DOE Bioenergy Technologies Office 2023 Project Peer Review

ABBA: Advanced Biofuels and Bioproducts with AVAP®

April 3, 2023

Systems Development and Integration Session B

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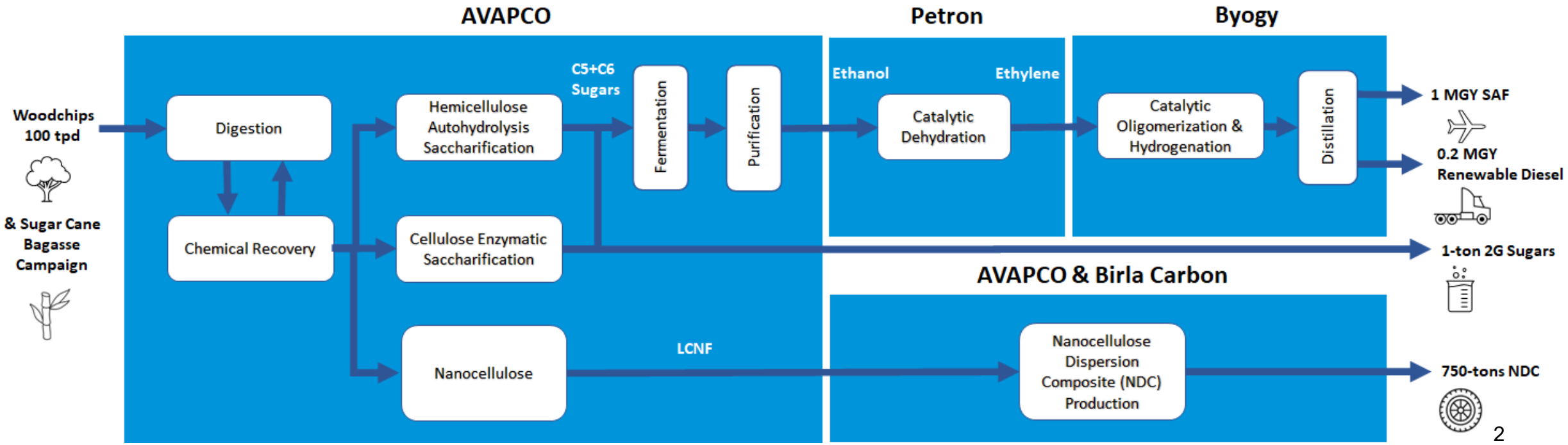
AVAPCO LLC

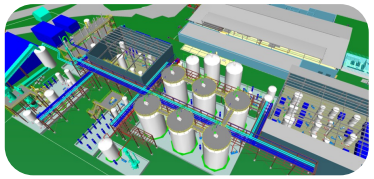
Project Overview- Goals

- Perform technical validation of integrated process, process optimization, and basic engineering for an AVAP® biomass demonstration plant for ***co-production of full replacement bio jet fuel, diesel and nanocellulose***
- Demonstrate how ***low-volume, high-value nanocellulose*** co-produced with ***high-volume commodity liquid fuels*** enables a profitable biorefinery at reasonable scale.



Project Overview- History

*The project partners have invested more than 10 years in the development of low carbon footprint **cellulosic SAF** and **renewable diesel** along with **high-value co-products.***



- 2010 — Byogy ATJ Piloting
- 2011 — AVAP Bench Optimization
- 2012 — Thomaston Biorefinery Start-Up
- 2013 — AVAP Sugar to Biochemical Trials
- 2014 — Byogy SAF Testing under FAA Clean Fuels Program
- 2015 — AVAP Nanocellulose Start-Up
- 2016 — Petron Commercial Process Optimization
- 2017 — AVAPCO "ABBA" DOE Award
- 2018 — NDC Laboratory Development with Birla Carbon
- 2019 — Byogy SAF ATJ-SPK Pathway Certification
- 2020 — "ABBA" DOE Verification Complete
- 2021 — Byogy 2G SAF Pilot in Japan Start-Up
- 2022 — NDC Continuous Pilot Trials
- 2023 — "Enabling NET ZERO" DOE Award

Project Overview- Enabling Net Zero™ Project

Capacity
1.2 million gallons per year SAF and renewable diesel biofuels from woody biomass

Start-Up
Q3 2026

GHG Reduction Potential
SAF GHG reduction potential of ~95% over conventional jet fuel

Growth
Builds on previous DOE award for project's technical validation and design phase

Funding
$80 million cost share by DOE

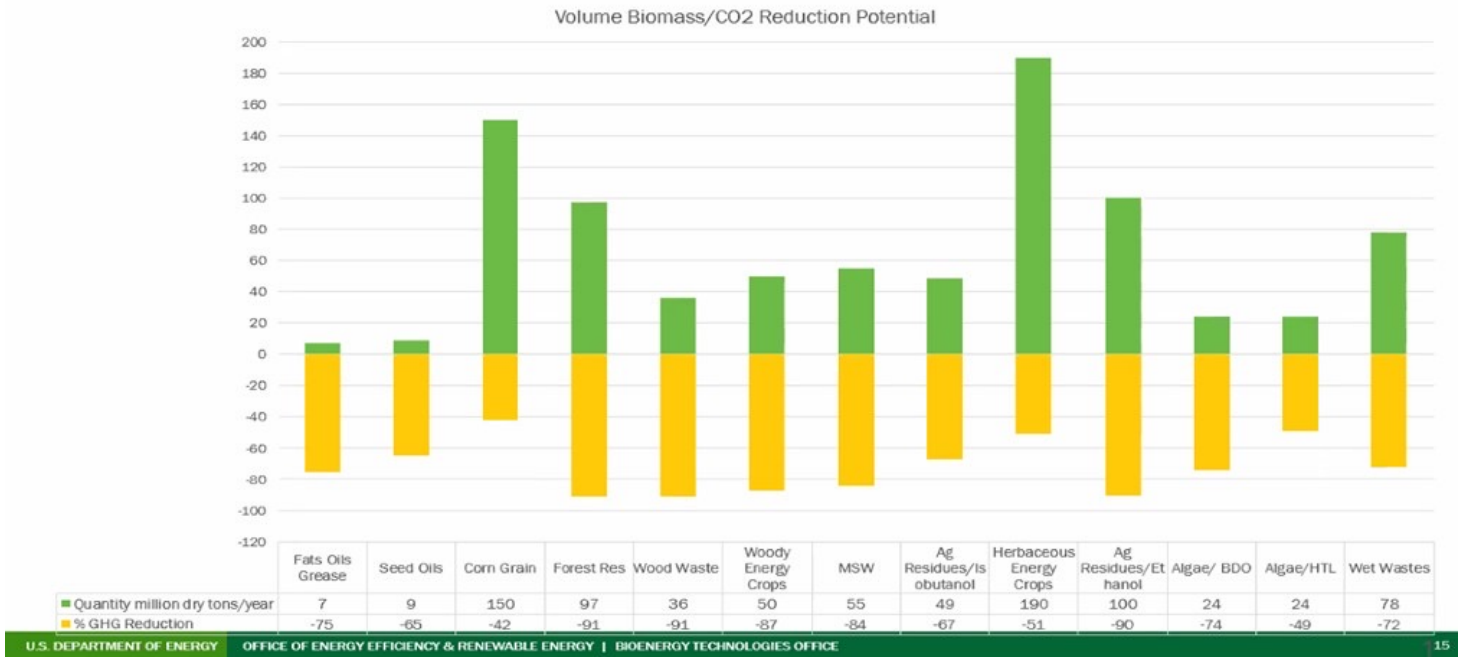
Location
Thomaston GA

Project Overview- Process Advantages

- **AVAP Fractionation & Saccharification**
  - Biomass feedstock agnostic
  - Separate pure streams of hemicellulose, cellulose, and lignin allow co-product utilization
  - Low enzyme consumption resulting from cellulose purity
  - High sugar and ethanol yields and low production costs
- **Ethanol-to-Ethylene**
  - More than 80% of world's commercial ETE plants use Petron's technology
- **Ethanol-to-Jet**
  - Production and control of aromatics for "Drop-In", "Full Replacement" SAF from Byogy process
- **Nanocellulose**
  - Patented lignin-coated nanocellulose allows for use in plastics and rubber
- **Nanocellulose Dispersion Composite™**
  - Drop-In form ensures uniform distribution of nanocellulose in tires required to enhance properties

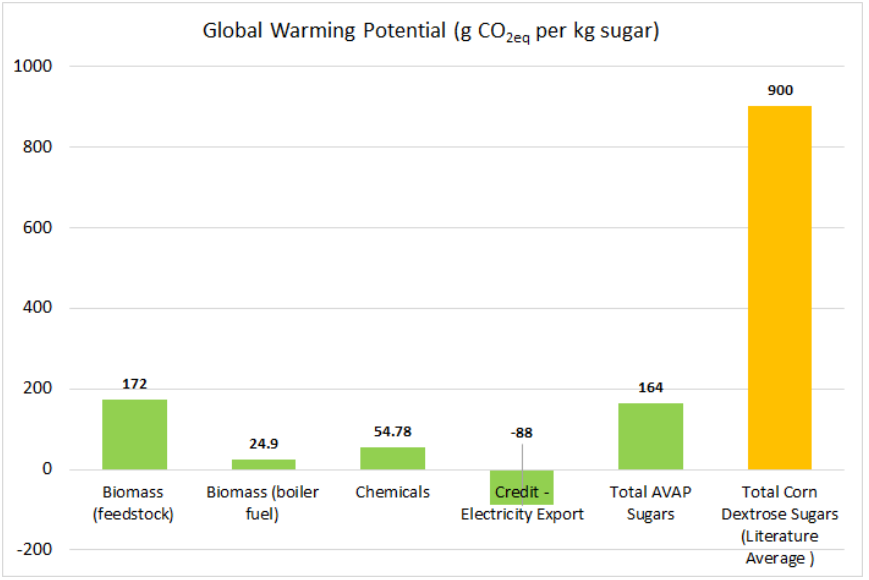
Project Overview- Alcohol-to-Jet SAF from Biomass Advantages

- **Tunable Product Slate**
  - Approved ATJ-SPK-2 SAF without aromatics (50% blend)
  - Pending ATJ-SKA #1 with aromatics (50% blend)- Approval estimated mid-2024
  - Pending ATJ-SKA #2 with aromatics (100% replacement)- fuel for engine testing to be produced under project
- **Abundant 1-Billion tons of biomass available in U.S.**
  - Commercially available SAF from HEFA has limited feedstock supply (waste oils and fats)
- **Biomass-based SAF offers the highest GHG reduction potential over conventional jet per DOE**
  - 90+% reduction



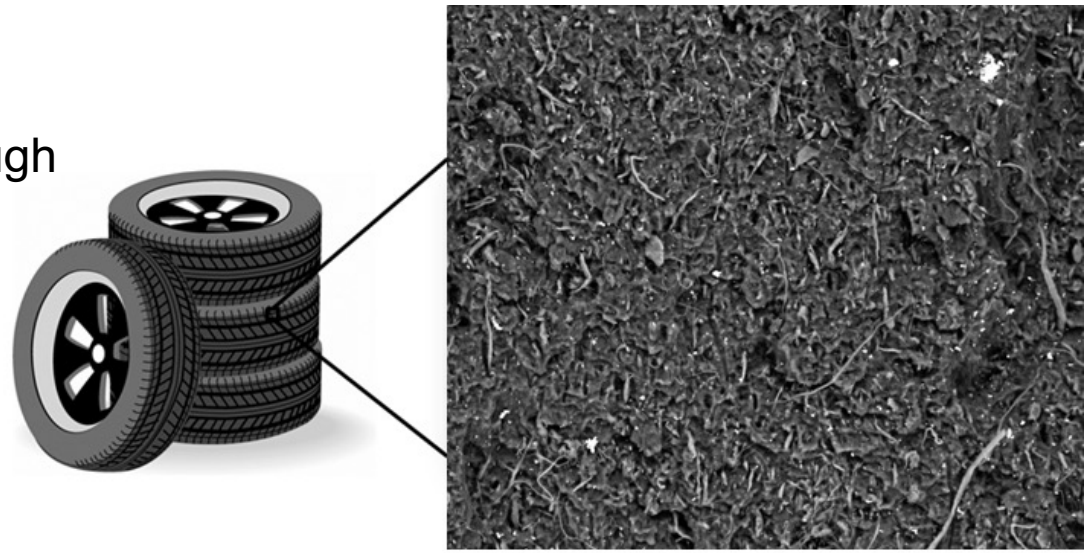
Project Overview- AVAP Cellulosic Sugars Advantages

- Total sugar yield is 87–97% of theoretical based on integrated pilot runs of various feedstocks at the Thomaston Biorefinery
- Sugars are highly fermentable to biochemicals
  - Glucose performs similar to starch-based dextrose as confirmed by external partners for a variety of fermentation products including n-butanol, ethanol, BDO, lactic acid and succinic acid
  - Hemicellulose sugars fermented to cellulosic ethanol, or polished for other fermentation products
- The GHG emissions of AVAP sugars from wood are ~82% less than corn dextrose sugars according to a third-party LCA
- The 2050 market size of sugar-derived biochemicals is estimated to reach 113 million tons



Project Overview- NDC Advantages

- Addresses most-pressing tire industry goals
  - 100% sustainable raw materials
  - Lower fuel consumption and GHG emissions through lower rolling resistance
- Replaces 20% of carbon black filler in tire
- Lowers rolling resistance by 10%
- Improves physical properties
- Drop-In form requires no tire production process or equipment modifications



MICHELIN

"100% sustainable tires by 2050"

BRIDGESTONE

"100% sustainable materials" by 2050"

Continental

"100% sustainably produced materials by 2050"

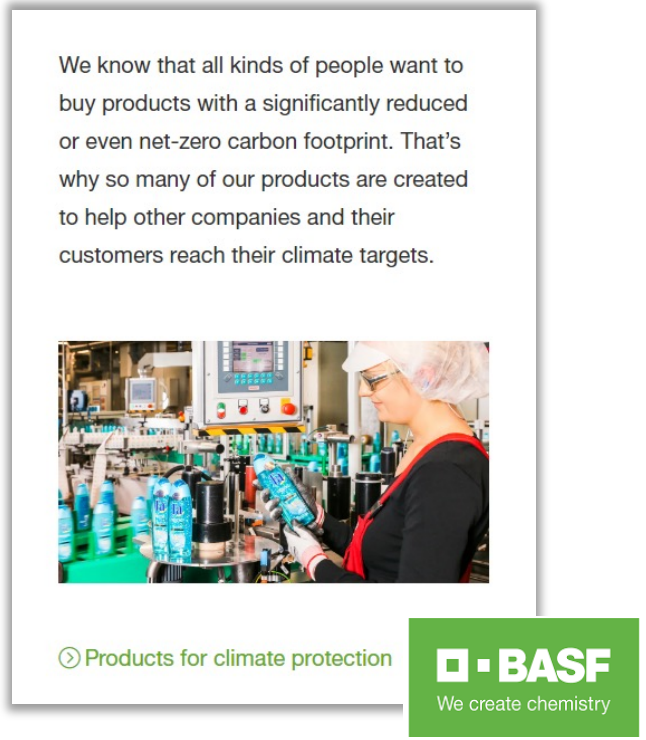
Project Overview- Relevance to BETO Goals

- AVAPCO's **"Whole Barrel"** Biorefinery approach demonstrates how ***low-volume, high-value coproducts*** along with ***high-volume commodity liquid fuels*** enables profitable biorefineries.
- There is growing demand for **sustainable, low carbon footprint fuels, chemicals and materials** that are not derived from food.
- Market sizes for demo plant products:
  - SAF = about 160 billion gallons per year
  - Sugar-derived biochemicals = 113 million tons by 2050
  - Green tires = 870 million tires by 2030

"The Program is focused on developing and demonstrating technologies that are capable of producing low-carbon drop-in biofuels at $2.50 per gallon gasoline equivalent (GGE) by 2030, as well as associated renewable chemical co-products to achieve this target"

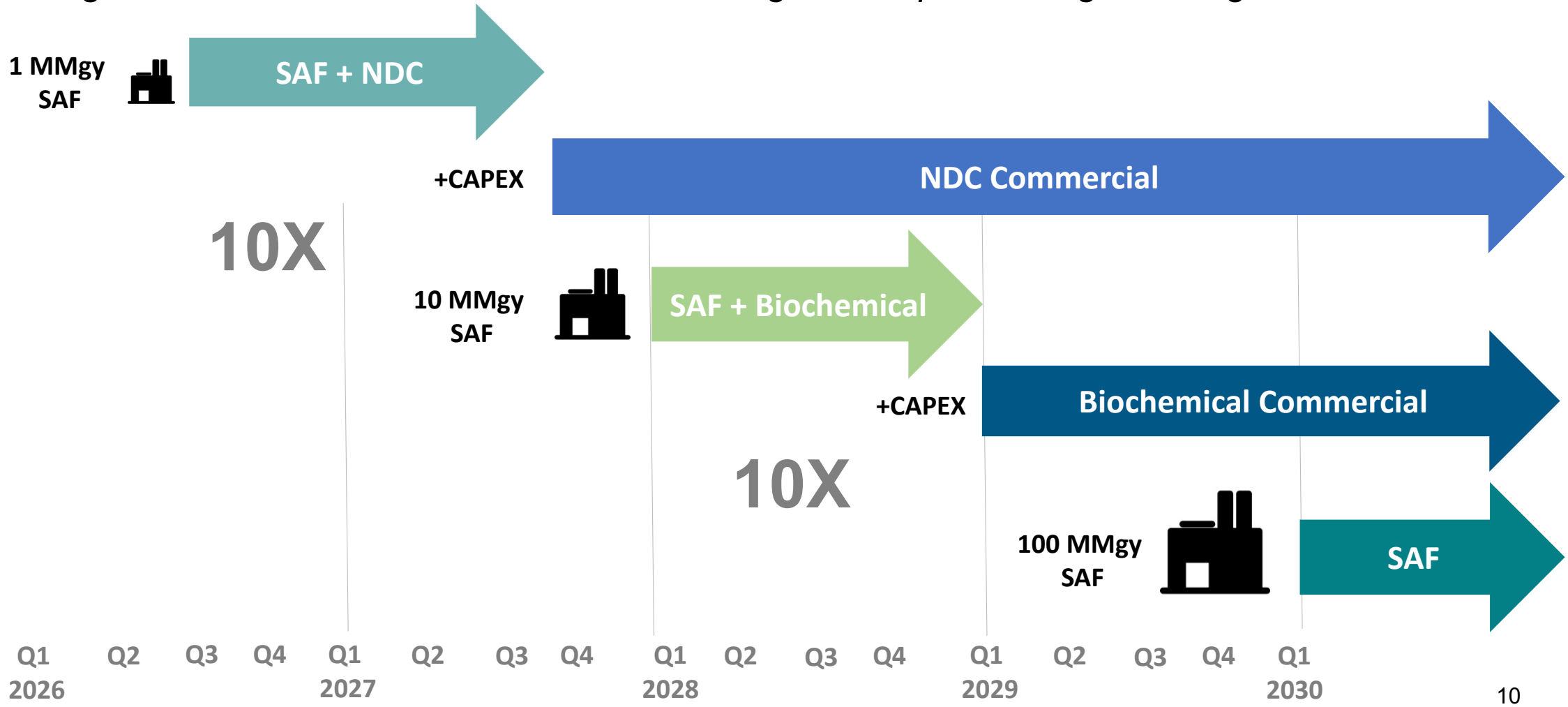
"***Enabling a diverse product slate from a biorefinery*** **can substantially reduce risks associated with early biofuel plants and biorefineries."**

"Bioproduct production can also significantly de-risk upstream infrastructure and processes needed for biofuels by providing an increased economic incentive for construction of pioneer biorefineries"
- BETO

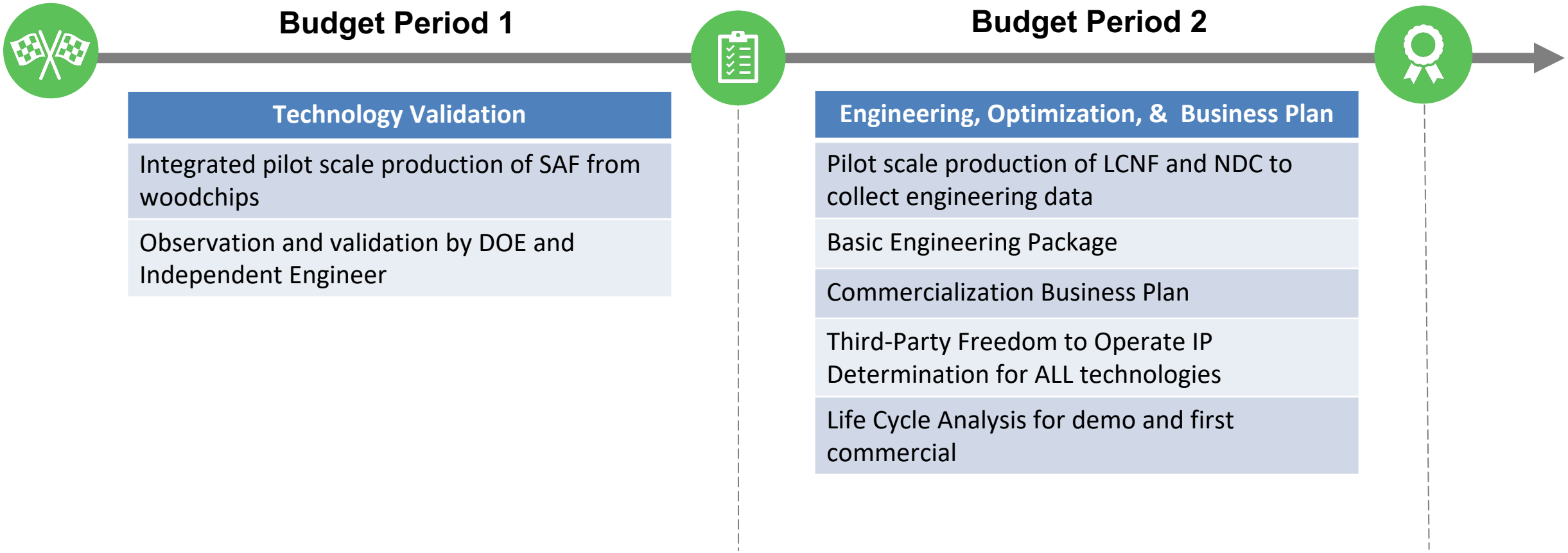


Project Overview- Relevance to Commercialization Goals

The demo plant and first commercial can be converted to commercial-scale AVAP co-product plants after collecting the necessary techno-economic data for the next scale-plant, thereby extending the useful life of each asset and reducing scale-up financing challenges



1. Approach- Major Tasks



1- Approach- Challenges & Risks

- **Top Challenges Faced**
  - Inflation related price escalation and uncertainty about future pricing at time of procurement & construction
  - Obtaining firm quotes prior to fully funded Demo plant Execution stage gate

- **Top Risks & Mitigation**
  - Low product sales volume due to extended commissioning phase- Pro Forma assumes 50% of plant capacity will be sold
  - First-of-a-Kind Financing Risk- Demo plant construction and operation was selected for $80 million from DOE which increases success rate for additional investment

The Atlanta Journal-Constitution | Saturday, January 28, 2023

NEWS

RENEWABLE ENERGY

Plant gets $80M to make jet fuel from wood chips

Georgia grant is biggest among several from feds.

By Drew Kann
drew.kann@ajc.com

A Georgia plant turning wood residue into jet fuel is receiving a big chunk of new federal funding to boost production, in the hopes that its products can eventually lower the climate change impact of the airline industry and other sectors.

The Department of Energy announced that it is awarding an $80 million grant to AVAPCO LLC, a biofuel, biochemical and biomaterials company that operates a refinery in Thomaston, about 60 miles west of Macon. The agency released $118 million to fund 17 projects around the country on Thursday, with AVAPCO's grant by far the largest.

Biofuels could make a significant contribution in diminishing aviation's carbon footprint, advocates say. A new plant, probably in Thomaston, aims to make that happen, and could be operating by 2026. AP FILE

aviation fuel. The company's process also produces nanocellulose, a fibrous material that can be used by rubber manufacturers to strengthen tires and other products.

Phase 1 of the company's project was successful, the DOE said. Now, the new federal money will be used to

grow back and pull heat-trapping carbon dioxide from the atmosphere in the process. However, exactly how much lower their emissions are depends on how they're produced, how the fuel is distributed and other factors.

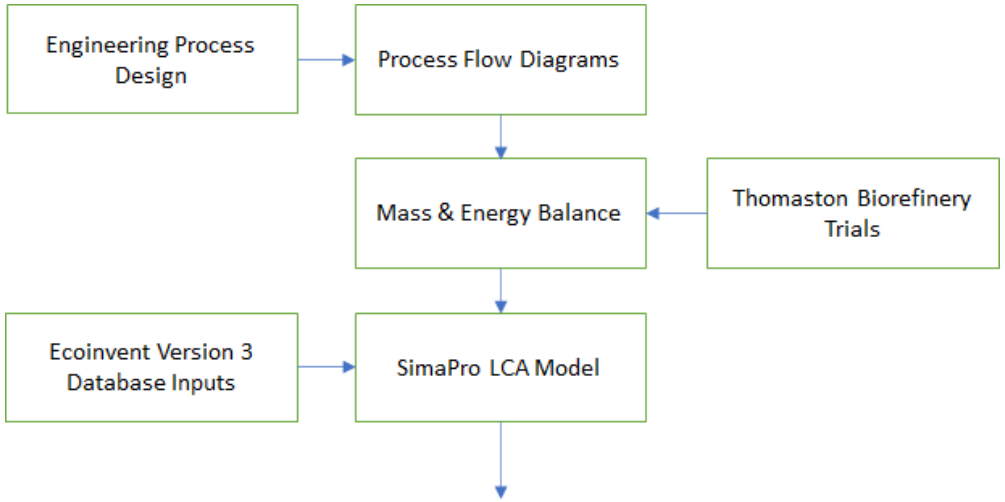
Nelson said she thinks biofuels hold great poten-

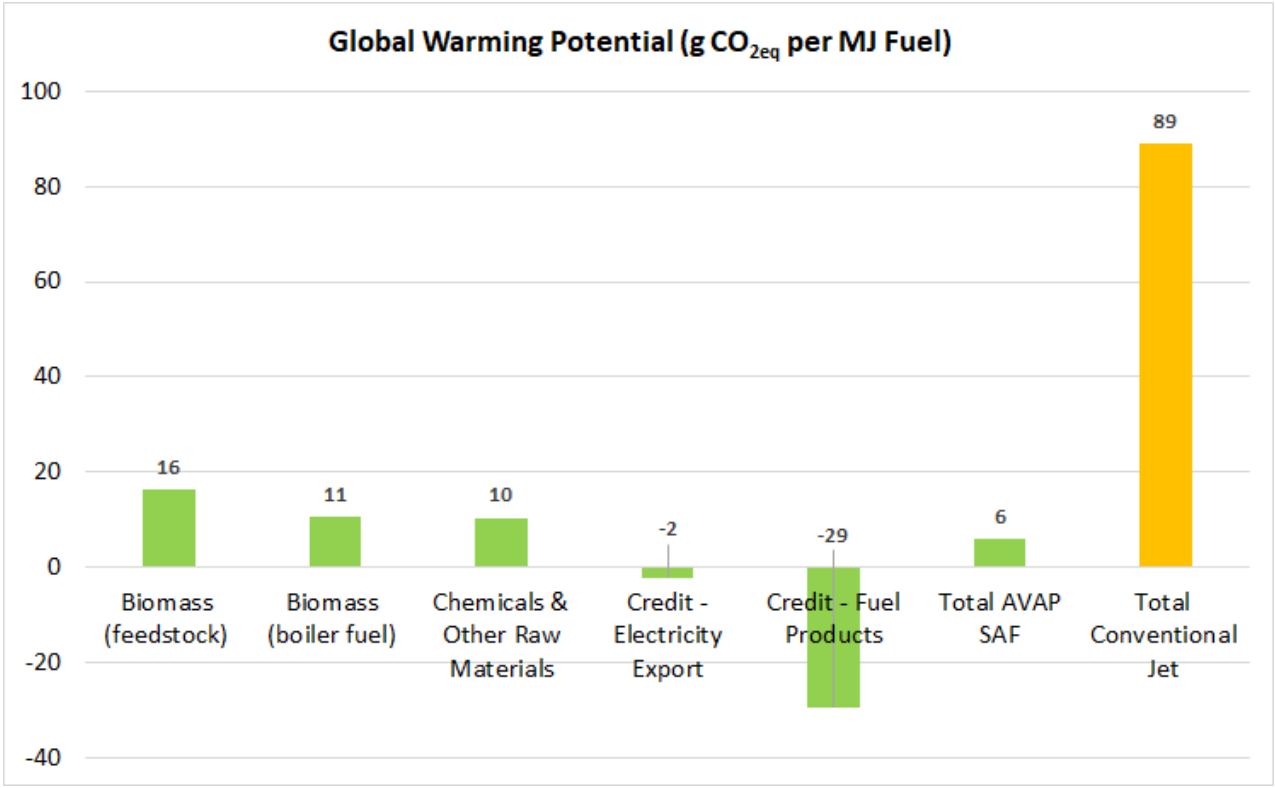
2- Progress and Outcomes- Design Package

Completed Design Basis Package	
Process Design Basis	Risk Mitigation Plan
Process Flow Diagrams	Strategy for regulatory approval of products
Refined Mass and Energy Balances	Life Cycle Analysis
Equipment Specifications and Lists	Technology Description
Process Hazard Reviews	Plant Inputs & Outputs
Utility Flow Diagrams	Commercial Plant Pro-Forma Cash Flow
Instrument Specifications and Lists	Sensitivity Analysis for feedstock cost and market price of products
General Arrangement Drawings	IP Secured
P&ID's	Project Site Secured
Electrical Single Line Diagrams	Scale-Up Analysis
Plot Plans	Detailed Project Schedule
3D Model	Project Management Plan

Third-Party Life Cycle Analysis

The GHG emissions reductions for AVAP-enabled SAF produced at a 10 MMgy commercial scale plant were calculated to be 93% compared to conventional jet fuel and diesel.

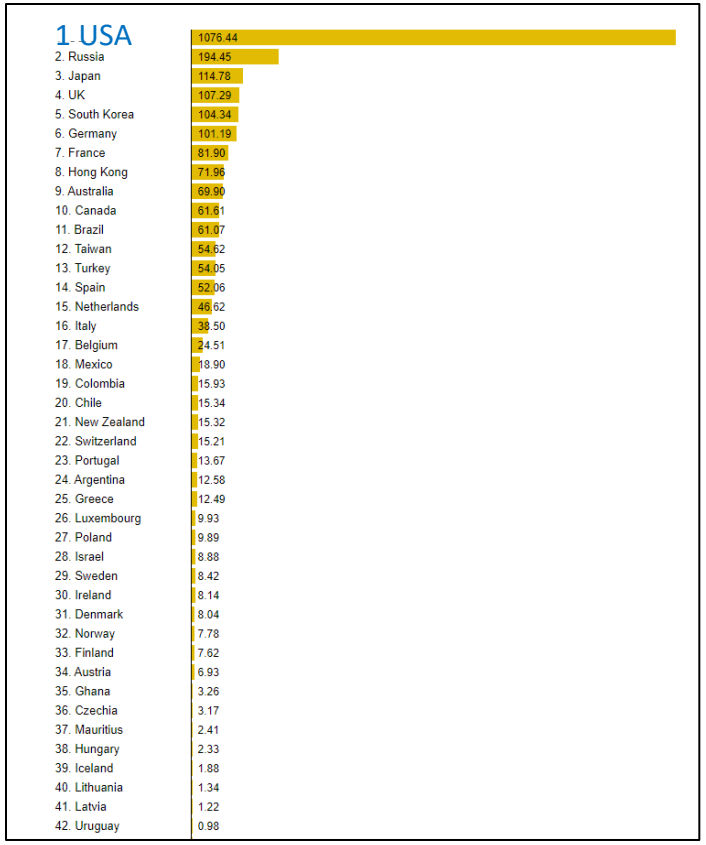


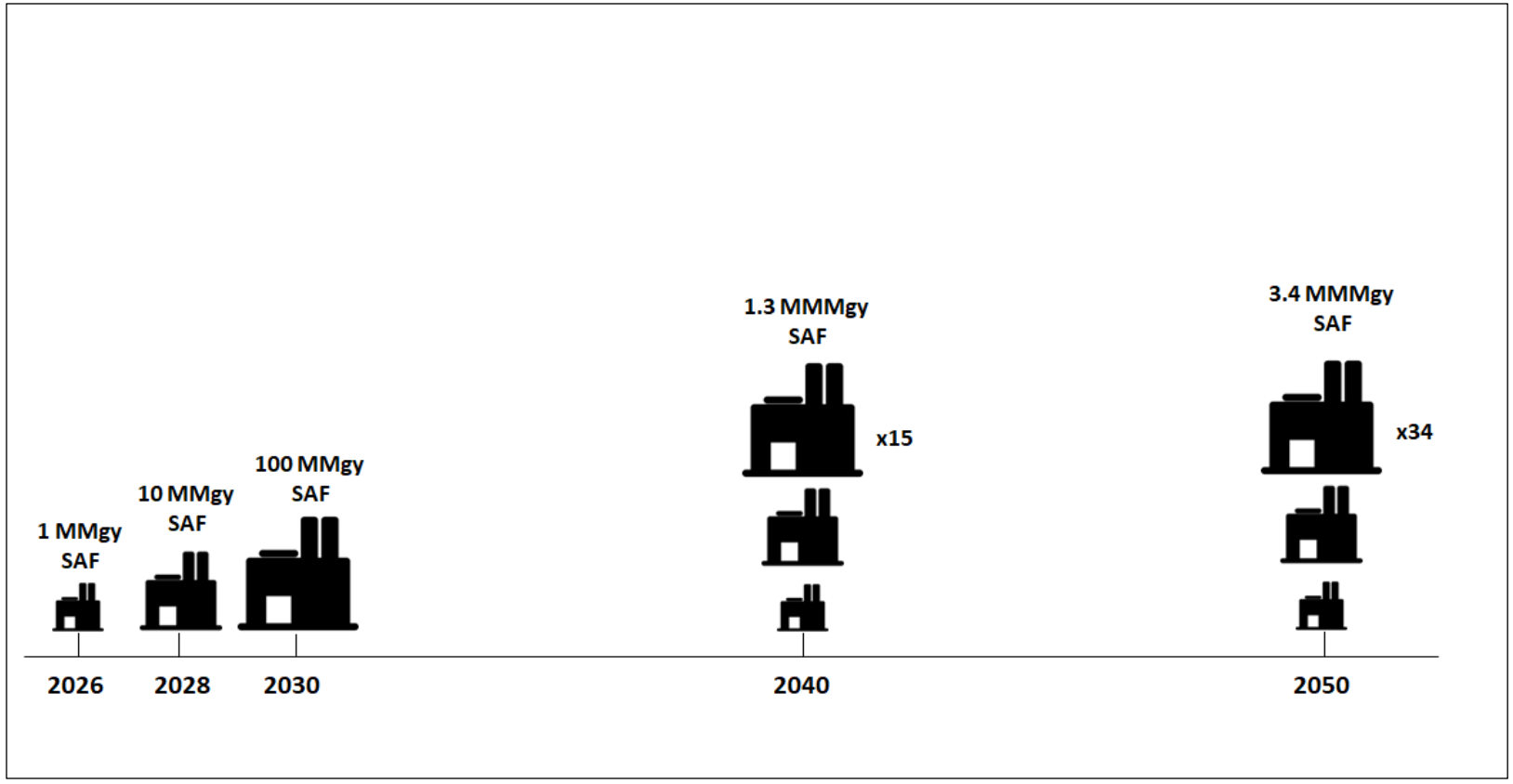


Michigan Technological University

3. Impact – Enable Replication of SAF Production

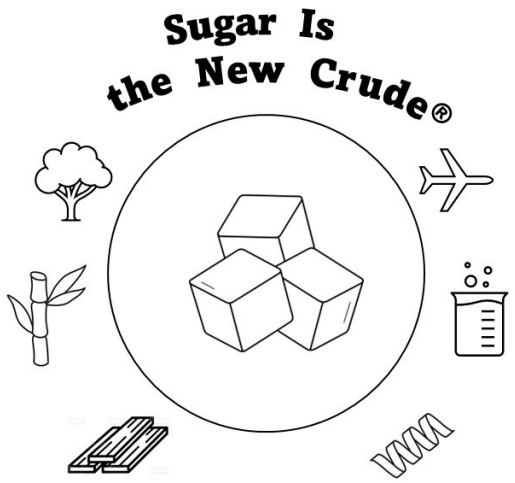
- The United States accounts for ~43% of global jet fuel consumption
- According to the Air Transport Action Group, global SAF demand could reach 160 billion gallons per year by 2050
- With a conservative 5% market penetration in the U.S., 34 AVAP-enabled SAF could be built domestically by 2050





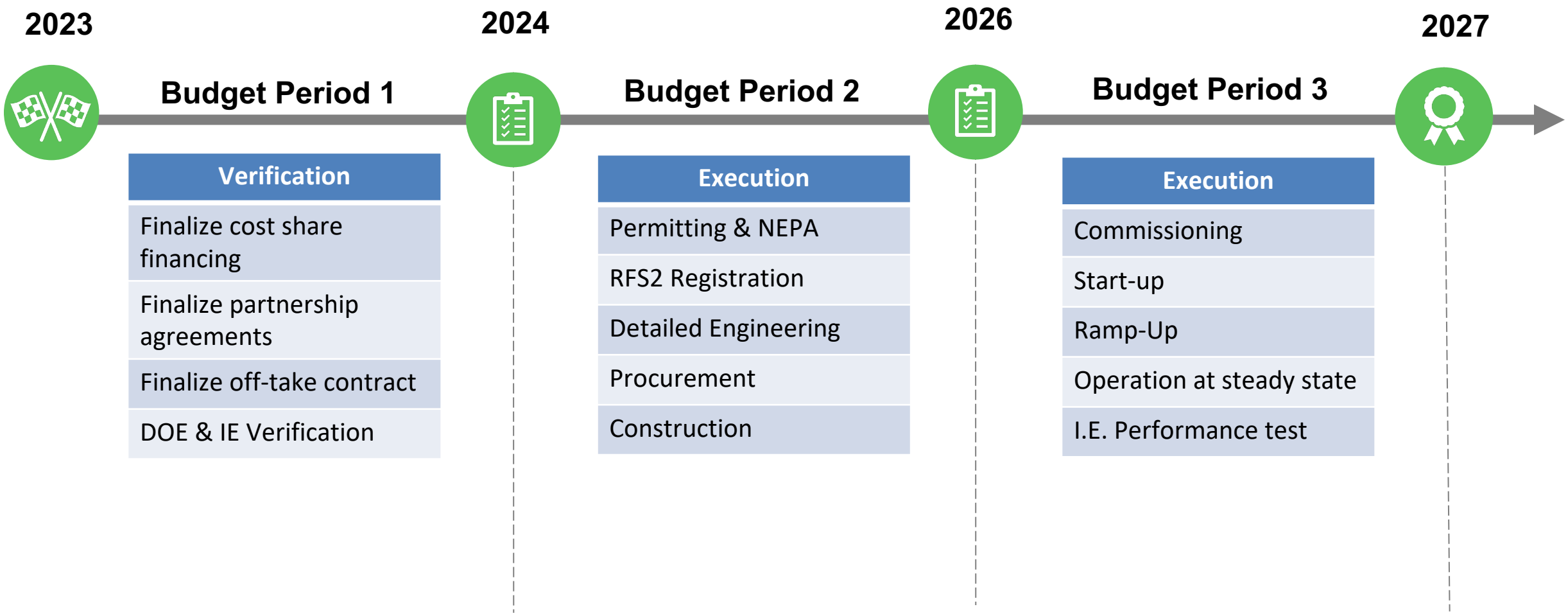
3. Impact- Support Utilization of U.S.'s Billion-Ton Biomass Resources

- **Approximately 340,000 tons dry biomass per day would be consumed by 34 AVAP-enabled SAF plants**
  - Roughly equivalent to the daily consumption of the U.S. Pulp & Paper Industry
  - The demo will utilize softwood, hardwood, and sugarcane bagasse to showcase the feedstock flexibility of the AVAP fractionation process.
  - Through a separate DOE-funded project, AVAPCO has shown that residual low-cost, woody-biomass alternatives can significantly reduce the price of cellulosic sugar intermediate for SAF
  - DOE estimates 85 million dry tons of construction waste, forest residues and energy cane will be available at $40-60/ton compared to $85/ton for woodchips



Summary

AVAPCO is currently negotiating the $80 MM grant from DOE for the Enabling Net Zero project that builds on the ABBA project's legacy.



Quad Chart Overview

Timeline

- *1/15/2017*
- *5/1/2023*

	FY22 Costed	Total Award
DOE Funding	*$1,032,229.62*	*$4,670,329.00*
Project Cost Share	*$1,032,229.62*	*$4,670,329.00*

Project Goal

Perform technical validation, process optimization, and basic engineering for an AVAP woody biomass demonstration plant for co-production of Sustainable Aviation Fuel and nanocellulose to demonstrate how low-volume, high-value nanocellulose co-produced with high-volume commodity jet fuel can enable a profitable biorefinery at reasonable scale.

End of Project Milestone

GO / NO-GO Decision to proceed with project implementation and plant construction.

Funding Mechanism

DE-FOA-0001232, Project Development for Pilot and Demonstration Scale Manufacturing of Biofuels, Bioproducts, and Biopower, 2016.

TRL at Project Start: 6
TRL at Project End: 7

Project Partners

- Petron
- Georgia Tech
- Byogy
- U.T.

Additional Slides

Responses to Previous Reviews' Comments

This project is well-run and is meeting its objectives on time and on target. It appears, however, that its main concern is developing nanocellulose and this appears to have a higher focus than it should. While co-products are important and nanocellulose will be used in a method that should impact the energy use and hence the GHG emissions from the transportation sector, it is not clear that the team is as focused on the co-development of biofuels.	Our previous DOE Peer Review focused on the jet fuel production process. For this Peer Review we focused on our recent, exciting developments in nanocellulose dewatering and drying funded portion of the project, including our product launch and commercialization efforts for low rolling resistance tires. Given the scale of the project (demonstration) the nanocellulose product is an important part of the facility product sales and cash flow.
It was unclear from the presentation at what scale the nanocellulose market will operate in the near and mid-future, which could significantly limit the amount of fuel that would be produced; while the goal of replacing the whole barrel cannot necessarily be met with just a single technology or single fuel, those that are selected for funding at demonstration scale (and larger) should demonstrate large scale impact in the fuels market.	The FOA stipulated a demonstration plant capacity of at least 50 dry metric tons per day of biomass feed. The ABBA project was designed to provide twice that capacity (100 dry metric tons per day of biomass feed). So, the ABBA project will have a relatively large impact on the current fuels market (1,000,000 gal/y), considering the fact that it is a demonstration plant. The commercial plants, as shown on slide 10, will have a solid impact on the fuels market.
The ATJ section (Petron for EtE and Byogy) look to be an add-on and a bit of an after-thought in order to fit in the FOA. Hard to see how they are commercially viable.	We apologize for the confusion. We have been working with Byogy since 2010 on jet fuel as part of our whole barrel biorefinery approach.

Commercialization

- The parties are in talks with numerous players throughout the Aviation Industry for SAF Off-Take
- AVAPCO and Birla Carbon have entered into commercial negotiations for nanocellulose masterbatch production and sale.
- AVAPCO and a confidential global chemical company have entered into negotiations for scale-up and commercialization of a proprietary bio-based chemical using AVAP sugars as feedstock

Thank You

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