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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP RESEARCH REPORT 165

Tracking Alternative Jet Fuel

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). ACRP carries out applied research on problems that are shared by airport operating agencies and not being adequately addressed by existing federal research programs. ACRP is modeled after the successful National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP). ACRP undertakes research and other technical activities in various airport subject areas, including design, construction, legal, maintenance, operations, safety, policy, planning, human resources, and administration. ACRP provides a forum where airport operators can cooperatively address common operational problems.

ACRP was authorized in December 2003 as part of the Vision 100—Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academy of Sciences formally initiating the program.

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Primary emphasis is placed on disseminating ACRP results to the intended users of the research: airport operating agencies, service providers, and academic institutions. ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties; industry associations may arrange for workshops, training aids, field visits, webinars, and other activities to ensure that results are implemented by airport industry practitioners.

ACRP RESEARCH REPORT 165

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COOPERATIVE RESEARCH PROGRAMS

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FOREWORD

By Theresia H. Schatz
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ACRP Research Report 165: Tracking Alternative Jet Fuel provides guidance to help airports and other interested stakeholders identify the potential needs for effectively and efficiently tracking alternative jet fuel into the airport. This guidance, along with a companion decision-support tool, compares different types of tracking mechanisms and evaluates their advantages and disadvantages, impediments to implementation, and potential impacts.

The aviation industry strongly supports the introduction of alternative jet fuels that have the potential to provide environmental, economic, and security-of-supply benefits compared to conventional fuels. These fuels are expected to be drop-in fuels, meaning that they can be used in existing aircraft and supporting infrastructure. Some airlines have started taking delivery of alternative jet fuel at Los Angeles International Airport (LAX), and other similar commercial arrangements are expected in the near future.

As alternative jet fuels start to enter the supply chain, there may be a need to keep track of such fuels for technical (e.g., quality control, fuel efficiency); regulatory (e.g., tracking reductions in local air quality pollutants or greenhouse gases); and commercial (e.g., contract verification, corporate social responsibility marketing/sustainability reporting) reasons. A logical point to institute fuel-tracking mechanisms may be at the airport because the supply chains for conventional and alternative jet fuels converge before the fuel gets loaded into the aircraft. Airports can play a key role to incentivize the commercialization of alternative jet fuels by helping to facilitate some of the logistics associated with using these drop-in fuels, in particular fuel tracking.

Under ACRP Project 02-65, research was conducted by Metron Aviation, Inc., in association with ACA Associates, Inc., Environmental Consulting Group, Inc., Futurepast: Inc., and LMI. As part of the research, the team explored different alternative fuel-tracking mechanisms, including physical segregation, mass-balance, book-and-chain, and hybrid approaches that included advantages, disadvantages, impediments to implementation, and potential impacts. The decision-support tool is available on the TRB website (www.TRB.org) by searching "ACRP Research Report 165." Appendix A provides a summary of sustainability frameworks and chain-of-custody requirements.

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Preamble: How to Use This Guidebook

The aviation industry supports the introduction of alternative jet fuels that have the potential to provide environmental, economic, and security-of-supply benefits not found with conventional fuels. These fuels are expected to be drop-in fuels, which means that they can be used in existing aircraft and their supporting infrastructure. As alternative jet fuels start to enter the supply chain, there may be a need to keep track of such fuel for technical (e.g., quality control, fuel efficiency), regulatory [e.g., tracking reductions in local air quality pollutants or greenhouse gases (GHGs)], and commercial [e.g., contract verification, corporate social responsibility (CSR) marketing/sustainability reporting] reasons. In the United States, there is not yet a regulatory need to track the use of alternative jet fuels or any attributes associated with such fuel batches. Furthermore, there is still no universally agreed sustainability framework that could define which sustainability attributes have a high potential for being required for tracking purposes. Until such time as additional policy mechanisms either require or incentivize the use of tracking, tracking will probably only be done on a voluntary basis by the airlines using the fuel.

As tracking requirements are considered, proposed, or promulgated, either to satisfy regulatory or voluntary initiatives, this guidebook and associated toolkit are intended to help airport managers, airline fuel purchasers, fuel handlers, producers of alternative fuel, government officials, nongovernmental organizations, and other stakeholders along the alternative fuel supply chain understand the fundamentals of alternative jet fuel tracking, taking into account current jet fuel supply chain practices and available tracking mechanisms. The purpose is to provide sufficient information to understand different options for tracking these fuels and to provide tools to facilitate their implementation.

The guidance materials are structured as follows:

- Chapter 1 provides a brief introduction to alternative jet fuels, the objectives of this guidebook and toolkit, and the reasons for tracking alternative jet fuel. It also discusses the major stakeholders along the supply chain and their interests in tracking alternative jet fuel.
- Chapter 2 presents an introduction to tracking mechanisms currently used in the industry for conventional jet fuel and for alternative fuels used in road transportation. This chapter also discusses potential new tracking mechanisms for alternative jet fuel.
- Chapter 3 includes a detailed discussion of the different tracking mechanisms, including descriptions of their main elements.
- Chapter 4 provides guidance with respect to comparing the attributes of the different tracking mechanisms and choosing the most appropriate approach for particular circumstances.
- Chapter 5 presents an overview of the toolkit that has been developed as part of this work to facilitate the introduction of tracking mechanisms for alternative jet fuel.
- Chapter 6 is the conclusion of this guidebook.

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CHAPTER 1

Introduction and Motivation

1.1 Introduction

For decades, the aviation industry has relied on petroleum-derived jet fuel to power aircraft. Today, the aviation industry wants to reduce its reliance on petroleum-based fuel with alternative jet fuels made from renewable sources. There are multiple benefits to be realized by nurturing an alternative jet fuel industry:[1,2,3,4]

- Supply diversity,
- Improved supply reliability and security,
- Enhanced national energy security,
- Jet fuel price volatility reduction,
- Regional economic benefits,
- Air quality benefits, and
- Net life-cycle greenhouse gas (GHG) emissions reductions.

To enable the introduction of alternative jet fuel, the aviation industry is promoting the development of drop-in alternative fuels (i.e., those that can be used in existing aircraft and their supporting infrastructure). To date, ASTM International has approved a number of alternative jet fuel pathways for use as drop-in fuels for aircraft.[5] Alternative fuel from these pathways must first be blended with conventional fuel in order to meet the requirements in ASTM D7566, Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons specification. (The blending requirement may be relaxed in future pathway approvals.) Once certified to D7566, the blended fuel is considered to meet the specification for conventional jet fuel (ASTM D1655, Standard Specification for Aviation Turbine Fuels) and can enter the existing fuel-handling infrastructure and equipment.

In the United States, the aviation industry has been working through the Commercial Aviation Alternative Fuels Initiative (CAAFI) to align the interests and resources of multiple government and private stakeholders, including several U.S. government agencies, airports, airlines, and original equipment manufacturers (OEMs). The U.S. Department of Defense (U.S. DoD) has also been a strong supporter of alternative jet fuels and has been collaborating with CAAFI on a number of key initiatives.

In 2016, airlines began to purchase and receive commercial quantities of alternative jet fuel. In Europe, Oslo Gardermoen airport started to distribute alternative fuel through its fuel hydrant system.[6] At Los Angeles International Airport (LAX), United Airlines started receiving alternative jet fuel from AltAir, an alternative jet fuel producer in California.[7] In addition, United Airlines and Southwest Airlines as well as FedEx Express have signed purchase agreements with Fulcrum BioEnergy and Red Rock Biofuels, respectively, for the near-term supply of alternative jet fuel in the United States.[8,9]

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To prepare for the routine use of alternative jet fuel, airports and other stakeholders may need to make plans to track and account for the new fuels as they move from the production source through the supply chain to the airports where they will be received and loaded into aircraft. Beyond airports, airlines, general aviation, and fixed-base operators (FBOs), there are numerous, diverse organizations that have an interest or stake in alternative jet fuels. These include biofuel feedstock suppliers; fuel producers and fuel transporters; governments at the local, state, and national level; and nongovernmental organizations that are focused on environmental or public policy. Because these fuels are designed to be drop-in and will be able to share the same infrastructure as conventional jet fuel, the tracking needs to consider both the mechanisms already in place for conventional jet fuel and the particular attributes of alternative jet fuel.

1.2 Objective

The objective of this guidebook is to help airports and other interested stakeholders:

- Proactively identify potential reasons for tracking alternative jet fuel;
- Compare the different types of tracking mechanisms; and
- Evaluate the advantages and disadvantages, impediments to implementation, and potential impacts of the different mechanisms for tracking alternative jet fuel through the supply chain.

A logical point for tracking alternative fuels may be the airport because this is the point where the supply chains of both alternative and conventional fuels have to converge before the fuel is loaded into the aircraft. In addition, airport fuel farms already have quality control and accounting mechanisms for conventional jet fuel that can be leveraged to enable tracking of alternative jet fuel in a manner that is consistent with current practices, would minimize additional workload, and has the potential to be effectively implemented.

While this guidance and associated toolkit are focused on the airport, this material is also intended to be useful to additional stakeholders along the supply chain. In particular, airlines, producers, and third-party providers who are considering the implementation of tracking mechanisms for alternative jet fuel may benefit from this information.

1.3 Reasons for Tracking Alternative Jet Fuels

Establishing tracking mechanisms for alternative jet fuels will enhance the ability of all stakeholders to more fully realize the potential benefits of their introduction. These reasons can be classified in at least three categories:

1. **Technical,** such as for quality control purposes to ensure that the fuel containing alternative components meets the required specification. Alternative jet fuels must meet rigorous standards set by standard-setting organizations such as ASTM International and the U.K. Ministry of Defence Standards (Def Stan). Fuel producers and fuel handlers need to conform to the accepted specifications and ensure that when their fuel is blended and transported to an airport, it qualifies as a drop-in fuel. Tracking the use of alternative fuels can support quality assurance and quality control practices.
2. **Regulatory,** such as for compliance with policies or regulations associated with the use of alternative fuels at the local, national, or international level. For example, because alternative jet fuels may be an important mechanism for reducing life-cycle carbon dioxide (CO_2) and have the potential to reduce local air quality emissions, it might be important for interested airports and other stakeholders to be able to track the quantity, source, and composition of alternative jet fuels passing through their tank farms. Compliance with regulations needs to be based on quantitative data from an accurate, consistent, and transparent tracking system.

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3. **Commercial,** such as for ensuring that specified amounts of alternative jet fuel are being delivered as agreed in purchase contracts and for verification purposes related to corporate social responsibility (CSR), sustainability, and other voluntary reporting. To make legitimate claims about alternative jet fuel use on sustainability reports or marketing documentation, it may be necessary to track the use of these fuels.

1.4 Conventional and Alternative Jet Fuel Tracking

Current industry practice for tracking conventional jet fuel is to confirm that the fuel meets the relevant safety specification (e.g., ASTM D1655) and to measure the volume of fuel, adjusted for temperature. In the United States, fuel transfer accounting and financial transfers are based on fuel volume, measured in gallons. [Occasionally, a container's volume is unknown; therefore, it is necessary to measure fuel mass in pounds (or tons), which is then converted to volume using fuel density.] This system meets the industry's needs, is simple to administer, and provides transparency in commercial transactions.

Tracking alternative jet fuel should be done on a similar basis to minimize the need to change current practices and limit any added administrative burden. However, tracking sustainability attributes such as life-cycle GHG reduction benefits and potential local air quality benefits associated with unique batches of alternative jet fuel is an important and potentially complicated addition to the system. Because alternative jet fuels are designed to be drop-in, once they enter the existing jet fuel handling and distribution infrastructure, they lose their physical distinctiveness, and the sustainability attributes of the fuel may be ensured through an administrative paper trail or tracking system.

A tracking system for alternative jet fuel may require information about the origin of the fuel to confirm its environmental benefits and sustainability attributes. It may also need to be flexible enough to accommodate several regulatory and tracking systems for diverse fuel supply chains that may be developed and used in other countries. Only with precise and verifiable data can industry stakeholders ensure that they are receiving economic value, obtaining reliable performance, and meeting essential safety requirements while achieving their emission reduction targets.

In many cases, fuel farm operators or FBOs are under no obligation to provide detailed fuel throughput information to fuel consortiums or airlines on an ongoing basis. They instead may provide only a total volume of fuel received and used over a period of time. When this is the case, flexibility in the system is limited, and airports interested in tracking the composition of fuel (to claim emission reduction credits, for example) would have to rely on fuel-handling entities further up the supply chain to supply this information.

1.5 Tracking Alternative Jet Fuel Along the Supply Chain

Evaluating the sustainability of alternative fuel requires an understanding of the feedstock used in its production. Because the fuels can be blended at different points along the supply chain, it is essential that each link in the supply chain be considered when developing a tracking system for alternative jet fuel. For the purposes of this project, the researchers have identified the following stakeholders along the supply chain that have an interest in and play a key role in this process of alternative jet fuel tracking:

- **Feedstock suppliers and processors:** Feedstock suppliers and processors may be able to gain a sustainability premium by manufacturing products that maximize life-cycle CO_2 reductions and other social, economic, and environmental benefits. Information about

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these sustainability characteristics is carried forward along the supply chain to the fuel producer and the end user.

- **Fuel producers:** Beyond ensuring the technical quality of their fuel, producers want to ensure that their customers and other stakeholders can claim the most benefits from using alternative fuels through accurate accounting of product movement and use.
- **Fuel handlers, including FBOs, fuel farms, and into-plane operators:** Fuel handlers play a key role in the transportation, storage, and distribution of alternative jet fuels. In addition to producers, fuel handlers are very likely to operate facilities where neat alternative fuel is blended with conventional jet fuel to produce alternative jet fuel that meets the relevant specification. Fuel handlers must ensure that other fuel products are not mixed with the neat alternative jet fuel. They would then be responsible for blending the fuel with conventional jet fuel to produce a certified drop-in fuel. Blending to proper proportions and appropriate accounting will require effective quality assurance and quality control procedures.
- **Airports:** While airports themselves are rarely directly involved in the fuel-handling process, they are the last inventory and accounting control point prior to fuel reaching the aircraft. As such, airports are interested in ensuring that alternative fuels passing through the airport fuel storage facilities meet required safety specifications and fuel quality standards before they are dispensed to aircraft. In addition, there is some evidence that alternative jet fuels may slightly improve fuel efficiency compared to conventional jet fuel,[10] which may slightly reduce an airport's local air emissions and measures of criteria pollutants. To verify and quantify this potential impact, it may be necessary to track the use of alternative fuels. There may also be a desire to track airlines' use of alternative jet fuel as part of airports' sustainability or CO_2 management programs. [Note that under current GHG accounting structures, only fuel producers report the fuel quantities produced, and only aircraft operators are responsible for aircraft fuel use (Scope 1 for aircraft operators). Also, under the Airport Carbon Accreditation (ACA) program, as noted in Appendix A (Section 2.1), ACA Level 3 and 3+ airports (those reporting Scope 3 emissions) only report emissions in the landing/take-off (LTO), which is approximately 25% or less of total jet fuel related emissions.]
- **Fuel users:** Airlines, aircraft owners, and the U.S. military operate the aircraft that consume jet fuel and, consequently, are the entities that purchase essentially all jet fuel, which often is one of their largest operating expenses. Accurately tracking fuel consumption is critical for their operations. Also necessary for safe operations is ensuring that the fuel meets specification and acceptance criteria. It is important to have consistent accounting rules so that fuel users can confirm their life-cycle CO_2 emissions savings in a transparent and consistent way that also ensures the credibility of the system. Current jet fuel accounting practices enable them to meet these needs for conventional fuels. However, introducing alternative fuels into this system means that fuel users may also have to track additional fuel specifications and sustainability certifications. Effectively doing this will ensure that the alternative fuel components are consistent with their commitments for sustainability targets as well as demonstrate compliance with current or future regulatory requirements and internal sustainability goals.
- **Local, state, and federal governments:** All levels of government have indicated interest in promoting alternative jet fuel development as a means to reduce emissions, stimulate employment, and effectively use available resources. They also have a stake in the environmental impact of aircraft emissions. Tracking systems for alternative jet fuel may be an important means for tracking fuel use by type and ensuring that the varied goals of governmental entities are being met reliably.
- **Nongovernmental organizations (NGOs):** NGOs have an interest in ensuring that airlines, airports, and the aviation industry live up to commitments for emissions reductions and other sustainability attributes. Their interests require quantitative measurements and the reporting of fuel volumes and life-cycle CO_2 reduction potential of the alternative fuel component.

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Table 1. Stakeholder matrix for alternative jet fuel tracking.

Stakeholder	Purpose	Interests		
		Technical	Regulatory	Commercial
Feedstock suppliers and processors	Contract verification, inventory, sustainability certification and reporting		√	√
Fuel producers	Contract verification, inventory, quality, sustainability certification and reporting	√	√	√
Fuel handlers, including FBOs, fuel farms, and into-plane operators	Contract verification, inventory, quality	√		√
Airports	Regulatory, quality, sustainability certification and reporting	√	√	√
Fuel users (e.g., airlines, general aviation, military)	Contract verification, quality, sustainability certification and reporting, regulatory	√	√	√
Local, state, and federal governments	Regulatory, public policy	√	√	
Nongovernmental organizations	Community impacts, public policy, sustainability		√	√
International parties	Regulatory, public policy	√	√	√

- **International parties:** The International Civil Aviation Organization (ICAO), Airports Council International (ACI), and the International Air Transport Association (IATA) are some of the focal points for the aviation industry's goals and commitments to sustainability and reduction of life-cycle CO_2 emissions. Being able to track total alternative jet fuel use is essential for monitoring progress toward achieving these goals.

Table 1 summarizes the reasons stakeholders along the supply chain have for quantifying and tracking alternative jet fuel.

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CHAPTER 2

Current and Potential Tracking Mechanisms

2.1 Introduction to Jet Fuel Logistics and Procurement

It is critical to understand three key elements needed to properly develop mechanisms for alternative jet fuel tracking:

1. Physical supply of jet fuel to the wing of the aircraft,
2. Jet fuel purchasing mechanisms and associated documentation, and
3. Inventory tracking at the airport fuel farm.

These three elements are discussed in more detail in this section.

2.1.1 Physical Supply of Jet Fuel to the Wing of the Aircraft

Physical supply of jet fuel to an airport occurs in stages, as shown in Figure 1. Here the process has been simplified to (1) production, (2) transportation from the refinery to the airport storage (fuel farm), (3) airport storage, and (4) loading into the aircraft (into-plane).

Production

Conventional jet fuel production takes place at crude oil refineries, which produce a variety of petroleum-based products, including lubricants, chemicals, and an array of gaseous and liquid fuels. All crude oil refineries work by separating hydrocarbon molecules of differing lengths out of the crude oil, yielding component products, including jet fuel.

There are a number of different ways to produce and manufacture alternative jet fuels, depending on raw material, conversion technology, and other circumstances. A full description of the different pathways is outside the scope of this work, but interested readers are encouraged to consult recent ACRP publications on the topic,[11,12] the FAA's website on Sustainable Alternative Jet Fuels,[13] or the Department of Energy's website for the Office of Energy Efficiency and Renewable Energy.[14]

A key step in the production process is certifying that the jet fuel (conventional or alternative) meets the relevant specifications for use in commercial aircraft. ASTM D1655, Standard Specification for Aviation Turbine Fuels, and United Kingdom's Def Stan 91-91, Turbine Fuel, Aviation Kerosine Type, Jet A1, are the primary standards used around the world to certify conventional jet fuel. Within the United States, ASTM standards are used for all commercial aviation fuels. The Def Stan standards are used in other countries but are often used as a reference in the United States. The ASTM D1655 specification not only sets standards that the fuel must meet to be certified but also identifies appropriate methods that can be used to test the fuel.

ASTM D7566, Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons, is the specification that applies to alternative jet fuel blends containing no more

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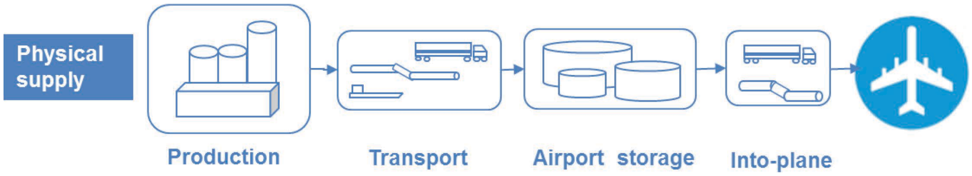

Figure 1. Schematic of jet fuel logistics.

than 50% neat alternative fuel, although the blend requirement may not continue in the future. D7566 contains two types of specifications—one that applies to the neat alternative fuel after production and one that applies to the blend of alternative and conventional fuel. Once the blend of alternative and conventional fuel has met the requirements of D7566, it is then redesignated as D1655 fuel and may be treated as such throughout the remainder of the supply chain.

When a batch of fuel leaves the refinery after being certified relative to the requirements of D1655 or D7566, a Refinery Certificate of Quality (RCQ) must be issued that identifies the batch number of the fuel, the manufacturing refinery, the specification the fuel was manufactured to, and details of any additives used in the manufacture of the fuel. Downstream of the point of manufacture, one or multiple Certificates of Analysis (COAs) are issued after the completion of full conformity testing. A COA is generally issued each time a new party becomes responsible for a particular batch of fuel, so by the time a batch reaches the airport, there are usually multiple COAs associated with it. All COAs must include the batch number, the manufacturing refinery, and the tested properties required in D1655 or D7566.[15]

These quality documents are the building blocks of the safety tracking mechanisms for jet fuel used in the industry today. These documents accompany the fuel from its point of origination all the way to the point of final consumption. Thus, they are key sources of information for tracking alternative jet fuels. However, it must be noted that there is no standard method of collection or database that currently consolidates these data in a centralized location. Therefore, while the data exist, it is not yet clear how accessible they might be for use in a tracking system.

Transportation (Refinery to Airport Storage)

The most common methods of transporting jet fuel to the airport are shipping by pipeline, rail, barge/vessel, or truck. However, depending on the local circumstances unique to each airport, some of these options might not be available. In general, large airports are supplied by pipeline or multiple pipelines, while smaller airports tend to be supplied by trucks and, when available, pipelines.

While there are cases where fuel is delivered directly from a refinery to airport storage (via a series of filters and fuel/water separators), the majority of large airports use a system where fuel leaves the refinery via pipeline and passes through a clay filter and fuel/water separator prior to deposition into a supply terminal. This supply terminal is generally off-airport and can serve multiple airports.

As fuel is transported from the refinery to the airport, there are multiple opportunities for contamination to occur. Since the receiving party is responsible for fuel quality after it accepts a delivery, strong quality control practices are necessary at each transfer point.

Airport Storage

For larger airports, onsite fuel storage consists of an array of different tanks that are used for specific purposes. Airports that produce a high turnover of fuel generally have three or more storage tanks. One tank is used to receive and accept a load of fuel and is designated as the

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receiving tank. A second tank is used for holding the fuel and allowing time for sediment and moisture to settle to the bottom of the fuel. Once the recommended settling time (dependent on fuel type and volume) has been met, fuel is either pumped into a third tank that is used as the actual dispensing tank, or the settling tank is redesignated as a dispensing tank and the fuel is dispensed directly from there.

Smaller airports that have only one or two tanks for jet fuel deal with fuel delivery differently. For example, these airports must carefully plan their fuel deliveries to ensure that fuel will have enough time to settle prior to its use. In the case of an airport with two fuel tanks, one tank is used for both receiving and settling, and the second is used for dispensing. In the case of an airport with only one fuel tank, fuel must be allowed to settle prior to dispensing and use—necessitating good fuel management practices by the FBO or airport fuel operator.

Aircraft Loading

Once a batch of fuel has reached airport storage and the fuel quality has been verified, the fuel is prepared for delivery to the aircraft in one of the following ways:

- **Hydrant fueling system:** The fuel is piped to an underground hydrant system with a pit at each gate.
- **Vehicular refueling:** The fuel is loaded into refueling trucks or dispensers.
- **Central dispensing system:** The fuel is piped to a central dispensing pump.

A hydrant fueling system can be either a fuel pit system or a hydrant pit system. A fuel pit system consists of a hose, reel, filter, and air eliminator connected to an underground fuel line. These are positioned at each aircraft parking position and in most cases do not require any additional infrastructure. A hydrant pit system has a smaller footprint and does not include a hose assembly. Instead, a hydrant service cart or hydrant truck is used to connect the ground fueling point to the aircraft. Fuel pit systems and hydrant pit systems are the predominant fueling methods in use at large- and medium-sized airports around the world today.

Smaller airports that do not have an underground hydrant system installed generally use a fleet of refueling trucks for aircraft refueling. These trucks have self-contained pumps, filters, and metering systems and can have a capacity of up to 17,500 gallons of jet fuel. This amount is enough to fully fuel a Boeing 757 for a transcontinental flight. Generally, airports with a flight portfolio that includes flights exceeding this range or aircraft size have hydrant systems. Since the fuel flow rates of trucks are lower than those of large hydrant systems, fueling large aircraft can take significantly longer when using this method.

Other small airports, especially those that do not service large aircraft on a regular basis, use a stationary fuel dispensing system for refueling. With a stationary system, aircraft must taxi up to a remote fueling point that connects to a storage tank, which can be either aboveground or underground, depending on the system design. This type of fueling system is generally seen at airports that primarily serve general aviation traffic, and the system itself is primarily associated with self-service fueling.

2.1.2 Jet Fuel Purchasing Mechanisms

Airlines have different ways to purchase fuel that are described based on where they take possession of the fuel. Understanding where and when airlines take title to the fuel is important with respect to tracking mechanisms for alternative jet fuel because it determines what documentation may be available at different steps of the supply chain and which parties may have access to that documentation.

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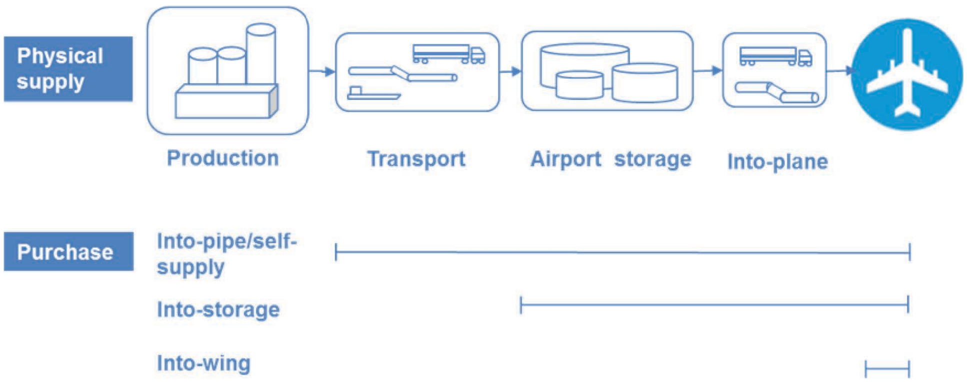

Figure 2. Diagram of jet fuel supply logistics and common purchasing mechanisms.

Three common jet fuel purchasing mechanisms are illustrated in the lower portion of Figure 2. The bars indicate the point in the supply chain at which the airline takes and retains title to the fuel. These common jet fuel purchasing mechanisms are further described in the following.

Into-Pipe/Self-Supply

The airline takes title to the product from the fuel company at a pipeline or truck terminal and then ships it to the airport. The airline has access to all the documentation from the point the fuel leaves the pipeline or truck terminal all the way to the wing of the aircraft.

Into-Storage

The fuel company ships the product to the airport, and the airline takes title to the fuel into-storage at the fuel farm. The airline would have access to the invoice and quality documents as the fuel enters the fuel farm. For information related to the fuel upstream of the fuel farm, the airline would need to request it from the producer or third-party vendor handling the logistics. Depending on the supply chain, this may involve more than one entity.

Into-Wing

The fuel company and possibly third-party providers are responsible for shipping the product to the airport and loading it into the aircraft, at which point the airline takes title to the fuel. The airline would need to request additional documentation from the fuel provider to understand where the fuel originated.

2.1.3 Inventory Tracking at the Fuel Farm

It is important to understand inventory processes at the fuel farm in order to integrate with and fully take advantage of those processes when developing tracking mechanisms for alternative jet fuel. Fuel farm operators play a key role with respect to keeping track of inventories for different users of the facility. This is especially true at airports with commingled storage, such as those managed by airport consortiums. At these locations, the fuel farm operator receives fuel on behalf of the airline(s) and, after completing all the proper testing and paperwork, puts it into shared storage. At the same time, the fuel farm operator works with the into-plane service providers to keep track of how much fuel they are loading into which aircraft. This is done via fuel tickets (paper or electronic), which provide information such as amount of fuel loaded, date, airline, aircraft tail number, and gate.

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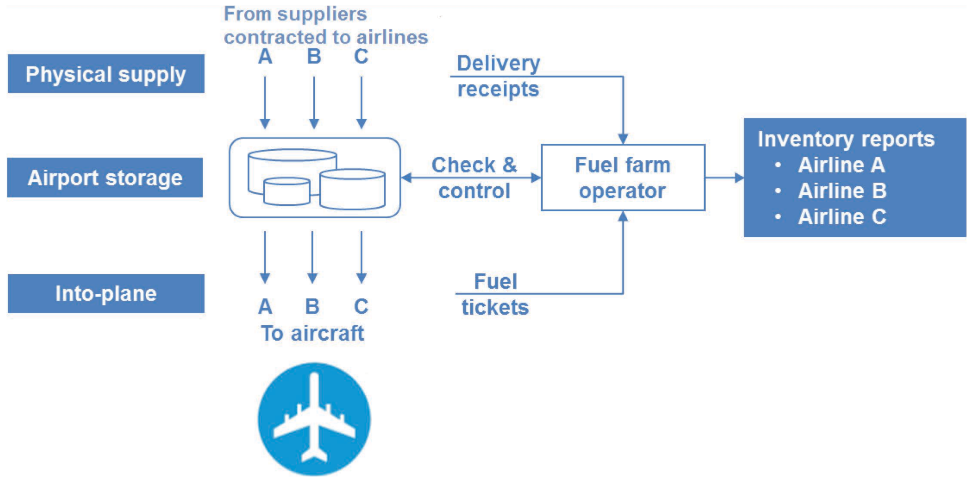

Figure 3. Schematic of fuel inventory tracking at airports with commingled storage.

Once the fuel enters commingled storage, physical tracking is not possible, and the fuel farm operator must rely on its accounting system to determine inventory levels for each of the parties storing fuel at the farm. The fuel farm operator uses delivery receipts and fuel tickets to keep track of fuel inventories for different customers. This is illustrated in Figure 3.

Airlines for America (A4A), an industry trade group formerly known as the Air Transport Association, has developed guidance materials to help fuel farm operators with fuel inventory practices. These guidelines are known as Spec 123: Procedures for the Accounting of Jet Fuel Inventory,[16] and while they are not mandatory, they are widely used at many airports in the United States. Spec 123 consists of a short handbook and two spreadsheets to assist with inventory tracking. At a very high level, the inventory tracking spreadsheet has entries for fuel receipts and fuel disbursements. In addition, the spreadsheet automatically helps to account for gains/losses and to explain variances in fuel inventory due to truck/pipeline receipts and changes in temperature. This kind of template has been considered by the researchers for this project as the basis for a tracking tool for alternative jet fuel.

Fuel consortiums are common at larger airports, and the situation explained here is fairly common across many airports. Arrangements and infrastructure are different from one airport to the next; therefore, the tracking system will need sufficient flexibility for the variations across airports. At smaller airports, inventory tracking may be simpler, especially if there is only one FBO providing fuel services, and all airlines purchase the fuel into-wing.

2.2 Introduction to Alternative Fuel Tracking Mechanisms

Tracking mechanisms for alternative fuels for use in road transportation have traditionally been developed to ensure the accurate communication of the sustainability attributes associated with those fuels from their point of manufacture to their point of consumption. Sustainability attributes vary depending on the specific framework being used and include information such as feedstock type, feedstock origin, production location and process, other inputs into the production process, and emissions and other discharges into the environment. It is critical to understand these tracking mechanisms for the purposes of this project because they are the foundation upon which to develop a tracking mechanism for alternative jet fuel. Tracking requirements vary according to the specific sustainability certification program and framework being used and are explored in more detail in the following.

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2.2.1 Overview of Sustainability Certification Frameworks for Alternative Jet Fuel

While no sustainability framework has been formally established for alternative jet fuels, numerous frameworks exist that potentially could be used to create mechanisms to evaluate and certify the sustainability attributes of alternative jet fuels.[17,18,19] These frameworks can be divided into two broad categories: regulatory and voluntary. Regulatory frameworks are mandatory in nature and tend to apply only in those jurisdictions where the legislation exists. Examples of regulatory frameworks are the Renewable Fuel Standard (RFS) in the United States and the European Union Renewable Energy Directive (EU RED) in Europe. Voluntary frameworks are not mandatory; they exist to provide businesses and other private entities a means by which to certify the sustainability attributes of their alternative fuels even when a regulatory framework does not exist (or in addition to one). Examples of voluntary frameworks are the Roundtable for Sustainable Biomaterials (RSB) and the International Sustainability and Carbon Certification (ISCC) system. A more complete list and descriptions of regulatory and voluntary frameworks are presented in Appendix A.

While there are differences among all these frameworks, a common feature is the existence of a chain of custody (CoC). CoC refers to the chronological, physical, or electronic documentation of the acceptance/purchase, custody, control, transfer, and disposition of a product or its associated characteristics.[20] CoC is a key requirement in many alternative fuel voluntary certification and regulatory frameworks to ensure that the feedstocks and processes used in the production of the alternative fuel conform to said frameworks. Therefore, if applied to alternative jet fuels, CoC establishes a set of requirements on the mechanism for tracking alternative jet fuel that must be fulfilled in order for that fuel to comply with the appropriate framework and receive sustainability certification.

2.2.2 Chain-of-Custody Approaches for Alternative Fuels

In the case of alternative fuels for aviation or other uses, common CoC categories are (1) physical segregation, (2) mass-balance, and (3) book-and-claim. These categories are further described in the following.

Physical Segregation

In this CoC approach, the alternative fuel that has been certified[21] for sustainability remains physically separated from noncertified fuel beginning at the alternative jet fuel production facility (see Figure 4). Once the certified alternative fuel is produced, it remains physically segregated from noncertified fuel all the way to the airport and possibly into the aircraft wing. At no point in the supply chain is the fuel or any intermediate product mixed with noncertified equivalents, except when it is blended with conventional Jet A to meet ASTM quality certification requirements.

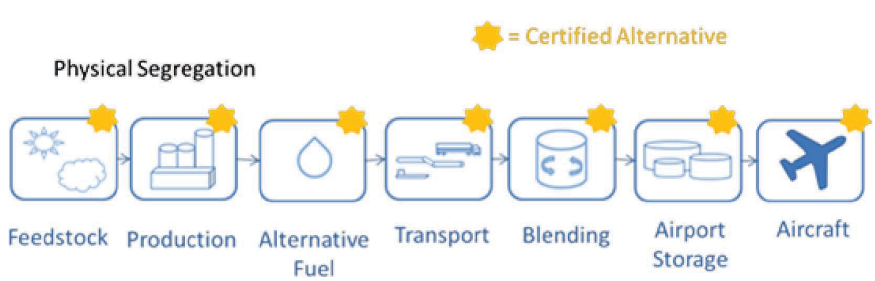

Figure 4. Schematic of a physical segregation CoC approach.

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Factors that make physical segregation feasible include a short supply chain with fewer actors involved and physical proximity to the airport. Therefore, physical segregation is easier to implement for aviation fuel if the alternative fuel production facility is located on or near airport property. Airports with excess fuel storage capacity and tanker truck (not hydrant) fueling systems can more readily implement physical segregation.

The main attributes of physical segregation are:

- It allows for the long-term study of a particular fuel's use in engines for performance and emissions monitoring;
- It allows clear-cut marketing claims without caveats or excessive customer education (e.g., this plane runs on 50% renewable fuel);
- It can assist with compliance with more stringent local airshed emissions requirements in National Ambient Air Quality Standards (NAAQS) nonattainment areas;[22]
- The location for blending with 50% (or greater) petroleum Jet A to meet ASTM standards is irrelevant so long as the batches of blended fuel with alternative content remain in separate storage from the 100% petroleum fuel; and
- It is easier to avoid double counting than in other CoC mechanisms.[23]

Mass-Balance

Here, the amount of certified[24] alternative fuel is tracked at each step of the supply chain (see Figure 5). Commingling with noncertified fuel is allowed, but the quantity of certified fuel is tracked as the fuel moves along the supply chain. Quantity tracking ensures that only the original amount of certified fuel is credited once the fuel reaches its final destination. For example, assume that 100,000 gallons of certified alternative fuel are produced and shipped via pipeline to a given airport. If 300,000 gallons of petroleum-based Jet A were mixed with the 100,000 gallons of alternative fuel, the delivery documentation would show a 25% mass-balance of alternative fuel in the shipment [100,000/(300,000 + 100,000)]. The recipient of the certified fuel is thereby informed that it can only take credit for 100,000 gallons of the certified fuel. While the alternative fuel is physically commingled with conventional fuel for transport and storage, it remains separate administratively through accounting procedures.

The mass-balance CoC mechanism tracks the proportion of certified alternative fuel molecules in the fuel supply from production to storage or delivery of alternative fuels. The mass-balance approach does not require additional physical infrastructure so long as common carrier transport providers and fuel service companies participate in tracking mass-balance information.

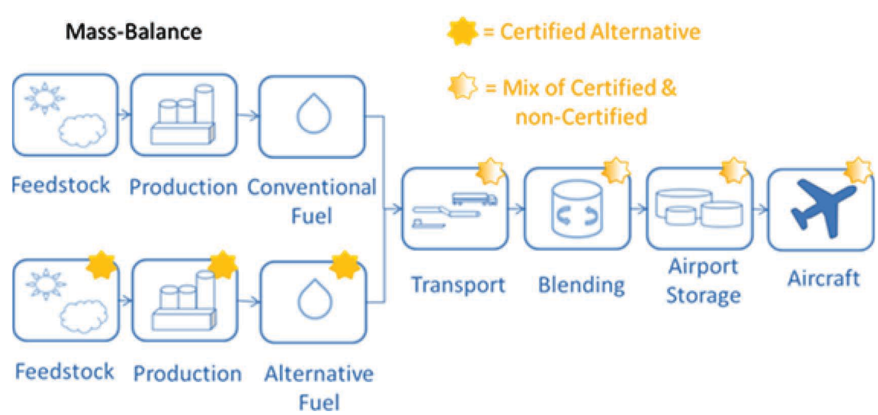

Figure 5. Schematic of a mass-balance CoC approach.

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The main attributes of mass-balance are:

- It allows for traceability at each stage of the supply chain;
- It may allow airports where alternative jet fuel is dispensed to claim reductions in air pollutants such as particulate matter (PM) and sulfur oxides; and
- It is easier to avoid double counting than in book-and-claim.[25]

Book-and-Claim

In book-and-claim, sustainability information related to the alternative fuel is decoupled from the physical product at some point along the supply chain. As shown in Figure 6, once the fuel is produced according to the requirements in the certification scheme, the certificate is separated from the fuel prior to transporting it to the airport. This means that the buyer can claim credits associated with the alternative fuel even though there is no requirement that the buyer consume the fuel. For example, a fuel is produced in Nevada and inserted into the conventional fuel supply chain, but the credits for that fuel's sustainability attributes are sold to an airport or airline in California.

The generation of Renewable Identification Numbers (RINs) under the U.S. Environmental Protection Agency's (U.S. EPA) RFS is an example of a book-and-claim system. In this system, fuel producers book one RIN for each gallon of fuel produced. RINs associated with volumes of fuel sold may be conveyed to the buyer of the fuel or claimed separately by an RIN buyer. This system allows parties with surplus RINs to sell them to parties in deficit with respect to their renewable volume obligations (RVOs) without having to physically transfer a corresponding volume of fuel. Obligated parties use this market-based mechanism to achieve compliance with their RVOs assigned by the EPA under the Renewable Fuel Standard 2 (RFS2). The RSB is developing a book-and-claim CoC method that may be used with alternative jet fuel.

As with mass-balance, book-and-claim does not require additional infrastructure for handling alternative jet fuel, but a robust accounting system between the producers and the final users is necessary to guard against duplication, double counting, mistakes, or fraud. (As mentioned earlier, end-to-end auditing in book-and-claim is no longer possible after alternative fuel molecules are introduced into the fuel supply system.) When considering book-and-claim for sustainability information, if quality information by fuel batch is already being tracked down to the airport level, then the additional burden of including sustainability information that allows traceability and auditability back to the fuel producer should be small.

The main attributes of book-and-claim are:

- There is no new transportation or storage infrastructure or equipment required from refinery to aircraft wing; and
- It can be used as a platform to introduce the trading of emissions credits between the different sellers and buyers of alternative fuels.

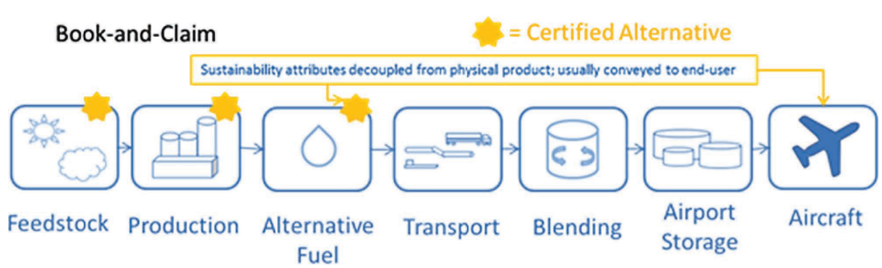

Figure 6. Schematic of a book-and-claim CoC approach.

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Hybrid Chain of Custody

In practice, some situations might suggest shifting the CoC approach at defined points between raw feedstock and aircraft wing. A hybrid CoC approach may be used in order to simplify CoC tracking and meet several voluntary standards and alternative fuel requirements of multiple jurisdictions all at once. How the CoC method for a product may be hybridized depends on customer expectations, obligations for compliance by supply chain operators, limitations of physical infrastructure, testing capabilities, current accounting practices, and affordability.

One hybrid approach used in the road transportation sector combines mass-balance and book-and-claim.[26] It uses mass-balance from fuel production up to a defined control point. Beyond that control point, book-and-claim is used to track the progression of the alternative fuel and its sustainability attributes along the supply chain.

2.2.3 Chain-of-Custody Examples

CoC is now common in industries where products with different sustainability attributes exist in the same marketplace and where products with superior sustainability performance can demand a price premium. [While this is true for many products, it remains to be seen whether jet fuel (a commodity product) would be able to generate such a premium.] Supply chain management for sustainability of alternative jet fuel might benefit from evaluating the benefits and impacts of the attributes of CoC programs implemented in other economic sectors.

Organic Food Industry Uses Physical Segregation

Organic farm products are currently a good example of the physical segregation CoC method. In response to consumer demands for food that is produced with fewer chemicals and the use of agricultural practices that are less harmful to land and water resources, the U.S. Department of Agriculture established uniform standards for organic products that claim environmental benefits when compared to conventional ones. To qualify as organic, the produce must be kept physically segregated from conventional produce beginning at the farm and through every link in the supply chain. Certified organic products may not be mixed with noncertified products at any stage of the supply chain, from farm field to grocery store shelf.[27]

Forest Products Industry Uses Mass-Balance

A mass-balance CoC method is used to meet the requirements of the nongovernmental Forest Stewardship Council (FSC). The FSC certification applies to forest products, such as lumber, sawdust, woodchips, and pulp for paper. Beginning with their harvest in certified forests, sustainably produced forest products are tracked along the supply chain from woodlot to mill and beyond to the distribution networks that supply retail hardware stores and the printing industry. Certified CoC controls ensure that FSC-compliant wood and fiber are marked in accordance with the FSC standard. FSC allows for the mixing of FSC-certified products and non–FSC-certified products under certain circumstances, making it a mass-balance CoC system.[28] FSC has rules for what types of noncertified products the certified products may be mixed with. FSC exercises strict control over the use of its trademarks so that only wood and paper products that use fiber derived from FSC-managed forests can bear the FSC mark. FSC certification of forests is widespread in North America and Europe (each with more than 60 million hectares of certified forests).

Renewable Electricity Industry Uses Book-and-Claim

Power produced from renewable sources like solar or wind is indistinguishable to the electrical grid operator from power produced from coal or natural gas. As such, Renewable Energy Certificates (RECs)[29] are generated by administratively separating the environmental attributes

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of electricity produced from renewable sources. RECs can be used for compliance with state-level statutes, referred to as renewable portfolio standards (RPSs), or are sold for use in voluntary GHG and sustainability programs. RECs are created, bought, sold, and accounted for in a book-and-claim CoC framework. The impossibility of tracking electrons produced from renewable sources makes mass-balance and physical segregation infeasible for renewable electricity. RPSs and the RECs associated with them exist in 29 states and the District of Columbia. States with RPSs accounted for 55% of total U.S. retail electricity sales in 2012.[30]

2.3 Tying It All Together

The three logistics elements listed previously (physical supply, purchasing, and inventory tracking) are critical for determining how much fuel (conventional or alternative) has been delivered and consumed at a given airport (see Figure 7). They reflect the mechanisms in place today to track conventional jet fuel use. CoC is an additional mechanism that could work in conjunction with the certification of alternative fuel operators throughout the supply chain. It might enable tracking of sustainability attributes of alternative fuels from production to fuel blending and delivery by defining methods for data collection and transmission.

The main elements needed to implement mechanisms for tracking alternative jet fuel based on existing logistics, infrastructure, and sustainability certification practices are summarized in Table 2. The elements identified in the table can be described as follows:

1. **Fuel delivery mechanism:** There are different ways to deliver jet fuel to an airport, including by pipeline, barge, rail, or truck. The type of delivery mechanism will greatly influence the ability to implement a certain fuel tracking approach. For example, for physical segregation, the need to keep the fuel segregated at all times favors fuel deliveries by truck, rail, and, to some extent, barge. Pipeline delivery of segregated fuel would be more difficult to achieve unless there were dedicated pipeline access to the airport from a refinery or terminal and the ability to physically ship and keep batches of alternative jet fuel separated.

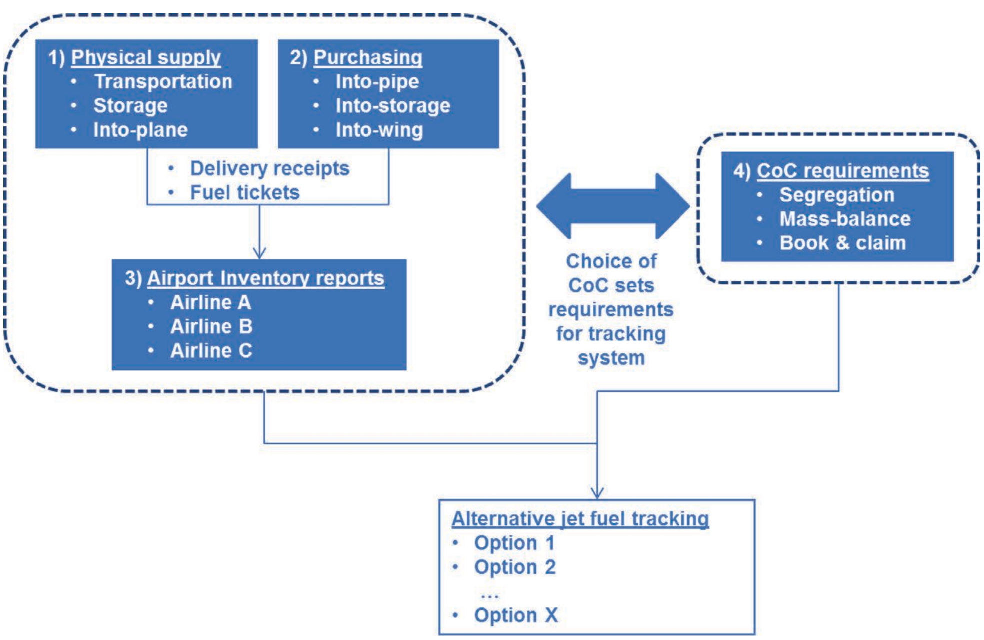

Figure 7. Key elements for the development of a tracking system for alternative jet fuel.

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Table 2. Main elements needed to implement jet fuel tracking mechanisms.

Element	Conventional Jet Fuel	Alternative Jet Fuel			
		Physical Segregation	Mass-Balance	Book-and-Claim	Hybrid
Fuel delivery mechanism to the airport	√	√√√	√	√	√
Fuel logistics at the airport	√	√√√	√	√	√
Blending location		√	√	√	√
Data aggregation and management	√	√	√	√√√	√√√
Auditing	√	√	√√√	√√√	√√√

Legend: √ – applies √√√ – strongly applies.

2. **Fuel logistics at the airport:** Similar to the previous element, fuel farm storage and into-plane operations can have a great influence on fuel tracking mechanisms. For example, if most of the storage at the airport is commingled and the primary means for into-plane refueling is via hydrant, physical segregation becomes difficult to implement unless dedicated storage and refueling trucks can be made available.
3. **Blending location:** The point at which alternative jet fuel is blended with conventional fuel is of critical importance for fuel tracking mechanisms. The neat, unblended alternative jet fuel cannot enter the conventional jet fuel supply chain until it has been blended and the blend has been certified to ASTM standards. Thus, up to the blending location, the alternative jet fuel has to be kept segregated, which facilitates any of the tracking mechanisms, including physical segregation. Once the alternative jet fuel blend has been certified, it can enter the conventional jet fuel supply chain. At this moment, depending on how the fuel is transported to the airport and handled at the airport, different tracking mechanisms may be easier or more difficult to implement, as discussed previously.
4. **Data aggregation and management:** A main component of tracking mechanisms is to identify, aggregate, and manage the relevant product volume, quality, and sustainability information associated with alternative jet fuel. Implementation of this element will be different depending on the selected tracking mechanism. For example, for physical segregation, since the fuel molecules and the sustainability information travel together, it is easier to track both as they move through the system. In contrast, in a book-and-claim or hybrid approach, the fuel molecules and the sustainability information are separated at some point in the supply chain, and this needs to be taken into account when designing the system. This may require a centralized third party to collect and manage all the data.
5. **Auditing:** A critical element for any mechanism for tracking alternative jet fuel is the ability to audit and verify the integrity of the data. This is particularly important to approaches such as book-and-claim that rely on data management to establish the connection between fuel molecules and their sustainability attributes. Having a robust and auditable collection and documentation system that also prevents double counting of credits such as GHG emissions reductions is important for stakeholders interested in environmental or other credits associated with alternative jet fuel use.

A summary of documents and data associated with each of these key elements is presented in Table 3. While not exhaustive, this list reflects the main information that may need to be available according to current practices along the supply chain. These options address the needs of airports and other supply chain stakeholders identified in the previous section.

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Table 3. Summary of data items and documents associated with the key elements for development of a tracking system for alternative jet fuel.

Data Items	Generated Document(s)	Information
1) Physical supply	- RCQ/COA - Bill of lading	- Fuel specification, specification test results, manufacturing facility, manufacture date, batch number, volume - Product specification, seller, buyer, point of origin/destination, volume, batch number, date
2) Purchasing	- Invoice	- Product specification, seller, buyer, point of uplift/transfer of title, volume, price, batch number, date
3) Airport inventory	- Fuel ticket	- Volume, airline name, flight number, aircraft tail number, date
4) CoC information	- Proof of sustainability	- From feedstock supplier/processor: sustainability certification of feedstock (archived by producer), feedstock mass (archived by producer) - From fuel producer: life-cycle CO_2 estimate,[1] pathway identifier (ID),[2] sustainability certification of fuel[3] - From fuel handlers (including FBOs, fuel farm, and into-plane operators): blend proportion

Notes: (1) This is found by utilizing life-cycle assessment tools using data supplied to the fuel producer by the feedstock producer, the fuel producer's own process inputs, and estimates of downstream processes. In RFS2 and RSB, for example, the GHG estimate is computed by the fuel producer and then verified by the regulator or a third party. (2) Pathway ID describes the feedstock, fuel production process, and the fuel type. In the RFS2, pathways must receive prior approval from the U.S. EPA in order to qualify for RINs. For more information, see http://www.epa.gov/otaq/fuels/renewablefuels/new-pathways/what-is-a-fuel-pathway.htm. (3) Certified fuel must be made from certified feedstock in a certified conversion process. Requirements for certification of feedstock and certification of fuel vary by regulation and voluntary standard. Receiving certification requires many data elements, but certification simplifies the need for data element tracking on behalf of the end user.

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CHAPTER 3

Detailed Discussion of Tracking Mechanisms

3.1 Introduction

As discussed in Chapter 2, the most common approaches for tracking alternative fuels are physical segregation, mass-balance, and book-and-claim. In addition, hybrid approaches combining these mechanisms are possible. For example, a mass-balance approach could be employed up to the point where alternative fuel is blended with conventional jet fuel or delivered to an airport fuel farm. From that point forward, a book-and-claim method could be used. These tracking mechanisms are explained in detail in the following.

Note that this chapter covers only the supply chain downstream from the producer of alternative fuel. The upstream components of alternative fuel production include the cultivation or collection of feedstock, any intermediate processing, and transportation of the resulting material to the location where fuel is produced. The details of the upstream portion of the alternative jet fuel supply chain vary depending on the type of feedstock used. Although important, the main interest of both airports and fuel purchasers in the upstream processes is the knowledge that the sustainability aspects of the alternative fuel have been reviewed and certified for sustainability by a third party. Evidence of certification of the participating operators in the supply chain is publicly available information and does not need to accompany fuel delivery documentation. Evidence of the downstream certification of the sustainability of alternative fuel, on the other hand, does need to be conveyed to the purchaser through documentation associated with each purchase and hence is the focus of this chapter. (The descriptions in this chapter assume that the buyer is purchasing the physical fuel as well as the sustainability attributes associated with it. The researchers have not considered a case in which a buyer is just buying the sustainability credits associated with a fuel without buying the fuel.)

3.2 Detailed Presentation of Tracking Mechanisms

3.2.1 Physical Segregation

Overview

Physical segregation means that at no point is certified alternative fuel or alternative fuel blend commingled with noncertified fuel.[31] Common supply chain equipment such as tanks, rail cars, trucks, barges, and pipelines that are used to transport various liquids can be used with physical segregation as long as sufficient controls are followed to prevent commingling of the alternative fuel with noncertified batches of fuel. In this CoC method, the airport fuel farm would most likely need to keep a separately designated tank for alternative fuel storage, or alternative fuel would have to be trucked directly from the blending location to the aircraft wing.

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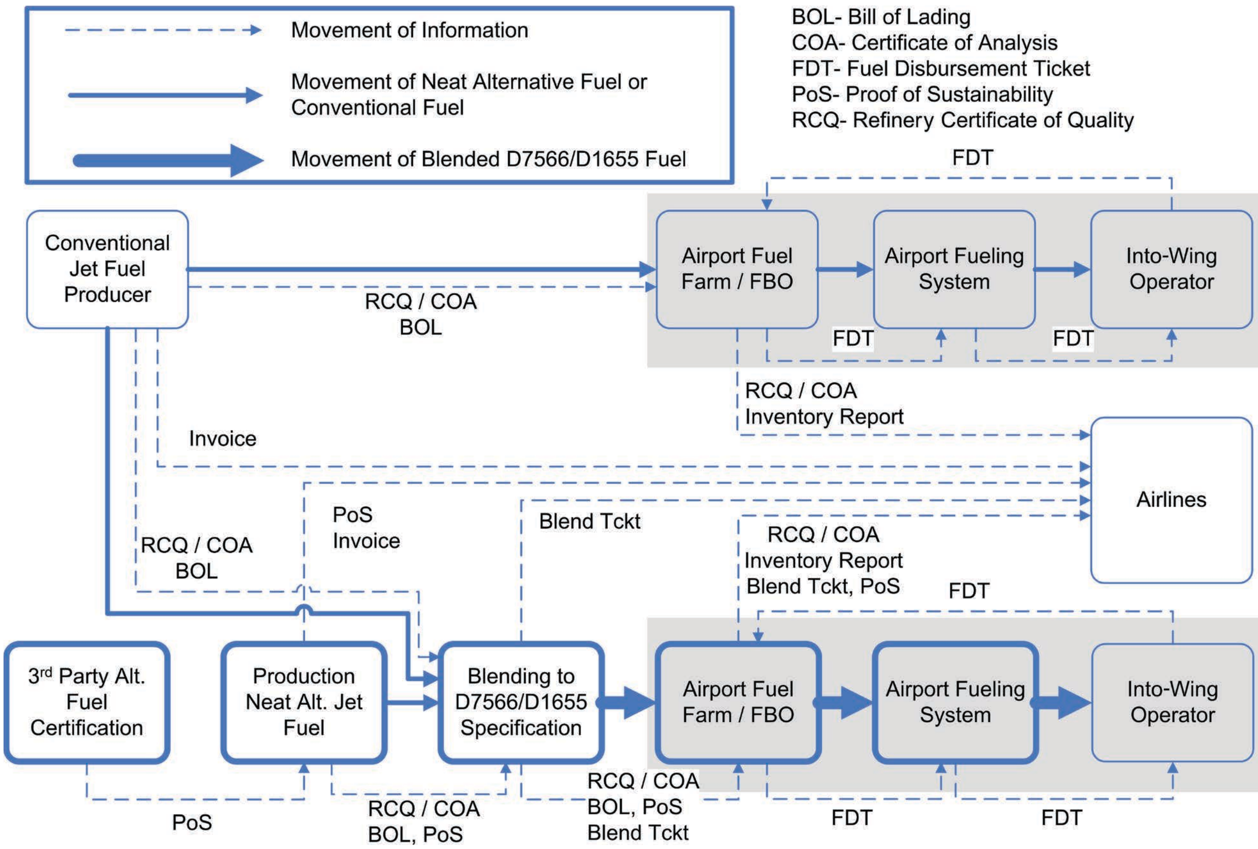

Figure 8. Downstream portion of the alternative jet fuel supply chain using the physically segregated CoC method.

Figure 8 shows the downstream movement of fuel from the fuel producer to the wing of the aircraft and the corresponding flow of information from the fuel producer to the blender, fuel transporter, fuel farm operator, airport fuel service provider, and the airlines. Gray areas indicate facilities on airport property; boxes with thicker lines indicate new infrastructure.

As the figure shows, physical segregation completely isolates blended alternative jet fuel from conventional fuel after the blending step, creating two separate pathways from production to wing. The box second from the left at the bottom represents the alternative jet fuel producer. From this box, the path of the produced fuel and accompanying sustainability information are tracked to the airlines as fuel purchasers and tracked to the airport. After production, neat alternative fuel must be blended before it can complete its journey to the aircraft wing. Blending is shown as taking place at a location between the production facility and the airport fuel farm, although blending may also be undertaken at the production facility or at the fuel farm itself if desired for logistical purposes. However, the blending location does not change the requirements for physical segregation. Physically segregated blended alternative fuel will be transferred to dedicated tanks at the airport tank farm. From there, the fuel is ready to be delivered to the aircraft via segregated infrastructure such as dedicated refueler trucks.

The sustainability information associated with the alternative fuel can follow the same path to the airport as the physical molecules. This can be in the form of a separate document [e.g., a proof of sustainability (PoS) form], or it can be included as part of the documentation associated with the physical fuel. For example, if the fuel is shipped by truck, additional information on the sustainability attributes of the fuel can be added to the bill of lading (BOL). Alternatively, sustainability information could be transmitted with invoicing information instead of with the alternative fuel.

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The fuel farm operator takes receipt of the alternative fuel and any associated documentation, including the PoS form, if available. This information is then forwarded to the airline along with fuel inventory and consumption information. The airport operator may obtain summaries of alternative fuel use directly from the airline or the fuel farm operator.

Infrastructure and Functional Elements

The main infrastructure and functional elements required to implement this tracking mechanism are:

1. **Fuel delivery mechanism:** The need to keep the fuel segregated at all times favors fuel deliveries by truck, rail, and, to some extent, barge. Pipeline delivery of segregated fuel would be more difficult to achieve unless there were dedicated pipeline access to the airport from a refinery or terminal and the ability to physically ship and keep batches of alternative jet fuel separated.
2. **Fuel logistics at the airport:** Dedicated storage and refueling trucks.
3. **Blending location:** Dedicated blending tanks with sufficient storage capacity to keep the neat alternative fuel and the blended fuel segregated.
4. **Data aggregation and management:** Airport fuel-farm operators need to track deliveries of alternative fuel into airport storage and loading of alternative fuel into aircraft. The information should allow fuel buyers to reconcile the amount of alternative fuel purchased with volumes actually loaded into their aircraft. Given appropriate data-sharing agreements between the airport operator and fuel buyers, the fuel farm operator would be in a position to share all or part of this information with the airport operator. Existing fuel tracking and inventory practices, such as those described in Spec 123, could be the basis for developing a data aggregation and management system for alternative fuels.
5. **Auditing requirements:** Auditing by the purchaser of alternative jet fuel may be performed at two levels. First, monthly reconciliation reports may be audited on a periodic basis to confirm that volumes and types of alternative fuels received at the fuel farm match invoiced amounts and that purchased fuel meets the sustainability requirements specified by the purchaser. Second, on a periodic basis, an audit of the producer of alternative fuel may be performed to ensure that the facility selling alternative fuel complies with applicable voluntary certification and regulatory requirements. This audit may be performed by individual alternative fuel purchasers or by an industry organization representing them.

Data Items

The main data items that might be necessary for implementing a tracking mechanism based on physical segregation are:

1. **Physical supply:** For transportation by truck and rail, shippers complete a BOL that provides information required by U.S. DOT for common carriers. This documentation may physically accompany the shipment or may be made available electronically through a transportation provider's website. For pipeline shipments, meter tickets are typically provided. In addition to this information, the shipment may be accompanied by an RCQ or COA. This documentation may change hands as the product flows through the supply chain and must accompany the fuel as it is received by the fuel farm operator at the airport. The data with these documents may include:
   - Delivery date and location;
   - Batch number;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location, and blending date;
   - Alternative fuel pathway identifier (ID)[32] or production facility name;

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- Alternative fuel feedstock type and production process; and
- CoC method.

These data may be included as part of the quality documents (e.g., RCQ/COA) or in a separate document.

2. **Purchasing:** Invoices reflecting the sale of the alternative fuel should be generated by the producer and delivered to the buyer. Invoices do not need to travel with the physical fuel and can be transmitted directly to the fuel buyer. The data with these documents may include:
   - Delivery date and location;
   - Batch number;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location, and blending date;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process;
   - CoC method; and
   - Price.

   Alternatively, a PoS form with the sustainability information listed here can be attached to invoices regularly used for conventional jet fuel.
3. **Airport inventory:** The fuel farm operator maintains inventory of fuel and alternative fuel by keeping track of fuel deliveries and disbursements. As described previously, fuel deliveries are recorded via BOLs or pipeline meter tickets. Fuel tickets keep track of fuel loaded into individual aircraft. Inventory reports and copies of fuel tickets are routinely forwarded to fuel buyers. Information on fuel disbursement tickets (FDTs) may include:
   - Date and location;
   - Aircraft tail number and flight number;
   - Batch number;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location, and blending date;
   - Alternative fuel pathway ID or production facility name; and
   - CoC method.
4. **Chain-of-custody information:** The producer of the alternative fuel is responsible for completing a PoS form and delivering it to the purchaser of the fuel. The PoS form may accompany the physical fuel as it is transported to the airport fuel farm, or it may be sent directly to the fuel buyer. The data with these documents may include:
   - Delivery date and location;
   - Transportation mode to delivery point;
   - Batch number of alternative fuel;
   - Batch number of conventional fuel used for blending;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location, and blending date;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process;
   - CoC method;
   - Estimated greenhouse gas emissions associated with the alternative fuel (grams of CO_2e/MJ and grams of CO_2e/gal);[33]
   - Estimate of life-cycle assessment (LCA) CO_2e footprint for the blended fuel;
   - Sustainability standard to which the alternative fuel complies;
   - Name of the third-party certification body;
   - Applicable on-product claim of sustainability; and
   - If desired, credits associated with the alternative fuel (e.g., RIN numbers).

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Roles and Responsibilities

The main roles and responsibilities associated with implementing a tracking mechanism based on physical segregation are shown in Table 4.

Some fuel farm stakeholders feel that physical tracking of the alternative fuel molecules should cease upon arrival of the fuel at the airport fuel farm. Continued tracking would place considerable administrative burden on the fuel farm operator in addition to necessitating a dedicated storage tank and a dedicated fuel dispensing truck. Physical segregation of blended alternative

Table 4. Summary of main roles and responsibilities for physical segregation.

Tracking System Element	Role	Responsibility Associated with Tracking Alternative Fuels
Producer of alternative fuel	- Produce alternative fuel and ensure that it meets quality and sustainability requirements - Coordinate transportation of alternative fuel to delivery location	- Generate and transmit physical supply documents, invoice, and PoS form
Blender	- Blend neat alternative fuel with conventional Jet A and ensure that alternative fuel blend meets the D7566 specification - Coordinate transportation of blended fuel to next delivery location	- Generate and transmit physical supply document for blended fuel - Transmit PoS form associated with alternative fuel
Transporter of alternative fuel	- Transport alternative fuel	- Transmit physical supply documents - May transmit invoice and PoS form associated with alternative fuel
Fuel farm operator	- Oversee fuel quality control - Manage inventories at airport fuel farm	- Receive physical supply documents - May receive invoice and PoS form associated with alternative fuel - Archive physical supply documents and fuel tickets - Maintain fuel farm inventory - Provide inventory reports on a regular basis
Into-plane operator	- Take fuel from fuel farm and deliver it to the aircraft	- Generate fuel tickets associated with fuel loadings into aircraft - Provide copies of fuel tickets to fuel farm operator and fuel buyer
Airline	- Purchase alternative fuel	- Define tracking requirements for alternative fuel - Receive fuel inventory reports from tank farm operator and fuel tickets from into-plane operator and reconcile with invoices - Can generate reports associated with use of alternative fuel and related sustainability information
Airport operator	- May prepare summaries of alternative fuel usage - Manage communications	- May arrange with airlines to share volume of alternative fuel and sustainability information - May record aggregate usage of alternative fuels by all airlines at the airport - May report usage of alternative fuel as part of airport emissions inventories - May inform relevant stakeholders of known environmental benefits from usage of alternative jet fuels at airport

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fuel at the airport fuel farm is not necessary from a safety or quality perspective since the fuel must conform to ASTM D1655 just like 100% conventional fuel, meaning that it is as safe as conventional fuel to be transported, stored, and dispensed using common airport fuel-farm infrastructure and equipment.

3.2.2 Mass-Balance

Overview

In the mass-balance approach, the fuel producer documents the physical mass (e.g., metric tons or volume convertible to mass) of sustainability-certified fuel shipped in a batch. The batch may also contain noncertified fuel whose sustainability characteristics are not tracked.[34] Once commingled, the molecular identity of the certified alternative jet fuel is lost, but documentation of the mass of certified fuel present in the batch continues to be tracked through the supply chain. Fuel producers who use the mass-balance CoC method must maintain an accounting balance of certified fuel sold versus certified fuel produced. The balance of alternative fuel input and output can be accounted for over a discrete period or continuously. For example, if the period for balancing is 1 month, a fuel producer that makes 50,000 gallons of certified fuel over the course of a month may only sell 50,000 gallons of certified fuel in that same month. Within the fuel producer's accounting system, the certified fuel is accounted for separately from any noncertified fuel shipped in the same batch. The mass of certified fuel produced must equal or exceed the mass of certified fuel sold over the balancing period.[35] The length of the balancing period is defined in third-party certification program rules.

Figure 9 shows the movement of alternative fuel from the producer to the wing of the aircraft and the corresponding flow of information from the fuel producer to the airport fuel service provider, to the fuel purchaser, and to airport management. In the diagram's lower left corner, the box labeled "3rd Party Alt. Fuel Certification" represents the organization that certifies the upstream portion of the alternative fuel supply chain.

The box second from the left at the bottom of the figure represents the alternative jet fuel producer. After production, neat alternative fuel must be blended before it can complete its journey to the aircraft wing. Blending may take place at the production facility, at another location near the airport, or at the airport tank farm. Figure 9 illustrates a situation where alternative jet fuel is blended after leaving the fuel production site and is then transported to airport storage and dispensing tanks. In the mass-balance approach, the mass (or volume convertible to mass) of sustainability-certified alternative fuel included in any batch is documented. This information accompanies the blended alternative fuel to the airport fuel farm.

There are two possible fates for a mass-balance fuel batch once it reaches the airport fuel farm. The first possibility is that the identity of the batch is preserved and the fuel is transferred to a tank or tanks dedicated to alternative fuel dispensing. In this option, it remains possible for the owner of the fuel to take delivery of fuel from a tank from which the mass of alternative jet fuel is known because each addition to the tank is composed of batches of mass-balance fuel that contain a known amount of sustainability-certified alternative jet fuel. In many respects, this CoC method resembles physical segregation because the identity of the fuel is maintained to the fuel farm tank level. In theory, if all batches of mass-balance fuel delivered to the tank were of identical volume and each time contained the same volume of alternative fuel, then the airlines into whose planes the fuel was dispensed could know the exact proportion of alternative fuel that was consumed by each flight.

The second possible fate for a mass-balance batch of alternative fuel is that it is treated as any other fuel received by the fuel farm and assigned to shared storage. In this case, the identity of the certified alternative fuel is lost at the point that it enters the common fueling system. The fuel purchaser still

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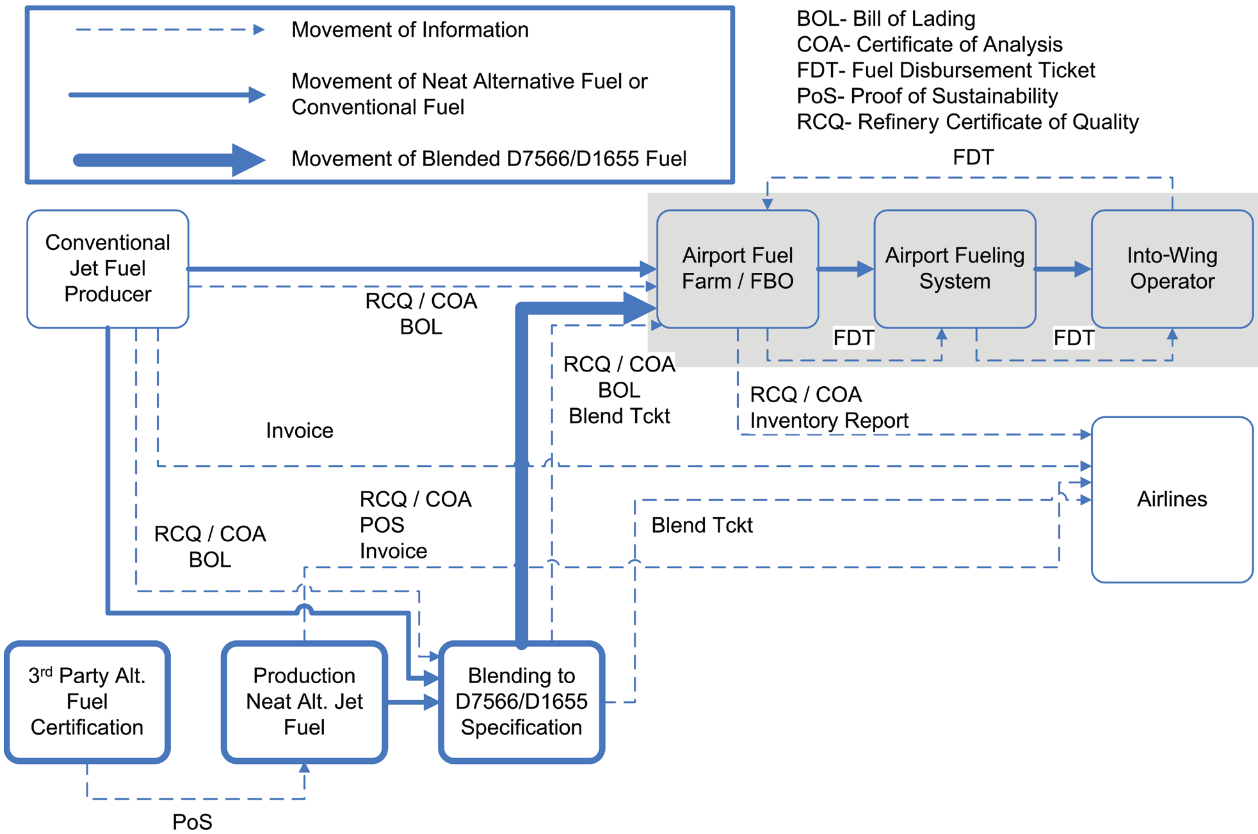

Figure 9. Downstream portion of the alternative jet fuel supply chain using the mass-balance CoC method.

receives information about the mass (or volume convertible to mass) of alternative fuel received at that airport location but is no longer able to follow the molecules into the wings of its aircraft or those of any other aircraft operator receiving fuel from common fuel-farm tanks.

The sustainability information associated with the alternative fuel can follow the same path to the airport as the physical molecules. This can be in the form of a separate document (e.g., a PoS form) or it can be included as part of the documentation associated with the physical fuel. For example, if the fuel is shipped by truck, additional information on the sustainability attributes of the fuel can be added to the BOL. If the fuel is shipped by pipeline, transmitting the sustainability information may be more challenging since the meter tickets associated with pipeline deliveries use a standardized format that would need to be changed. Alternatively, sustainability information could be transmitted with invoicing information instead of with the alternative fuel.

The fuel farm operator takes receipt of the alternative fuel and any associated documentation, including the PoS form. This information is then forwarded to the airlines along with fuel inventory and consumption information. The airport operator may obtain summaries of alternative fuel use directly from the airline or the fuel farm operator.

Infrastructure and Functional Elements

The main infrastructure and functional elements required to implement a mass-balance tracking mechanism are:

1. **Fuel delivery mechanism:** Unless the option of identity preservation to a final dispensing tank is selected, mass-balance batch shipments may use any fuel delivery mechanism. If identity

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preservation to a final dispensing tank is desired, the need to keep the fuel segregated until delivery favors fuel deliveries by truck, rail, or barge. Pipeline delivery of segregated fuel would be more difficult to achieve with identity preservation unless there were dedicated pipeline access to the airport from a refinery or terminal and the ability to physically ship and keep batches of alternative jet fuel separated.

2. **Fuel logistics at the airport:** Use of common tanks and dispensing methods is possible except in the case of identity preservation to the final dispensing tank. In that case, dedicated storage and refueling trucks would be needed.
3. **Blending location:** Dedicated blending tanks with sufficient storage capacity to keep the neat alternative fuel and the blended fuel segregated.
4. **Additional fuel logistics infrastructure:** Except where identity preservation is desired, no additional fuel handling, storage, and distribution infrastructure is required.
5. **Data aggregation and management:** Airport fuel-farm operators need to track deliveries of alternative fuel into airport storage and loading of alternative fuel into aircraft. In the case where the identity of mass-balance fuel batches is preserved to an airport dispensing tank, and the fuel buyer is interested in identity preservation all the way to the wing of the aircraft, into-plane operators should provide fuel tickets representing alternative fuel loaded into individual aircraft. Given appropriate data-sharing agreements between the airport operator and fuel buyers, the fuel farm operator would be in a position to share all or part of this information with the airport operator. Existing fuel tracking and inventory practices, such as those described in Spec 123, could be the basis for developing a data aggregation and management system for alternative fuels.
6. **Auditing:** There are two levels of auditing that could be performed by the purchaser of alternative jet fuel. First, monthly reconciliation reports should be audited on a periodic basis to confirm that volumes and types of alternative fuels received at the fuel tank farm match invoiced amounts and that purchased fuel meets the sustainability requirements specified by the purchaser. Second, on a periodic basis, an audit of the producer of alternative fuel could be performed to ensure that the facility selling alternative fuel complies with applicable voluntary certification and regulatory requirements. This audit may be performed by individual alternative fuel purchasers or by an industry organization representing them.

Data Items

The main data items necessary for implementing a tracking mechanism based on mass-balance are:

1. **Physical supply:** For transportation by truck and rail, shippers complete a BOL that provides information required by U.S. DOT for common carriers. This documentation may physically accompany the shipment or may be made available electronically through a transportation provider's website. For pipeline shipments, meter tickets are typically provided. In addition to this information, the shipment may be accompanied by an RCQ or COA. This documentation may change hands as the product flows through the supply chain and must accompany the fuel as it is received by the fuel farm operator at the airport. The data for tracking alternative fuels may include:
   – Delivery date and location;
   – Batch number;
   – Total volume;
   – For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
   – Alternative fuel pathway ID or production facility name;

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- Alternative fuel feedstock type and production process; and
- CoC method.

These data may be included as part of the quality documents (e.g., RCQ/COA) or in a separate document.

2. **Purchasing:** Invoices reflecting the sale of the alternative fuel should be generated by the producer and delivered to the buyer. Invoices do not need to travel with the physical fuel and can be transmitted directly to the fuel buyer. The data with these documents may include:
   - Delivery date and location;
   - Batch number;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process;
   - CoC method; and
   - Price.

   Alternatively, a PoS form with the sustainability information listed here can be attached to invoices regularly used for conventional jet fuel.
3. **Airport inventory:** The fuel farm operator maintains inventory of conventional and alternative fuel by keeping track of fuel deliveries and fuel disbursements. As described previously, fuel deliveries are recorded via BOLs or pipeline meter tickets. Fuel tickets keep track of fuel loaded into individual aircraft. Inventory reports and copies of fuel tickets are routinely forwarded to fuel buyers. Information on fuel tickets may include:
   - Date and location;
   - Aircraft tail number and flight number;
   - Batch number;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process; and
   - CoC method.
4. **Chain-of-custody information:** The producer of the alternative fuel is responsible for completing a PoS form and delivering it to the purchaser of the fuel. The PoS form may accompany the physical fuel as it is transported to the airport fuel farm, or it may be sent directly to the fuel buyer. The data with these documents may include:
   - Delivery date and location;
   - Transportation mode to delivery point;
   - Batch number of alternative fuel;
   - Batch number of conventional fuel used for blending;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process;
   - CoC method;
   - Estimated greenhouse gas emissions associated with the alternative fuel (grams of CO_2e/MJ);
   - Estimate of LCA CO_2e footprint for the blended fuel;

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- Sustainability standard to which the alternative fuel complies;
- Name of the third-party certification body;
- Applicable on-product claim of sustainability; and
- If desired, credits associated with the alternative fuel (e.g., RIN numbers).

Roles and Responsibilities

The main roles and responsibilities associated with implementing a tracking mechanism based on mass-balance are shown in Table 5.

Table 5. Main roles and responsibilities for mass-balance.

Tracking System Element	Role	Responsibility Associated with Tracking Alternative Fuels
Producer of alternative fuel	- Produce alternative fuel - Generate quality documents (RCQ/COA) - Generate PoS form	- Ensure that alternative fuel meets quality and sustainability requirements - Coordinate transportation of alternative fuel to blender - Transmit RCQ/COA to blender - Transmit PoS form and invoice to fuel buyer
Blender	- Blend neat alternative fuel with conventional Jet A and ensure that alternative fuel blend meets the ASTM D7566 specification - Coordinate transportation of blended fuel to next delivery location	- Generate and transmit physical supply document for blended fuel - Transmit PoS form associated with alternative fuel
Transporter of alternative fuel	- Deliver neat alternative fuel to blender - Deliver blended fuel to airport fuel farm	- Meet regulatory requirements for safe transport of alternative fuel - Transmit shipping documentation, COA, and PoS form to fuel buyer
Fuel farm operator	- Oversee fuel quality control - Manage inventories at airport fuel farm - Record information	- Receive alternative fuel shipment and log relevant information - Perform ASTM D1655 quality check on fuel - In case of identity preserved, transfer alternative fuel to specified tank - Provide fuel purchaser with monthly log of delivered alternative fuel and associated sustainability information
Into-plane operator	- Deliver fuel to aircraft wing	- In case of identity preserved, ensure that fuel from segregated tank is transported to the aircraft for loading - Provide fuel ticket to fuel farm operator and fuel buyer
Airline	- Purchase alternative fuel	- Define requirements for alternative fuel - Receive fuel delivery logs from tank farm operator and reconcile with invoices - Provide airport operator summary of information about purchased alternative fuel and its sustainability information
Airport operator	- May prepare summaries of alternative fuel usage - Manage communications	- May arrange with airlines to share volume of alternative fuel and sustainability information - May record aggregate usage of alternative fuels by all airlines at the airport - May report usage of alternative fuel as part of airport emissions inventories - May inform relevant stakeholders of known environmental benefits from usage of alternative jet fuels at airport

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3.2.3 Book-and-Claim

Overview

The defining element of the book-and-claim CoC method is the use of credits representing sustainability attributes. "Credit" relates to an accounting unit within a third-party–administered book-and-claim system. Credits in units of one metric ton of neat alternative jet fuel are created when the fuel is produced and are booked with the book-and-claim system administrator. In the book-and-claim system, credits are accounting entries separate from the physical molecules of the underlying neat fuel they represent.

Figure 10 illustrates a potential book-and-claim system. It depicts the process from the point that a producer of alternative fuel registers the alternative jet fuel product with the book-and-claim administrator and shows how product credits subsequently flow through to the airlines. The figure demonstrates that the flow of alternative fuel to an airport tank farm and ultimately to the wing of an aircraft is completely separate from the documentation of book-and-claim credits. As in Figure 8 and Figure 9, Figure 10 illustrates a situation where alternative jet fuel is blended after leaving the fuel production site and then is transported to airport storage and dispensing tanks. Information about the transfer of the alternative fuel from common carrier to the airport fuel farm is conveyed on BOLs if shipped by truck or on meter tickets if shipped via pipeline. No sustainability information is required to be sent along with the physical fuel.

The book-and-claim system provides the greatest amount of flexibility to the purchaser of alternative jet fuel. In this system, claims associated with the use of alternative fuel are independent of the physical delivery of fuel sold into the fuel supply chain. Using book-and-claim, a fuel buyer

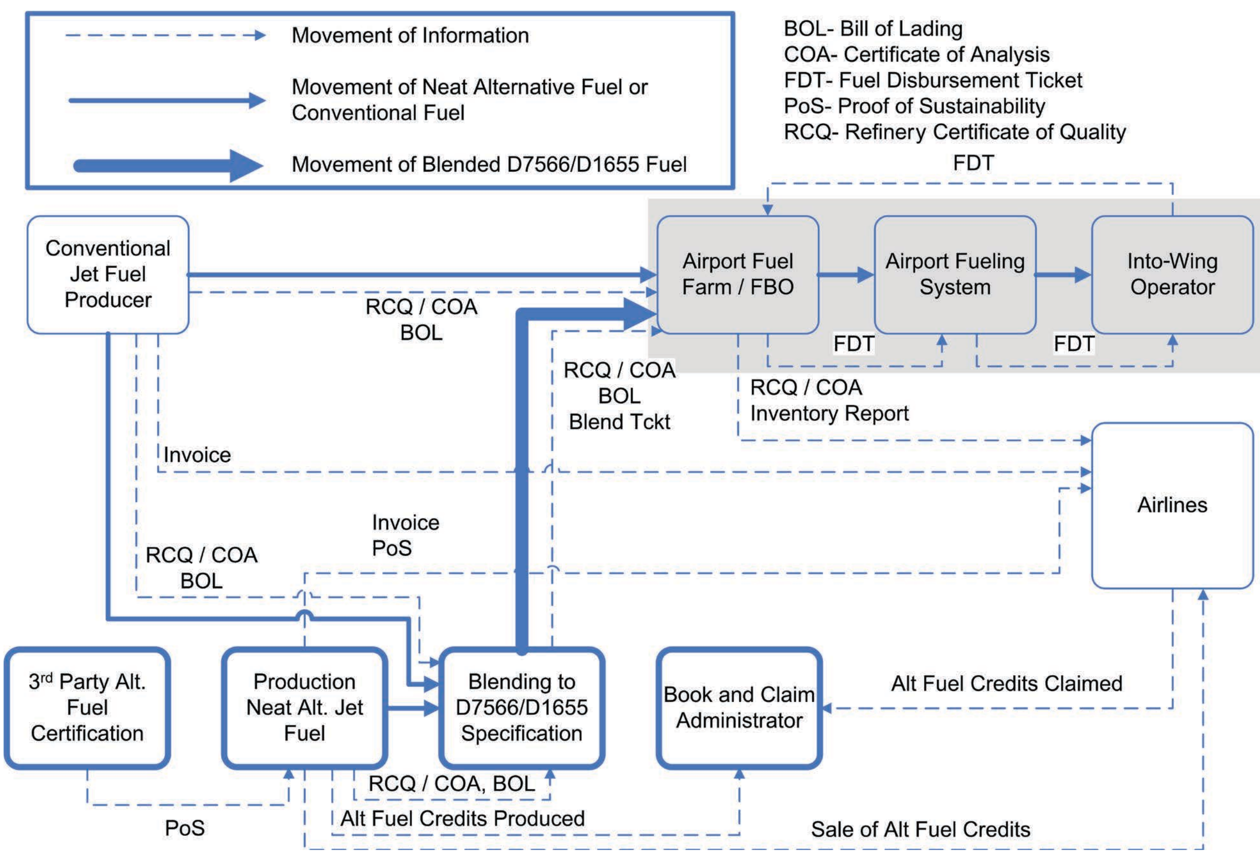

Figure 10. Downstream portion of the alternative jet fuel supply chain using the book-and-claim CoC method.

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takes title to all the attributes of alternative fuel but without the obligation to take physical delivery of it. Instead, the fuel produced in this system is commingled with conventional fuel and is treated as such in the supply chain.

Infrastructure and Functional Elements

The main infrastructure and functional elements that may be required to implement this tracking mechanism are:

1. **Fuel delivery mechanism:** Alternative fuel shipments under book-and-claim may use any fuel delivery mechanism.
2. **Fuel logistics at the airport:** Fuel may be stored in common tanks, and all dispensing methods are applicable.
3. **Blending location:** Dedicated blending tanks with sufficient storage capacity to keep the neat alternative fuel and the blended fuel segregated.
4. **Additional fuel logistics infrastructure:** No additional fuel handling, storage, or distribution infrastructure is required.
5. **Data aggregation and management:** The blended alternative fuel is now fully commingled in the supply chain, and it is no longer possible or necessary to track it separately; thus, existing mechanisms for tracking conventional fuel at the airport fuel farm are used. However, a system for tracking the sustainability information associated with the alternative fuel may be needed. These systems are expected to be operated and maintained by the entities performing the certification of the alternative fuel. For example, as mentioned previously, the electricity industry uses book-and-claim for compliance with state-level renewable portfolio standards, with states maintaining a tracking system and database (e.g., WREGIS[36]). For compliance with the Renewable Fuels Standard, the U.S. EPA maintains the EPA Moderated Transaction System (EMTS) to record all transactions involving RINs.
6. **Auditing:** The book-and-claim administrator bears primary responsibility for ensuring that sustainability information associated with alternative jet fuel is audited. The actual audits are performed by accredited third-party auditors. One of the purposes of these audits is to ensure that the producer of alternative fuel does not double count fuel production by registering credits for the same fuel that is sold with PoS documentation under another CoC method.

Data Items

The main data items necessary for implementing a tracking mechanism based on book-and-claim are:

1. **Physical supply:** No additional documentation from what is currently used for conventional jet fuel is necessary since the alternative fuel is expected to be fully commingled with the conventional fuel. Basic information related to the alternative fuel production, such as manufacturer and date of last quality certification, is expected to be included in the appropriate documents (e.g., BOLs, pipeline meters, or RCQs/COAs); however, there is no expectation that any sustainability information related to the alternative fuel will be included or transmitted along with the physical fuel.
2. **Purchasing:** Invoices reflecting the sale of the alternative fuel should be generated by the producer and delivered to the fuel buyer. Invoices are not expected to travel with the physical fuel and can be transmitted directly to the fuel buyer. The data with these documents may include:
   – Delivery date and location;
   – Batch number;
   – Total volume;
   – For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;

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- Alternative fuel pathway ID or production facility name;
- Alternative fuel feedstock type and production process;
- CoC method; and
- Price.

Alternatively, a PoS form with the sustainability information listed here can be attached to invoices regularly used for conventional jet fuel.

3. **Airport inventory:** No additional documentation from what is currently used for conventional jet fuel is necessary because the alternative fuel is expected to be fully commingled with the conventional fuel.
4. **Chain-of-custody information:** The producer of the alternative fuel is responsible for completing a PoS form and delivering it to the purchaser of the fuel. The PoS form is sent directly to the fuel buyer and does not need to travel with the fuel; thus, it is not expected that the airport fuel-farm operator would have access to this information. The data with the PoS form may include:

- Delivery date and location;
- Transportation mode to delivery point;
- Batch number of alternative fuel;
- Batch number of conventional fuel used for blending;
- Total volume;
- For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
- Alternative fuel pathway ID or production facility name;
- Alternative fuel feedstock type and production process;
- CoC method;
- Estimated greenhouse gas emissions associated with the alternative fuel (grams of CO_2e/MJ);
- Estimate of LCA CO_2e footprint for the blended fuel;
- Sustainability standard to which the alternative fuel complies;
- Name of the third-party certification body;
- Applicable on-product claim of sustainability; and
- If desired, credits associated with the alternative fuel (e.g., RIN numbers).

The producer of alternative fuel or the blender is responsible for registering credits equal to the mass of alternative jet fuel produced and sold under the book-and-claim CoC method. Airlines that purchase book-and-claim credits from the producer of alternative fuel or the blender are responsible for reporting their purchases to the book-and-claim administrator within a certain period of time. In addition, airlines may provide summary reports on their annual consumption of alternative fuels and purchase of credits to the public.

Roles and Responsibilities

The main roles and responsibilities associated with implementing a tracking mechanism based on book-and-claim are shown in Table 6.

3.2.4 Hybrid of Mass-Balance and Book-and-Claim

Overview

The mass-balance and book-and-claim CoC methods described previously can be deployed not only singly, but also in combination. This is a hybrid approach in which the upstream portion of the supply chain is accounted for using mass-balance. Mass-balance accounting would also be employed by the neat fuel producer and by all operators until a suitable control point. At the control point, mass-balance accounting ceases and book-and-claim accounting begins. The location of the control point is flexible and should be chosen based on

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Table 6. Main roles and responsibilities for book-and-claim.

Tracking System Element	Role	Responsibility Associated with Tracking Alternative Fuels
Producer of alternative fuel	- Produce alternative fuel - Generate quality documents (RCQ/COA) - Register credits	- Ensure that alternative fuel meets quality and sustainability requirements - Coordinate transportation of alternative fuel to blender - Transmit RCQ/COA to blender - Transmit registration information to book-and-claim administrator
Blender	- Blend neat alternative fuel with conventional Jet A and ensure that alternative fuel blend meets the ASTM D7566 specification - Coordinate transportation of blended fuel to next delivery location	- Generate and transmit physical supply document for blended fuel - May transmit invoice and PoS form associated with alternative fuel
Transporter of alternative fuel	- Deliver neat alternative fuel to blender (optional) - Deliver blended fuel to airport fuel farm	- Meet regulatory requirements for safe transport of alternative fuel - Transmit shipping documentation and COA to fuel buyer
Fuel farm operator	- Oversee fuel quality control - Manage inventories at airport fuel farm	- Receive fuel shipment and log relevant information (note: at this point, alternative fuel undistinguishable from conventional fuel) - Perform ASTM D1655 quality check on fuel
Into-plane operator	- Deliver fuel to aircraft wing	- Provide fuel delivery ticket to fuel purchaser
Airline	- Purchase alternative fuel credits	- Negotiate credit purchases with producers of alternative fuel - Report credit purchases to the book-and-claim administrator - May publicly report annual summary of purchased alternative fuel credits
Airport	- Oversee requirements for fuel quality - May prepare summaries of alternative fuel usage - Manage communications	- May arrange with airlines to share volume of alternative fuel and sustainability information - May record aggregate usage of alternative fuels by all airlines at the airport - May report usage of alternative fuel as part of airport emissions inventories (note: GHG emissions reporting for use under book-and-claim is still under development) - May inform relevant stakeholders of known environmental benefits from usage of alternative jet fuels at airport

local conditions. Beyond the control point, sustainability information is not expected to be transmitted further downstream with the alternative jet fuel. The sustainability information and associated credits may be registered with the third-party certification program authority as required by regulation or policy of the chosen framework. These credits, now booked, can be sold or traded to end users of fuel so that they may be claimed. The attraction of the hybrid approach is that it maintains the accounting and traceability advantages of the mass-balance approach throughout most of the supply chain while easing accountability requirements and reducing information gathering and transmitting requirements at and near the point of fuel use.

Figure 11 represents the hybrid mass-balance and book-and-claim system. The producer of the alternative fuel is the originator of the physical alternative fuel and receives sustainability

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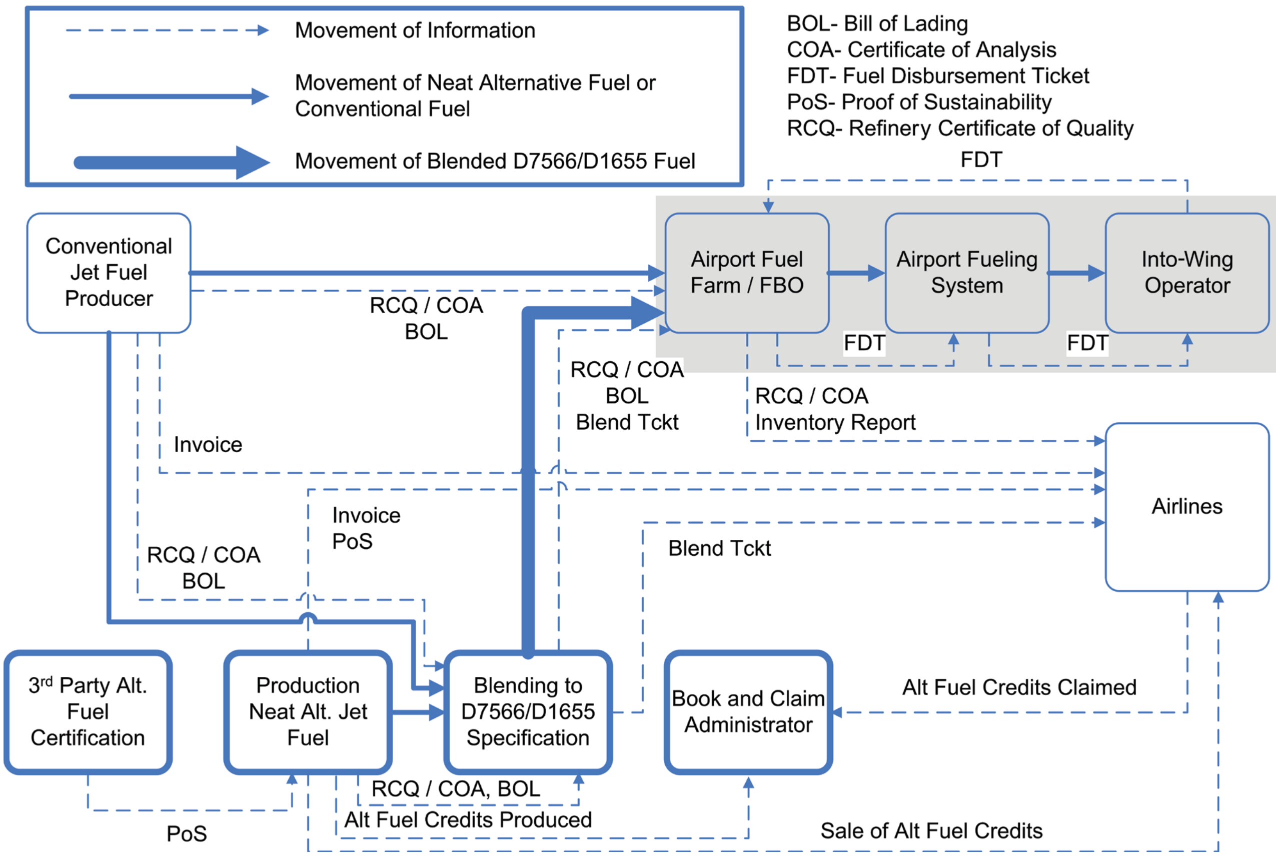

Figure 11. Downstream portion of the alternative jet fuel supply chain using a hybrid mass-balance and book-and-claim CoC method.

information from the third-party certification entity. The fuel and sustainability data are sent along the supply chain until they reach the control point, which is identical to what is done in the mass-balance CoC method. For illustration purposes, the control point in this example is at the point of blending, but it can be elsewhere depending on local conditions. Beyond the control point, Figure 11 demonstrates that the flow of alternative fuel to an airport tank farm and ultimately to the wing of an aircraft is completely separate from the sustainability documentation.

In the pure mass-balance CoC method, two variants were possible. The first was a mass-balance approach that documented only the mass of sustainability-certified alternative jet fuel included in any batch. The second variant was the mass-balance approach with identity preserved, which allowed mass-balance tracking as far down the supply chain as a specific storage tank in a fuel farm. In the hybrid mass-balance/book-and-claim system, only the first method of mass-balance accounting makes sense because the purpose of introducing book-and-claim at the point of fuel usage is to simplify the tracking of alternative fuel molecules from the control point to final dispensing into aircraft. Beyond the control point, the alternative fuel is handled just as conventional jet fuel.

Compared to a pure book-and-claim system, the main attribute that the hybrid system offers is the knowledge that given quantities of alternative fuel are delivered to the control point. If the control point were at the airport, then it would be possible to track the alternative fuel molecules to that airport. Using a pure book-and-claim system, it might be difficult to know with certainty the physical fate of any alternative jet fuel batches that have been booked.

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Infrastructure and Functional Elements

The main infrastructure and functional elements required to implement this tracking mechanism are:

1. **Fuel delivery mechanism:** Up to the control point, similar conditions as for mass-balance apply; thus, unless the option of identity preservation to the control point is selected, mass-balance batch shipments may use any fuel delivery mechanism. With identity preservation to the control point, the need to keep the fuel segregated at all times favors fuel deliveries by truck, rail, or barge. Pipeline delivery of segregated fuel would be more difficult to achieve with identity preservation unless there were dedicated pipeline access from a refinery or terminal to the control point and the ability to physically ship and keep batches of alternative jet fuel separated. Beyond the control point, the fuel would be shipped under book-and-claim rules using any fuel delivery mechanism.
2. **Fuel logistics at the airport:** Assuming that the control point is upstream of the airport, no modifications to existing infrastructure and handling practices are required. If the control point is at the airport, use of common tanks and dispensing methods is possible, except in the case of identity preservation to the final dispensing tank. In this case, dedicated storage would be needed.
3. **Blending location:** Dedicated blending tanks with sufficient storage capacity to keep the neat alternative fuel and the blended fuel segregated.
4. **Additional fuel logistics infrastructure:** Except where identity preservation is desired upstream of the control point, no additional fuel handling, storage, or distribution infrastructure is required.
5. **Data aggregation and management:** The entity in charge at the control point (e.g., blender or airport fuel farm) would take on the additional responsibilities of becoming a participating operator in an administered book-and-claim system. This status subjects the operator to third-party certification by an approved certification body. Participating operators must submit to an audit in which they demonstrate that they have a management system enabling them to meet applicable sustainability principles and criteria, conduct their operations using a risk management approach, manage inventory in accordance with CoC rules, and conform to all the requirements of the book-and-claim administrator.

   As with the mass-balance CoC approach, control point operators need to track deliveries of alternative fuel into the facility. This includes information related to physical deliveries as well as PoS. Beyond the control point, the blended alternative fuel is now fully commingled in the supply chain, and it is no longer possible or necessary to track it separately; thus, existing mechanisms for tracking conventional fuel are used. However, a system for tracking the sustainability information associated with the alternative fuel may be needed. These systems are expected to be operated and maintained by the entities performing the certification of the alternative fuel. For example, the U.S. EPA maintains the EMTS to record all transactions involving RINs as part of RFS2.
6. **Auditing:** Upstream of the control point, the two levels of auditing associated with mass-balance apply: first, monthly reconciliation reports should be audited on a periodic basis to confirm that volumes and types of alternative fuels received at the control point match invoiced amounts and that purchased fuel meets the sustainability requirements specified by the purchaser. Second, on a periodic basis, an audit of the producer of the alternative fuel should be performed to ensure that the facility selling alternative fuel complies with applicable voluntary certification and regulatory requirements. This audit may be performed by individual alternative fuel purchasers or by an industry organization representing them.

   Downstream of the control point, audit requirements for the sustainability information associated with registered alternative jet fuel credits required by the book-and-claim administrator apply. The actual audits are performed by accredited third-party certification bodies.

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Data Items

The main data elements necessary for implementing a hybrid tracking mechanism based on mass-balance and book-and-claim are:

1. **Physical supply:** For transportation of the alternative fuel to the control point, the same documentation used for mass-balance applies. The information may be included as part of the quality documents (e.g., RCQ/COA) or in a separate document. This documentation may change hands as the product flows through the supply chain and must accompany the fuel as it is received by the responsible entity at the control point. The data for tracking alternative fuels may include:
   - Delivery date and location;
   - Batch number;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process; and
   - CoC method.

   Beyond the control point, typical documentation associated with conventional fuel (e.g., BOLs, meter tickets, RCQ/COAs) will accompany the physical fuel, but the sustainability information does not need to be included.
2. **Purchasing:** As with mass-balance and book-and-claim, invoices reflecting the sale of the alternative fuel should be generated by the producer and delivered to the buyer. Invoices do not need to travel with the physical fuel and can be transmitted directly to the fuel buyer. The data with these documents may include:
   - Delivery date and location;
   - Batch number;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process;
   - CoC method; and
   - Price.

   Alternatively, a PoS form with the sustainability information listed here can be attached to invoices regularly used for conventional jet fuel.
3. **Airport inventory:** Unless the control point is at the airport fuel farm, no additional documentation from what is currently used for conventional jet fuel is necessary since the alternative fuel is expected to be fully commingled with the conventional fuel.

   If the control point is at the fuel farm, the fuel farm operator would be in charge of maintaining inventory of both conventional and alternative fuel by keeping track of fuel deliveries and fuel disbursements. As described earlier, fuel deliveries are recorded via BOLs or pipeline meter tickets. Fuel tickets keep track of fuel loaded into individual aircraft. Inventory reports and copies of fuel tickets are routinely forwarded to fuel buyers. Information on fuel tickets may include:
   - Date and location;
   - Aircraft tail number and flight number;
   - Batch number;
   - Total volume;

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- For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
- Alternative fuel pathway ID or production facility name; and
- Alternative fuel feedstock type and production process.

4. **Chain-of-custody information:** The producer of the alternative fuel is responsible for completing a PoS form and delivering it to the purchaser of the fuel. The PoS form is sent directly to the fuel buyer and does not need to travel with the fuel; thus, it is not expected that the airport fuel-farm operator would have access to this information. The data with the PoS form may include:
   - Delivery date and location;
   - Transportation mode to delivery point;
   - Batch number of alternative fuel;
   - Batch number of conventional fuel used for blending;
   - Total volume;
   - For blends of alternative fuel with conventional fuel: blend ratio, blending location and date, and any other relevant information so that the mass of the alternative fuel component can be computed;
   - Alternative fuel pathway ID or production facility name;
   - Alternative fuel feedstock type and production process;
   - CoC method;
   - Estimated greenhouse gas emissions associated with the alternative fuel (grams of CO_2e/MJ);
   - Estimate of LCA CO_2e footprint for the blended fuel;
   - Sustainability standard to which the alternative fuel complies;
   - Name of the third-party certification body;
   - Applicable on-product claim of sustainability; and
   - If desired, credits associated with the alternative fuel (e.g., RIN numbers).

   Note that beyond the control point, credits equal to the mass of alternative jet fuel produced and sold under the book-and-claim CoC method need to be recorded with the appropriate administrator. At the very least, the entity in charge of the control point should be responsible for this. Airlines that purchase book-and-claim credits are responsible for reporting their purchases to the book-and-claim administrator within a certain period of time. In addition, airlines may provide summary reports to the public on their annual consumption of alternative fuels and purchase of credits.

Roles and Responsibilities

The main roles and responsibilities associated with implementing a hybrid tracking mechanism based on mass-balance and book-and-claim are shown in Table 7.

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Table 7. Main roles and responsibilities for a hybrid tracking mechanism based on mass-balance and book-and-claim.

Tracking System Element	Role	Responsibility Associated with Tracking Alternative Fuels
Producer of alternative fuel	- Produce alternative fuel - Generate quality documents (RCQ/COA) - Generate PoS form	- Ensure that alternative fuel meets quality and sustainability requirements - Coordinate transportation of alternative fuel to blender - Transmit RCQ/COA to blender - Transmit PoS form and invoice to fuel buyer
Blender	- Blend neat alternative fuel with conventional Jet A and ensure that alternative fuel blend meets the ASTM D7566 specification - Coordinate transportation of blended fuel to next delivery location - If control point located here, blender would serve as participating operator for book-and-claim framework	- Generate and transmit physical supply document for blended fuel - May transmit invoice and PoS form associated with alternative fuel - If blender is the participating operator, transmit registration information to book-and-claim administrator
Transporter of alternative fuel	- Deliver neat alternative fuel to blender - Deliver blended fuel to airport fuel farm	- Meet regulatory requirements for safe transport of alternative fuel - Transmit shipping documentation, COA, and PoS form to fuel farm operator, as appropriate
Fuel farm operator	- Ensure fuel quality control - Manage fuel farm inventory - If control point located here, fuel farm operator would serve as participating operator for book-and-claim framework	- Receive alternative fuel shipment and log relevant information - Perform ASTM D1655 quality check on fuel - If fuel farm operator is the participating operator, transmit registration information to book-and-claim administrator
Into-plane operator	- Deliver fuel to aircraft wing	- Provide fuel delivery ticket to fuel purchaser
Airline	- Purchase alternative fuel credits	- Negotiate credit purchases with producers of alternative fuels - Report credit purchases to the book-and-claim administrator - May publicly report annual summary of purchased alternative fuel credits
Airport	- May prepare summaries of alternative fuel usage - Manage communications	- May arrange with airlines to share volume of alternative fuel and sustainability information - May record aggregate usage of alternative fuels by all airlines at the airport - May report usage of alternative fuel as part of airport emissions inventories (note: GHG emissions reporting for use under book-and-claim is still under development) - May inform relevant stakeholders of known environmental benefits from usage of alternative jet fuels at airport

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CHAPTER 4

Comparing the Requirements of the Different Mechanisms for Tracking Alternative Jet Fuel

This chapter presents guidance on comparing the different tracking mechanisms for alternative jet fuel. In addition, it includes factors to consider when choosing the right tracking mechanism according to local conditions and particular circumstances associated with the procurement of alternative jet fuel.

4.1 Main Considerations for Comparing Tracking Mechanisms

4.1.1 Infrastructure Requirements

Each tracking mechanism has somewhat different equipment/infrastructure requirements and information transfer needs. As a result, the cost of implementing the different mechanisms varies.

The physical segregation tracking mechanism requires the most significant additional investment in equipment/infrastructure of all of the mechanisms since the alternative jet fuel must remain separate from the conventional fuel all the way into the wing of the aircraft. That means additional storage (either tanks or trucks) is required at the airport along with additional transfer equipment (e.g., pumps, hoses, piping, meters) that is needed to keep the fuel separate.

As was shown in Figure 9 (the diagram for the mass-balance tracking mechanism), a minimal amount of additional equipment is required compared to conventional fuel delivery. The alternative jet fuel producer must ship fuel to the blending location through dedicated equipment, whether by truck, barge, or pipeline. The blended fuel must then be shipped to the airport fuel farm, where the blended alternative jet fuel, which now meets the D1655 specification, can be "dropped into" the airport's storage tanks used for conventional fuel.

Book-and-claim has similar equipment/infrastructure requirements to mass-balance, with the addition of a book-and-claim administrator (as was shown in Figure 10). The book-and-claim administrator is an accounting function and carries with it certain costs, but there are no additional capital requirements for book-and-claim compared to mass-balance.

The hybrid book-and-claim and mass-balance mechanism has the benefits of both mechanisms, but its costs are essentially the same as book-and-claim since it must include a book-and-claim administrator.

4.1.2 Data Requirements

In addition to the additional equipment/infrastructure needed for different tracking mechanisms for alternative jet fuel, additional data or other information is needed for different mechanisms. In general, however, the additional data requirements are not significant since

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RCQs/COAs, invoices, BOLs, and fuel delivery tickets are fairly routine requirements for commerce in any fuels. Blend tickets, required for alternative jet fuel delivery for use in aircraft, only require fairly routine, readily available data.

There may be two new types of documents or data elements that could be of significance to the airport fuel farm. The first is the sustainability certification/PoS documents, which will be created based on detailed analysis and auditing of the alternative jet fuel production facility. Generation of these documents typically happens in conjunction with sustainability certification of the facility according to a chosen voluntary or regulatory framework, such as RSB or RFS2, respectively. This certification may be relatively expensive but may only need to be updated once every few years. The second, which will be new in this context, is alternative fuel credits. These are financial instruments that have significant value and are managed by a centralized third-party administrator. As such, the accounting, auditing, and surety requirements may be expensive to produce and maintain.

Table 8 presents a summary of the data transfer requirements for the different mechanisms. For each document identified, the data elements that are commonly incorporated are shown

Table 8. Comparison of data requirements for tracking mechanisms for alternative jet fuel.

Tracking System Documents	Data Elements	Field Content	Data Producer	Data Consumer	Cost to Implement
	Attribute codes>>>	Unit of measure, code or specification, text description	P – Producer B – Blender T – Transporter S – Storage operator A – Airport C – Carrier F – FBO/into-plane operator	P – Producer B – Blender T – Transporter S – Storage operator A – Airport C – Carrier F – FBO/into-plane operator	Nil Low Medium High
RCQ/COA	Fuel specification	ASTM spec	P	B,T,S,A,C,F	Medium
	Spec test results	Various	P	B,C,F	Medium
	Manufacturing facility	Name/location	P	C,F	Nil
	Manufacture date	mm/dd/year	P	C,F	Nil
	Batch number	#	P	C,F	Nil
	Volume	Gallons (net)	P	B,T,S,A,C,F	Low
	Creation frequency	Every batch	–	–	–
Sustainability certification/PoS	Producer name	Name/location	P	B,C,F	Nil
	Certification number	#	P	B,C,F	Nil
	Producer certification	#	P	B,C,F	Nil
	Certification system	(e.g., RSB/ISCC)	P	B,C,F	High
	Feedstock data	–	P	B,C,F	High
	GHG emissions	CO_2e/MJ	P	B,C,F	High
	Quantity	Gallons (net)	P	B,C,F	Low
	Creation frequency	Required audit schedule	–	–	–
Invoice	Product specification	ASTM spec	P	C,F	Nil
	Seller	Name	P	C,F	Nil
	Buyer	Name	P	C,F	Nil
	Uplift point/title transfer	Name/location	P	C,F	Nil
	Volume	Gallons (net)	P	C,F	Nil
	Price	$	P	C,F	Nil
	Batch number	#	P	C,F	Nil
	Date	mm/dd/year	P	C,F	Nil
	Creation frequency	Every batch	–	–	–

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Tracking Alternative Jet Fuel

Table 8. (Continued).

Tracking System Documents	Data Elements	Field Content	Data Producer	Data Consumer	Cost to Implement
	Attribute codes>>>	Unit of measure, code or specification, text description	P – Producer B – Blender T – Transporter S – Storage operator A – Airport C – Carrier F – FBO/into-plane operator	P – Producer B – Blender T – Transporter S – Storage operator A – Airport C – Carrier F – FBO/into-plane operator	Nil Low Medium High
BOL	Product specification	ASTM spec	P,B,T	B,T,S,A,F	Nil
	Seller	Name and origination location	P,B,T	B,T,S,A,F	Nil
	Point of fuel transfer	Name and transfer location	P,B,T	B,T,S,A,F	Nil
	Volume (gross and net)	Gallons	P,B,T	B,T,S,A,F	Low
	Fuel temperature	°F	P,B,T	B,T,S,A,F	Low
	Batch number	#	P,B,T	B,T,S,A,F	Nil
	Date	mm/dd/year	P,B,T	B,T,S,A,F	Nil
	Buyer	Name	P,B,T	B,T,S,A,F	Nil
	Creation frequency	Every transfer	–	–	–
Blend ticket	D7566 fuel	Gallons	B	T,S,A,F	Low
	Fuel temperature	°F	B	T,S,A,F	Low
	D7566 supplier	Name	B	T,S,A,F	Nil
	D1655 fuel	Gallons	B	T,S,A,F	Low
	Fuel temperature	°F	B	T,S,A,F	Low
	D1655 supplier	Name	B	T,S,A,F	Nil
	Buyer	Name	B	T,S,A,F	Nil
	Batch number	#	B	T,S,A,F	Nil
	Blend date	mm/dd/year	B	T,S,A,F	Nil
	Creation frequency	Every blend	B	–	–
Fuel disbursement ticket	Volume	Gallons	S,F	C,F	Low
	Fuel temperature	°F	S,F	C,E	Low
	Airline name	Carrier code	S,F	C,F	Nil
	Flight number	#	S,F	C,F	Nil
	Aircraft tail number	N#	S,F	C,F	Nil
	Date	mm/dd/year	S,F	C,F	Nil
	Creation frequency	Every fueling	–	–	–

with information on who produces the information and who captures it (i.e., who consumes it), as well as a general characterization of how much it costs to generate each data element.

4.2 Choosing the Right Tracking Mechanism

Deciding which tracking mechanism to choose will require a balance between the desire to track alternative jet fuel molecules all the way to the wing of the aircraft, and the infrastructure and data requirements associated with each tracking mechanism. Potential requirements have been described in detail in the preceding sections, but specific requirements will not be known until policy decisions are made. Here, concise, high-level guidelines are provided to aid in the selection of the right tracking mechanism. This guidance summarizes the advantages, disadvantages, and impediments to implementation associated with each tracking mechanism.

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4.2.1 Physical Segregation

- **Overview:** This mechanism requires dedicated infrastructure for alternative fuel storage and handling between the production facility and the wing of the aircraft. It allows for the tracking of alternative jet fuel molecules all the way to the wing of the aircraft.
- **Advantages:** One of the main advantages of this mechanism is that the alternative fuel and its sustainability attributes as captured by a certificate or similar quality document move together through the supply chain to the wing of the aircraft. By not mixing alternative fuel in the common storage and delivery system with any other fuel, greater control over the supply and greater certainty over fuel quality are maintained. Additional advantages of this mechanism are that it is easy to audit and is the least likely to allow undetected fraud.
- **Disadvantages:** The main disadvantages of this mechanism are the need for additional infrastructure to keep the alternative fuel segregated and the associated disruption it would cause to the existing system should it be introduced at a large scale.
- **Implementation considerations:** Given the need for separate infrastructure, widespread adoption of this mechanism is likely to be difficult to implement. However, this mechanism may have a role to play in those circumstances where tests of specific alternative jet fuels are being conducted or the output of a dedicated refinery can be readily transported to separate fuel tanks at an off-site fuel depot or to an airport fuel farm.

4.2.2 Mass-Balance

- **Overview:** This mechanism does not segregate the alternative jet fuel from the conventional fuel, but it keeps track of the proportion of sustainability-certified product at each step of the supply chain and transmits that information to the next steps. This system relies on periodically verifying that the sustainability information is consistent with the volumes of alternative fuel being transported. Mass-balance mechanisms may either include information about the alternative fuel source or convey only information about the total proportion of conforming product within a specified batch. Preservation of identity increases the complexity of this CoC accounting mechanism and, therefore, the cost of implementation. However, it may be important to preserve identity if the time comes when refiners market alternative fuels that have arrived at the refinery from different fuel pathways or that are mixed with alternative fuels deriving from separate pathways before final transportation to the airport fuel farm. Without preservation of identity, different GHG emission reduction values could be lost, along with other characteristics of the fuel that may be of interest to airline end users, airports, regulators, and other stakeholders.
- **Advantages:** Mass-balance provides a way to ensure that sustainability information accompanies the alternative jet fuel from feedstock generation to the wing of the aircraft without requiring the same level of infrastructure as physical segregation. Moreover, while no CoC system is immune to potential fraud, the mass-balance mechanism is more readily auditable and enforceable than book-and-claim because it provides more points for the addition of data and application of controls.
- **Disadvantages:** Implementation of a mass-balance system can be complex, in particular if identity preservation is desired, because this requires keeping track of sustainability attributes for potentially several components along the supply chain.
- **Implementation considerations:** Mass-balance may provide an alternative for users interested in tracking the sustainability attributes of alternative jet fuel along the supply chain without the need for dedicated infrastructure. While only physical segregation can guarantee the specific sustainability attributes of the alternative fuel in a given location, mass-balance can at least provide information about aggregate sustainability characteristics. It must be taken into account that mass-balance may require a complex data tracking and management system.

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4.2.3 Book-and-Claim

- **Overview:** In this mechanism, the sustainability information associated with a physical volume of alternative fuel is allowed to be separated from the fuel as it travels along the supply chain. This mechanism uses common fuel storage and delivery infrastructure for both the conventional and alternative fuels that have been properly blended and certified to the relevant quality standards.
- **Advantages:** The book-and-claim approach provides the greatest simplicity and ease of implementation from the perspective of existing transportation, storage, and procurement systems. The main advantage of this mechanism is the ability to mix alternative fuels with conventional fuels with no further differentiation of fuel types or additional infrastructure.
- **Disadvantages:** The main disadvantages of book-and-claim are that the sustainability information is separated from the physical molecules once they enter the commingled infrastructure and the control of information about the specific amounts of alternative fuel delivered to each customer is lost. Claims of alternative fuel use can be made on an aggregate basis, but customers do not know how much blended alternative fuel they received in each delivery.
- **Implementation considerations:** While the book-and-claim approach does not require additional physical infrastructure, it may need a sophisticated data collection and management platform to ensure data integrity and prevent fraud. A third-party administrator would be required to keep track of credits generated by alternative fuel providers and claimed by end customers.

4.2.4 Hybrid Mass-Balance and Book-and-Claim

- **Overview:** In this mechanism, mass-balance is kept from the refinery up to an intermediate control point in the supply chain—for example, a blending location close to an airport. After this intermediate location, book-and-claim is used.
- **Advantages:** An advantage of this mechanism is that it allows some level of certainty with respect to the location of the molecules of alternative jet fuel up to the intermediate control point and the use of common infrastructure beyond the control point.
- **Disadvantages:** A potential disadvantage of this mechanism is the complexity of implementing and managing a hybrid approach. In addition, there may be the need to convince external stakeholders that this is a viable and credible approach.
- **Implementation considerations:** Implementation of a hybrid approach may arise when a compromise between a book-and-claim and mass-balance is sought. For example, end users would probably favor book-and-claim because this offers the least disruption to existing supply chain practices; however, regulators or other external entities (e.g., NGOs) may want a higher level of traceability of the alternative jet fuel. Thus, the needs of the relevant stakeholders will have to be clearly stated and taken into account when developing a hybrid approach.

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CHAPTER 5

Alternative Fuels Tracking and Greenhouse Gas Tracking Toolkit

This chapter presents the toolkit developed in conjunction with this guidebook. The toolkit consists of two components: an alternative fuels inventory tracking spreadsheet and a GHG calculator for alternative fuels.

5.1 Inventory Tracking Spreadsheet

The first part of the toolkit is an alternative fuels inventory tracking spreadsheet (available on the TRB website). It represents one example of how alternative fuel deliveries may be recorded at an airport fuel facility. It covers the physical delivery of fuel only and can be used to support additional sustainability accounting methods. This design assumes that the alternative fuel is dropped in together with conventional fuel in the receiving tanks (mass-balance, book-and-claim, and hybrid tracking methods). When the alternative fuel is kept physically segregated from the main fuel supply, a separate copy of the spreadsheet can be used and the conventional fuel totals set to zero. A screenshot of the inventory tracking spreadsheet with an illustrative example is shown in Figure 12.

The spreadsheet can be used alone or in conjunction with the Spec 123 spreadsheet available from A4A that is widely used by fuel farm operators to track inventory. If using the spreadsheet with Spec 123, copy the total fuel receipts from "tank, receipt, ip temps" tab and paste special as values. This total includes all fuel deliveries, conventional and alternative. If any bonded fuel was received, the Spec 123 sheet subtracts the bonded portion from the total automatically. If not using with Spec 123, enter fuel receipts manually. Enter any bonded fuel received (if applicable) and subtract bonded fuel from total receipts. Enter the alternative jet fuel receipts from each provider, including gross and net gallons and blend percentage. Total alternative fuel received and neat gallons equivalent are calculated.

Detailed instructions and more information on the tool can be found in the "Instructions and Description" tab.

5.2 GHG Calculator

The second part of the toolkit (available on the TRB website) involves a GHG calculator and represents one example of how sustainability metrics may be tracked. It is intended for use by airport management, but it also may be of use to any other stakeholders in the supply chain. The calculator allows the calculation of information related to the life-cycle greenhouse gas of the airport fuel supply over a given time period. The GHG tool takes information elements from the fuel farm operator and the fuel producer and calculates numbers useful to airport management. From the fuel farm

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Total Receipts (gallons)

	net	gross
Bonded/FTZ	10,000	10,000
All Domestic (including alt fuel)	26,033,998	26,160,551
Domestic Conventional	23,225,665	23,363,406
Alt Fuel ASTM D7566/D1655	2,808,333	2,797,145
All fuel	26,043,998	26,170,551

<-- Enter total fuel receipts

Alternative Jet Fuel Receipts (ASTM D7566/D1655, gallons)

Fuel Producer	Proportion of Total Fuel Supply	net	gross	Blend Proportion		
PineFuel Co	0.00960	250,000	249,004	0.50		
Pendulum Inc	0.02496	650,000	647,410	0.40		
Avion Re	0.03200	833,333	830,013	0.50		
Clean Flight	0.02208	575,000	572,709	0.50		
AirGrease LLC	0.00384	100,000	99,602	0.25		
Farnesene Inc	0.01536	400,000	398,406	0.10		
		-	-			
		-	-			
		-	-			
		-	-			
		-	-			
		-	-			
		-	-			
		-	-			
SUM		2,808,333	2,797,145		1,149,568	Neat gallons equivalent

<-- Enter Alt fuel receipts and blend proportion

Figure 12. Alternative fuels tracking spreadsheet.

operator, the user would receive information on the amount of which alternative fuel was delivered to the fuel farm, the proportion of alternative fuel in each delivery (since most ASTM-approved alternative fuels to date are blends of conventional petroleum fuel and a neat alternative component), and the producer of each type of alternative fuel delivered. GHG reduction percentages of each fuel compared to conventional Jet A can be found by contacting the fuel producer or the airline buying the fuel. The calculator is not dependent on the CoC method employed for the transfer of sustainability information. The tool is built using constants found from information in the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) LCA database software developed by Argonne National Labs, the FAA, and the Energy Information Administration.

For any given time period under calculation, the GHG calculator can give the user:

- The proportion of alternative jet fuel in the airport's jet fuel supply as a percentage.
- The average GHG emissions intensity of the airport's jet fuel supply per gallon, labeled as "blended well to wake gCO_2/gallon" in the calculator. This number will be lower the greater the proportion of alternative fuel that is delivered to the airport.
- The expected GHG emissions from using the airport's jet fuel supply (assuming FAA averages for CO_2/gallon combusted).
- The baseline GHG emissions from using a 100% conventional jet fuel supply.
- The reduction in GHG emissions from using the airport's jet fuel supply versus using a 100% conventional jet fuel.

These numbers might be useful to an airport wishing to keep track of its Scope 3 GHG emissions related to aircraft fuel. The tool could also be used for scenario planning and estimating amounts of alternative fuel necessary to meet an airport's GHG reduction goals. The tool presents

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an option for calculating sustainability metrics that could be included in airport planning and reporting. Airports might use a similar approach to track reductions in criteria pollutants that result from alternative fuel usage once that information becomes more readily available.

In order to function, the GHG calculator requires the user to input the blended normal volume of fuel in gallons, the alternative proportion of the fuel delivery as a percentage, and the GHG reduction of the neat alternative fuel compared to conventional fuel for each producer supplying fuel to the airport. An illustrative example is shown in Figure 13. For record-keeping consistency, the user should also select the fuel specification for each kind of fuel being supplied to the airport and the time period under calculation. Consistent and uniform records of fuel deliveries for the time period under calculation are important for the accuracy and usefulness of the GHG calculator.

The GHG calculator works in gallons of fuel, grams of CO_2 emissions per gallon, and tonnes of CO_2 per fuel producer. All estimates of grams of CO_2 per megajoule of fuel must be converted to grams of CO_2 per gallon before being inputted into the GHG calculator.

The calculator assumes that the CO_2 emissions due to the combustion stage of the jet fuel life cycle (product to wake) are equivalent for both conventional fuel and alternative fuel. This assumption is made because all ASTM-approved alternative jet fuels (ASTM D7566) are chemically similar enough to be considered drop-in fuels (i.e., interchangeable with conventional fuel; ASTM D1655) in engines and fueling equipment. This assumption may be changed by altering

	Time Period under Calculation			
	Jan-1-2017	to	Mar-31-2017	
Producer	**Fuel Specification**	**Blended Normal Volume (gallons)**	**Proportion alternative (%)**	**Neat Alternative Fuel's GHG reduction percentage vs Conventional**
Refinia Corp	ASTM D1655	18,149,362	0%	0.00%
Extractex	ASTM D1655	8,000,000	0%	0.00%
PineFuel Co	ASTM D7566 annex A1 FT	250,000	50%	78.90%
Pendulum Inc	ASTM D7566 annex A1 FT	650,000	40%	81.00%
Avion Re	ASTM D7566 annex A2 HEFA	833,333	50%	74.00%
Clean Flight	ASTM D7566 annex A2 HEFA	575,000	50%	52.00%
AirGrease LLC	ASTM D7566 annex A2 HEFA	100,000	25%	30.00%
Farnesene Inc	ASTM D7566 annex A3 SIP	400,000	10%	89.00%
HexChem	ASTM D7566 annex A4 SPK/A	200,000	10%	20.00%
TOTAL		29,157,695		
Weighted AVERAGE			4.03%	

Figure 13. GHG calculator inputs.

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Neat Alternative Normal Volume (gallons)	Neat Conventional Normal Volume (gallons)	Neat Conventional Well to Wake gCO2/gallon	Neat Alternative Well to Wake gCO2/gallon	Blended well to wake gCO2/gallon	Baseline GHG, tonnes of CO2	Actual net GHG, tonnes of CO2	Percentage Reduction compared to Baseline
-	18,149,362	12357	N/A	12357	224,268	224,268	0.00%
-	8,000,000	12357	N/A	12357	98,854	98,854	0.00%
125,000	125,000	12357	2607	7482	3,089	1,871	39.45%
260,000	390,000	12357	2348	8353	8,032	5,430	32.40%
416,667	416,667	12357	3213	7785	10,297	6,487	37.00%
287,500	287,500	12357	5931	9144	7,105	5,258	26.00%
25,000	75,000	12357	8650	11430	1,236	1,143	7.50%
40,000	360,000	12357	1359	11257	4,943	4,503	8.90%
20,000	180,000	12357	9885	12110	2,471	2,422	2.00%
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
-	-	N/A	N/A	N/A	-	#VALUE!	#VALUE!
1,174,167	27,983,529				360,296	350,235	
		12357	3789	12,012			2.79%

Figure 14. GHG calculator outputs.

the "Jet Fuel Constants" tab in the GHG calculator tool Excel file. A screenshot with sample output is shown in Figure 14.

It is important to note that for aircraft, CO_2 emissions are equivalent to CO_2e emissions because CO_2 is the only relevant greenhouse gas combustion product according to the FAA Order 1050.1F Desk Reference. The GHG emissions calculator Excel spreadsheet has six tabs: Instructions and Description, Calculator Tool, Example Entries, Jet Fuel Constants, List, and Weights.

Detailed instructions and more information on the tool can be found in the "Instructions and Description" tab.

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CHAPTER 6

Conclusion

As alternative jet fuel commercialization advances and becomes part of the fuel mix, airports should be aware that they may need to support the associated changes in the jet fuel supply system to accommodate the needs of their customers for using these new fuels. As noted in this guidebook, airlines and other aircraft owners have committed to purchasing alternative jet fuels for a variety of reasons, including diversification of their supply chains and reduction of their GHG emissions.

Alternative jet fuels may have to be tracked separately from conventional jet fuels to ensure that the fuel purchasers receive full credit for their use. With respect to choosing an appropriate tracking mechanism, airport managers and other interested stakeholders should keep in mind that:

- The needs for tracking will ultimately be decided by regulations and policies still under development;
- Several different fuel tracking mechanisms are available to meet the different needs of fuel purchasers, regulators, and other stakeholders;
- The costs of implementing different fuel tracking mechanisms vary depending on the mechanism and existing fuel handling infrastructure;
- Any or all of these fuel tracking mechanisms may be used to meet the needs of different stakeholders; and
- The selection of appropriate tracking mechanism(s) should be done in consultation with the fuel purchaser(s).

As part of this guidebook, a toolkit consisting of a spreadsheet for tracking and accounting for alternative fuel use as well as a spreadsheet for computing GHG emissions from the use of the fuel has been provided. These spreadsheets are meant to demonstrate the type of information and computations that may be required to track alternative jet fuels and some of their potential benefits.

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APPENDIX A

Summary of Sustainability Frameworks and Chain-of-Custody Requirements

A.1 Sustainability Certification and Chain of Custody, Regulatory

A.1.1 U.S. Renewable Fuel Standard

In legislation originally enacted in 2005, the U.S. Congress established the Renewable Fuel Standard. It established an accounting mechanism for the production and use of alternative fuels made from renewable biomass. Amendments passed in 2007 updated the RFS's requirements, and it is now often referred to as the "RFS2." The RFS2 has volumetric mandates for the use of renewable fuels in road transportation (shown in Figure 15). These fuels are required to meet reductions in life-cycle[37] GHG emissions when compared to conventional petroleum fuel (shown in Table 9). Many alternative jet fuels would potentially qualify for compliance with the RFS2's mandates, depending on the fuels' feedstock and life-cycle GHG emissions.

The mandate for renewable fuel production is referred to as the Renewable Volume Obligation, and there is an RVO for each category of fuel in the RFS (Figure 15 and Table 9). The RVO for each year is determined based on statute and the EPA's evaluation of the market. All gallons of renewable biomass fuel produced are assigned Renewable Identification Numbers at the production facility. Alternative jet fuel is not mandated under the RFS2, but many types of alternative jet fuel are eligible to receive RINs. The EPA developed a software system for managing RIN transactions for compliance with the RFS2 called the EPA Moderated Transaction System. Each gallon of fuel generates an RIN in EMTS, and those are usually bundled into batches. This can be described as a book-and-claim system because once the alternative fuel leaves the production facility, the RINs associated with produced gallons may be conveyed with the fuel or be separately sold. RINs are financial instruments designed to facilitate compliance with the RFS2, but they do not communicate the environmental attributes of a fuel or represent a greenhouse gas reduction credit. The EPA does not certify or validate RINs, but a voluntary third-party quality assurance program now exists for RINs to reduce the legal risk that improperly generated or fraudulent RINs are used for compliance.[38] The value of a RIN depends in part on its D code, which determines its ability to be retired for compliance with an RVO.

For an alternative fuel to comply with the RFS2, the fuel must come through an EPA-approved pathway from feedstock to refinery. The production facility self-certifies that its feedstock and processes conform to an EPA-approved pathway. Once the fuel is in finished form (no longer a "feedstock" or "intermediate"), the fuel molecules cease being tracked for compliance purposes. RINs are generated by the fuel producer using the EMTS and are then sold to petroleum refiners or fuel importers along with the alternative fuel volume or separately from the fuel. The EMTS acts as a marketplace and tracking mechanism for compliance. Petroleum refiners and fuel importers are the "obligated parties" under the RFS2, who then retire RINs to comply with the RFS2's RVOs. Fuel blenders are not explicitly obligated parties under the RFS2. After RINs

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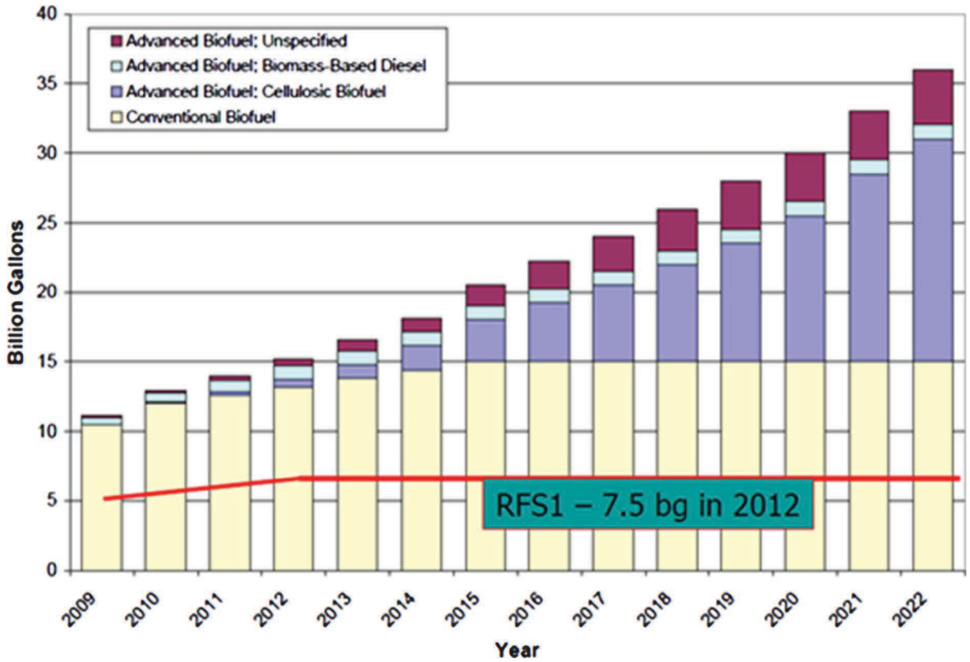
Tracking Alternative Jet Fuel



Source: U.S. Environmental Protection Agency, Office of Transportation and Air Quality, April 2010. National Renewable Fuel Standard Program – Overview, https://www.epa.gov/sites/production/files/2015-09/documents/rfs2-workshop-overview.pdf.

Figure 15. Production mandates for alternative fuels under the RFS2 regulation.

are retired by the obligated parties, the CoC requirements do not extend to the fuel retailer (airport fuel farm) or to the fuel user (airplane). For road fuel—as of this report overwhelmingly corn ethanol and soy biodiesel—fuel blenders, transporters, and vendors continue to track the alternative fuel for quality purposes, product differentiation, and blend wall limitations. The RVOs of the RFS, without intervention by Congress to amend, supersede, or revoke the law, are left solely to the EPA's discretionary authority after 2022.[39] The structure and requirements for U.S. biofuels policy after 2022 remain unclear and contentious.

A.1.2 Clean Air Act Regulations on GHGs

Clean Air Act (CAA) regulations on aircraft GHG emissions may eventually necessitate CoC tracking mechanisms for life-cycle GHG accounting of aviation fuels. As of the time of this

Table 9. RFS2 fuels.

Category	Eligible Feedstock	Required Life-Cycle GHG Reductions	RIN
Advanced biofuel: unspecified	Any renewable biomass except corn starch	50% compared to petroleum baseline	D code 5
Advanced biofuel: biomass-based diesel	Any renewable biomass except corn starch	50% compared to petroleum diesel baseline	D code 4
Advanced biofuel: cellulosic	Cellulose, hemicellulose, or lignin	60% compared to petroleum baseline	D code 3, or D code 7
Renewable fuel (conventional biofuel)	Any renewable biomass including corn starch	20% compared to 2005 petroleum baseline, or from grandfathered ethanol facilities	D code 6

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report's writing, the CAA aircraft regulation[40] is not final, and compliance strategies are still speculative. While the current Advanced Notice of Proposed Rulemaking does not yet mention alternative fuels as a means of reducing GHG emissions, it is possible that this will be added at a future time when the GHG benefits of using alternative fuels are more widely understood.

A.1.3 United States Department of Defense

U.S. national defense authorizations have included provisions that statutorily require the U.S. DoD to include sustainability criteria—particularly life-cycle GHG values—in its procurement of alternative jet fuels.[41,42] The U.S. DoD acquires alternative fuels for strategic reasons. It has its own CoC regulations for aviation fuel in addition to slightly different quality requirements than those prescribed for commercial aviation in ASTM D1655 and ASTM D7566. The DoD has provided important assistance to producers of alternative fuels who may not yet make a cost-competitive product for commercial aviation purposes. The department is generating demand for alternative jet fuel as one of the world's largest buyers of the fuel. U.S. DoD fuel CoC requirements may be relevant for commercial airports co-located with military bases or having the National Guard as a tenant.

A.1.4 U.S. State of California

California has laws pertaining to the CoC of alternative fuels to ensure that sustainability requirements are met. These requirements include improvements to the life-cycle GHG footprints of alternative fuel when compared to petroleum fuel. The California Low Carbon Fuel Standard (LCFS) currently excludes fuels used in aircraft;[43] however, the aviation industry is working toward having aviation alternative fuels be eligible to generate credits under the LCFS.

A.1.5 EU Renewable Energy Directive

The EU RED imposes a mass-balance CoC method for the alternative fuel supply chain, including aviation fuel. Any EU RED acceptable voluntary sustainability certification program must include requirements for mass-balance CoC; book-and-claim is not acceptable for EU RED compliance. EU RED does not mandate less carbon-intensive aviation fuel. Instead, reductions in GHG emissions are regulated through the extension of the EU Emissions Trading System to the aviation sector. However, emissions reductions in road transportation fuel do apply to ground service equipment used at airports.[44]

A.2 Sustainability Certification and Chain of Custody, Voluntary

The certification programs described in the following have been discussed in more detail in previous reports.[45,46,47,48] Critical to the long-term success of any of these sustainability certification programs is their legitimacy in the eyes of relevant stakeholders.[49] Most voluntary programs for sustainability certification require that a PoS document be generated by the fuel producer and then transmitted to the buyer/end user. A proof of sustainability includes an estimate of the life-cycle GHG emissions intensity of the fuel, which some fuel producers consider proprietary.[50] While the following are possible voluntary programs with CoC requirements applying to alternative jet fuels and their feedstocks, only a few of these programs currently are being used to certify jet fuel being dispensed at U.S. airports. This is primarily due to the early stage of commercialization of alternative jet fuels. The list of programs is not comprehensive and includes only the programs that are most commonly associated with aviation.

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A.2.1 Airport Carbon Accreditation[51]

ACI-NA's Airport Carbon Accreditation[52] program bears an indirect relationship to the deployment of alternative jet fuel at airports. At Level 1, the ACA program certifies airports that have implemented a carbon management policy and reported their airport-specific GHG emissions. ACA Level 2 builds on Level 1 by requiring that an airport establish goals for GHG emission reductions in a carbon management plan. At Levels 3 and 3+, airports are required to quantify, as indirect emissions, the GHG emissions of aircraft during the LTO cycle up to or below an altitude of 3,000 ft.[53] The airport reports these aircraft emissions in its GHG inventory as "indirect emissions." Altering the life-cycle GHG footprint of the fuel used in the LTO cycle may affect the airport's GHG inventory. At a busy airport, the quantity of indirect aircraft emissions from the combustion of petroleum-based fuels could easily dwarf in absolute numbers the airport's own direct and energy indirect emissions.

At Levels 3 and 3+ in the ACA program, airports commit to work with tenants and air carriers on strategies to reduce airport emissions. The introduction of alternative jet fuel at an airport may reduce aircraft LTO emissions below the 3,000-ft ceiling and could help an airport meet its targets for overall GHG emission reductions. Thus the ACA program may provide an incentive for airports to work with air carriers and fuel suppliers to facilitate access to alternative jet fuels and to track the usage and sustainability characteristics of those fuels.

A.2.2 Bonsucro[54]

Bonsucro is an international multi-stakeholder organization established in 2008 to develop and maintain a standard for sustainable production of sugarcane—an important tropical feedstock for biofuels used in the EU, Brazil, and California. The Bonsucro standard applies to the production and processing of sugarcane and sugarcane products, which can be labor-intensive and compete for land with sensitive ecosystems such as rainforests. Aviation fuel producer Amyris' sugarcane feedstock for its farnesene additive conforms to both the Bonsucro and RSB standards.[55] Bonsucro allows for mass-balance, physically segregated, and book-and-claim CoC methods.

A.2.3 ISO 13065[56]

The International Organization for Standardization (ISO), an independent nongovernmental membership organization and the largest developer of voluntary international standards,[57] in 2015 published ISO 13065, Sustainability Criteria for Bioenergy. This standard provides a framework for considering environmental, social, and economic aspects that can be used to evaluate and compare bioenergy production and products, supply chains, and applications. It is not clear whether the standard will be used for certification purposes.

A.2.4 International Sustainability and Carbon Certification[58]

The ISCC program began in 2006 as a project of the German Federal Ministry of Food, Agriculture, and Consumer Protection. Its bioenergy program was developed to comply with the EU RED but has since expanded, with voluntary certification offerings workable in any jurisdiction. Its criteria can be applied to a multitude of feedstocks for alternative jet fuel and include specific certification criteria based on the stage of the supply chain and final product. The ISCC standard can use a mass-balance or physically segregated CoC method, but it does not allow book-and-claim. ISCC users are primarily European, but the program now operates as an international multi-stakeholder system and includes feedstock cultivators, processors, traders, end users, and representatives of environmental and social organizations.

Participants in the ISCC process depend on it to fulfill the legal requirements for CoC regarding production, processing, utilization, traceability, and GHG emissions of sustainable biomass.

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Although there are more than 9,000 facilities with certificates under ISCC, most of them are involved in the supply chain of European road fuels, and there do not appear to be any producers of aviation fuel listed as certificate holders.[59]

A.2.5 Roundtable on Sustainable Biomaterials[60]

The RSB is a nongovernmental, global, multi-stakeholder coalition that promotes the sustainability of biomaterials and publishes a set of standards to which alternative jet fuels may be certified sustainable. RSB standards can apply to many forms of biomass whose processed materials are incorporated into many different products, including fuels. The RSB certification system is based on 12 principles encompassing environmental, social, and economic criteria and indicators. RSB certification operates globally and includes organizations from all phases of the alternative jet fuel chain of production.[61] The RSB framework currently allows for physically segregated and mass-balance CoC approaches. An RSB book-and-claim approach is under development.

The Sustainable Aviation Fuel Users Group (SAFUG)[62] has cited RSB as an exemplary source for certification and associated CoC requirements. SAFUG is made up of 28 airlines and five related companies.[63] Member airlines, which are based in North America, Europe, the Middle East, Asia, and Oceania, are committed to the "development, certification, and commercial use of environmentally and socially sustainable aviation fuel."[64]

As examples of RSB certification, Amyris has received RSB certification for its Brazilian operations.[65] Amyris' farnesene fuel additive can be blended up to 10% with petroleum Jet A under ASTM D7566. U.S. fuel producer AltAir Fuels is currently seeking RSB certification for its operations supplying fuel to LAX airport under a contract with United Airlines.[66] Airline KLM has used a RSB-certified alternative fuel in the United States made by Dynamic Fuels, LLC from used cooking oil feedstock.[67] The fuel was loaded into flights at New York's JFK Airport bound for Amsterdam Schiphol.[68] SkyNRG currently supplies an RSB-certified used-cooking-oil-based fuel to KLM's operations at Schiphol Amsterdam Airport,[69] and all users of the common fuel supply at Oslo Airport Gardermoen[70] and Karlstad Airport.[71] As of the time of this report's writing, five entities involved in the production of jet fuel have been certified by RSB.[72]

A.2.6 Roundtable on Responsible Soy[73]

Applicable on a worldwide level, the Roundtable on Responsible Soy (RTRS) standard for responsible soy production is designed to ensure that soy production is environmentally correct, socially appropriate, and economically feasible. Concerns exist about land-use change to grow soy, which is a feedstock for biodiesel and a potential feedstock for alternative jet fuel. The RTRS standard is designed to guard against deforestation of the rainforest to grow soy, particularly in South America. The RTRS allows for physical segregation and mass-balance CoC methods.[74]

A.2.7 Roundtable on Sustainable Palm Oil[75]

Started in 2004, the Roundtable on Sustainable Palm Oil (RSPO) has developed standards for the production of palm oil and CoC certification. Palm oil production has grown significantly for use in food and fuel since the 1990s. Palm oil plantations in Southeast Asia use land that would otherwise be rainforests and habitat for orangutans; as result, there is a demand for palm oil that does not come from deforested lands. Fuel producer Neste Oil planned to supply alternative jet fuel made from palm oil to airline FinnAir in 2011 but discontinued the initiative over sustainability concerns.[76] Airline Garuda Indonesia planned to start blending palm-oil–derived jet fuel with conventional Jet A in 2016.[77] The RSPO certifies physically separated supply chain operators to its standard but also has programs that allow for book-and-claim and mass-balance CoC methods.[78]

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Acronyms and Abbreviations

A4A – Airlines for America
ACA – Airport Carbon Accreditation
ACI-NA – Airports Council International–North America
BOL – Bill of lading
CAA – Clean Air Act
CAAFI – Commercial Aviation Alternative Fuels Initiative
CO_2 – Carbon dioxide
CO_2e – Carbon dioxide equivalent
COA – Certificate of Analysis
CoC – Chain of custody
CSBP – Council on Sustainable Biomass Production
CSR – Corporate social responsibility
Def Stan – U.K. Ministry of Defence Standards
DLA – Defense Logistics Agency
EMTS – EPA Moderated Transaction System
EU RED – European Union Renewable Energy Directive
FBO – Fixed-base operator
FDT – Fuel disbursement ticket
FSC – Forest Stewardship Council
GBEP – Global Bioenergy Partnership
GHG – Greenhouse gas
GREET – Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
IATA – International Air Transport Association
ICAO – International Civil Aviation Organization
ID – Identifier
IPIECA – International Petroleum Industry Environmental Conservation Association
ISCC – International Sustainability and Carbon Certification
ISO – International Organization for Standardization
LAX – Los Angeles International Airport
LCA – Life-cycle assessment
LCFS – Low Carbon Fuel Standard
LTO – Landing/take-off
MJ – Megajoule
NAAQS – National Ambient Air Quality Standards
NGO – Nongovernmental organization
OEM – Original equipment manufacturer
PM – Particulate matter
PoS – Proof of sustainability

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R&D – Research and development
RCQ – Refinery Certificate of Quality
REC – Renewable Energy Certificate
RFS – Renewable Fuel Standard
RFS2 – Renewable Fuel Standard 2
RIN – Renewable Identification Number
RPS – Renewable portfolio standard
RSB – Roundtable on Sustainable Biomaterials
RSPO – Roundtable on Sustainable Palm Oil
RTRS – Roundtable on Responsible Soy
RVO – Renewable Volume Obligation
SAFUG – Sustainable Aviation Fuel Users Group
U.S. DoD – U.S. Department of Defense
U.S. DOT – U.S. Department of Transportation
U.S. EPA – U.S. Environmental Protection Agency
WREGIS – Western Renewable Energy Generation Information System

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Endnotes

1. Miller, B., T. Thompson, M. Johnson, M. Brand, A. McDonald, D. Schenk, J. Driver, L. Leistritz, A. Leholm, N. Hodur, D. Plavin, D. Glassman, A. Anumakonda, R. Altman. *ACRP Report 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting,* Transportation Research Board of the National Academies, Washington, D.C., 2012. Available at http://www.trb.org/Main/Blurbs/166622.aspx.
2. *Review of the Potential for Biofuels in Aviation,* available at http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=E296A64BF3E834001B8281496DA49C7D?doi=10.1.1.170.8750&rep=rep1&type=pdf.
3. *Near-Term Feasibility of Alternative Jet Fuel,* available at http://web.mit.edu/aeroastro/partner/reports/proj17/altfuelfeasrpt.pdf.
4. Opportunities for DoD Use of Alternative and Renewable Fuels, FY10 NDAA Section 334 Congressional Study, available at http://energy.defense.gov/Portals/25/Documents/Blog/20110718_Opportunities_DoD_Use_Alternative_Fuels.pdf.
5. For more information on ASTM International, please visit http://www.astm.org/. More specifically, the list of approved alternative jet fuel pathways can be found in the ASTM D7566 active standard that is available for download from that site.
6. http://skynrg.com/wp-content/uploads/2016/01/20160122_Press-Release_SkyNRG-Avinor-and-Air-BP-make-first-volumes-of-sustainable-jet-fuel-a-reality-for-Lufthansa-KLM-and-SAS-at-Oslo-Gardermoen-Airport.pdf.
7. http://www.prnewswire.com/news-releases/united-airlines-makes-history-with-launch-of-regularly-scheduled-flights-using-sustainable-biofuel-300234887.html.
8. http://newsroom.united.com/2015-06-30-United-Airlines-Purchases-Stake-in-Fulcrum-BioEnergy-with-30-Million-Investment.
9. http://www.biofuelsdigest.com/bdigest/2015/07/21/fedex-southwest-airlines-combine-to-buy-entire-jet-fuel-output-of-red-rock-biorefinery-through-2024/.
10. For more information, see http://www.puresky.de/en/#/results-of-the-six-month-long-term-trial/engine-condition-monitoring/.
11. Miller, B., Thompson, T., Johnson, M., Brand, M., McDonald, A., Schenk, D., Driver, J., Leistritz, L., Leholm, A., Hodur, N., Plavin, D., Glassman, D., Anumakonda, A., Altman, R. *ACRP Report 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting,* Transportation Research Board of the National Academies, Washington, D.C., 2012. Available at http://www.trb.org/Main/Blurbs/166622.aspx.
12. Miller, B., D. Johnson, P. Jones, T. Thompson, M. Johnson, M. Hunt, D. Schenk, J. Driver, G. Biscardi, J. Lavin, D. Plavin, R. Dunkelberg, C. Fussell, P. Van Pelt, D. Glassman, H. Peace, J. Norris, D. Fordham, and R. Altman. *ACRP Report 83: Assessing Opportunities for Alternative Fuel Distribution Programs.* Transportation Research Board of the National Academies, Washington, D.C., 2013. Available at http://www.trb.org/Main/Blurbs/168378.aspx.
13. https://www.faa.gov/about/office_org/headquarters_offices/apl/research/alternative_fuels/.
14. http://www.energy.gov/eere/bioenergy/technology-pathways.
15. For more information on jet fuel quality practices, see *R&D Control Study: Plan for Future Jet Fuel Distribution Quality Control and Description of Fuel Properties Catalog,* available at https://www.faa.gov/about/office_org/headquarters_offices/apl/research/alternative_fuels/media/Metron_Fuel_Quality_Final.pdf.
16. Available at https://publications.airlines.org/CommerceProductDetail.aspx?Product=178.
17. *Sustainability Certification for Biofuels,* available at http://www.nrdc.org/energy/files/biofuels-sustainability-certification-report.pdf.
18. *Alternative Aviation Jet Fuel Sustainability Evaluation Report,* available at http://ntl.bts.gov/lib/43000/43100/43137/DOT-VNTSC-FAA-12-03.pdf.

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19. *Assessment of Sustainability Standards for Biojet Fuel,* available at http://www.ecofys.com/files/files/ecofys-2015-assessment-of-sustainability-standards-for-biojet-fuel.pdf.
20. This definition of chain-of-custody for commodities was adapted by the International Petroleum Industry Environmental Conservation Association (IPIECA) from a chain-of-custody definition for evidence in criminal trials. IPIECA has written on this topic in *Chain of Custody Options for Sustainable Biofuels,* available at http://www.ipieca.org/publication/chain-custody-options-sustainable-biofuels.
21. "Certified" in this context refers to sustainability certification, such as by programs like the RSB or the ISCC. For aviation alternative fuel, this means that neat alternative fuel that meets RSB or ISCC requirements is never mixed with neat alternative fuel that has not been certified. This usage of the word "certified" does not preclude blending of physically segregated fuel with conventional Jet A to meet ASTM D1655 fuel quality standards as long as the molecules of neat, certified, alternative fuel are not commingled with batches of alternative fuel (neat or blended) that have not also followed the physical segregation CoC method to the final dispensing tank.
22. *ACRP Report 46: Handbook for Analyzing the Costs and Benefits of Alternative Aviation Turbine Engine Fuels at Airports,* available at http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_046.pdf.
23. Double counting occurs when more than one supply chain operator takes credit for the environmental benefits attributed to the same amount of certified alternative fuel. To reduce the risk of double counting, systems that audit the entire supply chain (so-called end-to-end audits) can be implemented, as is the case in, for example, RSB and ISCC. In physical segregation, since production and sales records make it possible to track volumes of fuel introduced into the supply chain from feedstock production to delivery of final product, the information should be readily available to perform an end-to-end audit. In contrast, in a book-and-claim system, for example, the claim of environmental benefits is disassociated from the physical product, which can make it more difficult for auditors to find all the relevant information for performing an end-to-end audit.
24. See Note 21.
25. Similar to the situation for physical segregation explained in Note 22, mass-balance provides more opportunities to audit the movement of the physical product and its sustainability information along the supply chain. Therefore, it can provide more information to auditors, which makes it more difficult to double count.
26. http://www.ecofys.com/files/files/ecofys-2015-accounting-methods-for-biojet-fuel.pdf.
27. USDA, National Organic Program. http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=organic-agriculture.html.
28. FSC, Chain of Custody Certification, https://ic.fsc.org/chain-of-custody-certification.39.htm.
29. For a more in-depth description of how RECs work, please consult the EPA's Green Power Partnership publication on Renewable Energy Certificates. http://www.epa.gov/greenpower/documents/gpp_basics-recs.pdf.
30. Presentation by Galen Barbose of Lawrence Berkeley National Laboratory, available at http://emp.lbl.gov/sites/all/files/rps_summit_nov_2013.pdf.
31. See Note 21.
32. The pathway of an alternative aviation fuel identifies the fuel production facility, the feedstock used to produce the fuel, and the destination of the fuel. At present, no uniform system for ascribing pathway identification numbers for alternative aviation fuel exists. Pathway identification systems in current use include the U.S. EPA's RFS2 system and California's Low Carbon Fuel Standard. Neither applies specifically to alternative aviation fuel and may not necessarily reflect the specific sustainability benefits depending on the supply chain design, particularly from the standpoint of GHG emissions reduction over a petroleum fuel baseline.
33. "CO_2e" is "carbon dioxide equivalent."
34. "Noncertified" in this context could refer to alternative aviation fuel that does not qualify for certification under sustainability program rules. It could also refer to conventional aviation fuel that has been added to a batch of certified alternative aviation fuel. In the context of alternative aviation fuel, it is most likely that "noncertified" will refer to conventional Jet A mixed with a certified alternative aviation fuel. Users of this report should remember, however, that "noncertified" can also refer to an alternative aviation fuel that has not been certified by a third party to sustainability standards such as RSB or ISCC.
35. A variation on this process is a continuous accounting period where the mass of certified fuel forwarded by the operator is never allowed to exceed the mass of certified fuel that the operator produces.
36. Western Renewable Energy Generation Information System, https://www.wecc.biz/WREGIS/Pages/Default.aspx.
37. Environmental life-cycle assessment is one of the methods for evaluating sustainability of aviation fuel, regardless of the certification program. It is a standardized analytical methodology for understanding the environmental impacts of a product, process, or system from cradle to grave. The U.S. EPA uses the GREET model for LCA developed by Argonne National Lab (https://greet.es.anl.gov/) for approving fuel pathways under the RFS2.
38. http://www.epa.gov/otaq/fuels/renewablefuels/qap.htm.

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39. Page 18 of *Options for Reforming the Renewable Fuel Standard,* http://bipartisanpolicy.org/wp-content/uploads/2014/12/BPC-Options-for-Reforming-the-RFS1.pdf.
40. Proposed Finding That Greenhouse Gas Emissions from Aircraft Cause or Contribute to Air Pollution That May Reasonably Be Anticipated to Endanger Public Health and Welfare and Advance Notice of Proposed Rulemaking, http://www.gpo.gov/fdsys/pkg/FR-2015-07-01/pdf/2015-15192.pdf.
41. EISA Section 526: Impacts on DESC Supply, www.dtic.mil/get-tr-doc/pdf?AD=ADA502264.
42. More detailed information on the U.S. DoD and alternative fuels can be found in the DLA Energy Biofuel Feedstock Metrics Study, http://www.dtic.mil/dtic/tr/fulltext/u2/a575119.pdf.
43. Low Carbon Fuel Standard regulation, Exemptions for Specific Applications, page 3, http://www.arb.ca.gov/fuels/lcfs/CleanFinalRegOrder112612.pdf.
44. http://ec.europa.eu/energy/en/topics/renewable-energy/biofuels.
45. *Alternative Aviation Jet Fuel Sustainability Evaluation Report,* Futurepast Report for Volpe, http://ntl.bts.gov/lib/47000/47600/47652/Alternative_Aviation_Jet_Fuel_Sustainability_Evaluation_Report.pdf.
46. *DLA Energy Biofuel Feedstock Metrics Study,* LMI Report for DLA, http://www.dtic.mil/dtic/tr/fulltext/u2/a575119.pdf.
47. *Assessment of Sustainability Standards for Biojet Fuel* Ecofys Report for IATA, http://www.ecofys.com/files/files/ecofys-2015-assessment-of-sustainability-standards-for-biojet-fuel.pdf.
48. *Biofuel Sustainability Performance Guidelines,* NRDC Report, http://www.nrdc.org/energy/files/biofuels-sustainability-certification-report.pdf.
49. Palmer, W. J. *Will Sustainability Fly: Aviation Fuel Options in a Low Carbon World,* Ashgate Publishing, 2015, p. 135.
50. Interview with Matt Rudolf of the Roundtable on Sustainable Biomaterials, August 20th, 2015.
51. http://www.airportcarbonaccredited.org/.
52. http://www.airportcarbonaccredited.org/airport/4-levels-of-accreditation/introduction.html.
53. The LTO cycle is defined in ICAO's *Airport Air Quality Guidance Manual* (document 9889).
54. Bonsucro, http://bonsucro.com/.
55. Amyris Joins Bonsucro, the Leading Sustainability Standard for Sugarcane, http://investors.amyris.com/releasedetail.cfm?ReleaseID=746974.
56. ISO 13065. Sustainability Criteria for Bioenergy, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=52528.
57. International Organization for Standardization, http://www.iso.org/iso/home/about.htm.
58. International Sustainability and Carbon Certification, http://www.iscc-system.org/en/.
59. ISCC, All Certificates, http://www.iscc-system.org/en/certificate-holders/all-certificates/.
60. Roundtable on Sustainable Biomaterials, http://rsb.org/.
61. RSB, Member List, http://rsb.org/about/organization/member-list/.
62. Sustainable Aviation Fuel Users Group, http://www.safug.org/.
63. SAFUG Members, http://www.safug.org/members/.
64. SAFUG Our Pledge, http://www.safug.org/safug-pledge/.
65. Amyris, Renewable Mobility, Jet Fuel, https://amyris.com/products/jet-fuel/.
66. Altair Fuels, http://altairfuels.com/about/.
67. https://klmtakescare.com/en/content/weekly-flight-using-sustainable-biofuel.
68. Green Air Online. KLM Plans Drive-Down of Jet Biofuel Price Premium as It Starts Regular Series of Biofuel Transatlantic Flights, http://www.greenaironline.com/news.php?viewStory=1883.
69. https://klmtakescare.com/en/content/welcome-new-biofuel-partners-.
70. http://www.bp.com/en/global/bp-air/press/oslo-airport-first-location-to-supply-air-bp-biojet-via-main-fue.html.
71. http://skynrg.com/nordic/.
72. RSB, Participating Operators, http://rsb.org/certification/participating-operators/.
73. http://www.responsiblesoy.org/en/.
74. http://www.responsiblesoy.org/en/certification/tipos-de-certificacion/cadena-de-custodia/.
75. Roundtable on Sustainable Palm Oil, http://www.rspo.org/.
76. Greenair Online. Finnair Postpones Early Plans to Use Jet Biofuel on Commercial Flights Citing Sustainability and Price Issues, http://www.greenaironline.com/news.php?viewStory=1052.
77. The Jakarta Post, Garuda to Use Biofuel in 2016 to Reduce Emissions, http://www.thejakartapost.com/news/2014/08/27/garuda-use-biofuel-2016-reduce-emissions.html.
78. RSPO Supply Chains, http://www.rspo.org/certification/supply-chains.

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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