From Mill to Wing: A Sustainable Pathway To Drop-In Fuels

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LanzaTech

Company Profile

LanzaTech

- **Founded in January 2005**
- **Corporate Headquarters in Chicago, IL, R&D in New Zealand, Operations and BD office in China**
- **Funding**
  - Series A: Khosla Ventures - $US 12M in 2007
  - Series B: Qiming Ventures - $US 18M in 2010
  - Series C: Burrill MLSF - $US 56M in 2011
- **Team**

  CSO/Founder: Dr. Sean Simpson

  CEO: Dr. Jennifer Holmgren
  - Over 140 staff
    - Synthetic Biology
    - Analytical
    - Engineering
- **IP Portfolio**
  - >160 Patents filed
  - 6 proprietary microbe families

The LanzaTech Process

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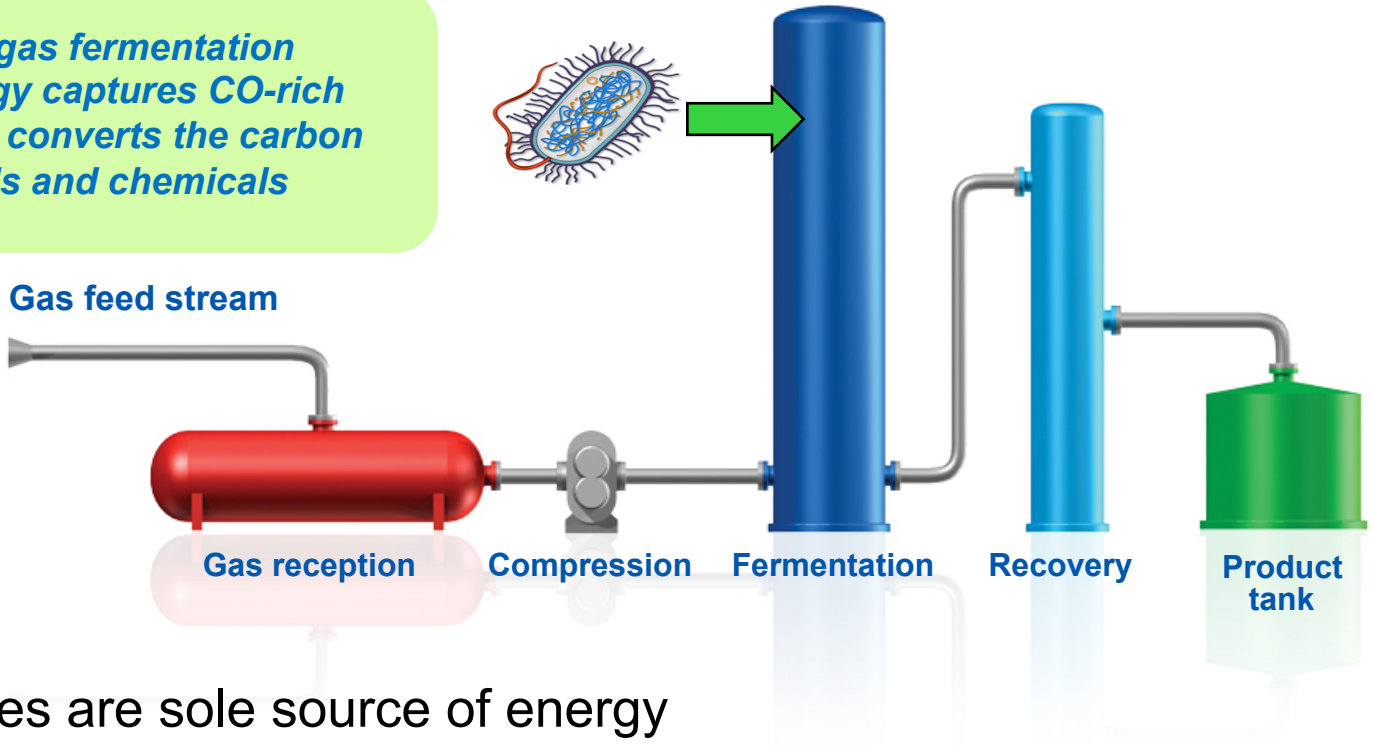
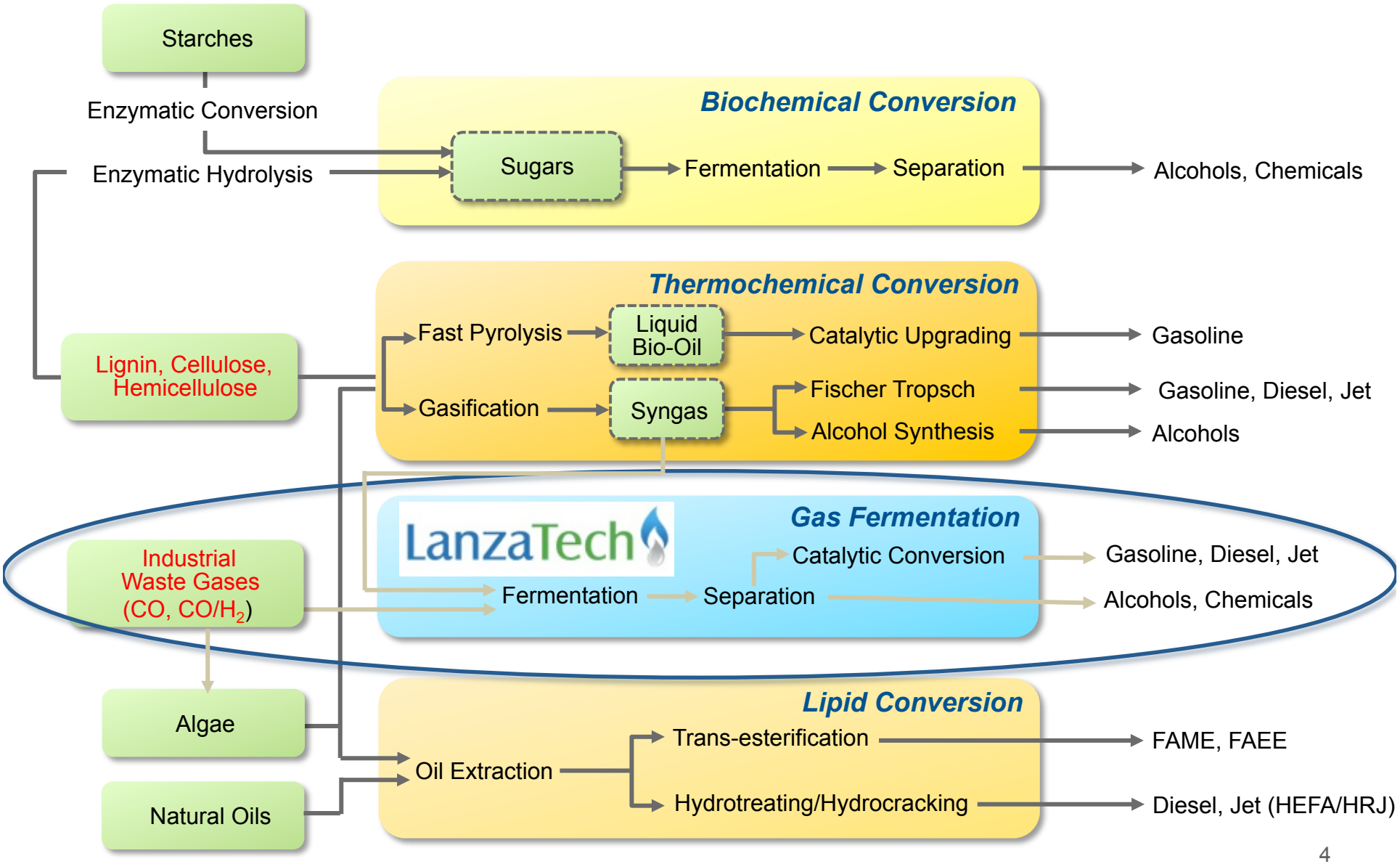
Novel gas fermentation technology captures CO-rich gases and converts the carbon to fuels and chemicals



- Gases are sole source of energy
- Production of fuels and chemicals
- Potential to make material impact on the future energy pool (>100s of billions of gallons per year)
- Completely outside of the food value chain
- Biofuel, carbon capture and energy efficiency technology solution

Diverse Pathways to Drop-In Fuels



LanzaTech Gas to Liquid Platform

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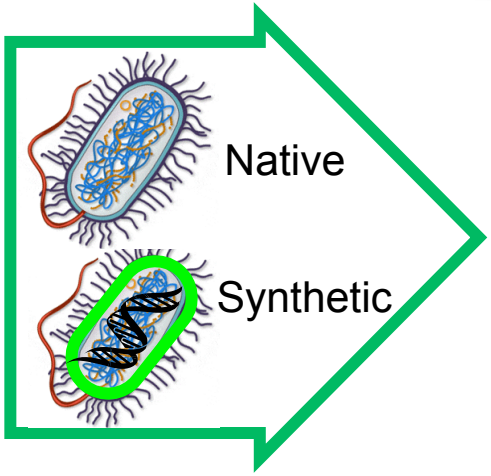
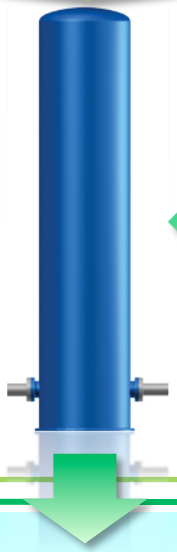
Resources

- CO — Industrial
- CO / H_2 — Syngas: Biomass, Coal, Methane
- H_2 / CO_2 — COG, Chemical
- CO_2 — Power

Customized Catalysts





Engineering
Control
Chemistry

Product Suite

C_2	C_3	C_4	C_5	*Other*
• Ethanol • Acetic acid	• *i*-propanol • acetone	• BDO • *n*-Butanol • *i*-Butanol • Succinic acid	• Isoprene	• PHB • …….

Thermochemical Approaches

Product Suite

- Hydrocarbon Fuels (diesel, jet, gasoline)
- Chemical Intermediates
- Olefins
- Chemicals

On a Fast Path to Commercialization

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2008

Pilot
BlueScope Steel Mill

BAOSTEEL

2012

Operational

Freedom Pines Biorefinery

In Design
US

MSW In Design

首钢集团 SHOUGANG GROUP

Groundbreaking
February 27
China

2012

Getting to Scale

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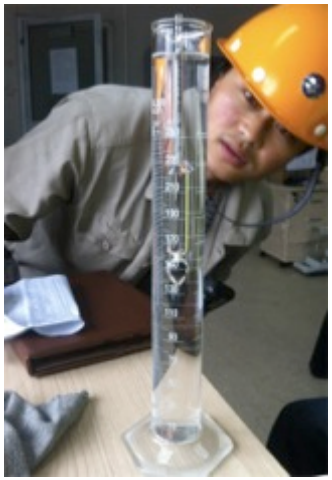
LanzaTech BAOSTEEL



LanzaTech Global Partnerships

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Creating Value through Diversification

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Industry	Partners/Projects	End User/Markets
Steel	posco, BAOSTEEL, 首钢集团 SHOUGANG GROUP, HARSCO, JINDAL STEEL & POWER, BLUESCOPE STEEL	virgin atlantic, BOEING
Oil/Natural Gas	इंडियनऑयल IndianOil, PETRONAS	Mitsui, PETRONAS, इंडियनऑयल IndianOil
Coal	HNCC, 兖矿集团 WWW.YKJT.CN	
Biomass	Freedom Pines Biorefinery	INVISTA
Chemicals	LCY, INVISTA, GLOBAL BIOENERGIES	LCY

Specific Drivers for Aviation Biofuels

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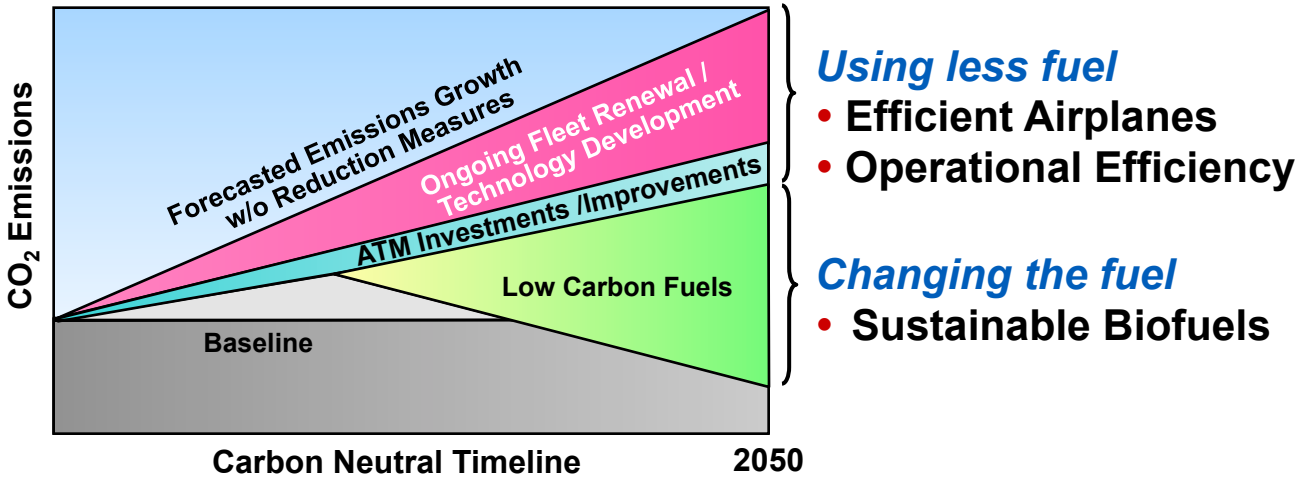
- Commercial aviation commitments to carbon neutral growth
  - Visibility of aviation industry dictates sustainability is a key factor
  - European ETS dictates C reductions starting in 2012
- US Defense Sector commitments
  - Air Force: 50% of all domestic aircraft running on 50/50 blend by 2016
  - Navy: 50% of all systems running on alternatives by 2020
- Global jet fuel consumption (2008)
  - 5 M bpd or 80 B gpy
  - US Military: 0.3 M bpd or 4.5 B gpy

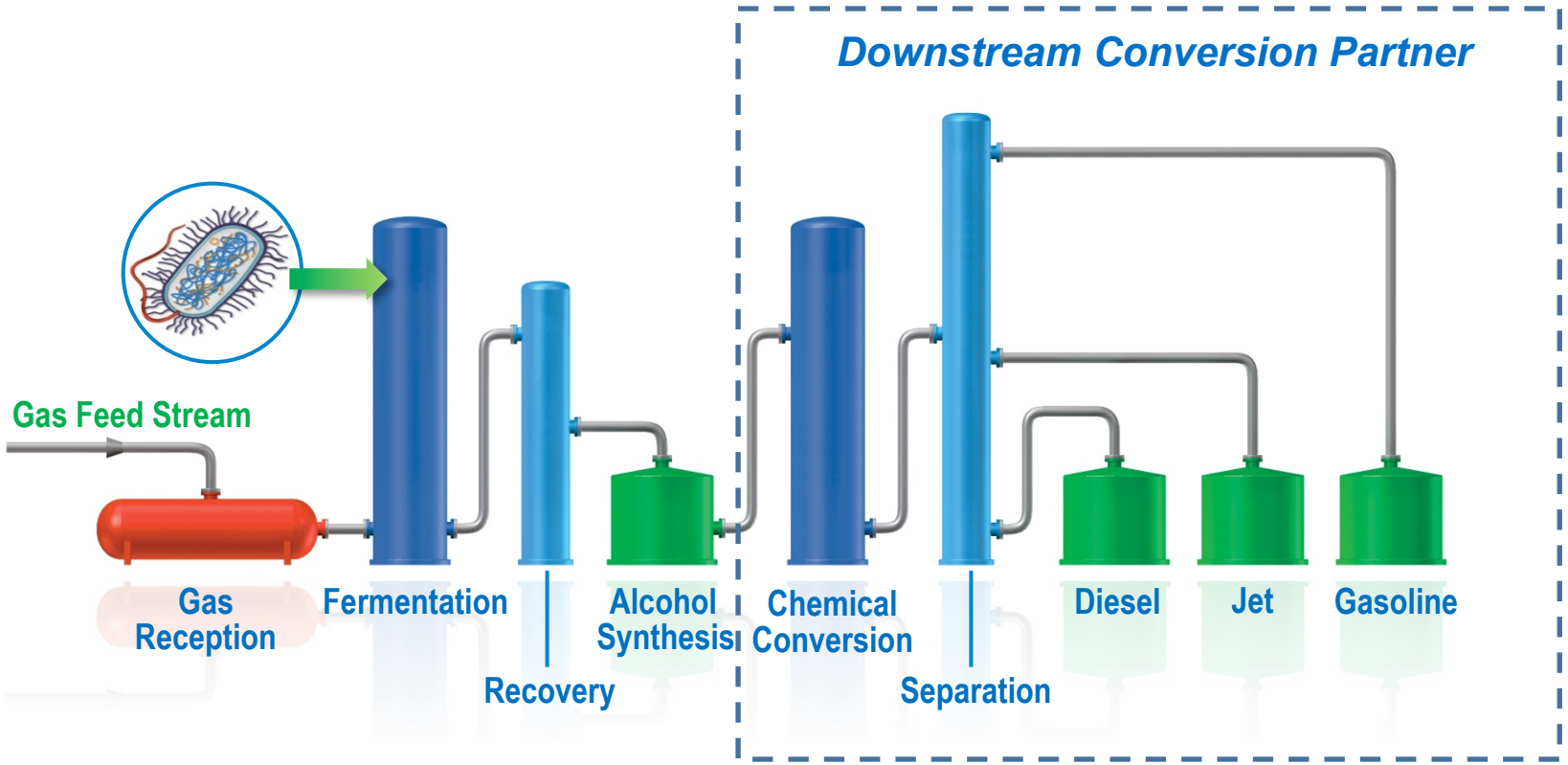
Key Drivers of Emissions Reductions



Presented to ICAO GIACC/3 February 2009 by Paul Steele on behalf of ACI, CANSO, IATA and ICCAIA

End Users Pulling the Industry

Hydrocarbon Fuels Process



Gas Feed Stream

- **CO from Industrial Waste Gases**
- **Syngas from Biomass, MSW, Reformed Natural Gas or Other Sources**

Novel Route to Low Cost Drop in Hydrocarbon Fuels

Overview of Alcohol to Jet (ATJ) Pathways

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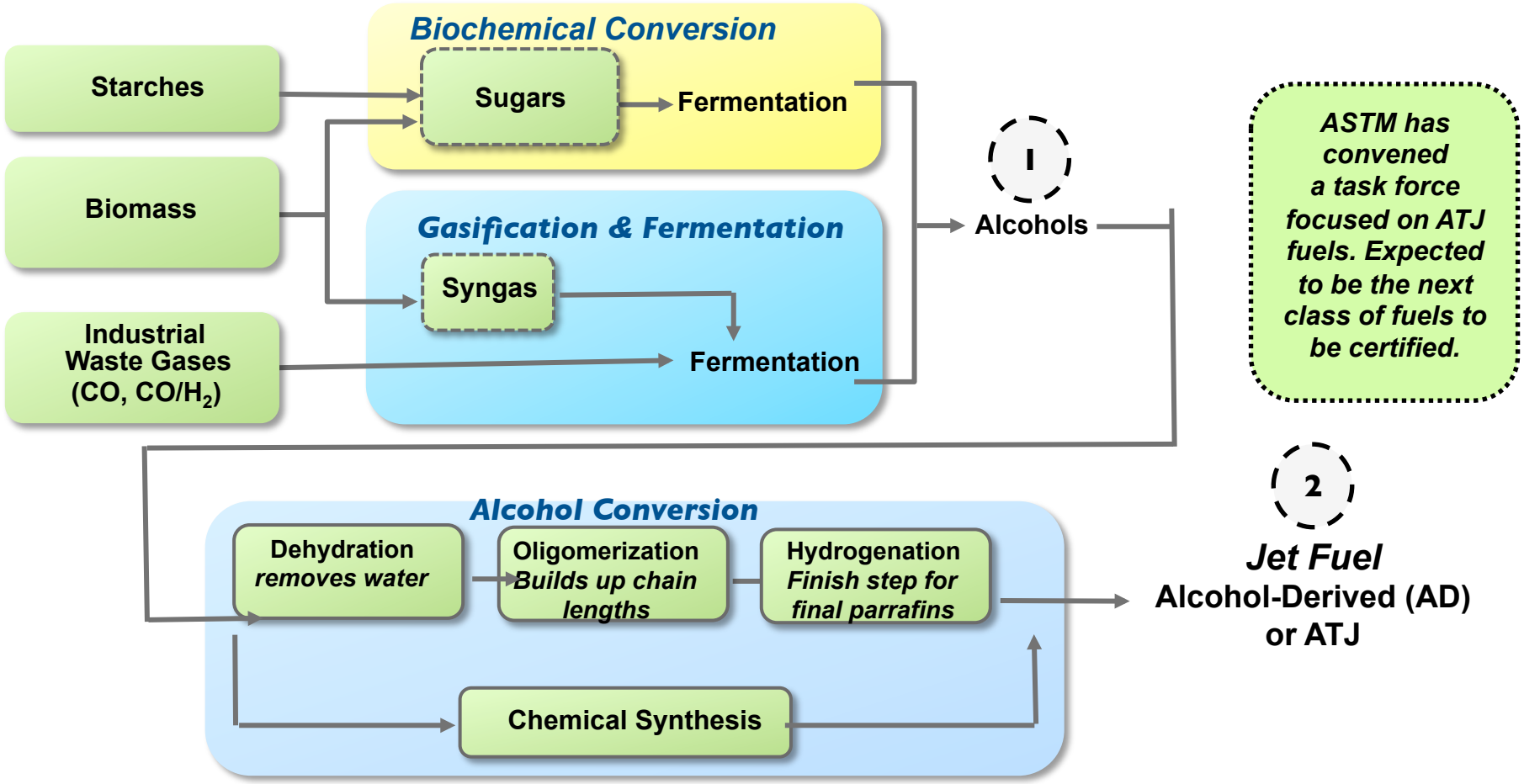

- **ATJ requires two principal conversion steps:**
  1) conversion of primary feedstocks to alcohol intermediates; then
  2) chemical conversion of alcohols to jet fuel hydrocarbons
- **Three steps (dehydration, oligomerization, hydrogenation) make the chain length longer, whereas the "HEFA" process is about cracking and making the chain shorter.**

A Hybrid Catalytic Route to Fuels from Biomass Syngas

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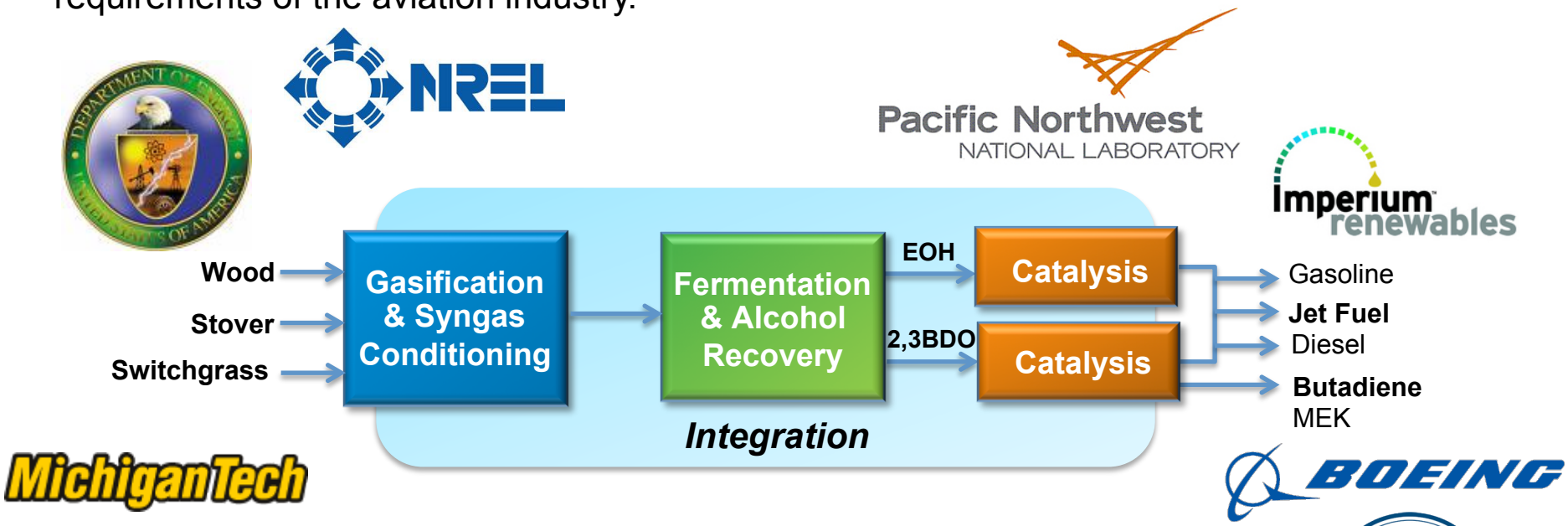
Project Objectives:

Develop a cost-effective hybrid conversion technology for catalytic upgrading of biomass-derived syngas to jet fuel and chemicals to meet the price, quality and environmental requirements of the aviation industry.



US Government (Department of Energy) support to Improve Economics and Process Sustainability

Sustainable Alternative Jet Fuel from Waste Gases & Biomass

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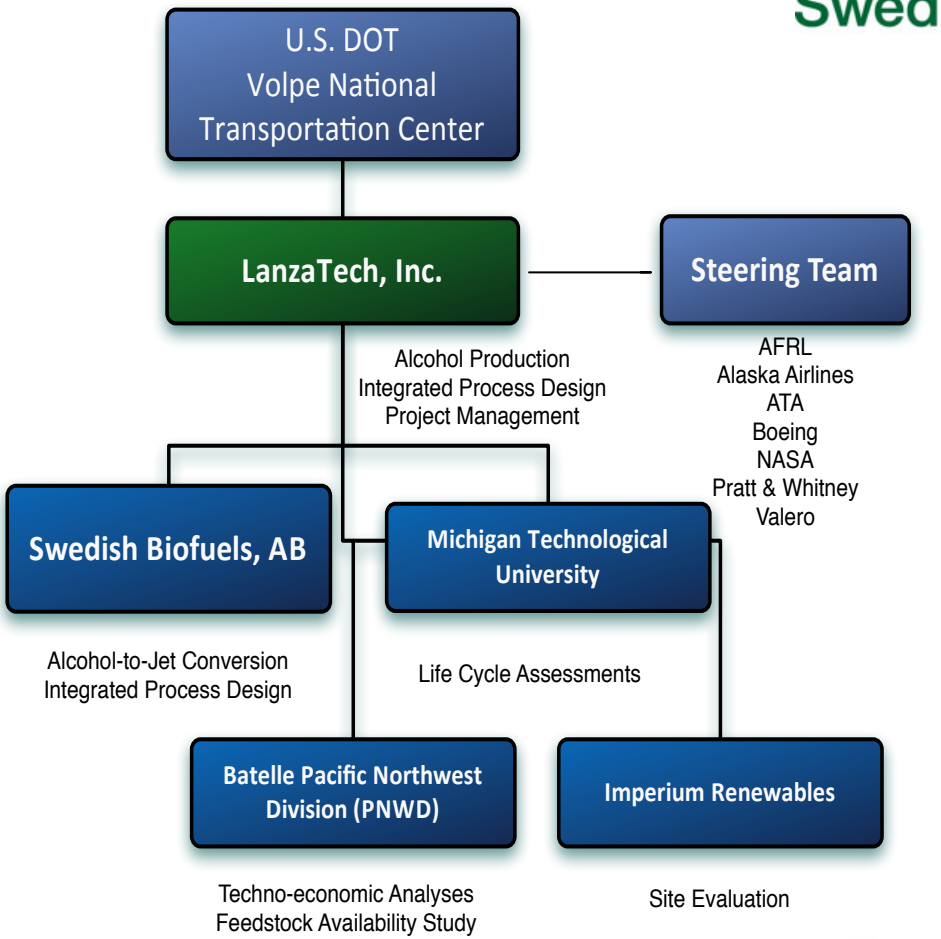
Project Team:



Swedish BioFuels

FEDERAL AVIATION ADMINISTRATION

Volpe Center/FAA Objectives:

- Optimize ATJ fuel process, using steel mill off gases and lignin
- Produce 100+ gallons of *fully-synthetic* alternative jet fuel for certification testing
- Develop preliminary design, TEA and LCA for commercial-scale facility
- Assess feedstock availability and potential commercial sites

MichiganTech

Pacific Northwest NATIONAL LABORATORY

Imperium renewables

Development and Commercialization Collaboration

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BOEING

Swedish BioFuels

Imperial College of London

RSB
ROUNDTABLE ON SUSTAINABLE BIOFUELS

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virgin atlantic

Team Work is Key to Success

Sustainability Perspective

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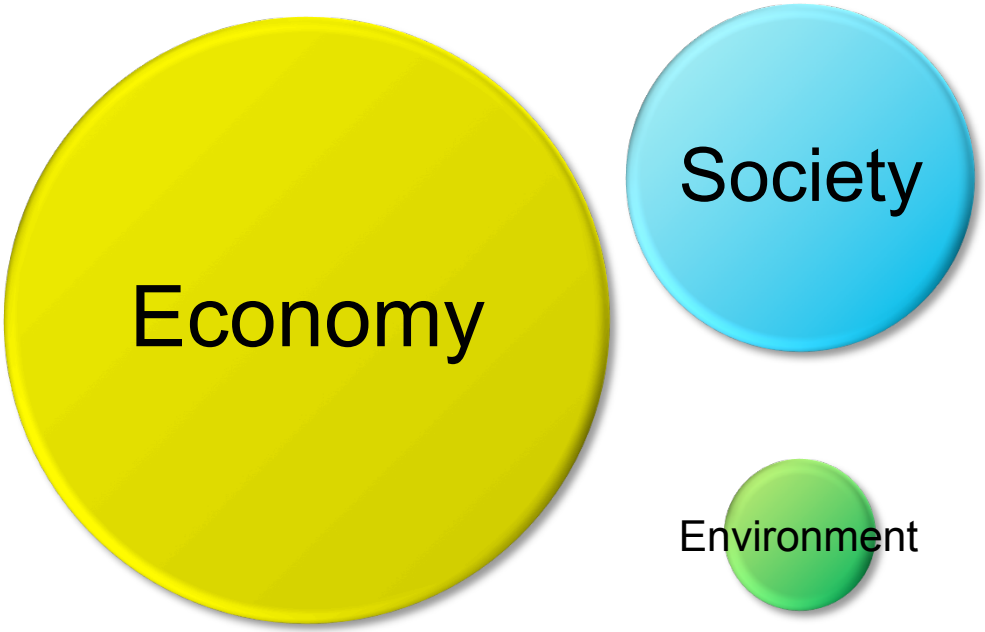
Typical Business View



Sustainability View

Global Goals and Regional Solutions Create Long-Term Sustainability

Roundtable on Sustainable Biofuels

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- A global standard and certification scheme for socially, environmentally and economically sustainable biomass and biofuels
- International multi-stakeholder initiative coordinated by the Energy Center at EPFL in Lausanne
- RSB Certificates are recognized by the European Union under the Renewable Energy Directive.
- Two entities: RSB Standards and RSB Services
- Farmers, companies, non-governmental organizations, experts, governments, and inter-governmental agencies

Greenhouse Gas Emissions

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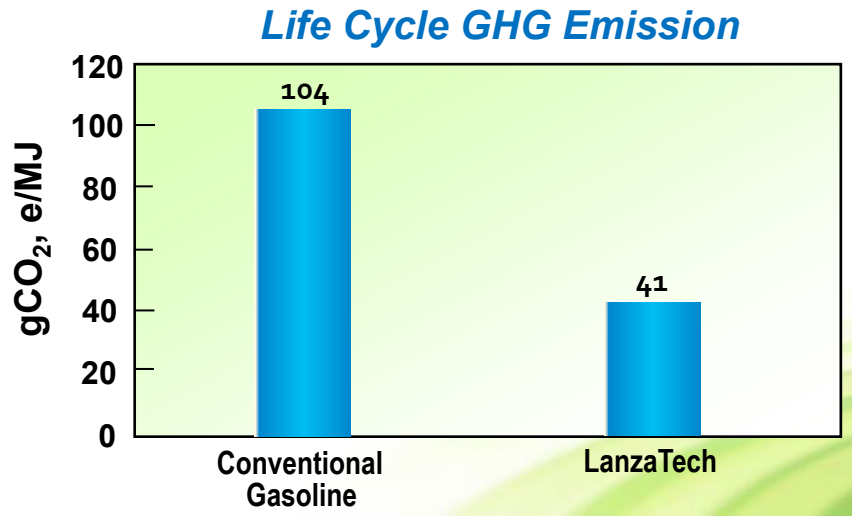
- **LCA is ongoing part of development process, collaborating with:**
  - Michigan Technological University
  - Tsinghua University

LanzaTech Basic Oxygen Furnace (BOF) Gas Process ~ 60% reduction

Based on LCA analyses performed by Michigan Technological University and Tsinghua University relative to petroleum gasoline.

LanzaTech Waste Biomass Syngas Process > 90% reduction (preliminary)

Based on a custom pathway in the GREET model, initial results have shown >80% GHG reduction relative to petroleum gasoline.



GHG footprint is ~40% of the footprint of producing petroleum fuels

RSB Principles and Criteria

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Principle 1 - Legality
Biofuel operations shall follow all applicable laws and regulations.

Principle 2 – Planning, Monitoring and Continuous improvement
Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent, and consultative impact assessment and management process and an economic viability analysis.

Principle 3 – Greenhouse Gas Emissions
Biofuels shall contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to fossil fuels.

Principle 4 – Human and Labor rights
Biofuel operations shall not violate human rights or labor rights, and shall promote decent work and the well-being of workers.

Principle 5 – Rural ad Social Development
In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural and indigenous people and communities.

Principle 6 – Local food security
Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions.

Principle 7 - Conservation
Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and conservation values.

Principle 8 - Soil
Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health.

Principle 9 – Water
Biofuel operations shall maintain or enhance the quality and quantity of surface and ground water resources, and respect prior formal or customary water rights.

Principle 10 - Air
Air pollution from biofuel operations shall be minimized along the supply chain.

Principle 11 - Use of technology, Inputs, and Management of waste
The use of technologies in biofuel operations shall seek to maximize production efficiency and social and environmental performance, and minimize the risk of damages to the environment and people.

Principle 12 – Land rights
Biofuel operations shall respect land rights and land use rights.

Summary

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- To meet growing energy demand & stabilize atmospheric CO_2 levels, need to diversify fuel pool and introduce >30% drop-in zero carbon fuels
- Sustainability in all dimensions is critical for long-term, regionally-appropriate solutions
- LanzaTech addresses need with feedstock flexible processes suitable for a broad range of feedstocks
- Collaborating with leading conversion partners, industry agencies, and certification bodies to develop *sustainable, low cost, integrated drop-in fuels and chemicals processes* from non-food sources
- Although the global policy environment is a patchwork of mandates and regulations, with sustainability increasing in importance

Thank You