Title: Refinery to Wing: Transportation Challenges Associated with Alternative Jet Fuel Distribution

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1. Gap(s) / Problem Statement

Drop-in sustainable alternative jet fuel (SAJF) is generally considered interchangeable with existing petroleum-based jet fuel and does not require alterations to jet engines or fuel delivery systems. However, in spite of its drop-in nature, there are challenges associated with integrating SAJF into the existing petroleum jet fuel transport and distribution infrastructure. These challenges are related to a) geographic concentration of production; b) constraints of existing infrastructure; and c) tracking SAJF through the supply chain to ensure blending requirements are met.

CAAFI's goal is to promote the development of SAJF options that offer equivalent levels of safety and compare favorably on cost with petroleum-based jet fuel, while also offering environmental benefits, energy security, and cost stability over petroleum-based jet fuel. The challenges and opportunities for SAJF to enter the supply chain due to potential transportation-related constraints are highlighted in this white paper.

2. Background

Commercial aviation in the United States consumed approximately 24.6 billion gallons of jet fuel in 2016 (1). While worldwide demand is expected to increase by an average 4.9 percent annually through 2030 (2), the aviation industry is committed to achieving net carbon neutral growth in international aviation from 2020 onward. Engine and other technological advancements (e.g., materials & aerodynamic upgrades) and operational efficiency improvements (e.g., optimized flight routing and linear descent) will not be enough in the near-term to accomplish the industry's goal. To accelerate the reduction of carbon dioxide (CO_2) emissions in the aviation sector, the industry is now looking to SAJFs as part of its solution. SAJF that achieve a reduction in life-cycle CO_2 emissions have the immediate potential to lower net global CO_2 emissions from commercial aviation because, as drop-in fuels, they are compatible with existing aircraft and infrastructure (3) and those that are qualified in ASTM D7566 are approved for use today fueling any civil aviation, jet-powered flights. However, challenges still exist with regard to getting SAJF into the existing transport and distribution systems.

2.1. Traditional Jet Fuel Delivery Approaches

Along the distribution chain from the refinery to the airport, jet fuels are transported in batches (called tenders) via pipelines, marine vessels, and road tankers. The tenders, which regularly exceed 400,000 gallons, are often stored in intermediate bulk oil storage facilities (between the refinery and the airport) and are usually transported to the airport via pipeline due to their large volume (4). There are dedicated pipelines used solely for the transport of jet fuel, but jet fuel can also be transported in multi-product pipelines that handle a variety of liquid petroleum products (5).

Fuel volumes that cannot be transported via pipeline for various reasons rely on existing rail and waterway infrastructure. Rail carloads of petroleum increased 40-fold between 2008 and 2013 (4). Conventional jet fuel is transported by rail using specialized tank cars typically owned by independent, private tank car supply and service companies, rather than by common carriers (railroad owners) or fuel companies (4). Barges on waterways are the second most efficient and cost effective means to transport jet fuel: one 15-barge tow, for example, can carry as much cargo as 216 rail cars or more than 1,000 trucks (4). Private barge carriers contract with refineries to transport jet fuel. Barge transport is particularly prevalent for jet fuel in New England (4). Tanker trucks generally only transport jet fuel from the intermediate storage facility to smaller airports because the mode is only economical when tenders are small (4).

Fuel farms (end-user storage) can be located on or off airport property, depending on factors related to the land available, such as environmental and site preparation costs, and the efficiency of methods for final delivery to the aircraft (6). Airports that produce a high turnover of jet fuel on a daily basis usually have three or more storage tanks: one tank is used as a receiving tank and accepts new fuel loads; a second tank acts as a holding and settling tank to allow time for contaminants to settle; and the third tank is called the operating tank from which fuel is drawn for daily use (6). From these storage tanks, fuel is either piped to a central dispensing pump or a decentralized underground hydrant fuel system with a pit at each aircraft gate, or is loaded into refueler trucks or dispensers for final delivery to the aircraft (6). For fuel truck delivery, vehicles first receive a load of fuel from a loading area and are then driven to each aircraft requiring fuel at a designated airport. This design allows for flexibility, but the size of the vehicle limits the amount of fuel available (typically between 1,000 and 15,000 gallons) and the amount of maneuvering space in proximity to an aircraft (6).

Airlines typically prefer to source their fuel through contracts with fuel suppliers that deliver fuel directly to an airport's fuel farm. Fuel farms as a whole are managed by fixed-base operators (FBOs), on behalf of airports or airlines (4). At large hub airports, airlines purchase separate tenders from more than one supplier, partially to reduce risk from supply interruptions (e.g., natural disasters and fuel infrastructure problems). In general, these contracts have a length of 1–2 years and specify the delivery point, volume, and price of fuel (4).

2.2. Special Considerations for Jet Fuel versus other fuel types.

Jet fuel is subject to stringent property and performance requirements that drive quality control systems to ensure the fuel continues to meet these requirements as it travels through the supply chain, necessitating special equipment and engineering for fuel production, handling, and transport to achieve compliance. Jet fuel pipelines require treatment to mitigate corrosion and fuel contamination and must allow for periodic cleaning and inspection. At jointly operated facilities such as marine berths, where dedicated jet fuel pipelines are not available, jet fuels are transported on the oil lines reserved for middle distillates. With multi-product pipelines, jet fuels are at higher risk for contamination (i.e., from surfactants, free water, and particulate matter) due to commingling of batches. Recertification, typically via use of physical testing properties, is generally mandatory with multi-product pipeline transport to ensure the quality of the fuel is not compromised. Batch planning and tracking is of particular importance to avoid jet fuels failing quality requirements (5) and to delineate ownership of the fuel in the event additional processing (e.g. filtration, additive treatment, etc.) is required to bring fuel back into compliance.

Other considerations for jet fuel transport include those common to multiple delivery processes, which must be taken into account regardless of how the jet fuel is derived. For example, to avoid self-scouring velocity and static electricity generation, the rate at which jet fuel flows through the pipeline must also be taken into account. For storage, fixed cone roof tanks are required to mitigate the ingress of free water, rain, and particulate matter that will contaminate the fuel (5).

3. Current Status

3.1. Geographic Concentration of Production

Current U.S. production of petroleum-based jet fuel is concentrated by geographic region, with approximately 50% of U.S. production coming out of Texas, Louisiana, and California, that is then transported by pipeline, marine vessels, and road tankers to end-users (4). Jet fuel producers typically deliver fuel to their end-users through various methods including by pipeline, which is normally the most efficient and cost-effective mode. Pipeline routes have been determined by demand patterns, and supply chains for petroleum jet fuel production are relatively streamlined. For example, many of the largest jet fuel producing refineries are located near large airports.

In contrast, biorefineries are generally envisioned to be located close to their various feedstocks and are not grouped in the same locations as petroleum-jet fuel refineries. Currently, there is little infrastructure in place to easily transport finished SAJF from its distributed production pattern to end-users. Ideally, fuels produced from non-petroleum sources would use much of the same infrastructure already in place for conventional aviation fuels. One option proposed by Idaho National Laboratory is to co-locate petroleum and biorefineries so that the two fuels might utilize the same infrastructure for transport to end-users, assuming the SAJF is drop-in and can be introduced effectively into the supply chain (4). However, the current differences in the geographic location of conventional jet fuel production and SAJF production may pose challenges for SAJF entry into the existing jet fuel distribution system.

3.2. Constraints of Existing Infrastructure

By definition, drop-in fuels do not require duplicate storage or distribution and require no modifications to existing infrastructure to utilize it. However, identifying and having access to the transportation mode that has the most available capacity and is most ideal for delivering SAJF to airports, in terms of distance from biorefineries and cost, is a key consideration. While pipelines are the most efficient means of fuel transport and can accommodate large batches of fuel at relatively low costs, many product pipelines have minimum batch requirements. Currently, SAJF production is in its infancy and unable to meet these minimum batch size requirements. This constraint hinders the producers' ability to deliver SAJF to the end-user in a cost-effective manner.

Many airports get fuels delivered only via pipeline, so constraints on pipeline use for SAJF pose a major problem. Even if SAJF producers were able to meet the minimum batch requirement, recent increases in crude oil production in the United States have filled most product pipelines to capacity. And increasing pipeline capacity requires building new pipeline infrastructure which is a prohibitively lengthy, complex and expensive process (4). But, even if new pipelines were built, the logistics for transporting SAJF from the biorefinery to the pipeline would still need to be considered.

Whether or not a sufficient SAJF supply can be delivered to airports by a mode other than pipeline also remains a question. If the fuel is delivered through infrastructure not currently in use, then additional hookups will be necessary. For example, if an airport currently receives conventional jet fuel through a pipeline from a refinery and starts to receive SAJF by railroad, then a hookup, most often a fuel truck, between the railroad car and the pipeline is required (8). In this case, terminal ramps and access roadways must then be designed to accommodate heavy fuel truck movements (6). The other modes also have their own capacity constraints, such as the cyclic and sporadic shortages of rail capacity that could affect how and whether SAJF can be delivered reliably to airports.

3.3. Blending and Tracking of Fuel

There is no current evidence to indicate that SAJF has more quality control problems than conventional jet fuel. However, the potential proliferation of many new fuel providers (8) and tracking the SAJF they inject into the supply chain could prove complex. SAJF has blending constraints, and without a proven methodology in place to certify blend levels are acceptable at the end-user, pipeline operators and airlines may have concerns about co-mingling the fuels in the pipeline and unintentionally exceeding certified blend levels. The blender will need to determine that the blending of any fuel has not exceeded the maximum blending level.

There are two ways SAJF can be delivered to the end-user: a) neat (not blended with petroleum-based jet fuel prior to arriving at the airport) or b) blended. SAJF is currently qualified and approved for use in existing jet fuel infrastructure as blends only. Therefore, if SAJF is delivered to the airport neat, it must be blended on-site before going into the aircraft and there are on-site blending challenges for airports. For example, with limited infrastructure, dedicating tanks for blending may not be possible without adding additional infrastructure (another tank). Additionally, specific chemical compatibility and regulatory constraints on mixing SAJF with jet fuel upstream of the blending location may pose challenges for SAJF entering particular parts of the system (4) because with blending could come blend-level uncertainty due to unintentionally blending neat SAJF with already blended SAJF, resulting in a product above the certified blend limit. These challenges have yet to be realized as the current supply of SAJF is small and easily managed, but as the industry continues to grow blending locations and tracking issues should be addressed.

4. Solvability and Approaches

Limitations of the current SAJF supply chain (e.g., SAJF availability, transport options, and blend walls) restrict the industry from fully realizing the benefits of SAJF (e.g., CO_2 emissions reduction, energy security, etc.). To capitalize on these benefits, the industry must identify solutions to supply chain obstacles and add significant quantities of SAJF to the commercial jet fuel supply chain.

Fuel consortia, where airlines collectively seek a free market for fuel pricing and fuel system operations at major airports (9), have become a common operational model in the United States and around the world, including airlines operating at mid-size to smaller airports. Consortia offer an opportunity for airlines to collaborate, along with airport management, and to manage collective activities more efficiently and cost-effectively (9). Fuel consortia have made it possible to transfer petroleum jet fuel from just about any U.S. refinery to any U.S. airport as long as the airline is willing to meet the transportation and maintenance costs (10). It is feasible to incorporate SAJF into this model once demand is sufficiently high and benefit-cost analyses support its use. The industry has expressed interest in leveraging the existing fuel consortia model to locate an alternative fuel production facility on, adjacent to, or with access to an airport to take advantage of known demand (11).

The industry should agree on acceptable points of entry of SAJF into the petroleum-based jet fuel supply chain. As pipeline transport is usually the most efficient and cost-effective means to transport SAJF, SAJF industry partners should work with the pipeline industry to determine the challenges associated with establishing new entry points into the existing pipeline system and identify the scope of potential solutions.

To avoid the blend wall issues, the industry must determine the best entry point in the jet fuel supply chain (e.g., refineries, fuel farms, intermediate storage, airport storage tanks) to blend SAJF with conventional jet fuel. Additionally, the industry needs to decide whether the fuel producer, airport, fuel handler, and/or airline should be responsible for maintaining and, therefore, tracking to ensure blend level requirements are not surpassed.

Typically, the sourcing and handling of jet fuel is the responsibility of airlines, and the airport's jet fuel infrastructure is managed and maintained by third-party vendors (11). However, there are opportunities for airports to get involved and be supportive of SAJF projects by conducting studies to identify the feasibility of introducing SAJF (11). Infrastructure assessments resulting from feasibility studies could determine the best location for blending and introducing SAJF into the fuel supply.

There are at least four options to ensure blend wall requirements aren't exceeded. One is to only allow blended fuel into the airport (i.e., producers have to send their HEFA as a 50% blend, etc.) With this approach there is no possibility of exceeding blend limits because every unit of SAJF brings its own associated unit requirements of petroleum-based fuel. Another option is co-processing (processing SAJF at a petroleum-based production facility), which if accepted widely as a practice, will allow for larger batch sizes and likely, pipeline transport of SAJF (7). Also, there are some new pathways for producing SAJF in development that have the potential to meet the fuel property and performance requirements as neat fuels that wouldn't require blending with petroleum jet fuel (8). A third option is delivering neat SAJF to an existing refinery for blending and subsequent delivery. A fourth option is to allow a fuel supplier to handle all the logistics at their existing facilities.

5. Benefits to Industry as a Whole

It will be difficult to fully realize the potential benefits of SAJF until it holds a larger share of the jet fuel market. To reduce risk and increase investment in the sector, the industry should do all it can to mitigate risk (e.g., contamination and cost). To do so, the industry must increase its supply volumes of SAJF, agree upon an entry point(s) for SAJF into the petroleum-based jet fuel supply chain, and pursue neat SAJFs that do not require blending. Fuel that is cheaper and more easily transported is likely to be used in higher volumes, allowing the benefits provided by SAJF to be more widely realized (e.g., greenhouse gas emissions reductions, energy security, and price stability).

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