Modeling Sustainable Aviation Fuel Supply Chain Feasibility Using System Dynamics: Insights from Lipid-Based Pathway

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Abstract

Decarbonizing aviation while maintaining global air transport growth requires expanding sustainable aviation fuel (SAF) production. Among currently approved technologies, the Hydroprocessed Esters and Fatty Acids pathway is the most commercially mature, yet large-scale deployment remains constrained by feedstock availability, economic competitiveness, and policy uncertainty. This paper applies a System Dynamics modeling framework, to examine the structural conditions that influence the development of lipid-based SAF supply chains. The model captures interactions among land allocation, farmer participation, feedstock generation, production capacity, and economic incentives. Several scenarios are explored to evaluate how facility scale, policy incentives, and farmer adoption affect feedstock availability and industry growth. The results show that SAF expansion depends on the alignment of sufficient biomass supply, supportive policy mechanisms, and economic conditions that enable investment in new facilities. The analysis illustrates how System Dynamics can help identify structural constraints and policy leverage points shaping SAF industry development.

Keywords: Sustainable aviation fuel, System Dynamics, Biofuel supply chains, HEFA pathway, Energy policy

1. Introduction

The aviation sector faces increasing pressure to reduce greenhouse gas emissions while maintaining the growth of global air transport. Commercial aviation currently accounts for about 2.5% of global CO_2 emissions, and projected increases in air traffic could significantly raise fuel consumption and emissions by mid-century if mitigation measures are not implemented [1], [2], [3]. International initiatives aimed at achieving net-zero emissions have therefore placed strong emphasis on technological improvements, operational efficiencies, and the development of sustainable aviation fuels (SAF) as key pathways for decarbonizing the sector [4], [5].

SAF refers to non-fossil jet fuels produced from biomass or waste feedstocks and certified under ASTM D7566 for commercial aviation use [6]. These fuels can be blended with conventional jet fuel in proportions ranging from 10% to 50%, depending on the production pathway and certification limits [7]. Among the currently approved technologies, the Hydroprocessed Esters and Fatty Acids (HEFA) pathway represents the most mature and widely deployed option for Potential SAF production [6], [8].

Despite this technological maturity, the large-scale deployment of SAF remains limited. Feedstock availability, high production costs, infrastructure constraints, and policy uncertainty continue to slow market expansion. Lipid feedstocks suitable for HEFA production are also frequently diverted toward renewable diesel, which benefits from stronger policy incentives and more established markets [9], [10]. In addition, concerns related to land-use change, food security, and environmental sustainability complicate the expansion of biofuel production in many regions. These challenges highlight the need for analytical approaches capable of evaluating the interactions and trade-offs across economic, environmental, and logistical dimensions of SAF supply chains [11], [12]

Traditional analytical tools such as techno-economic assessment (TEA) and life-cycle assessment (LCA) provide valuable insights into production costs and environmental performance. However, these methods often evaluate systems under static assumptions and may not capture the dynamic interactions among feedstock supply, infrastructure development, policy incentives, and market behavior over time. System Dynamics (SD) modeling offers an alternative approach by representing feedback loops, delays, and nonlinear interactions that shape the long-term behavior of bioenergy systems. Previous SD studies have explored biofuel supply chains by examining how resource availability, land-use dynamics, and policy interventions influence industry development [13], [14], [15], yet relatively few studies have applied this approach specifically to sustainable aviation fuel supply chains.

Preliminary elements of this research were presented as a work in progress at the 2025 International System Dynamics Conference, where an initial modeling framework was proposed to explore the feasibility of Potential SAF production in the Dominican Republic using lipid [16]. Building on that work, this study further develops the System Dynamics model to analyze the structural behavior of HEFA-based SAF supply chains. The model integrates feedstock availability, land allocation dynamics, production capacity, and economic performance within a unified framework that allows the exploration of policy and investment scenarios over time.

2. Research Context and Modeling Gap

The expansion of Potential SAF production depends on the coordinated development of feedstock supply, processing infrastructure, and market demand. These elements interact through investment cycles, land-use decisions, and policy signals that influence the pace and scale at which new facilities are deployed. In practice, the feasibility of SAF industries is shaped not only by technological performance but also by the structural relationships among biomass availability, resource competition, and economic incentives. Understanding these interactions is particularly important in emerging SAF markets, where infrastructure and feedstock systems are still developing.

This study addresses this challenge by developing a System Dynamics model that represents the structural behavior of HEFA-based sustainable aviation fuel supply chains. The model integrates feedstock availability, land allocation dynamics, production capacity expansion, and economic performance within a unified framework. By capturing the interactions among these variables, the model enables the exploration of policy and investment scenarios and helps identify the structural conditions that enable or constrain the development of SAF industries.

Table 1 summarizes relevant literature related to the modeling of sustainable aviation fuel and biofuel supply chains. Because this study builds upon a modeling framework previously presented as a work in progress and intended for application in the Dominican Republic, the review includes both general approaches used for SAF supply chain analysis and SD applications focused on biofuel systems in Latin America. Incorporating these two perspectives helps contextualize the modeling challenges associated with emerging biofuel industries in the region. Despite the growing body of work in both areas, limited research has applied System Dynamics to represent the structural interactions that shape the development of lipid-based SAF supply chains, highlighting the modeling gap addressed in this study.

Table 1. Literature review for SD and other modeling approaches for SAF and biofuel supply chains

Criteria	Research's summary	References
Modeling approaches for SAF supply chains	Previous studies analyze sustainable aviation fuel supply chains using a range of modeling techniques, including mixed-integer linear programming (MILP), optimization models, and simulation frameworks. These works evaluate feedstock availability, infrastructure requirements, logistics, and policy incentives across different regional contexts. Strategic assessment tools have also been used to examine national readiness for SAF deployment and to support supply chain planning.	[17], [18], [19], [20], [21], [22]
SD modeling approaches for biofuels supply chains in Latin America	System Dynamics applications in Latin America examine how biofuel expansion interacts with land use, agricultural production, environmental impacts, and policy frameworks. Studies in countries such as Brazil, Colombia, Mexico, and Argentina analyze trade-offs among energy production, food security, and land-use change,	[13], [14], [15], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33]

highlighting the usefulness of dynamic models for evaluating long-term sustainability strategies in the region.

3. Model Structure

This study relays in STELLA Architect tool to build the SD model. A pull supply chain configuration is adopted where Palm Oil and Used Cooking Oil (UCO) are the main feedstock to produce SAF. Palm Oil can be sourced domestically by new cropping or by using a portion of the exports, depending on the country's production. The UCO was added only as an import. The upstream section of the supply chain is presented in Figure 1, the midstream and upstream (fuel consumption) are represented in Figure 2.

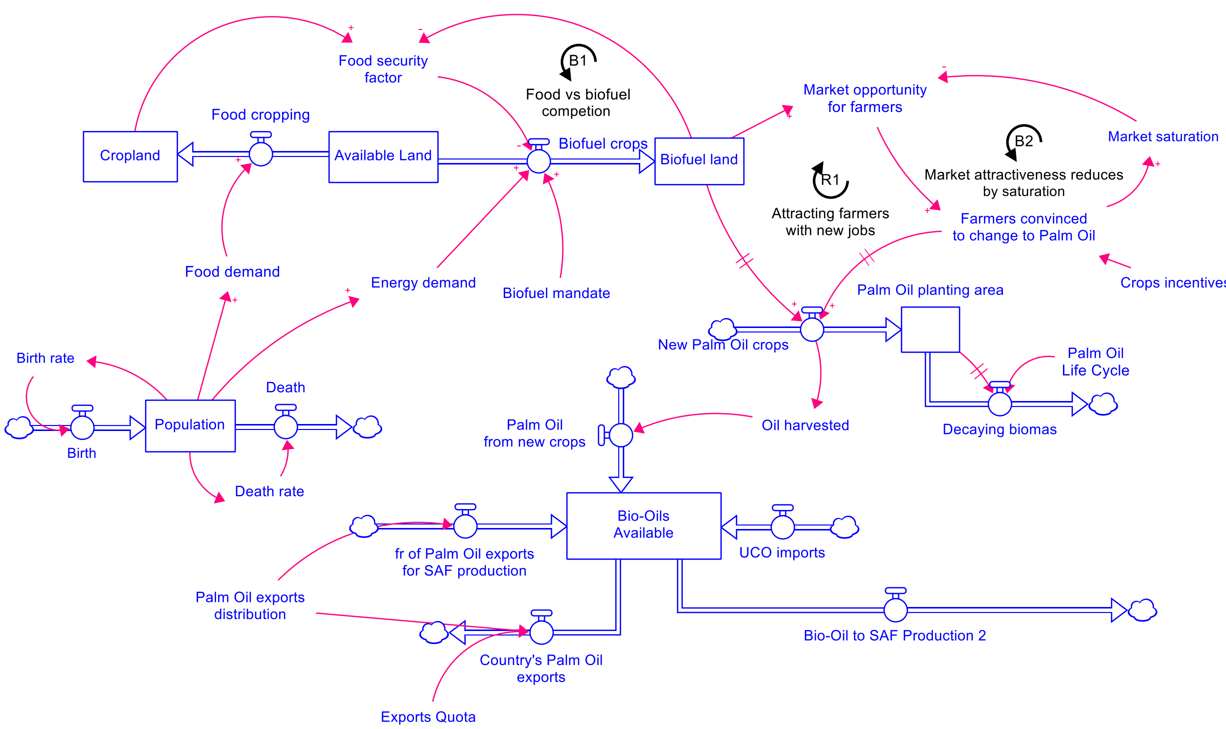

Figure 1. Hybrid CLD/SF diagram representing the upstream part of the SAF supply chain based on UCO and Palm Oil

Figure 1 represents the upstream dynamics that determine the availability of lipid feedstocks for Potential SAF production. The structure links demographic growth, land allocation, and farmer decision-making to the production of bio-oils derived from palm oil and UCO. Population growth increases food demand, which competes with biofuel crops for available agricultural land. This interaction forms a balancing mechanism where food security considerations limit the expansion of biofuel cultivation. At the same time, market opportunities and policy incentives encourage farmers to shift land toward palm oil production, creating a reinforcing dynamic that increases the area planted and the volume of oil harvested. Palm oil production follows the biological lifecycle of the crop, introducing delays between planting and harvest. Alongside agricultural production, additional feedstock sources enter the system through UCO imports and the diversion of palm oil exports. These flows accumulate in the stock of bio oils available, which represents the pool of lipid feedstock that can be used for Potential SAF production.

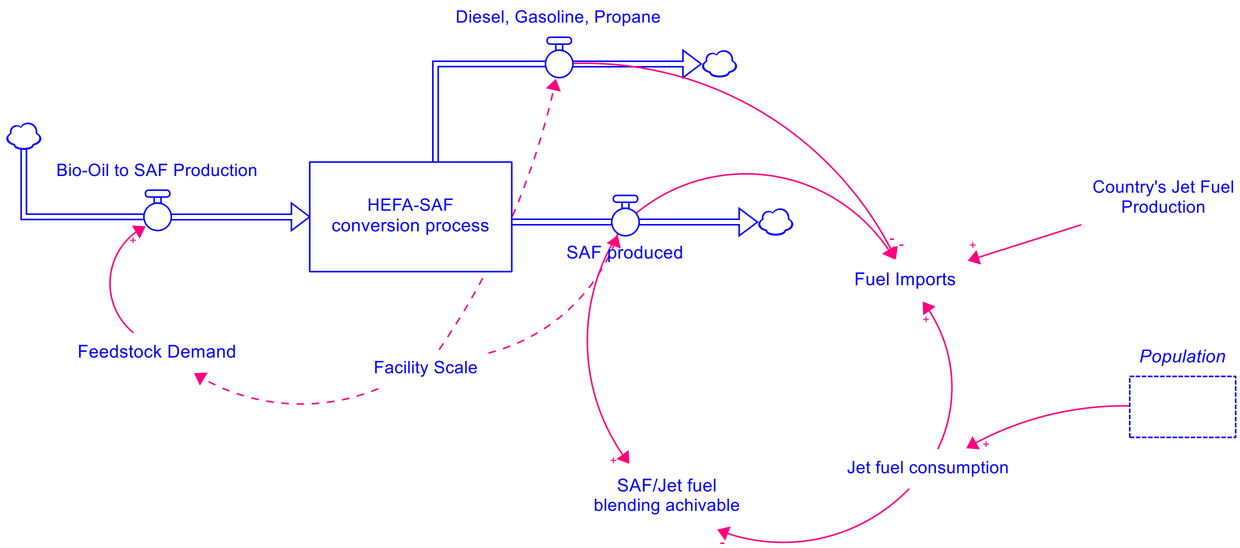

Figure 2. Hybrid CLD/SF diagram representing the midstream and downstream parts of the SAF supply chain based on UCO and Palm Oil

Figure 2 illustrates the midstream and downstream stages of the supply chain, where available bio-oils are converted into sustainable aviation fuel through the HEFA process. In this structure, the conversion process transforms lipid feedstock into SAF, which then contributes to the national fuel supply. The resulting Potential SAF production affects the achievable blending ratio between SAF and conventional jet fuel. This relationship interacts with jet fuel consumption and imports, which are driven by national demand linked to population and economic activity. As Potential SAF production increases, the potential blending level rises, reducing the need for imported jet fuel and creating feedback between domestic production capacity and fuel dependency. This structure captures how upstream feedstock availability translates into downstream fuel supply and how the aviation fuel market responds to the introduction of SAF.

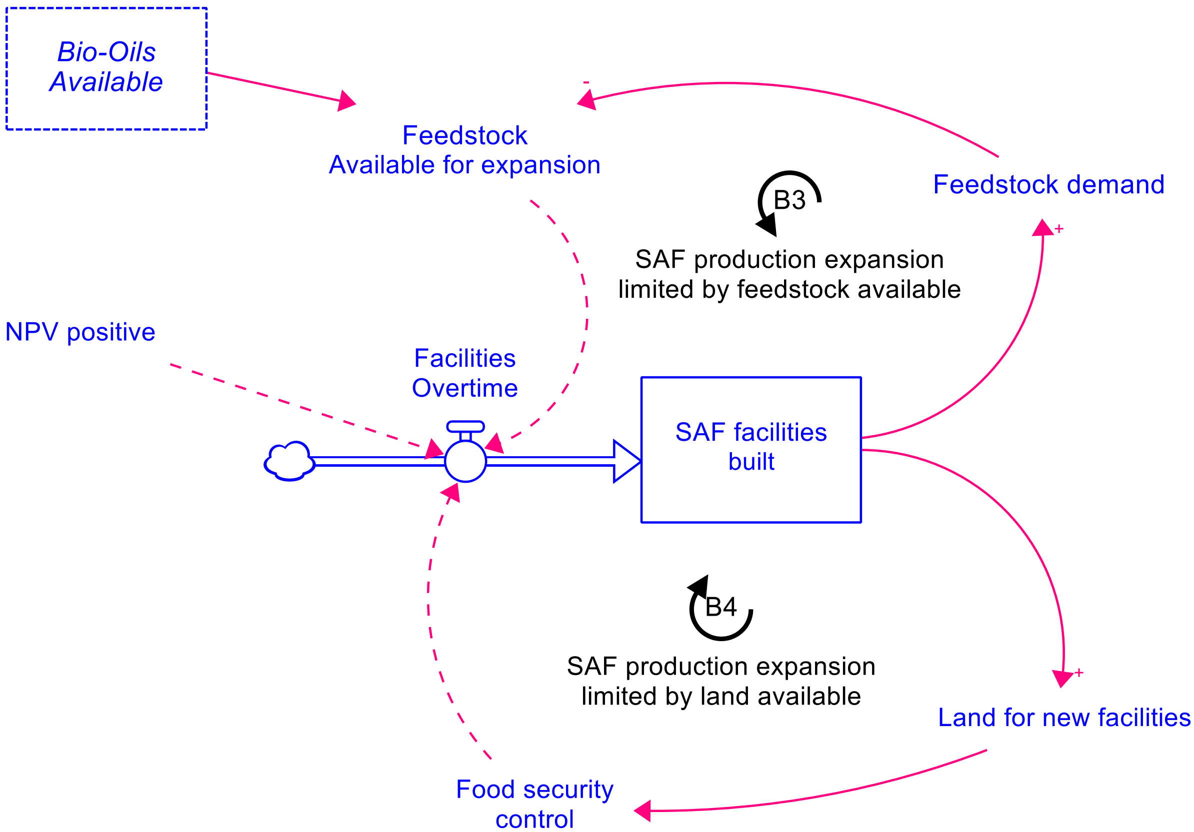

Figure 3. Hybrid CLD/SF structure representing the interactions affecting the SAF industry growth

Figure 3 represents the structure governing the expansion of the SAF industry over time. The construction of new SAF facilities depends on two main factors: the availability of feedstock and the economic viability of investment. As the number of facilities increases, feedstock demand rises, which can constrain further expansion if biomass resources become limited. At the same time, land availability and food security considerations act as additional balancing mechanisms that restrict the allocation of land for biofuel crops. Economic performance, represented through indicators such as positive net present value (NPV), influences the rate at which new facilities are built. When investment conditions are favorable and sufficient feedstock is available, reinforcing dynamics promotes industry growth. However, resource constraints and land competition eventually limit expansion, producing the characteristic bounded growth behavior observed in biofuel supply chains.

Together, these three structures represent the core dynamics of the SAF system: feedstock generation, fuel production, and industry expansion. By linking these subsystems, the model captures how resource availability, market demand, and economic incentives interact to determine the long-term development of HEFA-based SAF supply chains.

4. Results and scenarios testing

A detailed techno-economic analysis of the SD model presented in this study has been developed and is currently under review for publication as a separate paper. That work focuses on the economic structure of the HEFA pathway and provides a comprehensive assessment of minimum selling price (MSP), sensitivity to feedstock costs, and the financial performance of different facility scales. The economic parameters used in the present study are derived from that analysis and from the techno-economic framework proposed by Brandt et al. (2024) [34] for HEFA-Potential SAF production. The manuscript describing the economic formulation of the model, titled “A System Dynamics Tool to Assess the Development Potential of HEFA-SAF Supply Chains at National and Regional Scales” [35], provides a detailed description of the TEA assumptions and validation procedures.

In contrast, the objective of the present paper is not to provide an exhaustive techno-economic evaluation but rather to explore the dynamic behavior of the SAF supply chain from a SD perspective. The simulations are designed to identify the structural conditions that enable or constrain the feasibility of SAF deployment over time. Particular emphasis is placed on understanding how feedstock availability, land-use constraints, industry growth, and economic incentives interact to determine whether Potential SAF production can become viable within a national context.

Although Figures 1 to 3 describe the physical and structural dynamics of the SAF supply chain, the economic decision logic used to trigger facility construction is represented separately in **Figure 4**. This structure links production costs, revenue streams, policy incentives, NPV, and feedstock sufficiency. Cost drivers such as feedstock price, capital cost, hydrogen and utilities, logistics, labor, taxes, and operation and maintenance costs determine the MSP required for each facility scale. Revenue and support mechanisms, including SAF selling price, co-product revenue, blender’s tax credits, tax exemptions, and supplementary subsidies, influence the project’s NPV.

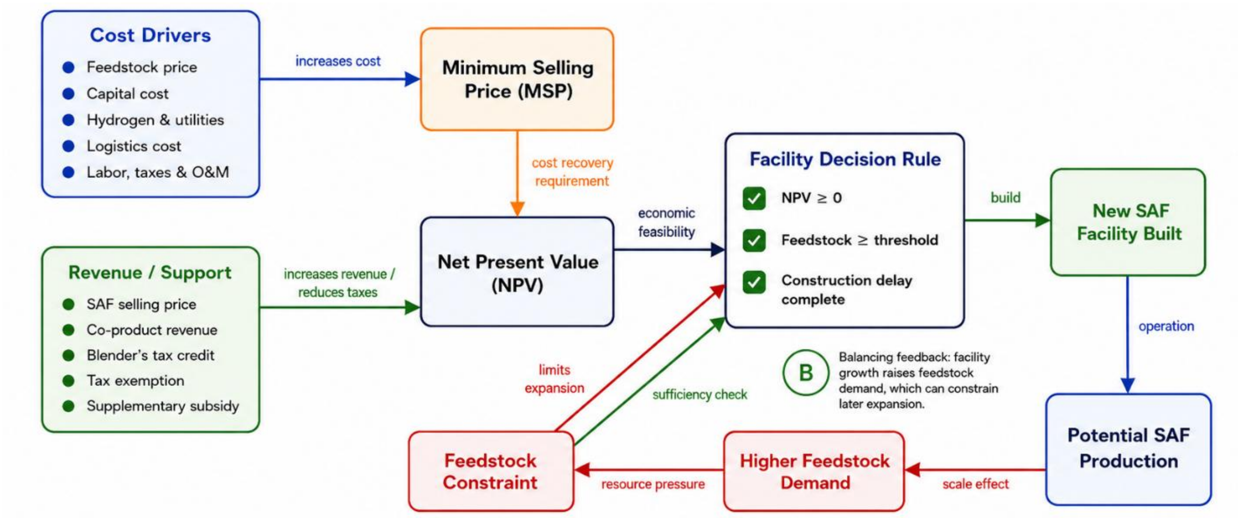

Figure 4. Economic decision structure for HEFA-SAF facility growth overtime

In the model, facility construction occurs only when three conditions are satisfied: NPV is nonnegative, feedstock availability meets the minimum operating threshold, and the construction delay has been completed. This means that potential SAF production is not driven only by available feedstock or facility size, but by the combined effect of economic feasibility and resource sufficiency. Once a new facility is built, potential SAF production increases, which raises feedstock demand. Higher feedstock demand can then create a balancing feedback by increasing pressure on available lipid feedstocks and limiting later expansion. Therefore, the simulated production results should be interpreted as potential SAF production under the specified assumptions and incentives, rather than as market-clearing production forecasts.

For the scenario testing presented in this section, the simulated country represents a generalized case rather than a specific nation. However, the economic assumptions embedded in the HEFA conversion process follow U.S. techno-economic conditions based on Brandt et al. (2024) [34]. This hybrid setup allows the model to test structural feasibility conditions while maintaining a realistic economic baseline for Potential SAF production.

The simulated country should not be interpreted as a forecast for a specific national context. It is used as a generalized test case to evaluate the structural behavior of the model under internally consistent assumptions. This approach allows the model to isolate the interactions among feedstock availability, facility scale, land allocation, economic feasibility, and policy incentives before applying the framework to a country-specific case. Because the assumptions are not calibrated to a single country, the results are interpreted as scenario-based potential outcomes rather than forecasts. Future work will adapt the model to country-specific datasets for national policy assessment.

To reduce dependence on a single hypothetical configuration, future applications should include sensitivity analysis on land availability, UCO supply, palm oil export diversion, feedstock prices, facility scale, and farmer adoption.

The models show results for five preselected Potential SAF production scales: 30, 100, 350, 500, and 750 MML/year (reduced size, Small 1, Small 2, medium, large, respectively). These facility sizes were selected using the SAF-HEFA production in U.S. were the largest one are 150 and 260 Mgal/year (around 560 to 980 MLL/year) [36]. These two facilities supply the demand for Los Angeles International Airport (LAX) [36].

The facility construction starts at 2030 (or when the feedstock demand for production is met) and lasts three years. The facility's lifespan is 20 years, and the model runs from 2025 to 2054, with 5 years prior to 2030 to allow new crops to grow. The parameters representing the X country under test is shown in Table 2, and in Table 3, the economic and production parameters used by Brandt et al. 2024 [34] TEA are detailed.

Table 2. Parameters for the imaginary country under test

Parameter	Value
Population in 2024 (million people)	50
Birth rate	0.008
Death rate	0.006
Agricultural land (million ha)	10
Cropland share in agricultural land	50%
Arable land share in agricultural land	40%
Fraction of arable land suitable for new crops of palm oil	20%
Fraction allocated of the available land for new palm oil crops	50%
Hectares of Palm Oil needed per farmer ***Assuming small farmers. Industrial-scale farmers are not considered***	2.0
Total employees in the agricultural sector	800 000
Small farmers share in the agricultural sector	70%
UCO imports (ton/year)	250 000
Palm Oil production destined for exports (ton/year)	800 000

Fraction of palm oil exports used for Potential SAF production	50%
Jet fuel consumption from 2015 to 2024 (million barrels)	Graphical input
UCO price (USD/ton) ***USDA 2025, 2020-2024 average price for yellow grease***	1004
Palm Oil price (USD/ton) ***USDA 2025, 2022-2024 average price for palm oil***	1115
Imports average distance (km) ***Assuming imports are coming from China to America***	1 700

Table 3. US-centric economic and production parameters from Brand et al. 2024 TEA used in the model

Economic parameters	
Parameter	***Value***
Cost year	2021
Cost Equity (%)	0.1
Inflation (%)	0.02
Equity Share (%)	0.3
Loan interest (%)	0.08
Loan terms (yrs)	10
Labor burden (%)	0.6
Corporate tax rate (%)	0.172
Local tax rate (%)	0.015
Production parameters	
Jet fuel yield (wt/wt)	0.46
Diesel yield (wt/wt)	0.22
Naphtha yield (wt/wt)	0.07
Propane yield (wt/wt)	0.09

4.1 Upstream

In the scenario tested, the country uses half of its palm oil exports for Potential SAF production (400 kt/year) and allocates around 400,000 ha to producing new palm oil crops. On the UCO side, it imports around 250 kt/year from China. Figure 5 shows the relationship between the feedstock available from this setup and the biomass demand for Potential SAF production, depending on the facility scale. The results show that in the early years of the simulation, the available feedstock is insufficient to support most facility sizes. As new palm oil crops reach productive stages and imports stabilize, feedstock availability increases and eventually surpasses the requirement for the Small 2 facility scale, while remaining below the demand for Medium and Large plants for most of the simulation period.

Although the available feedstock does not fully meet the medium facility's nominal demand for most of the simulation period, the model allows construction and operation when at least 75% of the required feedstock is available. This threshold represents partial utilization during early deployment rather than full nameplate operation. Therefore, the medium-scale case is included in the downstream analysis as a constrained-operation scenario. In contrast, the large-scale facility remains infeasible because the simulated feedstock supply does not reach the minimum threshold needed for stable operation.

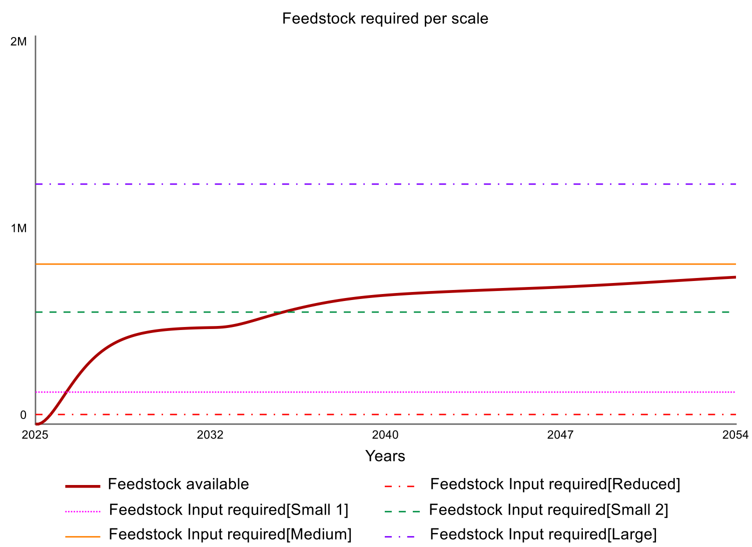

Figure 5. Feedstock available based in the setup conditions

Figure 6 presents the interaction between population growth, arable land availability per capita, and the food security threshold used in the model. Population increases steadily throughout the simulation horizon, which gradually reduces the amount of arable land available per capita. The blue curve shows that although arable land per capita declines slightly over time, it remains above the food security threshold defined in the model (red dashed line). This threshold is 10% of arable land available per capita, based on the recommendation of Porter (2015) [37]. This indicates that the expansion of palm oil crops for Potential SAF production does not compromise the minimum land availability required for food production under the conditions tested.

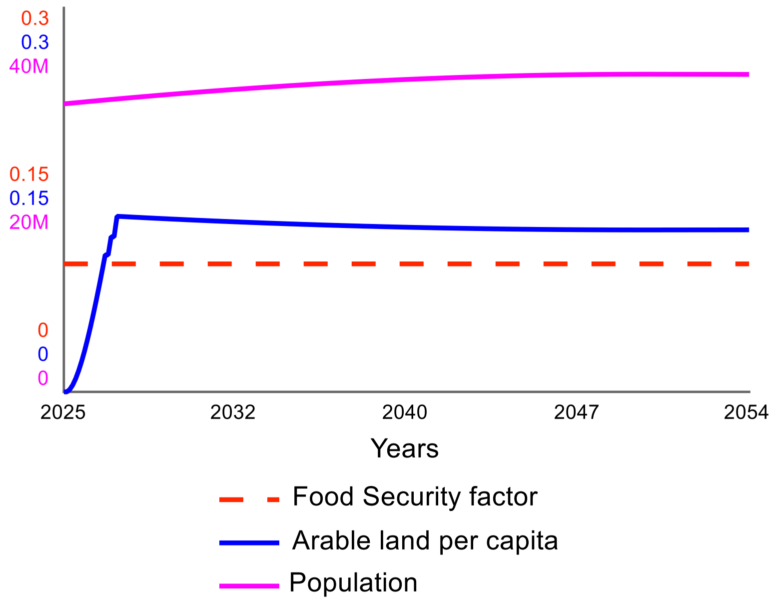

Figure 6. Population growth and food security factor

4.2 Midstream and Downstream

Figure 7 shows the simulated Potential SAF production trajectories for the five facility scales considered in the model. Production begins once the feedstock availability threshold is satisfied and the facility construction period is completed. The initial increase in production observed for each facility includes a small step up during the first operational year. This behavior results from the production ramp assumption adopted from the techno-economic analysis used as the economic basis of the model, where facilities operate at 75% of their nominal capacity during the first year before reaching full operation in the following year. After this ramp-up period, production stabilizes according to the available feedstock and the facility scale. A temporary overshoot then reduction in production can be observed for the small 2 and medium-scale facilities shortly after they come online. This occurs because the rate of Potential SAF production and consumption initially exceeds the rate at which new feedstock becomes available from palm oil production. As palm oil crops mature and feedstock supply stabilizes, the system reaches equilibrium and production returns to a steady level.

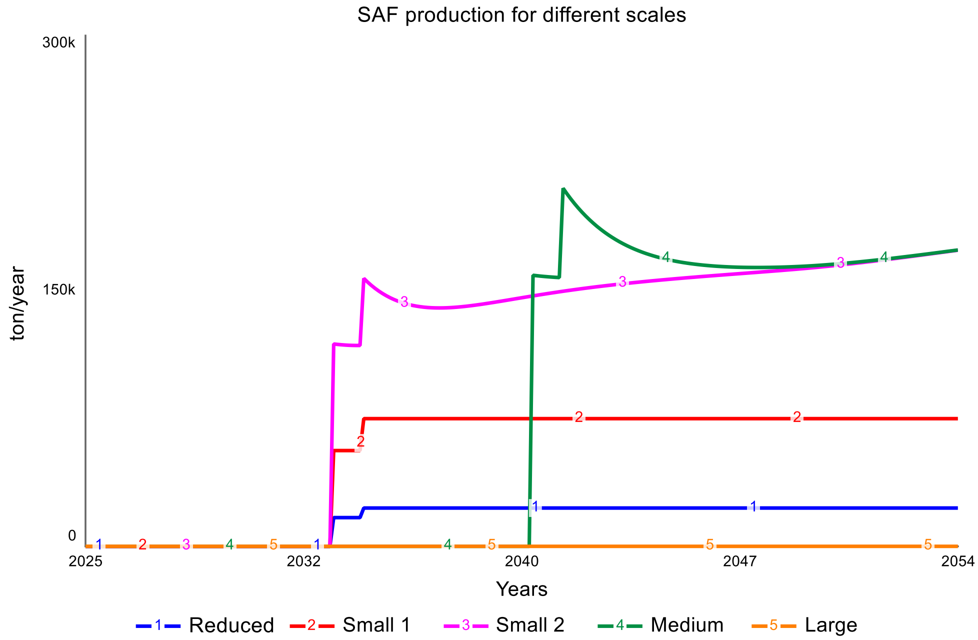

Figure 7. Potential SAF production output per facility scale

Figure 8 translates these production levels into the achievable SAF blending ratio with conventional jet fuel. The blending fraction increases rapidly once Potential SAF production begins and reflects the relative contribution of domestic SAF to total jet fuel demand. Larger facilities produce higher blending ratios, with the medium and Small 2 scenarios reaching the highest shares. However, the blending ratio gradually declines in later years for several scenarios. This occurs because jet fuel demand continues to grow over time, driven by population growth and increasing aviation activity, while Potential SAF production remains constrained by feedstock availability.

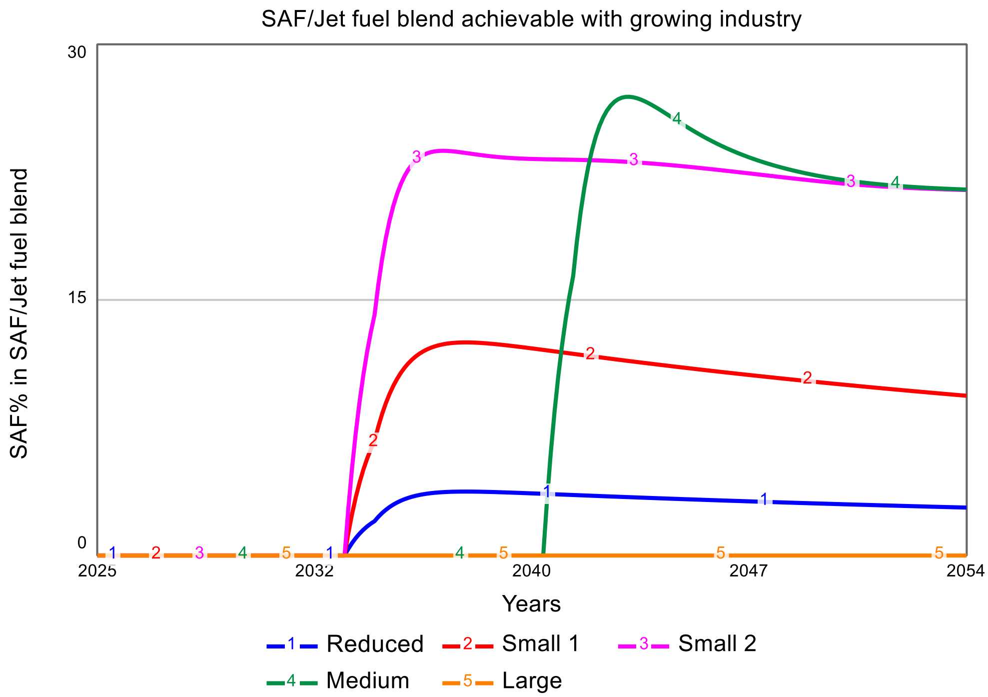

Figure 8. SAF% in the Maximum achievable SAF blending ratiomix achievable based on Potential SAF production and Jet fuel demand

4.3 **Economic results**

The economic performance of the simulated facilities is summarized in Table 4 and Figure 9. The minimum selling price (MSP) of SAF varies significantly with facility scale due to differences in capital intensity and feedstock demand. The reduced-size facility (30 MML/year) results in an MSP of 2.19 USD/L, while the Small 1 configuration (100 MML/year) achieves the lowest MSP at 1.66 USD/L, reflecting improved economies of scale. As facility size increases further, the MSP rises to 2.56 USD/L for the Small 2 configuration (350 MML/year) and 3.22 USD/L for the medium facility (500 MML/year). This increase is partly explained by the timing at which sufficient feedstock becomes available for each facility scale. Because the optimization procedure targets a NPV equal to zero within the simulation time frame, facilities that begin production later require a higher MSP to recover investment costs within the same period. The large facility (750 MML/year) is not economically feasible under the modeled conditions because the feedstock requirements exceed the system's sustainable supply, preventing stable operation.

Table 4. Optimization results for the Minimum Selling Price of SAF per facility scale

Facility Scale	Potential SAF production (MML/year)	Minimum Selling Price (USD/L)
Reduced size	30	2.19
Small 1	100	1.66
Small 2	350	2.56
Medium	500	3.22
Large	750	N/A

Figure 9 compares these MSP values with the projected international jet fuel price used in the model. The reference jet fuel price trajectory is based on projections reported in the U.S. Energy Information Administration Annual Energy Outlook 2025, which provides long term forecasts of global petroleum product prices. This projection was developed before the current political tensions in the Middle East, and therefore actual future prices may differ from those projected. For reference, the international jet fuel price at the end of 2025 was approximately 0.56 USD/L. Under these assumptions, the projected international jet fuel price remains significantly below the MSP of most Potential SAF production scales throughout the simulation period.

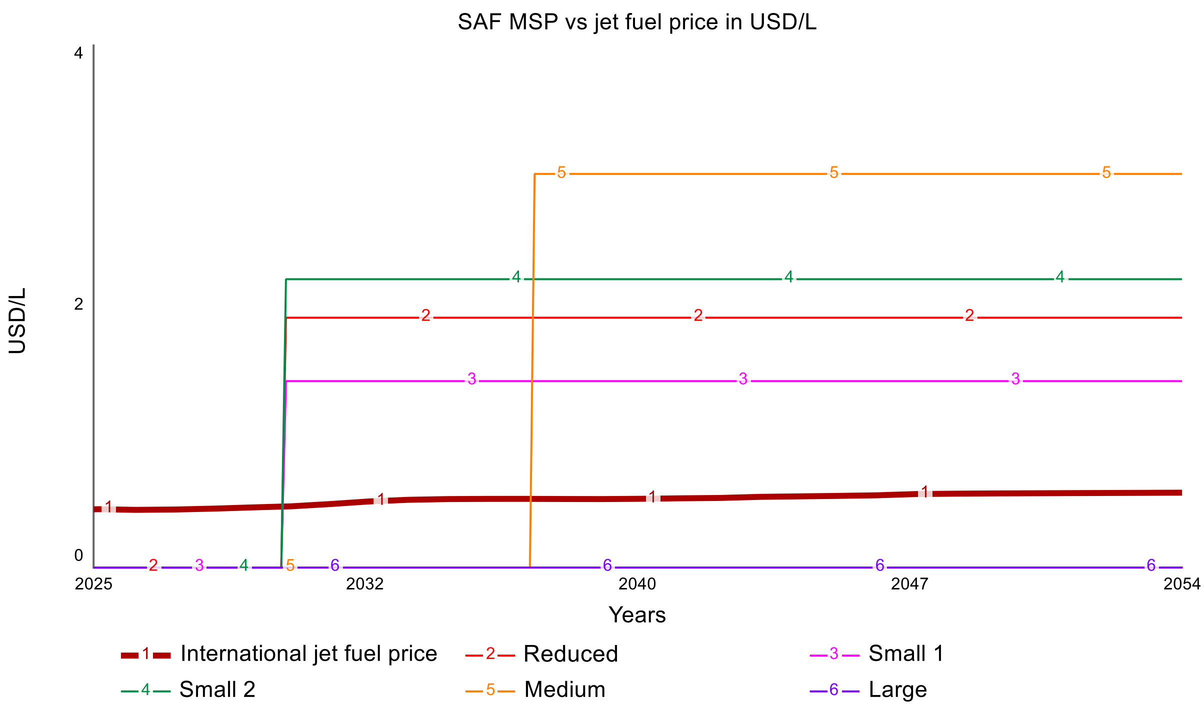

Figure 9. Comparison of international jet fuel price and the MSP for SAF

4.4 Economic incentives effect

To evaluate the potential role of policy instruments in improving the economic viability of Potential SAF production, several incentive mechanisms targeting producers were tested in the model. These incentives represent downstream policy interventions that reduce production costs at the refinery level. Two main policy instruments were analyzed: a blender's tax credit (BTC) and a temporary tax exemption. The BTC values were guided by existing U.S. policy frameworks for SAF incentives (Alternative Fuels Data Center, U.S. DOE) and were implemented in the model as 0.20 USD/L for SAF and 0.05 USD/L for non-aviation co-products. The second policy mechanism consisted of a five-year tax exemption applied to the facility during its initial years of operation. In addition to testing each policy independently, a combined scenario incorporating both incentives was evaluated to assess their cumulative effect on the MSP.

Table 5 summarizes the resulting MSP values under the different policy scenarios. Both incentives reduce the MSP across all feasible facility scales, with the BTC generally producing slightly larger reductions than the tax exemption alone. The combined policy scenario provides the largest improvement, reducing the MSP to 1.91 USD/L for the reduced facility and 1.43 USD/L for the Small 1 facility. However, even under the combined incentive case, Potential SAF production remains substantially more expensive than the reference jet fuel price of approximately 0.56 USD/L used in the model. This indicates that moderate producer-side incentives alone are insufficient to close the economic gap between SAF and conventional jet fuel under the modeled conditions.

To explore what level of policy support would enable industry expansion, an additional scenario was tested in which the combined incentives were supplemented with a subsidy of 1.0 USD/L of SAF produced. **Figure 10** shows the resulting industry growth across the different facility scales. Under these stronger policy conditions, the model predicts that several facility scales become viable and new plants are constructed over time as feedstock availability allows. The results highlight that significant external policy support would be required to trigger sustained SAF industry growth within the modeled system.

Table 5. Effect of incentives in the MSP of SAF

Facility Scale	MSP baseline (USD/L)	MSP BTC	MSP 5 years of tax exemption	Combined incentives
Reduced size	2.19	2.03	2.07	1.91
Small 1	1.66	1.50	1.58	1.43
Small 2	2.56	2.38	2.38	2.21
Medium	3.22	3.05	3.18	3.02
Large	N/A	N/A	N/A	N/A

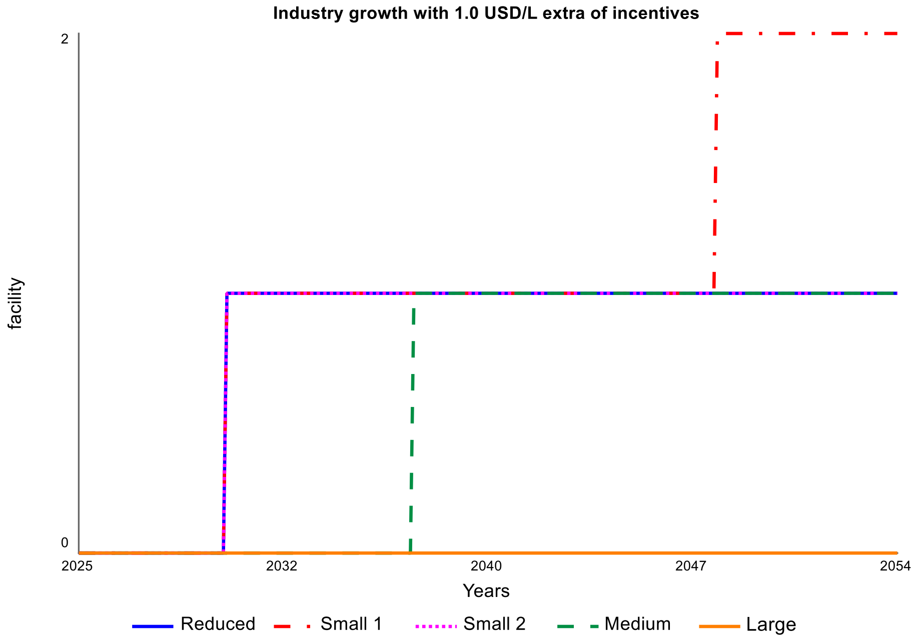

Figure 10. Industry growth with incentives and policy scenario

4.5 Farmers decision impact

Feedstock availability in the model is directly linked to the amount of land allocated to new palm oil crops, which ultimately depends on farmers' willingness to convert part of their land to biofuel feedstock production. Because the agricultural sector in many developing economies is dominated by small farmers, land-use decisions are determined not only by market prices and national policy targets but also by these producers' adoption behavior. To explore the influence of this social dimension, the model evaluates how different levels of farmer willingness to adopt new palm oil crops affect the long-term availability of bio-oils for Potential SAF production. This scenario illustrates the potential impact of policies aimed at farmers, such as crop incentives or targeted subsidies designed to encourage feedstock production.

The simulation tests several adoption scenarios representing the percentage of small farmers willing to switch to palm oil cultivation, ranging from 5% to 50% of the available farmer population. As shown in **Figure 11**, higher levels of farmer participation produce a significant increase in the total bio-oil available for Potential SAF production over time. While low adoption levels generate only modest increases in feedstock supply, higher adoption levels substantially expand the system's biomass base. In the scenario where 50% of small farmers adopt palm oil cultivation, feedstock availability approaches the level required to sustain the largest facility scale evaluated in the model, as seen in **Figure 12** where the feedstock available in the 50% adoption scenario is simulated.

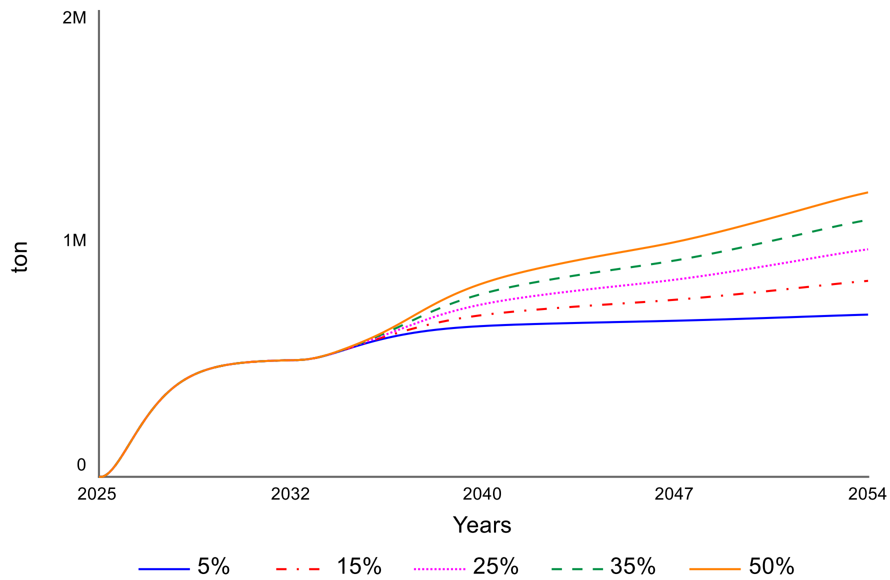

Figure 11. Effect of farmer's willingness to change in feedstock availability

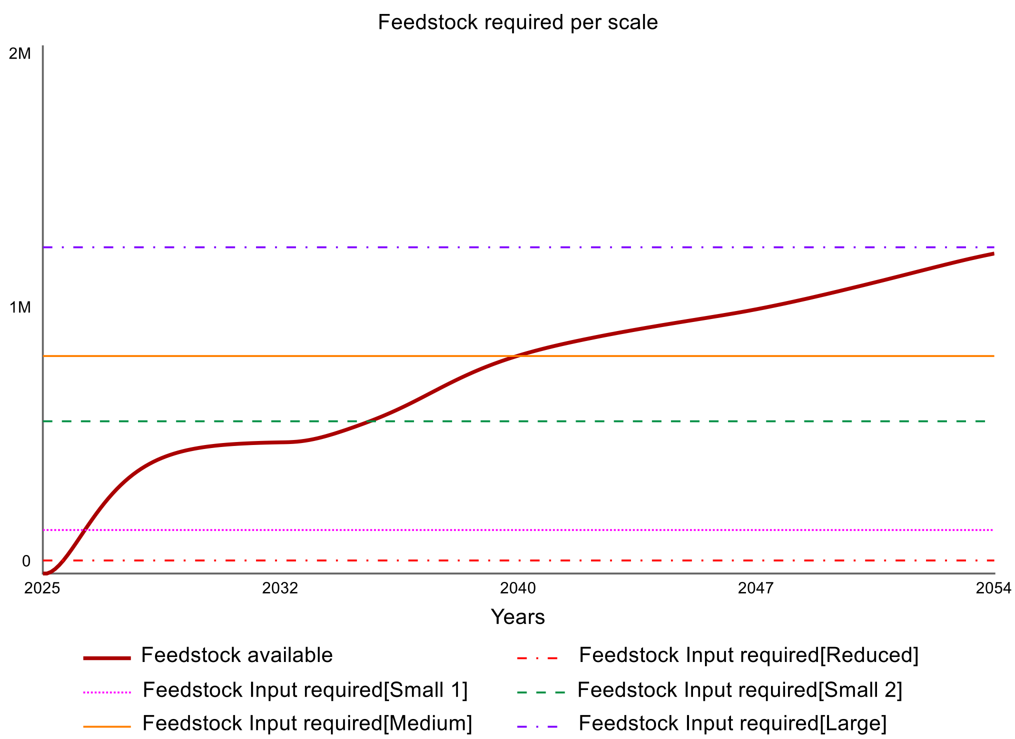

Figure 12. Feedstock availability in a 50% acceptance to change in the farmer population

5. Conclusion

This study used a SD model to examine the structural conditions required for the development of lipid-based SAF supply chains. The results show that the feasibility of Potential SAF production is determined by the interaction between feedstock availability, land-use constraints, economic performance, and policy incentives. Feedstock availability emerged as one of the primary limiting factors. Even under favorable land allocation scenarios, the supply of lipid feedstocks constrained the scale of SAF facilities that could be supported over time. Small and medium production facilities were structurally feasible under the modeled conditions, while larger facilities exceeded the sustainable feedstock supply and therefore could not operate stably within the system.

Economic viability represents an additional constraint. The MSP values estimated for the different facility scales remain significantly higher than the projected international jet fuel price. Although producer-oriented incentives such as BTC and tax exemptions reduce the MSP, the results indicate that moderate incentives alone are insufficient to close the economic gap with conventional jet fuel. The scenario analysis suggests that stronger policy interventions, including direct subsidies or broader market mechanisms, would be required to stimulate sustained industry growth.

The analysis also highlights the importance of social dynamics in determining feedstock availability. Farmer willingness to adopt new biofuel crops significantly influences the amount of biomass that can enter the supply chain. Higher adoption levels substantially increase feedstock supply and enable larger facility scales to become feasible. These results suggest that policies targeting agricultural producers, such as crop incentives or support programs, may be as important as downstream incentives directed at fuel producers.

More broadly, the study demonstrates how SD can support the evaluation of emerging SAF systems by capturing the feedback among land use, resource availability, economic incentives, and industry expansion. Rather than evaluating isolated components of the supply chain, the modeling framework allows the identification of structural conditions that enable or constrain SAF deployment over time. By integrating feedstock dynamics, infrastructure development, and policy mechanisms within a single system representation, SD provides a useful tool for exploring long-term strategies for SAF industry development.

6. References

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