Systems Modeling of Sustainable Aviation Fuel Supply Chains in Virginia: A Comparative Analysis of Imported and In-State Pathways

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A

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Abstract

Sustainable aviation fuel (SAF) offers multiple benefits compared to conventional fossil jet fuel, including decarbonized aviation, reduced reliance on imported foreign petroleum from geopolitically challenging regions, and opportunities to valorize domestic feedstocks, thereby stimulating local agriculture and economic development. U.S. federal agencies and others have made significant investments in SAF infrastructure over the last several years through the SAF Grand Challenges, leading to appreciable growth in SAF production on the West Coast and in the Midwest. However, SAF production and use on the East Coast lag behind other regions.

It is anticipated that the commercialization of SAF in Virginia could have multiple economic benefits for the Commonwealth, including protecting the competitiveness of Washington Dulles International Airport and stimulating economic development in the agricultural, forestry, and biomass processing and transport industries. Accordingly, the Commonwealth has supported SAF supply chain research for more than a decade, with a focus mostly on supply chains operating entirely within state borders. The goal of this study is to update the understanding of SAF supply chain readiness and competitiveness in Virginia to account for several new approaches to increase SAF availability, most notably imports from newly operational production facilities. Two well-known, previously validated federal modeling tools, the Federal Transportation Optimization Tool (FTOT) and ASCENT techno-economic assessment (TEA) workbooks, were used to quantify SAF production and transportation costs, assuming multiple different SAF production platforms and various multimodal transport networks. Results suggest that importing SAF is more cost-effective in the near term. Average minimum selling prices (MSPs) are **$4.41/gal and $8.00/gal,** respectively, without relevant

incentives, for import versus production in hypothetical (not yet existing) Virginia facilities. Applying current federal incentives, anticipated MSPs are reduced to **$4.22–$4.14/gal (± $0.10/gal)** for imported SAF and **$7.70–$7.62/gal** for hypothetical in-state production (based on previously published work).

Estimated values of MSP for two different import-based supply chains are not meaningfully different from one another, and the average estimated value is comparable to the historical price of fossil-derived jet fuel over the past 10–15 years (i.e., **$2.22/gal**). A recently proposed Virginia SAF incentive would reduce the MSP for in-state SAF to approximately **$7.89/gal**, but it would intentionally exclude SAF produced out of state. Given the various kinds of economic benefits that are possible via SAF commercialization, it is critical that Virginia and other states fully understand how differently structured incentives applied to various parts of the supply chain (life cycle) of SAF or other bio-products could create benefits of different magnitudes for different stakeholders (e.g., airlines, airports, farmers, foresters, converters, exporters, etc.), before locking in specific investments.

1.0 Introduction

Sustainable aviation fuels (SAF) are biofuels designed explicitly for aviation and produced from renewable resources such as plant materials, agricultural residues, and waste fats or oils. Under current practice, finished SAF can be directly blended with conventional jet fuel for use in aircraft engines. Use of Sustainable Aviation Fuel (SAF) offers multiple benefits, including reduced lifecycle greenhouse gas (GHG) emissions, improved energy security through reduced reliance on imported petroleum, and the use of domestic feedstocks to support agricultural and economic development (International Civil Aviation Organization, 2022).

To achieve these benefits, multiple U.S. federal agencies, including the **U.S. Department of Energy, U.S. Department of Transportation,** and **U.S. Department of Agriculture,** established the **SAF Grand Challenge in 2021**. This initiative was designed to accelerate the production, commercialization, and adoption of SAF in the United States through coordinated policy, research, and investment efforts (DOE, 2021). As part of this effort, the United States set production targets, including achieving 3 billion gallons of SAF annually by 2030 and scaling production to 35 billion gallons per year by 2050 to meet 100% of projected U.S. aviation fuel demand.

Various federal agencies have made significant economic investments to support the goals *of the SAF Grand Challenge,* including creation of the Federal Aviation Administration's (FAA) Fueling Aviation's Sustainable Transition (FAST-SAF program. Tier 1 FAST-SAF awards were to support research, planning, and supply chain analysis to evaluate SAF production and distribution opportunities, including the work presented in this thesis. Tier 2 FAST-SAF awards represent substantially larger investments, typically ranging from tens to hundreds of millions of dollars, and are focused on deploying infrastructure for SAF production, blending, storage, and distribution at or near major airport hubs.

Investments made by federal agencies and other entities over the past several years have led to appreciable growth in SAF production. Still, activity has been mostly concentrated on the West Coast and the Midwest. SAF is now being produced at multiple locations in the U.S.

Figure 1. shows the locations in the U.S. where SAF is currently being produced.

Facility	Feedstock	Conversion Method
World Energy (Paramount, CA)	- Waste fats - Inedible agricultural feedstocks	HEFA
New Rise Renewables (Reno/McCarran, NV)	- Corn oil - Soybean oil	HEFA
Phillips 66 Rodeo (Rodeo)	- Waste oils, - Fats, greases - Vegetable oils	HEFA
Montana Renewables *(Great Falls, MT)*	- Tallow - Canola oil - Camelina oil	HEFA
Diamond Green Diesel (Darling/Valero JV)	- Animal fats, - Cooking oil - Corn oil	HEFA
LanzaJet – Freedom Pines (Soperton, GA)	- Ethanol	ATJ

Figure 1. Map of the U.S. showing the geographic distribution of current SAF production facilities. The legend indicates which feedstocks and conversion methods are used at each facility.

Geographic Distribution of SAF Production Facilities

As shown in Figure 1, there are currently no SAF production facilities particularly close to Washington-Dulles International Airport (IAD), the primary airport in this study. Most facilities are located on the West Coast or, more recently, in the Gulf Coast region. All but one of the currently operational production facilities are of to-processed Esters and Fatty Acids (HEFA), which convert feedstocks of fats, oils, and greases (FOG) into a bio-crude that can be refined to produce SAF, (bio)diesel, and other (bio)distillates. HEFA-based production facilities include Diamond Green Diesel in Port Arthur, Texas; LanzaJet Freedom Pines Fuels in Soperton, Georgia; and multiple West Coast facilities, such as World Energy (Paramount, California), Phillips 66 (Rodeo, California), and New Rise Renewables (Reno, Nevada).

Additionally, there is only one HEFA facility located in Great Falls, Montana. The lack of SAF at a production facility in Ior or other East Coast airport nodes highlights the importance of transportation infrastructure in enabling future SAF deployment. The reliance on long-distance transport underscores the role of pipeline connectivity and multimodal logistics in determining delivered fuel costs. Finally, although it is not directly evident from the figure, current SAF production is largely concentrated in regions with strong feedstock availability, with existing refining infrastructure, and/or local (state) incentives for biofuels production or use. In contrast, SAF production nodes are not well distributed amongst locations with high demand.

Accordingly, SAF supply chains are inherently long-distance systems, where infrastructure availability and routing efficiency play a critical role in connecting production facilities to end-use locations such as airports. This reinforces the need for strategic planning of future SAF facilities, particularly in regions closer to major aviation hubs, to reduce transportation burdens and improve overall system efficiency.

Table 1. CORSIA-certified processes for SAF production, with relevant information by life-cycle stage. (Adapted from ICAO, n.d.)

Pathway	Chemical Process	ASTM Standard(s) and Blend Ratio	Feedstock, Transport Mode	Airports & Producers[1]
Hydroprocessing Esters and Fatty Acids **(HEFA)**	Triglyceride feedstocks are broken down into fatty acid chains, which are then processed into fuel	HEFA-SPK, ASTM D7566 Annex A2 Max Blend = 50%	Vegetable oils, animal fats, and cooking oils Pipeline, Truck	World Energy New Rise Renewables Phillips 66 Montana Renewables Diamond Green
23Alcohol to jet synthetic paraffinic kerosene **(ATJ-SPK)**	Bio-feedstocks are biologically fermented to produce alcohols, which are processed into fuel	ASTM D7566 Annex A5 Max Blend = 50%	Ethanol, isobutanol, and isobutene from biomass Truck	British Airways, Nippon Airways, Lanza Jet
Integrated hydro-pyrolysis and hydroconversion **(IH2)**[2]	Lignocellulosic feedstocks are thermally decomposed into hydrocarbons that are processed into fuel	TBD2 Max Blend = 5%	Waste biomass such as seaweed, aquatic plants, algae, bagasse, corn stover, and municipal solid waste ("trash")	Shell (R&D)
Fischer-Trosch hydroprocessed synthesized paraffinic kerosene **(FT, SPK)**	Woody biomass is gasified to produce syngas, which is then transformed into fuel	ASTM D7566 Annex A4 Max Blend = 50%	Municipal solid waste, agricultural and forest wastes, energy crops Pipeline, Truck	N/A

[1] Airports are designated using IATA codes: IAH (George Bush Intercontinental Airport, Houston, TX); LAX (Los Angeles International Airport, Los Angeles, CA). ORD (O'Hare International Airport, Chicago, IL); MSP (Minneapolis–Saint Paul International Airport, Minneapolis–Saint Paul, MN). DTW (Detroit Metropolitan Wayne County Airport, Detroit, MI); JFK (John F. Kennedy International Airport, New York, NY). Airlines: British Airways (London, United Kingdom); All Nippon Airways (ANA) (Tokyo, Japan); Lanza Jet, Inc. (Soperton).

[2] The pyrolysis pathways (IH2) have not yet been formally certified under CORSIA (Csonka et al., 2023).

Table 1. Processes that have been certified under the international framework governing SAF production, CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation). The table also summarizes information about which feedstocks are most compatible with each conversion platform and indicates which airports are currently using appreciable SAF volumes produced via each pathway. Notably, most of the SAF produced in the US is consumed on the West Coast (specifically California) or, to a lesser extent, in the Midwest. Reiterating from above, many of these regions have created local (state) incentives for the production and/or use

of SAF. The East Coast lags other regions in the US in producing and consuming SAF, in part because there are no local (state) incentives for SAF among East Coast states (Peterson et al., 2024).

This regional imbalance shows a clear gap in where SAF is being produced and used across the United States. As a result, East Coast airports, including major hubs like Dulles International Airport, rely more on SAF that is transported from other regions. This increases transportation distances and adds complexity to the overall supply chain. Expanding production in these regions or introducing supportive policies could help improve efficiency and reduce overall fuel costs.

SAF commercialization in Virginia could have multiple economic benefits for the Commonwealth, arising from each stage of the SAF life cycle (Figure 1). Virginia produces abundant **feedstocks**, most notably woody biomass and agricultural residues, which could be used as SAF feedstocks for various conversion pathways (Table 1). Such activity could stimulate and revitalize Virginia agriculture and forestry. Similarly, siting **conversion** facilities at old papermill locations could revitalize historic industries within the Vicinity of energy, water, and transportation connectivity, as the biomass-handling equipment already in place exists at those sites. Increased **refining** activity will generate new employment opportunities and industrial development at several existing refineries within the state. Also, transportation and logistics operations associated with feedstock movement and fuel distribution could strengthen regional supply chain networks (e.g., the Colonial Pipeline, which traverses the state). Finally, increased SAF availability could enhance the competitiveness of Washington Dulles International Airport and support long-term aviation decarbonization goals.

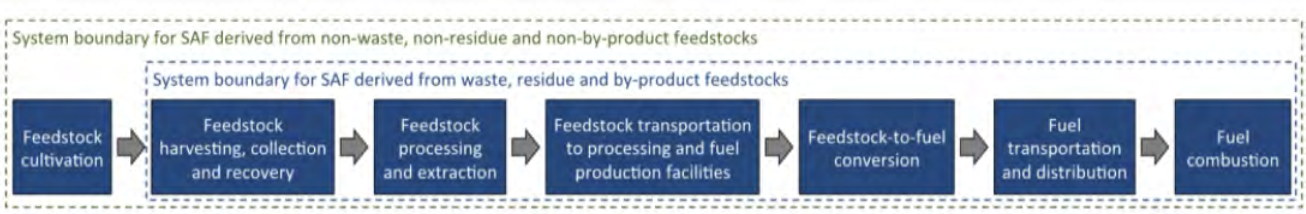


Figure 2. ICAO's representation of the SAF life cycle under CORSIA. (from ICAO, 2022)

Given the many ways that SAF commercialization could benefit Virginia, the Commonwealth has supported SAF supply chain research for more than a decade. The original work was motivated by the desire to ensure that Dulles Airport (in Virginia) could access enough SAF supply to stay competitive with other airports for trans-Atlantic flights. The European Union and other parts of the world have been consistently committed to SAF commercialization, and it was anticipated that a lack of SAF could make Dulles Airport less competitive as a regional hub, in which case Virginia would lose a significant source of economic revenue. Since SAF was not being produced anywhere in the US when the Virginia Department of Aviation commissioned its early SAF supply chain studies, it was presumed that SAF would need to be created in Virginia if it were going to be used in Virginia (i.e., Dulles). Accordingly, previous SAF supply chain analysis research focused on supply chains operating entirely within state borders.

Previous SAF supply chain research conducted at the University of Virginia (UVA) by Davis et al. (2024) focused on two regionally abundant feedstocks, namely woody biomass and agricultural residues. These feedstocks are compatible with various SAF production platforms (Table 1). However, at the time the work was undertaken, two conversion pathways seemed especially compelling: Gasification with Fischer–Tropsch (GFT) and Alcohol-to-Jet (ATJ). Two feedstocks applied to two possible conversion pathways yielded four modeled cases. The

previous study focused on answering several key questions about those four possible SAF pathways, including: *WHERE* should production facilities be located (by county); *HOW MUCH* SAF could be produced (gallons per year) relative to the historical fuel demand at Dulles; and *HOW MUCH* hypothetical (not yet existing) financial incentive would be needed from the Commonwealth or other entities to make locally produced (in-Virginia) SAF cost competitive with fossil jet fuel?

To answer these questions, the UVA team created supply chain models for the four SAF pathways of interest (two feedstocks × two platforms). They applied two widely used, previously validated modeling tools from federal agencies, i.e., the Freight and Fuel Transportation Optimization Tool (FTOT) and the ASCENT techno-economic analysis (TEA) workbooks.

They used the tools to estimate SAF production costs, output volumes, life-cycle greenhouse gas (GHG) emissions, and other metrics. Examples of key findings from the previous SAF supply chain analysis, focusing on the production of SAF from Virginia feedstocks at locations within Virginia (Figure 3.B), are summarized in (Figure 3.C). These results show the comparison along minimum selling prices (MSPs) for SAF produced via (GFT or pyrolysis in "pilot" (near-term future) or "mature" (longer-term future) facilities, with and without incentives as they existed at the time of the study. Notably, it was anticipated that either platform might produce SAF that was cost-competitive with fossil jet fuel under the "mature" supply chain cases. The UVA team followed up on their SAF supply chain analysis with a technical report ("letter") written in response to queries from Virginia state legislators following the 2024 legislative session, during which several SAF-related bills came up but ultimately did not pass. The technical report was approved by the Virginia Secretary of Agriculture and Forestry in February 2025 (Peterson et al., 2024).

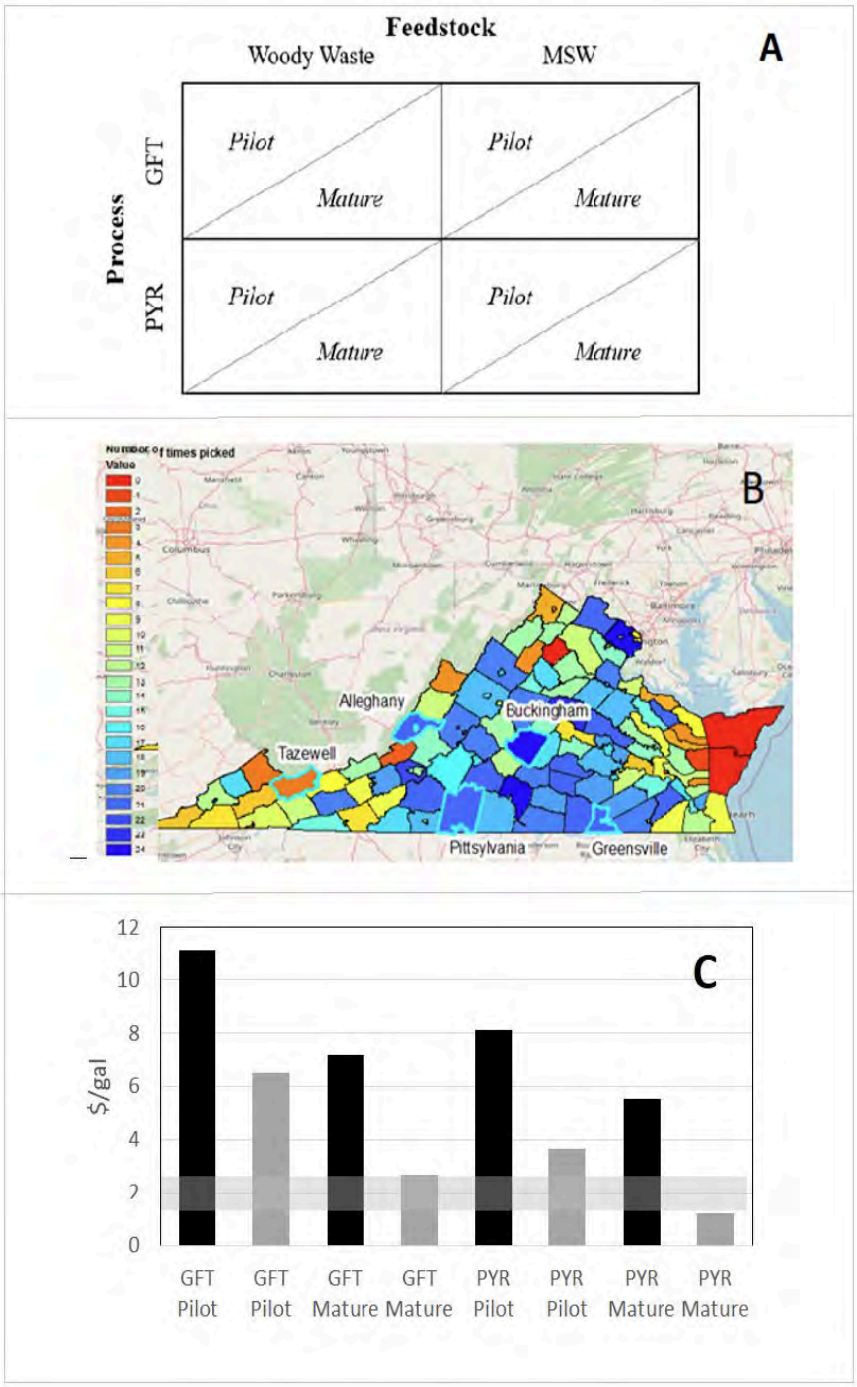


Figure 3. Overview of SAF pathway modeling scenarios and results. (A) Conceptual framework showing combinations of feedstock (woody waste and municipal solid waste) and conversion pathways (GFT and pyrolysis), each evaluated under pilot- and mature-scale assumptions. (B) Spatial distribution of selected feedstock sourcing locations across Virginia. (C) Resulting minimum selling price (MSP) estimates ($/gal) for each pathway scenario, illustrating cost variation across feedstock–conversion combinations and technology maturity levels.

The supply chain analysis research published by Davis et al. (2024) and the "letter" for the Virginia state legislature reflected the current state of the SAF landscape as it existed at the time those studies were written. The US SAF landscape has evolved markedly since then. Several key changes, for example. It is now possible for Dulles Airport (and other East Coast entities) to import SAF, as it is produced at multiple locations in the U.S. Also, the Gasification/Fischer–Tropsch (GFT) pathway, which seemed so promising just a few years ago, has proven less reliable and more expensive than anticipated. In contrast, the HEFA process has emerged as the leading SAF production pathway in regions with sufficient availability of lipid-based feedstock, owing to its technological maturity and commercial deployment (U.S. Department of Energy, 2023). Finally, there has been significant volatility in U.S. federal support for sustainability and decarbonization efforts, including SAF, creating uncertainty for long-term policy and investment decisions.

The goal of this study was to compare the imported and in-state sustainable aviation fuel (SAF) supply chains in Virginia to understand better which options are most practical and cost-effective given the current U.S. SAF landscape. In particular, it was of interest to estimate the MSP for SAF produced at two "nearby" locations: Diamond Green Fuels in Port Arthur, Texas, and the Lanza Jet facility in Soperton, Georgia) and compare the results with previous estimates of MSPs for SAF produced via various pathways in hypothetical (not yet existing) SAF production facilities in Virginia

2.0 Methods

2.1 Overview and Description of Selected Operational SAF Production Facilities

The approach in this study is based on previous work by Davis et al. (2024). Existing modeling tools are used to represent the operations of two recently established SAF production facilities "near" to Virginia, to anticipate how the cost of importing SAF from one or both of those facilities would compare to existing estimates of minimum selling price (MSP) for SAF produced in Virginia at hypothetical (not yet existing) facilities (Davis et al., 2024). MSP for the import cases is estimated by summing the estimated production costs from the ASCENT TEA workbooks and the estimated fuel transportation costs from FTOT. The subsections below provide additional information on each tool, its use in this study, and the MSP calculation.

The two selected SAF production facilities were Diamond Green Diesel and LanzaJet Freedom Pines Fuels. Diamond Green Diesel is located in Port Arthur, Texas, and LanzaJet Freedom Pines Fuels is located in Soperton, Georgia. Features of each location were collected from publicly available sources and incorporated into each modeling tool to represent current operations as accurately as possible, without direct coordination with facility personnel.

Diamond Green Diesel uses the HEFA production process. She is one of the largest renewable diesel production sites in the U.S., with a total production capacity of approximately 1.2 billion gallons per year (Diamond Green Diesel, 2026). This output corresponds to SAF, biodiesel, and other co-distillates, because HEFA creates a mixed bio-crude that is then refined to produce individual distillates. Most SAF production processes in Table 1, including HEFA, cannot produce SAF independently. The facility began operations in 2013 and has undergone

multiple expansions, including a major infrastructure expansion supporting efforts on the Gulf Coast. It benefits from extensive existing refinery infrastructure, strong feedstock supply chains, and direct pipeline connectivity along the U.S. Gulf Coast.

LanzaJet Freedom Pines Fuels utilizes the Alcohol-to-Jet (ATJ) conversion pathway. It is the first and only commercial-scale SAF facility using the ATJ platform. The facility has an estimated production capacity of approximately 10 million gallons per year and began operations in 2024 (LanzaJet, 2026). Again, this output corresponds to a mixture of distillates, since the bio-crude produced from ATJ requires refining to yield individual distillates, including SAF. However, for this study, a projected expansion scenario of approximately 1 billion gallons per year of SAF and renewable diesel combined by 2030 was modeled (LanzaJet, 2026). Together, these two facilities represent SAF production pathways, scales, and levels of infrastructure integration, providing a useful basis for comparing imported SAF supply chain configurations in Virginia.

2.2 Production Cost Analysis

The Aviation Sustainability Center (ASCENT) techno-economic analysis (TEA) was conducted to estimate SAF production costs across multiple conversion pathways and system configurations. ASCENT generates minimum selling price (MSP) estimates by accounting for both capital expenditures (CAPEX) and operating expenditures (OPEX), with CAPEX already levelized within the framework. These outputs represent production costs for all SAF supply chain stages, excluding transportation (Figure 2), which is modeled separately using FTOT and later combined to version the Different ENT workbooks, which were available as Excel workbooks. The most recent version of each workbook for HEFA and the ATJ processes was

downloaded from the ASCENT website (ASCENT, n.d.). TEA model inputs were selected to correspond ("match") what is known about current operations – i.e., feedstock type, scale of production. All other values in the ASCENT TEAs were left unchanged relative to the default values. For the subset of inputs for which the TEAs had multiple choices (via drop-down input menus), all possible combination cases were evaluated. For the HEFA workbook, which was used to represent the Diamond Green facility, multiple input options were available: **feedstock type (FOGs, Vegetable Oil, and FOGs + Vegetable Oil)** and **distillate split (55:26:19 and 71:10:19)**. Therefore, **six (6) combination cases** were evaluated. For the ATJ workbook, which was used to represent the LanzaJet facility, multiple input options were possible for **feedstock type (Ethanol and Isobutanol)** and **distillate split (70:0:30, 35:35:30, and 70:20:10)**, excluding cases that did not produce SAF. Therefore, **six (6) combination cases** were evaluated. Each case was "run" to produce estimates of MSP and other outputs.

The raw MSP values computed by each ASCENT TEA workbook were computed using a discounted cash-flow return-on-investment method. The *minimum* price of SAF would be required to make the net present value (NPV) of the built scenario equal zero over the plant's lifetime. In this case, it levels capital costs and ensures that overall costs (CAPEX plus OPEX) are recovered while maintaining the required rate of return.

$$NPV = \sum_{t=1}^{N} \frac{R_t - C_t}{(1+i)^t} = 0$$

R_t = total revenue in year t
C_t = total cost in year t
i = discount rate
N = plant lifetime

Revenue includes the sale of SAF and various co-distillates, such as diesel, naphtha, propane, etc., as well as the purchase of feedstock, operating expenses, and annualized capital expenditures. Accordingly, when estimating SAF MSP, the model must make assumptions about sale prices for other distillates. Therefore, the assumed selling prices for various co-distillates have a strong influence on the MSP estimated for SAF. It was observed that the different Excel workbooks (HEFA adidTJ) were not using the same assumed selling prices for diesel and other co-distacross various runs. This lack of uniformity created toifactual variability among models' predictions of SAF MSP. To make the MSP results more comparable across all model runs, the raw MSP values were manually adjusted in Excel. The costs and revenues computed in each run were preserved. However, the selling prices ($/gal) for diesel and gasoline/naphtha were manually adjusted to have consistent values across all runs, $0.96/gal and $0.89/gal, respectively, for HEFA pathways, and $0.81/gal and $0.41/gal, respectively, for ATJ pathways. Goal Seek was then used to determine the revised minimum selling price (MSP) for SAF required to maintain the original revenue (i.e., NPV = 0) for each model run. Figure 4 illustrates this manual post-processing approach, which standardizes background economic assumptions and enables more consistent comparison across pathway scenarios.

FOG 35:26:19	Revenue Generating Product	Annual Production	Units	MSP	Units	Total annual revenue, MM$		
Scenario 2	SAF	532	MM liter/year	$0.97	$/liter	$515.73		
Scenario 2	Diesel	213	MM liter/year	$0.96	$/liter	$204.48		
Scenario 2	Naphtha	77	MM liter/year	$0.89	$/liter	$68.53		
Scenario 2	Propane	157	MM liter/year	$0.40	$/liter	$62.80		
Scenario 2	Output Incentives		MM liter/year		$/liter	$0.00	$3.67	SAF Conversion, Refining Cost ($/gal)
Scenario 2	Total Revenue		MM liter/year		$/liter	$851.54	$0.00	Revenue
FOG 71:10:19								
Scenario 3	SAF	687	MM liter/year	$0.93	$/liter	$642.00		
Scenario 3	Diesel	82	MM liter/year	$0.96	$/liter	$78.72		
Scenario 3	Naphtha	77	MM liter/year	$0.89	$/liter	$68.53		
Scenario 3	Propane	157	MM liter/year	$0.40	$/liter	$62.80		
Scenario 3	Output Incentives		MM liter/year		$/liter	$0.00	$3.54	SAF Conversion, Refining Cost ($/gal)
Scenario 3	Total Revenue		MM liter/year		$/liter	$852.05	$0.00	Revenue

Figure 4. Screenshot of post-processing to harmonize assumptions about co-distillate selling prices across all ASCENT model runs Hig. Highlighted "revenue" cells illustrate that there is no difference ("$0.00") between the total revenue originally calculated in each run and the total revenue computed using adjusted co-distillate selling prices.

2.3 Transportation Cost Analysis

Freight and Fuel Optimization Tool (FTOT)

The Freight and Fuel Optimization Tool was developed by the U.S. DOT's Volpe Center to provide modeling estimates of end-to-end supply chain costs for a user-defined fuel system. In this study, FTOT was used to optimize transportation networks connecting each SAF production facility (origin node) to Dulles Airport (demand node). The analysis assumed a 1:1 blended fuel during transportation, in which SAF and conventional jet fuel were moved together from origin to destination. The Model selects from existing pipelines, roadways, and waterways. Railways and other transport connections to find the lowest-cost option. Based on stakeholder input from Virginia agencies, two versions of transportation routes were designed for each SAF production facility, one each including and excluding the Colonial Pipeline.

The FTOT modeling is driven by a series of highly structured Microsoft Excel input spreadsheets. The user-friendly spreadsheets allow one to use input cells to define parameters. Key parameters include feedstock type, production or blending facility cost, facility location, and

final destination (airport). Only transportation-related parameters were relevant to this study, since ASCENT was used to represent all other life cycle stages. The finalized input specifications are then saved and imported into the FTOT-specific Python window. Once run, FTOT produces results that can be opened in plain-text (Notepad) format. These results will include cost breakdowns and map visualizations for final routing decisions. These results were interpreted to identify the optimal transportation pathway and costs. With the final product, GDB can be input into ArcGIS for visualization of the supply chain system.

2.4 Integration of Conversion and Transportation Costs

To estimate the total delivered cost of SAF, conversion costs obtained from ASCENT were added to transportation costs from FTOT:

$$MSP_{\text{delivered}} = MSP_{\text{conversion}} + C_{\text{transport}}$$

This approach provides a comprehensive estimate of SAF cost, accounting for all life-cycles (Figure 2). MPS results are reported in $/gallon, making them directly comparable with results from previously published SAF supply chain, e.g., Davis et al (2024).

3.0 Results and Discussion

3.1 ASCENT Modeling Results

The ASCENT TEA modeling tools were used to generate estimates of MSP for the production facilities currently operated by Diamond Green (HEFA) and LanzaJet (ATJ). Multiple

runs of each model were necessary to cover all possible combinations of select inputs, as it was not possible to have full knowledge of current operations at each facility.

Table 2 summarizes MSP results from model runs of the HEFA tool, which was used to present Diamond Green Diesel's operations in **Port Arthur, Texas**. The MSP values summarized in the table were adjusted via post-processing to reflect the assumed prices of other co-distillates, so that all runs of both models (HEFA and ATJ) used the same values. Based on the various possible input options for two parameters, i.e., three choices of feedstock and two choices for distillate breakdowns, a total of six runs were required for the HEFA case.

Table 2. SAF production pathway scenarios, illustrating HEFA runs across varying feedstocks (FOGs, vegetable oil, and blends) and distillate splits (55:26:19 and 71:10:19). Distillate breakdown corresponds to jet fuel (i.e., SAF), diesel (D), and other products (e.g., naphtha and propane, "NP"). **The label breakdown is SAF: labeled D: NP.**

Run #	Feedstock Type	Distillate Breakdown	Final MSP ($/gal)
1	FOGs	55:26:19	3.67
2	FOGs	71:10:19	3.54
3	Vegetable Oil	55:26:19	5.24
4	Vegetable Oil	71:10:19	4.76
5	FOGs + Vegetable Oil	55:26:19	4.46
6	FOGs + Vegetable Oil	71:10:19	4.15

The results in Table 2 illustrate that feedstock is a stronger driver of variability (MSP) than distillate breakdown. Greater variation in MSP is observed among the three different feedstock categories (blue, green, orange) than is observed for different distillate breakdown values within

a given feedstock. However, within each feedstock category, model runs assuming higher yields yield lower MSP values for SAF. This outcome occurs because the model solves “backward "for the minimum price of SAF required to set NPV = 0, such that assigning high revenues for diesel (more gallons or a higher price per gallon) makes it such that SAF does not need to generate as much revenue to break even with costs. Although the model did not articulate a strong influence on MSP, the fuel market is very complicated. Prices for all distillates tend to go up and down together based on market trends. Also, since production facilities have some flexibility in choosing the active volumes of each distillate they want to produce, diesel and SAF can compete with one another. Accordingly, producers choosing to make more diesel because it earns a higher price could reduce the amount of SAF that is produced, even though both distillates are produced together.

Table 3 summarizes MSP results from model runs of the ATJ tool, which was used to represent LanzaJet’s operations in **Soperton, Georgia**. The MSP values presented in the table were obtained through post-processing to standardize the co-distillate prices and stillates across all runs. Based on the possible input combinations for two parameters—feedstock type (two options) and distillate breakdown (three options)—a total of six runs were conducted for the ATJ case. This post-processing approach ensured that all model runs, across both HEFA and ATJ pathways, were evaluated under consistent co-product pricing assumptions.

Table 3. SAF production pathway scenarios, illustrating ATJ runs across varying feedstocks (ethanol and isobutanol) and distillate splits **(35:35:30, 70:0:30** Distillate breakdown colabeled responds to jet fuel (i.e., SAF), diesel (D), and gasoline (G). **The distillate breakdown is labeled SAF:D:G.**

Run #	Feedstock Type	Distillate Breakdown	Final MSP ($/gal)
1	Ethanol	35:35:30	3.25
2	Ethanol	70:0:30	2.93
3	Ethanol	70:20:10	2.98
4	Isobutanol	35:35:30	6.76
5	Isobutanol	70:0:30	4.69
6	Isobutanol	70:20:10	4.74

Similar to the HEFA case at Diamond Green, feedstock type has a greater influence on MSP than distillate breakdown. Greater variability in MSP is observed between feedstock categories (e.g., gray versus green) than within each category than occurs across different distillate breakdowns within a single feedstock category. However, as observed with the HEFA results, distillate breakdowns with higher diesel fractions tend to have lower SAF MSP values. These results also highlight the importance of policy design. If the primary objective is to maximize SAF availability for airport use, incentives must be structured to specifically target SAF production rather than broadly supporting all distillate outputs.

Figure 5 shows the sets of MSP values from Tables 2 and 3 as distributions, wherein the outputs produced by each individual model run are treated as independent outcomes.

HEFA (MSP) Uncertainty Analysis **ATJ (MSP) Uncertainty Analysis**

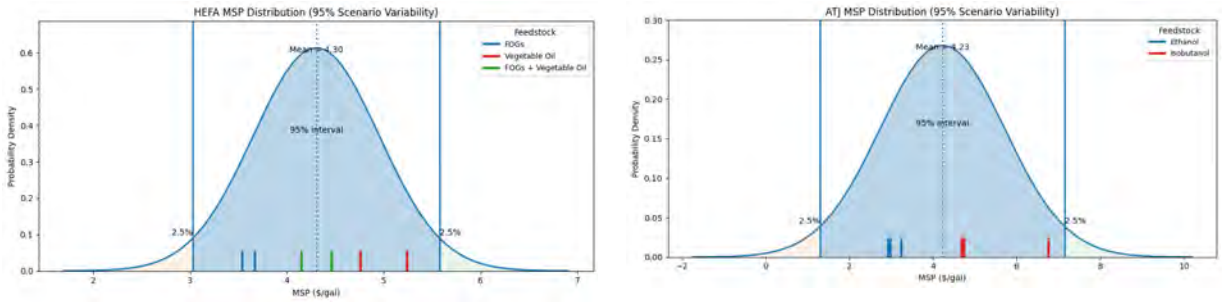


Figure 5. Side-by-side uncertainty distributions illustrating 95% MSP confidence intervals for HEFA and ATJ pathways.

The HEFA distribution exhibits a relatively tight clustering of MSP values across the evaluated scenarios, indicating moderate variability. Based on the modeled results, the mean HEFA MSP is approximately **$4.30/gal**, with a standard deviation of approximately 0.65, resulting in a 95% outcome interval of:

$$\approx 4.30 \pm 1.96(0.65) \Rightarrow [3.02,\ 5.58]\ \mathrm{USD/gal}$$

This relatively narrow interval suggests that the MSP estimates produced for the HEFA are intended to represent operations at the Diamond Green facility and are fairly robust. While some variability is observed—primarily driven by higher-cost vegetable oil scenarios—the overall spread remains limited. This stability is further reinforced by the relatively low coefficient of variation (15%), indicating moderate sensitivity to input assumptions.

In contrast, the ATJ distribution shows a significantly wider spread of MSP values, reflecting higher variability across scenarios. The mean ATJ MSP is approximately **$4.23/gal**, with a standard deviation of approximately 1.48, resulting in a 95% outcome interval of:

$$\approx 4.23 \pm 1.96(1.48) \Rightarrow [1.33,\ 7.13]\ \mathrm{USD/gal}$$

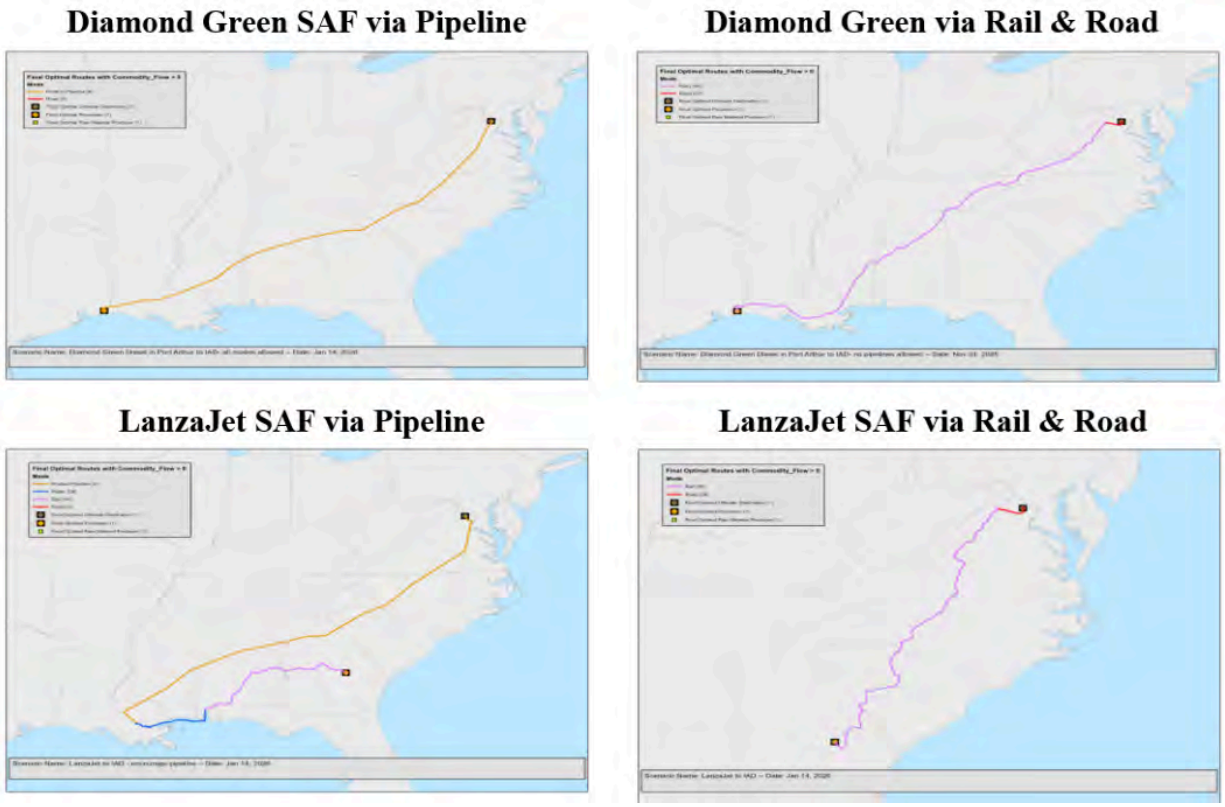
The appreciable width of this indicates that ATJ modeling meant to represent operations at the LanzaJet facility is more sensitive to assumptions about feedstock choice and distillate breakdown; i.e., it is more difficult to produce a good estimate of MSP for their current operations. The MSP distribution reveals a clear separation between Lower-cost ethanol pathways (**$2.9–$3.3/gal)** and higher-cost isobutanol pathways (**$4.7–$6.8/gal)**. This variability is also evident in a higher standard deviation and a higher coefficient of variation (30%+) than in the HEFA pathway. The ATJ MSP values also exhibit a much wider 95% interval than the MSP results for HEFA. Although the mean MSP values for both platforms, HEFA and ATJ, are relatively similar, their uncertainty profiles differ substantially. HEFA provides more consistent economic performance across scenarios, while ATJ presents greater uncertainty but also the potential for lower-cost outcomes under favorable conditions.

3.2 FTOT Modeling Results

FTOT was used to estimate the cost of transporting SAF from each production facility of interest to Dulles Airport. For each facility, FTOT was used to identify two “optimized” transportation routes, one each including and excluding the Colonial Pipeline. FTOT is generally used to find one agle “optimized” route to connect the origin and destination nodes. Still, this study was particularly interested in comparing costs with and without the pipeline. There is

widespread expectation among stakeholders that the use of the pipeline will deliver substantial reductions in transport costs. There is also a strong desire to avoid adding large volumes of truck traffic on roadways to deliver the SAF if the pipeline cannot be used.

Figure 6. Summarizes FTOT results for each production facility with and without the use of Colonial Pipeline



The results from the Freight and Fuel Transportation Optimization Tool (FTOT) illustrate how production location influences access to low-cost transportation infrastructure, thereby influencing the overall cost of delivered SAF. FTOT's optimized routes for the Diamond Green facility look similar, with and without the pipeline. Both routes traverse mostly the same states, with similar travel distances: 1,200 miles with the pipeline and 1,400 miles without the pipeline (road and rail). Transportation costs for Diamond Green Diesel to IAD were estimated at

approximately **$0.05/gal** via pipeline and **$0.23/gal** using all transportation modes, indicating a clear cost advantage for pipeline delivery.

FTOT's optimized routes for the LanzaJet facility look different depending on whether the pipeline is included or excluded. The two routes traverse different sets of states and have different total transport distances.

When the pipeline is included, the total transport distance is approximately 1,749 miles. A substantial portion of this route travels south along the Gulf Coast, away from the target destination, a pipeline injection point. The route then turns and moves eastward. The associated transportation cost is estimated at **$0.11 per gallon.**

When the pipeline is excluded, transport occurs only via road and railway. Total transportation distance decreases to approximately 762 miles, reflecting a more direct routing structure. The estimated transportation cost for this network is **$0.18 per gallon.** These results reveal that the estimated transport cost increases when the pipeline is assumed to transport SAF from the LanzaJet facility. This outcome is at odds with stakeholder intuition and other FTOT results produced in this study.

3.3 Integration of Conversion and Transportation Costs

Average production costs from ASCENT were added to transportation costs from FTOT to generate estimated MSP estimates SAF produced at either Diamond Green or LanzaJet and consumed at Dulles Airport. Table 4 summarizes the calculation of the overall MSP for select import-based supply chain configurations corresponding to each production facility of interest.

Table 4. Summary of conversion and transportation cost estimates for selected import-based supply chains delivering SAF to Dulles Airport.

Table 4. Comparison of Delivered Minimum Selling Price (MSP) for Imported SAF Pathways

Production Facility (Location)	Conversion Pathway	Transport Mode	Conversion Cost ($/gal)	Transport Cost ($/gal)	Delivered MSP ($/gal)
Diamond Green (Port Arthur, TX)	HEFA	Pipeline	$4.30	$0.05	$4.35
Diamond Green (Port Arthur, TX)	HEFA	Road & Rail (No Pipeline)	$4.30	$0.23	$4.53
Lanzajet (Soperton, GA)	ATJ	Pipeline	$4.23	$0.11	$4.34
Lanzajet (Soperton, GA)	ATJ	Road & Rail (No Pipeline)	$4.23	$0.18	$4.41

Note. Delivered MSP equals conversion cost plus transportation cost under each infrastructure scenario.

Results in Table 4 reveal that transportation mode and cost significantly influence the overall delivered SAF price for both production facilities of interest. This observation, whereby most of the cost for SAF arises from production rather than transportation, is consistent with results from previous SAF supply chain research focusing on in-state Virginia SAF pathways. However, it is emphasized that the transport distances for both import cases evaluated in this study are much larger than those represented in previous in-state models. It is therefore perhaps evident that transport still accounts for a relatively minor fraction of the overall final per-gallon SAF cost.

Transportation Impacts: FTOT Results for LanzaJet SAF via Rail & Road

3.4 Comparison of Import-Based vs. In-State SAF Supply Chain Costs

Figure 7 compares in-state and import-based SAF supply chains for Virginia. The import cases (orange bars) correspond to results from this study (Table 4). The in-state results (blue bars) are taken from previously published research by Davis et al. (2024). The plotted results correspond to MSP estimates that do not account for relevant incentives.

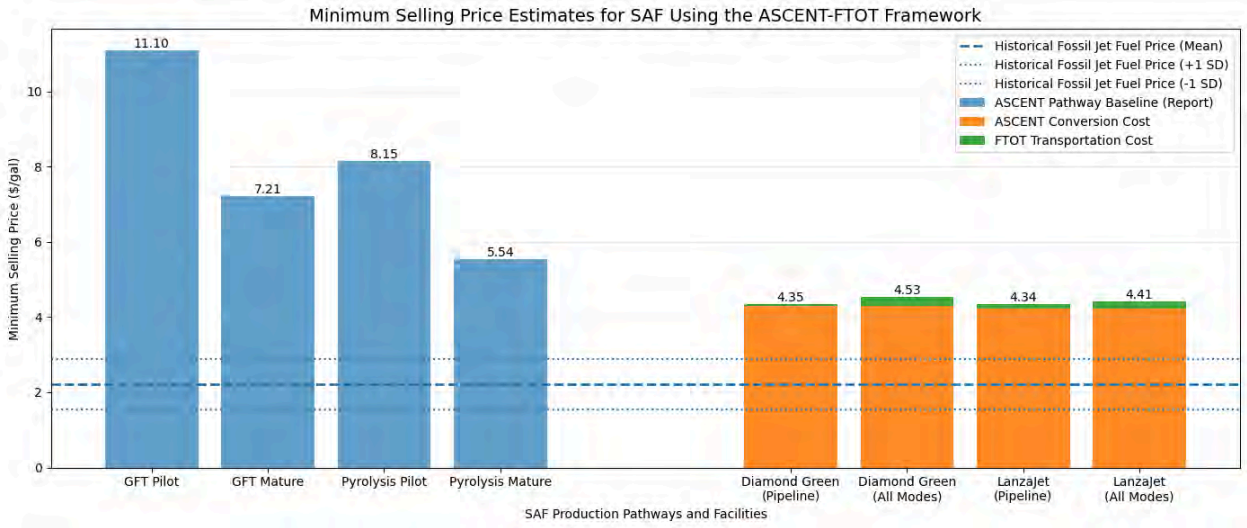


Figure 7. Comparison of SAF MSP estimates for in-state (blue) and import-based orange) SAF supply chains fpr Virginia without accounting for federal incentives.

As shown in Figure 7, the estimated MSP for in-state SAF supply chains ranges from approximately **$5.54 to $11.10 per gallon**, with an average near **$8.00 per gallon**. In contrast, import results show markedly lower MSPs, ranging from **$4.35/gal** to **$4.53/gal.** Across all modeled scenarios, transportation costs contribute only a small portion of total cost (1-5%)**,** while conversion costs are the dominant component.

Thus, the estimated transportation cost for LanzaJet is appreciably lower than the lowest estimated transportation cost for Diamond Green. The results in Figure 7 reveal very little variability in MSP values arising from multiple possible import-based supply chain configurations. In other words, all four estimates of the MSP for SAF imported from currently operational facilities are essentially the same, such that there is no clear indication that either Diamond Green or LanzaJet would be preferred over the other. This outcome is positive, insofar as it gives Virginia greater flexibility to procure SAF from more than a single operational entity. Finally, the average estimated MSP for import-based configurations remains higher than the average historical fossil jet fuel benchmark (approximately **$2.22/gal**). Thus, SAF remains more expensive than conventional jet fuel. However, the updated results show a significant narrowing of the cost gap relative to what has been reported in previous research (2024)

Accounting for Policy Incentives

U.S.-based SAF producers are currently eligible to receive federal incentives in the form of Section 45Z Clean Fuel Production Credits, which were established under the Inflation Reduction Act of 2022 (Inflation Reduction Act, 2022). The base value of this incentive is nominally **$1.25 per gallon**. Additional incentive can be earned for fuels that achieve a more than 50% reduction in life-cycle global warming potential (GWP). The maximum valuntive is nominally **$1.75 per gallon**. In reality, different incentive magnitudes can be earned in different years, which makes it necessary to apply a discounted cash-flow analysis to assess the true reduction in anticipated MSP. This calculation can be done within the ASCENT TEA methodology.

Figure 7 shows the comparison between in-state and import-based SAF supply chains for Virginia wit, with federal incentives under 45Z. Because the federal incentive applies to reducing, understanding, and cooperating in import cases in Virginia and other states, the incentive can be applied to both sets of bars (blue and orange). Because both sets of configurations (in-state and import) are adjusted downward by essentially the same amount, the relative comparison between the two options remains unchanged. Ho remains unchanged; however, the difference between the import case (orange) and the average historical price for fossil jet fuel decreases further when the incentive is applied. The 95% confidence interval for the estimated average MSP for import-based supply chains nearly overlaps the historical benchmark price.

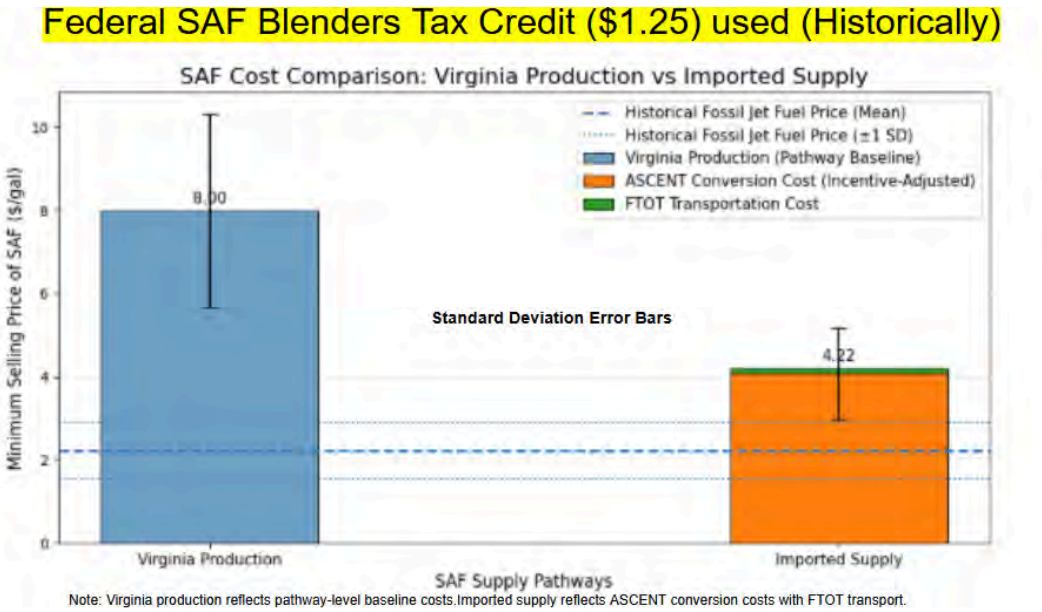


Figure 8. Comparison of SAF MSP estimates for in-state (blue) and import-based orange) SAF supply chains for Virginia without accounting for federal incentives under 45z.

It is well understood that additional incentives, beyond what is currently available via the 45Z tax credits, will be necessary to close the gap between SAF and fossil jet diesel. Other states

have created additional incentives for production and/or use of SAF (Peterson et al., 2024). Virginia has not yet established SAF incentives, but the topic has come up during several of the most recent legislative sessions. Most recently, in early 2026, HB1230 was proposed to establish a new state tax credit of $0.75/gallon for SAF produced in Virginia. Maximum expenditures under the proposed bill were $20 million per year. The bill was not passed, but it will be discussed again during the 2027 session. Accordingly, it is reasonable to anticipate that additional SAF incentives may be forthcoming.

Figure 9 shows the cost comparison between in-state and import-based SAF supply chains for Virginia, accounting for several existing and anticipated incentives. Because the proposed state incentive (HB1230) requires SAF to be produced in Virginia, it can be applied to the in-state supply chain configurations (blue) but not the import-based configurations (orange).

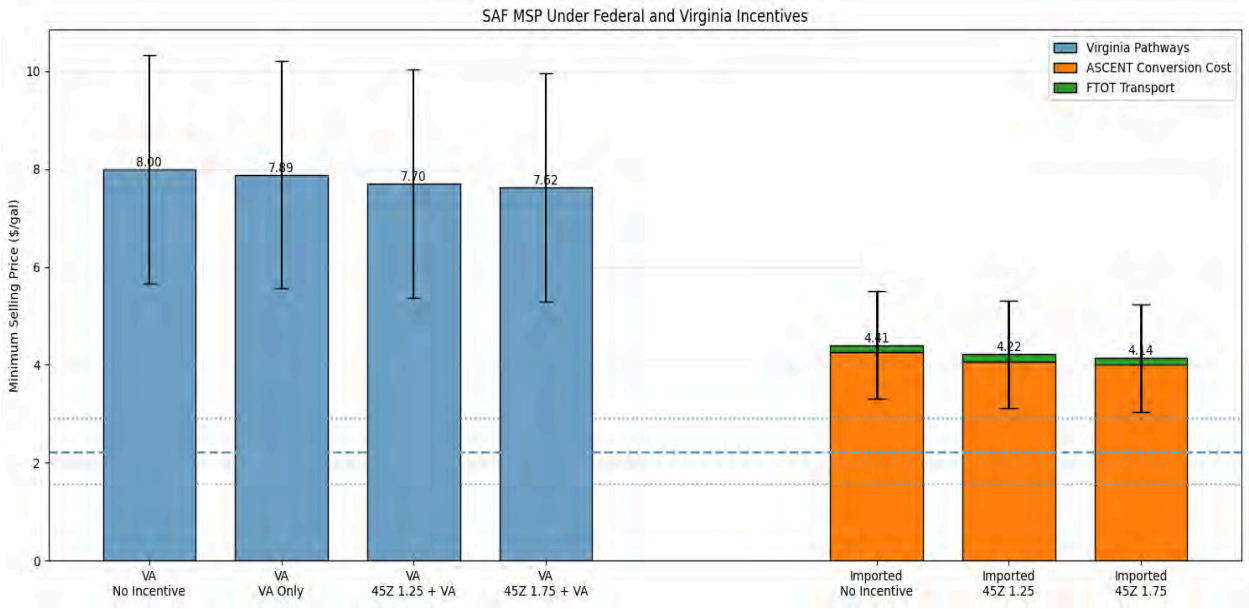


Figure 9. Comparison of SAF MSP estimates for in-state (blue) and import-based orange) Significantly, NIA, without accounting for several existing and proposed federal laws, aligns with the maximization of incentives

It is significant that different policy framings (i.e., different incentive structures) align with the maximization of different benefits of SAF supply chains. The federal incentives are not restricted based on advanced location. They are therefore reduced to maximize all SAF production values, to maximize aviation decarbonization, and to reduce dependence on imported petroleum. In contrast, the state incentive is structured to maximize the benefits of valorizing a local feedstock and stimulating the local economy. All kinds of outcomes are valuable, but policy creators should carefully prioritize among various possible benefits before locking in on a particular outcome.

4.0 Conclusions

This thesis applied an integrated systems modeling approach to evaluate the delivered cost of imported SAF. The use of existing open-access tools produced by government agencies contributes to the transparency and credibility of MSP estimates produced in this study. Results show that import-based supply chains are significantly more cost-competitive than in-state configurations assessed in previously published work. The in-state exhibited scenarios average approximately $8.00/gal, while imported scenarios exhibited MSP of approximately $4.41/gal, including transportation. There was no meaningful variability among the different modeled import-based scenarios.

Across all scenarios, conversion cost is the dominant driver of total SAF cost, while transportation costs contribute a smaller but still important component. However, transportation mode and infrastructure access have influenced the transport costs. It is not a major difference, but it does reflect a different value. Scenarios that utilize pipeline infrastructure consistently

achieve slightly lower transportation costs, while rail- and truck-based systems result in slightly higher delivered costs.

When policy incentives are applied, they reduce SAF costs across all scenarios but do not eliminate the cost gap between imported and in-state production. Even with incentives applied, imported pathways remain more cost-competitive, indicating that underlying production methods have a greater impact than transportation or policy alone. This further emphasizes that conversion efficiency, extended by importingology, is the primary driver of SAF cost competitiveness.

5.0 Future Work

This study extended SAF supply chain modeling results for Virginia to account for the possibility of importing SAF from newly operational facilities. This is one significant change in the SAF landscape since Davis et al. (2024) published the previous Virginia SAF supply chain modeling analysis. Another significant evolution in the SAF landscape is the growing interest in "co-processing" as a way to leverage existing infrastructure to reduce SAF procurement costs by lowering capital expenditures and driving down MSP. Co-processing refers to several strategies by which parts of the SAF supply chain are co-located and/or cooperated with traditional refining activities in existing refineries. Figure 10 shows a conceptual comparison of SAF production configurations, including stand-alone systems, co-located facilities, and integration with existing petroleum refineries. The same methodological approach used in this study could be adapted to compare MSP for East Coast supply chains, providing SAF for use at Dulles, with and without repurposing existing refining infrastructure.

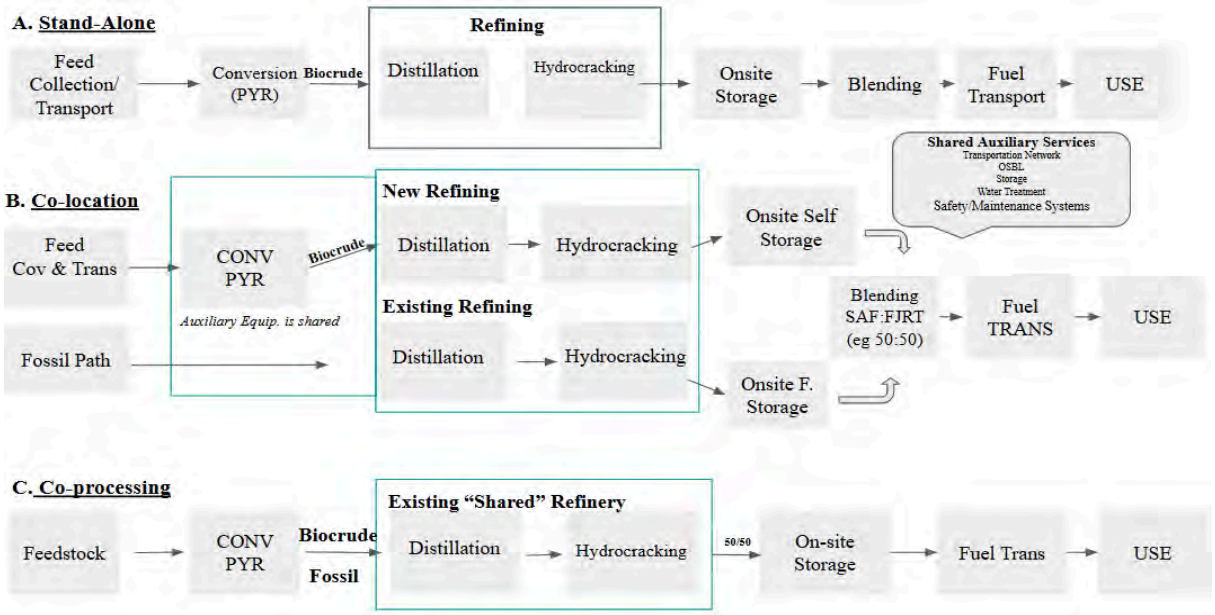


Figure 10. Comparison of SAF production configurations, stand-alone systems, co-location with refining infrastructure, and co-processing in existing refineries

SAF co-processing using existing infrastructure has been the topic of several recent studies, which have mostly focused on supply chains operating in the Midwest, e.g., (Bianco et al., 2026). Results compiled for other regions suggest that integrating SAF production with existing petroleum refinery infrastructure can significantly reduce capital and operating costs while improving supply chain efficiency by leveraging existing blending and distribution systems. Stand-alone SAF systems rely on fully independent conversion and refining infrastructure, offering greater conversion flexibility but requiring the highest capital investment. Intermediate configurations, such as colocation with existing refineries, enable partial integration by leveraging shared refining, storage, and blending systems, ultimately reducing infrastructure requirements. Co-processing introduces bio-based feedstocks directly into existing refinery units, minimizing capital costs but limiting control over SAF-specific outputs. Therefore, future work should assess whether these tradeoffs would be similarly beneficial in Virginia.

Preliminary exploration of co-processing to increase SAF availability in Virginia and elsewhere on the East Coast reveals that seemingly promising infrastructure exists near areas of interest. Notably, the Bayway Refinery in Linden, New Jersey, operated by Phillips 66, has not produced SAF at its East Coast location; however, it has manufactured SAF in California and established agreements with United Airlines and British Airways.

Similarly, World Energy operates a facility in Camp Hill, Pennsylvania, and they are already producing SAF in Texas and California, supplying fuel to San Francisco International Airport. Finally, the Trainer Refinery in Pennsylvania, acquired by Delta Airlines in 2012, is unique in that its fuel infrastructure is owned by an airline. The involvement of various entities in the aviation sector that are committed to the goals of the SAF Grand Challenge is significant.

The presence of relevant capital infrastructure near Dulles Airport presents an opportunity to enhance systems modeling, which can help decision-makers fully understand the impact that repurposed infrastructure could have if designated as potential SAF production sites. These systems can be analyzed using the FTOT and ASCENT tools to better understand the extent to which co-processing could decrease SAF production costs and expand SAF availability on the East Coast.

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