DOE Bioenergy Technologies Office (BETO) 2019 Project Peer Review

Low Carbon Hydrocarbon Fuels From Industrial Off Gas

March 4-8, 2019
Technology Session Area Review

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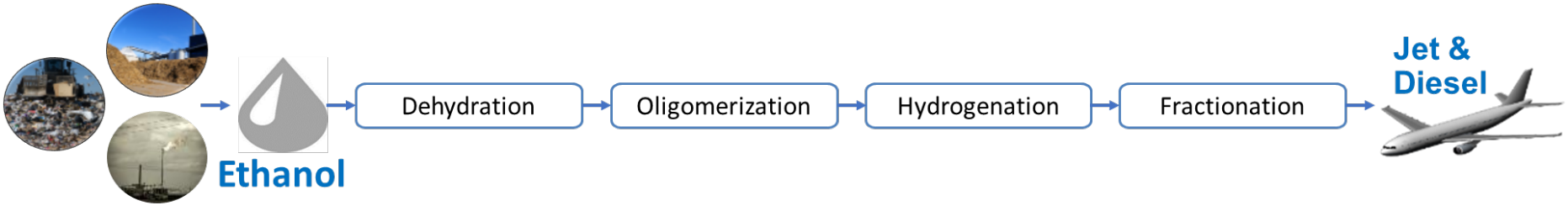
Goal Statement

Project Goal:

To accelerate commercialization of a new flexible pathway to hydrocarbon fuels by designing, building, and operating a facility to produce jet and diesel from ethanol intermediates



Key Project Outcomes:

- Demonstrate production of low-cost jet and diesel with >70% GHG reduction
- > 1000 hours of operational data to validate technology and inform next stage of scale up
- Deliver first commercially-relevant quantities of jet and diesel from ethanol, with validated business model, cost model, and distributed supply chain model

Key Phase 1 Outcomes:

- Implementation site selected, with required permits and NEPA approval
- FEL-3 (-5/+15%) ISBL and OSBL cost estimates
- Implementation plan with supply, offtake, and financing agreements

Relevance to Bioenergy Industry/Impact:

- Establishes route to jet from diverse feedstocks, including biomass residues, industrial gases, and MSW, which reduces GHG emissions and displaces petroleum-derived jet.
- Enables rapid expansion of domestic alternative jet supply to meet CORSIA obligations

Quad Chart Overview

Timeline

- Start: January 15, 2017
- End: March 30, 2019
- 70% complete

Barriers

- Barriers addressed
  - Ot-C. Risk of Financing Large-Scale Biorefineries
  - Ct-F. Increasing the Yield from Catalytic Processes
  - ADO-A. Process Integration
  - ADO-D. Technology Uncertainty of Integration and Scaling

Budget (Fiscal Years)

	FY 17 Costs	FY 18 Costs	Total Planned Funding (FY 19-Project End Date
DOE Funded	242,785	1,210,470	2,190,853
Project Cost Share (LanzaTech)	268,028	1,336,326	-45,679
Project Cost Share (Partners)	0	0	2,464,325

Partners

Partners*

- LanzaTech (40%)
- EPC (35%)
- Universities (5%)
- Industry Partners (20%)

*Percentage involvement per original budget

1 - Project Overview

Project Overview

FOA: Project Development for Pilot and Demonstration Scale Manufacturing of Biofuels, Bioproducts, and Biopower (PD2B3)

- Project development and execution plans for the manufacture of Advanced or Cellulosic Biofuels
- Scale-up and validation of process technologies to enable the industry to build future pioneer- and commercial-scale facilities

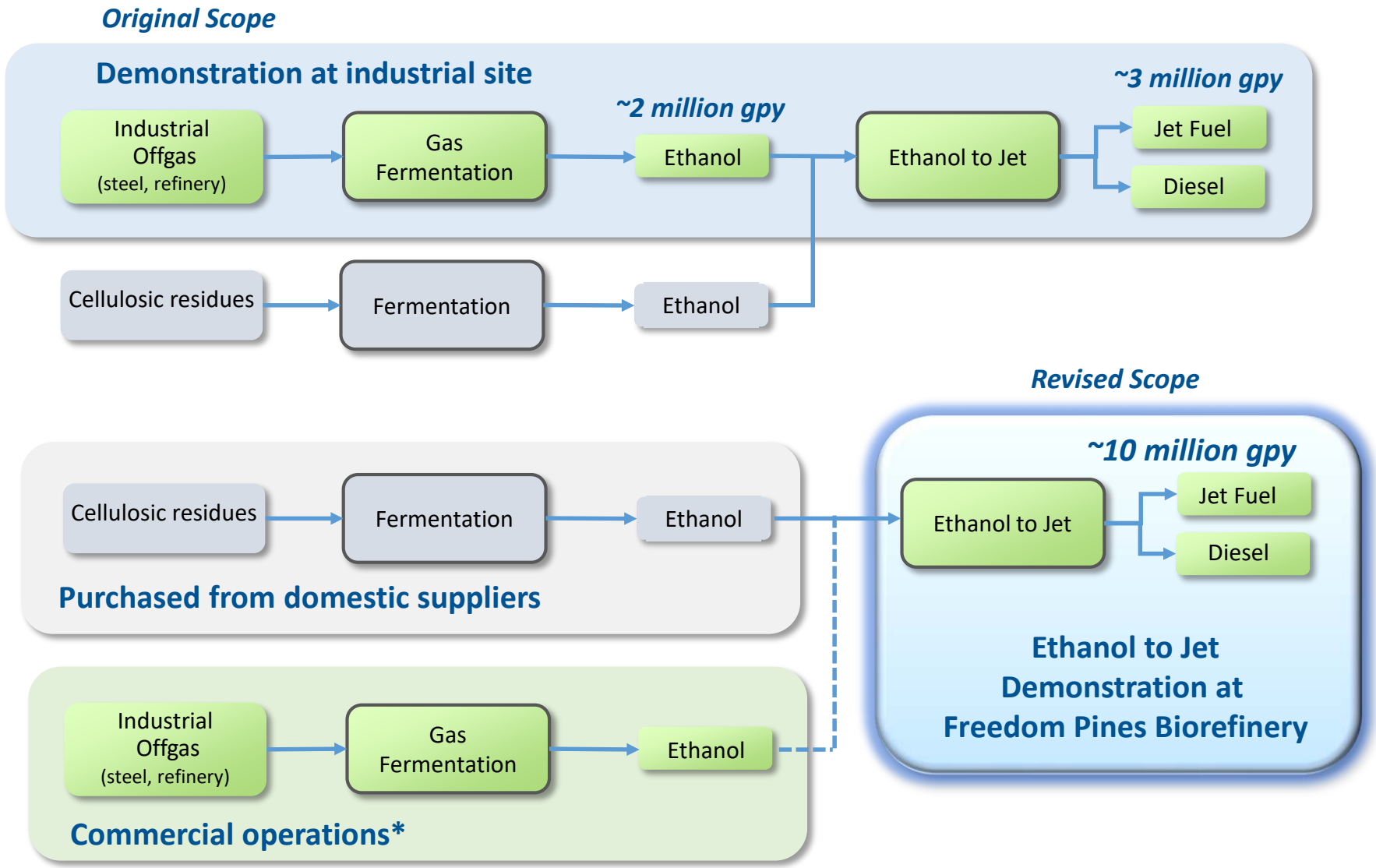
Progress Relative to Plan

- Transition to BP2 was later than anticipated
- Scope revised based on commercial developments external to project
- All activities projected to be completed on schedule within remaining resources

Changes in Project Team:

- Selected new EPC partner
- Added specialty contractors for environment/permitting and site design

Project Scope



*First commercial plant started up May 3,2018 (China, 16 million gpy)

Project Overview – Plans and Achievements

Primary Phase 1 Outcomes	Achievements	Plans for Completion
IE validation of gas fermentation and ethanol to jet processes	• **Completed** on-site evaluations and IE report issued	N/A
Develop technology transfer package for EPC	• **Completed** fermentation design and operations packages • **Completed** ATJ process design package	N/A
Finalize project site	• **Developed** detailed site criteria • **Evaluated** multiple industrial and non-industrial locations • **Selected** Freedom Pines (Soperton, GA)	N/A
Obtain or amend federal, state, and local permits and obtain NEPA FONSI (if needed) for construction and operation	• **Developed** permitting plan • **Quantified** environmental impacts • **Conducted** site assessments and surveys • **Drafted** permit applications • **Analyzed** prior NEPA applications & approvals and existing permits	• Finalize and submit permit applications based on final engineering and plant design • Determine NEPA requirements and complete EA if necessary • Augment EH&S protocols for construction and operation
Supply, offtake and financing agreements	• **Developed** business model, offtake & financing term sheets • **Initiated** supply, offtake and finance discussions with multiple parties	• Develop feedstock supply agreements • Complete conditional supply and offtake agreements
Phase 2 Plans and Applications		

Plans and Achievements –FEL-3 (-5/+15%) estimate

Primary Phase 1 Outcomes	Achievements	Plans for Completion
ISBL		
Heat and Mass Balance	• **Completed** preliminary H&M Balance	• Finalize H&M Balance
Piping and Instrumentation Diagrams	• **Completed** and reviewed preliminary P&IDs	• Updated P&IDs review • Final P&IDs
Equipment	• **Generated** preliminary equipment lists	• Equipment quotes • Final equipment costs • Final equipment layout
Instrumentation	• **Generated** preliminary instrument list	• Final instrument selection • Instrumentation quotes • Final instrumentation costs
Process lines	• **Completed** preliminary line sizing	• Final line sizing
Electrical and controls		• Electrical design and control architecture
Safety	• **Completed** preliminary Process Hazard Analysis	• Final Process Hazard Analysis
FEL-3 (-5/+15%) estimate	• **Completed** preliminary cost estimate	• Final cost estimate
OSBL and Facility		
Gap Analysis for Utilities	• **Completed** initial assessment	• Incorporate into final cost estimate
Logistics for Feed/Product	• In Progress assessment	• Finalize cost estimate
Storage for Feed/Product	• In Progress analysis and design	• Finalize cost estimate

2 – Approach (Technical)

Approach (Technical)

Overall Technical Approach

- Leverage data from prior scales studies of ethanol based alcohol to jet process chemistry.
- Apply detailed process modeling to inform engineering and catalyst design and costing for a technologically new demonstration scale manufacturing facility which produces drop-in hydrocarbon fuels from cellulosic or waste feedstocks

Critical Success Factors

- Technical:
  - Complete the necessary design and engineering required to achieve a -5/+15 cost estimate.
  - Acquire the necessary approvals to construct a 10 million gallon/yr demonstration facility at the LanzaTech Freedom Pines Biorefinery
  - Complete fit for purpose testing and summarize data for review by OEM's, FAA and ASTM committees to obtain approval for the ethanol based alcohol to jet pathway

- Business:
  - Conditional agreements for ethanol supply and product offtake
  - Establish term sheet(s) for financing

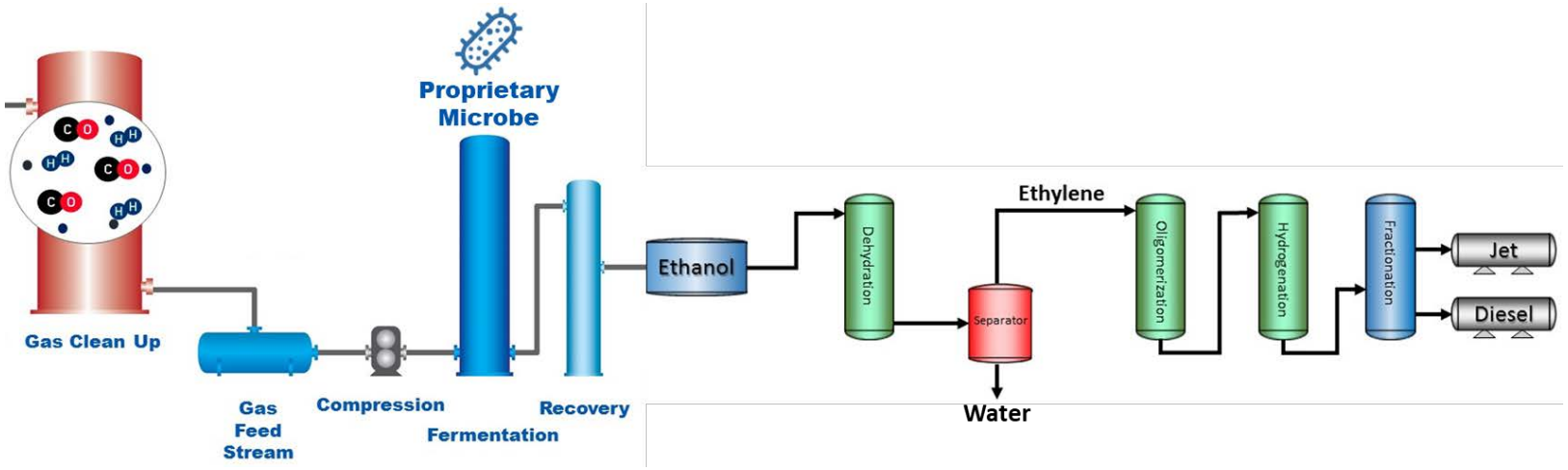
Potential Challenges

- Identifying near term sources of qualifying ethanol in sufficient quantities
- Continued low oil prices create a challenge for alternative jet (and diesel), although offset by incentives

Proposed Technology Ready For Scale Up

Gas Fermentation

Ethanol to Jet



Each Technology Component Commercial or Proven

Each Integrated Technology Proven at Demo Scale

Commercial Gas Fermentation

Started up May 3, 2018

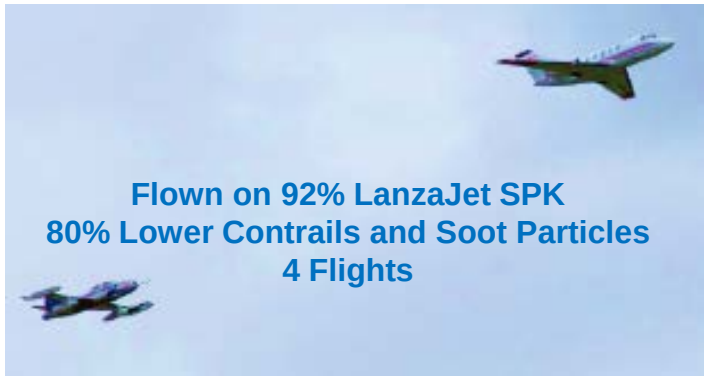
LanzaJet: Ready for Commercial Use

✓ 4,000 gallons Jet
✓ 600 gallons Diesel
Waste Gas Ethanol from RSB Certified Facility
Grain Ethanol

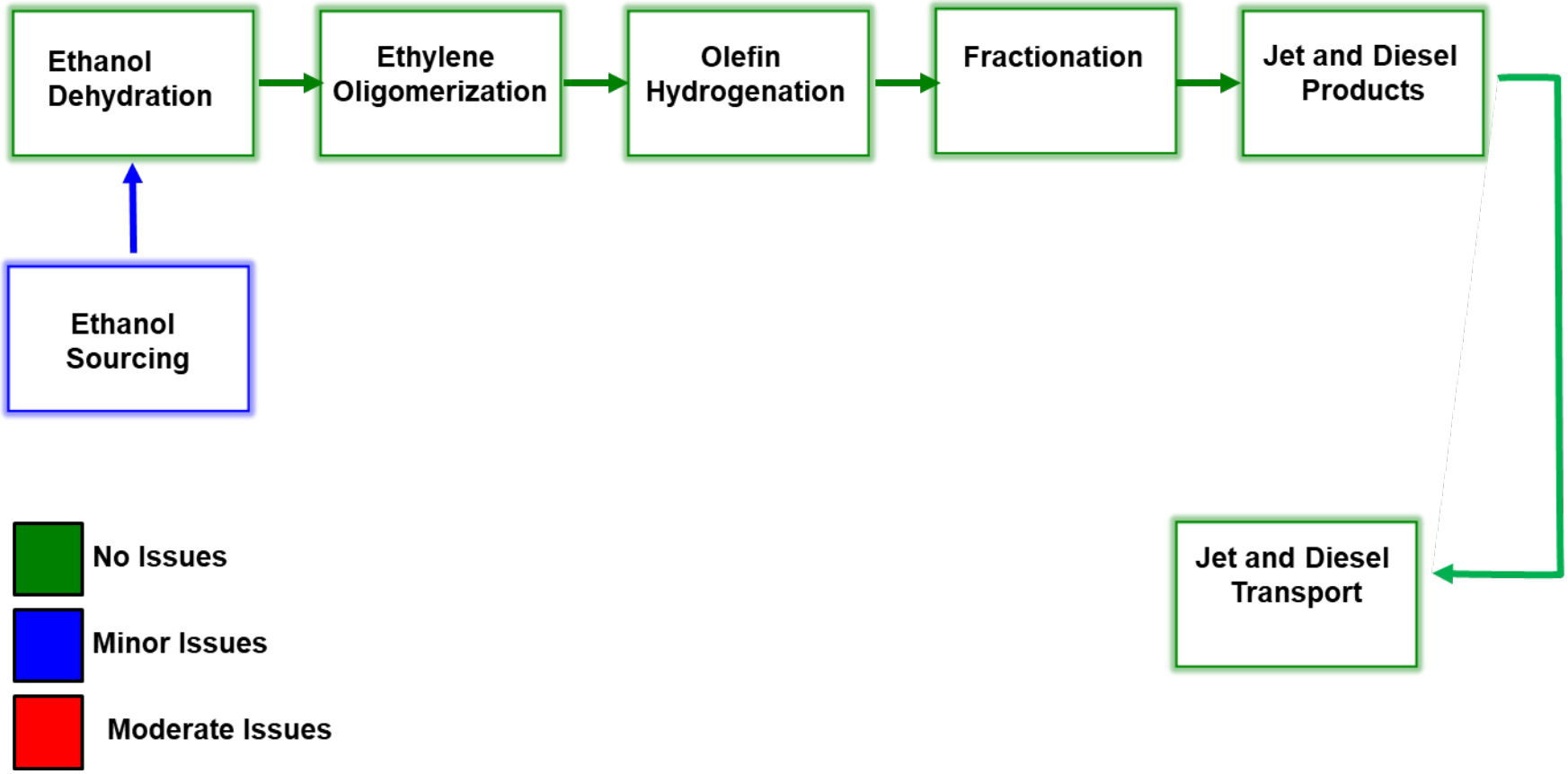
Fuel Property	Jet A Spec	LanzaTech ATJ-SPK	50/50% v with Jet A
Freeze Point, °C	-40 max	-61	-54
Energy Density, MJ/kg	42.8 min	44.4	43.8
Thermal Stability	Baseline	Excellent	Excellent
Viscosity @ -40 °C mm^2/sec	12 max	7.0	9.3
Hydrogen %	13.4 min	15.1	14.5
Aromatics %	8 min, 25 max	Nil	8.8
Sulfur, total mass %	0.30 max	<0.001	0.02

ASTM INTERNATIONAL

April 1, 2018
D7566 ATJ SPK Annex A5
✓ Ethanol feedstock
✓ Final blend ratio to max 50 %



Ethanol to Jet Process Operations Block Diagram



2 – Approach (Management)

Project Management Approach

Project Management Platform

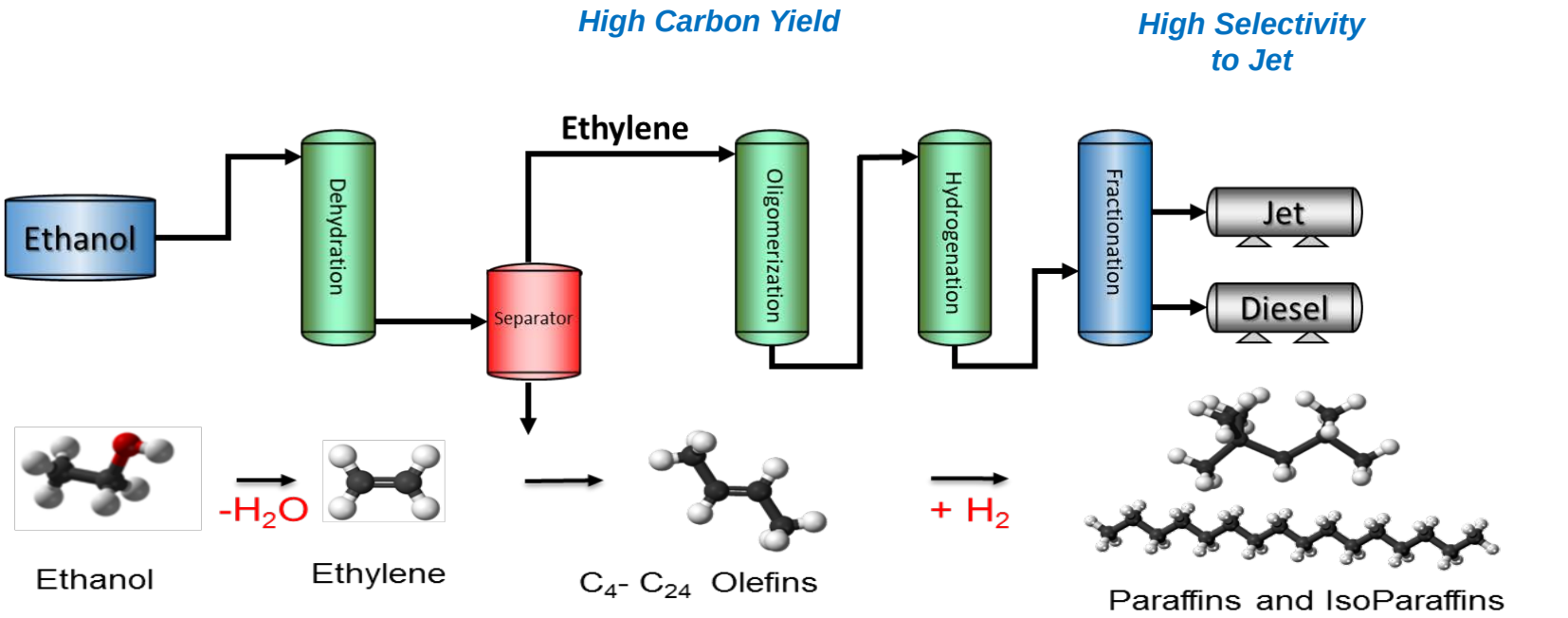
- Developed through LanzaTech's experience in managing multi-task, multi-million-dollar R&D and engineering projects.
- Robust project management platform that minimizes project execution risk and increases the certainty of a successful project outcome.
- Robust ERP/project management software that produces weekly detailed financial and resource management (hours) reports.
- Experienced cost accounting personnel with robust processes, policies and oversight.
- Platform follows generally accepted project management principles and guidelines

Project Coordination

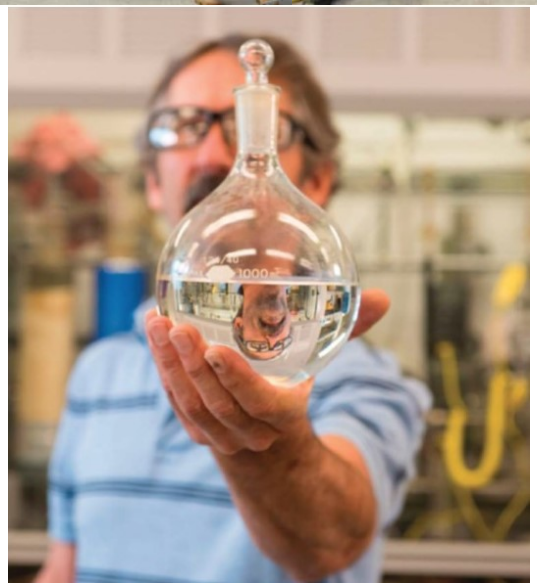
- At least weekly phone meetings with key technical partners, such as EPC and environmental subcontractors
- In-person planning and review meetings at contractor or project sites
- Monthly budget and schedule reviews

3 – Technical Accomplishments/ Progress/Results

Ethanol to Jet Process



Modeling Based on Prior-Scale Production



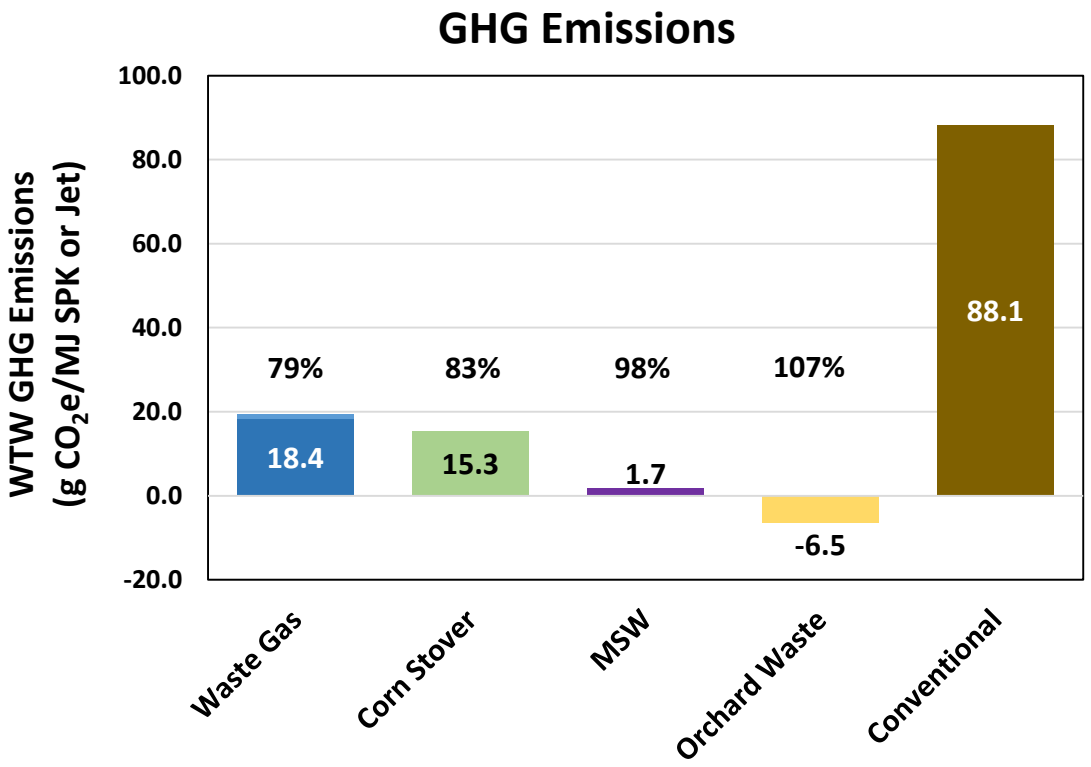
Environmental and Permitting Considerations

- Project site previously developed and permitted for commercial thermochemical biorefinery
- Prior NEPA EAs & FONSIs expediting additional NEPA reviews, minimal incremental impacts
- Physical footprint of the developed site will not change, Project leverages existing permits
- Project engineering designs and equipment specs reviewed to quantify process inputs and outputs needed to inform EA and permit applications / modifications
- Analyzed existing air, water, and other permits and updated cultural and wetland surveys
- Comprehensive permitting plan established and initiated

Conclusion: Minimum Environmental Impacts at Site, Permitting Underway

Life Cycle Assessments

Emissions calculated for ATJ produced from a variety of waste-based ethanol sources



Reductions based on GREET comparator (88.1 g-CO_2e/MJ), shown at right.

Business and Supply Chain Models

LanzaJet

30M gpy | 30M gpy | 30M gpy

Build Freedom Pines facility

Create Entity & Raise Cash

Accelerating Path to Commercial Through Creation of Subsidiary

Distributed Feedstock

Centralized Production

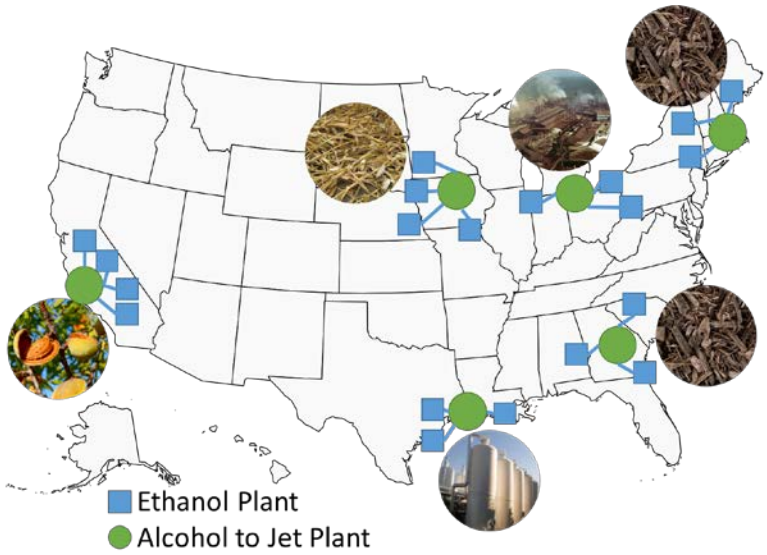
4 – Relevance

Relevance

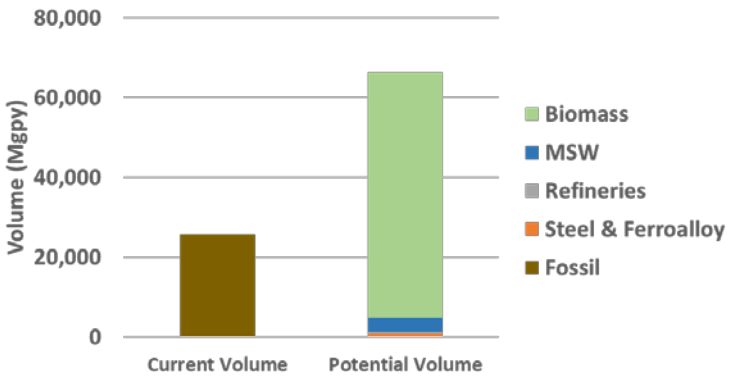
Directly supports BETO's strategic goal:

*Develop **commercially viable** bioenergy and bioproduct technologies to enable the **sustainable nationwide production** of biofuels that are **compatible with today's transportation infrastructure**, can reduce greenhouse gas emissions relative to petroleum-derived fuels, and can displace a share of petroleum-derived fuels to reduce U.S. dependence on oil and encourage the creation of a new domestic bioenergy industry.* [1]

...sustainable nationwide production



...can displace a share of petroleum-derived fuels



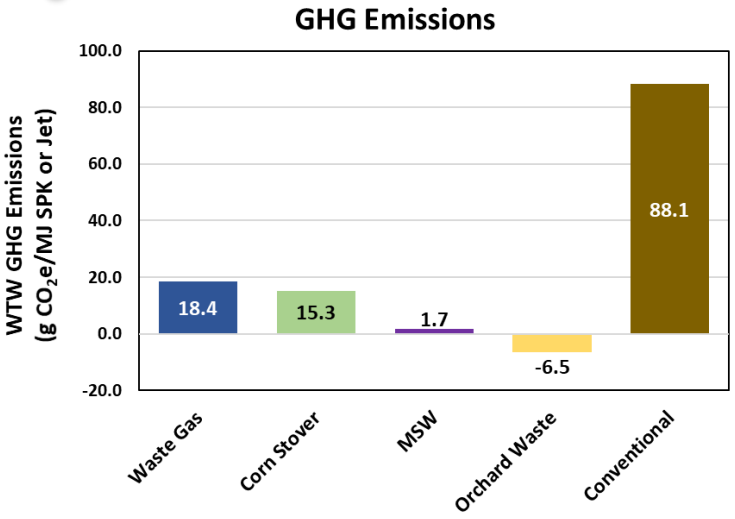
Directly supports BETO's objective to:

By 2022, validate successful runs of one biofuels manufacturing processing using a hydrocarbon fuels pathway at demonstration-scale. [2]

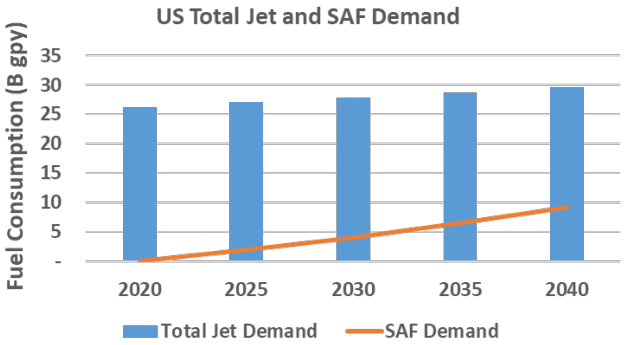
1. MYPP, p. 1-19; 2. MYPP, p 1-32.

Relevance

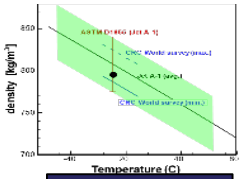
…reduce greenhouse gas emissions

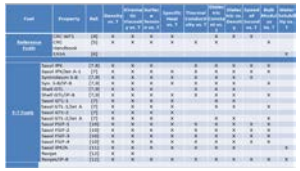


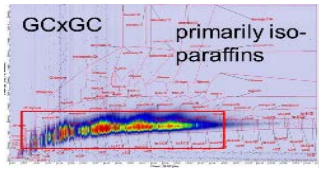
…encourage the creation of a new domestic bioenergy industry



…compatible with today's transportation infrastructure







On April 1, 2018 ASTM Intl. Revised D7566 ATJ SPK Annex A5

- Added Ethanol as a feedstock
- Increased final blend ratio to max 50 %

…commercially viable

5 – Future Work

Future Work

Design and Engineering

- Complete Basic Engineering Package
- Complete FEL-3 -5/+15 cost estimate (ISBL, OSBL, facilities)

Business, Regulatory, and Environmental

- Complete permit applications and NEPA review
- Finalize feedstock and offtake agreements
- Finalize financing plan
- Finalize logistics plan

Documentation and Planning

- Develop Phase 2 plans and application documents

Go/No-Go Decision

- Independent Engineering Review at end of Phase 1

Remaining budget is sufficient to complete the proposed tasks.

Summary

Technology Status and Approach

- Technology is ready for deployment at planned scale
- Sustainable aviation fuel qualified and demonstrated in commercial flight
- Process models completed as basis for design and engineering tasks

Technical and Business Accomplishments

- Site selected and committed
- Engineering and cost estimation are on track for completion
- Plans for integration with existing facility are well underway
- Feedstock and product logistics plans outlined
- Initial evaluation of environmental impacts complete, showing minimal impact at site
- Business and financing model well-developed

Relevance of Project

- Fully supports BETO's strategic mission
- Will lead to a reliable and expanding ethanol market, independent of road transport
- Paves the way for a domestic sustainable aviation sector built around diverse waste and residue feedstocks

Future Work

- On track for completion of Phase 1 activities with remaining resources