Solutions We Didn’t Know We Needed

“If I had asked people what they wanted, they would have said: FASTER HORSES...”

Henry Ford
Evolution of Go…Steam, Electricity and Coal
TODAY’S TECHNOLOGIES ARE NOT ENOUGH
NEW FEEDSTOCKS, NEW APPROACHES ARE NEEDED

INNOVATION = OPPORTUNITY
Recycling Carbon

Industrial Off Gas

✓ Steel
✓ Refining
✓ Ferroalloy

Gas Feed Stream

Compression → Fermentation → Recovery → Product Tank

Proprietary Microbe

LanzaTech

capturing carbon. fueling growth.
Building a Technology Platform

Gas Feed Stream

Gas Reception  Compression  Fermentation  Recovery  Product Tank

Hydrocarbon Fuels
- Propanol
- Butanol
- Ethanol
- Butanediol
- Nylon
- Acrylonitrile Butadiene Styrene (ABS)

Butanol

Ethanol

Butanediol

Nylon

Acrylonitrile Butadiene Styrene (ABS)
New Technology is Not for the Faint of Heart

Multiple Demo plants at various scales; >60,000 hours operation

Commercial Scale-up Factor Less Than What Has Been Proven at Demo Site
Commercial Scale Facilities

Caofeidian, China
16M gallons/year
2017

Gent, Belgium
21M gallons/year
2018
Commercial Scale Beyond Steel

Hayrana, India
13M gallons/year
Refinery offgas
2019

Modesto, California
8M gallons/year
Biomass Syngas
2018
Getting a New Fuel to Market

Chemical Synthesis

Ethanol

Diesel & Jet Fuel

HSBC

Virgin Atlantic

Boeing

GE

U.S. Department of Energy

Energy Efficiency & Renewable Energy

Pacific Northwest National Laboratory

LanzaTech: capturing carbon, fueling growth.
LanzaTech Jet Fuel Production

- Demonstrated feedstock flexibility
  - 1,500 gal from Lanzanol
  - 2,500 gal from Grain Ethanol

- Lanzanol produced in an RSB-certified facility
  - Shougang-LanzaTech 100,000 gal/yr China demonstration plant

✅ 4000 gallons Jet
✅ 600 gallons Diesel

Increased Run Time and Production Rate
Improved Product Yield
Reduced Operating Cost

Lower Cost Commercial Product
Qualification of Alternative Jet Fuels

Alternative Jet Fuels qualified through a rigorous process of testing and review by engine and aircraft OEMs.

Mark Rumizen, FAA. “Alternative Jet Fuel (AFJ) Certification” ICAO Seminar on Alternative Fuels (Montreal), February 8-9, 2017
Great Progress on AJF Qualification

“Less than a decade ago, the prospect of flying commercial aircraft on sustainable aviation fuels (SAF) seemed unrealistic due to the associated technical and safety challenges, the developments have been impressive!” IATA Roadmap

<table>
<thead>
<tr>
<th>Type</th>
<th>ASTM approval</th>
<th>When</th>
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</thead>
<tbody>
<tr>
<td>Fischer Tropsch (FT) (or BtL)</td>
<td>Max 50% blend</td>
<td>2009</td>
</tr>
<tr>
<td>Hydrotreated Esters and Fatty Acids (HEFA)</td>
<td>Max 50% blend</td>
<td>2011</td>
</tr>
<tr>
<td>Renewable Synthesized Iso-Paraffinic (SIP)</td>
<td>Max 10% blend</td>
<td>2014</td>
</tr>
<tr>
<td>FT-SPK/A</td>
<td>Max 50% blend</td>
<td>2015</td>
</tr>
<tr>
<td>Butanol to Jet Fuel (ATJ)</td>
<td>Max 30% blend</td>
<td>2016</td>
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...but qualification requires large volumes of fuel plus time, cost and effort by all parties
A Model to Expedite Qualification

Mark Rumizen, FAA. “Alternative Jet Fuel (AFJ) Certification” ICAO Seminar on Alternative Fuels (Montreal), February 8-9, 2017
What is Required for Success from a Producer’s Perspective?

- Technology-neutral, performance-based standards for new fuels and fuel components
- Clear process and data requirements for qualifying new fuels and additives in the context of current and future engines
- Structure and resources for stakeholder engagement (fuel producers, engine and vehicle OEMs, government agencies)
- Technology-neutral regulatory framework(s) that can encompass new fuels and additives without legislative change

All elements must be in place with sufficient lead time to provide certainty for investment in scale-up and commercial deployment
TECHNOLOGY NEUTRALITY IS KEY

All Headed in Same Direction

CAN’T PREDICT DISRUPTION

TECHNOLOGY NEUTRALITY IS KEY