Fueling Up Sustainable Aviation

A Roadmap for SAF in the Rocky Mountain Region — Colorado, New Mexico, Utah, and Wyoming

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About RMI

RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut climate pollution at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; Abuja, Nigeria; and Beijing.

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Introduction

Momentum is building nationally to accelerate sustainable aviation fuel (SAF) deployment to decarbonize the aviation sector. The Rocky Mountain region (RMR), consisting of Colorado, New Mexico, Utah, and Wyoming, is well-positioned to take advantage of this push because it has growing demand, significant SAF feedstocks, existing industrial infrastructure, and legislative support. Though it is widely recognized as a pivotal solution for sustainable aviation, there is no significant SAF production in the RMR yet. However, the region possesses untapped opportunities to foster a blossoming SAF industry as the aviation industry accelerates net-zero operations.

This report explores the production potential of SAF in the RMR with a focus on the availability of feedstock in the region as well as policy options to encourage SAF production and uptake. The report looks at the potential of available in-region feedstocks to meet an ambitious target for SAF supply based on the US SAF Grand Challenge, a collaborative effort launched in 2021 by the US Department of Energy (DOE), US Department of Transportation, and US Department of Agriculture, and options to fill the remaining gaps.

Significant strides have been made at the national level to provide support for SAF suppliers, off-takers, and other stakeholders, and some states have begun to provide additional support to attract the production of SAF. By providing a holistic view of the SAF landscape in the RMR, this report seeks to contribute to discourse and understanding of the short-, medium-, and long-term actions that must take place to strategically aid SAF development within the region.

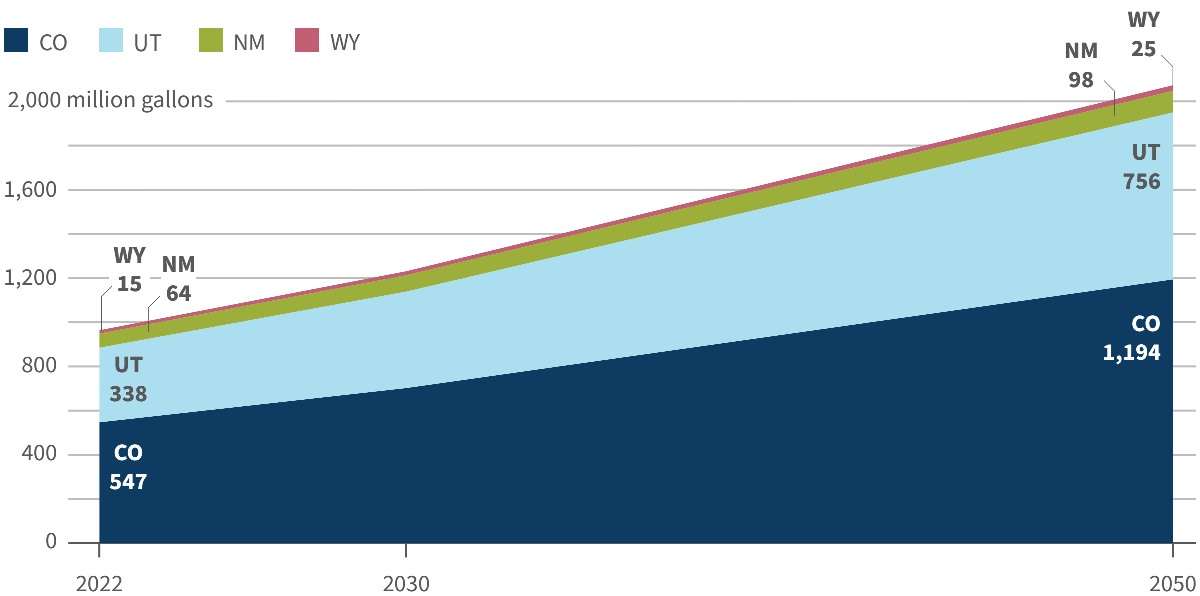
Jet Fuel Demand in the Rocky Mountain Region

Airports in the RMR currently rely on conventional fossil-based jet fuels. Generally, SAF is an alternative fuel made from nonfossil feedstocks that reduce emissions compared with fossil-based jet fuels. The SAF Grand Challenge defines SAF as those fuels that have a 50% life-cycle greenhouse gas (GHG) emissions reduction relative to fossil jet fuel. There is limited SAF supply in the region, with no active SAF producers. The current and growing projected demand for jet fuel in the region represents an opportunity for SAF producers and offtake partners.

Aviation demand for jet fuel is driven by economic activity. The growing economy of the United States and the world, therefore, continues to provide an expanding foundation for aviation. The Federal Aviation Administration (FAA) estimates US carrier domestic passenger traffic will grow by 2.7% per year over the next 20 years.[1] From 2022 to 2050, the population growth rate in the RMR is projected to almost double that of the national rate.[2] This increase in population is expected to bring growing demand for commercial air travel and, in turn, increase demand for commercial jet fuel use within the region at a pace above the national average (see Exhibit 1).

The RMR currently faces a significant gap between jet fuel demand and in-region refinery capacity, with only one large jet fuel production facility in each of the four states (see Exhibit 2, next page). The demand for jet fuel is already higher than in-region refinery capacity. As the demand is projected to increase significantly over time, the gap between in-region production capacity and in-region demand can be expected to widen, which represents an opportunity for the region to produce and use SAF locally.

Exhibit 1 **RMR Jet Fuel Demand**



RMI Graphic. Source: RMI analysis based on data from Bureau of Transportation Statistics, **https://www.transtats.bts.gov/Fields.asp?gnoyr_VQ=FMF**

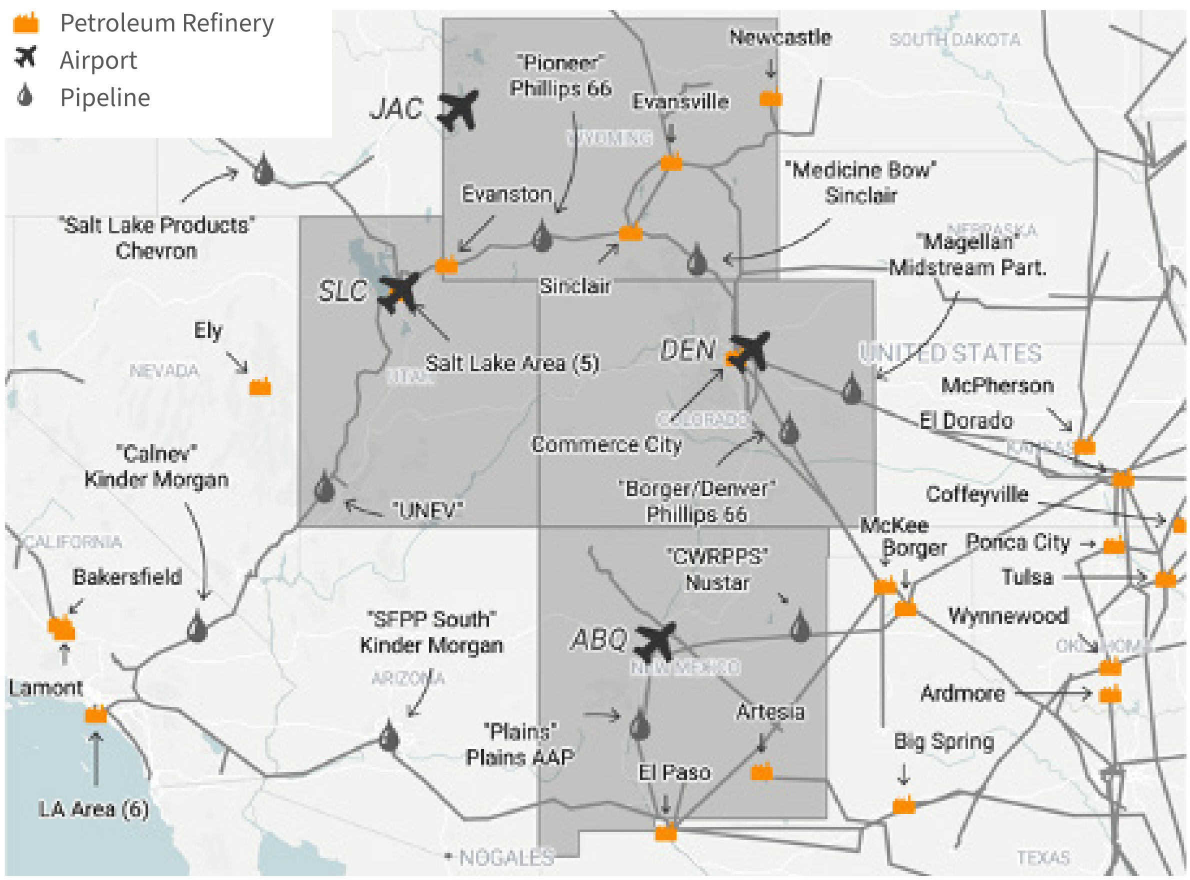
The RMR is near significant out-of-region jet fuel producers, most notably in California and Texas. In Exhibit 3,[3] note that pipelines from the refinery-filled Los Angeles and El Paso areas, for example, flow into the region's largest and most significant airports.

Exhibit 2 Active Refinery Capacity in the Rocky Mountain Region

State	Operator Name	Site	Production Capacity (Million Gallons/Year)
CO	Suncor Energy (USA) Inc.	Commerce City West	175
NM	HF Sinclair Navajo Refining LLC	Artesia	217
UT	HF Sinclair Woods Cross Refining LLC	Woods Cross	42
WY	HF Sinclair Wyoming Refining Co.	Sinclair	203
Total			637

RMI Graphic. Source: U.S. Energy Atlas (eia.gov), **https://atlas.eia.gov/**

Exhibit 3 Map of Airports, Refineries, and Major Pipelines



RMI Graphic. Source: Energy Information Administration Energy Atlas, **https://atlas.eia.gov/apps/e1c92d7601b9490697d22dfe2da1b4ac/explore**

In the RMR, three airports represent 94% of total regional jet fuel demand: Denver International Airport (54%), Salt Lake City International Airport (34%), and Albuquerque International Sunport (6%).[4] These airports and their nearby population centers need to be at the forefront of efforts to improve SAF uptake in the region.

While one of the key advantages of SAF is its flexibility to fit into established supply chains and operational systems, it requires specialized infrastructure for production. Feedstocks must be aggregated, shipped, stored, and processed into SAF, and SAF can only be transported in pipelines or used in engines after blending with conventional Jet A at a ratio meeting ASTM D7566 or D1655 standards. Currently, maximum blend ratios range from 5% to 50%, depending on the conversion pathway, although more commercial and near commercial pathways are approved at a 50% blending ratio. This requirement may motivate the aviation industry to construct SAF infrastructure for blending at or near airports, as large airports have entrenched fuel processing and storage infrastructure. Additionally, producing SAF close to demand centers could reduce associated transportation costs and improve the feasibility of SAF uptake.

The SAF Grand Challenge calls on the United States to build enough supply infrastructure to produce 3 billion gallons per year by 2030 and 35 billion gallons by 2050. The Grand Challenge coordinates federal agencies to inspire SAF production, including streamlining permitting, sharing of knowledge among agencies, and providing funding for SAF development and deployment.[5] For the RMR, which is projected to make up 4.2% of national demand in 2030 and 4.7% in 2050, the SAF Grand Challenge translates to a regional target of 126 million gallons of SAF in 2030 and 1.631 billion gallons of SAF in 2050.[6] While the SAF Grand Challenge does not specify that each region should produce SAF in proportion to its share of national demand, this target serves as a useful benchmark for our analysis to evaluate how the region can align with national goals.

Meeting this target will require SAF supply and demand within the RMR to scale together. The SAF Grand Challenge, however, is not a binding target for SAF production and deployment. Currently, it relies on voluntary SAF demand, which can be complemented with supply-side incentives at the federal and state levels or solidified via demand-side policies such as mandates or fuel standards. With SAF technology rapidly evolving, iterating, and improving, there are many potential feedstocks and production pathways at varying degrees of technological maturity (see Exhibit 4).

Recently, Virgin Atlantic and World Energy independently conducted transatlantic flights powered 100% by SAF, without any blending with conventional jet fuel. These milestones indicate that the limitations on blending SAF with conventional fuel may become more flexible as aircraft engines continue to advance.

Exhibit 4 **SAF Production Pathways and Blending Limitations**

Pathway	Blending Limitation	Feedstocks
Fischer-Tropsch (FT) synthetic paraffinic kerosene (SPK)	50%	Municipal solid waste (MSW), agricultural and forest wastes, energy crops
Hydroprocessed esters and fatty acids (HEFA) SPK	50%	Oil-based feedstocks, such as camelina, tallow, and used cooking oil (UCO)
Hydroprocessed fermented sugars (HFS) to synthetic isoparaffins (SIP)	10%	Sugars
FT-SPK/A (aromatics)	50%	MSW, agricultural and forest wastes, energy crops
Alcohol-to-jet (ATJ) SPK	50%	Cellulosic biomass (isobutanol or ethanol)
Catalytic hydrothermolysis jet (CHJ or CH-SPK)	50%	Fatty acids, fatty acid esters, or lipids (e.g., soybean oil, camelina oil, carinata oil)
Hydrocarbon (HC) HEFA-SPK	10%	Algal oil (Botryococcus braunii)
Synthetic paraffinic kerosene with aromatics (ATJ- SKA)	50%	C2–C5 alcohols from biomass
Esters and fatty acids co-processing	5%	FT biocrude processed with petroleum
FT co-processing	5%	FT biocrude processed with petroleum
HEFA co-processing	10%	Biomass

RMI Graphic. Source: International Civil Aviation Organization, **https://www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx**

SAF Supply in the Rocky Mountain Region

There are currently no active SAF producers in the RMR. However, significant bio-based feedstock potential exists in the RMR for the following four feedstock types:

- Used cooking oil (UCO)
- Corn ethanol
- Municipal solid waste (MSW)
- Forest residues

Note that this analysis focuses on feedstocks that are produced in large quantities within the four states in the RMR, but it is recognized that the SAF value chain can extend beyond these boundaries.

Based on these existing feedstocks that are produced in large quantities in the RMR, this analysis focuses on four bio-based pathways:

- HEFA
- ATJ, using corn ethanol
- FT, using MSW as feedstock
- FT, using forest residues as feedstock

There are additional possible pathways for SAF production, such as ATJ using MSW or forest residues as feedstock, but they were excluded from this analysis as they are associated with higher emissions or are less feasible for the region than the selected pathways.

In addition to bio-based pathways, the analysis includes power-to-liquid (PtL) e-kerosene, which is an umbrella term for pathways that use electricity, ideally from renewable energy, to synthesize hydrocarbons rather than using bio-based inputs. It is important to note that a PtL process can produce SAF according to ATJ or FT ASTM standards. In this report, PtL processes have been depicted separately from the ASTM pathways in the interest of simplicity.

These five pathways are evaluated based on feedstock availability, cost, life-cycle carbon intensity (CI), and current technology readiness level (TRL). Exhibit 5 (next page) shows the comparative advantages of each pathway as well as required hydrogen input.

Cost

Currently, all SAF production pathways result in a higher cost compared with traditional jet fuel, but federal and state-level incentives, coupled with expected cost decline of infrastructure in the longer term, have the potential to drive costs to parity. Production cost will also depend on the region-specific infrastructure requirement for each process. Fischer-Tropsch (FT) processes using MSW or forest residues as feedstocks are currently more costly compared with HEFA and ATJ SAF, because of the additional infrastructure needed for feedstock processing and decontamination of MSW and difficulties in feedstock collection and transport of forest residues.

PtL e-kerosene SAF is rapidly advancing, but costs remain significantly higher than other SAF pathways and prohibitively high for near-term scaling, specifically because of the high cost of the input requirement of

Exhibit 5 **Comparison of SAF Production Pathways**

Pathway	Feedstock Availability	Cost	Carbon Intensity*	Current TRL	Hydrogen Required (kg / gal SAF)
HEFA using UCO/Tallow	Medium-Low	$	73%–84%	Commercial Scale	~0.15
ATJ using corn ethanol	Medium	$	85%–94%	Commercial Scale	~0.07
FT using forest residues	Medium-Low	$$	85%–94%	Commercial Pilot	~0.05
FT using MSW	Medium	$$	85%–94%	Pilot Scale, with Challenges at Large Scale	~0.05
PtL	Unlimited	$$$	99%	Commercial Pilot in 2025	~1.6–2.2

*Carbon intensity reduction compared with conventional jet fuel

RMI Graphic. Source: RMI analysis

renewable electricity as well as hydrogen and CO_2. However, as costs for renewable electricity and green hydrogen decrease over time, costs for producing PtL SAF will decrease as well. Net-zero carbon capture and storage will also need to scale for PtL SAF to become commercially viable. As PtL SAF technology improves, the cost of production will likely decrease along with a decline in the costs of the necessary inputs.

A significant barrier for SAF stakeholders is obtaining low-cost financing. RMI, in cooperation with leading global banks (BNP Paribas, Citi, Crédit Agricole CIB, Societe Generale, and Standard Chartered), recently launched the Pegasus Guidelines, a voluntary framework for the aviation sector designed to help banks measure and disclose the emissions intensity of their aviation lending portfolios.[7] This framework recognizes that financial entities hold a critical position to fund a range of solutions within the aviation industry that contribute to a low-carbon economy. Other banks, including Caixa Bank and CIC, have announced they will use the Pegasus Guidelines, with additional banks considering joining too. These guidelines signal that there is significant interest in the financial sector to support SAF projects.

Carbon Intensity

HEFA SAF from UCO/tallow is estimated to have a life-cycle CI significantly lower than that of conventional jet fuel (89 g CO_2e/MJ).[8] Variability in life-cycle assessment figures can come from different boundary conditions (i.e. starting at cattle growth versus tallow rendering for tallow feedstock) or different baseline models (i.e., Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET), E3, etc.).[9]

For the corn ethanol to ATJ SAF pathway, there are additional factors to consider. Because ethanol is not considered a waste, there will be upstream emissions attached for the life-cycle assessment (LCA) that go beyond transporting the feedstock and producing the final fuel. In the case of corn ethanol, this involves induced land use change (ILUC), which is designed to account for GHG emissions associated with demanding a first-generation product that requires the conversion of land from a previous use (vegetation, other crops, animals, etc.). Some models show that because of this ILUC factor, the life-cycle CI of corn ethanol ATJ SAF may be as high as conventional jet fuel, and possibly even higher.

To qualify for incentives in the Inflation Reduction Act (IRA), a SAF's life-cycle CI must be 50% below conventional jet fuel. Updates to the GREET model published for application of the 2024 40B Sustainable Aviation Fuel Tax Credit, which focuses exclusively on HEFA and ATJ pathways, give standards for "climate smart agriculture" (CSA). If these CSA standards are adhered to, corn ethanol SAF could reach the 50% reduction threshold and qualify for the incentive.[10] This is discussed further in Section 4.

The life-cycle CI of the FT SAF pathways is heavily dependent on the composition of feedstock, specifically the amount of inorganic matter, such as plastics, included in mixed waste. The possibility of high non-biogenic-carbon content raises concerns about increased actual life-cycle CI of the SAF product, which is associated with its qualification for federal tax credits.

PtL e-kerosene SAF has the potential for a nearly net-zero life-cycle CI, which is a key advantage over bio-based pathways. This can be achieved by using hydrogen produced from electrolysis powered by renewable electricity, together with captured CO_2. PtL can refer to processes that use ATJ or FT to create SAF, so long as the original input is electricity rather than a biogenic source. Currently, updates to the GREET model have not provided guidance for the LCA CI assessment of FT or PtL e-kerosene SAF.

Current Technology Readiness Levels

Comparatively, HEFA is the most mature and commercially deployed pathway. HEFA plants and products dominate the SAF market. There are also ATJ plants in operation and projects that have been announced in recent years, demonstrating the viability and potential of this technology. FT is slightly behind ATJ in terms of commercial deployment, but there are existing and planned pilot projects and others under development. Among all pathways discussed in this analysis, PtL is the least mature, but significant progress has been made in recent years as well, moving from technology research and development to commercial pilots planned to start in 2025, indicating the industry's confidence in the potential of PtL.

Hydrogen Required

The emissions associated with hydrogen input required for SAF production have significant implications for the CI of the SAF product. HEFA SAF produced with green hydrogen (0 kg $CO_2e/kg\ H_2$) could have a 30% lower overall life-cycle CI compared with HEFA SAF produced with grey hydrogen (10 kg $CO_2e/kg\ H_2$). SAF produced through the ATJ and FT pathways requires minimal supplemental hydrogen. Hydrogen is a key input to the production process of PtL SAF, more so than other processes analyzed. Hydrogen is estimated to make up about 15% of the total upfront capital needed to produce PtL.[11]

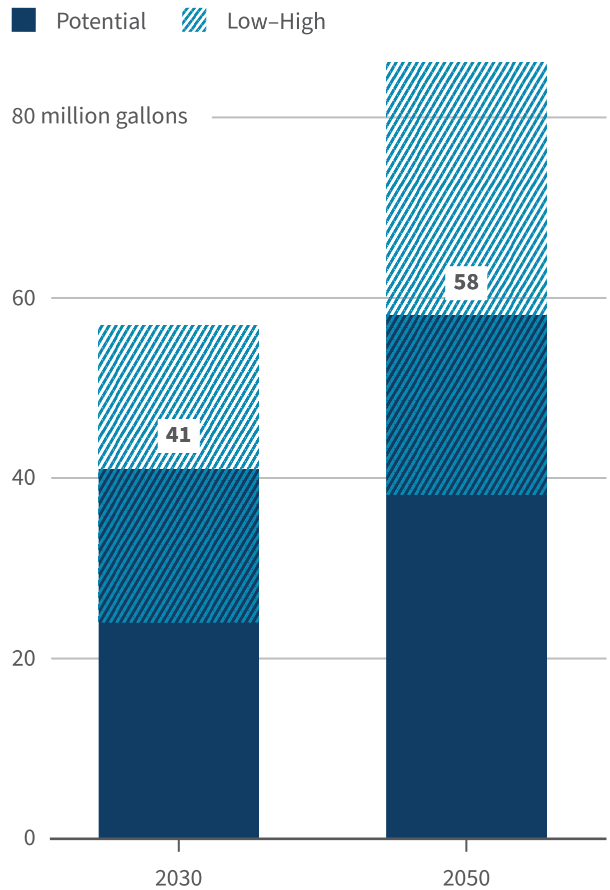
For each kilogram of green hydrogen, approximately 50.6 kilowatt-hours (kWh) to 52.5 kWh of renewable energy are is needed at current electrolyzer efficiencies. Sourcing this electricity and producing the large quantities of green hydrogen needed for aviation, as well as other rapidly decarbonizing industrial sectors, would entail high costs. Costs are expected to decrease over time as renewables and hydrogen projects achieve economies of scale.

Hydroprocessed Esters and Fatty Acids (HEFA)

As discussed, the use of SAF in the RMR must increase significantly to keep pace with SAF Grand Challenge regional benchmarks (126 million gallons in 2030; 1.631 billion gallons in 2050). While HEFA is currently the most technologically mature SAF pathway, the constraint on sources of feedstock limits the potential to scale. Considering limiting factors, it is estimated that with about 225,000 tons of UCO and tallow in the region, HEFA SAF production potential in the RMR is 41 million gallons in 2030, which could account for about one-third of that year's SAF Grand Challenge goal. However, the 58 million gallons in the 2050 estimate would be able to fulfill less than 4% of the 2050 target (see Exhibit 6). These figures suggest that while HEFA will play a significant role in the short term, its role will diminish over time as other production pathways with more abundant feedstocks advance technologically. Regional HEFA SAF production potential would increase with improved feedstock aggregation, further advancements in technology, a favorable policy environment, and reduced competition for feedstock from alternative products (i.e., biodiesel).

Exhibit 6

RMR HEFA SAF Production Potential



RMI Graphic. Source: RMI analysis

SAF Case Study: Montana Renewables

Montana Renewables, a subsidiary of Calumet, operates a site powered by renewable energy in Great Falls, Montana. The company converted existing assets at the site and now can take feedstocks of vegetable oil, corn oil, used cooking oil, and tallow, and produce renewable diesel, renewable naphtha, and SAF. Total investment since 2012 has been over $1 billion. The site additionally uses green hydrogen as an input in its process, further lowering the CI of end products. The expected capacity of the facility is 184 million gallons of products annually, including 30 million gallons per year of SAF. The facility could potentially serve as a significant supplier of SAF to Denver International Airport because of its strategic location.

Alcohol-to-Jet (ATJ)

After the HEFA production pathway, ATJ SAF makes up the majority of current commercially active SAF production.[12] The ATJ pathway takes feedstocks of sugary, starchy biomass, such as sugarcane, miscanthus, corn grain, and waste products, and uses fermentation to create bio-based ethanol or iso-butanol.

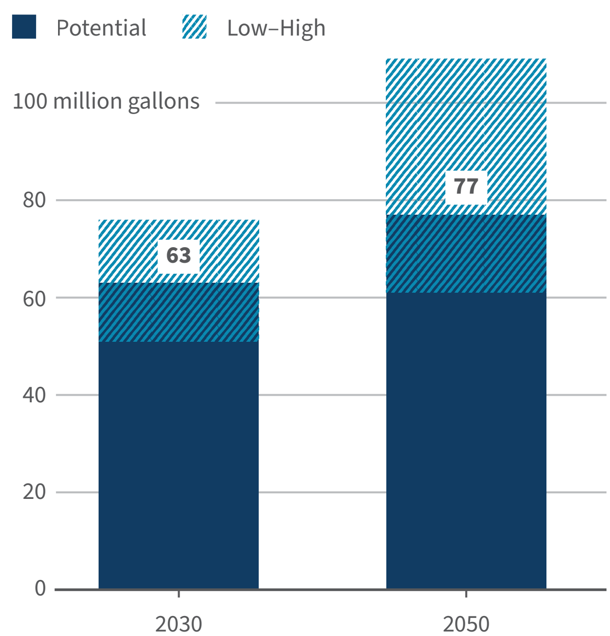
The RMR already produces ethanol for use in non-SAF biofuels. There are many sources of demand for ethanol for use in biofuels due to the low cost of corn feedstock. In 2021, the RMR accounted for about 160 million gallons of ethanol production per year, or 1% of US ethanol production capacity.[13] Like HEFA, there are many competing demand sources for corn grain, both as a food source and as an input to production of other biofuels, including renewable diesel for on-road transportation.

Because ATJ SAF has only recently become commercially available, the technology will need more time to mature compared with HEFA SAF. RMI analysis suggests that the production potential of using corn ethanol as feedstock for ATJ will result in 63 million gallons of production potential in 2030, increasing to 77 million gallons in 2050. Comparatively speaking, ATJ SAF is potentially more scalable than HEFA SAF, but it could potentially take longer for the technology to mature. (see Exhibit 7).

Nevertheless, the potential of ATJ SAF is significant. Because ethanol has been used in other biofuel production processes for a considerable time, infrastructure and technology already exist to make ethanol available quickly for SAF production as the sector matures. Additionally, the electrification of other industries, such as ground transportation, may make additional ethanol available over time for SAF.

Exhibit 7

ATJ SAF Production Potential



RMI Graphic. Source: RMI analysis

SAF Case Study: LanzaJet Freedom Pines

Situated in Soperton, Georgia, the LanzaJet Freedom Pines facility has an annual capacity of 10 million gallons and became operational in early 2024. The plant will use an ATJ process based on ethanol. The plant's funding is complete, and it has secured offtake contracts for the upcoming decade. The facility plans to manufacture 9 million gallons of SAF and 1 million gallons of renewable diesel. The project is backed financially by the US DOE, Microsoft's Innovation Fund, and a grant from Breakthrough Energy.

Biomass Gasification Integrated Fischer-Tropsch Synthesis

Biomass gasification integrated FT synthesis refers to the process in which biomass is converted to synthesis gas (syngas) using gasification. The syngas is then converted to SAF through an FT synthesis reaction. Primary feedstocks of this pathway include forest residues and waste derivatives.

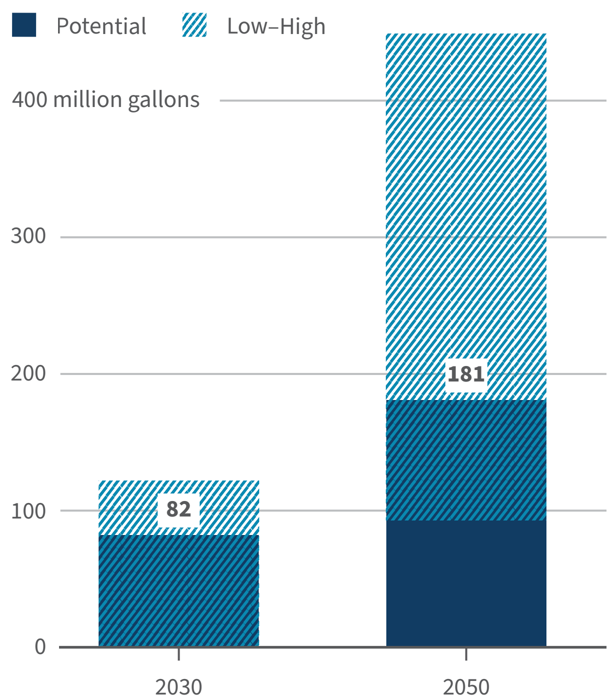
Fischer-Tropsch with Municipal Solid Waste as Feedstock

In 2030 there will be an estimated 9.7 million dry tons of mixed MSW disposed of at landfills across the four states in the RMR, increasing to 13 million dry tons in 2050.[14] This presents an opportunity to use readily available and aggregated organic waste for SAF production. Diverting MSW from landfills for beneficial end uses can have climate benefits, including GHG emissions mitigation and reduction of local air pollutants.

Because of the variety of material types, sizes, and energy content in landfilled MSW, sorting, processing and decontamination are needed before it can be gasified to produce syngas. For example, certain waste types, including metal, textiles, and glass, are not suitable for gasification,[15] and the feedstock combination will affect the actual life-cycle CI of the SAF produced.[16] On average, the estimated local MSW feedstock suitable for SAF production has the potential to produce 82 million gallons of SAF in 2030 and 181 million gallons in 2050 (see Exhibit 8).

Exhibit 8

FT-MSW SAF potential



RMI Graphic. Source: RMI analysis

There have been a few pilot projects in different countries using the FT-MSW pathway to produce SAF, but they have seen limited success. Most recently, Fulcrum Bioenergy's Reno, Nevada plant faced challenges caused by the build-up of "a thick cement-like material" throughout the plant's gasification system with the accumulating nitric acid.[17] The company has now halted all operations, indicating challenges to scale. The production potential estimate in 2030 also reflects this concern.

It is worth noting that there are ongoing initiatives to improve separation of organic waste from plastics and other materials with lower energy content, among which the latter is less suitable for use as SAF feedstock, as well as to strengthen de-contamination technologies and landfill gas capture efficiency. In the long term, these initiatives could improve the potential for using MSW as feedstock by enhancing feedstock quality and lowering life-cycle CI of this production pathway. However, the same improvements also could decrease the amount of feedstock available for SAF production if it is increasingly diverted to other uses, such as composting and anaerobic digestion. The estimated production potential in 2050 accounts for these advancements, as well as the increase in waste generation based on population growth and movement, with a larger range compared with the 2030 estimate.

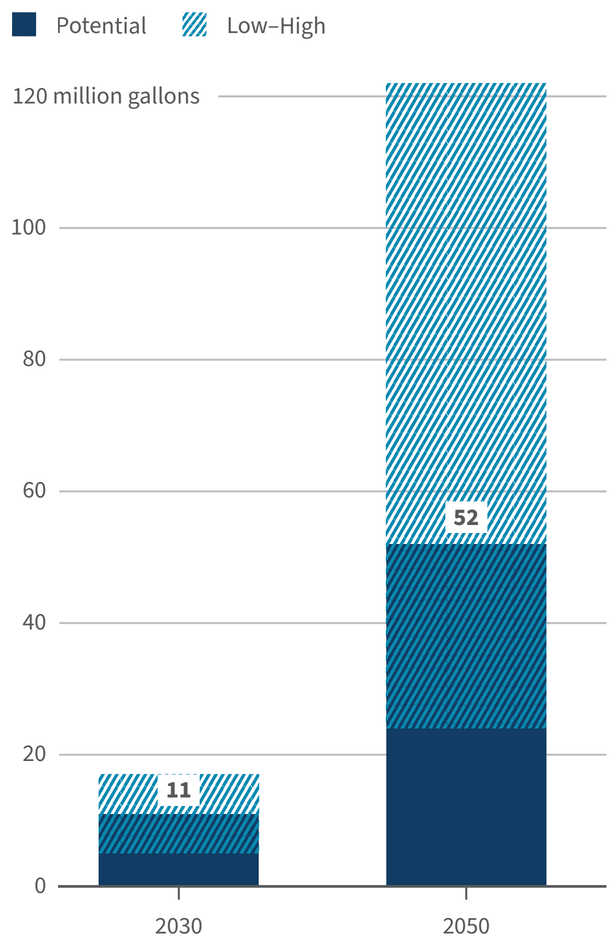
Fischer-Tropsch with Forest Residues as Feedstock

Forest residue, or woody biomass, is another primary feedstock for the FT pathway. It is estimated that 529,000 dry tons of forest residues will be available in 2030 in the RMR, and 2.1 million dry tons will be available in 2050. Among the four states, Colorado has the highest availability of forest residues (41%), followed by Utah (30%), New Mexico (16%), and Wyoming (14%). On average, total SAF production potential in the RMR using forest residue as feedstock is estimated at 11 million gallons in 2030 and 52 million gallons in 2050 (see Exhibit 9). The estimated increase in the long term accounts for a potential infrastructure cost reduction and new woody biomass becoming available in the region, although additional biomass might be available at a higher cost.[18]

Generally speaking, forest residues are a less-used form of biomass because of unique challenges, and higher costs for collection, transportation and processing, as well as the potential of local air pollution. However, a unique synergy could exist if trees removed from forests for wildfire mitigation and prevention are leveraged for SAF production.

Exhibit 9

FT-Forest Residues SAF potential



RMI Graphic. Source: RMI analysis

SAF Case Study: Bayou Fuels Biorefinery

The Bayou Fuels biorefinery, set to be constructed in Natchez, Mississippi, will produce 25 million gallons of SAF annually. The SAF will be produced using regionally available waste woody biomass. This SAF production has been secured through offtake agreements with Southwest Airlines for 15 years and a memorandum of understanding with IAG/British Airways for 10 years. The facility will operate entirely on renewable energy.

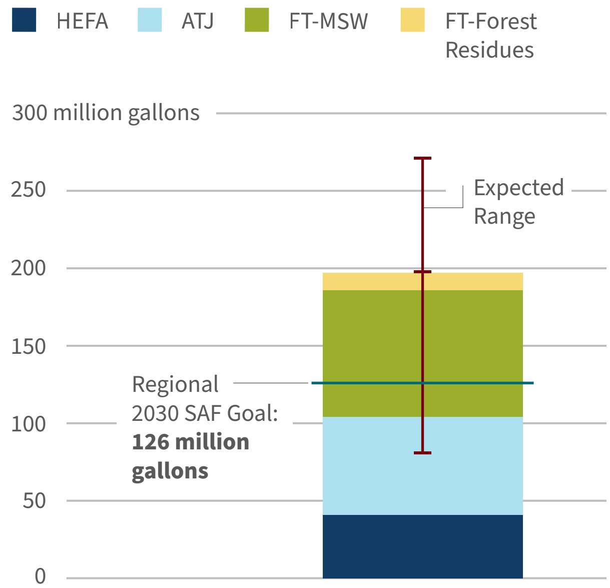
SAF Production Potential in the Rocky Mountain Region

Based on the in-region feedstocks considered and associated pathways, the total production potential of bio-based pathways in the RMR is estimated to be 197 million gallons in 2030, which exceeds the 2030 regional SAF Grand Challenge benchmark of 126 million gallons (see Exhibit 10).

However, the SAF production potential in 2050 using feedstocks available in the RMR falls short of the long-term regional SAF Grand Challenge benchmark. The estimated total production potential of 368 million gallons only accounts for 23% of the regional goal of 1.631 billion gallons. Even if the full technical potential is realized, where the bio-based feedstocks discussed above are aggressively used to produce SAF, the total production potential of 766 million gallons accounts for less than half of the regional goal (see Exhibit 11).

Exhibit 10

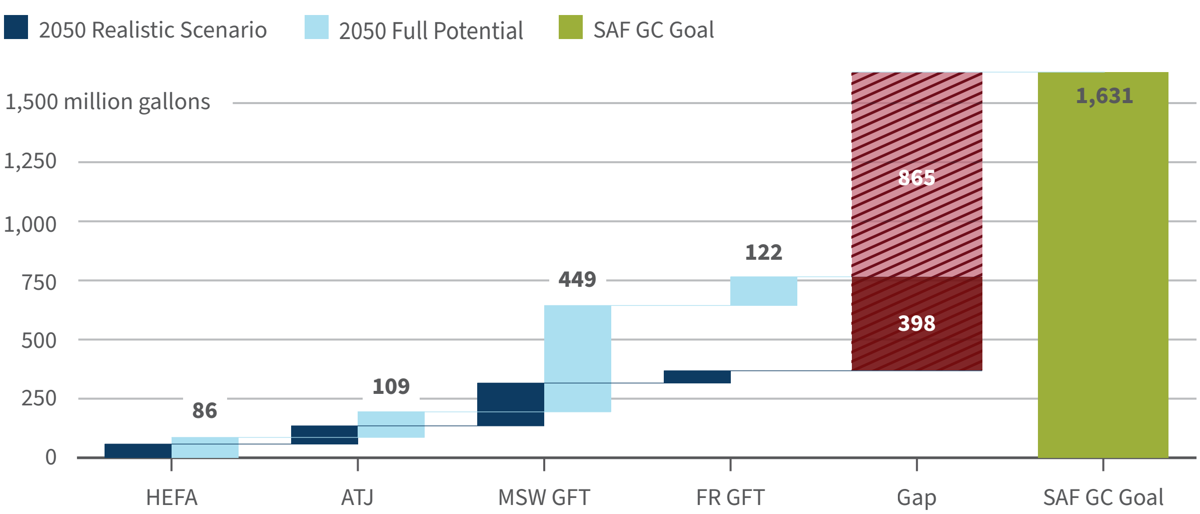
RMR 2030 SAF potential



RMI Graphic. Source: RMI analysis

These results suggest that meeting the regional benchmark of the SAF Grand Challenge will require additional supply. Three general options are (1) use PtL SAF production, which does not incur the same feedstock needs and competition with biofuels for other end uses, (2) import SAF from outside the region, or (3) import feedstock from outside the region to support in-region SAF production.

Exhibit 11 **RMR 2050 SAF Potential and Gap**



RMI Graphic. Source: RMI analysis

Power-to-Liquid

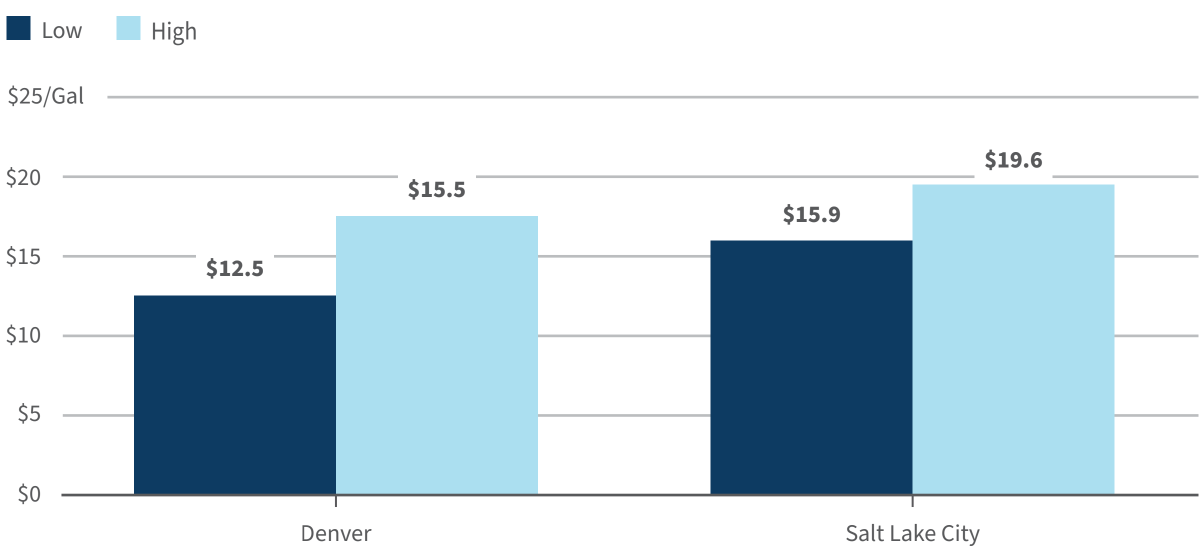
Power-to-Liquid (PtL) SAF is a unique form of SAF production that, despite being the least technologically mature pathway, has the greatest potential for meeting the gap between scaled demand in 2050 and bio-based SAF pathways. The PtL pathway uses renewable electricity, efficient supplies of carbon dioxide, and hydrogen to yield a liquid synthetic "e-fuel" through ASTM-certified pathways, including ATJ and FT.[19] PtL creates the opportunity to achieve nearly 100% decarbonization and does not share similar feedstock input constraints with the biogenic HEFA, ATJ, and FT pathways.

Currently, PtL pathways are prohibitively expensive. Based on RMI's 2030 cost estimates of PtL production, producing the estimated 865 million gallons of PtL necessary to fill the smallest 2050 gap identified above would cost approximately $16-$20 per gallon, using 2030 costs and depending on production location. (Denver and Salt Lake City were evaluated for this analysis — see Exhibit 12.)

Producing enough PtL to meet half of the 2050 gap (433 million gallons), assuming the rest was met by imported feedstock or imported finished SAF, would cost approximately $13–$16 per gallon, using 2030 costs and depending on production location. This high cost relative to that of jet fuel, which currently is about $2–$4 per gallon, highlights the need to invest in research and development now.[20] PtL SAF production costs will need to see a compound annual cost reduction of approximately 8% to become competitive with jet fuel in 2050. This would be a significant cost decrease but is on par with other technology cost reductions, such as for solar and microchips. Regional gaps can be filled with imported SAF or feedstocks, but decarbonizing aviation nationally and globally will require PtL.

Significant cost reductions in procurement of hydrogen, carbon dioxide, and scaled electricity will be necessary to bring PtL SAF to the market. There is momentum accumulating across the aviation value chain to support research and development on PtL, as the lack of biogenic feedstock constraints, for which the RMR serves as a case study, represents a massive opportunity.

Exhibit 12 PtL Cost in 2030



RMI Graphic. Source: RMI analysis

At this time, at least 36 MWh of renewable energy is needed to produce 1 ton (about 330 gallons) of synthetic fuel, of which 60%–80% (198–264 gallons) can be used as SAF.[21] If direct air capture is used to source carbon, total electricity demand could reach 52 MWh per ton of fuel.

Currently, annual renewable energy production in the RMR is about 54 million MWh.[22] A continuing and accelerated scaling of renewable energy is needed to make PtL SAF feasible at commercial scale. This renewable energy would be spread across the production process, as it would power the carbon capture (industrial point-source, biogenic point-source, or direct air capture), the hydrogen sourcing (green hydrogen through electrolysis), and the fuel synthesis itself.

While the extensive need for renewables buildout is daunting, PtL SAF will not be the only demand signal for significant renewable energy over the coming decades. There is huge potential for PtL SAF to meet the gap while other bio-based SAF pathways discussed (HEFA, ATJ, FT) are not sufficient to act as a permanent solution to decarbonize aviation in the long term.

Imports

The SAF production potential from local bio-based feedstock supply falls short of meeting the SAF Grand Challenge benchmark in 2050. However, neighboring and nearby states, such as Montana, Texas, and California, have established SAF supply chains and have existing infrastructure connections to the RMR. Leveraging these nearby sources could play a pivotal role in bridging the gap and ensuring consistent SAF supply in the RMR. Note that our preceding analysis did not account for interstate feedstock imports, which could have a significant impact on the region's SAF production landscape and the life-cycle CI of SAF products. Depending on the type and number of local financial incentives and cost premiums in different regions, producers might explore importing feedstocks across state boundaries, thereby bolstering the RMR's position as a key player in SAF production and aviation decarbonization.

Policy and Infrastructure

Federal Policies

To fully understand how states in the region can best support the deployment and uptake of SAF, it is important to first understand the existing policy landscape. The IRA represented a watershed moment in SAF support, not only providing financial support for SAF production and offtake, but also funneling dollars and policy assurance to feedstocks, hydrogen, and carbon required for future aviation fuels.

40B and 45Z: Inflation Reduction Act SAF Tax Credits in a Two-Phased Approach

The 40B Sustainable Aviation Fuel Tax Credit is available for SAF that achieves a life-cycle GHG reduction of at least 50% compared with traditional jet fuel and sold after January 1, 2023, and December 31, 2024.[23] For all SAF credits, CI is calculated using the federal 40BSAF-GREET 2024 model, which was released in April 2024.[24] This tax credit is accompanied by a suite of other fuel-specific tax credits, such as the extension of the Second-Generation Biofuel Incentive and the Biodiesel and Renewable Diesel tax credits.[25] Starting in 2025, these tax credits will be subsumed into the 45Z Clean Fuel Tax Credit, which incentivizes the same fuels but changes the calculation of how fuel qualifies for the credit.[26] The 45Z tax credit value is calculated based on the fuel type and whether or not its production meets certain wage and labor requirements. See Exhibit 13 for more details and Exhibit 14 (next page) for a visualization based on CI.[27]

Exhibit 13 **Federal SAF Tax Credits**

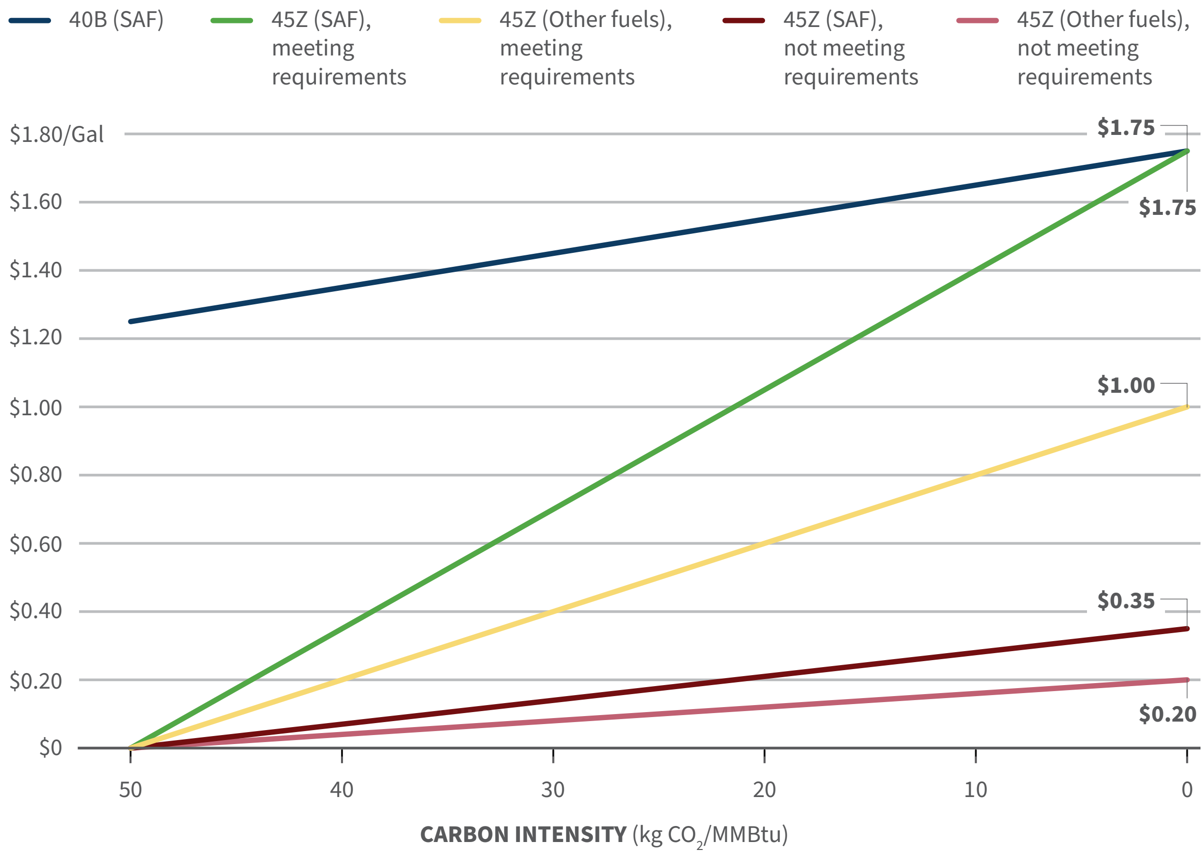
Credit by fuel type	Credit Calculation
40B	The base credit is worth $1.25 per gallon of SAF, then add $.01 for each extra percentage point above 50 the fuel reduces GHG emissions compared with traditional jet fuel.
45Z for SAF that meets wage requirements	Subtract the fuel's emission rate from the baseline emissions rate of 50 kg CO_2e/MMBtu , divide by 50, and multiply that amount (the emission factor) by the base credit of $1.75.
45Z for non-SAF that meets requirements	Subtract the fuel's emission rate from the baseline emissions rate of 50 kg CO_2e/MMBtu, divide by 50, and multiply that amount (the emission factor) by the base credit of $1.
45Z for SAF that does *not* meet requirements	Subtract the fuel's emission rate from the baseline emissions rate of 50 kg CO_2e/MMBtu, divide by 50, and multiply that amount (the emission factor) by the base credit of $0.35.
45Z non- SAF, does not meet requirements[i]	Subtract the fuel's emission rate from the baseline emissions rate of 50 kg CO_2e/MMBtu, divide by 50, and multiply that amount (the emission factor) by the base credit of $0.20.

Note: MMBtu stands for million British thermal units.

RMI Graphic. Source: The White House Inflation Reduction Act Guidebook, **https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf**

i Non-SAF fuels include biodiesel, agri-biodiesel, renewable diesel, and second-generation biofuel.

Exhibit 14 Impact of 45Z scenarios



RMI Graphic. Source: RMI analysis based on The White House Inflation Reduction Act Guidebook, **https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf**

The federal SAF tax credits are technology-neutral — they reward any SAF that decreases GHG emissions compared with traditional jet fuel. This allows all types of SAF to qualify for the credit, ensuring that the government does not prematurely favor a subset of approaches. The credits are also focused on supporting the supply side of the equation — SAF refiners and producers — rather than off-takers. Future state or federal policies will be needed to support demand for SAF.

Grants: The FAST-SAF and FAST-Tech Programs

In addition to tax credits, the IRA also funded the Fueling Aviation's Sustainable Transition (FAST) Grants: FAST-SAF and FAST-Tech.[28] These grants provide incentives for SAF production, transportation, and storage and for low-emissions aviation technology design, testing, and deployment and are designed to complement other FAA programs. The FAST-SAF program was funded with $244.53 million to be granted to projects that produce, transport, blend, or store SAF. The FAST-Tech program has $46.53 million for projects that design, prototype, and test low-emissions aviation technologies. The application period for these programs is closed, and the FAA is currently evaluating applications and was expected to announce recipients in August 2024.

Federal Renewable Fuel Standard

The federal Renewable Fuel Standard (RFS) is a program implemented by the Environmental Protection Agency (EPA) that requires transportation fuel blenders to blend certain volumes and types of renewable fuel into their supply. When a gallon of sustainable fuel is added to the market, it generates a Renewable Identification Number (RIN). Different types of fuel can generate more or fewer RINs per gallon. Obligated parties under the RFS must meet a Renewable Volume Obligation (RVO) each year.[29] They use RINs that they have either purchased or generate themselves to prove compliance with the RVO. While airlines are not obligatory parties, SAF can produce RINs to be sold on the RFS market, incentivizing production. The RFS has no planned expiration timeline and, therefore, offers support for banking decisions and a stable source of incentivization for SAF investment and production.

However, certain features of how the RFS is structured undermine investment in SAF. For fuels like diesel and gasoline, the RFS acts as both a demand-side policy guaranteeing a market of a certain size for renewable alternatives as well as a supply-side policy incentivizing them via RIN value. However, because aviation fuel is not obligated to participate, the RFS works only on the supply side for SAF. This systematically incentivizes renewable fuel producers who must decide between using their feedstocks to produce renewable diesel versus producing SAF to often produce more renewable diesel. Furthermore, renewable diesel produces 1.7 RINS per gallon compared with SAF's 1.6 RINS per gallon. The result of this policy structure is clear: the RFS reported about 3 billion gallons of renewable diesel and only about 16 million gallons of SAF in 2022.[30]

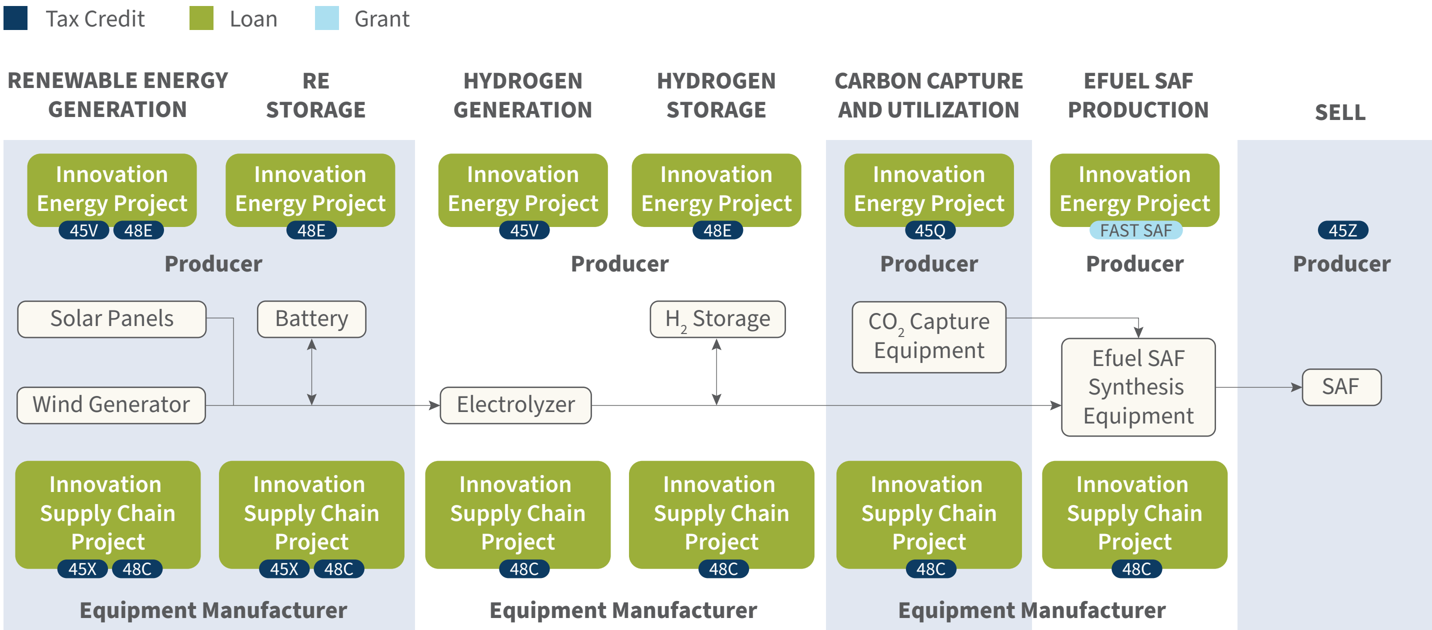
DOE's Loan Program Office

The DOE's Loan Program Office (LPO) leverages federal funding with guaranteed loans through its Title 17 for innovative energy projects. IRA provided an important boost to the LPO office by appropriating $11.7 billion to issue new loans and increasing its existing loan program authority by $100 billion.[31] Projects engaged in the production and storage of renewable energy, hydrogen, and SAF are eligible for the loans. Additionally, manufacturers of the equipment used in such projects are eligible for LPO loans under LPO's Title 17 Innovative Energy and Innovative Supply Chain.

While there is no minimum loan size, guarantees are usually $100 million and cannot exceed 80% of the anticipated project costs. Projects eligible under Title 17 must include new or significantly improved technology not widely adopted in the United States. They must demonstrate that the technology is used in three or fewer facilities and can catalyze the market by being employed in other commercial projects.

Taken together, these federal tax credits and LPO loans offer incentives across the SAF value chain (see Exhibit 15, next page.)[32]

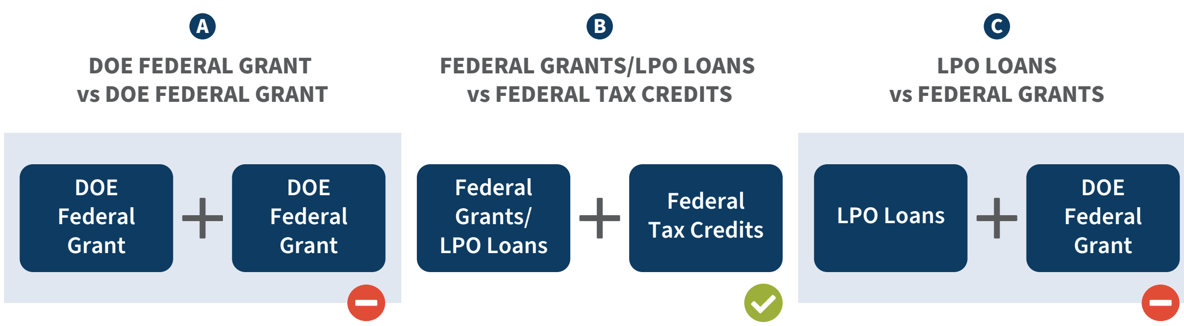
Exhibit 15 Federal Tax Credits and LPO Loan Eligibility Through the SAF Value Chain



Note: LPO Title 17 Clean Energy Financing program for Innovative Energy and Innovative Supply Chain projects require projects to employ a new or significantly improved technology based on LPO criteria and assessment.

RMI Graphic. Source: RMI analysis.

Exhibit 16 Stackability Rules for Federal Fundings Mechanisms



RMI Graphic. Source: RMI analyses based on LPO Title 17 Program and Federal tax credits guidance.

Several funding mechanisms from the federal government are stackable, but there are some limitations based on the project's scope that they are supporting, as shown in Exhibit 16.

(a) Two federal grants cannot support the same project, scope of project, or budget.
(b) Federal tax credits are stackable with DOE federal grants and LPO loans.
(c) LPO loans are not stackable for projects that are expected to benefit directly or indirectly from another federal support, such as a grant.
(d) Unless otherwise specified in the state policy (uncommon), state incentives can be stacked with federal incentives.

State Policies

In addition to federal policies, Colorado and New Mexico in the RMR have passed state policies relevant to SAF production and use.

Colorado

Colorado recently passed and signed into law a bill that provides a state income tax credit for entities that use clean hydrogen to decarbonize hard-to-abate sectors, including aviation. The $1/kg hydrogen ($H_2$) tax credit will be provided for end uses that use electrolytic hydrogen produced with less than 0.45 kg CO_2/kg H_2.[33] For hydrogen produced with between 0.45 and 1.5 kg CO_2/kg H_2, the tax credit will be $0.33/kg H_2. There are also strict rules regarding emissions accounting, including that the hydrogen must be produced from new zero-carbon energy and matched on an hourly basis with hydrogen production.[34]

Signed into law by Governor Jared Polis in May 2023, Colorado's Tax Policy That Advances Decarbonization includes an SAF production facility tax credit. Starting in 2024, SAF producers are eligible to claim an income tax credit up to 30% of the cost to construct their production facility in 2024–2026, 24% in 2027, 18% in 2028, and 12% in 2029–2032.[35] Importantly, the amount of tax credits that can be issued is capped at $1 million in 2024, $2 million per year in 2025 and 2026, and $3 million per year in 2027–2032.[36]

New Mexico

In early 2024, New Mexico passed its Clean Transportation Fuel Standard (CTFS), becoming the fourth state in the United States with such a program (after California, Washington, and Oregon). The purpose of the program is to reduce the CI of transportation fuels in the state at least 30% by 2024 by using annually decreasing carbon limits for transportation fuels.[37] Transportation fuels are defined in the law as "electricity or a liquid, gaseous or blended fuel, including gasoline, diesel, liquefied petroleum gas, natural gas and hydrogen, sold, supplied, used or offered for sale to power vehicles or equipment for the purposes of transportation."[38]

While the law does not specifically instruct agencies to include aviation fuel in the new fuel standard, the definition of transportation fuels certainly leaves an opening for aviation fuel to be included in the standard. It will be up to the agencies that promulgate rules (a process that will likely begin in fall 2024) to decide if and how SAF may be incorporated.

Utah and Wyoming

As of this writing, there are no state policies to incentivize the production or offtake of SAF.

States outside of the RMR

Other states including Washington and Oregon allow SAF to generate credits but not deficits under their rules. California has recently proposed a rule to fully regulate all interstate flights under its Low Carbon Fuel Standard (LCFS), while other flights can generate credits but not deficits. The Canadian province of British Columbia has minimum SAF mixing mandates and GHG emissions–reductions requirements for aviation under its LCFS. These all provide potential models for how New Mexico may approach SAF within its CTFS.

Key Recommendations for Future Policy Considerations

Even though there is critical momentum to incentivize SAF from the federal government, the existing Rocky Mountain states' policy landscapes leave gaps that must be filled to accelerate its uptake within the region. There is still a green premium gap between traditional jet fuel and all SAF options. Furthermore, it is likely that, at least in the near term, multiple types of SAF will be needed to reach deployment and decarbonization goals. As such, supply- and demand-side policies should be technology-neutral but performance-based to ensure a high bar for emissions reductions while technologies still are developing and maturing. Furthermore, given the economic and geographic relationships among Rocky Mountain states, it will be crucial that each state writes policies and regulations with an eye toward the actions of the other states, harmonizing where necessary.

The following six policy recommendations provide a set of options for states to consider in support of SAF deployment in the region:

A. Provide further demand incentives for in-state SAF based on performance to ensure higher emissions reductions.

The current cost gap between all SAF pathways and conventional jet fuel is a major challenge to close long-term offtake agreements. These contracts are key for suppliers to make projects bankable because they can provide constant demand over time. Thus, states can provide additional financial support to close the cost gap in the near term and help projects reach final investment decisions. State policy to incentivize SAF offtake in-state can take different forms, including tax credits or targeted subsidies.

To incentivize the best performing fuels, it is key that policymakers add guardrails to tie incentives to performance regarding the reduction of emissions in comparison with conventional jet fuel as the baseline. An example of this would be Washington's 2023 tax credit worth up to $2 per gallon for the purchase of SAF with a CI at least 50% lower than conventional jet fuel. The tax credit increases for each 1% in reduction in emissions beyond the 50% baseline.[39]

Tax credits, in particular, may be a valuable form of state-level incentivization. While it is unlikely that a tax credit will span the difference in price between traditional jet fuel and SAF, a state-level tax credit with a long-time horizon might provide some assurance to the SAF market. This is especially true given that federal tax credits for SAF are some of the shortest-lived credits in the IRA — many SAF projects will reach the final investment decision after federal credits time out. While hopefully those federal credits will be extended to last for a longer, more useful period, states can step in in the meantime and give additional support.

B. New Mexico should designate intrastate aviation fuel as an opt-in reporting fuel to clean fuel standards and explore stricter regulation options.

As New Mexico policymakers draft the regulations and rules of the forthcoming CTFS program, they should plan to integrate SAF, at the very least, as an opt-in fuel. While it is still unclear how US states without extensive intrastate air travel can more rigorously regulate aviation fuel, New Mexico should keep an eye toward creative regulatory methods to more fully bring aviation fuels under the CTFS umbrella, perhaps even exploring something closer to the British Columbia model or the proposal in front of the California Air Resources Board to obligate intrastate jet fuel under the LCFS. Furthermore, other states in the RMR should explore the possibility of passing a similar clean fuel standard and harmonizing requirements and goals with New Mexico's program.

C. Use federal support to provide state-guaranteed loans for local production of SAF.

A state entity can act as a State Energy Financing Institution (SEFI) to leverage LPO funding for SAF.[40] LPO already is supporting SAF production projects under its Title 17 program, with three projects in its queue.[41] State green banks are well-equipped to take this role and co-lend as SEFIs. One of the main benefits of this structure is that by co-lending through a SEFI, the project does not have to comply with the innovation requirement to access the loan.

Another alternative is that green banks directly provide state guarantee loans for projects within the state, to mirror the LPO program.

D. Ease a key bottleneck by smoothing siting and permitting processes for SAF refineries.

Permitting new facilities is time-consuming and expensive. States can support deployment by developing streamlined permitting processes and technical assistance for SAF and H_2 production facilities and the necessary infrastructure (including pipelines, electricity infrastructure, and clean energy generation). For projects that may leverage infrastructure across state lines, states should work to harmonize safety and handling regulations.

This should include implementing streamlined approaches to permitting and regulatory approval. The initiative also should aim to facilitate project rollout by enabling quick commissioning, to reduce delays, through centralized permitting processes and environmental impact assessments.

E. Apply for federal workforce development grants to upskill and reskill workers to be prepared for SAF and associated technologies.

The federal government currently offers many different financial support mechanisms for upskilling and reskilling workers to work in green transition industries. The FAA provides $5 million annually for the Aviation Maintenance Technical Workers Workforce Development Grants Program, with individual grants for workforce development ranging from $25,000 to $500,000 per grant and no cost-sharing requirements.[42]

States also can adapt existing training and workforce development programs to develop the new skill force required for SAF production and use, especially for PtL.

F. Pass policies to draw crucial SAF feedstocks within state borders.

Existing SAF policies at the state and local level provide incentives for SAF production and supply but tend to be feedstock and process agnostic. There is increasing competition for traditional SAF feedstocks (particularly fats, oils, and grease)(FOGs) for other biofuels such as renewable diesel. There is an opportunity for policies that either: (a) focus on underutilized feedstock, such as MSW and forest residues that are going to waste or (b) provide an advantage to switch feedstock from renewable diesel to SAF production because diesel end uses can be electrified.

Infrastructure Buildout

The region holds significant potential for SAF production. However, the lack of existing, dedicated SAF infrastructure poses an obstacle. SAF must be blended before it can be transported through jet fuel pipelines. Consequently, potential producers in the RMR face the dilemma of necessary additional investment in infrastructure modifications or establishing new facilities altogether.

While the region benefits from a robust pipeline network, the vast distances between population centers entail extensive transportation routes for SAF delivery to airports. This results in risks for increased CI due to added transportation emissions if fuel is transported via trucking.

To mitigate these challenges, strategic infrastructure development is imperative. Establishing SAF refineries close to major airports, such as Denver International Airport, could streamline the transportation process and minimize increased life-cycle CI associated with long-distance transport. By co-locating production facilities near demand centers, producers can reduce complexity and position themselves well for forging agreements with offtake partners.

Investment in storage and transportation infrastructure specifically designed for SAF also will be essential. This includes the development of dedicated storage facilities, specialized transportation systems optimized for SAF transport, and SAF blending infrastructure. Support from financial stakeholders may be necessary to enable the SAF industry in the RMR to materialize.

Conclusion

Increasing SAF production and use are essential ways to decarbonize the aviation industry. With growing recognition and momentum building in the sector, there is an important opportunity for states in the RMR to ride the wave by supporting the use of in-region feedstock supply and infrastructure buildout and by leveraging existing policy mechanisms at the federal and state levels.

There are multiple pathways to produce SAF in the region, both bio-based pathways and through PtL production. Analysis on the production potential of bio-based SAF demonstrates that in the short term, the region has necessary feedstocks to develop regional SAF production, which will complement, not supplant, jet fuel as demand increases. However, in the long term, producing SAF using local feedstocks is insufficient to meet the projected demand without imported supplies, feedstocks, or PtL.

To meet the future decarbonization targets, the region needs SAF projects to take off now. Policymakers can support SAF by:

- Providing additional state-level incentives to close the cost gap between SAF and fossil-based jet fuel, including tax credits and state-guaranteed loans
- Smoothing the siting and permitting process of refineries and hydrogen production facilities
- Harmonizing safety and handling regulations to enable projects that build and leverage infrastructure across state borders

Seizing the current momentum in the aviation industry for increasing SAF production and use presents a pivotal opportunity for states in the RMR to facilitate regional decarbonization efforts through strategic policy support and investment in diverse production pathways, ensuring that sustainable aviation fuel becomes a cornerstone of future air travel.

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