loss, %	Max	1.5	0.6	0.6	0.6	D86	✓
Flash Point, °C	Min	38	44	42	40	D56	✓
Density @ 15 °C, kg/m <sup>3</sup>	Range	730-770	761	763	759	D4052	✓
Freezing Point, °C	Max	-40	<-75	-61	-56.5	D2386	✓
Thermal Stability Temperature , °C	Min	325	>340	>340	>340	D3241	✓
Filter pressure , mm Hg	Max	25	0	0	0		✓
Tube Rating	Less than	3	1	1	1		✓

**Both Grain ethanol (GRE) and Lanzanol (LZ) Neat Fuel meet ATJ-SPK specifications**



## D7566 Table A5.2 Other Detailed Requirements; Alcohol to Jet (ATJ-SPK)

Property	Limit	ATJ-SPK spec	ATJ Lab	GRE ATJ Demo	LZ ATJ Demo	ASTM Method	
<b>Hydrocarbon Composition</b>							
Cycloparaffins, mass%	Max	15	4	3	3	D2425	✓
Aromatics, mass%	Max	0.5	<0.2	<0.2	<0.2	D2425	✓
Paraffins, mass%	None	Report	96	97	97	D2425	✓
Carbon & Hydrogen mass%	Min	99.5	99.5	99.5	99.5	D5291	✓
<b>Non-hydrocarbon Composition</b>							
Nitrogen, mg/Kg	Max	2	0.3	<0.1	<0.3	D4629	✓
Sulfur, mg/kg	Max	15	<1.0	<0.1	<0.1	D5453	✓
Water, mg/kg	Max	75	55	63	20	D6304	✓
Metals( Al, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Pd, Pt, Sn, Sr, Ti, V, Zn), mg/kg	Max	0.1 per metal	<0.1 per metal	<0.1 per metal	<0.1 per metal	D7111	✓
Halogens,mg/kg	Max	1	<1	< 1	<1	D7359	✓

**Both Grain ethanol (GRE) and Lanzanol (LZ) Neat Fuel meet ATJ-SPK specifications**



## ASTM 7566 Table 1 Detailed Requirements of Aviation Fuel Containing SPK( 50% ATJ/50% Jet A)

Property	Limit	Jet A/A-1 spec	50% ATJ Lab /50%Jet A	50%GRE Demo /50% Jet A	50%LZ Demo /50% Jet A	ASTM Method	
Acidity, KOH mg/g	Max	0.1	0.008	0.002	0.002	D3242	✓
Aromatics, vol%	Max	25	8.7	8.8	8.6	D1319, D6379	✓
Sulfur, mercaptan mass%	Max	0.003	0.000	0.001	0.001	D3227	✓
Sulfur, total mass%	Max	0.30	0.021	0.027	0.027	D5453,D2622	✓
Distillation Temp, °C 10% ,Temp (T10)	Max	205	173	177	173	D86	✓
50 %, Temp(T50) °C	None	Report	201	204	203	D86	✓
90 %, Temp(T90) °C	None	Report	243	244	241	D86	✓
Final boiling point, °C	Max	300	265	270	264	D86	✓
Distillation Residue,%	Max	1.5	1.3	1.2	1.2	D86	✓
Distillation Loss, %	Max	1.5	1.0	0.3	0.1	D86	✓
Flash Point, °C	Min	38	44	45	42	D56	✓
Density @ 15 °C, kg/m <sup>3</sup>	Range	775-840	782	782	787	D4052	✓
Freezing Point, °C	Max	-40 Jet A, -47 Jet A1	-58	-51	-51	D2386,D5972	✓
Viscosity@-20 °C mm <sup>2</sup> /sec	Max	8.0	4.4	4.7	4.5	D445	✓
Net Heat of Combustion, MJ/kg	Min	42.8	43.3	43.8	43.6	D4809	✓

**Both Grain ethanol (GRE) and Lanzanol (LZ) Blended with 50% Jet A meet D7566 specifications**



## ASTM 7566 Table 1 Detailed Requirements of Aviation Fuel Containing SPK( 50% ATJ SPK/50% Jet A)

Property	Limit	Jet A/A-1 spec	50% ATJ Lab /50%Jet A	50%GRE Demo /50% Jet A	50%LZ Demo /50% Jet A	ASTM Method	
Smoke Point, mm	Min	25.0	31.4	29.1	29.1	D1322	✓
Copper Strip, 2h 100°C	Max	No 1	1a	1a	1a	D130	✓
Thermal Stability Temperature , °C	Min	260	>325	>325	>325	D3241	✓
Filter pressure, mm Hg	Max	25	1	0	0		✓
Tube Rating	Less than	3	1	1	1		✓
Existent Gum, mg/100ml	Max	7	<1	<1	<1	D381	✓
Microseparometer Rating W/O additive	Min	85	99	100	97	D3948	✓

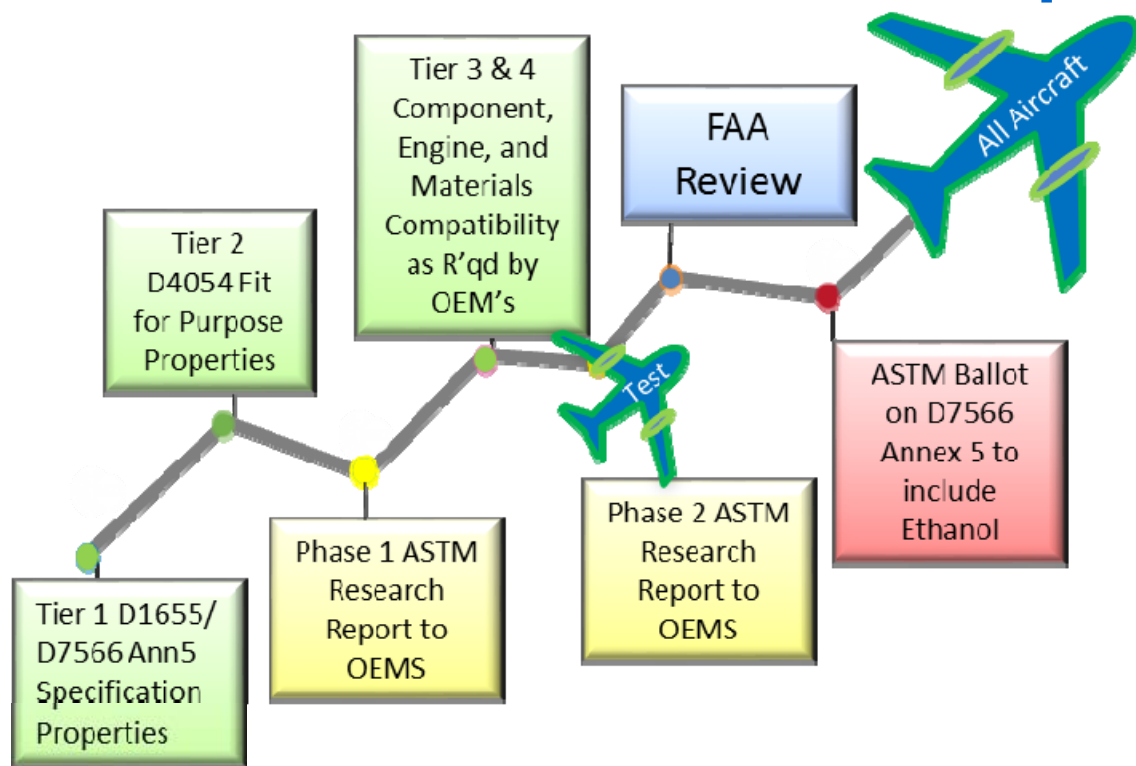
## ASTM 7566 Table 1 Part 2 Extended Requirements of Aviation Fuel Containing SPK (50% ATJ /50% Jet A)

Property	Limit	Jet A/A-1 spec	50% ATJ Lab /50%Jet A	50%GRE Demo /50% Jet A	50%LZ Demo /50% Jet A	ASTM Method	
Aromatics, vol%	Min	8, 8.4	8.7	8.8	8.6	D1319, D6379	✓
Distillation T50-10, °C	Min	15	28	27	30	D86	✓
Distillation T90-10, °C	Min	40	70	67	68	D86	✓
Lubricity, mm	Max	0.85	0.59	0.70	0.70	D5001	✓
Viscosity@-40 °C mm <sup>2</sup> /sec	Max	12	9.1	9.9	9.3	D445	✓

**Both Grain ethanol (GRE) and Lanzanol (LZ) Blended with 50% Jet A meet D7566 specifications**



# Demonstration Fuel Next Steps



- ✓ Phase 1 Report submitted to ASTM Coordinators September 2016
- ✓ Report in queue to progress through the step by step process
  - Review of Phase 1 FFP data by engine and aircraft OEMs

- On-going OEM data analysis and review to determine required Tier 3 & 4 components
  - Engine, materials compatibility, and flight demonstration data for inclusion in Phase 2 Report
- Completion of OEM review process and balloting to the ASTM membership for eventual incorporation into D7566 specification for drop-in jet fuel

*Goal: Add ethanol to isobutanol as an approved ATJ feedstock in D7566 Annex 5*

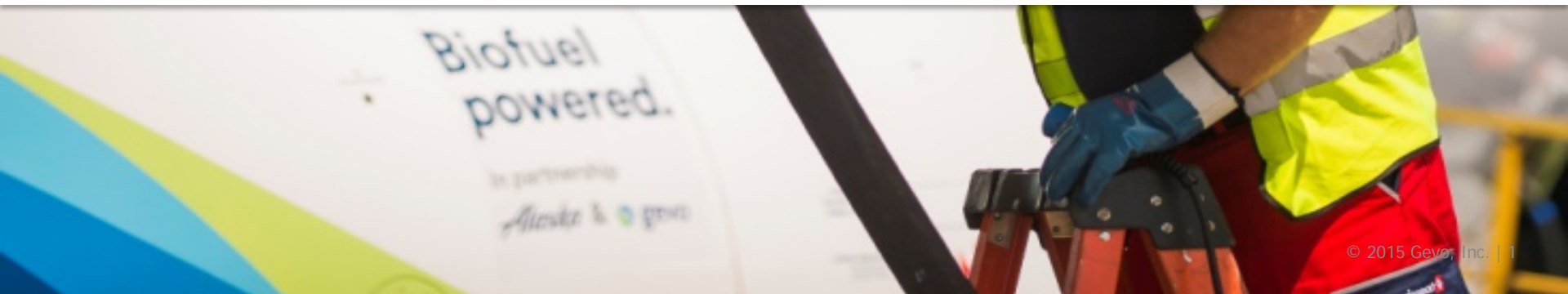






CAAFI Biennial General Meeting  
Washington, D.C.

Oct 26<sup>th</sup>, 2016



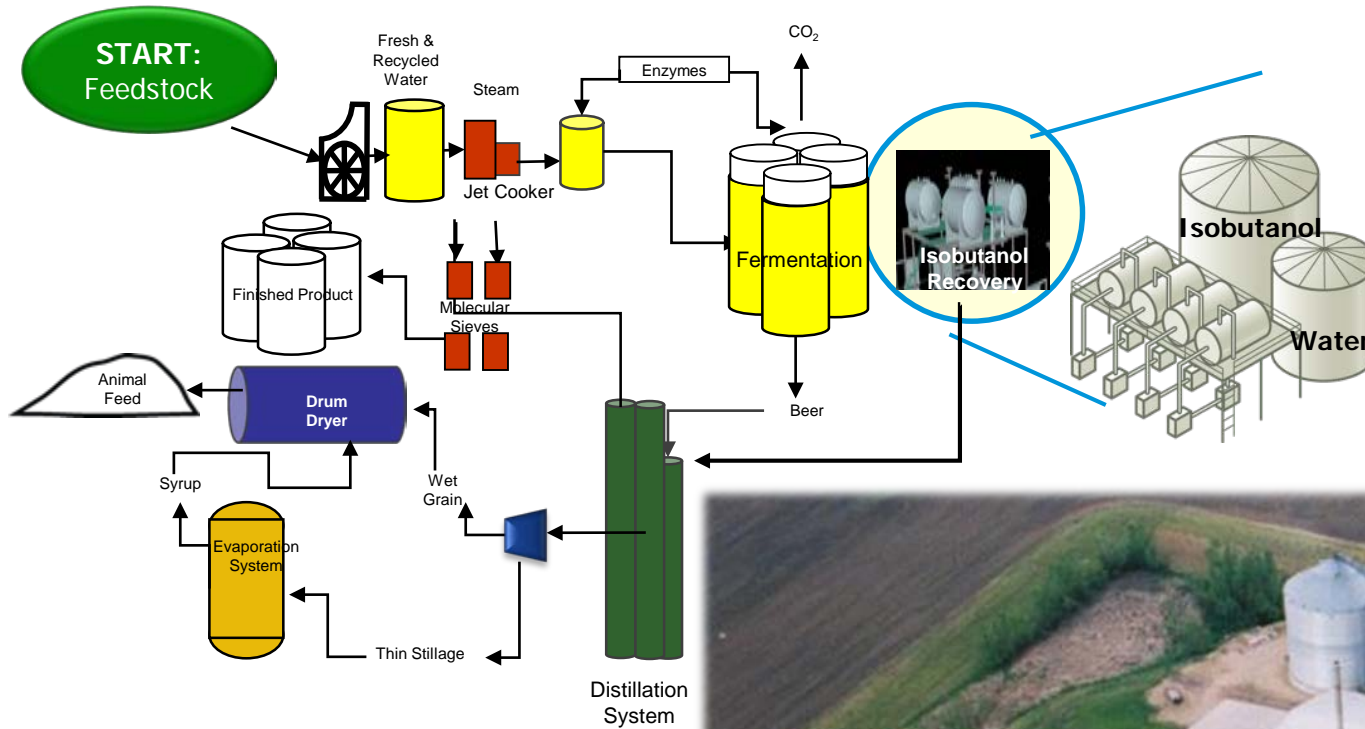
Certain statements within this presentation may constitute “forward-looking statements” within the meaning of the Private Securities Litigation Reform Act of 1995. Such statements relate to a variety of matters, including but not limited to: the timing and costs associated with and the availability of capital for Gevo’s scheduled retrofits of existing ethanol production facilities, its future isobutanol production capacity, the timing associated with bringing such capacity online, the availability of additional production volumes to seed additional market opportunities, the expected applications of isobutanol, including its use to produce renewable paraxylene, PET, isobutanol-based fuel blends for use in small engines, and ATJ bio-jet, production costs and sensitivities, capital costs and sensitivities, tax credits and RIN pricing and availability, addressable markets, and market demand, Gevo’s ability to produce commercial quantities of isobutanol from cellulosic feedstocks, the suitability of Gevo’s iDGs™ for the animal feed market, the expected cost-competitiveness and relative performance attributes of isobutanol and the products derived from it, the strength of Gevo’s intellectual property position and other statements that are not purely statements of historical fact. These forward-looking statements are made on the basis of the current beliefs, expectations and assumptions of Gevo’s management and are subject to significant risks and uncertainty. All such forward-looking statements speak only as of the date they are made, and Gevo assumes no obligation to update or revise these statements, whether as a result of new information, future events or otherwise. Although Gevo believes that the expectations reflected in these forward-looking statements are reasonable, these statements involve many risks and uncertainties that may cause actual results to differ materially from what may be expressed or implied in these forward-looking statements. For a discussion of the risks and uncertainties that could cause actual results to differ from those expressed in these forward-looking statements, as well as risks relating to the business of the company in general, see the risk disclosures in Gevo’s Annual Report on Form 10-K for the year ended December 31, 2014, and in subsequent reports on Forms 10-Q and 8-K and other filings made with the Securities and Exchange Commission by Gevo.

This presentation has been prepared solely for informational purposes and is neither an offer to purchase nor a solicitation of an offer to sell securities.



## Alcohol to Hydrocarbons

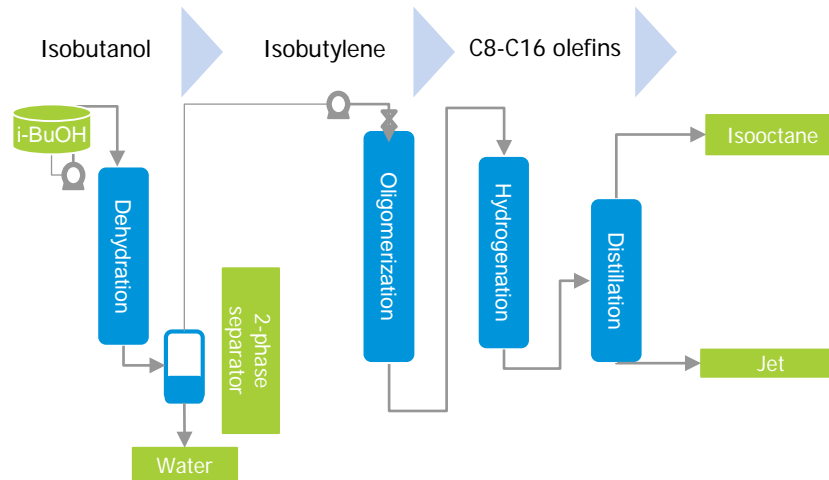
# How We Produce Isobutanol (GIFT®)



## Technology overview

- Proprietary processing based on standard unit operations leads to high yields, with minimum of co-products.
- Gevo has been producing jet fuel and isooctane since 2011.
- Simple product mix of isooctane and jet, yields at 98% of theoretical.

## Process Flow





Designation: D7566 – 16

An American National Standard

## Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons<sup>1</sup>

This standard is intended under the broad designation D7566; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last approval. A superscript symbol (1) indicates an editorial change since the last revision or approval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

### 1. Scope<sup>2</sup>

1.1 This specification covers the manufacture of aviation turbine fuel that consists of conventional and synthetic blending components.

1.2 This specification applies only at the point of batch origination, as follows:

1.2.1 Aviation turbine fuel manufactured, certified, and released to all the requirements of Table 1 of this specification (D7566), meets the requirements of Specification D1655 and shall be regarded as Specification D1655 turbine fuel. Duplicate testing is not necessary; the same data may be used for both D7566 and D1655 compliance. Once the fuel is released to this specification (D7566) the unique requirements of this specification are no longer applicable; any reclassification shall be done in accordance with Table 1 of Specification D1655.

1.2.2 Field blending of synthesized paraffinic kerosene (SPK) hydrocarbons, as described in Annex A1 (FT SPK), Annex A2 (HEPA SPK), Annex A3 (SDP), synthesized paraffinic kerosene plus aromatics (SPK/A), or Annex A5 (ATJ) as described in Annex A4 with D1655 fuel (which may be the whole or in part have originated as D7566 fuel) shall be considered batch origination in which case all of the requirements of Table 1 of this specification (D7566) apply and shall be evaluated. Short form conformance test programs commonly used to ensure transportation quality are not sufficient. The fuel shall be regarded as D1655 turbine fuel after certification and release as described in 1.2.1.

1.2.3 Once a fuel is redesignated as D1655 aviation turbine fuel, it can be handled in the same fashion as the equivalent refined D1655 aviation turbine fuel.

1.3 This specification defines specific types of aviation turbine fuel that contain synthesized hydrocarbons for civil use in the operation and certification of aircraft and describes fuel found satisfactory for the operation of aircraft and engines. The

specification is intended to be used as a standard in describing the quality of aviation turbine fuels and synthetic blending components at the place of manufacture but can be used to describe the quality of aviation turbine fuels for contractual transfer at all points in the distribution system.

1.4 This specification does not define the quality assurance testing and procedures necessary to assure that fuel in the distribution system continues to comply with this specification after batch certification. Such procedures are defined elsewhere, for example in ICAO 9977, EURO Standard 1530, JG 1, JG 2, API 1543, API 1595, and ATA-103.

1.5 This specification does not include all fuels satisfactory for aviation turbine engines. Certain equipment or conditions of use may require a wider, or require a narrower, range of characteristics than is shown by this specification.

1.6 While aviation turbine fuels defined by Table 1 of this specification can be used in applications other than aviation turbine engines, requirements for such other applications have not been considered in the development of this specification.

1.7 Synthetic blending components, synthetic fuels, and blends of synthetic fuels with conventional petroleum-derived fuels in this specification have been evaluated and approved in accordance with the principles established in Practice D4954.

1.8 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.9 This standard does not purport to address all of the safety concerns if any associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

### 2. Referenced Documents

- 2.1 ASTM Standards:<sup>3</sup>
  - D56 Test Method for Flash Point by Tag Closed Cup Tester

<sup>1</sup>For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>2</sup>A Summary of Changes section appears at the end of this standard.  
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## D7566 – 16

TABLE A4.2 Other Detailed Requirements: SPK/A<sup>1</sup>

	SPK/A	Test Method <sup>2</sup>
Min	10 <sup>3</sup>	D2426
Max	20	D2426
Min	98.8	D2426
Min	2	D4029P-079
Min	75	D2616 or IP 488
Min	15	D5616, D5622
Min	0.1 per total	SPK/A or UOP 589
Min	1	D7566

Items of Table A4.2, see 7.4 and 8.1.4.2.

Current experience with the approved synthetic fuels and is within the range of what is typical for refined jet fuel.

### JET-TO-JET SYNTHETIC PARAFFINIC KEROSENE (ATJ-SPK)

Jet synthetic paraffinic blending component for aircraft and engines. The end use for synthetic fuels is defined in this section. The end use for synthetic fuels is defined in this section. The end use for synthetic fuels is defined in this section.

ATJ-SPK is the ultimate objective of this committee to permit use of all C2 to C20 alcohols for production of ATJ-SPK, once sufficient test data is available for these other alcohols.

A5.2 Detailed Batch Requirements

A5.2.1 Each batch of synthetic blending component shall conform to the requirements prescribed in Table A5.1.

A5.2.2 Test Methods—Determine the requirements established in this annex in accordance with the following test methods.

A5.2.2.1 Density—Test Method D1298/1P 160, D4052 or IP 385.

A5.2.2.2 Distillation—Test Methods D86 or IP 123, and D2897/1P 406.

A5.2.2.3 Flash Point—Test Method D56, D3829, IP 170, or IP 525.

A5.2.2.4 Freezing Point—Test Method D5972/1P 435, D7153/1P 529, D7154/1P 528, or D2386/1P 16. Any of these test methods may be used to certify and reclassify jet fuel.

However, Test Method D2386/1P 16 is the reference method. An interlaboratory study (RR-D60-1572)<sup>3</sup> that evaluated the ability of freezing point methods to detect jet fuel contamination by diesel fuel determined that Test Methods D5972/1P 435 and D7153/1P 529 provided significantly more consistent detection of freeze point changes caused by contamination than Test Methods D7154/1P 528 and D7153/1P 529. It is recommended to certify and reclassify jet fuel using either Test Method D5972/1P 435 or Test Method D7153/1P 529, or both, on the basis of the reproducibility and cross-contamination detection reported in RR-D60-1572.<sup>3</sup> The cause of freezing point results outside specification limits by automated methods should be investigated, but such results do not disqualify the fuel from aviation use if the results from the reference method (Test Method D2386/1P 16) are within the specification limit.

A5.2.2.5 Total Acidity—Test Method D1334/1P 354.

A5.2.2.6 Thermal Stability—Test Method D3240/1P 325.

## D7566 – 16

Requirements: Alcohol-to-Jet (ATJ-SPK)<sup>1</sup>

	ATJ-SPK	Test Method <sup>2</sup>
Min	0.0%	D2426P-204
		D86 <sup>3</sup> or IP 123 <sup>3</sup>
Min	206	
		160/40
Min	300	
		21
Min	1.8	
Min	1.5	
Min	20 <sup>3</sup>	D56, D3829 <sup>3</sup> , IP 170 <sup>3</sup> or IP 525 <sup>3</sup>
Min	75 to 77 <sup>3</sup>	D7153/1P 529, D7154/1P 528, D7153/1P 529, D7154/1P 528, D7153/1P 529, D7154/1P 528, D7153/1P 529, D7154/1P 528
Min	-43	D5972/1P 435, D7153/1P 529, D7154/1P 528, D7153/1P 529, D7154/1P 528, D7153/1P 529, D7154/1P 528
Min	0.1	SPK/A or UOP 589
Min	1	D7566

Items of Table A4.2, see 7.4 and 8.1.4.2.

Current experience with the approved synthetic fuels and is within the range of what is typical for refined jet fuel.

ATJ-SPK is the ultimate objective of this committee to permit use of all C2 to C20 alcohols for production of ATJ-SPK, once sufficient test data is available for these other alcohols.

A5.2 Detailed Batch Requirements

A5.2.1 Each batch of synthetic blending component shall conform to the requirements prescribed in Table A5.1.

A5.2.2 Test Methods—Determine the requirements established in this annex in accordance with the following test methods.

A5.2.2.1 Density—Test Method D1298/1P 160, D4052 or IP 385.

A5.2.2.2 Distillation—Test Methods D86 or IP 123, and D2897/1P 406.

A5.2.2.3 Flash Point—Test Method D56, D3829, IP 170, or IP 525.

A5.2.2.4 Freezing Point—Test Method D5972/1P 435, D7153/1P 529, D7154/1P 528, or D2386/1P 16. Any of these test methods may be used to certify and reclassify jet fuel.

However, Test Method D2386/1P 16 is the reference method. An interlaboratory study (RR-D60-1572)<sup>3</sup> that evaluated the ability of freezing point methods to detect jet fuel contamination by diesel fuel determined that Test Methods D5972/1P 435 and D7153/1P 529 provided significantly more consistent detection of freeze point changes caused by contamination than Test Methods D7154/1P 528 and D7153/1P 529. It is recommended to certify and reclassify jet fuel using either Test Method D5972/1P 435 or Test Method D7153/1P 529, or both, on the basis of the reproducibility and cross-contamination detection reported in RR-D60-1572.<sup>3</sup> The cause of freezing point results outside specification limits by automated methods should be investigated, but such results do not disqualify the fuel from aviation use if the results from the reference method (Test Method D2386/1P 16) are within the specification limit.

A5.2.2.5 Total Acidity—Test Method D1334/1P 354.

A5.2.2.6 Thermal Stability—Test Method D3240/1P 325.

NARA – Northwest Advanced Renewables Alliance (Gevo is the technology supplier for fermentation and Renewable Jet) has been conducting a demonstration project to convert wood waste to jet fuel.

NARA

SUPPLY CHAIN

Northwest Advanced Renewables Alliance



FRP

## FOREST RESIDUES PREPARATION

Primary feedstock targets include forest residues from logging and thinning operations. We are also considering mill residues and discarded woody material from construction and demolition, in regions where these materials are under utilized.



T

## TRANSPORTATION

Feedstocks are transported from the collection site to a conversion facility. Chipping can take place at the loading or in a preprocessing facility.



PT

## PRE-TREATMENT

Wood chips are treated to make the sugar polymers (polysaccharides) accessible to degrading enzymes. These processes allow the lignin to be available for separation.



EH

## ENZYMATIC HYDROLYSIS

Specific enzymes are added to hydrolyze (deave) the polysaccharides and generate simple sugars (monosaccharides).



F

## FERMENTATION

Specialized yeast convert the monosaccharides into isobutanol.

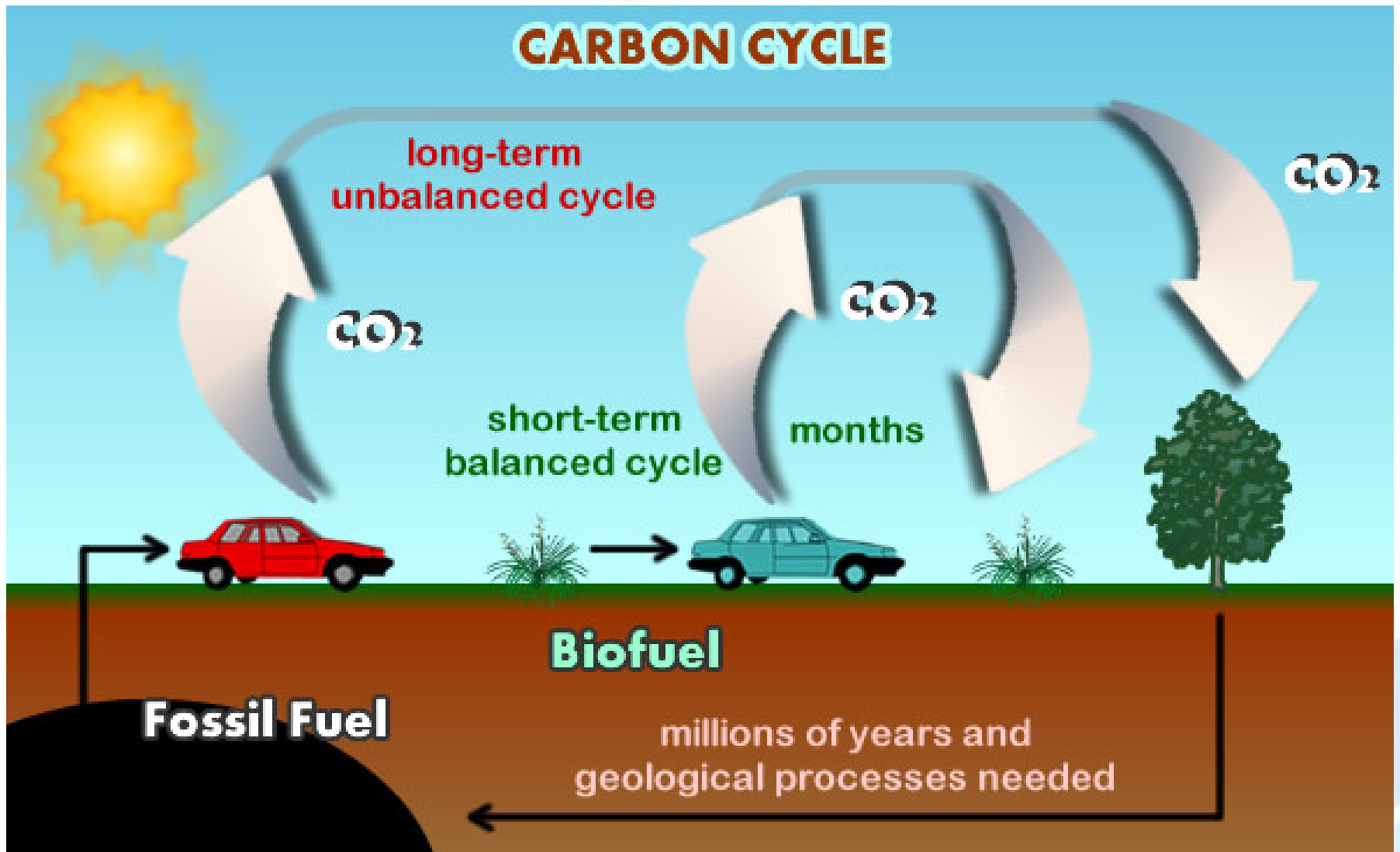


BCP

## BIOJET & CO-PRODUCTS

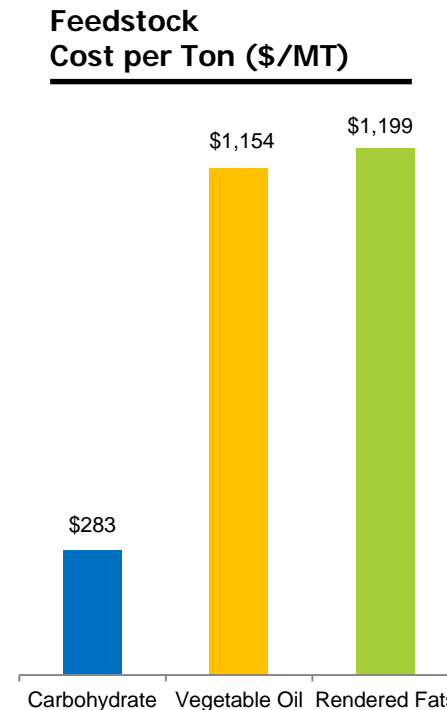
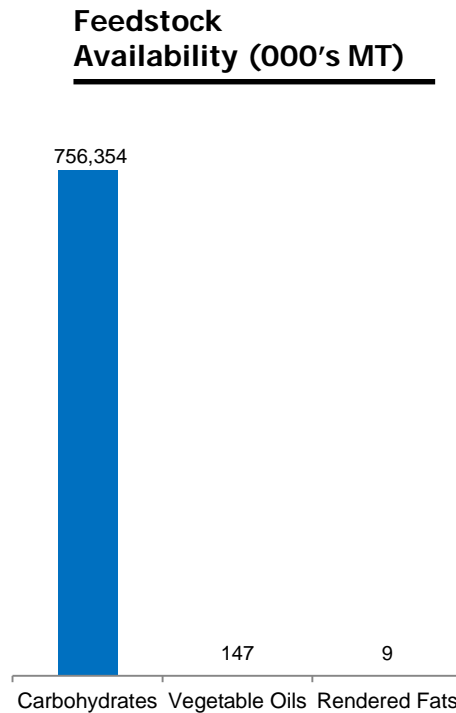
Aviation fuels can be generated from the platform molecules derived from wood sugars. Lignin can be used to generate co-products such as epoxies, structural materials and bio-based plastics. As an alternative, lignin can be burned to produce renewable energy.

## First Commercial Volume Cellulosic Renewable Jet Fuel





- The large size of the jet fuel market means large scale feedstocks are important
- Carbohydrates are significantly more abundant and cost less to obtain than other feedstocks used

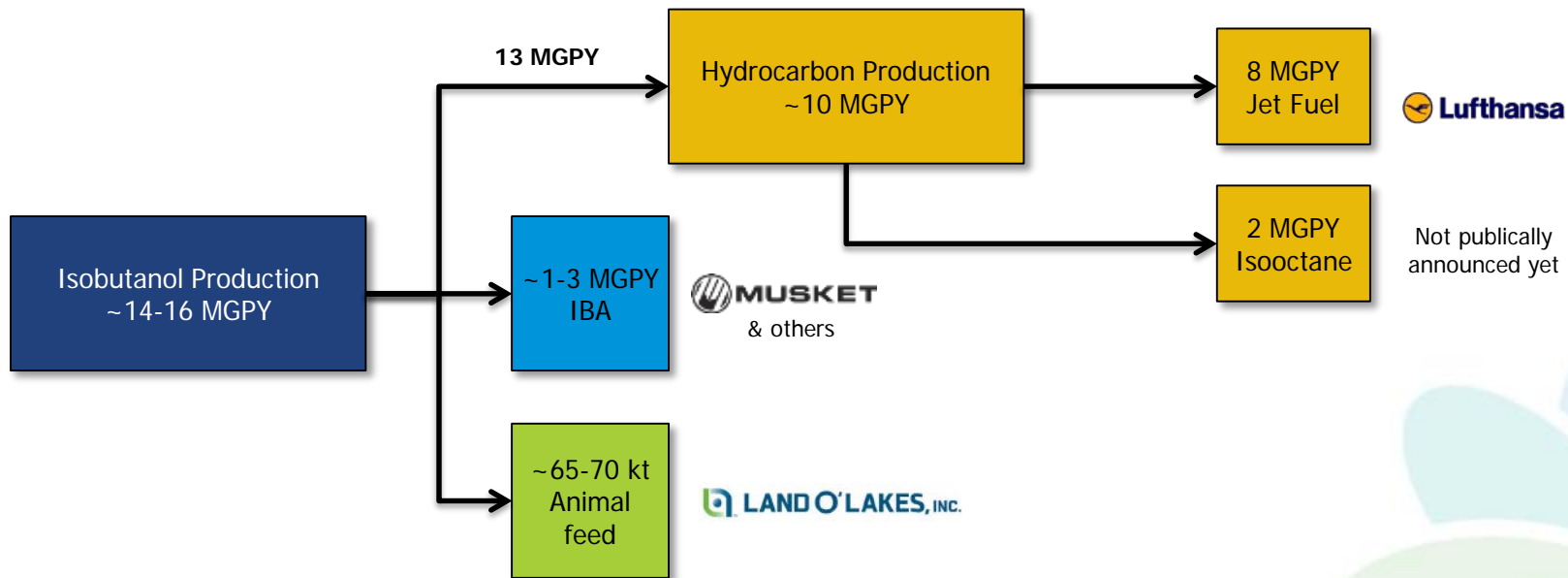


*\*Based on updated Nexant Models and engineering projections  
Assumed \$3.60/bu corn, average tallow/grease price from NRA market report*

*Source: 2010/2011 USDA Foreign Agriculture Service (FAS), NRA 2015*

- Strategy: Leverage installed assets at Luverne and adding the capability to produce 7-10 MGPY of hydrocarbons.
- Luverne is a proving ground for products and supply chain development.
- Currently completing FEL2 (Front-end loading) engineering for construction which includes robust planning and design.

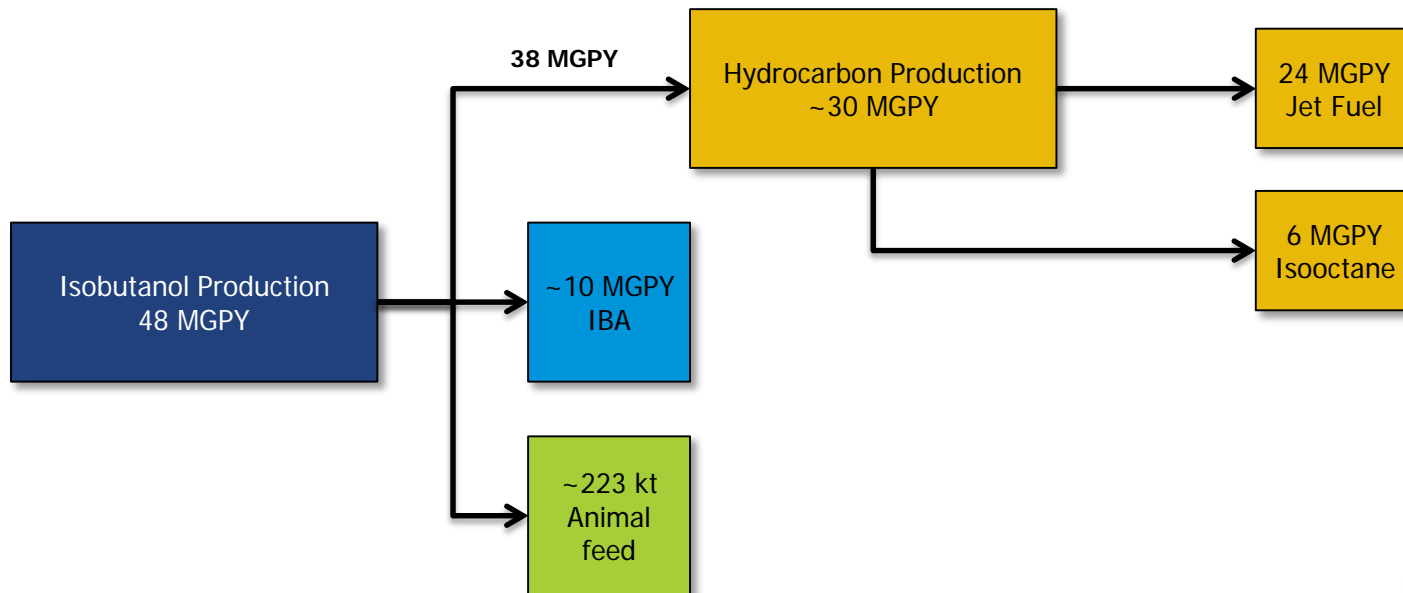
## Potential Buildout Overview



- Link term sheets of Luverne build-out to commercial build-out
- Those participating at Luverne will be advantaged for future volumes

## Commercial Buildout Overview (Beyond Luverne)

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Thank you

**Glenn Johnston**  
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