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WORKING PAPER

The Future of Sustainable Aviation Fuel in the Midwestern United States

Finding alternatives to crop-based biofuels

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Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues.

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Highlights

- Current US plans to decarbonize aviation rely on shifting from fossil fuel to biomass-based sustainable aviation fuel (SAF) using food crops, which could increase emissions and raise food prices.
- This research examines using corn stover, an agricultural residue, as a SAF feedstock.
- Corn stover is abundant in the Midwest and could be responsibly collected to replace three billion gallons of jet fuel annually (the United States' SAF Grand Challenge 2030 goal) without using additional arable land.
- A stover-based SAF and carbon dioxide removal (CDR) industry could support as many as 99,000–214,000 jobs, $7 billion–$15 billion in labor income, $9 billion–$32 billion in gross domestic product (GDP), and $4 billion–$10 billion in tax revenue on a gross basis in the Corn Belt, though some gains may replace existing activity.
- The direct annual operational jobs and GDP from a three-billion-gallon SAF and CDR industry (11,000 jobs; $3.9 billion GDP) could match the existing corn ethanol industry (8,000 jobs; $3.8 billion GDP).
- SAF is more costly than fossil jet fuel and would require $39 billion–$131 billion in capital investment, making policy support necessary for scaling.
- The Corn Belt has enough stover to meet the 2030 3-billion-gallon goal but not the 2050 35-billion-gallon goal, so additional decarbonization options would be needed.

Executive summary

Introduction

Aviation is considered a hard-to-abate sector—one where reducing greenhouse gas (GHG) emissions is particularly challenging—and existing strategies to decarbonize aviation rely heavily on replacing fossil jet fuel with alternative aviation fuel (often called sustainable aviation fuel, or SAF). This fuel would be synthetic or biomass based. Conventional biofuels made from food and feed crops, like corn and soy, are currently the most mature technologies to produce alternative aviation fuel. But to supply a significant share of jet fuel, they would require large areas of arable land, raising concerns about their global impacts on food prices, deforestation, and GHG emissions (Lark et al. 2022; Searchinger et al. 2018). Thus, many international policymakers are becoming increasingly skeptical about relying on conventional biofuels for SAF. Instead, there is growing interest in producing SAF from agricultural residues, which can be a more climate-friendly biomass feedstock option when harvested responsibly. Synthetic fuel made from hydrogen and captured carbon dioxide (known as electrofuel, or e-fuel) is another option to decrease net aviation emissions. US policies support conventional, food crop–based biofuels for SAF to support the domestic agricultural economy, but there has been little research into the economic benefits that a residue-based SAF industry could provide.

About this working paper

This paper explores the potential economic impact of a shift to residue-based or e-fuel SAF or CDR. It examines relevant SAF and CDR technologies that utilize corn stover, the most abundant agricultural residue in the United States. The harvest of corn in the Midwestern United States, commonly referred to as the Corn Belt, leaves behind millions of tons of residue in the form of stalks, leaves, husks, cobs, and other cellulosic, nonfood parts of the plant. These materials are collectively referred to as corn stover. This paper assesses the gross economic impacts that a residue-based or e-fuel SAF and CDR industry could bring to the Corn Belt. To evaluate the impacts of such an industry, we reviewed literature on different SAF and CDR technologies to determine their relevance to the region. We selected the most suitable technologies and conducted a preliminary economic impact analysis to understand the potential benefits they could bring to the Corn Belt in terms of jobs, labor income, value to regional GDP, tax revenue, and revenue for farmers. The economic analysis was conducted using the Jobs and Economic Development Impact (JEDI) and IMPLAN input-output models.

Key findings

Certain SAF technologies can take advantage of resources that are plentiful in the US Midwest, particularly corn stover (Figure 1). These technologies include alcohol-to-jet (AtJ), Fischer-Tropsch (FT), and power- and biomass-to-liquid (PBtL). In addition to using corn stover to make fuel, power-to-liquid (PtL) is an e-fuel technology that could be sited in the Midwest and use carbon captured from ethanol facilities. Airlines could also potentially meet decarbonization requirements by purchasing permanent CDR to compensate for fossil jet fuel emissions. One way CDR can be achieved with agricultural residues is by pyrolyzing corn stover (heating the feedstock to extremely high temperatures without oxygen) and injecting the resulting bio-oil underground.

- **AtJ is a near-term solution that takes advantage of existing ethanol infrastructure; however, it is the least efficient in terms of the feedstock volume needed to produce SAF.**
- **FT uses large facilities and therefore requires large initial capital investment, but that can bring many construction-related jobs and economic benefits.**
- **PtL, also known as e-fuel, is not limited by the biomass feedstock supply, but scaling is presently restricted by the cost of electrolytic hydrogen, renewable energy, and captured carbon.** Currently, the cheapest source of captured carbon is from existing corn ethanol plants, but this technology is flexible and can eventually use carbon from other sources such as cellulosic ethanol production or direct air capture.
- **PBtL provides the highest volume of fuel per volume of corn stover but presently faces the same cost constraints as PtL.**
- **The CDR pathway considered here requires high investment, but also creates many jobs distributed across the region.** It is not a pathway for SAF itself, but it instead pyrolyzes corn stover to create bio-oil for permanent carbon sequestration, which could compensate for aviation emissions. It is unique in that it uses a decentralized model of smaller, distributed facilities located close to the biomass source, reducing the burden of transporting residues.

We analyzed the gross economic impact of developing a residue-based SAF industry in the Corn Belt. In a hypothetical policy scenario where airlines were required to replace three billion gallons of jet fuel with SAF or CDR, adoption of these technologies in the Midwest could support as many as

Figure 1 | **Five ways to produce SAF or remove carbon in the Midwest**

	Alcohol-to-jet	Fischer-Tropsch	Power-to-liquid	Power- and biomass-to-liquid	Carbon dioxide removal
HOW DOES IT WORK?	Corn stover is treated and fermented ↓ Produces ethanol and/or isobutanol ↓ Converted to SAF	Corn stover is gasified ↓ Chemical reactions between carbon monoxide and hydrogen create hydrocarbon fuel	Electricity splits water to isolate hydrogen ↓ Combined with carbon captured from ethanol facilities to produce liquid fuel	Electricity splits water to isolate hydrogen ↓ Combined with gasified corn stover to produce liquid fuel	Corn stover is pyrolyzed to create bio-oil ↓ Bio-oil is injected underground for permanent carbon sequestration
KEY TAKEAWAYS	Builds on existing ethanol infrastructure Least-efficient use of stover	Requires more investment than alcohol-to-jet	Scaling restricted by cost of inputs Largest range of cost estimates Most ongoing jobs supported	Scaling restricted by cost of inputs Most-efficient use of stover	Highest capital investment Lowest LCA emissions Most construction jobs supported

Notes: The five technologies considered in this paper each use different methods to create SAF or compensate for jet fuel emissions. Each of these five technologies—four fuel based, one carbon dioxide removal—has unique advantages and disadvantages; SAF = sustainable aviation fuel; LCA = life cycle analysis.

Source: Authors.

99,000–214,000 jobs, $7 billion–$15 billion in labor income, $9 billion–$32 billion in value to regional GDP, and $4 billion–$10 billion in tax revenue each year. These are gross amounts and do not account for potential displacements of existing jobs and revenue. This level of SAF and CDR production could be achieved with between 18 and 89 million tons of stover, within sustainable limits of corn stover supply (estimated at 90 million tons). However, to achieve the US goal of 35 billion gallons of SAF per year by 2050 (DOE 2022), additional feedstocks would be needed. Each of the pathways considered here is at a relatively early stage of development and it is not clear which has the greatest potential to become more cost-effective and scale up, so investing in a portfolio of pilot projects to verify and validate the various technologies will be important rather than relying on a single solution alone.

While the regional economic benefits of a residue-based SAF industry could be substantial, policy support would be vital to develop these technologies and understand which ones will ultimately be able to scale. The current costs of producing stover SAF greatly exceed the price (and subsidies) for selling it. Current costs for manufacturing SAF from crops are substantially higher than the price of conventional jet fuel as well. Potential policy avenues for incentivizing SAF production include obliging airlines to reduce emissions, supporting SAF research and development, and helping farmers collect corn stover in a responsible manner.

Introduction

Aviation currently accounts for 2.4 percent of global greenhouse gas emissions, and in the United States, aviation emissions are expected to grow 43 percent in the next two decades (SEEIC n.d.). Attempts to decarbonize the aviation sector rely on various strategies, but most emissions reductions through mid-century are expected to come from the adoption of alternative aviation fuel (often referred to as sustainable aviation fuel, or SAF) to replace fossil jet fuel.

In 2021, the Joe Biden administration announced the SAF Grand Challenge, which set a goal of producing 3 billion gallons of SAF annually by 2030 and 35 billion gallons by 2050. In the Midwest United States, this presents an opportunity to build an industry based on using corn stover, an abundant agricultural residue in the region.

The purpose of this paper is to understand the role that residue-based technologies could play in both reaching near-term SAF goals and contributing to the regional economy of the Midwest United States. This paper asks the following questions:

1. What are relevant technologies for the Midwestern US region to replace three billion gallons of jet fuel annually with residue-based or electrofuel (e-fuel) SAF or carbon dioxide removal (CDR)?
2. If three billion gallons of jet fuel were replaced annually by residue-based or e-fuel SAF and CDR technologies, what would be the gross impact on the economy in Midwestern states (see Box 1)?

Box 1 | **Gross versus net economic impacts**

Gross impact on the economy refers to the additive effect from construction and operation of the SAF and CDR facilities on the overall economy, measured here in jobs, labor income, addition to gross domestic product (GDP), and tax revenue. These impacts may, in part, replace existing jobs and revenue. Due to limitations of the modeling methods used here, we did not calculate net impacts, which would take into account the substitution effect or opportunity cost of the gross economic impacts.

Reliance on SAF to decarbonize aviation

The International Council on Clean Transportation explored scenarios for reducing aviation emissions, including curbing air traffic growth, reducing warming from airplane contrails, making operational improvements, and building zero-emission aircraft. Nonetheless, 59–64 percent of emission reductions in these scenarios relied on SAF through 2050 (Graver et al. 2022). Similarly, the Clean Air Task Force examined alternative fuel mixes for decarbonizing aviation, including biomass-based SAF, e-fuels, and planes running on hydrogen. Even under optimistic assumptions about hydrogen aircraft, 71 percent of alternative jet fuel would still need to come from SAF produced from some combination of biomass, captured carbon dioxide, and hydrogen (Walker et al. 2024).

SAF is therefore key to decarbonizing aviation. In 2024, the Department of Energy (DOE) published a report on commercializing the domestic SAF industry (Howe et al. 2024). It found US production capacity will likely reach 1.8 billion–2.3 billion gallons per year by 2030. To achieve this, airlines would need long-term offtake agreements, and additional policy support would be needed to meet the three-billion-gallon goal.

However, DOE's projections assume that about two-thirds of US SAF supply in 2030 will come from hydroprocessed esters and fatty acids (HEFA) derived from used cooking oil (UCO) and soybean oil, about one-quarter from alcohol-to-jet (AtJ) technology using corn ethanol, and less than 10 percent from power-to-liquid (PtL) (Howe et al. 2024, 26).

This mix reflects expectations that in the near term, a lot of SAF will come from crop-based biofuels. Corn ethanol is currently the largest US biofuel industry, so its inclusion is unsurprising. While DOE discusses HEFA from waste oil, like UCO, many expect production will require virgin vegetable oil due to limited UCO supply (Bukowski et al. 2025). Reports already indicate fraudulent UCO imports that are actually virgin vegetable oil (Valdmanis and Baertlein 2024). HEFA can also be made from soybean oil, but this diverts food and feed to fuel, increasing the risk of indirect land-use change (European Commission n.d., 2025).

Though not emphasized in DOE's report, SAF can also be produced from domestic agricultural residues, which can scale without diverting food or feed.

Conventional biofuels versus next-generation SAF

HEFA is currently the only technology producing SAF at scale, but it raises climate concerns. Diverting vegetable oil from food markets to fuel causes land-use change around the world, including deforestation of carbon-rich tropical forests (Smith 2025).

Using corn ethanol for SAF also carries climate risks. Applying the carbon opportunity cost method (WRI and WBCSD 2026) to estimate indirect land emissions indicates that using corn ethanol for ground transportation emits more greenhouse gases than gasoline on a global life cycle basis. Converting it to SAF worsens impacts, since 1.7 gallons of ethanol are needed to produce 1 gallon of jet fuel (Wang et al. 2016).

Next-generation SAF technologies can use more sustainable feedstocks, like wastes, residues, and clean energy. They reduce global land-use change and lower the land carbon cost of fuel production. These technologies include advanced biofuels like cellulosic AtJ and Fischer-Tropsch (FT) fuels, as well as e-fuels like PtL fuel. These technologies are less mature and more expensive, but research and development is underway.

Technologies for CDR offer another option for decarbonizing aviation. While there are legitimate concerns about using CDR to compensate for emissions from continued use of fossil fuels, in hard-to-abate sectors like aviation, it may be appropriate and cost-effective (Lebling et al. 2023).

Biofuels and the US Midwestern agricultural economy

US policy has historically supported conventional food crop–based biofuels with the intent of lowering emissions and reducing dependence on fossil fuel imports. Support is also driven by perceived economic benefits for farmers, especially in the Midwest Corn Belt. The Renewable Fuel Standard, established in 2005, mandates blending biofuels into transportation fuel and has helped create a large US corn ethanol industry. It is widely supported by agricultural interests and Midwest officials because it ensures enduring and diversified demand for corn and increases revenue for producers and processors.

US biofuel policy benefits mostly large corporate farms and biofuel companies rather than small- and medium-sized farmers (Leslie-Bole et al. 2025). Large corporate farms and biofuel refineries stand to benefit from ambitious SAF targets and increased production of conventional food crop–based SAF.

As SAF demand grows, the US biofuels industry stands at a crossroads: either double down on conventional biofuels or develop more climate-friendly next-generation fuels that use underutilized residues without competing for land with food production (Box 2). Our research examined the feasibility and economic impact of using these residues. We found that the Corn Belt has the capacity to build residue-based SAF and CDR industries that support aviation decarbonization and bolster the regional economy.

Box 2 | **SAF policy in the United States**

The Biden-era US SAF Grand Challenge goals are not legally binding, but they guide private sector investment and policy. The only SAF-specific federal policy is the 45Z tax credit, which provides up to $1 per gallon for alternative transportation fuels, including aviation fuel, based on life cycle greenhouse gas emissions.

Recent policy shifts reduce federal support for residue-based and e-fuel SAF. The 2025 budget reconciliation bill amended 45Z by removing the premium for SAF over ground transportation fuels. It also revised emissions accounting by removing penalties for indirect land-use change (ILUC). The bill further eliminated tax credits for wind and solar power (48E, 45Y) and hydrogen production (45V) after 2027, which are critical inputs for e-fuels.

The net effect of these changes is to favor conventional food crop–based fuels for ground transportation over genuinely low-emission aviation fuel. Removing ILUC penalties makes it easier for food crop–based fuels to qualify for credits, while eliminating the SAF premium reduces incentives to produce aviation fuel instead of ethanol for cars or diesel fuel for trucks.[a] The earlier phaseout of the clean hydrogen credit will also raise e-fuel costs.

Under current policies, there is little federal incentive to produce SAF, and what remains will likely support conventional biofuel SAF, which could increase aviation emissions.

Source: a. Starr and Lewis 2025.

Methodology

(1) What are relevant technologies for the Midwestern US region to replace three billion gallons of jet fuel annually with residue-based or e-fuel SAF or CDR?

We assessed which technologies are most relevant and feasible for the American Midwest to replace three billion gallons of jet fuel annually with SAF or CDR. We conducted a literature review on the costs and efficiencies of SAF technologies suitable for the US Corn Belt, defined here as Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

The literature review focused on work by established organizations, such as the International Energy Agency; the US Department of Energy; and the National Renewable Energy Laboratory, now called the National Laboratory of the Rockies (NLR), along with expert referrals and targeted keyword searches on SAF technologies, pathways, and feedstocks. When studies reported differing cost or capacity estimates, we compared assumptions, such as technology maturity, feedstock availability, and regional factors, and selected our best estimates for Corn Belt conditions, informed by expert interviews.

To be considered relevant, technologies had to meet three criteria:

- **Use climate-friendly feedstocks.** Following European Union (EU) policy, SAF should rely on nonfood (and nonfeed) feedstocks to avoid land-use competition that could raise food prices and drive deforestation (European Commission n.d., 2025). EU guidelines also require at least a 65 percent life cycle emissions reduction relative to fossil jet fuel (European Parliament 2018). Accordingly, we limited feedstocks to wastes, residues, and renewable energy, excluding food and energy crops.[1]
- **Suit the Midwestern US region.** This includes pathways that utilize abundant regional feedstocks (e.g., corn stover) or existing infrastructure and supply chains.
- **Replace three billion gallons of jet fuel** without exceeding the climate-beneficial supply of regional wastes and residues.

We chose the volumetric goal of three billion gallons per year by 2035 because it mirrors the US SAF Grand Challenge goal for 2030 while allowing a 10-year scale-up from 2025. Although the current SAF landscape is not on track to reach this goal, for this analysis we assumed this production volume will be mandated and become feasible, defined here as being technically deployable and having costs that are not prohibitive under policy support, within a decade. Relevance criteria do not include analysis of commercial profitability.

Selected technologies mainly use corn stover, which makes up the vast majority of agricultural residues in the Midwest. The DOE's *2023 Billion-Ton Report* estimates that corn stover accounts for 87 percent of US agricultural residues, largely concentrated in the Corn Belt (Hellwinckel et al. 2024).

To compare stover needs for three billion gallons of SAF with availability, we defined "available" stover using Lawrence Livermore National Laboratory's *Roads to Removal* report (Pett-Ridge et al. 2023). *Roads to Removal* provides county-level estimates of stover availability that is constrained to

- not exceed soil-loss limits set by the US Department of Agriculture's Natural Resources Conservation Service; and
- maintain long-term soil organic matter (Muth et al. 2013).

Under these constraints, Pett-Ridge et al. (2023) estimate that about 90 million tons of corn stover are currently available annually in the Corn Belt.

(2) If three billion gallons of jet fuel were replaced annually by residue-based or e-fuel SAF and CDR technologies, what would be the gross impact on the economy in Midwestern states?

For the second part of our analysis, we assumed a policy requiring airlines to procure a portion of the three-billion-gallon target based on their share of jet fuel consumption in 2035. Airlines could either purchase qualifying SAF or purchase CDR to compensate for emissions from the equivalent amount of conventional jet fuel.

We included five technologies meeting the criteria in our analysis of the economic impact of such a policy. These include four SAF technologies and one CDR technology (described in "Results of I/O modeling: economic impacts"). Because it is unclear which SAF or CDR technology will dominate the market, we expect the aviation sector to pursue a diverse portfolio of technologies in the near term. We estimated the gross economic impact of each technology if scaled to replace three billion gallons of jet fuel annually by 2035, and a scenario where three billion gallons are equally divided among the five technologies.

This analysis does not predict market winners, but rather compares efficiency, costs, and impacts across technologies and estimates the general magnitude of economic impact from SAF production or CDR compensation for fossil jet fuel on a scale of three billion gallons per year.

We used input-output (I/O) modeling to estimate the gross economic impacts from our policy scenario, using IMPLAN and the NLR's Jobs and Economic Development Impact (JEDI) models. Both use empirical data to trace flows of goods and services across the economy, and are able to estimate employment from investments in the five selected technologies.

IMPLAN maps user-specified investments to industry sectors in a region to estimate interactions among industries, households, and government, and in doing so, estimates the number of jobs associated with the investment. Reported jobs are an industry-specific mix of part time, full time, and seasonal roles, reflecting underlying Bureau of Labor Statistics and Bureau of Economic Analysis data. JEDI similarly combines inputs, such as project location, facility size, and year of construction, with empirically derived estimates of how investment money ripples up and down connected sectors to estimate job creation. Inputs for each technology include capital investment, annual production capacity, operating costs, and feedstock requirements (see Appendix A for more detail).

Results are reported as direct, indirect, and induced employment, labor income, GDP value added, and tax revenue.

- **Direct effects** reflect initial activity (e.g., construction workers hired to build a new SAF facility).
- **Indirect effects** include the backward linkages and supply-chain responses (e.g., manufacturing jobs to meet the increased demand for construction equipment).
- **Induced effects** reflect household spending by direct and indirect workers (e.g., restaurant jobs supported by construction workers having disposable income and eating at local restaurants).

We deduced state-level gross economic impact according to assumptions about production facility siting. We assumed facilities that use corn stover are located near feedstock supply using *Roads to Removal* data (Pett-Ridge et al. 2023). We assumed e-fuel facilities are sited according to least-cost SAF production pathway data from the Electrofuel Pathways to Lower Aviation to Net-Zero Emissions (ePLANE) dashboard (Phadke et al. 2024). We distributed the revenues from corn stover sales geographically using the distribution of corn farmer employment across Corn Belt states (see Appendix A for more details on facility siting assumptions).

We did not analyze SAF from conventional crop-based biofuels and made no assumptions about changes in their production.

Model limitations

I/O models are static and do not incorporate changes to labor and capital productivity over time. They are neither dynamic nor equilibrium-seeking models, meaning they do not reflect price changes as markets adjust to shifts in supply or demand. Models like IMPLAN and JEDI rely on a Social Accounting Matrix, which uses data from the US Bureau of Economic Analysis and state agencies to track economic flows.

I/O results represent gross impacts. Assumed investment is exogenous to the model, so new projects always generate positive gross impact on the economy and employment. These models do not consider opportunity costs or job displacement in other industries, nor do we have a business-as-usual scenario. To the extent that jobs, income, and tax revenue come from workers who would otherwise be employed in other sectors in the region, net impacts would be smaller. As a result, I/O models often produce larger economic impact estimates than general equilibrium models.

In this analysis, given recent out-migration from the Midwest (Winikoff 2025), we interpreted results as jobs, income, and tax revenue sustained or added to the region by new industry supported in part by airlines and airline passengers. However, we did not quantify net impact.

For state-level results, facility-siting assumptions determined impacts. In practice, siting decisions will affect outcomes across states.

Literature review results: relevant next-generation SAF technologies

We selected five technologies that meet the relevance criteria; they include four SAF technologies and one CDR technology that could be used to compensate for the emissions associated with fossil jet fuel. Of the SAF technologies, AtJ and FT pathways are the most technologically ready in the near term to produce SAF from corn stover. We also considered PtL and power- and biomass-to-liquid (PBtL) pathways. PtL does not utilize stover directly but instead uses a related resource that is also abundant in the Midwest: captured carbon from ethanol plants. The cost estimate for PtL in this analysis uses captured carbon from ethanol plants because that is the pathway currently being used by PtL companies and is what can be expected in the near term. However, this technology is flexible and could eventually shift to using carbon from other sources, like cellulosic ethanol production or direct air capture (DAC). PBtL uses corn stover gasification as a carbon source.

In addition to these fuel technologies, we considered CDR via pyrolysis of corn stover and injection of the resulting bio-oil. CDR was deemed an important consideration as it has the potential to be a cost-effective option for reducing aviation's carbon emissions while contributing to the Midwest economy.

Alcohol-to-jet

AtJ involves fermenting biomass to produce ethanol and/or isobutanol, which can be chemically converted into jet fuel. AtJ SAF is often discussed in the context of utilizing corn ethanol made from kernels rather than stover. Corn ethanol AtJ fuel is a relatively mature technology. But making ethanol from cellulosic feedstocks, like corn stover, requires technology that is far less ready or commercially viable (Uddin et al. 2025). Still, some consider AtJ SAF one of the best short-term options to bridge the gap while other SAF technologies develop because it can utilize existing ethanol infrastructure. When the Renewable Fuel Standard was enacted in the early 2000s, hope flourished that a breakthrough in cellulosic biofuel production would make scaling possible. But two decades later, these hopes have not come to fruition, so there is understandable skepticism around the prospects for this technology.

Despite these concerns, AtJ produced from corn stover remains one of the more promising SAF pathways that does not utilize food crops. The National Laboratory of the Rockies has developed an advanced cellulosic biomass pretreatment process called deacetylation and mechanical refining, which can prepare corn stover for fermentation without requiring the high temperatures and pressures used in previous methods (Ringle 2024).

To meet the three-billion-gallon goal, based on current capacity estimates, five AtJ facilities would be needed to produce 600 million gallons of SAF annually, one-fifth of the goal. They would likely be sited near corn farms to minimize the cost of transporting corn stover (Appendix A).

Fischer-Tropsch

The FT process entails gasifying corn stover and converting it to a liquid hydrocarbon fuel through a series of chemical reactions between carbon monoxide and hydrogen. FT is a relatively mature technology, but its economic viability for producing jet fuel from corn stover is hindered by challenges associated with biomass gasification, specifically the high capital costs to build the FT facilities, feedstock variability, and mechanical complexity involved in converting solid feedstocks into synthesis gas. With corn stover, logistical challenges include the high cost of transporting it to a centralized facility, wear and tear on machinery when processing nonuniform biomass, and high moisture content necessitating extra purification of the synthesis gas (syngas) produced.

An estimated three FT facilities would be needed to produce 600 million gallons of SAF annually (Appendix A).

Power-to-liquid with captured carbon

PtL fuels, also known as e-fuels, are created by using clean, non-emitting electricity to break apart water molecules in a process known as electrolysis. Once hydrogen is isolated from oxygen, the hydrogen molecules are combined with carbon to form a liquid hydrocarbon fuel. This process requires a lot of energy, and when considering using this energy to produce liquid fuels like SAF versus using it to decarbonize the power grid, the latter is a more effective way to reduce overall emissions. Therefore, PtL SAF only truly reduces emissions when it is created with additional clean electricity that would not have otherwise been built to decarbonize the grid. Another major obstacle for PtL is the complexity of making it affordable by co-locating all the infrastructure needed: renewable energy, hydrogen, biomass sources, and processing. Co-locating the other infrastructure with existing corn ethanol facilities is currently the cheapest way to source a relatively pure stream of captured carbon from ethanol production. However, using carbon dioxide (CO_2) from corn ethanol production raises questions of where to allocate the direct and indirect emissions associated with corn ethanol production, whether that be to the ethanol, the e-fuel, or a mix of both. As an alternative to corn ethanol, carbon could be sourced from biomass waste (see "Power- and biomass-to-liquid" below), from cellulosic ethanol production, or from DAC of carbon dioxide, although DAC is currently prohibitively expensive.

To produce 600 million gallons of SAF annually, an estimated 32 PtL facilities would be needed.

Power- and biomass-to-liquid

PBtL involves gasifying biomass, such as corn stover, and using this gas as a carbon source for e-fuel. Electrolysis produces hydrogen as it does in the PtL process, and FT synthesis combines that hydrogen with carbon monoxide to make liquid fuel. By combining biomass gasification with external hydrogen production, the PBtL is able to produce 2.5 times as much SAF per ton of biomass feedstock as the FT process and 1.5 times as much SAF per ton of hydrogen as the PtL process (Phadke et al. 2024).

An estimated 54 PBtL facilities would be needed to produce 600 million gallons of SAF annually. Optimal siting is based on co-location of renewable energy, hydrogen production, and biomass sourcing and processing (Phadke et al. 2024).

Pyrolysis and bio-oil injection for carbon dioxide removal

Not a fuel production technology, this CDR pathway instead permanently sequesters carbon to compensate for fossil jet fuel emissions. This technology pyrolyzes corn stover to create bio-oil, which can be injected into former oil wells, locking the carbon underground permanently. The resulting bio-oil could alternatively be processed to produce SAF, which raises emissions and costs. However, this analysis examines the impacts of simply using the resulting oil for carbon storage. Pyrolysis differs from carbon capture technologies that need to achieve economies of scale to reduce costs. This is because it can rely on many mobile, small pyrolyzers deployed near biomass sources, rather than collecting and hauling biomass to a single, central facility. These mobile units can pyrolyze material on-site and then transport the bio-oil to injection sites (Dubey et al. 2025). One benefit of such a distributed system is the reduced need to transport stover long distances. Rather than economies of scale, this technology is being developed to achieve "economy of numbers" (Dubey et al. 2025).

An estimated 2,079 of these small pyrolysis facilities would be needed to offset the estimated 6,450,000 tons of CO_2 that are emitted from the use of 600 million gallons of traditional jet fuel.

Climate impact comparison

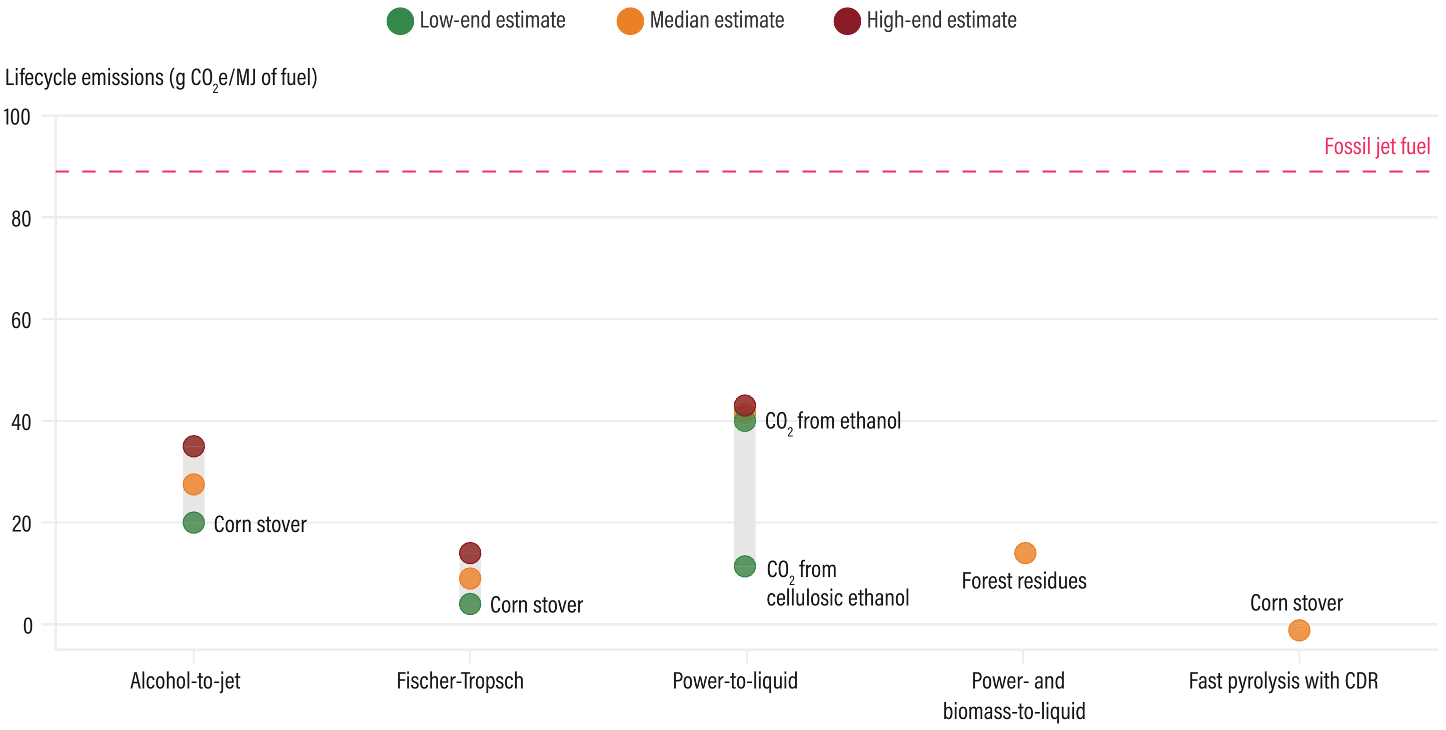
Life cycle analyses (LCAs) provide a way to gauge and compare the relative climate impact of different fuel pathways and technologies, accounting for the emissions associated with feedstock production, transportation, and processing (Figure 2).

LCAs for stover AtJ estimate a carbon intensity range of 20–35 grams of carbon dioxide equivalent per megajoule (g CO_2e/MJ) of fuel (Han et al. 2017; Uddin et al. 2025; de Jong et al. 2017), while LCA estimates for FT range between 4 and 14 g CO_2e/MJ. The ranges are influenced by whether AtJ production is sited near the ethanol plant (Han et al. 2017); whether co-products, like exported electricity, are credited for emissions reductions (de Jong et al. 2017); or if impacts to soil organic carbon from stover removal are accounted for (Stratton et al. 2010). By comparison, fossil jet fuel has emissions of 89 g CO_2e/MJ.

LCA literature on PBtL and PtL is limited. One analysis of PBtL with forest residues estimates life cycle emissions to be 14 g CO_2e/MJ (Rojas-Michaga et al. 2025). For PtL, estimates vary by the source of CO_2: 11.4 g CO_2e/MJ using CO_2 from cellulosic ethanol and between 40 and 43 g CO_2e/MJ using CO_2 from corn ethanol (Zang et al. 2021). For both pathways, emissions can be reduced or even provide carbon dioxide removal if some CO_2 goes to permanent storage, but sequestering CO_2 comes with a trade-off in how much SAF can be produced for a given quantity of stover (Zang et al. 2021).

The CDR pathway can remove 0.45 tons of CO_2e per ton of dry biomass, which in LCA terms is equivalent to −1.18 g CO_2e/MJ (Dubey et al. 2025). When fossil jet fuel is paired with CDR, it can offset part or all of its emissions.

Figure 2 | **Emissions from life cycle analysis**



Note: High- and low-end estimates are included where available. For comparison, life cycle emissions for fossil jet fuel are included in the chart; g CO_2e/MJ = grams of carbon dioxide equivalent per megajoule; CDR = carbon dioxide removal; CO_2 = carbon dioxide.

Sources: Alcohol-to-jet: Han et al. 2017; Uddin et al. 2025; de Jong et al. 2017. Fischer-Tropsch: de Jong et al. 2017; Stratton et al. 2010. Power-to-liquid: Rojas-Michaga et al. 2025. Power- and biomass-to-liquid: Zang et al. 2021. Carbon dioxide removal: Dubey et al. 2025. Fossil jet: ICAO 2025.

Feedstock efficiency comparison

SAF technologies for converting corn stover to aviation fuel vary in efficiency. Since corn stover is a limited resource, efficiency determines the capacity of these fuels to meet volumetric SAF targets. Overall, PBtL makes the most efficient use of corn stover, producing an estimated 163 gallons of fuel per ton of corn stover (Phadke et al. 2024). On the other end of the spectrum, AtJ and FT produce an estimated 34 (Han et al. 2017) and 52 (Shahriar and Khanal 2022) gallons of fuel per ton of corn stover, respectively. Notably, the FT and AtJ pathways generate CO_2 that could be captured and used as an input to PtL as an alternative to CO_2 from conventional ethanol plants, which would increase the combined stover efficiency of these technologies. The CDR pathway would compensate for the emissions from 79 gallons of petroleum jet fuel per ton of corn stover (Charm Industrial n.d.).

A three-billion-gallon residue-based SAF industry would likely use between 18 and 89 million tons of stover per year (Table 1). In the unlikely scenario where the least-efficient technology, AtJ, is alone used to produce three billion gallons per year, the industry would approach the limit of current sustainable supply of corn stover, 90 million tons (Pett-Ridge et al. 2023). Other technologies could produce three billion gallons per year without coming close to exhausting the sustainable supply of stover.

PtL with captured carbon does not use corn stover, but efficiency can be considered in terms of the conversion of carbon dioxide to SAF. Carbon efficiency estimates for PtL range between 10 and 15 kilograms (kg) of CO_2 per gallon of SAF. This scales up to 6 million–9 million tons of CO_2 needed to produce 600 million gallons or 30 million–45 million tons of CO_2 to produce 3 billion gallons of SAF. This is just within estimates of the available CO_2 produced by the existing US ethanol industry, which is estimated to be around 45 million tons (Irwin 2024). Additional CO_2 could be sourced from stover-based ethanol and AtJ facilities. Similar to corn stover, there may be sufficient CO_2 supply from the ethanol industry to support production of 3 billion gallons, but there is not enough to reach the

Table 1 | **Feedstock efficiency and stover requirements**

FUEL	FEEDSTOCK EFFICIENCY (GALLONS/TON OF STOVER)	MILLION TONS OF STOVER TO REPLACE 600 MILLION GALLONS OF JET FUEL	MILLION TONS OF STOVER TO REPLACE 3 BILLION GALLONS OF JET FUEL
Alcohol-to-jet	33.8	17.8	88.8
Fischer-Tropsch	52.4	11.4	57.2
Power- and biomass-to-liquid	163.0	3.7	18.4
Carbon dioxide removal	79.0[a]	7.6	38.0

Notes: a. Because the CDR pathway is not producing jet fuel, the feedstock efficiency value listed presents the gallons of jet fuel offset per ton of stover used for CDR.
Sources: Han et al. 2017; Charm Industrial n.d.; Shahriar and Khanal 2022.

35-billion-gallon goal. Moreover, given the emissions associated with ethanol production, using CO_2 from ethanol facilities could lower the net climate benefits of PtL.

Obstacles to using corn stover

As a feedstock, corn stover presents challenges. Stover is made up of the cellulosic material consisting of corn stalks and leaves. Because it is bulky and less uniform than corn starch, transporting stover is expensive, and processing it can be unwieldy and damage machinery. Moreover, harvesting residues on a large scale requires a general willingness of farmers to participate in collection efforts. Since stover decomposition contributes to soil productivity by contributing carbon, farmers would need to be sure that stover removal would not negatively impact soil health and long-term crop yields. Sufficient compensation for changes to land management, such as delayed planting schedules to allow time for stover harvest, would be crucial to induce farmers to enter a stover market. If the quantity of stover removed required increased fertilizer application, it would risk negating the economic and climate benefits of stover utilization.

The *Roads to Removal* analysis (Pett-Ridge et al. 2023) assessed biomass availability in the United States by updating biomass supply curves from the *2016 Billion-Ton* study (Langholtz et al. 2016) and estimating the farmgate price farmers would have to receive to make it economical to harvest different volumes of stover. The report findings indicate that 66 million tons of stover could be available in Corn Belt states for $50/ton, and 90 million tons could be available at $100/ton.

Biofuel production is not the only potential market for corn stover, and from a climate perspective, SAF may not be the optimal end use of this resource. Trade-offs must be considered between using stover for fuel versus other end uses, such as for livestock feed or bedding, as a substitution for fossil feedstocks for chemical production, or for carbon removal (Redfearn et al. 2019).

The question of how much corn stover can be sustainably removed from farm fields is complex and dynamic. It varies across geographies and depends on climatic conditions and how land is managed. Stover removal can affect soil nutrient levels, soil organic carbon, yield, and erosion. In water-scarce areas of the Midwest, residue removal could lower yield by increasing evaporation from the soil. In contrast, in wet, cold parts of the region, some residue removal could improve yields by allowing soil to warm up earlier in the season (Andrews 2006).

In terms of climate impact, residue left on the ground can add to the soil carbon pool, but in places where yields are particularly high, like Iowa, some residue removal can reduce the need to apply nitrogen fertilizer, thereby reducing nitrous oxide emissions (Castellano et al. 2025; Liska et al. 2014). Another important consideration is whether SAF production displaces existing uses of the stover. A small percentage (<10 percent) of stover is currently used for livestock bedding and feed roughage (Hellwinckel et al. 2024). If shifting that stover to SAF production causes farmers to replace it with other, more emissions-intensive materials, that may lower the net climate benefit of SAF. The primary value of corn stover to farmers is soil nutrient replenishment, including nitrogen, phosphorus, and potassium. If stover harvest necessitates changes in nutrient application, associated emissions impacts would have to be considered, but this will vary by geography and management type.

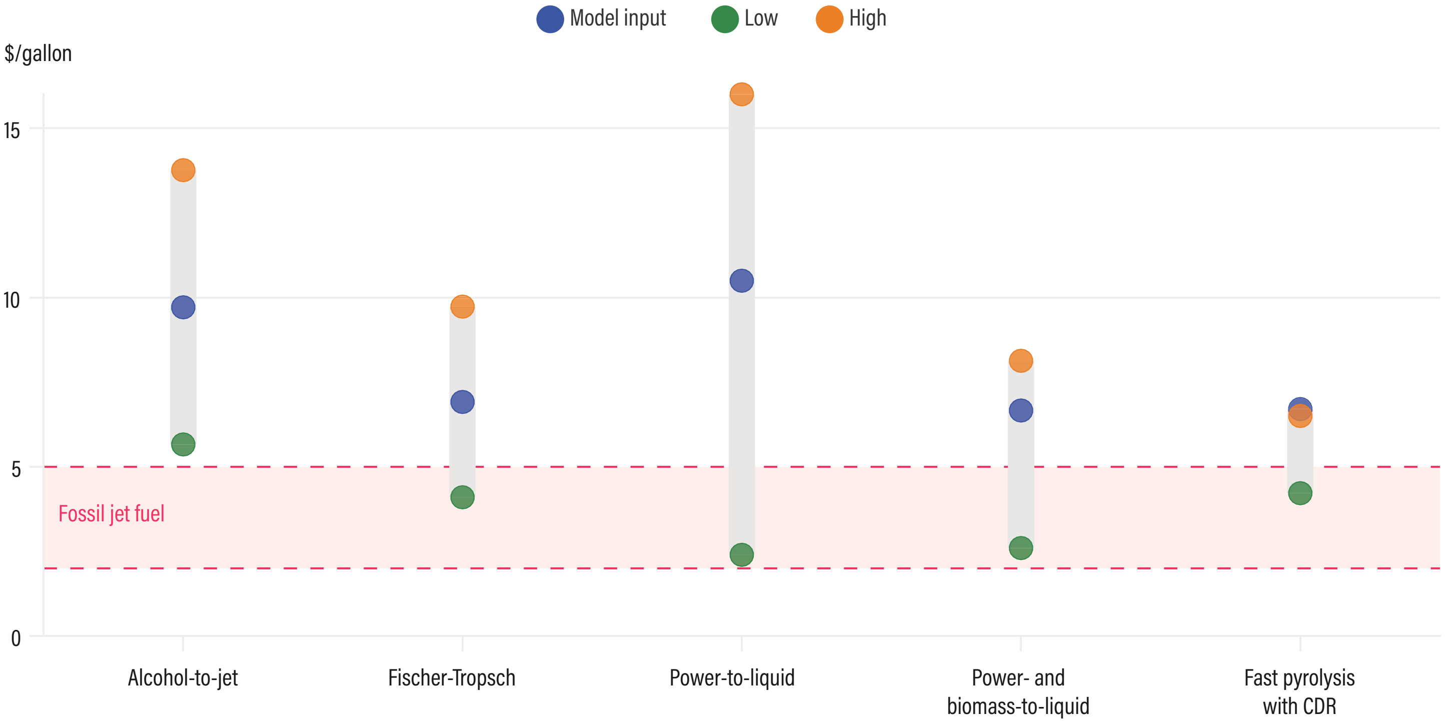
Cost comparison

SAF fuels are more expensive to make than conventional fossil jet fuel. In addition, uncertainty surrounds current and future production costs for the five technologies analyzed here. Costs hinge on varying assumptions about technological maturity, co-location with other infrastructure, and the presence or absence of subsidies. Our literature review found production costs ranging between $2.40 and $16.00 per gallon of SAF produced (Figure 3), depending on the technology and various factors involved in each pathway (Appendix B). The PtL pathway lies on both the low and high ends of the overall range. This is because the cost of PtL is highly uncertain and depends heavily on the costs of hydrogen, renewable energy, and carbon source, and estimates for these vary widely.[2] PBtL shows a smaller price range because sourcing carbon from biomass (in this case corn stover) is relatively cheap compared with other sources of carbon. The lowest cost estimates for PtL and PBtL account for tax credits that have since been reduced, and assume production is optimally located with carbon sources and low-cost hydrogen production nearby. They represent highly optimistic cost projections, including the potential for large cost reductions for these technologies. Notably, the average price of fossil jet fuel in 2024 was $2.34 per gallon, lower than all technologies examined here.

A policy that requires airlines to collectively replace three billion gallons of jet fuel with SAF or CDR would raise airline operating costs and likely be at least partially passed through to customers in ticket prices. The Energy Information Administration projects that airlines will consume a total of 26.3 billion gallons of jet fuel in 2035 (EIA 2025), meaning that each airline would be required to procure SAF for 11.4 percent of its fuel in this scenario.

To get a sense of the impact, consider a flight from New York to Los Angeles in an Airbus A321-251N, the most efficient narrow-bodied jet in commercial operation in 2019. This aircraft has room for 192 passengers and burns 4,755 gallons of fuel on this itinerary if fully loaded (Aircraft Commerce 2019). Assuming an average capacity factor of 85 percent, this implies fuel

Figure 3 | **Production cost range and the model input production cost for each technology**



Notes: Model inputs for the economic analysis were determined by taking an average of production costs derived from our literature review (Appendix B). The ranges shown include both current and future costs and reflect differing assumptions in the underlying literature; these costs are not necessarily comparable as they come from various sources and are not adjusted to the same US dollar year. (Literature on costs of these sustainable-aviation-fuel technologies is unfortunately inconsistent and untransparent, thereby limiting our ability to harmonize cost estimates for comparability. These issues are evidenced and explained further in Albrecht et al. [2017].) The costs shown here include varying assumptions on the price of corn stover from original source materials. The CDR pathway's price range in $/gallon is based on a price range estimate for carbon removal of $146.80–$328.80 per ton of carbon dioxide (CO_2) removed, 89 grams of CO_2 emissions per megajoule (MJ), and 142 MJ/gallon for petroleum jet fuel to get a removal price per gallon of $1.88–$4.16, plus an average of $2.34 per gallon of fossil jet fuel; CDR = carbon dioxide removal.

Sources: Fischer-Tropsch: Huang et al. 2019; Detsios et al. 2023. Alcohol-to-jet: Howe et al. 2024; Yang and Yao 2025. Power-to-liquid and power- and biomass-to-liquid: Phadke et al. 2024. Carbon dioxide removal: Dubey et al. 2025.

consumption of 29 gallons per passenger (neglecting the small reduction in fuel requirements from operating below maximum capacity). If SAF costs an average of $6 per gallon more than conventional jet fuel, the 2035 SAF requirement would cost $20 per passenger for this cross-country flight.

Future projections of the different technology pathways reveal how much technology maturation could potentially bring down production costs. PtL and PBtL still have a long way to go in terms of technology maturation. Costs could come down significantly, but it may take longer than the 10-year period examined here (Phadke et al. 2024).

Results of I/O modeling: economic impacts

A policy mandating that airlines purchase SAF or CDR from agricultural residues or e-fuels presents a potential economic opportunity for the Midwest, including jobs in construction and operations, tax revenue, and farm income. Overall, an investment in building and operating a three-billion-gallon-per-year industry could support 26,000–109,000 gross annual jobs in the region for 10 years during the construction phase (259,000–1,091,000 job-years) and between 71,000 and 135,000 gross ongoing jobs during the operational phase. These would be a mix of full-time and part-time jobs, and they may, in part, replace existing jobs in the region.

If the three-billion-gallon production were equally distributed across the five technologies considered here (i.e., each

Table 2 | **Economic impacts by technology**

		EMPLOYMENT	LABOR INCOME (BILLION $)	GDP VALUE (BILLION $)	TAXES (BILLION $)
Alcohol-to-jet	Total construction-phase impacts (job-years)	259,000	19.4	30.9	9.9
	Annual operations-phase impacts (annual jobs)	73,000	4.9	5.7	3.2
	Total average annual impacts[a]	**99,000**	**6.8**	**8.8**	**4.2**
Fischer-Tropsch	Total construction-phase impacts (job-years)	648,000	48.4	83.8	16.2
	Annual operations-phase impacts (annual jobs)	71,000	6.0	13.2	2.6
	Total average annual impacts[a]	**136,000**	**10.8**	**21.6**	**4.3**
Power-to-liquid	Total construction-phase impacts (job-years)	322,000	24.1	41.7	8.1
	Annual operations-phase impacts (annual jobs)	135,000	12.5	27.0	5.8
	Total average annual impacts[a]	**168,000**	**14.9**	**31.2**	**6.6**
Power- and biomass-to-liquid	Total construction-phase impacts (job-years)	358,000	26.7	46.2	9.0
	Annual operations-phase impacts (annual jobs)	86,000	7.9	17.2	3.7
	Total average annual impacts[a]	**122,000**	**10.6**	**21.8**	**4.6**
Fast pyrolysis with CDR	Total construction-phase impacts (job-years)	1,091,000	80.1	116.8	27.3
	Annual operations-phase impacts (annual jobs)	105,000	5.6	9.0	7.3
	Total average annual impacts[a]	**214,000**	**13.6**	**20.6**	**10.0**
Equal technology distribution scenario[b]	Total construction-phase impacts (job-years)	536,000	39.7	63.9	14.1
	Annual operations-phase impacts (annual jobs)	94,000	7.4	14.4	4.5
	Total average annual impacts[a]	**148,000**	**11.3**	**20.8**	**5.9**

Notes: a. Average annual construction-phase impacts (assuming 10-year construction period) plus operations-phase impacts. b. Three billion gallons equally divided among the five technologies (600 million gallons each); CDR = carbon dioxide removal.

Source: Authors.

Table 3 | **Direct employment and GDP contribution of modeled SAF industry and existing ethanol industry**

INDUSTRY	EMPLOYMENT	GDP (BILLION $)
Existing 15-billion-gallon ethanol manufacturing industry (metrics for 2024)	8,000	3.8
Modeled 3-billion-gallon SAF industry annual operations (equal technology distribution scenario[a])	11,000	3.9

Notes: a. Three billion gallons equally divided among the five technologies (600 million gallons each); These numbers reflect direct operations employment and GDP contribution; they include neither construction-phase impacts nor indirect and induced impacts; GDP = gross domestic product; SAF = sustainable aviation fuel.

Sources: Ethanol manufacturing industry data are from CE&A n.d. Modeled SAF industry data are from this paper's authors.

technology replacing 600 million gallons of jet fuel per year), the industry would support an average of almost 54,000 gross annual jobs during the construction phase and almost 94,000 gross ongoing jobs during the operations phase (Table 2).

In this scenario, the direct operations-phase employment and GDP value supported by a residue-based SAF and CDR industry would be comparable to that of the existing ethanol industry in the region (Table 3) (CE&A n.d.).

Employment supported by construction of this new industry would create $19.3 billion–$80.1 billion in labor income ($39.7 billion if each technology were to produce 600 million gallons per year), $30.9 billion–$116.8 billion ($63.9 billion) in GDP value, and $8.1 billion–$27.3 billion ($14.1 billion) in tax revenue sustained in the region. Ongoing operations would support $4.9 billion–$12.5 billion ($7.4 billion) in labor income, $5.7 billion–$27.0 billion ($14.4 billion) in GDP value, and $2.6 billion–$7.3 billion ($4.5 billion) in tax revenue for the region on an annual basis (Table 2).

While each of the five technologies examined here presents opportunities for the Midwest, their economic impacts vary by technology.

Employment

Stover pyrolysis for CDR supports the most jobs during the construction phase and the second-highest operations employment per gallon of compensated jet fuel (Figure 4). The high job creation during construction stems from the capital investment needed, approximately $44/gallon of annual jet fuel offset capacity. SAF production technologies and facilities modeled require much less up-front capital investment: between $13 and $26 per gallon of annual production capacity.

The FT pathway supports the second-largest number of jobs. FT's high capital investment costs, driven by expensive gasifiers and electrolyzers, would contribute to high construction-phase employment. The PBtL pathway supports fewer operations jobs than PtL, driven by lower operations costs because of lower electricity demand (Albrecht et al. 2017). AtJ supports the fewest number of jobs in the construction phase because a higher percentage of construction-phase spending occurs outside the Corn Belt region compared with other technologies like fast pyrolysis. Across every technology, more than half of the operations jobs supported are indirect jobs (Appendix C). This is primarily due to the purchase of feedstocks but also includes the transportation of intermediate goods and waste management.

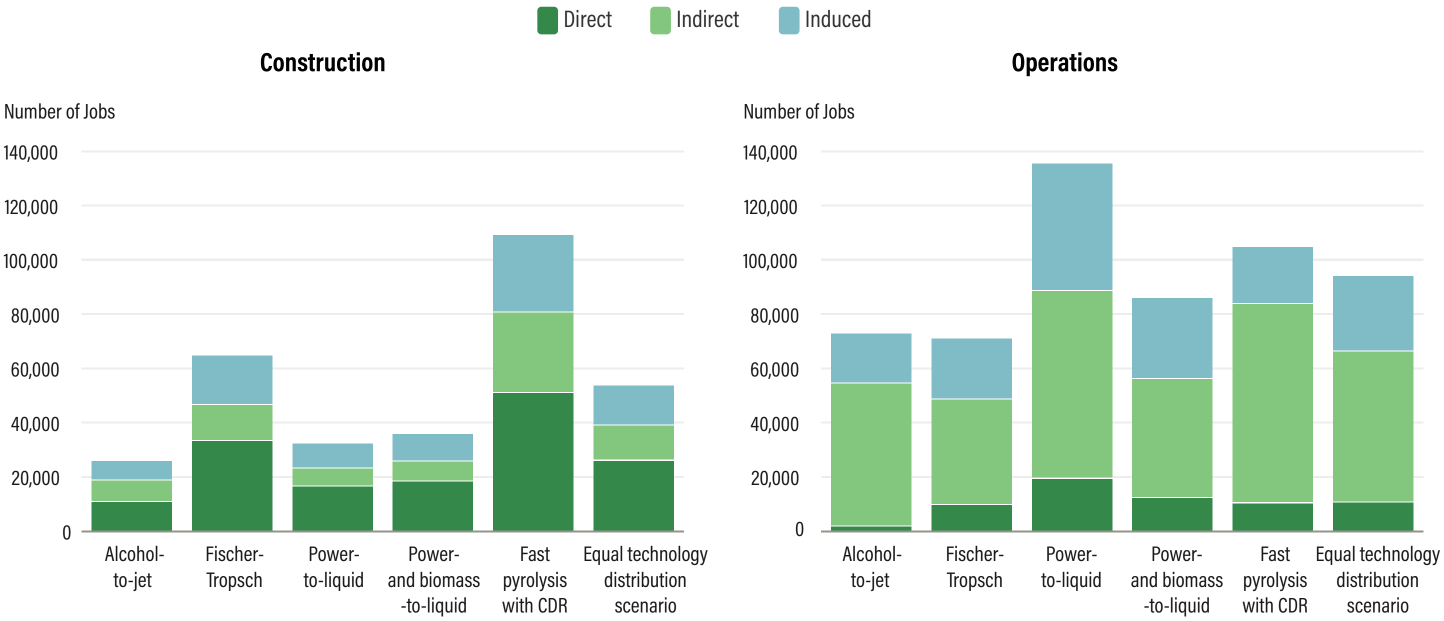
In the scenario where three billion gallons are divided equally among the five technologies, Iowa, Minnesota, and Nebraska see the highest demand for construction jobs (see Appendix A for facility siting assumptions). Most facilities (across all five technologies) are assumed to be sited in these states because of their abundance of corn stover. Illinois, Michigan, and Ohio see the highest demand for operations jobs, primarily from indirect jobs (upstream supply chain jobs) and from the CDR and PtL technologies (Figure 5).

Investment

Scaling a residue-based SAF industry to three billion gallons per year could require between $39 billion and $131 billion. Fast pyrolysis CDR would require the most investment, while each SAF pathway would require between $39 billion and $78 billion (Figure 6). If three billion gallons were divided equally among the five technologies, the industry would require $67.5 billion in capital investment across the region.

CDR and FT pathways contribute the largest economic benefits because of their high capital expenditure needs. Most pathways support 11–13 jobs (4–5 direct jobs) for each $1 million invested, except for AtJ, which supports only 8 jobs (2.3 direct jobs) per $1 million invested (Figure 7).

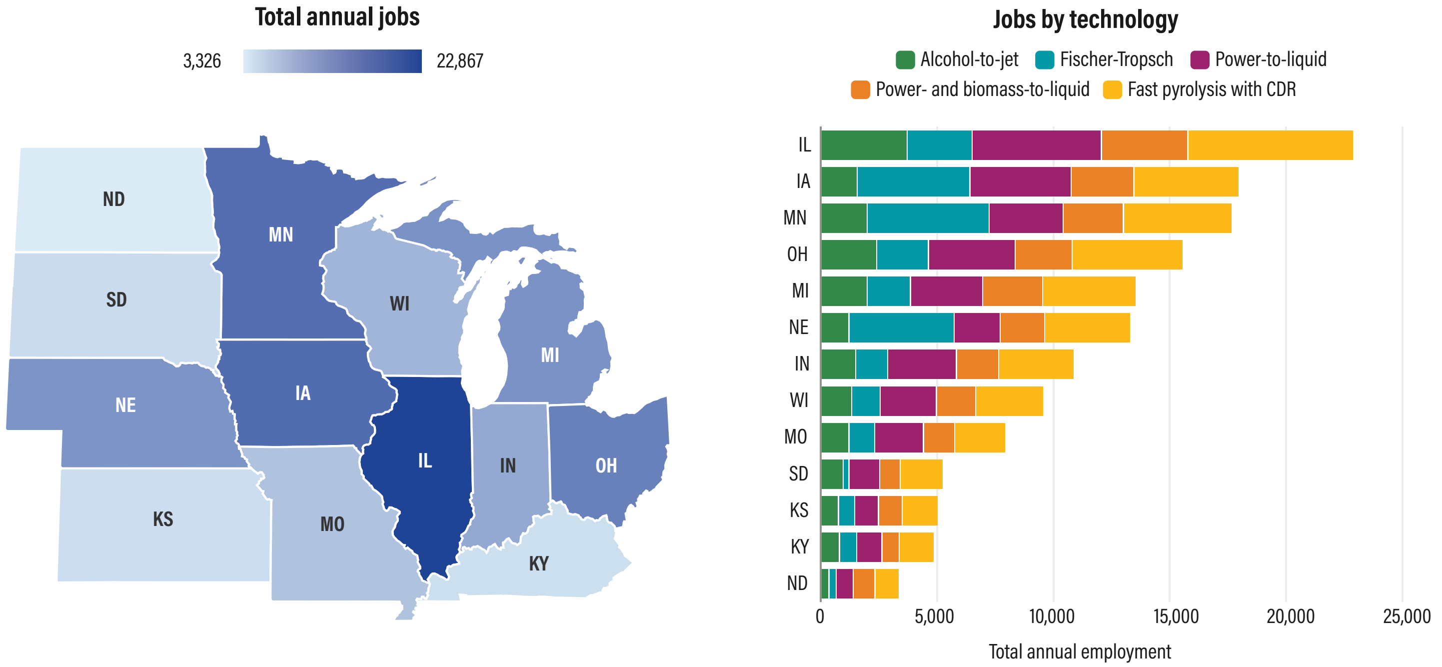
Figure 4 | **Annual jobs supported by replacing three billion gallons of jet fuel**



Notes: "Equal" assumes 600 million gallons of jet fuel are replaced annually by each technology. Annual jobs during the assumed 10-year construction period are shown separately from annual operations jobs. Jobs are separated into direct, indirect, and induced; FT = Fischer-Tropsch; CDR = carbon dioxide removal; AtJ = alcohol-to-jet; PtL = power-to-liquid; PBtL = power- and biomass-to-liquid.

Source: Authors.

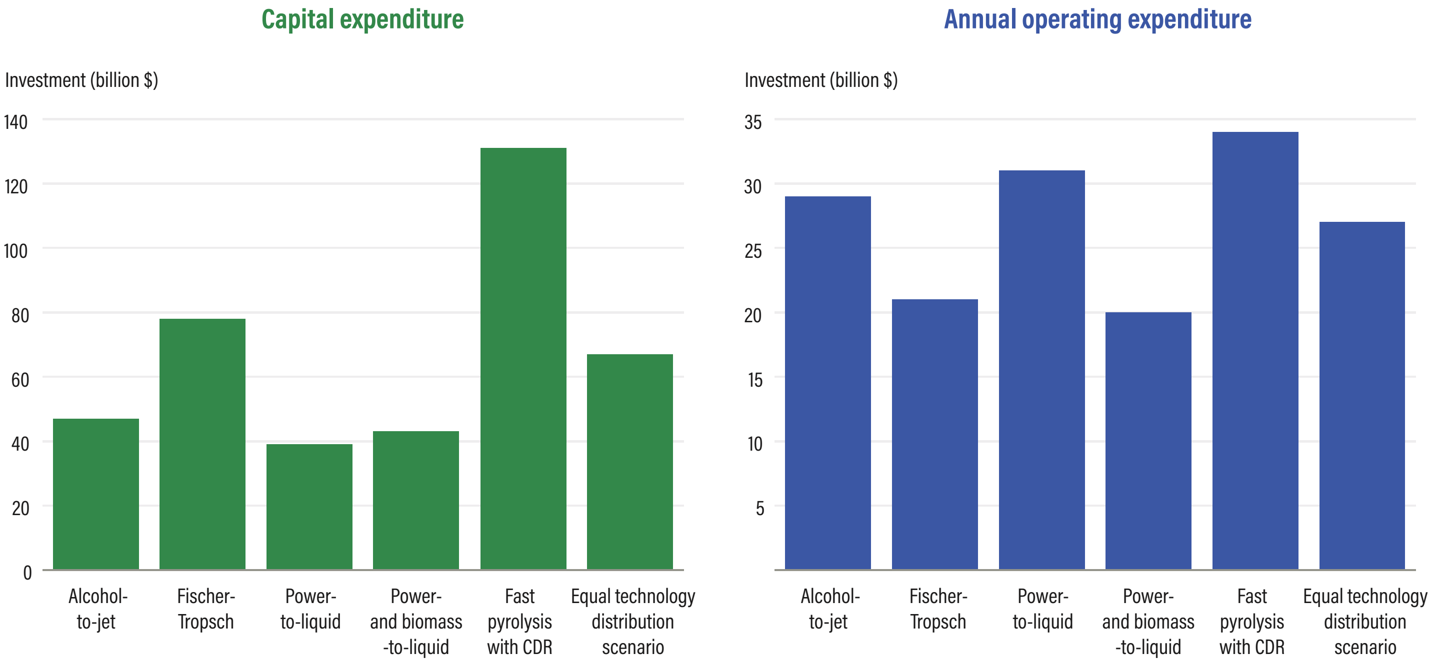
Figure 5 | **Annual gross employment supported by state and by technology**



Notes: Total annual jobs includes both construction (over a 10-year period) and operations. Assumes 600 million gallons of jet fuel are replaced annually by each technology. CDR = carbon dioxide removal.

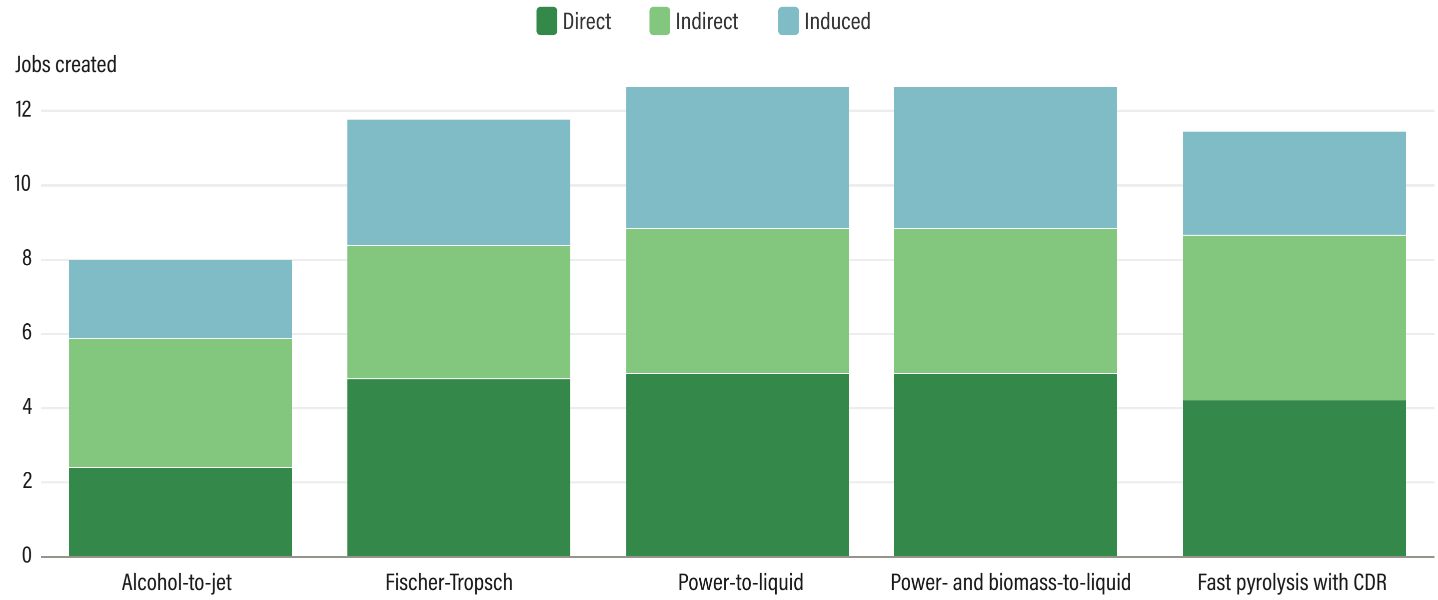
Source: Authors.

Figure 6 | **Total investment needed by technology to replace three billion gallons of jet fuel annually**



Notes: "Equal" assumes 600 million gallons of jet fuel are replaced annually by each technology. CDR = carbon dioxide removal.
Source: Authors.

Figure 7 | **Jobs created per $1 million invested for each technology**



Notes: Jobs include total construction jobs, which are temporary, and annual operations jobs; CDR = carbon dioxide removal.
Source: Authors.

Revenue for corn farmers

If each technology replaced 600 million gallons of jet fuel, the cumulative amount of stover needed would equal 40 million tons. In this scenario, the sale of 40 million tons of corn stover would provide $2 billion in annual revenue to farmers to support the additional labor and other costs needed to harvest the corn stover. This revenue is estimated based on the *Roads to Removal* corn stover supply curves, which indicate that 40 million tons of stover would be available in the Corn Belt at a price of $50/ton of stover (Pett-Ridge et al. 2023). If demand for stover reached 90 million tons, the supply curve indicates that the price would rise to $100/ton (Pett-Ridge et al. 2023), meaning farmer revenue from a 90-million-ton stover industry could reach $9 billion per year. The amount of SAF produced for any given amount of stover would be larger for the pathways that use less stover per gallon of SAF.

Discussion

Producing SAF from corn stover, or compensating for fossil jet fuel emissions by sequestering carbon contained in corn stover, is technically feasible, and investment in this industry could contribute significantly to the Midwest economy. While technologies that convert stover to SAF are less mature than those using corn starch or vegetable oil, they have the distinct advantage of not requiring food crops and dedicated cropland for fuel production. This avoids driving up food prices and prompting additional land-use change that releases greenhouse gasses.

Our literature review and economic analysis show there is no one silver bullet for replacing jet fuel with residue-based or e-fuel SAF or CDR. Moreover, SAF is currently much more expensive than jet fuel, making it economically unfeasible without policy support and cost reductions. The five technologies considered here have different advantages and disadvantages:

- **Alcohol-to-jet**
    - AtJ can take advantage of existing ethanol industry infrastructure plus alcohol-to-jet conversion facilities already under construction to process corn ethanol. AtJ appears to be competitive with other corn stover pathways in the near term but may have less potential for cost reductions.
    - AtJ would not provide as many gross jobs, GDP value added, or tax revenue to the region as other technologies.
- **Fischer-Tropsch**
    - FT requires large thermochemical plants to gasify corn stover and convert syngas into SAF. Like AtJ, the FT chemical synthesis process uses a relatively mature technology, but handling and gasifying large quantities of stover presents logistical challenges. FT is somewhat more efficient than AtJ at converting stover to SAF.
    - FT would generate the second-most gross total jobs and value added to farmers. On the other hand, since production is concentrated among a few large facilities, the jobs created by FT will be more geographically concentrated and depend on where facilities are sited.
- **Power-to-liquid with captured carbon**
    - PtL could produce up to about four billion gallons per year of SAF using CO_2 from the existing corn ethanol industry and could scale up indefinitely by using CO_2 captured from the atmosphere, but will be limited by the cost and availability of clean hydrogen and captured carbon. PtL has the largest range of cost estimates, from the least to most expensive per gallon of SAF.
    - PtL would support more ongoing jobs during the operations phase than the other technologies due to its higher electricity requirements but would not provide direct revenue to farmers.
- **Power- and biomass-to-liquid**
    - PBtL can produce 2.5 times as much SAF per ton of stover than FT synthesis using stover alone. PBtL has the potential to be among the most cost-effective ways to make SAF, but like PtL, that depends on low-cost hydrogen.
    - PBtL would support more construction jobs than PtL, but fewer ongoing jobs.
- **Pyrolysis and bio-oil injection for carbon dioxide removal**
    - CDR through pyrolysis of corn stover is more efficient in terms of the stover required per gallon of fuel "neutralized" than AtJ or FT. CDR adds to the cost of jet fuel but could become a relatively low-cost way to reduce emissions from aviation if capital costs are reduced by mass producing pyrolizers and if there is a market for biochar as a soil amendment.
    - CDR could support many jobs in the region, particularly construction jobs, but it also requires substantial capital investment to build many small facilities.

The amount of stover required to replace three billion gallons of jet fuel falls within the 90 million tons of stover that is potentially currently available in the Midwest without reducing soil carbon stocks (Pett-Ridge et al. 2023). The technologies considered here could produce an average of 84 gallons of jet fuel per ton of stover, meaning that 90 million tons of stover would be enough to replace 7.5 billion gallons of jet fuel. If SAF were produced from the most efficient technology, PBtL, that 90 million tons of stover could produce 14.5 billion gallons of SAF. At the same time, it is clear that there is not enough stover to produce the 35 billion gallons of jet fuel that would be needed to fully replace petroleum in US aviation. This implies that carbon sources in addition to stover will be needed, whether to produce SAF or for sequestration, to decarbonize the aviation sector. And, because SAF is currently substantially more expensive than petroleum jet fuel, scaling it up would require a large investment.

Policy recommendations

FOCUS POLICY SUPPORT ON DEVELOPING GENUINELY LOW-CARBON SAF

Replacing three billion gallons of jet fuel requires a $39 billion–$131 billion investment. Policy support will be needed to drive near-term investment in genuinely low-carbon SAF and determine which technologies will reduce costs enough to eventually scale up.

While airlines have pledged to cut their emissions and have made some small-scale investments in SAF production, they will not voluntarily pay a substantial premium for the volume of SAF needed to reach the 3-billion-gallon goal established by the SAF Grand Challenge in the United States, let alone the 35 billion gallons that would be needed to fully replace conventional jet fuel.

Our hypothetical policy scenario represents one policy option: requiring airlines to reduce emissions, potentially by mandating that fossil jet fuel be replaced via the purchase of SAF or CDR. Other policy mechanisms could include targeted research and development (R&D) or technology subsidies for SAF or CDR producers that use residue feedstocks or e-fuel technology. While early-stage support for these technologies can be justified, in the long run, using public funds to subsidize large-scale SAF production (which would primarily benefit large businesses and high-income airline passengers) presents equity concerns.

MAKE POLICY SUPPORT TECH NEUTRAL BUT NOT FEEDSTOCK NEUTRAL

There is not yet a clear “winner” technology in terms of cost-effectiveness or economic benefits for the Corn Belt. This means R&D policy support should focus on reducing costs and discovering which residue-based or e-fuel SAF technologies may be most likely to scale commercially.

SUPPORT FARMERS IN RESPONSIBLY COLLECTING CORN STOVER

Corn stover is a potentially valuable climate-friendly feedstock for SAF and CDR because it is produced in large quantities on existing cropland. Midwestern farmers can responsibly collect sufficient stover to replace or compensate for at least three billion gallons of jet fuel.

To maximize climate benefit, stover must be collected without compromising food production or soil carbon stocks. This requires leaving some portion of stover on farm fields; but even with this constraint, the potential supply in the Corn Belt is currently estimated to be 90 million tons per year (Pett-Ridge et al. 2023).

Grants and agricultural extension support could be used to deploy equipment, techniques, and knowledge for responsibly harvesting stover and avoiding negative impacts. Until an adequate farmgate price exists for corn stover, policy support may be needed to reduce extra costs for farmers to harvest.

Conclusion

SAF can be made from agricultural residues without dedicated land use and could significantly aid in decarbonizing aviation. Corn stover in the Midwest United States is an abundant resource that could be responsibly collected to replace or compensate for 3 billion–14.5 billion gallons of jet fuel. Additional strategies will be needed to fully decarbonize the 35 billion gallons projected for 2050, and more research is needed on scalable, cost-effective options beyond corn stover SAF.

Developing a stover-based SAF industry in the Midwest could substantially benefit the regional economy, including providing additional revenue for farmers. Scaling these industries requires large capital investment and policy support, as costs remain higher than those for fossil jet fuel. Near-term policies could support stover collection or subsidize early-stage projects. However, large-scale subsidies could reduce net regional benefits if they divert public spending from other programs.

One long-term policy option is to require airlines to purchase genuine low-emission SAF or compensate for their climate impacts with high-quality, permanent carbon removal. This would help internalize the costs of decarbonizing air travel within the aviation industry.

Appendix A. Methodology

Summary of input-output models

I/O modeling is used to generate employment estimates based on different investments or changes in a given economy over time. The research team used two I/O models, IMPLAN and NLR's JEDI model software, for this purpose. I/O models illustrate the interdependent relationships among sectors of a region's economy. Investments or activities in a given sector are used as inputs into the model to estimate the ripple or multiplier effect on business, household, and government expenditures and industry employment.

I/O models are static and do not incorporate changes to labor and capital productivity over time. They are not dynamic models or equilibrium-seeking models, and thus do not incorporate changes to prices due to changes in supply or demand given an economic event. I/O models like IMPLAN and JEDI rely on a Social Accounting Matrix, which uses US Bureau of Economic Analysis data and state-level economic agency data to track expenditures throughout the economy. The IMPLAN models (used for PtL, PBtL, FT, and bio-oil injection) use 2023 data because IMPLAN's 2024 data were released after the models were run. The JEDI Fast Pyrolysis and Upgrading Plant model was last updated by NLR in late 2016 and the Biological Conversion of Sugars to Hydrocarbons model (used for AtJ) was last updated by NLR in early 2017, when the most recent IMPLAN data would have been from 2015. Since there were no statistical analyses run in the research team's use of I/O modeling, there is unfortunately no margin of error to be calculated. However, uncertainty can be grouped into two main categories:

1. **Scenario assumption uncertainty**, or uncertainty in assumptions about the future of the SAF market: The research team sought to avoid unnecessary scenario assumptions about market capture by technology, and instead calculated economic impacts based on an equal amount of SAF produced by each technology. The research team addressed the feasibility of market adoption of each pathway in a qualitative manner.
2. **Model build uncertainty:** This uncertainty lies in the research team's decisions on which IMPLAN industries or JEDI models best fit the activities and investments involved in the development of each SAF production pathway. This relied on the researchers' expertise and understanding of both the SAF technologies and the I/O modeling software. The research team sought to avoid this uncertainty by leveraging decades of experience in the energy economy and I/O economic modeling, by conducting a thorough literature review, by conducting executive interviews with SAF industry experts, and through a rigorous peer review.

I/O modeling outputs are broken down into direct, indirect, and induced impacts. **Direct effects** show the change in the economy associated with the initial economic activity. An example of a direct job would be a construction worker hired to work on the construction of a new SAF facility. **Indirect effects** include all the backward linkages or the supply chain responses resulting from the initial direct economic activity. An example of an indirect job added to the local economy would be a new worker at a fabrication company hired to handle the increased demand for construction equipment resulting from the initial investment. **Induced effects** refer to the effects of increased household spending and are the result of direct and indirect workers spending their wages within the local economy. An example of an induced job would be a local restaurant hiring more staff because construction workers during the construction phase have new disposable income and eat at this local restaurant.

IMPLAN runs user-input investment into one or more of its industry codes in a specific region through regional data, mapping economic interactions among industries, households, and governments to estimate job creation associated with the investment.[3] JEDI estimates job creation by running user input of project location facility size and year of construction in combination with the built-in model defaults and economic multipliers.[4]

Modeling framework and assumptions

Modeling was centered around a core scenario, which assumes that three billion gallons[5] of SAF will be produced in the Midwest Corn Belt region[6] annually by 2035, divided evenly among five selected production pathways: alcohol-to-jet, gasification with Fischer-Tropsch, power-to-liquid, power- and biomass-to-liquid, and pyrolysis with carbon dioxide removal through bio-oil injection. The modeling process followed six steps:

1. Determine inputs for each of the SAF production pathways. Inputs include information about capital investment, annual production capacity, operating costs for announced SAF facilities in the region, feedstock prices, and the amount of feedstock required to produce a gallon of SAF for each of the pathways.
2. Construct multipliers using JEDI and/or IMPLAN models for each SAF production pathway. Multipliers provide the number of direct, indirect, and induced jobs supported per million gallons of SAF produced. For more information, see "Multiplier design" below.
3. Determine the siting of the SAF facilities needed by state to reach the 600-million-gallon annual SAF production target for each of the identified technologies. Because we assumed that the facilities modeled in this report would source their feedstock from the Corn Belt region and their hydrogen from electrolyzers co-located with renewable energy–generating sources, facilities were sited depending on the availability of these resources in each state.

4. Apply the IMPLAN and JEDI employment multipliers based on the allocation described in Step 3 to calculate employment outputs. For example, by applying the AtJ multipliers, which provide the number of jobs supported per million gallons of SAF produced through the AtJ production process, to the 600-million-gallon annual production assumption, we were able to estimate the number of jobs supported by the AtJ production pathway across the Corn Belt region.
5. Using the siting assumptions developed by the team, we were able to break out the direct outputs calculated in the previous step by state. To capture the interstate support of SAF facilities, we allocated indirect outputs according to each state's share of agricultural, manufacturing, professional services, and other support service industries in the Corn Belt region. We then allocated the induced outputs supported by the sum of the direct and indirect outputs by state.
6. Report final modeling outputs, including direct, indirect, and induced jobs, GDP value added, labor income, and tax revenue by state in the defined Corn Belt region for each of the SAF production pathways. For more information, see "Model outputs."

Multiplier design

Across the SAF production pathways, we used investment and production information from SAF facility announcements in the Midwest Corn Belt region as inputs into IMPLAN or JEDI models to develop facility-specific multipliers for both capital expenditure (CAPEX) and operating expenditure (OPEX). Sometimes the OPEX numbers included some annualized capital costs. CAPEX and OPEX multipliers provide information on the number of direct, indirect, and induced jobs supported during the construction and operations phases of the project, respectively. We then divided those multipliers by the facility size (announced production capacity in million gallons per year) to arrive at standardized multipliers that provided the number of jobs supported per million gallons of SAF.

Alcohol-to-jet

The AtJ multipliers used facility size from the Avina Clean Hydrogen SAF production facility announced in southwest Illinois.[7] The 120 million gallons of annual production capacity were used as inputs into NLR's Biological Conversion of Sugars to Hydrocarbons JEDI model (NLR 2025). The JEDI model estimated a required capital investment of $1.89 billion. Taking the average of the low and high AtJ production cost estimates ($5.66 and $13.76 per gallon) provided by DOE's *Pathways to Commercial Liftoff: Sustainable Aviation Fuel* report, we assumed an operational production cost of $9.71/gallon[8] (Howe et al. 2024). We assumed the AtJ facilities modeled in this report would source their biomass feedstock from corn stover produced in the Corn Belt. Total capital investments were estimated to be $9.5 billion while annual operations investments totaled $5.8 billion. This was the total amount of CAPEX assumed to be required for the five AtJ facilities needed to produce 600 million gallons of SAF. It was a simple calculation of $1.89 billion for one site multiplied by the five sites needed. Similarly, the $5.8 billion in OPEX came from the $9.71/gallon production cost multiplied by 600 million gallons.

We modeled the siting of the five AtJ facilities needed to produce the 600 million gallons using the availability of corn stover in the Corn Belt from the Livermore Lab Foundation's *Roads to Removal* database.[9] This resulted in the distribution of facilities by state as shown in Table A-1.

Gasification with Fischer-Tropsch

The gasification with FT multipliers used facility size and investment amounts from DG Fuels' Fischer-Tropsch SAF production facility announced in Moorhead, Minnesota.[10] The $5 billion in announced investment was used as an input into IMPLAN Industry Code 46, Construction of New Manufacturing Structures, to produce CAPEX multipliers. We used the facility size to develop the OPEX multipliers and calculated the OPEX cost using the average of the FT production cost estimates found in the literature, ranging from $4.10 to $9.73 per gallon (Huang et al. 2019; Detsios et al. 2023, respectively). The 193 million gallons per year in production capacity was multiplied by the OPEX cost per gallon ($6.92/gallon)[11] to arrive at the operating cost per year for the facility. This value was then used as an input into IMPLAN Industry Code 155, Other Basic Organic Chemical Manufacturing, to produce the OPEX multipliers. We assumed the FT facilities modeled in this report would source their biomass feedstock from corn stover produced in the Corn Belt. Total capital investments were estimated to be $15.5 billion, while annual operations investments totaled $4.2 billion.

Table A-1 | **Distribution of AtJ facilities by state**

STATE	SHARE OF CORN BELT ATJ SITES	NUMBER OF ATJ FACILITIES
IA	19%	1
IL	13%	1
IN	5%	0
KS	2%	0
KY	1%	0
MI	4%	0
MN	15%	1
MO	1%	0
ND	3%	0
NE	18%	1
OH	5%	0
SD	9%	1
WI	5%	0

Note: AtJ = alcohol-to-jet.
Source: Authors.

We modeled the siting of the three FT facilities needed to produce the 600 million gallons using the availability of corn stover in the Corn Belt from the Livermore Lab Foundation's *Roads to Removal* database.[12] This resulted in the distribution of facilities by state as shown in Table A-2.

Power-to-liquid

The PtL multipliers used facility size and investment amounts from Twelve's PtL SAF production facility announced in Moses Lake, Washington.[13] While this facility is not within the designated study region, it is currently the only PtL SAF production facility announced in the United States. The $245 million in announced investment was used as an input into IMPLAN Industry Code 46, Construction of New Manufacturing Structures, to produce CAPEX multipliers. We used the facility size to develop the OPEX multipliers. The OPEX cost per gallon was $10.50. This value is the average of six PtL production-cost-per-gallon estimations (Albrecht et al. 2017; Isaacs et al. 2021; BloombergNEF 2023; Zhou et al. 2022; Brynolf et al. 2017; Hannula 2016). The 19 million gallons per year in production capacity was multiplied by the OPEX cost per gallon to arrive at the operating cost per year for the facility. We then used this value as an input into IMPLAN Industry Code 152, Industrial Gas Manufacturing, to produce the OPEX multipliers. We assumed the facilities modeled in the PtL pathway would source their hydrogen from electrolyzers co-located with renewable energy–generating sources. Total capital investments were estimated to be $7.7 billion, while annual operations costs totaled $6.3 billion.

We modeled the siting of the 32 PtL facilities needed to produce the 600 million gallons using the least-cost SAF production pathway data from the ePLANE dashboard published by Jose L. Dominguez Bennett (Phadke et al. 2024). These data showed the production capacity by county for the least-cost SAF pathway. This resulted in the distribution of facilities by state as shown in Table A-3.

Power- and biomass-to-liquid

To develop the PBtL multipliers, the research team hybridized the processes outlined in the FT and PtL pathways since PBtL is a hybrid of both technologies. Using modeled cost data reported in Habermeyer et al. (2024), the research team used the same IMPLAN industry codes used in the FT and PtL pathways but with different investment values to account for differences in the share of total cost for components in both CAPEX and OPEX. We assumed a required $159 million to construct each 11-million-gallon facility. To form this assumption, we used the total OPEX cost from Table 8 in Habermeyer et al. (2024) and applied a 1.17 dollar-to-euro conversion factor. We also assumed a production cost of $6.66/gallon. The $6.66/gallon figure is the average of four PBtL $/gallon estimations: $6.43, $8.13, $7.1, and $4.99 (Hillestad et al. 2018; Albrecht et al. 2017; Isaacs et al. 2021; Habermeyer et al. 2024, respectively). Total capital investments were estimated to be $8.6 billion, while annual operations investments totaled $4 billion.

Table A-2 | **Distribution of FT facilities by state**

STATE	SHARE OF CORN BELT FT SITES	NUMBER OF FT FACILITIES
IA	19%	1
IL	13%	0
IN	5%	0
KS	2%	0
KY	1%	0
MI	4%	0
MN	15%	1
MO	1%	0
ND	3%	0
NE	18%	1
OH	5%	0
SD	9%	0
WI	5%	0

Note: FT = Fischer-Tropsch.
Source: Authors.

Table A-3 | **Distribution of PtL facilities by state**

STATE	SHARE OF CORN BELT PTL SITES	NUMBER OF PTL FACILITIES
IA	33%	10
IL	9%	3
IN	9%	3
KS	1%	0
KY	0%	0
MI	1%	0
MN	12%	4
MO	2%	1
ND	5%	1
NE	12%	4
OH	2%	1
SD	9%	3
WI	5%	2

Note: PtL = power-to-liquid.
Source: Authors.

We modeled the siting of the 54 PBtL facilities needed to produce the 600 million gallons using the least-cost SAF production pathway data from the ePLANE data published by Jose L. Dominguez Bennett (Phadke et al. 2024). These data showed the production capacity by county for the least-cost SAF pathway. This resulted in the distribution of facilities by states in the Corn Belt as shown in Table A-4.

Pyrolysis with carbon dioxide removal through bio-oil injection

The CDR multipliers used facility size and investment amounts from DG Fuels' Fischer-Tropsch SAF production facility announced in Moorhead, Minnesota.[14] Information on annual production capacity and project construction costs at the DG Fuels facility were used as inputs into NLR's Fast Pyrolysis and Upgrading Plant JEDI model to produce CAPEX and OPEX multipliers for the pyrolysis pathway. The DG Fuels facility has a 193 million gallon/year production capacity and $5 billion construction cost. While the facility is a gasification plant rather than one for pyrolysis, it is used as a proxy because of limited information on stover-based pyrolysis plant costs. While FT and pyrolysis use the same cost inputs, they were differentiated by the models used to estimate economic impacts, which were tailored to capture the activities associated with each production process.

We included the carbon abatement from only bio-oil sequestration in our modeling, not biochar. To capture the additional impacts resulting from the CDR component of this production pathway, the team developed an additional IMPLAN model centered around bio-oil injection. NLR's *Techno-economic Analysis of Biomass Fast Pyrolysis to Transportation Fuels* paper provides information on the percentage of bio-oil yield by feedstock weight for favorable, base-case, and unfavorable conditions (Wright et al. 2010). The base-case percentage of bio-oil produced was multiplied by the amount of corn stover needed annually to support the 193-million-gallon annual production capacity of the DG Fuels facility to estimate the amount of bio-oil for CDR produced by the facility annually. We then multiplied this value by the cost per unit of bio-oil injection to arrive at the annual cost of bio-oil injection associated with the facility, which we used as an input into IMPLAN Industry Code 30, Drilling Oil and Gas Wells, to produce multipliers associated with CDR through bio-oil injection. We took the base case value of bio-oil yield (weight per weight feed) from Wright et al. (2010) and multiplied it by the tons of corn stover needed to produce 193 million gallons of SAF to find the tons of bio-oil yield from producing 193 million gallons of SAF. That value was then divided by the cost of bio-oil injection in 2022 US dollars/ton/year to arrive at the cost in 2022 US dollars/year.

Total capital investments were estimated to be $26.2 billion, and total annual operations investments, $6.8 billion, assuming a production cost of $6.70/gallon.[15]

Assuming 6,450,000 tons of CO_2 are emitted from the use of 600 million gallons of traditional jet fuel, we modeled the siting of the 2,079 CDR facilities needed to offset the 600 million gallons of jet fuel using the availability of corn stover in the Corn Belt from the Livermore Lab Foundation's *Roads to Removal* database.[16] This resulted in the distribution of facilities by state as shown in Table A-5.

Table A-4 | Distribution of PBtL facilities by state

STATE	SHARE OF CORN BELT PBTL SITES	NUMBER OF PBTL FACILITIES
IA	22%	12
IL	7%	4
IN	6%	3
KS	4%	2
KY	0%	0
MI	6%	3
MN	15%	8
MO	2%	1
ND	7%	4
NE	17%	9
OH	2%	1
SD	7%	4
WI	6%	3

Note: PBtL = power- and biomass-to-liquid.

Source: Authors.

Table A-5 | Distribution of CDR facilities by state

STATE	SHARE OF CORN BELT CDR SITES	NUMBER OF CDR FACILITIES
IA	19%	401
IL	13%	262
IN	5%	114
KS	2%	39
KY	1%	27
MI	4%	75
MN	15%	319
MO	1%	24
ND	3%	63
NE	18%	367
OH	5%	106
SD	9%	182
WI	5%	100

Note: CDR = carbon dioxide removal.

Source: Authors.

Revenue to farmers from corn stover collection

To produce the three billion gallons of SAF annually through an equal distribution of 600 million gallons produced by each SAF technology and 600 million gallons of traditional jet fuel offset through bio-oil CDR, about 40 million tons of corn stover would be required annually, which equates to about $2 billion in annual farmer revenue, using an assumption of $50 per ton. We distributed these revenues geographically in our economic modeling using the distribution of corn farmer employment across the Corn Belt states. We input these values into IMPLAN using Industry Code 2, Grain Farming, to calculate the annual economic impact of these revenues by state (see Table A-6).

Table A-6 | **Annual revenue to farmers from corn stover collection**

STATE	SHARE OF CORN FARMER EMPLOYMENT	ANNUAL REVENUE (MILLION $)
IA	11%	$223
IL	23%	$465
IN	15%	$303
KS	4%	$81
KY	3%	$61
MI	6%	$121
MN	10%	$202
MO	3%	$61
ND	3%	$61
NE	9%	$182
OH	5%	$101
SD	1%	$20
WI	7%	$142

Source: Authors.

Model outputs

Outputs were produced for each of the two project phases, CAPEX and OPEX; each of the 13 states in the Corn Belt region; and each of the five production pathways analyzed in this project. Outputs include the following:

- **Investment:** total capital and operational investments that serve as inputs to the model
- **Jobs:** measured as job-years in the CAPEX phase and annual jobs in the OPEX phase; jobs reported are measured in head count, and count full-time, part-time, and seasonal workers equally
- **Labor income:** the total payroll cost paid to employees (wages, salaries, benefits, payroll taxes) and payments received by self-employed individuals
- **GDP value added:** gross output less intermediate inputs; equivalent to GDP for national outputs and gross state product for state-level outputs; this is the net economic activity generated by the construction or operations of developments, less the cost of input materials to avoid double counting economic activity
- **Taxes:** local, state, and federal tax revenues generated

The research team produced the same outputs for each state in the Corn Belt region for the annual revenue to farmers from corn stover collection. To avoid double counting the indirect impacts associated with the purchase of corn stover during SAF production and the direct impacts associated with farmer revenue due to corn stover purchases, the research team reported these findings separately and discouraged the summation of economic impacts across the SAF production analysis and the farmer revenue analysis.

Appendix B. Production cost data and variables

Cost sensitivities for each technology estimate the high- and low-end production costs for these technologies based on various policy environments. Uncertainty in the cost of corn stover, renewable electricity, and hydrogen are the inputs expected to have the largest influence on costs across SAF technologies. Here are the cost ranges of these inputs from our literature review:

- Corn stover ($/metric ton): $44.09–$110.23 (R2R n.d.)
- 2035 land-based wind levelized cost of electricity (LCOE) (dollars per megawatt-hour, or $/MWh): $7.45–$53.66 (NLR 2024)
- 2035 utility solar electricity LCOE ($/MWh): $6.96–$34.72 (NLR 2024)
- 2035 utility solar with storage electricity LCOE ($/MWh): $33.36–$73.87 (NLR 2024)
- Hydrogen ($/kg): $2.16–$7.22 (Peterson et al. 2020)

We did not normalize costs to a single year because while some of the literature specified dollar years, others sources did not. The land-based wind, utility solar, and utility solar with storage were all normalized relative to each other, to 2022 US dollars. The cost of hydrogen is in 2016 US dollars. Sources were chosen based on their merits of having high institutional standing, producing research of high quality, and providing transparent methodology and data. Corn stover cost is a potential valuation range of corn stover prices in the future from the *Roads to Removal* report (Pett-Ridge et al. 2023).

The LCOEs for land-based wind, utility solar, and utility solar with storage do include the cost of land since CAPEX is a factor in the LCOE calculation and land acquisition costs are included in the CAPEX values.

Production costs are also affected by five relevant tax incentives: the §45Z Sustainable Aviation Fuel Tax Credit, §45V Clean Hydrogen Production Tax Credit, §48 Renewable Energy Investment Tax Credit, §45Y Clean Energy Production Credit, and §45Q Carbon Sequestration Credit.

To investigate cost uncertainty, the sensitivity analysis used high- and low-case estimates of these incentives in 2035. The low-case assumption for all policies was that they would no longer exist, since every incentive expires prior to 2035. The high-case assumption for all policies was that they would be extended through 2035 under their existing specifications in the 2025 budget reconciliation.

The cost ranges for each technology are the following:

- AtJ cellulosic: $5.66–$13.76 per gallon (Howe et al. 2024; Yang and Yao 2025)
- FT pathway: $4.10–$9.73 per gallon (Huang et al. 2019; Detsios et al. 2023)
- PtL pathway: $2.40–$16.00 per gallon (Phadke et al. 2024)
- PBtL pathway: $2.60–$8.13 per gallon (Phadke et al. 2024)
- CDR pathway: $146.80–$328.80 per ton of CO_2 removed (Dubey et al. 2025)—not including the value of biochar; cost could be lower if the carbon sequestered in biochar and potential revenue from selling biochar as a soil amendment were included

The literature shows the cost ranges for impactful production components. Model inputs for the economic analysis were determined by taking the mean of production costs found in our literature review, which are a combination of modeled costs and point-in-time production cost estimates for standing facilities.

Appendix C. Full model results

Employment, labor income, GDP value added, and tax revenue results for the construction and operations phases of each scenario, including four scenarios of three billion gallons per year of SAF production from each SAF technology, one scenario of compensating for three billion gallons of jet fuel per year from CDR with corn stover, and one scenario where the goal of three billion gallons per year is equally divided among all five technologies.

Table C-1 | **Full model results**

		EMPLOYMENT	LABOR INCOME (BILLION $)	GDP VALUE (BILLION $)	TAXES (BILLION $)
		Construction			
Alcohol-to-jet	Direct	110,000	8.7	13.7	4.3
	Indirect	78,000	6.0	9.1	2.7
	Induced	70,000	4.7	8.2	2.9
	Total	**259,000**	**19.4**	**30.9**	**9.9**
Fischer-Tropsch	Direct	336,000	25.5	43.0	7.0
	Indirect	132,000	11.6	19.7	4.4
	Induced	180,000	11.3	21.0	4.8
	Total	**648,000**	**48.4**	**83.8**	**16.2**
Power-to-liquid	Direct	167,000	12.7	21.4	3.5
	Indirect	66,000	5.8	9.8	2.2
	Induced	90,000	5.6	10.5	2.4
	Total	**322,000**	**24.1**	**41.7**	**8.1**
Power- and biomass-to-liquid	Direct	185,000	14.1	23.7	3.9
	Indirect	73,000	6.4	10.9	2.4
	Induced	99,000	6.3	11.6	2.6
	Total	**357,000**	**26.7**	**46.2**	**9.0**
Fast pyrolysis with carbon dioxide removal	Direct	511,000	43.9	59.0	11.8
	Indirect	297,000	18.3	29.0	7.4
	Induced	283,000	18.0	28.8	8.0
	Total	**1,091,000**	**80.1**	**116.8**	**27.3**
Equal technology distribution scenario[a]	Direct	262,000	20.9	32.2	6.1
	Indirect	129,000	9.6	15.7	3.8
	Induced	144,000	9.2	16.0	4.2
	Total	**536,000**	**39.7**	**63.9**	**14.1**

Table C-1 | **Full model results (cont.)**

		EMPLOYMENT	LABOR INCOME (BILLION $)	GDP VALUE (BILLION $)	TAXES (BILLION $)
		Operations			
Alcohol-to-jet	Direct	2,000	0.1	0.1	1.4
	Indirect	53,000	3.6	3.9	0.9
	Induced	18,000	1.2	1.8	0.9
	Total	**73,000**	**4.9**	**5.7**	**3.2**
Fischer-Tropsch	Direct	10,000	1.5	4.5	0.8
	Indirect	39,000	3.1	6.1	1.2
	Induced	22,000	1.4	2.6	0.6
	Total	**71,000**	**6.0**	**13.2**	**2.6**
Power-to-liquid	Direct	20,000	2.8	8.6	1.5
	Indirect	69,000	6.7	12.9	3.0
	Induced	47,000	2.9	5.5	1.2
	Total	**135,000**	**12.5**	**27.0**	**5.8**
Power- and biomass-to-liquid	Direct	12,000	1.8	5.5	1.0
	Indirect	44,000	4.3	8.2	1.9
	Induced	30,000	1.9	3.5	0.8
	Total	**86,000**	**7.9**	**17.1**	**3.7**
Fast pyrolysis with carbon dioxide removal	Direct	10,000	1.1	1.0	3.2
	Indirect	73,000	3.2	5.7	1.9
	Induced	21,000	1.3	2.3	2.1
	Total	**105,000**	**5.6**	**9.0**	**7.3**
Equal technology distribution scenario[a]	Direct	11,000	1.4	3.9	1.6
	Indirect	56,000	4.2	7.4	1.8
	Induced	28,000	1.7	3.1	1.1
	Total	**94,000**	**7.4**	**14.4**	**4.5**

Note: a. Three billion gallons equally divided among the five technologies (600 million gallons each).

Source: Authors.

Abbreviations

AtJ	alcohol-to-jet
CDR	carbon dioxide removal
FT	Fischer-Tropsch
PBtL	power- and biomass-to-liquid
PtL	power-to-liquid
SAF	sustainable aviation fuel

Glossary

biomass gasification: heating biomass at high temperatures in a low-oxygen environment to create synthesis gas

biomass pyrolysis: heating biomass at high temperatures in a zero-oxygen environment to create bio-oil and/or biochar

biomass wastes and residues: any plant material that would otherwise be unused; typically, they are by-products of agriculture, forestry, or other industries and can include materials such as corn stover, almond shells, sawdust, and felled trees

clean electricity: any non-emitting electricity generation, including wind, solar, geothermal, and nuclear

conventional food crop–based biofuels: also referred to as first-generation biofuels, these use food crops, such as corn and soy, as input feedstocks

corn stover: the nonfood parts of the corn plant, such as the leaves and stalks

synthesis gas (syngas): a gas made primarily of hydrogen and carbon monoxide that can be converted into biofuels

ton: US ton

Endnotes

1. More research is needed on the direct and indirect land impacts of using purpose-grown energy crops, like perennial grasses, winter oilseed, or cover crops for fuel production. For that reason, these feedstocks are not considered here.
2. Researchers at the University of California, Berkeley, cite cost variation of electrolyzers (to produce hydrogen) ranging between $200 and $2,300 per kilowatt, which could significantly impact the price per gallon of PtL SAF (Phadke et al. 2024).
3. For more information on IMPLAN and its data sources, see https://support.implan.com/hc/en-us/articles/360038285254-How-IMPLAN-Works.
4. While users have the option of inputting project-specific data (e.g., construction costs, equipment costs, annual operating and maintenance costs, financing parameters), JEDI provides default values (i.e., "average costs and spending patterns developed from a number of sources") for these categories if nothing is input by the user. These inputs are then run through the JEDI multipliers, which are derived from IMPLAN. For more information on the data used in the JEDI model, see https://www.nrel.gov/analysis/jedi/using-data.html.
5. Based on the Department of Energy's Sustainable Aviation Fuel Grand Challenge, which sets a goal of three billion gallons of domestic SAF production annually by 2030. For more information, see the "Sustainable Aviation Fuel Grand Challenge" webpage at the US Department of Energy: https://www.energy.gov/eere/bioenergy/sustainable-aviation-fuel-grand-challenge.
6. The Corn Belt is defined in this study as the region encompassing Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.
7. For more information about the Avina Clean Hydrogen SAF facility announcement, see "Avina Clean Hydrogen and Gov. Pritzker Announce Sustainable Aviation Fuel Facility in Southwest Illinois," Avina, December 20, 2024, https://avinah2.com/avina-clean-hydrogen-and-gov-pritzker-announce-sustainable-aviation-fuel-facility-in-southwest-illinois/.
8. $9.71/gallon is the average of the production cost range of $5.66–$13.76 found during our literature review.
9. See R2R (n.d.).
10. For more information on the DG Fuels facility, see "DG Fuels to Launch SAF Plant in Moorhead, Minnesota, Converting Biomass into High-Value Fuel," DG Fuels, October 30, 2024, https://dgfuels.com/2024/10/30/dg-fuels-to-launch-saf-plant-in-moorhead-minnesota-converting-biomass-into-high-value-fuel/.
11. $6.92/gallon is the average of the production cost range of $4.10–$9.73 found during our literature review.
12. See R2R (n.d.).
13. For more information on Twelve's PtL facility, see "Twelve Announces $645 Million in Funding Led by TPG to Transform CO_2 into Jet Fuel and eChemicals at Scale," Twelve, September 19, 2024, https://www.twelve.co/post/twelve-announces-645-million-in-funding-led-by-tpg-to-transform-co2-in-jet-fuel-and-e-chemicals-a-s.
14. The DG Fuels Fischer-Tropsch SAF production facility is used here as a proxy for a facility employing pyrolysis with CDR through bio-oil.
15. Production cost per gallon from JEDI model plus cost of carbon dioxide removal per gallon.
16. See R2R (n.d.).

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