ACRP 02 36: Assessing Opportunities for Alternative Fuel Distribution Programs

Contractor Final Report

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Prepared by:

Bruno Miller, Donovan Johnson, Philip Jones, Terry Thompson, Michael Johnson, Meghan Hunt
Metron Aviation

Donald Schenk, Judith Driver, Gerry Biscardi, Jack Lavin, David Plavin
ACA Associates

Ryk Dunkelberg, Cody Fussell, Peter van Pelt
Barnard Dunkelberg Corp.

Diana Glassman
Integration Strategy

John Norris, Hazel Peace
Ricardo-AEA

Damon Fordham
PPC

Richard Altman
RCB Altman Associates, LLC

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1 Introduction

This Contractor Final Report covers Tasks 1 through 10 of the ACRP Project 02 36 "Assessing Opportunities for Alternative Fuel Distribution Programs." A summary description of the work conducted and information utilized in each task is presented below. A summary of Tasks 1 through 5 was provided in the Interim Research Report dated December 7th, 2011. This summary has been updated and is reproduced below for completeness. A summary of Tasks 7 through 10 is also presented, including excerpts from the Working Paper on Airport Feedback submitted as part of Task 9.

1.1 Motivation and objectives

Alternative fuels have the potential to provide significant economic and environmental benefits to airports and their communities. Airports and airlines are already investigating the economic and environmental benefits and implementation challenges of alternative jet fuels. In addition to alternative jet fuels, there are co-products and other alternative fuels that may be of interest to airports and their communities. Given the concentrated demand for multi-modal transportation at airports, these facilities are ideally situated to become distribution centers for a variety of alternative fuels. This offers a unique opportunity for airports to develop a new line of business with the potential to provide significant environmental, economic, and employment benefits.

Alternative jet fuel facilities produce numerous co-products that can be used by the airport community, including tenants and off-airport customers. For example, a typical co-product of alternative jet fuel production is "green diesel" which can be used by most passenger or cargo vehicles. The airport-centered demand provides a natural focus for the distribution of transportation fuels, and many airports already have fuel distribution infrastructure elements to meet those needs. This symbiosis makes airports a natural point of convergence for alternative fuel producers and end-users.

The objective of this research is to provide a guidebook and toolkit for airport leadership that is interested in distributing alternative fuels. The guidebook and toolkit will be useful for airports that may be considering additional alternative fuels as part of a master plan or in response to a more immediate need.

The guidebook will provide management with a planning and evaluation tool that identifies the economic, environmental, and policy issues that need to be addressed to make alternative fuels a success. The guidebook will be designed to remain relevant in spite of the anticipated changes in the economics and technology of alternative fuels. Thus, the tools will be focused on the critical issues that need to be considered in arriving at a comprehensive picture of an airport-based alternative fuels distribution project. While the guidebook will be targeted primarily at airport leadership and their staff, it will also be helpful to other parties interested in alternative fuels, such as users and producers of alternative fuels. The guidebook will provide airports a framework for identifying factors that are unique to their situation and a toolkit for evaluating business opportunities and metrics to support quantitative assessments of the benefits and costs of becoming involved in an alternative fuel distribution program.

1.2 Overview of research approach

The research approach for this project was organized in ten tasks, as shown in Figure 1. The figure also indicates the major interim and final deliverables.

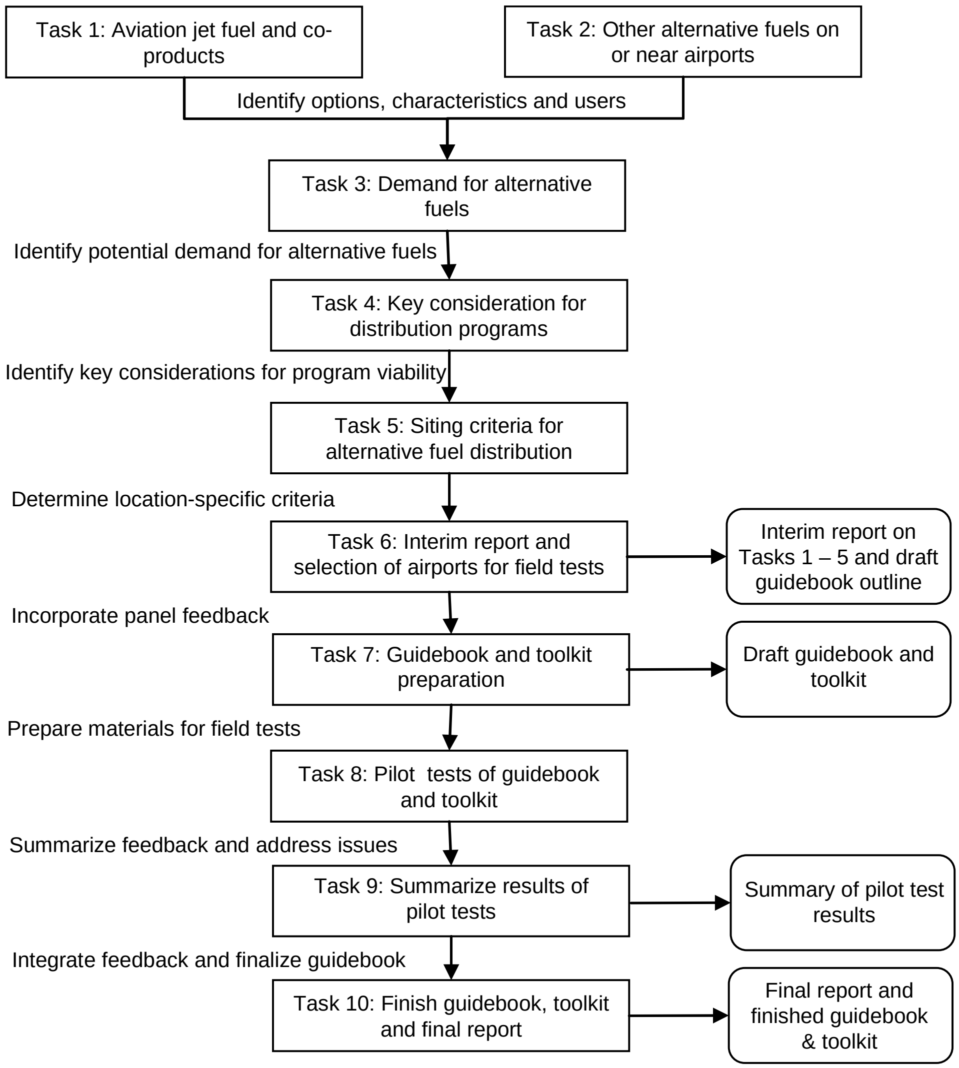

Figure 1: Overview of Research Approach

Task 1 was to identify the options, characteristics, and potential users of alternative jet fuel and associated co-products. Task 2 was conducted in parallel and focused on alternative fuels other than alternative jet fuel and its co-products that may be distributed at or near airports. Having identified the options, characteristics, and users for alternative fuels, Task 3 developed criteria to assess the potential demand for the fuels identified in Tasks 1 and 2. Task 4 identified the key considerations and opportunities for the viability of alternative fuel distribution programs at airports, including economic, environmental, financial, regulatory, and stakeholder engagement elements. Task 5 investigated the siting criteria for alternative fuel distribution programs. In Task 6, an interim report summarizing the outcomes from Tasks 1–5 was prepared. In addition, this interim report also contained a detailed outline of the guidebook and proposed components of the associated toolkit and a discussion of candidate airport selection at which to pilot test the guidebook and toolkit.

After the interim report was discussed with the review panel, the research team proceeded with Tasks 7-10. In Task 7, prototypes of the guidebook and toolkit were developed and shared with the panel for comments and review. In Task 8, the feedback from the panel was incorporated into the guidebook and toolkit. Then, the guidebook and toolkit were pilot tested with the airports approved by the panel. In Task 9, results of the pilot tests were summarized and changes to the guidebook and toolkit recommended. In Task 10, feedback from the airports and the review panel were used to prepare final versions of the guidebook and toolkit, as well as this Contractor Final Report.

2 Summary of Tasks 1 and 2: Main characteristics of alternative fuels

This section presents the results of Task 1 “Alternative jet fuels and co-products” and Task 2 “Other alternative fuels on or near airport.” It discusses the main characteristics of the alternative fuels considered for this study. These characteristics include the following:

- Status of technology
- Infrastructure and equipment requirements
- Potential environmental benefits
- Conditions under which alternative fuels are cost competitive
- Drawbacks
- Potential user groups

The presentation is divided in two parts. The first part focuses on alternative jet fuels and co-products, with focus on the two pathways for alternative jet fuel that have been approved for use on aircraft as of this date:

- Fischer-Tropsch (FT)
- Hydroprocessed Esters and Fatty Acids (HEFA)

The main co-products of these processes of interest for airport use include:

- Green diesel
- Excess heat for heating or electricity generation

This first part also introduces three other pathways that are being considered for approval in the short to medium term:

- Alcohols to Jet (ATJ)
- Fermentation Renewable Jet (FTJ)
- Pyrolisis Renewable Jet (PRJ)

The second part of this section discusses other alternative fuels, primarily those used for surface transportation. In contrast to alternative jet fuel, there are many different alternative fuels that could be used for surface transportation; however, the idea was to concentrate on those alternative fuels that have the most potential for being utilized in the airport setting. The selection of fuels studied was made based on current maturity of the production technology as well as current or expected used at airports across the United States. The selected alternative fuels include the following:

- Biodiesel (B20)
- Ethanol (E85)
- Compressed Natural Gas (CNG)
- Liquefied Petroleum Gas (LPG)
- Electricity

2.1 Alternative jet fuels

Alternative jet fuels include those fuels from non-petroleum sources that are approved for use on aircraft. These fuels are those that meet the specifications established by standard-setting organizations such as ASTM International (ASTM) and the United Kingdom's Defense Ministry (DEFSTAN). Alternative jet fuels can be made from many different sources or feedstocks including coal, natural gas, municipal solid waste, plant oils, and animal fats. The technology for producing alternative jet fuel is evolving rapidly in response to market and regulatory pressures. As a result, this section covers only those alternative jet fuels currently approved for aircraft used by ASTM and the three methods that appear likely to receive certification over the next few years: alcohol, fermentation, and pyrolysis.

Currently, there are only two processes for producing alternative jet fuels that have been certified by ASTM. They are either the Fischer Tropsch (FT) or Hydrotreated Esters and Fatty Acids (HEFA) processes (described below). The certification requirements for these fuels are specified in the ASTM D7566 specification (ASTM 2011); guidance is also provided by the FAA (FAA 2010a). Once the fuel is certified, it is considered to meet the ASTM D1655 specification which is the specification that applies to conventional jet fuel made from crude oil. In addition to FT and HEFA, researchers are pursuing other options for converting plant or animal-based carbon into jet fuel. These initiatives include using new feedstocks such as algae and municipal solid waste, using carbon monoxide from the production of iron, and converting sugars into jet fuel. These pathways are also discussed below.

"Drop-in" advantage of alternative jet fuels

A significant advantage of alternative jet fuel is that it is a "drop-in" fuel. A drop-in fuel in this context is a fuel that is found to have performance characteristics and chemical compositions essentially identical to conventional fuel (Miller et al. 2011). For example, once an alternative fuel is certified as an ASTM D1655 fuel, it can be distributed, handled, stored, and used without modifications to existing infrastructure or equipment. Similarly, co-products of the production of alternative jet fuel, such as diesel and naphtha, are also considered drop-in and can use existing infrastructure.

It is important to make a distinction between diesel as a co-product from an FT or HEFA process and "biodiesel." In this document, diesel manufactured as a co-product of the FT or HEFA process is called “green diesel.” The term “biodiesel” refers to fuels produced through esterification. These fuels are also known as Fatty Acid Methyl Esters (FAME). FAME biodiesel is not considered a drop-in fuel and must be handled with extra precautions, especially in multi-product infrastructure that may also handle jet fuel.

Blending requirement for alternative jet fuels

The ASTM D7566 specification requires that alternative jet fuels produced through the FT or HEFA processes be blended with conventional jet fuel up to a maximum 50/50 ratio. FT and HEFA jet fuels lack some compounds present in conventional jet fuel, such as aromatics, which are needed for the safe operation of aircraft engines. Blending these fuels with conventional jet fuel ensures the presence of the required compounds. While blending is not a difficult process, it requires some planning as conventional fuel must be procured and be available on-hand for blending prior to certification.

2.1.1 Fischer-Tropsch (FT)

The Fischer Tropsch (FT) process has been successfully used by SASOL in South Africa to convert coal to gasoline, diesel, and jet fuel for many years (Roets 2009). It was certified for use in U.S. commercial operations by ASTM in August 2009. FT can use most carbon-rich feedstocks but is best known for converting coal, natural gas, and municipal waste into a wide range of fuels.

The commercially proven FT technologies typically require multibillion dollar facilities and use coal and natural gas as feedstocks. New technologies are being developed which have the potential for using a variation on the FT process that hold the promise of being able to be cost effective on a much smaller scale. These more modest capital costs are essential to being able to use municipal waste such as the ones that are in the planning stage in Australia, U.S., and the United Kingdom.

The FT process produces a number of co-products (gasoline, diesel fuel, jet fuel, naphtha) plus heat which can be used to produce electricity. The typical product distribution of an FT production run is approximately 30% gasoline, 40% jet fuel, 16% diesel, and 14% fuel oil (IATA 2009).

Status of technology

FT production technology is well understood and has been proven on a commercial scale by several major companies, including SASOL and Shell Oil Company. The new small scale technologies are developmental.

Infrastructure and equipment requirements

No changes to existing storage and distribution infrastructure at the airport or equipment, including aircraft and engines, are required, because the fuel is drop-in.

Potential environmental benefits

FT fuels are chemically very similar to their petroleum equivalents; however the low hydrocarbon and sulfur contents are likely to result in lower secondary particulate matter (PM) emissions as well as hydrocarbon and sulphur emissions (e.g., sulphur oxides or SOx). Emissions of oxides of nitrogen (NOx) are more dependent on the temperature at which the fuel is burned and not the fuel formulation itself, so NOx emissions are unlikely to be affected.

The savings in terms of life-cycle greenhouse gas (GHG) emissions depend heavily on the feedstock. For example, coal and natural gas without carbon capture are likely to have higher GHG emissions than conventional jet fuel from petroleum, whereas switchgrass to fuel could result in significant reductions in GHG (Stratton et al. 2010). In the case of municipal solid waste, the content of the waste stream (plastics vs. paper, for example) influences GHG savings. Computation of life-cycle GHG savings is complex, and depends on the particular circumstances. For example, the transportation of feedstocks generates GHG emissions, so one facility properly sited may experience a decline in GHG while an identical but remote facility may experience a net increase. For a more detailed discussion of life-cycle GHG emissions estimation, please consult (Stratton et al. 2010) or (Miller et al. 2011).

Conditions under which it is cost competitive

FT is most competitive when the price of the feedstock based on energy content is significantly less than that of a barrel of oil. Such price anomalies occur where feedstocks have limited uses or its supply exceeds its demand. Municipal solid waste is a case in which the feedstock has limited alternative uses, and natural gas in the U.S. is a case in which the supply exceeds the current demand.

Other conditions under which FT is cost competitive include the following:

- Presence of feedstock suppliers willing to provide a long-term contract which covers volume and price.
- High demand for co-products, such as green diesel or green naphtha.
- Availability of low cost financing.
- Relevant governmental tax credits available for fuel produced from the proposed feedstock.

Drawbacks

- Current commercial-scale FT plants are very expensive, on the order of billions of U.S. dollars.
- Production economics depend on continual availability of very cheap feedstock.
- Environmental benefits are heavily dependent on the feedstock (see discussion above).

Potential user groups

Because the FT process produces a range of products, the potential users are diverse:

- Commercial airlines, military aircraft, and general aviation will use alternative jet fuel.
- Surface transportation will use green diesel; for example, taxis, cargo truck operators, bus operators, and rail operators.
- Green diesel can be used in airport ground support equipment.
- Excess heat and electricity can be fed into the grid or used to heat and power airport facilities or rail/light rail mass transportation.

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use an alternative fuels is discussed in Section 2.5.

2.1.2 Hydroprocessed Esters and Fatty Acids (HEFA) alternative jet fuels

ASTM certified HEFA-produced jet fuels in July 2011 (ASTM 2011). This process converts fatty acids that originate from either plants or animals into a combination of jet, diesel, and naphtha. HEFA jet fuel is becoming increasingly available and is currently being used in limited commercial operations by European and U.S. airlines (Miller et al. 2011).

While there are only a limited number of HEFA refineries producing jet fuel as of the writing of this guidebook, there are commercial-scale refineries that employ substantially similar technology to produce diesel. Commercial-scale HEFA refineries are expected to produce approximately 80–100 million gallons of diesel and jet fuel a year and are expected to use regional feedstocks to minimize transportation costs. The refining technology is sufficiently flexible that a HEFA refinery can be designed to use virtually any plant oil or animal fat. A HEFA facility run to produce maximum distillates would typically produce 20%–70% diesel, 15%–45% jet fuel, and the remainder naphtha, liquefied petroleum gas (LPG), and other by products (Pearlson 2011).

Status of technology

HEFA has been technologically proven, and some operators are willing to guarantee performance and have the financial strength to honor that guarantee. The number of commercial-scale facilities is expected to increase now that the HEFA jet fuel has been certified as drop-in for use on aircraft.

Infrastructure and equipment requirements

No changes to existing storage and distribution infrastructure at the airport or equipment, including aircraft and engines, are required since the fuel is drop-in.

Potential environmental benefits

As with FT fuels, HEFA fuels are expected to produce lower sulfur and PM emissions, with similar NOx emissions as conventional jet fuel.

The potential for life-cycle GHG emissions savings is substantial, but depends heavily on the feedstock. Of particular concern is the effect of land use change. For example, tallow-based HEFA jet fuel has low life-cycle GHG emissions because tallow is essentially a waste product and has minimal life-cycle GHG inputs (Stratton et al. 2010). Alternative jet fuel made from jatropha or camelina also has a lower life-cycle GHG footprint compared to conventional jet fuel. However, computation of life-cycle GHG savings is complex and will vary for each refinery.

Conditions under which HEFA is cost competitive

- Availability of low-cost local feedstocks, because this is the largest single cost of the alternative fuel.

- Availability of an existing refinery whose infrastructure can be used by the HEFA facility.

- Substantial demand for co-products.

Drawbacks

- HEFA refineries that rely on plant-based fatty acids must rely on locally grown crops or have access to bulk freight transportation of the feedstock (e.g., rail or pipeline) to be cost efficient.

- The business case is difficult without financial and contractual instruments to manage the long-term cost of the feedstock; this is a challenge being worked on by the U.S. Department of Agriculture (USDA).

- The use of any edible plant oils such as corn or soy oil as feedstock is controversial because of the potential to compete with the food supply (see discussion on “food-versus-fuel” in Section 4.4.3).

Potential user groups

Because the HEFA process produces a range of products, the potential users are diverse:

- Commercial airlines, military aircraft and general aviation will use jet fuel.

- Surface transportation will use green diesel; for example, taxis, cargo truck operators, bus operators, and rail operators.

- HEFA diesel can be used in airport ground support equipment.

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use alternative fuels is discussed in Section 2.5.

2.2 Main co-products of FT and HEFA processes

The main co-products of FT and HEFA processes of interest for airport use include green diesel and electricity. There are other co-products, such as green naphtha, that could be used on boilers and other specialized equipment. The discussion below concentrates on the two co-products with greatest potential use:

2.2.1 Green diesel

As mentioned in Section 2.1, the term “green diesel” is used here to describe diesel fuels produced from FT or HEFA processes, either as a co-product of alternative jet fuel production or as the main output of the production process. Green diesel is a drop-in replacement and can be used in both road and off-road vehicles (e.g., Ground Support Equipment (GSE) at airports), though it is often more acceptable as a blend. It can also be blended with diesel used in train engines, or with “marine distillate oil” for use in ships. Green diesel cannot be blended with bunker or heavy fuel oil. Given the limited number of commercial-scale FT and HEFA facilities in the United States, very little green diesel is currently available for use on U.S. airports although its availability is expected to increase as more production facilities come into operation.

Status of technology

No changes to existing infrastructure or equipment are required, because the fuel is drop-in.

Infrastructure requirements

Nothing additional is required beyond what already exists for conventional diesel. Similarly, there are no restrictions on the types of diesel engines that can use these fuels (GSE, buses, trucks, etc.), because it is a direct replacement to diesel.

Potential environmental benefits

Similar to alternative jet fuel, green diesel is chemically very similar to its conventional equivalent and has the potential to provide some environmental benefits. For example, the low hydrocarbon and sulfur content of green diesel are likely to result in lower secondary particulate matter (PM) emissions as well as lower sulfur emissions. In contrast, the levels of carbonaceous PM are unlikely to be substantially different. Emissions of oxides of nitrogen (NOx) are more dependent on the temperature at which the fuel is burned and not the fuel formulation, so NOx emissions are unlikely to be affected. The main savings in terms of emissions are from GHGs; however, these savings will depend on several factors, including feedstock choice, production process, and transportation.

Conditions under which it is cost competitive

- Green diesel is fully interchangeable with conventional diesel, and is typically cost competitive when the cost of crude petroleum oil is high (DOE 2011c).

- As demand for green diesel increases and more supply becomes available, economies of scale would help to decrease the cost of green diesel making it more attractive to produce.

Drawbacks

- Commercial-scale production of green diesel is currently limited.
- Green diesel produced through the HEFA process requires hydrogen and biomass feedstocks which may make large-scale production challenging.

Potential user groups for each fuel and co-product

Potential users are all those who use vehicles that consume diesel. These include:

- Airport authorities and their tenants operating airside equipment.
- Taxi drivers, cargo truck operators, bus operators.
- Non-road transportation providers – public transport and cargo via rail and water transportation.
- Users of airport infrastructure, e.g. standby generators.
- Private vehicles.

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use an alternative fuels is discussed in Section 2.5.

2.2.2 Electricity

Electricity is increasingly being used in airports around the world to power ground vehicles as well as aircraft when they are parked at the gate. This allows aircraft to meet their power needs without having to turn on the engines or auxiliary power unit (APU) with consequent savings in fuel burn and emissions.

Electricity can also be a by-product of alternative jet fuel production. The amount of electricity that is generated is a variable that depends on the overall production strategy for the facility. For example, in FT plants, the amount of electricity produced is a compromise between processing synthesis gas to produce maximum volumes of transportation fuel and burning it to produce heat and electricity. Typical ratios of liquid fuel production to electricity production for FT plants range between 2–3 million gallons liquid fuel per megawatt of electricity generated (Swanson et al. 2010; Liu et al. 2011).

Status of technology

Electricity is a widespread available and mature technology. Examples of airports adopting electrical vehicles include St. Paul's Airport, Minneapolis (EEN 2009), London's Heathrow Airport (SEV 2008), Tokyo's Haneda Airport (Frid 2008), and many others (FAA 2006; FAA 2010b).

Infrastructure requirements

Basic electricity infrastructure is widely available at airports. However, additional charging stations for electric vehicles must be provided. If principally overnight charging is used then limited additional infrastructure capacity may be needed. However, higher demand for electricity for vehicle or aircraft use will need the current infrastructure at airports (e.g., sub-stations, transmission lines, etc.) to be enhanced or upgraded, this usually entails concrete removal/replacement on the ramp and may need the purchase of additional real estate needs for sitting. Additional GSE fleet may also need to be purchased to cover charging downtime.

Potential environmental benefits

Electric vehicles generate zero emissions at the point of use. In addition, the use of electrified gates reduces fuel burn on aircraft engines or APUs while parked at the gate. Potential GHG benefits will depend on how the electricity is being generated.

Conditions under which electricity is cost competitive

Electricity rates and the market are well understood. Access to cheaper electricity than what is provided by the grid will have a positive impact on the project financials. However, any savings in electricity costs will need to be considered in the context of the overall cost of additional equipment and infrastructure and the payback time period."

Drawbacks

Electricity has relatively few drawbacks. Range of electric vehicles can be a concern; however, if vehicles are used primarily on or around the airport, this concern decreases. In cold weather climates, the battery specification will need to be considered and more expensive batteries will need to be used (i.e., not lead acid batteries) or, alternatively, when not in use, lead acid batteries would need to be kept warm (i.e., above freezing).

Profiles of potential user groups for green electricity

Electricity is used (or could be used) within airports in the following ways:

- within buildings – lighting, signage, escalators, lifts, baggage carousels
- out to planes – moving walkways, jetways
- airside transport – baggage tugs, belt loaders, forklift trucks, cargo tractors, pushback tractors
- other airside **–** fixed electrical ground power and for generation of pre-conditioned air (PCA) for aircraft
- landside road transport – passenger cars, electric vans, rental car and hotel shuttles, taxis
- other landside transport – inter-terminal transit systems, railways

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use an alternative fuels is discussed in Section 2.5.

2.3 Alternative jet fuels in development

As mentioned in section 2.1, the field of alternative jet fuels is in active development. Rapid progress is being made to develop processes other than FT and HEFA. The following sections describe three of the most promising processes, all of which are candidates to reach certification in the next few years.

2.3.1 Alcohols to Jet (ATJ)

ASTM has a task force that supports the certification of jet fuel produced from alcohols, with a target certification date of 2013 or 2014. This process converts alcohols into fuels using well-understood chemical processes. Several promising approaches exist, including the synthesis of alcohol from carbon monoxide and modification of bacteria and yeasts to convert sugar into alcohols.

Status of technology

Alcohol to jet fuel is young and unproven at commercial scale. The technology is very promising but it is still in development. The co-products of such approaches include green diesel and others that are not yet well established.

Infrastructure and equipment requirements

No changes to existing storage and distribution infrastructure at the airport or equipment, including aircraft and engines, are required, because the fuel is drop-in.

Potential environmental benefits with respect to NOx, PM, GHG emissions

It is to be expected that PM and sulfur emissions will be lower compared to conventional fuels, because the production process will be controlled to produce a clean fuel. Similar to other alternative fuels, NOx emissions will be largely unchanged from conventional fuels.

Although the agricultural feedstocks used in the ATJ process are renewable, the life-cycle GHG emissions of alcohol-based fuels are heavily affected by the resources expended to grow, harvest, and transport the feedstocks, and by the potential for diversion of arable land from production of human or animal food and the clearance of land to produce energy crops. To the extent biomass feedstock is comprised of agricultural waste, it is expected to have a relatively low life-cycle GHG footprint.

Conditions under which it is cost competitive

- Inexpensive feedstock.
- Minimizing feedstock transportation costs
- Adequate demand for co-products.

Drawbacks

- Technology is young
- Some feedstocks may compete with food.

Potential user groups

The potential user groups are those for aviation fuel. As each company is developing proprietary technology, it is not clear at this point which co-products may result from the various technologies being developed.

2.3.2 Fermentation Renewable Jet (FRJ)

This technology plans to use genetically engineered bacteria to convert sugars directly into alternative jet fuels. This direct conversion has the potential to significantly reduce cost. The co-products, if any, are not yet well established. There is no target certification date as of the writing of this report.

Status of technology

FRJ is young and unproven at commercial scale.

Infrastructure and equipment requirements

No changes to existing storage and distribution infrastructure at the airport or equipment, including aircraft and engines, are required, because the fuel is drop-in.

Potential environmental benefits with respect to NOx, PM, GHG emissions

Same as ATJ (see Section 2.3.1).

Conditions under which it is cost competitive

- Inexpensive feedstock
- Minimizing feedstock transportation costs
- Adequate demand for co-products

Drawbacks

- Technology is young
- Some feedstocks compete with food

Potential user groups

The potential user groups are those for aviation fuel. As each company is developing proprietary technology, it is not clear at this point what co-products may result from the various technologies being developed.

2.3.3 Pyrolisis Renewable Jet (PRJ)

Pyrolysis converts organic material under high temperature and little oxygen into “tar-like” crude bio oil, which is then converted into alternative jet fuel. PRJ technology is young. No path to certification has been announced by ASTM.

Status of technology

PRJ technology is young and unproven at commercial scale.

Infrastructure and equipment requirements

No changes to existing storage and distribution infrastructure at the airport or equipment, including aircraft and engines, are required since fuel is drop-in.

Potential environmental benefits with respect to NOx, PM, GHG emissions

Same as ATJ (see Section 2.3.1).

Conditions under which it is cost competitive

- Inexpensive feedstock. This is likely to account for 70% to 80% of the cost of the alternative fuel.
- Minimizing feedstock transportation costs.
- Adequate demand for co-products.

Drawbacks

- The technology is young.

Potential user groups

The potential user groups are those for aviation fuel. As each company is developing proprietary technology, it is not clear at this point what co-products may result from the various technologies being developed.

2.4 Other alternative fuels

In contrast to alternative jet fuels, alternative fuels for surface transportation have been available in the U.S. for decades. Furthermore, there are more options available for surface transportation fuels and equipment than there are for aircraft use. This section is limited to those alternative fuels considered to be most-commonly available for current and future use at airports in the U.S.

2.4.1 Biodiesel

In addition to green diesel, discussed in section 2.2.1, there are other biodiesels. These are generally made from vegetable oils such as palm, soya, and rape seed, and could be used as pure vegetable oils (PVO) or in a lightly processed form such as FAMEs. Vehicle and engine manufacturers for road transport and ground support equipment do not recommend the use of PVO, but do permit blends of low concentrations of FAME with petroleum diesel (e.g., at 20%). Consequently, the analysis below is for FAME only, and excludes PVO. In the remainder of the guidebook, we focus on biodiesel as a 20% mix with conventional diesel (B20). Other blend ratios are possible, but B20 is the most common blend in the U.S. (DOE 2011d).

Status of technology

Biodiesel technology is relatively mature. There are many production routes ranging from very small scale production, using for example a mechanism called phase separation, to large-scale production using distillation.

Infrastructure requirements

In terms of pipelines and storage infrastructure, there is little that needs to be changed at the airport setting; however, FAME is considered a pollutant in jet fuel, so care must be taken with storage and handling infrastructure used for both fuels. Furthermore, poorer stability of biodiesel means that when held in tanks, these fuels could have microbial growth or cause accelerated corrosion.

There are restrictions on the types of diesel engines that can use biodiesel, and at what blend strength. Biodiesel tends to gel at temperatures higher than conventional diesel, so its use in cold climates is not recommended. This characteristic impacts GSE, buses, trucks, and other vehicles common in the airport setting.

Potential environmental benefits

Same as green diesel (section 2.2.1).

Conditions under which it is cost competitive

- Biodiesel is typically cost competitive when the cost of crude petroleum oil is high (DOE 2011c).
- Historically, government incentives have helped to support the price competitiveness of biodiesel.

Drawbacks

- Can dissolve more water relative to conventional diesel. This can lead to corrosion of storage tanks, fuel tanks, and connecting pipes.
- FAME has a higher freezing point than conventional diesel. This can cause difficulties in cold-climate operations.

- Microbial growth can be an issue, relative to the quite sterile conventional diesel. This can lead to microbes growing in the fuel, which then blocks fuel filters, or injectors.
- Diesel engine warranties often restrict the concentration of biodiesel permitted in the fuel.
- There is the potential issue of fuel deteriorating, or even polymerising, in the tanks of vehicles or equipment left standing, e.g. standby generators.

Potential user groups

- Road transport—can be blended with petroleum diesel (up to 7% in Europe; based on ASTM D975 (ASTM 2008), up to 5% in the U.S.), or used in higher proportions in dedicated fleets.
- Rail—not generally used in the U.S. however, a study in the UK (RSSB 2006) indicates a blend up to 20% can be used (B20).
- Water transportation—not used for main engines, may be permitted for auxiliary engines. Oceangoing ships use bunker fuel, a heavy fuel oil that is semi-solid. Given its semi-solid state, bunker fuel cannot be blended with liquid fuel, particularly biofuels, prior to sailing. In addition, maritime shipping fuel tanks are often open to the atmosphere in a damp and salty environment over the sea, which means that use of biofuels can result in greater corrosion and microbial growth.

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use an alternative fuels is discussed in Section 2.5.

2.4.2 Ethanol

Ethanol is usually made from the fermentation of sugars (e.g., from cane and beet) or of starches (e.g., from corn or wheat). In the future it may be made from non-edible biomass such as wood or crop stalks (known as ligno-cellulosic derived ethanol). Ethanol can be blended with gasoline, and used in both road vehicles and off-road, spark ignition, vehicles. Ethanol is currently not used in diesel vehicles. Ethanol is typically blended at 10% with gasoline in all of the U.S. This guidebook focuses on mixtures with 85% ethanol (E85) which is considered an alternative fuel by the EPA (DOE 2011g).

Status of technology

Commercial-scale production of ethanol has been available for decades. Likewise, ethanol has been added in low concentrations to gasoline for about the same time. Ethanol can be blended with conventional gasoline. The limit has been 10% in the U.S. for around the last 30 years, the E10 standard. However, in November 2010 the EPA announced it would allow ethanol up to 15% for use in cars and light trucks built since 2007 (EPA 2010a). (This is more commonly known as the "first partial waiver.") Since then, further announcements have been made, indicating that a majority of vehicles manufactured since 2001 may safely use E15 (EPA 2011).

Furthermore, E85 is increasingly becoming available in the U.S., with one source suggesting E85 is available from around 2,650 stations in the U.S. in January 2011 (though this is still a small fraction of the approximately 140,000 publicly accessible gasoline stations in the U.S.). Price and availability of E85 are available from E85prices.com (E85 2011).

Infrastructure requirements

The main concern with ethanol is that it tends to absorb water from the atmosphere, which can be a challenge for storage infrastructure and engines. At low blend ratios (e.g., less than 15%), there are little to no concerns; however, high blend ratios, such as 85% (E85) used in flex-fuel vehicles, require modifications to a vehicle's fuel distribution system and dedicated storage tanks.

Potential environmental benefits

Generally, research has shown that for ethanol blends up to 25% (E25), PM shows a clear reduction, whereas for NOx and hydrocarbon emissions results are mixed, some showing significant reductions and others showing significant increases (AEA 2008). For the E85 blend, the review of available data indicated no change in the emission factors of NOx or hydrocarbons, but a 20% reduction in PM emissions. As in the cases of green diesel and biodiesel, the main potential benefit is from reductions in GHG emissions subject to specific assumptions regarding feedstocks, production, and transportation.

Conditions under which it is cost competitive

Generally, ethanol is cost competitive only when it is blended with gasoline, which means its application is limited to surface vehicles. However, because its energy density is around two thirds that of gasoline, vehicles require more fuel to travel the same distance, hence its costs need to be around two thirds that of gasoline. For the E85 blend, the cost needs to be around 70% that of conventional gasoline or 73% that of an E10 blend for the same fuel economy measured in dollars per mile driven.

Drawbacks

- As mentioned above, ethanol absorbs water from the atmosphere, which is a challenge for the smooth running of engines and storage infrastructure. Furthermore, it is water soluble; during a rainstorm, the rainwater further dilutes the ethanol blend. Pure gasoline is not water soluble; water that penetrates into the storage tank lies at the bottom.

- The presence of water leads to issues of corrosion.

- There are materials compatibility challenges for higher ethanol blends above E15 that affect fuel lines, seals, and other equipment.

- Low energy density relative to gasoline. A consumer needs 1.54 gallons of ethanol to achieve the same energy as one gallon of gasoline.

- Flex fueled vehicles are designed to use fuels ranging from 85% ethanol (E85) to 0% ethanol (E0). Therefore, more sophisticated fuel management systems must be used, and this leads to additional vehicle purchase costs.

- Ethanol also has drawbacks regarding fuel costing, especially if tax is charged on a volume basis because of the low energy density.

Potential user groups

The potential users are all those who currently use gasoline. Regarding the airport setting, there is little airside use for ethanol as most vehicles use diesel. However, for landside use the majority of fuel burned is gasoline.

There are two primary factors affecting the net financial benefit or cost of using E85. First, E85 has a fuel economy penalty which is constant at around 30%. Second, the price differential between E85 and gasoline fluctuates and currently favors E85 by about 10%. To achieve parity, the price differential needs to be at around 30%. Consequently, users of E85 are likely to need to make the conscious decision that they are willing to pay extra for the fuel in exchange for environmental benefits.

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use an alternative fuels is discussed in Section 2.5 .

2.4.3 Compressed Natural Gas (CNG)

Natural gas is an important fossil fuel, most commonly used for heaters, boilers, and electricity generation. Compressed natural gas (CNG) is also being increasingly used on surface transportation, most notably on buses and dump trucks.

Status of technology

CNG is available in commercial scale. The technology for distribution, storage, and road vehicles is also available.

Infrastructure requirements

There is a relatively extensive low-pressure natural gas infrastructure already in place, such as that reaching into many residential and commercial buildings in the U.S. For vehicle use, there is an additional requirement of safely providing compressed gas at around 3,000 psi which requires additional equipment to dry, compress, and store the gas at high pressure. In addition, dedicated vehicles are required to run on CNG.

Potential environmental benefits

If CNG is used to replace diesel in appropriate vehicles, there would be reduction in NOx and PM emissions. There is the potential for GHG emissions reductions on a life-cycle basis, but this is subject to assumptions regarding extraction, processing, and transportation. If CNG is used to replace gasoline, then there is likely to be a small reduction in GHG emissions and a moderate reduction in PM.

Conditions under which it is cost competitive

Natural gas is a fossil fuel whose price fluctuates somewhat similarly to the cost of crude oil but driven by its own market demands. Hence, its competitiveness is less affected by crude oil prices than many other alternative fuels. Prices of natural gas have been relatively low in the U.S. in recent years. Recent data suggests an average price of $2.07/gallon for CNG is equivalent to $3.68/gallon for regular gasoline (DOE 2011e)

Drawbacks

- The principal drawback of CNG is its low energy density and its need for heavier, larger storage tanks on vehicles. This results in more expensive vehicles and the need to refuel more often.

- The low energy density has limited the attractiveness of CNG in personal vehicles.

- A consequence of the relatively low number of CNG-powered vehicles is a much less mature refueling infrastructure. Around 900 refueling stations offer CNG compared to a total of approximately 140,000 gasoline stations in the U.S. (DOE 2011i).

Potential user groups

- Fleet operators, such as bus or shuttle operators, that operate a significant number of units to justify the investment in dedicated vehicles and infrastructure.

- Private vehicle owners may switch to CNG vehicles once the refueling infrastructure becomes more widespread.

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use an alternative fuels is discussed in Section 2.5.

2.4.4 Liquefied Petroleum Gas (LPG)

Liquid petroleum gas (LPG) is a fossil fuel comprising principally propane but sometimes containing small quantities of butane. These are gases at ambient temperatures but can be liquefied at relatively modest pressures (e.g., 100 psi). Consequently, refueling is nearly always by the transfer of liquid LPG.

LPG is close to a direct replacement for gasoline, and the conversion between fuel supplies is relatively straightforward. (However, some adaptation is required to meet the same high emission standards demanded for gasoline vehicles.) Consequently, a considerable number of different vehicle types (either as original builds or via conversions) are available alongside the gasoline fuelled equivalents. LPG is also widely used on certain types of equipment operating in enclosed facilities, such as forklifts.

Status of technology

- In terms of vehicles, LPG technology is commercially available but not as widespread as gasoline.

In terms of infrastructure, LPG production and refueling is commercially available but not as widespread as gasoline. The number of LPG refueling stations in the U.S. is almost triple that of CNG—around 2,600 compared to 900 for CNG (DOE 2011b).

Infrastructure requirements

Dedicated infrastructure is required to store and dispense LPG. However, given the relatively low pressures required to distribute, the infrastructure is not as expensive as for CNG. The number of LPG refueling stations in the U.S. is almost triple that of CNG—around 2,600 compared to 900 for CNG (DOE 2011b).

Potential environmental benefits with respect to NOx, PM, GHG emissions

When LPG is used to replace gasoline, there is likely to be a small reduction in GHG and a moderate reduction in PM.

Conditions under which it is cost competitive

A gallon of LPG has around 75% of the energy of a gallon of gasoline. Hence it needs to be cheaper than gasoline to be cost competitive. Recent data suggests an average price of $3.09/gallon for LPG is equivalent to $3.68/gallon for regular gasoline (DOE 2011e).

Drawbacks

Aside from the cost differential, there are few drawbacks to LPG as a fossil fuel alternative for gasoline

Potential user groups

Since in many respects LPG is a replacement for gasoline, the potential users are all those who currently use gasoline. Regarding the airport setting, there is little airside use for LPG as most vehicles use diesel. However, for landside use the majority of fuel burned is gasoline.

LPG is a common alternative fuel for fleets, buses, delivery trucks, and police cars in the United States, powering around 270,000 vehicles. However, overall this is only just over 0.1% of the number of registered vehicles in the US (DOT 2011). This implies that the number of potential consumers for LPG is enormous.

A more detailed discussion regarding potential user groups, their motivations, and their willingness to pay to use an alternative fuels is discussed in Section 2.5.

2.4.5 Electricity

Electricity can be a replacement for conventional fuels such as diesel and gasoline. The use of electricity as an alternative power source for vehicles in the airport setting was discussed in the context of electricity generation as a co-product of alternative fuel production. For more information, please refer to Section 2.2.2.

2.5 Potential user groups and their motivations

Potential users can be divided in two groups depending on their use of aviation or surface transportation alternative fuel:

2.5.1 Potential users of alternative jet fuel

This group includes users of conventional jet fuel such as passenger and cargo airlines and military aircraft. The aviation community has indicated their support and interest in using alternative jet fuels as a means to diversify the jet fuel pool, ensure reliability of supply, enhance energy security, and provide potential environmental benefits (ATA 2010).

2.5.2 Potential users of other alternative fuels

The key potential user groups for these fuels and their motivations for using these fuels are discussed below:

- Airport operators—airports of all sizes have their own fleet of vehicles that operate on a variety of fuels, mainly gasoline and diesel. These are clear candidates for using drop-in alternative fuels, such as green diesel or biodiesel. Airports could also be encouraged to use other alternative fuels that may require dedicated fleets, such as CNG or E85, with potential funding from state or federal programs such as the Voluntary Airport Low Emissions (VALE) program (FAA 2011c). Further motivations for airports' introducing alternative fuels include community outreach programs, energy purchasing contracts, and turning waste streams into energy.

- Airport tenants—airlines, ground service providers, rental car facilities, and other concessions operate significant amounts of vehicles. These operators can be encouraged to use alternative fuels via, for example, joint purchasing with airport GSE through a VALE grant. Alternative fuels can also be encouraged by variable charging structures for licenses to operate airside premises and services. In addition, joint energy purchasing contracts could help reduce energy costs and, at the same time, encourage use of alternative fuels.

- Public transport operators:

    - Buses and shuttles—these operators could be encouraged to use alternative fuels through preferential treatment by the airport. This preferential treatment could include allocation of bus and shuttle stops closer to terminal building exits and lower charges for operating airport services and parking. These incentives could be enough for adoption of drop-in fuels, such as green-diesel or biodiesel, which would require little to no modification to vehicles. For conversion to other types of alternative fuels that would require investment in dedicated vehicles, such as CNG or electricity, further incentives from the airport and local and federal programs may be required. Airports can work with operators to encourage more alternative fueled vehicles when vehicle replacement is an option.

- Taxis and limos—similar to buses and shuttles, taxis and limos could be encouraged to use alternative fuels by preferential vehicle treatment by the airport. This could include, for example, preferential allocation of taxi passengers by airport staff at terminal building exits and lower charges for operating at airport and related parking charges. Similarly, airports can work with taxi fleet operators to encourage more alternative fueled vehicles, including switching to other fuels such as CNG or electricity, when vehicle replacement is an option.

- Trains—as trains tend to operate over a fixed route and be fueled at a central depot, it is more feasible that airport operators work with county and state partners to encourage wider uptake of alternative fuels. These are likely to be limited to drop-in fuels in most cases. However, there is the possibility that new or even existing rail lines to an airport could be electrified, such as via an airport development project and agreements in terms of supplying electricity from an alternative fuel facility put in place.

- Cargo truck operators—Truck fleets based at the airport, such as those servicing air cargo or package delivery operations, are a potential significant source of demand for alternative fuels. These operators may be interested in supporting and benefitting from alternative-fuel refueling options on-site. Truck operators not based at the airport may be harder to influence, although incentives such as preferential buying from suppliers who use alternative fuel trucks may act as a form of motivation.

- Private vehicle operators—trips on private vehicles constitute a large percentage of the traffic to and from U.S. airports which present a significant potential demand for alternative fuels. It is unlikely that airports acting alone could encourage public car drivers to change their vehicles to ones running on alternative fuels. However, in collaboration with county and state partnerships, it is possible that a larger proportion of the public could be encouraged to drive alternatively fueled vehicles, such as by increasing fuel options at gas stations and other mechanisms. Airports could play a role by providing refueling options for alternative fuels, for example charging bays for electric vehicles and CNG dispensers, and incentives such as variable parking lot charges and dedicated spaces closer to terminal buildings.

- Water transportation (ocean or freshwater)—In those cases where airports or airport authorities are close to or have jurisdiction over water transportation, joint purchases of certain alternative fuels, such as green diesel, may be of interest.

When considering the motivations for operators to switch to alternative fuels, especially for surface transportation, it is important to keep in mind conclusions from observations and past experience:

- When purchasing a vehicle, a buyer becomes committed to using specific types of fuel, e.g. diesel or gasoline, as the vehicle cannot be switched between the two. Behavioral studies suggest commercial users take this into account when purchasing new vehicles (Anable and Lane 2008).

- When faced with choices of fuels compatible with a vehicle, price is a key motivation. Consumers often purchase a lower-priced fuel. At the same time, in many cases, a higher initial vehicle cost will dissuade buyers from choosing a fuel technology that has a lower life-cycle cost. Uncertainty regarding new and unproven technologies also plays a role.

- Operators of commercial vehicles shun fuels they believe contribute to higher maintenance or replacement costs. This is what happened in Germany recently, where operators balked at purchasing E10 in spite of widespread encouragement to do so (SOL 2011).

- For commercial operators profit is a key motivation and, as discussed above, pricing structures for airport related charges could be used to make alternative fuels more desirable.

- A perfect opportunity for considering alternative fuel vehicles is when the existing equipment reaches its useful life and replacements are being considered. This applies to both airport and non-airport vehicles. Grants and other incentives through local and federal programs can help reduce the cost of alternative fuel equipment.

3 Summary of Task 3: Demand for alternative fuels

This section presents the results of Task 3 “Demand for alternative fuels.” The objective of this task was to develop a set of criteria that airports can use in assessing the potential current and future demand for the alternative fuels identified in Tasks 1 and 2. In addition to developing a demand estimation methodology, the research team developed an accompanying evaluation framework in which the methodology is applied. Since demand estimation is central to the overall evaluation framework, the discussion of the development of both is included in this section.

3.1 Overview of the evaluation framework

The purpose of the framework is to guide the reader through a series of steps to identify and evaluate different options for alternative fuel distribution programs. The first step is to identify the current energy mix at the airport followed by a forecast of energy demand (see Figure 2). The forecast is based on measures of airport activity as well as policy choices with respect to what alternative fuels should be introduced and promoted. The third step is to define the distribution options according to how the fuels would be sourced, stored, and handled at the airport. The final step is to do a comparative analysis of the options identified in the previous step using a number of different parameters. Steps 1 through 3 are explained in more detail in the remainder of this section and Step 4 is discussed in Section 4.

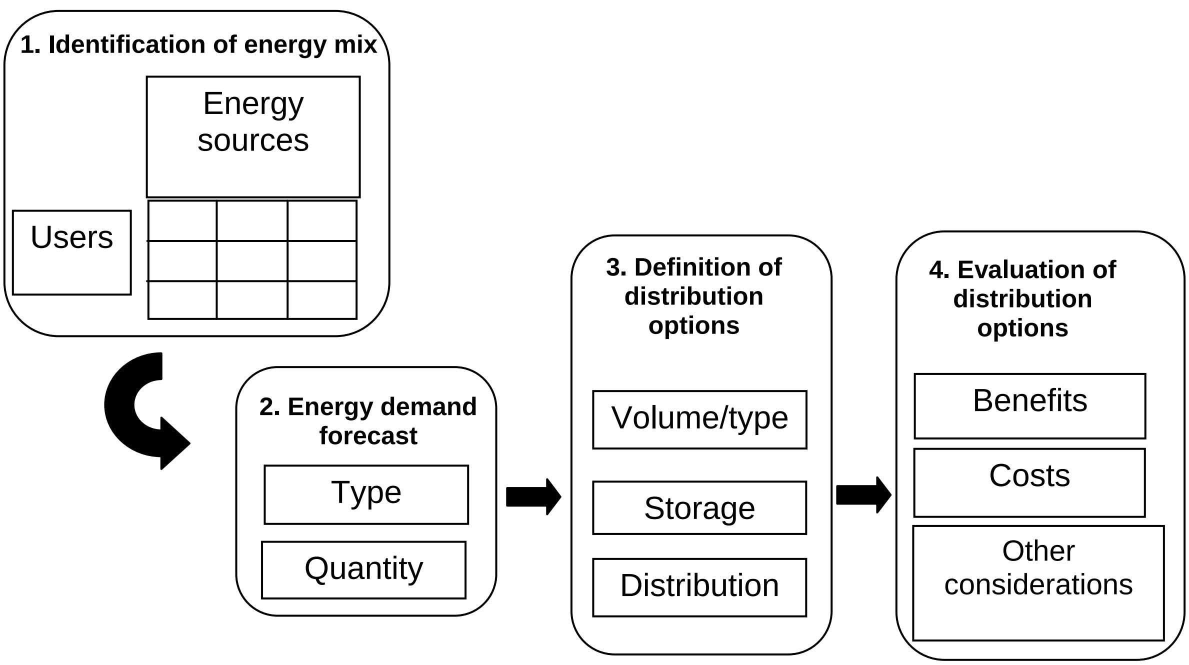

Figure 2: Schematic of evaluation framework

3.2 Step 1: Identification of energy mix at airports

The first step in the evaluation framework is to understand current energy use at the airport. In order to guide the analysis, a matrix similar to that in Figure 3 is suggested:

Airport Name
Year

		Current energy demand	Energy use (per year)											
			Conventional jet fuel (gal)	Alternative jet fuel (gal)	Gasoline (gal)	E85 (gal)	Diesel (gal)	Green diesel (gal)	Biodiesel (gal)	CNG (gal)	LPG (gal)	Electricity (kWh)	Other (gal)
Aircraft		Passenger jet aircraft											
		Cargo jet aircraft											
		Military jet aircraft											
Vehicles	Air-side	Passenger GSE											
		Cargo GSE											
		Military GSE											
		Airport Vehicles											
	Ground-side Passenger	Passenger Private Vehicle											
		Passenger Rental Cars											
		Passenger Taxis											
		Passenger On-Demand (Limos)											
		Passenger Scheduled Bus/Van											
		Passenger Courtesy Vans											
		Passenger Rail											
	Ground-side Employee	Employee Private Vehicle											
		Employee Scheduled Bus/Van											
		Employee Courtesy Vans											
		Employee Rail											
	Off-airport	Freight (Rail, Truck, Ship)											
Buildings / Other		Airport Buildings											
		Military Buildings											
		Other Buildings											
		Concessions											
		Military Other											

Figure 3: Current energy mix at airports

The categories on the left indicate the major areas where energy is used at airports: aircraft, vehicles, and buildings. The sub-categories of energy users are meant to be representative of many airports but may vary depending on local conditions. It is assumed that airports already have their own systems for keeping track of energy demand for those uses that they control, such as airport vehicles and buildings, and that those tracking systems could be used to provide the information for the appropriate rows in Figure 3. The forecasting methodology developed with this guidebook provides rough estimates for fuel demand by passenger and freight aircraft, passenger aircraft GSE, and passenger landside users; however, if the airport has access to more detailed sources, they should be used. For other categories, including airport employees, concessions, and military users, airports may have to rely on outside sources to obtain the pertinent information. It is important to indicate that the matrix is not representative of the conditions at all airports; for example, Freight Transportation and Military users will not be present at most small municipal airports. Thus, the reader is encouraged to modify the matrix to better reflect local conditions.

With respect to energy sources, the evaluation framework as presented here is limited to those shown in Figure 3 for simplicity. Similarly to the situation of the energy users, local conditions will determine whether more or fewer energy sources will be available and need to be included.

3.3 Step 2: Energy demand forecast

After the current energy mix at the airports is identified, the next step is to do a forecast of energy demand for those users and fuels of interest. The forecast will indicate the type of fuel and associated quantity projected to be required. Some airports may already have a means of forecasting demand for different fuels. For those that do not, a spreadsheet-based tool has been developed to provide rough estimates of potential fuel use for a number of users, including: passenger and freight aircraft, passenger aircraft GSE, and passenger landside users. This spreadsheet will be part of the toolkit associated with this guidebook (see Section 6.3 and Appendix A). Sections 3.3.1 and 3.3.2 explain the major components of the forecasting tool.

3.3.1 Introduction to the energy forecasting tool

This forecasting tool was developed to provide a rough order-of-magnitude estimate of potential demand for different types of fuel based on basic metrics of airport activity and user input. It is meant to help airports gain a high-level understanding of possible energy needs; it does not provide a detailed analysis of energy demand for each specific location.

The tool makes use of two widely accepted and available forecasts of aviation activity in the United States: the Terminal Area Forecast (TAF) (FAA 2011b) and the Aerospace Forecast (AF) (FAA 2011a). The TAF provides forecast information for enplanements and operations by airport twenty years into the future. The AF provides information on cargo, fuel use, and system capacity; however, the AF does not break down the data at the airport level. The AF also forecasts twenty years into the future. Another key data source for the forecasting methodology is the Form 41 data of air carrier activity (BTS 2011). For a more detailed discussion of the calculations used in the methodology, see Appendix A.

3.3.2 Using the energy forecasting tool

The main inputs for the energy forecasting tool can be divided in three separate blocks. The first block consists of basic airport information, as shown in Table 1. This information includes the baseline year, the forecast year, and the airport name. The airport name is used to reference TAF and Form 41 data to populate the fields related to enplanements and originating passengers. Note that even though the model retrieves data for each airport, the user can override it with more detailed or current information.

Table 1: Baseline model inputs

Model Inputs		
Airport name		
	Baseline	**Forecast**
Model years		
Annual enplanements		
Share of originating passengers		

Model Inputs		
Annual originating passengers		
Airport size		
Available Seat Miles (ASM)		
Available Ton Miles (ATM)		
Airports with access to rail - walking?		
Airports with access to rail - shuttle?		

The second block corresponds to the current fuel mix used at the airport for a number of airport access modes and vehicles used. This is the energy use matrix identified in Figure 3**.** Again, the forecasting methodology provides rough estimates for fuel demand by passenger and freight aircraft, passenger aircraft GSE, and passenger landside users; however, if the airport has more current or detailed information, it should be included. Likewise, the airport will need to provide the information for a number of users, if those users are of interest to the study. The information required in the matrix is the yearly consumption of alternative fuel by user.

The third block in the forecasting methodology is the future fuel mix to be used at the airport (see Figure 4). The structure of this matrix is identical to that of the current energy mix, but the information reflects the forecast energy use in a particular year of interest. As in the case of the current energy mix, there are two ways to provide the information for this matrix: first, the forecasting methodology provides rough estimate of projected future demand for a set of users (passenger and freight aircraft, passenger GSE, and landside passenger users); second, the user can provide revised estimates for these users in addition to estimates for the other users of interest.

Airport Name
Year

		Future energy demand	Energy use (per year)										
			Conventional jet fuel (gal)	Alternative jet fuel (gal)	Gasoline (gal)	E85 (gal)	Diesel (gal)	Green diesel (gal)	Biodiesel (gal)	CNG (gal)	LPG (gal)	Electricity (kWh)	Other (gal)
Aircraft		Passenger jet aircraft											
		Cargo jet aircraft											
		Military jet aircraft											
Vehicles	Air-side	Passenger GSE											
		Cargo GSE											
		Military GSE											
		Airport Vehicles											
	Ground-side Passenger	Passenger Private Vehicle											
		Passenger Rental Cars											
		Passenger Taxis											
		Passenger On-Demand (Limos)											
		Passenger Scheduled Bus/Van											
		Passenger Courtesy Vans											
		Passenger Rail											
	Ground-side Employee	Employee Private Vehicle											
		Employee Scheduled Bus/Van											
		Employee Courtesy Vans											
		Employee Rail											
	Off-airport	Freight (Rail, Truck, Ship)											
Buildings / Other		Airport Buildings											
		Military Buildings											
		Other Buildings											
		Concessions											
		Military Other											

Figure 4: Projected energy mix

The forecasting tool will provide different ways to visualize the data. This will range from simple graphics summarizing main trends to data tables containing all the details from the projections. Two examples of the summary graphs are shown in Figure 5 and Figure 6, below:

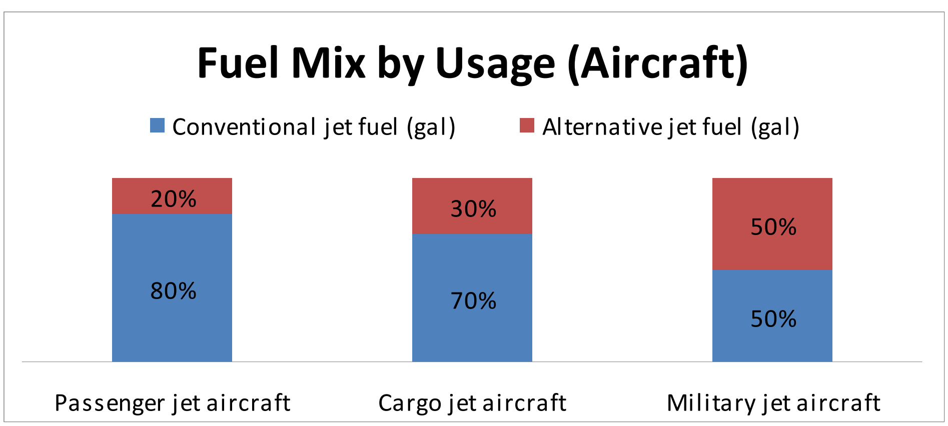

Figure 5: Sample data illustration from forecasting tool showing percentage use of conventional and alternative jet fuel by aircraft type

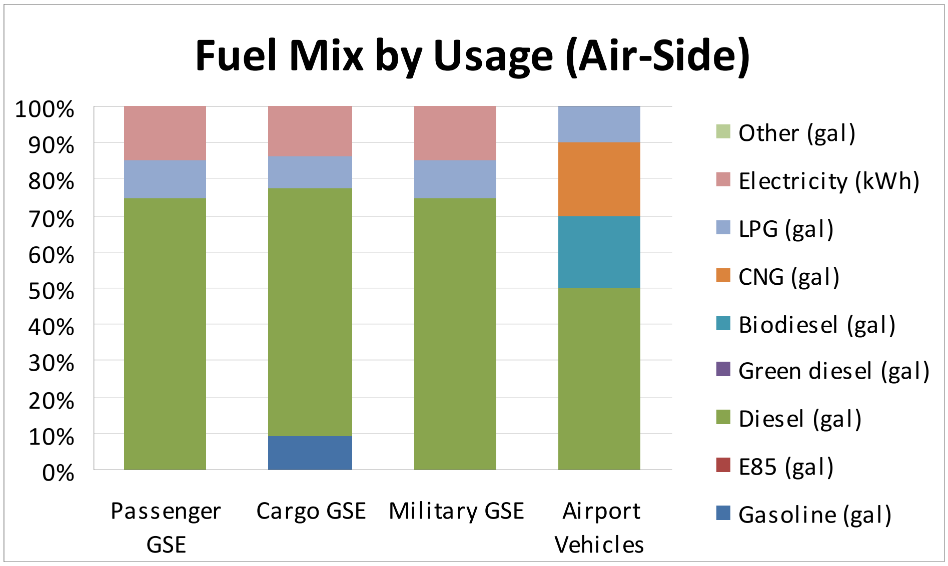

Figure 6: Sample data illustration from forecasting tool showing fuel mix of air-side vehicles

3.4 Step 3: Definition of distribution options

The distribution options for alternative fuels are defined in terms of three main components: 1) fuel type and quantity, 2) storage, and 3) distribution. The following sections explain each component in detail.

3.4.1 Alternative fuel type and quantity

The mix of alternative fuels and associated quantities can be defined with the projected fuel mix presented in Figure 4. The goal of this step is to project the demand for fuel by fuel type and by user. This is accomplished by defining the desired mix of alternative fuels used by particular users in the matrix. For example, planners can specify 20% of airport vehicles using green diesel, 40% CNG, and 20% LPG, while the remainder (20%) continue using conventional fuels. This step also involves some exploration, as there may be different approaches to introducing the alternative fuels. For example, airports may only be looking at their own vehicles and buildings, which will only involve two rows in the matrix. Airports may also consider partnering with passenger airlines to provide alternative jet fuel and green diesel for aircraft, airline GSE, and airport vehicles. Another option is to consider partnering with transit vehicles (buses and vans) to adopt CNG. For each one of the possible options, the planner completes a separate matrix.

3.4.2 Storage of alternative fuels

A key consideration for distribution options is to determine where the alternative fuels will be stored. The use of existing storage infrastructure has many obvious benefits, including the avoidance of building new infrastructure and experience with operation and maintenance; however, it may not be possible to use existing storage in all cases. New storage infrastructure may be required for a number of reasons, including insufficient available storage capacity in the existing infrastructure, incompatibility of alternative fuels with the existing infrastructure (especially for non-drop-in fuels), and location with respect to the distribution infrastructure.

This variable can be captured in a table as shown in Figure 7. When completing this table, consult the "Infrastructure" sections in chapter 2.

Storage requirements			Conventional jet fuel (gal)	Alternative jet fuel (gal)	Gasoline (gal)	E85 (gal)	Diesel (gal)	Green diesel (gal)	Biodiesel (gal)	CNG (gal)	LPG (gal)	Electricity (kWh)	Other (gal)
Aircraft		Current											
		Future											
Vehicles	Air-side	Current											
		Future											
	Ground-side Passengers	Current											
		Future											
	Ground-side Employees	Current											
		Future											
	Off-airport	Current											
		Future											
Buildings		Current											
		Future											

Figure 7: Storage requirements for distribution option

3.4.3 Distribution of alternative fuels

Another key consideration is to determine how the alternative fuels will be made available to final users. Similar to Storage, using the existing infrastructure has many benefits but may not be possible in all cases. In addition to insufficient capacity or incompatibility, the location of the distribution points may require new infrastructure depending on existing user access. This variable can be captured in a table as shown in Figure 8.

Distribution requirements			Conventional jet fuel (gal)	Alternative jet fuel (gal)	Gasoline (gal)	E85 (gal)	Diesel (gal)	Green diesel (gal)	Biodiesel (gal)	CNG (gal)	LPG (gal)	Electricity (kWh)	Other (gal)
Aircraft		Current											
		Future											
Vehicles	Air-side	Current											
		Future											
	Ground-side Passengers	Current											
		Future											
	Ground-side Employees	Current											
		Future											
	Off-airport	Current											
		Future											
Buildings		Current											
		Future											

Figure 8: Distribution requirements for distribution option

3.5 Summary of distribution options

The distribution options for alternative fuels at airports can be identified by following the process described in Section 3.4. At the end of the process, each option will be described in terms of the three main components: 1) alternative fuel type and quantity, 2) storage requirements, and 3) distribution requirements.

Once the different options are identified in terms of these components, the next step is to perform a comparative evaluation of the different options. The purpose of this step is to identify one or two promising options that should undergo a detailed feasibility analysis, which is outside the scope of this guidebook. The evaluation process is described in Section 4.

4 Summary of Task 4: Key considerations for distribution programs

This section presents the results of Task 4 “Identify key considerations for viability of distribution programs.” The information presented here corresponds to Step 4 in the evaluation framework identified in Figure 2. The objective of this section was to help airports identify the costs, benefits, and other key considerations and opportunities associated with the alternative fuel distribution programs identified in Section 3. In particular, this section provides information to evaluate the strengths and weaknesses of the different options in order to select those that should undergo a more detailed feasibility analysis. Table 2 lists the main considerations for evaluating a distribution option.

Table 2: Main considerations for comparative evaluation of alternative fuel distribution programs

Category	Sub-category
Benefits	Environmental
	Economic
Costs	Fuel
	Vehicles
	Infrastructure
Financial and Commercial	Commercial-scale alternative fuels
	Pre-commercial scale alternative fuels
Legal and Regulatory	FAA regulations
	Local, state, and federal regulations
Stakeholder Engagement and Community Acceptance	Stakeholder engagement
	Community outreach

The first two categories, Benefits and Costs, are discussed together for each alternative fuel, because they are very dependent on the type of fuel. For the remaining three categories (i.e., Financial and Commercial, Legal and Regulatory, and Community Acceptance), the discussion is not divided by alternative fuel, because the observations apply, in general, to all of them.

Airports are very different from one another, and some of these differences, such as size, governance structure, and involvement in the distribution of alternative fuels, will be important factors in how alternative fuel distribution programs can be evaluated and implemented. The guidelines and considerations presented here are expressed in general terms in order to apply to the majority of circumstances, although local conditions and circumstances will certainly influence their applicability.

4.1 Potential costs and environmental and economic benefits

The evaluation of potential costs and environmental and economic benefits associated with alternative fuels and their distribution are discussed in this section. First the criteria used to evaluate the alternative fuels are explained and summarized. Then, the potential costs and environmental and economic benefits of each fuel are discussed.

Criteria for evaluation of potential costs and environmental and economic benefits

The criteria for this evaluation were based on the team's expert knowledge and professional judgment from undertaking related studies (AEA 2008; AEA 2009; DfT 2010), a key study being ACRP 02-23 (Peace 2012). Relative criteria and other factors are shown in Table 3. ACRP 02-23 developed, as part of the project, a mechanism for weighting alternative fuels in terms of their capacity to reduce $PM_{2.5}$; to reduce other pollutants' emissions; and potential issues regarding use of those alternative fuels such as their associated costs. Most of the criteria listed below were developed in the ACRP 02-23 project, with the exception of 'Additional jobs.' Information related to emissions from ethanol were largely obtained during a previous literature review (AEA 2008), data pertaining to LPG and CNG obtained from sources cited in the text or the FAA's EDMS databases, green diesel and other biodiesels primarily obtained from EPA sources (EPA 2002). Other data, such as the availability of alternatively fueled vehicles and buildings, and the cost of fuel, were obtained from studies previously cited. The comparison of fuel costs is on gallon-equivalent basis. Other key references are also listed in the remainder of this section where appropriate. A complete discussion of how the values were generated is presented below after the observations.

Table 3: Criteria for evaluating the potential costs and environmental and economic benefits of alternative fuels distribution programs

Criterion	Definition	Rating
Relative benefit in PM and NOx emissions	The relative decrease in emissions compared with the dominant existing fuel/engine/plant (or vehicle).	H = >75% reduction M = between 25% and 75% reduction L = < 25% reduction
Relative benefit in life-cycle GHG emissions	Greenhouse gas (GHG) emissions of the alternative fuel relative to the primary conventional fuel. This figure includes the fuel processing (i.e. 'well to wheel') emissions.	H = >60% reduction M = Between 60% and 10% reduction L = <10% reduction
Additional jobs	Are there any additional jobs created at an airport, such as by the need to staff a new filling station. This is related to the level of infrastructure and facilities required.	H = More than 5 jobs created M = 2 to 5 jobs created L = 0 to 2 jobs created

Criterion	Definition	Rating
Relative cost of fuel	This is the marginal increase in fuel cost compared with the dominant existing fuel.	H = > 125% of conventional fuel M = Equivalent price to conventional fuel - between 75% to 125% of conventional fuel L = <75% of conventional fuel (N/A where no data on cost are available.)
Relative cost of vehicles/plant	This is the marginal increase in vehicle cost compared with the dominant existing vehicle/plant type.	H = > 200% M = between 110% and 200% L = <110% N/A = no additional cost (i.e. for drop-in fuels)
Relative cost to upgrade existing vehicles/plant	How much is it likely to cost to convert a typical vehicle/plant?	H = >$20,000 M = Between $200 and $20,000 L = <$200 N/A = no cost associated (i.e. for drop-in fuels)
Cost of additional infrastructure and facilities	What additional infrastructure is needed for the fuel to be used?	H = Additional equipment such as compressors, high-pressure buffers and tanks needed M = Additional tanks, similar to those already in existence, would be needed (e.g. for different blends) L = Assumes that diesel, electricity and gasoline are readily available on, or near, the site N/A = no additional cost associated

A summary of the potential costs and environmental and economic benefits of each alternative fuel in shown in Figure 9:

Potential environmental and economic benefits and costs		Conventional jet fuel (gal)	Alternative jet fuel (gal)	Gasoline (gal)	E85 (gal)	Diesel (gal)	Green diesel (gal)	Biodiesel (gal)	CNG (gal)	LPG (gal)	Electricity (kWh)
Environmental	**Relative benefit in PM and NOx emissions**	--	L	--	L	--	L/M	L	M/H	L	H
	Relative benefit in life-cycle GHG emissions	--	L	--	M	--	L/M	L/M	L	L	--
Economic	**Relative increased cost of fuel**	--	H	--	H	--	E/H	E/H	L	E	--
	Relative increase cost of vehicle/plant	--	L	--	L	--	L	L/M	M	M	H
	Relative cost to upgrade existing vehicle/plant	--	L	--	L	--	L	L	M/H	L	--
	Additional infrastructure storage cost	--	L	--	H	--	L	M	H	H	L/H[1]
	Additional facilities cost (e.g. filling station)	--	L	--	M	--	L	M	H	H	L
	Additional jobs	--	L	--	L	--	L	L	L	L	L

Note: Additional infrastructure costs are low for vehicle charging and high for pre-conditioned air (PCA) for aircraft

Figure 9: Summary of potential environmental and economic benefits and costs

There are a number of observations that can be drawn from the information in Figure 9 that can help in the evaluation of alternative fuel distribution programs:

- All alternative fuels have the potential to provide environmental benefits to some extent. As the discussion below highlights, specific benefits, especially life-cycle GHG emissions reductions, will depend on many factors and must be analyzed on a case-by-case basis.

- Drop-in alternative fuels, such as alternative jet fuel and green diesel (a co-product), have the cost advantage of not requiring any changes to the existing storage and distribution infrastructure and equipment (aircraft, engines, GSE, etc.). Some alternative fuels require small changes or modifications to existing equipment and infrastructure (e.g., vehicle components for B20 and storage tanks for E85), while others require either dedicated vehicles and/or infrastructure (e.g., E85, CNG, LPG, electricity).

- CNG has a significant price advantage compared to other conventional and alternative fuels. Alternative jet fuel and green diesel are not yet commercially available in the U.S. and, therefore, it is still uncertain how their price will compare to the other alternatives. Current projections indicate that their price will be higher but it is expected to decrease over time with the learning curve and as more capacity comes on-line. Other alternative fuels (e.g., E85, B20, LPG, electricity) have been available at commercial scales for many years and their price history is well documented.

- Few additional jobs are expected from the operation of alternative fuel distribution projects at airports outside of construction of facilities, if any are required.

Discussion of potential costs and environmental and economic benefits of alternative fuels

4.1.1 Alternative jet fuel

Relative benefit in PM and NOx emissions

Alternative jet fuels have the potential to reduce emissions of particulate matter (PM). There are indications that a modest reduction in NOx emissions could also be possible. However, because currently approved alternative jet fuels must be blended with conventional jet fuel up to a 50/50 ratio, the potential savings are reduced. Therefore, this is classified as low (L).

Relative benefit in life-cycle GHG emissions

The change in life-cycle emissions is highly variable as it depends on how the alternative jet fuel is generated. Furthermore, because currently approved alternative jet fuels must be blended with conventional jet fuel up to a 50/50 ratio, the potential savings are reduced. Therefore, this is classified as low (L).

Relative increased cost of fuel

The increase cost of alternative jet fuel is highly variable as it depends on how the alternative jet fuel is generated. Because very few commercial-scale facilities exist in the U.S., current costs are higher than for conventional jet fuel; however, as the technology matures and feedstock supplies develop, the cost is expected to decrease. Therefore, the relative cost of fuel is classified as high (H).

Relative increased cost of vehicle/plant

As discussed in Section 2.1, alternative jet fuels are drop-in fuels and, therefore, no changes to the transportation, storage, and distribution infrastructure or aircraft equipment is required. Consequently, any costs associated with infrastructure or aircraft are classified as low (L).

Relative cost to upgrade existing vehicle/plant

Low (L) because alternative jet fuel is drop-in.

Additional infrastructure storage cost

Low (L) because alternative jet fuel is drop-in.

Additional facilities cost (e.g. filling station)

Low (L) because alternative jet fuel is drop-in.

Additional jobs

The use of alternative jet fuel is unlikely to create any airport related jobs. Therefore this is rated as low (L).

4.1.2 Green diesel

Relative benefit in PM and NOx emissions

Green diesel is chemically very similar to petroleum diesel and therefore most of their pollutants are the same. Based on the discussion in section 2.2.1, the change in PM and NOx emissions is rated as low (L) for all blends of green diesel.

Relative benefit in life-cycle GHG emissions

The life-cycle emissions savings will depend on the production and transportation emissions that come from growing and processing of the crops involved, in addition to the tank-to-wheel reduction. Therefore low blends (up to 20%) are rated low (L) relative to standard diesel (because the GHG emissions of B20 are similar to conventional diesel), but higher blends are rated as medium (M) because their GHG emission reductions are more than 10% compared conventional diesel.

Relative increased cost of fuel

Green diesel is fully interchangeable with petroleum-derived diesel, and is typically cost competitive for low blends (up to about 20% green diesel), especially when the cost of crude oil is high (DOE 2011c). Therefore the relative cost is classified as Medium (M).

Higher blends are not currently cost competitive; however, as demand for green diesel increases, new suppliers will enter the market, and the mass-production dynamic will likely introduce a cost decline. Therefore the current relative cost is classified as high (H).

Relative increased cost of vehicle/plant

See the comments under “Cost of upgrading.” For the same reasons, the increased cost of vehicles is rated as low (L) for all green diesel blends.

Relative cost to upgrade existing vehicle/plant

Green diesel is fully interchangeable with petroleum-derived diesel, and no modifications are required for diesel engines to use green diesel blends of any strength. Some additional maintenance may be required, such as the changing of filters due to its lower aromatic content. Therefore, the cost of upgrading is classified as low (L) for all green diesel blends.

Additional infrastructure storage cost

No additional infrastructure beyond what already exists for petroleum-derived diesel is required. This is because the two fuels are so chemically similar and can be used in conventional vehicles. Therefore, the additional infrastructure cost is rated as low (L) for all blends.

Additional facilities cost (e.g. filling station)

The similarity of green diesel to petroleum-derived diesel, as discussed in previous sections, means that no additional facilities are required. Therefore this is rated as low (L).

Additional jobs

Changing from petroleum-derived diesel to blends containing green diesel will not create any additional on airport jobs. Therefore this is rated as low (L).

4.1.3 Biodiesel

Relative benefit in PM and NOx emissions

Changes in PM and NOx emissions will be dependent on blend strength. PM and NOx emissions are also dependent on vehicle technology, particularly changes in fuel delivery systems and combustion chamber design. A 2002 EPA summary suggests that using B20 may increase NOx emissions by around 2% (EPA 2002). A more recent study (AEA 2008) suggests that using B15 leads to changes in NOx emissions of +1% for heavy duty vehicles, and no change for passenger cars. For PM emissions there is strong evidence of a reduction. This ranges from 2% (or 5%) when using B5 in larger trucks (or passenger cars), rising to 7% (14%) when using B15. For B100 the reductions are 38% for both trucks and passenger cars.

Therefore the changes in emission reductions are rated as low (L) for both PM and NOx emissions for blends up to B20. For B100 the changes are still classified as low (around an 8% increase) for NOx (L) and a medium reduction for PM (M).

Relative benefit in life-cycle GHG emissions

The life-cycle emissions savings will depend on the production and transportation emissions that come from the growing and processing of the crops involved, in addition to the tank-to-wheel reduction. Therefore low blends (up to 20%) are rated low (L) relative to standard diesel (because the GHG emissions of B20 are similar to conventional diesel), and higher blends rated as medium (M) because their GHG emissions are less than 90% of conventional diesel.

Relative increased cost of fuel

Similar to the discussion for green diesel in section 4.1.2, biodiesel is typically cost competitive for low blends (up to about 20%), especially when the cost of crude oil is high. Therefore the rating for B20 is Medium (M).

Higher blends currently cost at least 125% of petroleum derived diesel. Therefore the current relative cost increase is classified as high (H) (DOE 2011e).

Relative increased cost of vehicle/plant

Most new vehicles can use blends up to about 20%, therefore the relative increased cost is zero (L) for new vehicles. However, older vehicles and for higher blends the relative cost increase is rated as medium (M).

Relative cost to upgrade existing vehicle/plant

The cost of upgrading is classified as low (L) up to 20% blends, but medium (M) for higher blends. This is because more changes need to be made to the base vehicle, taking the cost of conversion above $200.

Additional infrastructure storage cost

No additional infrastructure beyond what already exists for petroleum-derived diesel is necessary; however, due to warranty restrictions for some vehicles it is likely that additional tanks will be required for storage for higher blends (for example, above 5%) as both standard diesel and biodiesel blends would need to be offered separately. Therefore for low blends the additional infrastructure cost is Low (L) but for higher blends the infrastructure cost is classified as medium (M).

Additional facilities cost (e.g. filling station)

Potentially there is the need to install additional pumps for high blends; however, this depends on current pump availability. Therefore, for low blends (up to 5%) the additional facilities cost is zero (N/A), but for higher blends the facilities cost is classified as medium (M).

Additional jobs

No additional on airport jobs are likely, other than during the construction of the infrastructure. This is therefore classified as low (L).

4.1.4 Ethanol

Relative benefit in PM and NOx emissions

Generally, research has shown that for ethanol blends up to 25% (E25), PM shows a clear reduction, whereas for NOx and hydrocarbon emissions results are mixed, some showing significant reductions and others showing significant increases (AEA 2008). For the E85 blends, the available data indicate no change in the emission factors of NOx or hydrocarbons, but a 20% reduction in PM emissions. Therefore this is classified as low (L).

Relative benefit in life-cycle GHG emissions

The life-cycle emissions savings will depend on the production and transportation emissions that come from the growing and processing of the crops involved, in addition to transportation to the refueling station. Low blends (up to 15%) are rated as low (similar GHG to gasoline) (L), but higher blends classified as medium (M).

Relative increased cost of fuel

Ethanol is generally blended with gasoline. Based on the discussion in section 2.4.2, the cost for blends above 10% is rated as high (H) and blends below 10% as Medium (M).

Relative increased cost of vehicle/plant

Vehicles are currently available as E85 or flex-fuel vehicles for blends above 10%; therefore, the relative cost increase is classified as low (L). Blends of 10% or less, which can be used in new vehicles the relative cost increase is zero, are also rated as low (L).

Relative cost to upgrade existing vehicle/plant

As most gasoline vehicles can use up to E10, the cost of upgrading is not applicable to low blends (N/A); for blends above 10% the cost is still relatively low (L).

Additional infrastructure storage cost

In terms of storage and distribution, the needs of ethanol are substantially different from gasoline. The key issue is miscibility with water. Generally, ethanol is kept in separate storage tanks at wholesalers, and blended just before delivery to retailers or to industrial customers. Therefore the additional infrastructure cost can range from $40,000 to $200,000. To partially offset this, the current administration is offering incentives for installing E85 pumps (Loveday 2011). Regardless, the additional infrastructure storage cost is rated as high (H).

Additional facilities cost (e.g. filling station)

Potentially there is the need to install additional pumps for high blends; however, this depends on current pump availability, because a premium-grade pump may be switched to deliver high-strength ethanol blends. Therefore, for blends up to 10%, the additional facilities cost is zero (N/A), but for higher blends the facilities cost is classified as medium (M).

Additional jobs

For routine operation, the scope for additional jobs is assumed to be low (L), because it is anticipated that the additional high ethanol blend pumps will be placed alongside the normal fuel at an existing filling station. It is anticipated that a few additional pumps will not require additional staff to be employed.

Apart from routine operation, there would be temporary additional jobs created to install the new capacity (tanks and pumps) prior to them coming on-line.

4.1.5 CNG

Relative benefit in PM and NOx emissions

If CNG were used in place of diesel, with appropriate vehicles, it would lead to reductions in NOx and especially PM, such that this fuel is rated as high (H). Similarly, if CNG were used to replace gasoline, then there is likely a medium (M) reduction in PM.

Relative benefit in life-cycle GHG emissions

Replacing either diesel or gasoline with CNG is rated as Low (L); the GHG emissions from CNG are similar to those for conventional fuels.

Relative increased cost of fuel

The cost of CNG compared to gasoline and diesel is relatively low based on recent DOE data (DOE 2011e), therefore, this is classified as low (L).

Relative increased cost of vehicle/plant

The cost of new vehicles that use CNG compared to vehicles that use either diesel or gasoline is classified as medium (M).

Relative cost to upgrade existing vehicle/plant

In many instances, it is more cost-effective to convert an existing vehicle to run on CNG compared with the cost of buying a new vehicle—unless replacement is already under consideration for other reasons. It is cheaper to convert a gasoline engine to run on CNG than a diesel engine. Therefore, the cost of upgrading is rated as medium (M) for converting a gasoline engine and high (H) for a diesel engine.

Additional infrastructure storage cost

There is a relatively extensive low pressure natural gas infrastructure already in place. Therefore the additional infrastructure storage cost is rated as low (L).

Additional facilities cost (e.g. filling station)

For vehicle use, there is the safety requirement of providing compressed gas at around 3,000 psi. There are a variety of possibilities for refueling vehicles with CNG, ranging from a small compressor connected to a main gas supply, or low pressure storage tank, trickle filling a light commercial vehicle overnight at a cost of around $10,000. The minimum amount for a permanent facility refueling heavy duty vehicles is in the region of $200,000, whereas a large station serving dozens of vehicles may cost in the region of $750,000 (AEA 2011). In addition, there are currently just over 900 CNG filling stations in the U.S. (DOE 2011b). Therefore the cost of additional facilities is rated as high (H).

Additional jobs

For routine operation this is assumed to be low (L), because it is assumed that the additional CNG filling points will be placed on the same site as the normal liquid fuel pumps at an existing filling station. It is anticipated that a few additional filling points will not require further staff to be employed. Furthermore, there would be temporary additional jobs created to install the new capacity prior to their becoming available for routine filling of vehicles.

4.1.6 LPG

Relative benefit in PM and NOx emissions

Changes in PM and NOx emissions relative to gasoline for LPG is classified as low (L).

Relative benefit in life-cycle GHG emissions

LPG use has a comparable carbon footprint to gasoline. Therefore its GHG emissions reductions are classified as low (L).

Relative increased cost of fuel

A gallon of LPG has around 75% of the energy of a gallon of gasoline. Based on the discussion in section 2.4.4 the cost of LPG is classified as Medium (M).

Relative increased cost of vehicle/plant

The cost of LPG new vehicles compared to gasoline vehicles is classified as medium (M).

Relative cost to upgrade existing vehicle/plant

In many instances, it is more cost-effective to convert an existing vehicle to run on LPG compared with the cost of buying a new vehicle, unless replacement is already under consideration for other reasons. It is low (L) cost to convert a gasoline engine to run on LPG.

Additional infrastructure storage cost

Approximately 2,600 existing vehicle fueling stations provide LPG for road vehicles (DOE 2011b). Therefore, the additional infrastructure cost would be comparable to adding a new gasoline product line. This cost was taken as being around $40,000 up to $200,000 for E85 (see section 4.1.4), and it is assumed a similar figure applies to the addition of LPG to an existing filling station. Therefore the cost of additional infrastructure costs is rated as high (H).

Additional facilities cost (e.g. filling station)

Additional pumps will need to be added at filling stations, and therefore the additional facilities costs are classified as high (H).

Additional jobs

For the routine running of LPG filling stations, this is assumed to be low because it is anticipated that the additional LPG pumps will be placed alongside the normal gasoline and diesel pumps at an existing filling station. It is anticipated that a few additional pumps will not require further staff to be employed. This is therefore classified as low (L). In addition, there would be temporary additional jobs created to install the new capacity (tanks and pumps) prior to them coming on-line.

4.1.7 Electricity

Relative benefit in PM and NOx emissions

At the airport site, use of electricity over a combustible fuel would result in high reductions of on-site PM and NOx emissions (unless the electricity was generated on-site) Therefore this is rated has high (H).

Relative benefit in life-cycle GHG emissions

Highly variable as it depends on how the electricity is generated. For example, the EPA's eGrid data (Rothschild et al, 2009; EPA 2012) shows CO2 emissions varying from 499 to 1,960 lb CO2/MWh, with the average figure being 1,330 lb CO2/MWh. Combustion of sufficient gasoline to generate 1 MWh energy leads to direct emissions of 585 lb CO2, and 100 lb CO2 in its production. However, this total of 685 lb CO2 /MWh for gasoline is not a like for like comparison, because internal combustion engines are markedly less efficient than electric motors, requiring around 2.5 times the energy relative to the electricity reaching the recharging socket. Therefore, the direct comparison is that gasoline emissions of 1,700 lb CO2 are equivalent to, on average, emissions of 1,300 lb CO2 from an analogous electric vehicle. Therefore, this is classified as low (L) in terms of the relative benefit.

Relative increased cost of fuel

In terms of cents per kWh, the cost of electricity is highly variable and typically ranges from 4.07 to 28.10, with the average price being 9.83 in 2010[1]. This compares with the average price of $26.67 per million BTU[2] (equivalent to 9.10 cents per kWh) for gasoline. However, electricity is much more efficient when used in vehicles compared to gasoline and therefore the relative cost of fuel is classified as Low (L).

Relative increased cost of vehicle/plant

The capital costs of electric vehicles are generally high compared to their gasoline or diesel equivalents. However, the running costs (e.g. fuel, maintenance and repair) are anticipated to be significantly less than their gasoline or diesel equivalents. The relative cost of the vehicles is classified as high (H) due to the dominating capital costs.

Relative cost to upgrade existing vehicle/plant

It is not normally feasible to upgrade an existing internal combustion engine to run on electricity. Therefore this is not rated.

Additional infrastructure storage cost

See below.

Additional facilities cost (e.g. filling station)

For recharging of electric vehicles, assuming that trickle charging can be used and spare capacity already exists, little additional infrastructure development is needed. Therefore this is classified

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[1] Electric Sales, Revenue, and Average Price (data for 2010), http://www.eia.gov/electricity/sales_revenue_price/, US EIA.

[2] Clean Cities Alternative Fuel Price Report January 2011, US DOE

as low (L). However, issues may arise from parking vehicles or equipment for long periods; these items will require recharging, implying some degree of mobile or stationary charging stations. If the airport's power capacity needs to be increased then the cost of the additional infrastructure should be classed as High (H).

Gate electricity and preconditioned air (PCA) supply for reducing APU usage are likely to require more infrastructure development than smaller vehicle recharging points, and therefore this is classified as high (H).

Additional jobs

There would be temporary additional jobs created to meet the infrastructure requirements prior to this energy source coming on-line. Regardless, the use of electricity is unlikely to create any airport related jobs. Therefore this is rated as low (L).

4.2 Financial and commercial considerations

To discuss the commercial and financial considerations of alternate energy distribution by an airport, it is useful to divide the energy source into two broad categories: the first is fuels that are already being produced in commercial quantities, with known costs and developed markets and distribution infrastructure; the second is next-generation transportation fuels that are not yet commercially available. Table 4 shows which fuels are included in each category.

Table 4: Classification of alternative fuels

Commercial-scale available	Pre-commercial scale available
• Electricity • Compressed natural gas (CNG) • Liquid propane gas (LPG) • Biodiesel (B20) • Ethanol (E85)	• Alternative jet fuel and co-products: ▪ Green diesel ▪ Electricity

4.2.1 Commercial-scale available alternative fuels

An airport's involvement in commercially available alternative fuels can vary depending on the airport's own fuel and energy needs. Airports, large and small, have their own vehicle fleets that could run or be converted to run on alternative fuels. As discussed above, an airport's demand for alternative fuels can be combined with that of other users at the airport to benefit from economies of scale. Even if an airport is not interested or able to use alternative fuels, the airport can still be an active participant by encouraging their adoption by other users. The level of encouragement can range from mandating the use of a greener energy source as a condition of doing business at the airport (e.g., electric-powered GSE or CNG-powered buses) to financial incentives (e.g., reduced parking rates for hybrid vehicles or providing plug-in recharging stations for electric vehicles) to lobbying airport users to adopt greener fuels in support of local sustainability initiatives.

Although producers of the commercially-proven alternative fuels will understand their business needs and be adept at identifying new distribution opportunities, they may not have direct experience with airport uses. Thus, an airport should be prepared to facilitate distribution at the airport by, for example, helping producers obtain necessary regulatory approvals or making land available for storage and distribution on the airport. Indeed, an airport is likely to be in a position to earn revenue from facilitating the distribution of the fuel on airport property. Producers can be assumed to have a commercial interest in expanding their customer base, and are likely to have experience dealing with necessary infrastructure and financing, so an airport is unlikely to need to play a role in the ongoing distribution business.

An airport's involvement in increasing the use of electric vehicles by airport tenants may not follow the previous guidelines, because the airport's overall electric power capacity may be constrained by inadequate electricity distribution infrastructure. If additional infrastructure is required, the airport may need to play a role in funding the upgrades, although this would be subject to local contractual agreements with tenants and power suppliers.

4.2.2 Activities for promoting pre-commercial-scale alternative fuels

Alternative jet fuel and its co-products (e.g., green diesel and electricity) are not yet commercially available in the U.S. as very few commercial-scale production facilities exist to this day. Airports, in their role as nodes of multi-modal transportation, are in a unique position to serve as a producer's point-of-sale for all alternative jet fuel dispensed on-site to all tenants. Thus, airports can be instrumental in helping to develop this industry even if they are not direct consumers of alternative jet fuel. Some of the roles that airports can play to support the construction of alternative jet fuel facilities include:

- Bringing together local stakeholders—airlines, fuel producers, feedstock providers, local government entities, regulatory agencies.
- Helping stakeholders develop the business case.
- Championing the facility during its planning stages.
- Providing a site with easy access to the airport fuel distribution system.
- Using local political influence to facilitate state and federal financial support if available.
- In addition, an airport is a natural distribution point for the green diesel co-product to multi-modal users (e.g., GSE, ground transportation), and could purchase excess electricity and heat from a nearby facility. .

Alternative jet fuel and green diesel are drop-in fuels, requiring neither additional infrastructure nor different handling from the petroleum-based products they replace. Thus, airports can provide existing infrastructure to store and distribute these products; this contribution significantly lowers the challenges for commercial viability.

4.2.3 Pre-commercial scale alternative fuel business model considerations

Key considerations an airport should review when considering the business case for alternative jet fuel and co-product distribution programs include the following:

- Are customers willing to enter into binding purchase agreements to reduce the financial risks and improve a project's financial viability? Do the fuel buyers need to assume all the risk in a cost-plus contract or a fixed price agreement, or will the various participants in the project share the risks?

- Which stakeholders have the greatest interest in the project, and does that interest translate into their willingness to take a greater share of the risk?

- What are the availability of feedstock, its supply reliability, and its cost?

- Are new technologies for production of alternative fuels likely to impact the project? Are there upcoming production methods that could divert feedstocks to more efficient processes, or reduce the cost of competing fuels, especially for alternative jet fuels?

- What is the project's overall environmental sustainability, including water use, land use, and life-cycle GHG benefits? It is likely to face stiff local opposition which could increase its risk profile?

- Have all regulatory, permitting and social equity issues been identified and satisfactorily addressed?

- If existing or new federal, state, and local governmental policy is important to the project's economic viability, can the policy be changed during the project's life, and how would that affect the project's viability?

- What is the quality and depth of the team that will manage this project?

- Can the required financial capital be attracted?

4.2.4 General considerations for outside financing

In general, the higher the perceived risk of a project, the more expensive it will be to secure financing. As of 2011, it is estimated that alternative jet fuel production facilities are likely to require large amounts of capital, will probably use a technology that is unproven at scale, and will operate in an uncertain market environment. As such, this kind of project is likely to be considered high risk by financiers, and sources of financing that airports may turn to for other projects may not be interested in or able to finance these more risky ventures. Projects focused on other, more mature alternative fuels, such as CNG and LPG, have a reduced risk profile as the technology already exists and commercial-scale production is available; however, they still face certain risks—in particular from uncertain market conditions.

To help reduce project cost and align the interests of all concerned, credit-worthy stakeholders should be expected to contractually accept the business risks that they can control. Successful projects can be expected to depend on all involved parties honoring contractual obligations including feedstock supply (when applicable), infrastructure availability, and customer purchases, among others. To be willing to provide funds, a bank would need to be satisfied that all major risks were contractually covered. This may be challenging for new technology projects. To date, project developers have looked to government programs for both grants and loan guarantees to help reduce risks and move these projects forward.

Public sources of financing include local, regional, and the federal governments. Diverse local and regional initiatives may be in place to support regional economic development, and the involvement of an airport may enhance access to such support. The alternative transportation fuel industry is currently a high priority for the federal government, which, primarily through the Departments of Agriculture (USDA) and Energy (DOE), is providing incentives such as grants, loans, loan guarantees, subsidies, and tax credits.

The USDA offers extensive support programs to encourage rural development (USDA 2010b) and is committed to supporting the development of alternative aviation fuel as part of these initiatives. In particular, the Biorefinery Assistance Loan Guarantee Program - Section 9003 of the 2008 Farm Bill is of particular relevance to a developer of a jet fuel refinery (USDA 2010c). This program, administered by USDA Rural Development, provides loan guarantees for the construction or retrofitting of rural biorefineries to assist in the development of new technologies for the development of advanced biofuel made from renewable biomass other than corn (USDA 2010a). Such loan guarantees can be used to support private sector loans, and are intended to make it easier to obtain financing by reducing the risks a banker would have to assume.

4.2.5 Airport Improvement Program funding and fuel facilities

Federal grant funding opportunities for fuel facilities at airports are very limited. In general, the FAA’s Airport Improvement Program (AIP) makes grant funding available only for non-revenue producing airport projects, such as runways and taxiways. There is a provision in FAA Order 5100.36B, *Airport Improvement Program Handbook*, that allows for certain revenue-producing aeronautical support facilities (like new fueling facilities) at nonprimary airports to use AIP grant funding (FAA 2005a). Airport sponsors are required to ensure that adequate provisions for financing higher priority airfield projects are in place prior to applying for grant funding for fuel facilities. Nonprimary commercial service airports are defined as airports that have less than 10,000 annual enplanements. AIP grants for nonprimary airports are typically distributed at a 95 percent federal allocation, with a required five percent local match.

Many states have individual grant programs, usually funded with fuel tax revenues, which allow for grant support of revenue producing facilities such as fuel facilities; however, most of these programs are targeted to the smaller commercial service airports and general aviation facilities.

For airports that are able to secure AIP grant funding for fuel facilities or any other project, the airport sponsor must agree to certain legal obligations, known as FAA grant assurances (FAA 2005b). The current list includes 39 such obligations which require the recipients to maintain and operate their facilities safety and efficiently and in accordance with specified conditions. These assurances may be attached to the grant application for federal assistance and become part of the final grant offer, or be included in restrictive covenants to property deeds. The duration of these obligations depends on the type of recipient, the useful life of the facility being developed, and other conditions stipulated in the assurances.

4.2.6 Voluntary Airport Low Emissions Programs (VALE)

For larger commercial service airports, there may be state grant funding opportunities for the development of fuel storage facilities, but there are very few federal grant opportunities for these projects. However, for larger commercial service airports located in areas not in attainment with National Ambient Air Quality Standards (NAAQS), the FAA's Voluntary Airport Low Emissions (VALE) Program may be a possible source of funding. VALE is a national program to reduce airport ground emissions in nonattainment and maintenance areas. The program allows for the use of AIP and Passenger Facility Charge (PFC) funding for low-emission vehicles, refueling and recharging stations, gate electrification, and other airport air quality improvements. The program provides funding for clean airport technology and specifically encourages the use of domestic alternative fuels. Federal AIP funding of eligible costs is typically 75 percent for large and medium hub airports and 95 percent for smaller commercial service airports. PFC funding covers 100 percent of eligible costs. A list of eligible airports and a summary of projects to date is available at the FAA VALE website (FAA 2011c).

4.2.7 Clean Cities

Clean Cities is a government-industry partnership sponsored by the U.S. Department of Energy to promote means to reduce the use of petroleum-derived fuels in the transportation sector (Clean Cities 2011). Clean Cities has nearly 100 coalitions all over the U.S. working on bringing together government agencies and private companies to develop plans to promote advanced transportation alternative. Clean Cities helps create opportunities for alternative fuel vehicles, fuel economy, idle reduction and other emerging transportation technologies. Airports are encouraged to contact their local Clean Cities coordinators, where available, to inquire about possible projects and collaborations. A list of Clean Cities coordinators is available from (Clean Cities 2011).

4.2.8 Other potential sources of cost reductions for production of alternative fuel

Various government-sponsored initiatives can reduce the cost of using alternative fuels by providing tax credits, feedstock assistance, and other support. These schemes may be unreliable in the long term, because, for example, the level of support may be driven by unknowable market conditions or may be discontinued by Congress as budgets are tightened and are likely to be discounted by financiers when considering support of a production facility. Some of these programs are outlined below (Miller et al. 2011):

EPA Renewable Fuel Standards

The Environmental Protection Agency's Renewable Fuel Standard (RFS) RFS-2 sets out the minimum volume of renewable fuels that producers must produce by year into the future (EPA 2010b). Compliance is tracked through the issuance of a Renewable Index Number (RIN) for those fuels as they are produced, and obligated parties can purchase RINs from other producers rather than produce renewable fuels in order to meet their obligations in a given year. While aviation does not have a required biofuel contribution under RFS-2, producers of renewable aviation fuels that meet the standards set in RFS-2 are able to claim RINs and can sell them to others, effectively reducing the cost of green jet fuel. The value of RINs is largely driven by the market; in theory, the maximum value is the difference between the cost of producing renewable fuel and regular fuel, but actual value is driven by supply and demand.

Carbon Markets

One approach to encouraging a reduction in greenhouse gas emissions (GHG) is a "cap-and-trade" carbon market that going forward slowly reduces the amount of CO_2 that regulated industries are permitted to release into the atmosphere. In theory, such a market-driven scheme results in a cost-efficient way of reducing GHG emissions by allowing businesses to purchase the right to emit CO_2 from others rather than investing in the technology to reduce their own emissions. Regulation is usually based on a government issuing a permit to emit an amount of CO_2 in a given year, and the trading of these permits between regulated industries. It is envisaged that renewable fuels will reduce their users' carbon emissions and their need for emission permits, effectively reducing the cost of the green fuel compared with petroleum-based equivalents.

Such a market – the European Union Emissions Trading System (ETS) – has been in operation for carbon-intensive industries in the European Union since 2005, and is being expanded to include aviation in 2012. Although non-European airlines are legally challenging their inclusion in the scheme, European carriers have been leaders in the development of green jet fuel to help reduce their carbon emissions and their need to obtain carbon credits under ETS. At the time of this writing, the rules covering the verification of reduced carbon output for flights powered by renewable fuel are still being developed.

In the U.S., although a carbon market has been much discussed, the federal government has not acted to implement carbon-reduction targets at the national level. However, California recently adopted the first carbon emission regulations in the U.S. for industries within the state, instituting a cap-and-trade market that was introduced in the Global Warming Solutions Act of 2006, commonly known as AB 32 (CAEPA 2009). This act mandates a reduction in carbon emission back to 1990 levels by 2020. Beginning in 2013 the state's largest carbon emitters will be required to meet the caps or buy credits if they cannot. The second phase, beginning in 2015, is expanded to include producers of transportation fuels, although aviation is not included in AB 32.

Biofuel Tax Incentives

The federal government, through the IRS, has provided price-support in the past to encourage development of ethanol and diesel from agricultural sources. The programs introduced in 2005[3] (in the American Jobs Creation Act of 2004 and Energy Policy Act of 2005) provided as much as $1.00 per gallon tax credits for road transportation fuels. They have now expired, causing

[3] Apart from Small Ethanol Producer Credit which was introduced in 1990 in the Omnibus Budget Reconciliation Act of 1990

disruptions in the marketplace for these products. The 2008 farm bill contains provisions which extend and modify tax credits on ethanol produced from cellulosic feedstocks intended to spur investment in cellulosic ethanol production rather than from corn starch.

Bioenergy Program for Advanced Biofuels ("BPAB") – Section 9005 of 2008 Farm Bill

BPAB gives the Secretary of Agriculture broad discretion to create a program to provide production payments to eligible advanced biofuel producers "to support and ensure an expanding production of advanced biofuels" (USDA 2011). The proposed rules allow payments to qualifying bioenergy producers of an as-yet-to-be-determined amount based on the funding for the program, and the total amount of qualifying bioenergy produced – in BTUs – by all qualified producers. Our current understanding is that producers will get paid a pro rata share of the total funding depending on their share of eligible advanced BTUs produced in a given year. This is effectively a price support program for producers, but we do not expect sources of biorefinery equity or debt to take these payments into account because they will change over time in depending on how much bioenergy is produced.

Biomass Crop Assistance Program – Section 9011 of the 2008 Farm Bill

This program (USDA 2009) provides owners with dollar-for-dollar matching payments for the sale and delivery of eligible material to a Biomass Conversion Facility. The program also supports "establishing and producing eligible crops for the conversion to bioenergy through project areas and on contract acreage up to 5 years for annual and non-woody perennial crops or up to 15 years for woody perennial crops." These payments are limited to $45 per dry ton. They effectively subsidize the cost of feedstocks for advanced green fuel production, which could reduce the cost of the green fuel.

4.3 Legal and regulatory considerations

The legal and regulatory considerations for alternative fuels may be difficult to navigate given the many different regulatory and policy-making entities associated with them. The following sections are an effort to simplify the landscape and provide useful guidelines for these considerations.

4.3.1 FAA and associated airport regulations

There is a significant number of FAA and other regulations that influence the way airports operate and how infrastructure is developed. These regulations can be very site-specific, and are further influenced by local regulatory bodies. A full discussion of these rules and regulations is outside of the scope of this guidebook; however, Section 5 is devoted entirely to criteria for locating alternative fuel distribution programs on an airport site. That section presents and discusses the major considerations from an airport planning and regulatory perspective that should be taken into account when evaluating these projects.

4.3.2 Regulatory and policy framework on alternative jet fuels

The regulatory and policy framework for alternative jet fuels is very dynamic and evolves continuously as the industry itself grows and develops. The federal government as well as state and local entities have announced and implemented a number of programs to promote alternative jet fuels. These programs include an initiative announced by the White House in August 2011 collaboration between the U.S. Navy and the Departments of Agriculture and Energy to invest up to $510 million over three years in partnership with the private sector to support production of alternative jet and marine fuels (White House 2011). A recent ACRP publication (Miller et al. 2011) describes in more detail many of the regulations, policies, and other incentives in the U.S. supporting the development of alternative jet fuels. Other recommended sources for the latest information on alternative jet fuels include:

- The Commercial Aviation Alternative Fuels Initiative (CAAFI, www.caafi.org), a coalition of U.S. government, manufacturers, airlines, and airport organizations.
- Airlines for America (A4A, formerly the Air Transport Association of America or ATA, www.airlines.org), the leading trade association for U.S. airlines.
- The International Air Transport Association (IATA, www.iata.org), an international airline trade association.
- The Air Transport Action Group (ATAG, www.atag.org), an association that represents all sectors of the international air transport industry.
- The Sustainable Aviation Fuel Users Group (SAFUG, www.safug.org), a coalition of airlines, manufacturers, and other organizations involved with alternative jet fuel.
- Airport Cooperative Research Program (ACRP, http://www.trb.org/ACRP/ACRP.aspx), which supports a portfolio of projects on alternative fuels.

4.3.3 Regulatory and policy framework on other alternative fuels

The regulatory and policy framework for other alternative fuels is complex, in particular because many regulations and policies are fuel-specific and vary from state to state. For example, as of November 2011, there were 34 federal and 426 state incentives and laws for ethanol, and 37 federal and 434 state incentives and laws for biodiesel (see Table 5).

Table 5: Number of incentives and laws related to alternative fuels by jurisdiction (Source: (DOE 2011a))

Jurisdiction	Ethanol	Biodiesel	Natural gas	Propane (LPG)	Electric vehicles
Federal	34	37	27	26	22
State (total – all states)	426	434	359	287	335
State (average by state)	8	8	7	5	6

The Department of Energy's *Alternative Fuels and Advanced Vehicles Data Center* (DOE 2011c) is an excellent resource for identifying and tracking federal and state incentives and laws that apply to alternative fuels and vehicles. It has an entire section dedicated to incentives and laws that can be searched by technology and fuel, incentive, and state. It also has resources to find incentives and laws at the local level. Given that a large amount of regulations and incentives may apply to different projects based on the location and technology, airports are encouraged to use this website as their first step in identifying incentives and laws applicable to them.

4.4 Stakeholder engagement and community acceptance

4.4.1 Stakeholder engagement

Assessing the potential for obtaining stakeholder support is very important when evaluating alternative fuel distribution projects. An airport that considers engaging in such an effort must have a clear picture of what its customers and other constituents need before allocating scarce resources. It is also helpful for airports to understand institutional barriers and the incentives of a full range of other players that may contribute to the success of the project.

Many stakeholders are likely to become involved in an alternative fuel distribution project. As part of the evaluation for potential projects, airports should identify all the stakeholders that may be involved and understand their needs. To the extent that the project can meet those needs, stakeholder engagement and participation should contribute to advancing the project. Below is a partial list of those expected to play a significant role and whose participation will be required for a successful outcome. For completeness, this list includes stakeholders along the entire supply chain, from feedstock suppliers to end users; however, depending on the type of project, some stakeholders will be more prominent than others.

- Feedstock suppliers
- Fuel producers
- Fuel handlers
- Third-party concession operators
- Airports
- End users
- Vehicle and equipment manufacturers
- Unions
- Government entities
    - Municipalities

    - Metropolitan Planning Organizations (MPOs)
    - States
    - Federal government
- Funding sources
    - Public
    - Private
- Non-governmental organizations (NGOs)
- Community groups

Alternative fuel distribution projects are more likely to be successful when stakeholders actively support them. Stakeholders have different information needs and reasons for participating in an alternative jet fuel project. Following are some typical high-level motivations and needs by type of stakeholder.

- **Feedstock suppliers:**
    - Motivations: market diversification for existing production, new market opportunities.
    - Needs: higher financial returns than from supplying traditional feedstock to traditional customers, mechanisms to protect financial returns (e.g., crop insurance).
- **Fuel producers:**
    - Motivations: support existing customers, new market opportunities.
    - Needs: public/private sector financing, long-term supply and offtake contracts that match the terms of the financing arrangements, returns according to the risk of the project.
- **Fuel handlers:**
    - Motivations: support existing customers, new market opportunities.
    - Needs: partnership with producers and end users.
- **Third-party concession operators:**
    - Motivations: support existing customers, new market opportunities.
    - Needs: partnerships with producers, airports, and end users, long-term contract arrangements that match terms of financing, returns according to the risk of the project.

- **Airports:**
  - Motivation: support existing customers, diversify revenue streams, meet environmental goals, community outreach.
  - Needs: ability to demonstrate economic and environmental benefits, minimize infrastructure and fleet costs, long-term financial viability of the project.
- **End users:**
  - Motivations: environmental targets, diversification of fuel supply, energy security.
  - Needs: alternative fuel cost that is competitive in terms of price with conventional fuel, 100% confidence that alternative fuels are compatible with infrastructure and equipment.
- **Vehicle and equipment manufacturers**
  - Motivations: support existing customers, new market opportunities.
  - Needs: partnerships with airports, end users, and third-party providers.
- **Unions:**
  - Motivations: support environmental targets, job diversification and specialization.
  - Needs: conviction that high-paying jobs will be preserved or added and quality of work life and benefits will stay high.
- **Government entities (Municipalities, Metropolitan Planning Organizations, States, Federal government):**
  - Motivations: meet policy objectives, respond to constituents' needs.
  - Needs: quantifiable and non-quantifiable economic and political benefits.
- **Funding sources (private sector):**
  - Motivations: diversification, new market opportunities.
  - Needs: guaranteed rates of return according to the risk of the project.
- **Funding sources (public sector):**
  - Motivations: support policy objectives, respond to constituents' needs.
  - Needs: consistency with the political agenda of the entity, consistency with legislative mandates, and best use of limited available funds.
- **NGOs:**

  - Motivations: ensure alternative fuels provide benefits to the environment and the community.
  - Needs: conviction that alternative fuel provides benefits compared to conventional options.

- **Community groups:**
  - **Motivations:** ensure alternative fuels provide benefits to the environment and the community.
  - **Needs:** reassurance that jobs will not be lost or that jobs will be created, that property values will not decrease or that they could increase, and that the physical environment will be safe, clean, and attractive.

The interests and needs of stakeholders can be identified and documented using Table 6. This table provides a detailed template that can be useful to understand the needs of each stakeholder, to determine whether or not the project meets those needs, and to identify exactly what specific actions must be taken to ensure the stakeholder actively and energetically supports the project.

Table 6: Stakeholder needs analysis

Stakeholder Information	**Response**
Stakeholder (Name of entity):	
Role in project: (e.g., airport, airline, feedstock supplier, fuel producer, municipality/local government, public/private sector funder)	
Stakeholder mission:	
Economic	
Non-economic	
Is project consistent with mission? (yes, maybe/not sure, no)	
Explanation	
"Hurdle rate" —describe specific minimum requirements that project must meet to obtain stakeholder's participation	
Economic	
Non-economic	
Does project meet hurdle rate? (yes, maybe/not sure, no)	
Explanation	
Stakeholder concerns and risks	
Economic	
Non-economic	
Has an engagement strategy been developed? (yes, maybe/not sure, no)	
Explanation	
Actions required to obtain/enhance stakeholder participation	
Economic	
Non-economic	
Has a plan been developed to obtain/enhance stakeholder participation? (yes, maybe/not sure, no)	

Stakeholder Information	Response
Explanation	
Stakeholder decision-making process	
Is the stakeholder's internal and external decision-making process fully understood? (yes, maybe/not sure, no)	
What needs to be done/who needs to be consulted to understand decision-making process?	
Explanation	

4.4.2 Addressing particular concerns of airport leadership

Airport leaders should progress cautiously when considering significant changes in fuel sources, because the field is rapidly changing and stakeholders frequently have divergent interests. Below is a brief discussion on the key initial challenges that a proponent of alternative fuel could expect to encounter within an airport, and suggested approaches for addressing them.

- **Technical concerns that alternative fuels are safe:** Because alternative fuels may be new to many airports, knowledge about developments and the current status of alternative fuel among airport leadership, in particular alternative jet fuel, may be generally low. There is the risk that confusion about the benefits and drawbacks of different alternative fuels may make it difficult to obtain support for them. Addressing these concerns requires thoughtful, patient explanations from sources that airport executives deem credible.

- **Need for solid political and economic support:** Given that many alternative fuel projects require significant investments, airport executives will require solid evidence of political consensus and the potential for economic support. This is especially true for alternative jet fuel that does not yet have a commercial track record and will likely need public-sector financial support for the first few facilities.

- **Organizational challenges of institutions that can be large and conservative:** Most airports are conservative institutions whose core business is safely transporting people. Airport executives of both public and privately-owned airports must respond to, and balance, the needs of many constituents that include political figures, community activists, and customers. As a result, decision-making processes are generally complex and lengthy, especially in large airports.

  This challenge is best addressed with a pragmatic approach to airport stakeholder engagement. This involves identifying the airport's decision-making process and mapping all key individuals who make or critically influence decisions. Decision-makers and influencers can be found at all levels, including boards of directors, senior managers, employees, and union representatives. Each individual's support must be gauged, and a plan must be developed to secure energetic support. It is important to bear in mind that each individual's personal benefits and threats must be addressed.

4.4.3 Community acceptance

Alternative fuel distribution programs can provide many benefits to the airport and surrounding communities; however, it is important to keep in mind that there exist some high-level concerns among the general population that may create hesitation with respect to these types of projects, two of which are discussed in the following sections. A recommended course of action is to acknowledge these concerns, and to provide sufficient information to the community to discuss them.

Food-versus-fuel

Questions related to the use of agricultural food commodities for the production of alternative fuels have given rise to the concern of "food-versus-fuel." The debate seems to have originated after a spike in animal feed costs and food prices in 2008 and the rapid development and expansion of the corn ethanol industry. Currently, 30 percent of the domestic corn crop is used for ethanol production. This has resulted in concern that the use of corn as a feedstock for alternative fuel production will lead to higher food prices and perhaps even compromise food supplies. Others argue that the rapid increase in food prices in 2008 were the result of high energy costs not corn ethanol production. The issue has become very political and there is little consensus of the impact of alternative fuel production on food production and prices.

In order to avoid the controversy surrounding the food-versus-fuel debate, some organizations and user groups, such as the Commercial Aviation Alternative Fuel Initiative (CAAFI) and other stakeholders in the U.S. airline industry, support the use of feedstocks that do not compete with food availability. Therefore, these entities promote feedstocks that are not used for human food production and that, according to some, would not have an impact on food prices or security. Examples of these feedstocks include agricultural residues (e.g., wheat straw, corn stover), dedicated energy crops (switchgrass), woody biomass, municipal solid waste (MSW), alternative oilseed feedstocks (e.g., algae, jatropha), and non-food oilseeds (e.g., mustard seed, camelina) (Miller et al. 2011).

Water-Energy-Food Nexus

The "Water-Energy-Food Nexus" refers to the inextricable links between water, energy, and food. Increasing water scarcity and decreasing water tables are evident in many parts of the world, notably the Ogallala Aquifer, which underlies much of the U.S. breadbasket. At the same time, rising food and energy demand are further stressing already strained freshwater resources. As a result, the Water-Energy-Food Nexus has risen to the top of global environment, policy, and business agendas. Manifestations include public debates on food vs. fuel, hydraulic fracturing, and current and potential energy shortages due to lack of water to cool power plants.

Therefore, evaluations of alternative fuel projects must be aware of the potential impact on water resources associated with the extraction and production of alternative fuels. In particular, consideration should be given to water as 1) a production constraint, 2) a risk to business continuity and cost, and 3) a critical environmental resource. In addition, alternative fuel project evaluations ought to assume increased water scarcity in the years ahead.

At the same time, the limited availability of information to perform such evaluations must be recognized. In a 2011 paper, the World Policy Institute and EBG Capital note that non-politicized, peer-reviewed, current data are scarce, and calls for future researchers to systematically explore data weaknesses including in areas such as non-irrigated and second- and third-generation biofuels, the range of alternative feedstocks, and emerging technologies

(Glassman et al. 2011). That study also distinguished between the consumption, withdrawal, and quality of water.

> "'Consumption' refers to water that disappears or is diverted from its source, for example by evaporation, incorporation into crops or industrial processes, drinking water, etc. The source may or may not eventually be replenished. If replenished, the process could potentially take many years – decades, centuries, or longer. 'Withdrawal' refers to water that is essentially "sucked up" for a given use, but then returned to its source; the quality of the returned water may or may not be the same as it was prior to removal. 'Quality' is an umbrella term that can refer to pollutants that enter the water; changes to oxygen content, salinity, and acidity; temperature changes; destruction of organisms that live in the water; and so on."

Similarly, in 2006, the National Labs concluded that the best available data to date indicate that first-generation irrigated biofuels consume thousands of times more freshwater than petroleum or natural gas per BTU of energy produced (DOE 2006).

5 Summary of Task 5: Siting criteria

This section presents the results of Task 5: "Identify siting criteria for alternative fuel distribution programs." The objective of this task was to delineate the generalized planning process and siting criteria for installing alternative fuel storage and distribution facilities at airports. A suggested sequencing strategy was also included. This information was taken from and references several common sources in the airport planning practice, including:

- FAA AC 150/5300-13/*Airport Design*
- FAR Part 77/*Objects Affecting Navigable Airspace*,
- *Airport Improvement Program (AIP) Grant Assurances*,
- FAA Order 1050.1E/*Environmental Impacts: Policies and Procedures*,
- FAA Order 5050.4B/*National Environmental Policy Act (NEPA) Implementing Instructions for Airport Projects*,
- FAA AC 150/5230-4A/*Aircraft Fuel Storage, Handling, and Dispensing on Airports*, and
- National Fire Protection Association (NFPA) 407/*Standard for Aircraft Fuel Servicing*, as well as several other NFPA standards documents.

In addition, given that alternative fuels are not yet routinely included in airport projects, the team used its expert judgment and industry contacts to fill gaps not covered in the literature, such as developing a list of potential screening criteria for evaluating alternative fuel storage facility development sites.

In order to make the guidebook relevant to practitioners, the team selected Tulsa International Airport (TUL) as an example to illustrate various elements of the planning process for siting alternative fuel storage facilities on airports. TUL is classified by the FAA as a small hub airport, and was chosen because of the number and variety of existing fuel facilities located on airport property. Also, the existing fuel storage facilities at TUL are representative of typical facilities (e.g., a variety of storage tank farm configurations, aviation and non-aviation fuel types, and fuel distribution options) that are found at both smaller general aviation and larger commercial service airports throughout the country.

5.1 Overview of alternative fuels site planning process

Any successful site planning project begins with comprehensive knowledge and understanding of the operation, function, and use of the proposed facility. Planners must gather and assemble a variety of baseline information, which establishes the framework to conduct a detailed evaluation of any development proposal and to make recommendations regarding the alternative planning strategies.

A substantial amount of research and analysis that must be undertaken to identify and document the siting criteria required to properly locate, design, and operate the facility. The goal of this section is to identify and review the critical siting and location-specific criteria, as well as to document a suggested sequencing strategy for this evaluation and future development. A generalized list of these site planning criteria is presented in Table 7.

Table 7: General category and considerations for siting alternative fuel distribution programs at airports

Category	Key considerations
1) Inventory existing airport fuel storage facilities and distribution systems, and conduct initial site analysis	Identify location of existing aviation and non-aviation fuel storage facilities, document fuel types and quantities, and specify method of distribution
2) Identify and update existing and long-term alternative airport fuel storage facility and distribution system requirements	Determine if the existing fuel storage facility or distribution system noted above can accommodate the future alternative airport fuel storage requirements
3) Identify long-term alternative airport fuel storage facility and distribution system development goals & objectives	Determine which alternative airport fuel storage facilities and distribution systems should be considered, and identify the appropriate planning track for evaluation
4) Identify preliminary alternative fuel storage facility development sites	• Determine if existing airport fuel storage and distribution facilities can be expanded or redeveloped to accommodate alternative fuels • Determine if a new alternative fuel storage and distribution facility must be constructed • Determine if the existing fuel storage and distribution facility must be decommissioned
5) Screen preliminary alternative fuel storage facility development sites	Screen sites for compliance with FAA design standards, local planning and zoning, and local, state, and federal regulations
6) Select recommended alternative fuel storage facility site plans for planning approval process	• Initiate preliminary design and engineering drawings, including cost estimates • Complete FAA review and approval process for updating Airport Layout Plan Drawing Set • Complete NEPA process and receive compliance determination
7) Finalize recommended alternative fuel storage facility site plans for construction	Finalize construction drawings and obtain required construction and development permits

The following sections expand the categories of the site planning process, presenting them in a narrative format to help airports quickly identify the key considerations and make informed planning and development recommendations. A listing of reference documents that would likely be resourced for the various steps of the planning process is included at the end of this section. In addition, a flowchart diagram that graphically sequences these steps is included in Section 5.10.

5.2 Airport fuel storage facilities/distribution systems inventory

The first step in the process for evaluating the siting of alternative fuel storage and distribution systems is to complete a comprehensive inventory of the airport's existing facilities. It is important to note that there are a variety of possible ownership and operational arrangements relating to aviation fuel storage and distribution on airports. These arrangements can vary from airports that own and operate the aviation fueling facilities to others that simply lease property to individual fuel service providers who own and operate the facility. Specific examples of possible fuel storage facility ownership and distribution facility arrangements include the following:

- Airport Ownership and Distribution
- Airport Ownership and Self-Serve Distribution
- Airport Ownership and Fixed-Based Operator (FBO) Distribution
- FBO Ownership and Distribution
- Fuel Company Ownership and FBO Distribution
- Private Ownership and Distribution

Therefore, the fueling goals and objectives of airport operators can vary significantly, depending on the airport owner's interest and capabilities in the operation and maintenance of the fueling concession.

A detailed description of all fuel storage facilities and distribution systems should initially be prepared, along with a drawing that maps the locations of all improvements. The location of the airport's aviation fuel storage facilities is typically depicted on the Airport Layout Plan (ALP) drawing, or may be included in the airport's existing Geographic Information System (GIS). Also, many airports are likely have a Storm Water Pollution Prevention Plan (SWPPP) or a Spill Prevention, Control, and Countermeasure (SPCC) Plan that detail fueling facilities and systems inventories.

Depending on the size or classification of the facility, airports may have a variety of other fuel storage facilities that are related to aviation support facility functions. These include airline GSE, airport operations vehicles (Aircraft Rescue and Fire Fighting (ARFF) and maintenance), and rental-car facilities. Therefore, it is recommended that both aviation-related fuels (i.e., Jet A and Avgas) and non-aviation related fuels (e.g., unleaded gasoline, diesel, E85, CNG, and LPG) be inventoried separately, because each category would likely have different storage requirements, siting criteria, and distribution systems.

For each storage facility in the inventory, the following items should be documented: type and number, fuel type, storage capacity, condition, age, pumping capacity, ownership, lease terms, and environmental compliance status (See Figure 10 and Table 8). Once the inventory is complete, the airport should evaluate the facilities for the following:

- Compliance with existing zoning regulations

- Consistency with existing comprehensive planning documents
- Consistency with existing airport planning documents
    - Airport Master Plan
    - ALP
    - Airport Rules and Regulations
    - Airport Minimum Standards for Commercial Activities
- Compliance with FAA planning and design standards
- Compliance with NFPA guidance/regulations
- Compliance with local fire code regulations

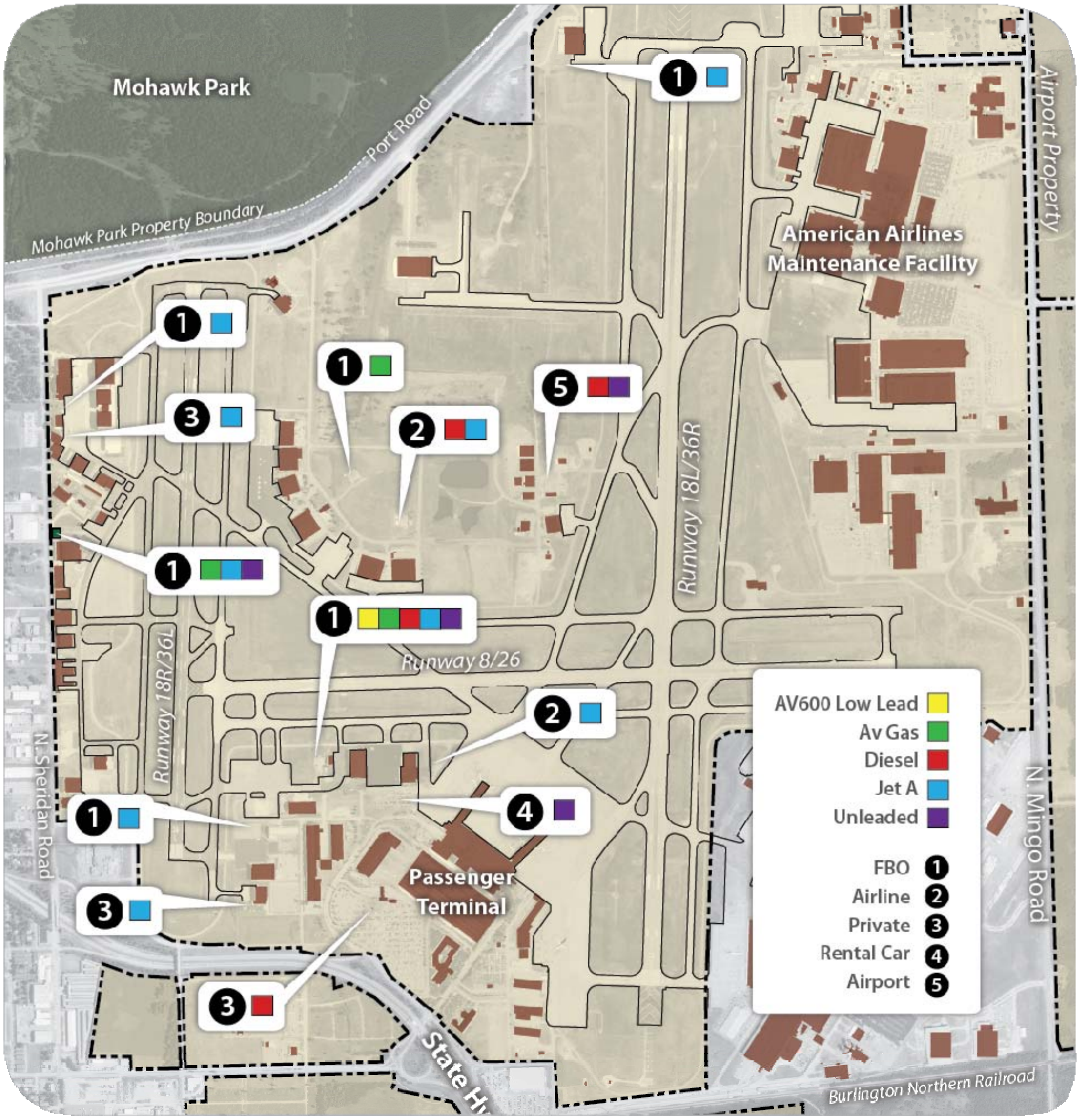

Figure 10: Example of fuel storage facilities at Tulsa International Airport

Table 8: Example Fuel Storage Inventory at Tulsa International Airport

Distributor	Tank Owner	Type	Size	Content
FBO	Atlantic Aviation	UST	30,000	Jet A
		UST	8,000	Av Gas
		UST	10,000	Diesel
		UST	10,000	Unleaded
		UST	30,000	Jet A
		UST	8,000	Av Gas

Distributor	Tank Owner	Type	Size	Content
		UST	30,000	Jet A
FBO	Bizjet	AST	2,000	Jet A
		UST	20,000	Jet A
		UST	20,000	Jet A
		UST	20,000	Jet A
Private	QuikTrip	UST	12,000	Jet A
FBO	Premier Jet/Legacy	AST	20,000	Jet A
		Truck	5,000	Jet A
FBO	Sparks/Sparrow hawk	UST	12,000	AV600 Low Lead
Airline	SWA/Sky Tanking	AST	112,000	Jet A
		AST	112,000	Jet A
FBO	TulsAir Beechcraft	UST	20,000	Jet A
		AST	12,000	Av Gas
		AST	500	Unleaded
		UST	20,000	Jet A
		Truck	1,200	Av Gas
		Truck	2,200	Jet A
		Truck	2,200	Jet A
		Truck	3,000	Jet A
		Truck	12,00	AV Gas
FBO	U. S. Aviation	UST	20,000	Jet A
		UST	20,000	Jet A
Private	World Publishing Co.	UST	20,000	Jet A
Rental Car	Alamo	UST	12,000	Unleaded
Rental Car	National	UST	12,000	Unleaded
Rental Car	Hertz	UST	12,000	Unleaded
Rental Car	Avis	UST	12,000	Unleaded
Rental Car	Budget	UST	12,000	Unleaded

Distributor	Tank Owner	Type	Size	Content
Rental Car	Thrifty	UST	12,000	Unleaded
Rental Car	Enterprise	UST	12,000	Unleaded
Rental Car	Dollar	UST	12,000	Unleaded
Private	American Parking	UST	2,500	Diesel
Airport	TAA Maintenance	UST	5,000	Diesel
		UST	5,000	Unleaded
Note: UST – underground storage tank; AST – above-ground storage tank				

5.3 Fuel storage requirements (existing/future)

The second step in the planning process is to document both existing and future fuel storage requirements, which requires an up-to-date assessment of the aviation and non-aviation fuel demand at the airport, and an identification of the fuel storage facilities necessary to accommodate that demand. Again, the airport's existing planning documents, such as the Airport Master Plan, may include an analysis of fuel storage requirements, and the ALP may illustrate the expansion or possible relocation of existing fuel storage facilities. Depending on the currency of these documents, this demand analysis will likely need to be updated, and the existing planning documents may only include fuel storage requirements for aviation-related fuels. In such case, an analysis of non-aviation related fuel storage requirements will also be necessary. This information is available from the tables describing the current and projected energy mix at the airport **(**Figure 3 and Figure 4, respectively) as discussed in Section 3.

Once the fuel storage demand (for both aviation and non-aviation related fuels) has been quantified, these requirements must be allocated to site-specific storage requirements for the various fuel types under consideration. Depending on the amount of aviation fuel dispensed by either refueler trucks or a hydrant system, and the proximity of the airport to the location of the bulk fuel storage terminal, a general rule-of-thumb is to target a fuel storage capability of 7–14 days of supply at the airport to allow for any equipment or delivery problems or tank outages. Also, these storage projections should be validated with existing fuel service providers (if applicable), to assist the airport in identifying any future fuel service goals (e.g., provision of additional fuel types, capacities, or distribution methods).

5.4 Alternative fuel storage and distribution goals

The third recommended step in the siting process is to incorporate the findings of Steps 1 and 2 into the formulation of specific goals for alternative fuel storage and distribution. This process should begin with a determination of whether enough aviation and non-aviation fuel is dispensed at the airport to warrant consideration of additional alternative fuel storage and distribution facilities.

Below is a listing of possible development scenarios that may arise relative to the future provision of alternative fuels on the airport:

- Expand existing airport fuel storage facility to accommodate increased demand.
- Relocate or decommission existing airport fuel storage facility due to issues related to environmental compliance or development and expansion constraints.
- Consolidate multiple existing fuel storage facilities.
- Develop new public-use alternative vehicular fuel dispensing facilities on airport property (facilities would serve private vehicles that operate on alternative fuels).
- Develop new private-use alternative vehicular fuel dispensing facilities on airport property (facilities would serve airport operation and maintenance vehicles, airline ground service vehicles, rental-car facilities, etc.).
- Install new fuel hydrant delivery system to serve the passenger terminal apron area (e.g., individual gate parking positions or an adjacent fuel depot to reduce travel times by refueler trucks). Note that hydrant systems have high capital costs and complex monitoring requirements once installed. Careful analysis should be conducted to assess if such a solution would be practical.

5.5 Preliminary alternative fuel storage facility development sites

The fourth recommended step in the process is to incorporate the findings of Steps 1, 2, and 3 to identify preliminary alternative fuel storage facility development sites. Typically, separate potential development sites would be identified for aviation and non-aviation related fuel storage; however, for some airports, it may be advantageous to consider the co-location of these fuel storage facilities.

Key planning considerations in the siting of fuel storage facilities on the airport include a) the provision of vehicular access, b) the method of fuel distribution, and c) the separation distances of storage tanks from adjacent buildings, property lines, and aircraft movement areas. With respect to vehicular access, the fuel storage sites must provide convenient landside access to both the fuel delivery tankers that utilize the regional roadway transportation system, as well as airside access to the refueler trucks that utilize a combination of internal non-licensed vehicle roads (NLVR) and airfield pavement to serve individual aircraft. These criteria include adherence to local roadway engineering design standards for tanker trailer maneuvering and emergency vehicle response (e.g., lane dimensions, curb radii, outside radius, roadway cul-de-sac dimensions, etc.). Ideally, fuel storage facilities are sited to minimize travel times to and from the designated aircraft fueling areas, and minimize or avoid the crossing of aircraft movement areas by refueler trucks.

For commercial service airports that dispense conventional jet fuel via a hydrant system from the storage facility to the terminal ramp, a piping system is required to supply the fuel to the hydrant valves located at the individual gate positions on the ramp. Therefore, a centralized fuel storage facility that is located in the general proximity of the terminal ramp area is preferred to reduce the expense associated with the underground piping distribution system. The advantages of implementing the hydrant fueling system at the terminal gate positions include a continuous supply of fuel to the aircraft that is not limited by the capacity and travel times of the refueler trucks, as well as the elimination of the refueler trucks from operating on the terminal ramp and their associated emissions.

In consideration of the specified separation distances between aviation fuel storage facilities and adjacent airfield development, the various NFPA documents offer some guidance contingent upon tank sizes and fuel types. For example, NFPA 407/*Standard for Aircraft Fuel Servicing*, 2012 provides specifications for the design, operation, maintenance, and location of fuel storage facilities, including aircraft fueling devices. NFPA 407 specifies that fuel storage tanks "located in designated aircraft movement areas or aircraft servicing areas shall be underground or mounded over with earth", and that the authority having jurisdiction (AHJ) shall determine the clearances required from adjacent airfield components with "due recognition given to national and international standards establishing clearances from obstructions". According to NFPA 415, "the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of the fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. Other generalized fuel storage facility design considerations specified in NFPA 407 include:

- Fuel Storage tanks shall conform to the applicable requirements of NFPA 30, *Flammable and Combustible Liquids Code* (e.g., siting criteria specifying separation/setback criteria from property lines, buildings or public ways, and spacing between tanks).
- Antennas of airport flight traffic and ground traffic surveillance radars shall be located so that the radar beam will be separated from any fuel storage area, loading racks, or aircraft fuel servicing areas by a minimum of 300 feet for flight traffic radar and 100 feet for ground traffic radar.
- Parking areas for unattended aircraft fuel servicing tank vehicles shall be arranged to provide a minimum 50-foot separation from any parked aircraft or building other than designated maintenance facilities for these vehicles.

In addition, the FAA/*Airport Design,* Advisory Circular (AC) 150/5300-13 prohibits the siting of fuel storage facilities within runway protection zones, and the Transportation Security Administration has published more comprehensive guidelines regarding the protection of fuel storage facilities. These security recommendations include the provision of security fencing that is access-controlled to monitor all traffic movements. Also, CCTV monitoring and various alarm systems should be considered for installation at fuel storage facilities to enhance security surveillance. These documents and others should be referenced extensively to ensure compliance with specified separation development standards.

Examples of typical siting of fuel storage infrastructure are shown in Figure 11, Figure 12, and Figure 13. Figure 11 presents an example of a general aviation fuel storage area at an airport including both above and underground fuel storage tanks located on the edge of an aircraft parking apron and adjacent to an aircraft taxilane. Some reference documents pertinent to this illustration include the following:

- See NFPA 409/Chapter 5/Apron Drainage: Ramps used for aircraft fueling adjacent to hangar structures shall comply with NFPA 415 (the apron or approach at the entrance to the hangar shall slope away from the hangar with a minimum grade of 1% for the first 50 feet).
- See NFPA 30/Chapter 22 for Aboveground Storage Tank (AST) location and separation criteria.
- See NFPA 30/Chapter 23 for Underground Storage Tank (UST) location and separation criteria.
- See NFPA 30/Chapter 5 for loading requirements of aircraft fuel servicing tank vehicles.
- Taxilane Object Free Area standards based on FAA Advisory Circular 150/5300-13 for Group III Aircraft (aircraft with wingspans up to but not including 118 feet).

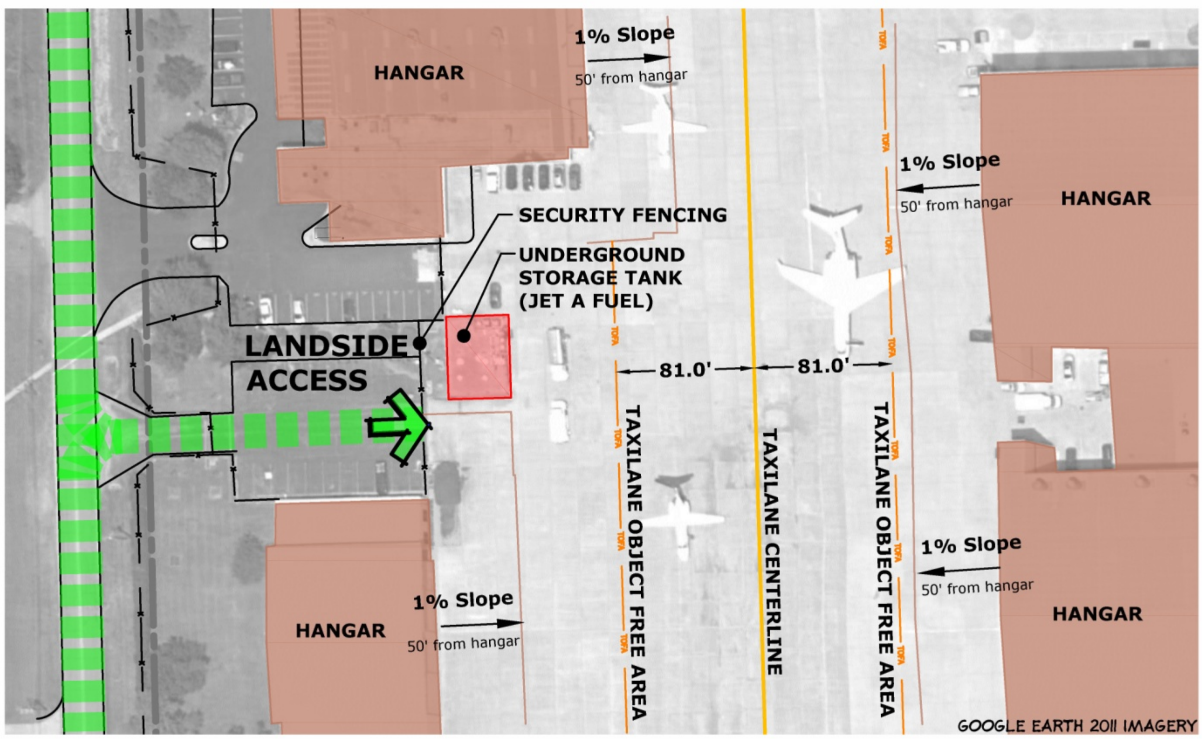

Figure 11: Example of general aviation fuel storage area at Tulsa International Airport

Figure 12 presents an example of a remote aviation fuel storage area with efficient landside access and a pipeline to the terminal area. Some reference documents pertinent to this illustration include the following:

See NFPA 30/Chapter 22 for Aboveground Storage Tank (AST) location and separation criteria.

- See NFPA 30/Chapter 22 for control of spills from aboveground storage tanks (i.e., remote impounding, impounding around tanks by open diking, impounding around tanks by closed-top diking, or secondary containment-type aboveground storage tanks.

- See local roadway engineering design standards for tanker trailer and emergency vehicle response maneuvering (e.g., typical outside turning radius @ 60 feet and curb radii at corners @ 30-40 feet)

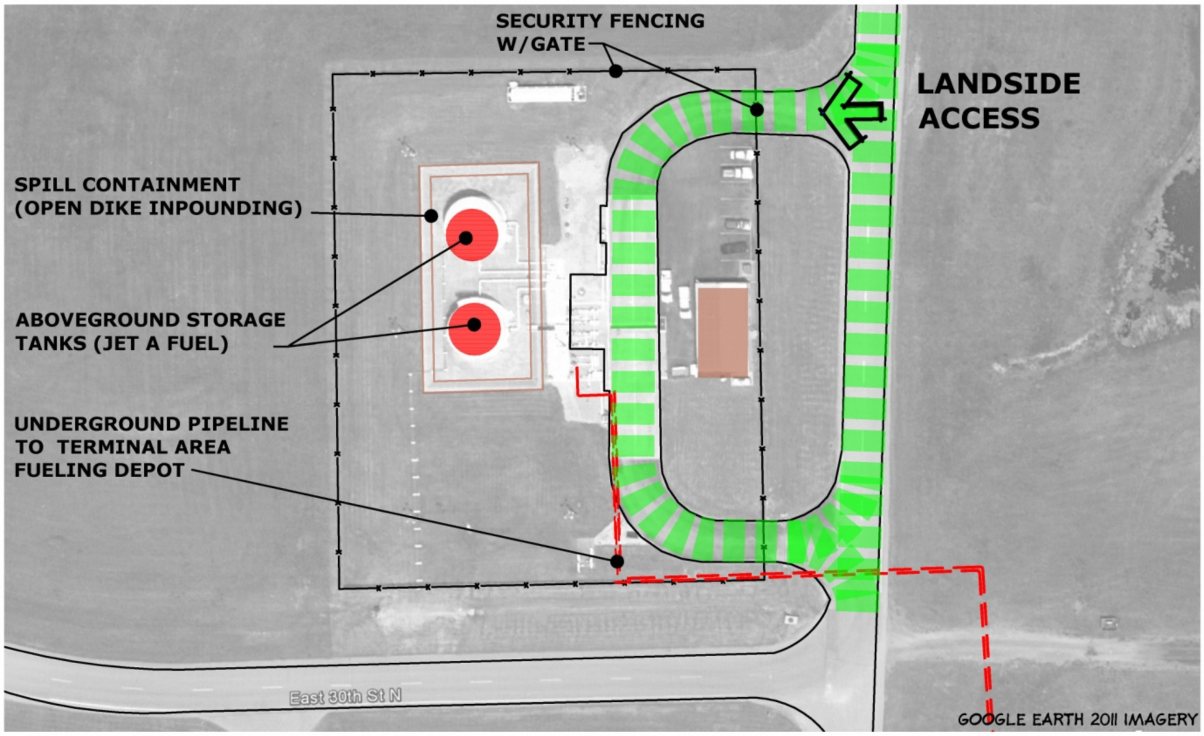

Figure 12: Example of remote aviation fuel storage with pipeline to terminal area fueling depot at Tulsa International Airport

Figure 13 presents an example of a terminal area refueler truck depot located in close proximity to the commercial aircraft parking areas and gates. Some reference documents pertinent to this illustration include the following:

- See NFPA 30/Chapter 5 for loading requirements of aircraft fuel servicing tank vehicles.
- See NFPA 415/Annex A/Apron Drainage @ Terminal Building: The apron shall slope away from the Terminal Building with a minimum grade of 1% for the first 50 feet.
- See local roadway engineering design standards for tanker trailer and emergency vehicle response maneuvering (e.g., typical outside turning radius @ 60 feet and curb radii at corners @ 30-40 feet).
- See NFPA 30/Chapter 21 for detection of leakage from underground storage tanks (e.g., maintain accurate inventory records and/or implement a leak detection program).
- Taxilane Object Free Area standards based on FAA Advisory Circular 150/5300-13 for Group III Aircraft (aircraft with wingspans up to but not including 118 feet).

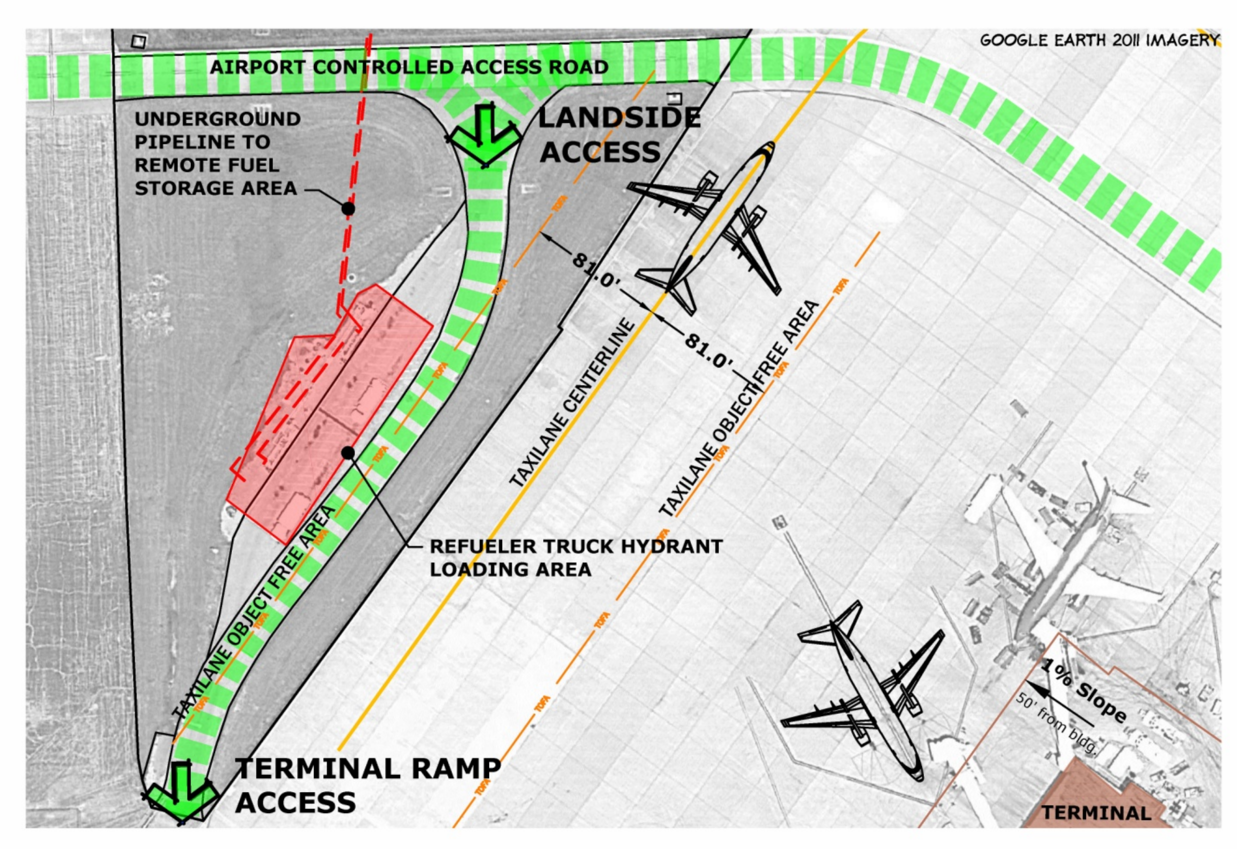

Figure 13: Example of terminal area refueler truck depot at Tulsa International Airport

5.6 Screening analysis and preliminary fuel storage facility site plans

The fifth recommended step in the process is to develop a draft schematic site plan and begin to screen the sites for compliance with applicable FAA design criteria, NFPA codes and standards, and local fire codes associated with fuel storage facilities and methods for distribution. In addition, for each alternative site, the airport should consider and document the following:

- Consistency with existing regional transportation planning documents
- Compliance with existing zoning and comprehensive planning documents
- Cursory compliance review of draft schematic site plan with applicable federal and state regulatory agencies
- Conduct supplemental hazard to flight analysis (e.g., FAA airport design criteria and FAR Part 77 *Objects Affecting Navigable Airspace*)
- Conduct a preliminary environmental review of the draft schematic site plans

It may also be helpful to develop a scoring or ranking system for the alternative sites in an effort to determine a preferred or recommended site.

5.7 Recommended fuel storage facility site plans

The sixth step in the process is to identify and select one or more recommended alternative fuel storage site plans. This step includes the initiation of preliminary design and engineering drawings with cost estimates for proposed development. In this step, it will be important to do the following:

- Identify those portions of the project that may be eligible for federal or state funding participation.
- Confirm FAA grant assurance compliance and legal considerations.
- Prepare FAA Form 7460-1 for airspace analysis.
- Update ALP Drawing Set to reflect selected alternative fuel storage facility site plans.
- Submit updated ALP Drawing Set to FAA for review and approval.
- Implement NEPA process (i.e., review for potential Categorical Exclusion for proposed action, or determine the need for environmental analysis based on potential for extraordinary circumstances). Review project for the potential need to conduct Environmental Assessment (EA) for those proposals involving a change to the ALP or federal funding participation.
- Apply for necessary state and local environmental permits, such as those pertaining to water quality, air quality, and noise.

5.8 Alternative fuel storage facility construction

The seventh recommended step in the process is to implement construction of the alternative fuel storage facility including the finalization of design and engineering drawings with cost estimates for proposed development. Also, if applicable, coordinate the phasing of any support projects that are related to the construction of the alternative fuel storage facility (such as access road, gates, etc.) and obtain local building or construction permits.

5.9 Resource documents for evaluating siting criteria

The following is a summary list of important documents for evaluating siting criteria for alternative fuel distribution programs:

- Applicable regional transportation planning documents
- Applicable zoning and comprehensive planning documents
- FAA/*Aircraft Fuel Storage, Handling, and Dispensing on Airports,* Advisory Circular (AC) 150/5230-4A, 2004
- FAA/*Airport Design,* Advisory Circular (AC) 150/5300-13, Changes 1 – 16
- FAA Airport Sponsor Grant Assurances

- Federal Aviation Regulation (FAR) Part 77/*Objects Affecting Navigable Airspace*

- NFPA 30A/*Code for Motor Fuel Dispensing Facilities and Repair Garages*, 2012 Edition (if applicable)

- NFPA 52/*Vehicular Gaseous Fuel Systems Code*, 2010 Edition (if applicable)

- NFPA 58/*Liquid Petroleum Gas Code*, 2011 Edition (if applicable)

- NFPA 59A/*Standard for Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 2009 Edition (if applicable)

- NFPA 407/*Standard for Aircraft Fuel Servicing*, 2012 Edition

- NFPA 415/*Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways*, 2008 Edition (if applicable)

- Transportation Security Administration/*Recommended Security Guidelines for Airport Planning, Design and Construction*, May 2011

- Code of Federal Regulations (CFR) Title 40 *Protection of Environment*, Part 112 *Oil Pollution Prevention* (This document specifies the federal requirements for above-ground storage tanks used for the store of petroleum products, and includes the requirements for SPCC Plans).

- Applicable Fire Code regulations (i.e., *International Fire Code, Uniform Fire Code, NFPA 1 Fire Code,* or other)

5.10 Planning process flowchart

A flowchart summarizing the planning process for siting alternative fuel storage and distribution facilities at airports is shown in Figure 14:

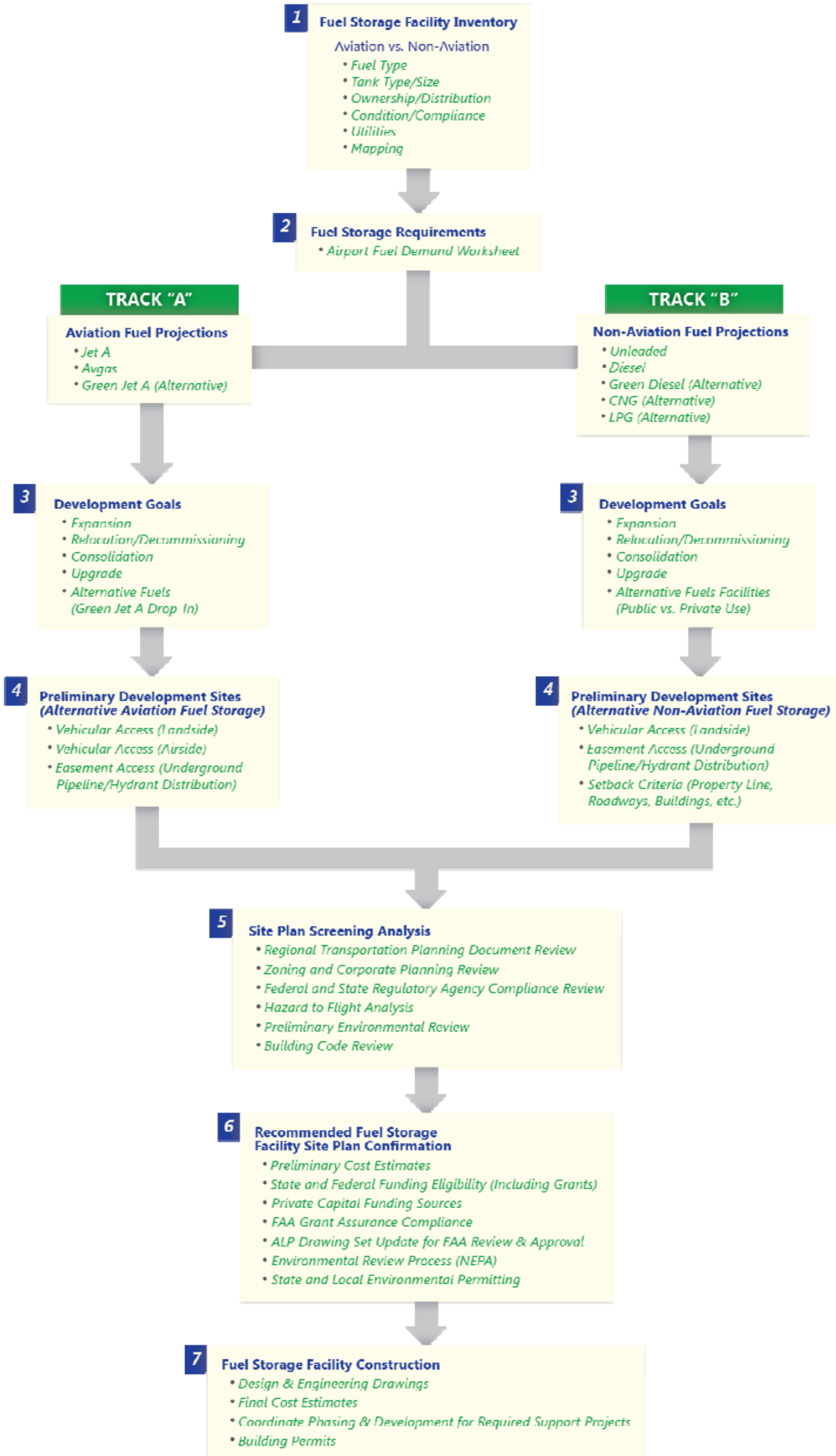

Figure 14: Planning process for siting alternative fuel storage and distribution facilities at airports

6 Summary of Task 6: Interim report and identification of airports for review

This section presents the results of Task 6 "Interim Report and Identification of Airports for Review." This task had four main components: 1) produce an interim report, 2) prepare a detailed outline for the guidebook, 3) prepare a description of the toolkit, and 4) identify airports to pilot test the guidebook and toolkit. These components are discussed below.

6.1 Interim report

The interim report presented the results of Tasks 1 through 6. Sections 1 through 6 of this Contractor Final Report are based on this interim report.

6.2 Detailed outline for the guidebook

Based on the results from Tasks 1 through 6, the following outline was proposed for the guidebook:

- Title
- Purpose of the Guidebook
- How to use this Guidebook
- Table of Contents

1. Introduction
    a. Introduction to alternative fuels
    b. Motivations for using alternative fuels
    c. Airport-specific motivations for using alternative fuels
    d. Airport roles to support alternative fuels
    e. Limitations of the Guidebook
    f. Resources for further information
2. Main characteristics of alternative fuels
    a. Alternative jet fuels
    b. Main co-products of alternative jet fuel production
    c. Alternative jet fuels in development
    d. Other alternative fuels

   e. Potential user groups and their motivations

3. Overview of evaluation framework
   a. General overview
   b. Identification of energy mix at airports
   c. Energy demand forecast
   d. Definition of distribution options
   e. Summary of distribution options
4. Comparative evaluation of distribution options
   a. Potential costs and environmental and economic benefits
   b. Financial and commercial considerations
   c. Legal and regulatory considerations
   d. Stakeholder engagement and community acceptance
5. Siting criteria
   a. Airport fuel storage facilities/distribution system inventory
   b. Fuel storage requirements (existing/future)
   c. Alternative fuel storage and distribution goals
   d. Preliminary alternative fuel storage facility development sites
   e. Screening analysis and preliminary fuel storage facility site plan(s)
   f. Recommended fuel storage facility site plan(s)
   g. Alternative fuel storage facility construction
   h. Resource documents for evaluating siting criteria
6. Frequently asked questions
7. Appendices
8. Bibliography
9. Glossary

10. Acronyms

11. References

6.3 Toolkit description

The toolkit associated with the guidebook was planned to have three main elements, described in the following sections.

6.3.1 Energy use planning and forecasting tool

The main quantitative tool in the toolkit is the "Energy use planning and forecasting tool" developed and explained in Task 3 "Demand for alternative fuels." This tool is based on a spreadsheet and has the following main components, as introduced in Section 3 and explained in more detail in Appendix A:

- **Current energy mix:** this component consists of a matrix that captures the current energy mix at the airport (see Figure 3). It includes a list of major energy users and alternative fuels available to each of them. This matrix is considered the cornerstone of the methodology developed in this guidebook as it identifies the current use of energy at the airport. Default calculations provide quantitative estimates of conventional fuel use by certain users (e.g., conventional jet fuel by airlines), but user input may be required to complete it. Furthermore, even though estimates are provided, users are encouraged to incorporate their own sources of data. The purpose of this matrix is to provide a standardized view of fuel consumption use to allow systematic evaluation and comparison of alternative fuel distribution options.

- **Energy demand forecast:** the structure of this matrix is identical to the "Current energy mix" (see Figure 4). This matrix reflects the projected energy forecast by user and alternative fuel type. As in the case of the current energy mix, the model provides default calculations to estimate the future energy needs for a number of energy consumers; however, the matrix allows input of other estimates that may be available to toolkit users.

- **Definition of distribution options:** this component allows the user to identify and define alternative fuel distribution options. For the purposes of this guidebook, distribution options are defined in terms of three characteristics: 1) energy use type and quantity, 2) storage, and 3) distribution. Energy use type and quantity is determined via the "Energy demand forecast" matrix explained above. Storage and distribution options are identified via matrices similar to those in Figure 7 and Figure 8. Together, these three characteristics summarize the types and quantities of alternative fuels projected to be used, the required storage and distribution facilities, and how those requirements compare to existing infrastructure. The tool allows the user to create several distribution options. These options can then be evaluated with the considerations presented in Section 4.

6.3.2 Worksheets

Worksheets were created to help guidebook users evaluate the alternative fuel distribution options according to the considerations presented in Section 4. These worksheets are simple templates to guide the user through the different evaluation criteria. As in the case of the "Energy use planning and forecasting tool," the objective is to create a standardized format to facilitate the systematic evaluation and comparison of different options. Worksheets were created to cover the following areas:

- Potential environmental and economic benefits
- Financial and commercial considerations
- Legal and regulatory considerations
- Stakeholder engagement and community acceptance
- Siting criteria

6.3.3 References

References to other studies, quantitative models, and guidebooks were provided as another tool available to the users of this guidebook. Given the large number of fuels considered in this project, in addition to the multiple considerations associated with them, it is best to make users aware of the many outside resources that are publicly available. Links to these resources, where appropriate, will be provided as part of the worksheets described above. In particular, the following references will be highlighted:

- Life-cycle analysis of greenhouse gas emissions, such as those presented in (Allen et al. 2009; Hileman et al. 2009; ANL 2011).
- Tax incentives and other legislative and regulatory support available to entities associated with alternative fuel production and use (DOE 2011h).
- Other ACRP reports dealing with alternative fuels, greenhouse gas inventories, and jet fuel consumption.
- Quantitative tools to evaluate specific alternative fuel projects, such as the Clean Cities “Vehicle and Infrastructure Cash-Flow Evaluation (VICE)” Model for CNG fleets (DOE 2011f).

6.4 Airports for consultation

The research team took a two-step approach to engaging with airports. The first step consisted of early consultations with a number of airports to obtain general feedback on key elements for airport management that should be included in the guidebook and associated toolkit. The goal of that step was to ensure that the work was effective, from an early start, in identifying the key decision makers and the information they need to support investments in alternative fuel distribution projects. A copy of the material and questions discussed with these airports is shown in Appendix B.

The second step consisted of more in-depth consultations with a subset of the airports approached in the first step in addition to other airports that may be identified in conjunction with the review panel. The goal of this second round of conversations was to show draft versions of the guidebook and toolkit to the airports and obtain their feedback. In addition, the research team assisted a number of interested airports in starting to apply the concepts and tools developed as part of this research.

The airports for the early consultations were selected with a systematic approach that evaluated candidate airports against the selection criteria in Table 9.

Table 9: Criteria used in the selection of airports for early consultation

Category	Criterion
Business case support	In PM non-attainment area, need for environmental credits
	Strong multi-modal demand for transportation fuels
	Significant demand for other co-products (diesel, electricity)
	Pipeline access
	Supply disruption potential above average
	Land management possibilities which could lend themselves to alternative fuel projects
Internal support	Internal champion track record
	Supportive airport management
	Willingness to share case study outcomes
	Participant in ACRP 02-18 or 02-23 consultations
External support	Support from end-users (e.g., airlines, military)
	Support from other supply chain stakeholders (e.g., feedstock producers, fuel producers)
	Strong governmental support for alternative fuels or aviation fuels
Technical and logistical feasibility	High potential for energy feedstocks on or near airport
	Feedstock readiness
	Maturity of fuel process

The airports in Table 10 were identified using the criteria indicated above and with feedback from the review panel.

Table 10: Airports selected for early consultation

Airport
Atlanta (ATL)
Baton Rouge (BTR)
Charleston (CHS)
Columbus (CMH)
Detroit (DTW)
Dallas-Fort Worth (DFW)
Los Angeles (LAX)
Port Authority of New York and New Jersey (EWR, JFK, LGA)
Portland, OR (PDX)
San Francisco (SFO)
Seattle-Tacoma (SEA)
Tulsa (TUL)
Washington-Dulles (IAD)

Early consultations were held with the following airports: ATL, CHS, CMH, DFW, IAD, LAX, PANYNJ, SEA, SFO, and TUL. Based on these discussions, the following airports were selected for pilot testing the guidebook and toolkit:

- Atlanta (ATL)
- Charleston, SC (CHS)
- Chicago O'Hare (ORD)
- Columbus, OH (CMH)
- San Francisco (SFO)
- Seattle (SEA)
- Tulsa, OK (TUL)

Below is a brief description of the unique circumstances that led to the selection of these airports and the benefits from including them in the feedback process:

6.4.1 Atlanta, GA

Unique circumstances

- Recently adopted a sustainability plan that includes an "Energy Park" on a 39 acre parcel owned by the airport.
- Interest from airport for municipal solid waste (MSW) to energy conversion to help with disposal of airport and city generated waste by diverting from land fill.
- Follow-up on case study outcomes as new phase (in parallel with other alternatives) of parcel usage evaluation as possible result of case study.
- Regional support from Georgia Economic Development formed basis for case study execution. Initial consideration is to identify possible fuel suppliers interested in building a processing facility at the Energy Park. Selection of fuels to be produced for airport/airline use to follow.

Benefits of airport selection

- Airport has practical use for case study.
- Guidebook and Toolkit can be used to identify and establish benefits of alternative fuel options to maximize benefits for varied facility outputs.
- Possibility for real follow-up based upon project interaction with airport.
- High profile template for other airports to follow regarding near or on airport site selection.

6.4.2 Charleston, SC

Unique circumstances

- Strongest military and commercial joint use facility in the country.
- Airport is in high growth region for multi-modal growth (marine, air and rail).
- Airport does not have pipeline supply and is subject to disruptions.
- Support from airport director.

Benefits of airport selection

- Guidebook and Toolkit provides framework for airport to develop rationale to inform own leadership as well as State, local, and regional stakeholders of alternative fuel options to ensure support.
- Inclination to extend multi-modal considerations to others in the community (Charleston Regional Development (CRDA) and Commercial Marine as well as Marine Aviation (Navy) and Air Force (C17 cargo planes)
- Connection to Rural South Carolina is important for the airport and Charleston if they are to receive State support on a broad front.

6.4.3 Chicago O'Hare, IL

Unique circumstances

- Leader in airport sustainability initiatives, including alternative fuels.
- In process of selecting contractor to build a multiple alternative fuel refueling station on airport-owned property
- Strong environmental drivers and committed leadership.
- Strong support through City of Chicago and governor's office.

Benefits of airport selection

- Facilitating the process to evaluate and select alternative fuel distribution projects like the multiple alternative fuel refueling station is a primary objective of ACRP 02-36
- Potential for airport to implement suggestions from Guidebook and Toolkit on current work

6.4.4 Columbus, OH

Unique circumstances

- Ohio has a broad focus for on aviation alternative fuels with strong support from the Columbus-based Ohio State University, Dayton-based Air Force and, GE Aviation in Evendale.
- Airport was in the midst of a broad review of a long term strategic plan to relocate fueling facilities with the goal of enabling diverse fueling operations to be more efficient and possible revenue enhancement features.
- Columbus is the home of NetJets, the nation's leading flyer of business jets.

Benefits of airport selection

- Timing of ACRP 02-36 activities matched well with private consultant activities.
- Case study addressed need on the table in the airport strategic plan.
- Opportunity to couple Columbus demand with that of other users in Ohio, such as Wright Patterson Air Force Base, Air National Guard, and GE Aviation test facilities, to aggregate demand for possible broader State-supported efforts.

6.4.5 San Francisco, CA

Unique circumstances

- Recognized opinion leader airport that is committed to alternative fuel introduction.
- Strong environmental drivers and committed leadership.
- Strong support through City of San Francisco.

Benefits of airport selection

- Examines effectiveness of Guidebook and Toolkit in a setting where strategic plans for alternative fuel have been approved and operational implementation is underway.
- Identifies possible infrastructure needs to introduce alternative fuels to the airport.

6.4.6 Seattle, WA

Unique circumstances

- Recognized opinion leader airport that is committed to alternative fuel introduction and is advanced in talks with suppliers.
- Regional and corporate support for alternative fuels through the Sustainable Aviation Fuels Northwest (SAFN) initiative, Alaska Airlines, and Boeing.
- Strong environmental drivers and committed leadership.
- Strong support through congressional delegations and Governor.

Benefits of airport selection

- Examines effectiveness of Guidebook and Toolkit in a setting where strategic plans for alternative fuel have been approved and operational implementation is underway.

6.4.7 Tulsa, OK

Unique circumstances

- Committed airport leadership investigating ways to introduce alternative fuels to the airport.
- Strong interest in alternative fuels to expand options for revenue generation on airport property.
- Diversified user base including commercial air carriers, general aviation, Air National Guard, and American Airlines' maintenance base.

Benefits of airport selection

- Support business case definition and evaluation for an airport interested in introducing alternative fuels.
- Since airport is not in an area with strong environmental constraints (e.g., it is not in a local air quality non-attainment zone), emphasis of the analysis is on the economic aspects of alternative fuels.

7 Summary of Task 7: Guidebook and Toolkit preparation

The guidebook and toolkit were prepared according to the material presented in the Interim Report and comments and suggestions from the review panel during an interim review meeting. The draft guidebook and toolkit were presented to the panel for review before sharing them with the airports selected for pilot tests.

8 Summary of Tasks 8 and 9: Pilot tests of guidebook and toolkit

The pilot tests were conducted between May and June of 2012. The feedback collection process, main feedback received, and recommendations for improvements of the guidebook and toolkit were summarized in a Working Paper on Airport Pilot Tests. The material in this section is taken from the working paper.

8.1 Airports and individuals that provided feedback

The list of airports and individuals that provided feedback on the Guidebook and Toolkit include:

Table 11: Airports and individuals that provided comments on the Guidebook and Toolkit

Airport	Individual(s)	Venue
Atlanta (ATL)	• Michael Cheyne, Director of Asset Management and Sustainability Planning & Development, City of Atlanta - Department of Aviation	• Multiple face-to-face meetings • Webex on June 25th
Charleston (CHS)	• Sean Tracey, Director of Special Projects, Charleston County Aviation Authority • Merle Johnson, Project Manager, Global Business Development, Charleston Regional Development Alliance • Charles Hoke, Allied Aviation	• Face-to-face meeting on May 3rd • Webex on June 4th
Chicago O'Hare (ORD)	• Amy Malick, Deputy Commissioner, Sustainability, Chicago Department of Aviation • Casey Venzon, Consultant, Ricondo Associates	• Face-to-face meeting on May 16th
Columbus (CMH)	• Paul Kennedy, Manager Energy and Environment, Columbus Regional Airport Authority • Tony Kyer, Columbus Regional Airport Authority • Blair Everett, Gersham Smith and Partners (GSP)	• Face-to-face meeting on April 26th • Webex on May 11th
San Francisco (SFO)	• Roger Hooson	• Face-to-face meeting on June 21st
Seattle (SEA)	• Elizabeth Leavitt , Director Aviation Planning and Environmental Programs • Russ Simonson, Senior	• Face-to-face meeting on May 22nd

Airport	Individual(s)	Venue
	Environmental Program Manager Aviation Environmental Programs • Leslie Stanton, Manager, Strategy & Sustainability Aviation Environmental Programs	
Tulsa (TUL)	• Jeff Mulder, Airports Director, Tulsa Airport Authority • Jeff Hough, Deputy Airports Director, Tulsa Airport Authority	• Face-to-face meeting on May 30th

8.2 Feedback collection

All reviewers received the latest versions of the Draft Guidebook and Toolkit as of May 2nd, 2012. The toolkit consisted of two separate spreadsheets, one focused on the Energy Mix and Forecasting Model ("Energy Mix" toolkit) and the second on the Workbooks for Evaluation of Project Considerations ("Workbooks" toolkit). Furthermore, a questionnaire was prepared for use by the research team when soliciting feedback from the airports (see Appendix B). The team used a semi-structured interviewing approach using the questionnaire as a starting point and letting the airport personnel comment on the elements of most importance to them.

In addition to face-to-face meetings, some airports requested an additional presentation of the Toolkit via webex. This was arranged and valuable feedback was collected from a step-by-step explanation of both spreadsheets.

8.3 Feedback summary

Below is a summary of the main themes in the feedback received from all entities and individual indicated in Table 11:

1) **People like to do … and then read!**
   It was very evident that people had a tendency to start using the Toolkit first and reading the Guidebook second, if at all. We built the Toolkit to be sufficiently self-explanatory and self-contained. For example, we included a User Guide, comment boxes to explain many of the cells in the spreadsheets, and references to applicable sections of the Guidebook. Nevertheless, this approach has limitations, especially if users are not familiar with the characteristics of alternative fuels that are explained in greater detail in the Guidebook. The Toolkit assumes that the user is familiar with this material and it is not practical to put all of this material in the spreadsheets.

2) **Toolkit generally easy to follow**
   Users indicated that the Toolkit had a logical flow and was generally easy to follow. There was some confusion about what to do in some of the tabs, especially in the Workbooks, but

once the relationship between the Guidebook and the Toolkit was explained, users seemed to be more comfortable.

3) **Energy Mix Toolkit helpful to identify "aggregate" demand for fuel at the airport and vicinity**
   Several users indicated that the Energy Mix toolkit is very helpful because it provides a means for airports to aggregate fuel demand from its own operations, its tenants, and other users in the vicinity. They see the ability to create a community-demand profile as important in building a potential business case for alternative fuels.

4) **Alternative fuels and the role of the airport**
   Airports with significant existing use of alternative fuels indicated that a key factor for their success is support from top airport and local political leadership. In addition, they stressed the importance of including all relevant stakeholders in the process and ensuring that their interests are taken into account.

5) **Web-based display of information**
   Several users indicated that a web-based platform to display and update the information in the Guidebook and Toolkit would be helpful to keep both documents current and making it more user-friendly. If this is not possible, having references to outside material that is updated regularly, such as the Alternative Fuels Data Center, provides users with resources to stay current on their own.

9 Summary of Task 10: Finish guidebook, toolkit, and final report

The purpose of Task 10 was to finalize the handbook based on the Working Paper on Airport Pilot Studies and comments from the review panel and to produce a final report documenting the whole research effort. The changes suggested in the Working Paper were incorporated into the Final Draft Guidebook and Toolkit. The Final Draft Handbook was submitted to the review panel on August 31st, 2012. Comments from the panel were received on October, 2012. Final documents were prepared for submission on December 6th, 2012.

10 Conclusion

10.1 Summary of key insights and lessons learned

In the course of this research project, the team has identified the following insights and lessons learned:

1. Early consultation with airports is very valuable for identifying the major themes that airports would find helpful in the guidebook. Some of the themes are common among all airports and not surprising. For example, airports stress that the business case will be a key element when evaluating any alternative fuel distribution program. Other themes are very airport-specific and somewhat surprising. For example, Tulsa airport manages an industrial park next to the airfield that includes a company working on developing alternative jet fuels. Furthermore, early consultations with airports helps to create a working relationship with the airports that will be important for subsequent collaboration, in particular for the review of the draft guidebook and toolkit which will require some additional effort on their part. This process has also allowed the identification of other airport personnel that should be included in the discussions.

2. Airports have unique ways of keeping track of energy use and traffic patterns. Some airports required commercial vehicles to be permitted in order to have access to the airport. This process allows the airport to keep track of the fleet composition, usage, and miles traveled. In some cases, this also allows the airport to create incentive programs to promote the use of alternative fuels. Some airports do passenger surveys on a routine basis that include questions related to how travelers access the airports. On the other hand, other airports do not have access to recent survey results or keep track of vehicle use at their locations.

3. The use of alternative fuels, especially for ground transportation, is not uncommon at U.S. airports. Many of the airports included in early consultation have some sort of alternative fuel programs, some of them very elaborate. Also, awareness regarding the use of alternative jet fuels appears to be on the rise, in particular after recent developments involving commercial flights by Alaska Airlines and United Airlines with alternative fuels.

4. Case studies are a good means of applying the material developed by the project to illustrate how it can be used by practitioners and also to test how users react to it. At the same time, it offers participant airports exposure to the project material and one-on-one tutoring.

11 Appendix A: Energy demand forecasting methodology

The purpose of the energy demand forecasting methodology discussed in Section 3 is to provide a means to help guidebook users in the estimation of potential energy use at airports. Given that there are many types of energy used at airports and that airports are very different from one another, this methodology provides a general approach to estimating energy demand as a first-order approximation. It is not meant to be a detailed and comprehensive tool to obtain detailed and precise estimates of energy demand.

There were three principles used in the development of this methodology:

1) **Concentrate on major energy uses:** the methodology is structured around three major energy-consuming groups: aircraft, vehicles, and buildings. Within these three groups, there are further sub-divisions, as shown in Figure 15.

			Future energy demand	Conventional jet (000 gal)	Alternative jet (000 gal)	AVGAS (000 gal)	Gasoline (000 gal)	E85 (000 gal)	Diesel (000 gal)	Green diesel (000 gal)	Biodiesel B20 (000 gal)	CNG (000 gal)	LPG (000 gal)	Electricity (000 kWh)	Custom 1 (000 gal)	Custom 2 (000 gal)	Custom 3 (000 gal)	Total Mix
Aircraft			* Passenger jet aircraft															
			* Cargo jet aircraft															
			Military jet aircraft															
			GA jet aircraft															
			GA piston aircraft															
Vehicles	Airside		* Passenger GSE															
			Cargo GSE															
			Military GSE															
			Airport Vehicles															
	Groundside	Private Vehicle	* Passenger															
			Employee															
		Passenger Light-Duty (Fleet)	* Rental Cars															
			* Taxis															
			* On-Demand (Limos)															
		Scheduled Bus/Van	* Passenger															
			Employee															
		Courtesy Vans	* Passenger															
			Employee															
		Rail	Passenger															
			Employee															
	Off-airport		Water Shuttle															
			Water Freight															
			Rail Freight															
			Truck Freight															
Buildings / Other			Airport Buildings															
			Military Buildings															
			Other Buildings															
			Systems															
			Concessions															
			Military Other															
			Custom															

Figure 15: Energy mix at airports (reproduced from Section 3)

Furthermore, the choice of energy types was limited to the following:

- For aircraft: conventional and alternative fuel
- For vehicles: gasoline, E85 (ethanol blend with gasoline at 85% ethanol), conventional diesel, green diesel, biodiesel (at a blend ratio of 20% or B20), compressed natural gas (CNG), liquefied petroleum gas (LPG), and electricity.
- For buildings: conventional diesel, green diesel, biodiesel, compressed natural gas (CNG), liquefied petroleum gas (LPG), and electricity.

The selection of these fuels was made based on the main energy types on use at airports today and the expectations for their future use. Other fuels, such as hydrogen, were not included since their current adoption is extremely limited and it does not appear to be significant in the future.

2) **Be quantitative when possible based on publicly-available information:** quantitative estimates of energy demand are provided when there is enough publicly-available information to support the calculations. Because this guidebook is intended as a general guide applicable to any airport, the calculations must be based on data that is detailed enough at the airport level and, at the same time, available to any airport. Consequently, quantitative estimates are provided for the following energy users:

- Aircraft: passenger and freight
- Vehicles:
  - Air-side: passenger ground support equipment (GSE)
  - Ground-side passenger: private vehicle, rental car, taxis, on-demand (limos), scheduled bus/vans, courtesy vans

Quantitative estimates for the other users are difficult to obtain because of the lack of detailed information at the airport level or because the required data is not publicly available. However, it is important to recognize that these users exist and that they should be incorporated into any alternative fuel distribution program because their energy demands can be significant. The purpose of including these users in the methodology framework is precisely to remind the guidebook user that they should be taken into account. Airports may be able to obtain this data through other means (see below).

3) **Airports know best:** the first-order approximation values provided with this methodology are no substitute for first-hand data that airports may have about their own energy use or that of their tenants and customers. Thus, the tool is structured to accept input values provided directly by the airport. Airports are in the best position to understand their current and projected energy use and that expertise should be used whenever possible. In addition,

airports may have access to confidential or proprietary data sources that a tool like this would not.

11.1 Overview of estimation methodology

The forecasting tool provides a rough order-of-magnitude estimate of potential demand for different types of fuel based on basic metrics of airport activity and user input. It is meant to help airports gain a high-level understanding of possible energy needs; it does not provide a detailed analysis of energy demand for each specific location.

The tool makes use of two widely accepted and available forecasts of aviation activity in the United States: the Terminal Area Forecast (TAF) (FAA 2011b) and the Aerospace Forecast (AF) (FAA 2011a). The TAF provides forecast information for enplanements and operations by airport twenty years into the future. The AF forecasts cargo, fuel use, and system capacity twenty years into the future; however, the AF does not break down the data at the airport level. Another key data source for the forecasting methodology is Form 41 data of air carrier activity (BTS 2011).

A high-level diagram showing the main data flows for the calculation of aircraft, GSE, and ground vehicle fuel use is shown in Figure 16.

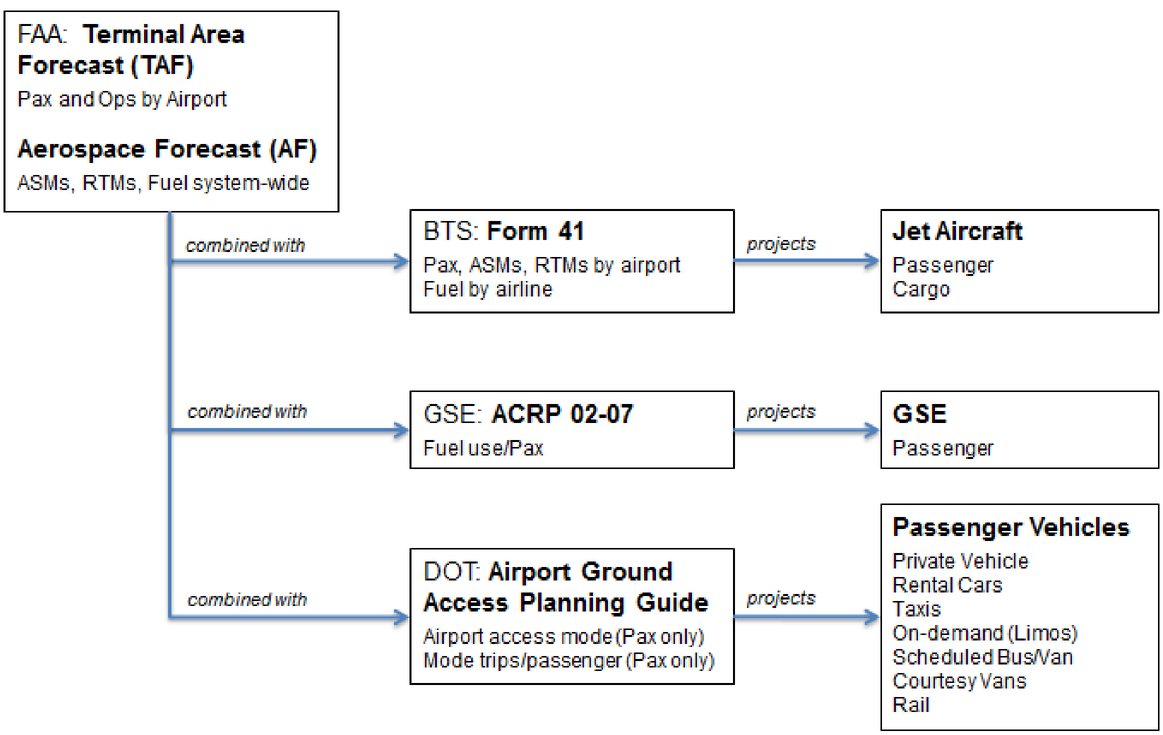

Figure 16: High-level diagram of calculation of fuel use

11.2 Estimating aircraft fuel use

For passenger aircraft, fuel use is estimated based on available seat miles (ASM). An ASM is a basic metric of airline capacity and describes an aircraft seat flown one mile. The information required to calculate ASMs by airport in the U.S. is available from the Bureau of Transport Statistics (BTS) (BTS 2011). To obtain fuel consumption, a simplifying assumption is made that aircraft fuel consumption is roughly proportional to ASM, as shown in equation 1:

$$\text{Aircraft\_fuel}_{\text{Passenger}} = \text{ASM} * \text{Average\_Fuel\_ASM}_{\text{Passenger}} \qquad (1)$$

where $\text{Average\_Fuel\_ASM}_{\text{Passenger}}$ is an average of total gallons of fuel divided by total ASMs flown by U.S. carriers.

For freight aircraft, a very similar approach is taken; however, instead of ASMs, the relevant metric is available ton-mile (ATM). This data is also available by airport from BTS. Fuel consumption for freight aircraft is given by equation 2:

$$\text{Aircraft\_fuel}_{\text{Freight}} = \text{ATM} * \text{Average\_Fuel\_ASM}_{\text{Freight}} \qquad (2)$$

where $\text{Average\_Fuel\_ASM}_{\text{Passenger}}$ is an average of total gallons of fuel divided by total ASMs flown by U.S. carriers.

For future year projections, the following assumptions are made:

1) At any specific airport, the ratio in ASM or ATM growth is identical to the growth in enplanements as indicated in the *Terminal Area Forecast* (TAF) (FAA 2011b). While enplaments and ASMs or ATMS are not always perfectly correlated, the TAF is the only forecast of aeronautical activity at the airport level in the U.S. that is publicly available. The TAF gives projections for enplanements and operations but not for ASMs or ATMs.

2) The $\text{Average\_Fuel\_ASM}_{\text{Passenger}}$ and $\text{Average\_Fuel\_ASM}_{\text{Freight}}$ are assumed constant for all future years at the 2010 value. This is certainly a limitation since changes in fleet fuel efficiency due to technological upgrades and operational improvements will have an effect on this metric; however, the future pace of fleet fuel efficiency is also uncertain and attempting to forecast a value would introduce another source of uncertainty to the model.

11.3 Estimating fuel use for passenger aircraft ground support equipment (GSE)

Estimates of fuel use for passenger aircraft GSE are based on the number of enplanements by airport. A previous ACRP study estimated the amount of diesel used by GSE equipment at 0.3 gallons per enplanement (Morser et al. 2010). Thus, diesel used by GSE equipment for passenger aircraft is calculated with equation 3:

$$\text{Passenger\_GSE}_{\text{Diesel}} = 0.3 \text{ (gallon/enplanement)} * \text{Enplanements} \qquad (3)$$

where Enplanements are obtained from the TAF for both the reference as well as the forecast year.

Estimates of use for other types of energy, including electricity, are calculated based on the value for GSE diesel use as well as fuel “gasoline gallon equivalent” (GGE) factors. GGE factors allow the comparison of fuels with different energy content. In GGE, the basis of comparison is gasoline. GGE factors used in this study are listed below in Table 12:

Table 12: Fuel Gasoline Gallon Equivalent (GGE) conversion factors (Source: DOE 2011j)

Parameter	Value
B20	1.126 GGE/gal B100
CNG @ 3000 psi	0.225 GGE/gal CNG
Diesel	1.147 GGE/gal diesel
E85	0.72 GGE/gal E85
Electricity	0.03 GGE/kWh
Gasoline	1 GGE/gal gasoline
LPG	0.74 GGE/gal LPG

11.4 Estimating fuel use for ground-side passenger vehicles

Fuel use for ground-side passenger vehicles is estimated based on the number of originating passengers at a given airport and assumptions regarding how passengers accessed the airport. The calculation can be described with Equation 4:

$$\text{Passenger\_ground-side}_{\text{Mode, Fuel}} = \text{Orig\_pax}_{\text{Mode}} * \text{Vehicle\_trips}_{\text{Mode}} * \text{Avg\_trip}_{\text{Mode}} / \text{Fuel\_eff}_{\text{Fuel}} \qquad (4)$$

where,

- $\text{Orig\_pax}_{\text{Mode}}$: number of originating passengers by access transportation mode. Calculated from the TAF and BTS statistics and Table 13:

Table 13: Mode of access to airport as a function of airport size (Source: DOT 1996)

Mode split	Annual originating passengers (Million)				Airports with access to rail - walking	Airports with access to rail - shuttle
	<0.5M	0.5-2.5M	2.5-5M	>5M		
Private Vehicle	45%	56%	51%	47%	49%	54%
Rental Car	27%	21%	18%	18%	12%	16%
Taxicab	7%	6%	13%	11%	13%	10%
Other on-demand	11%	4%	9%	13%	10%	7%
Scheduled bus/van	2%	5%	4%	6%	4%	5%
Courtesy vans	5%	6%	3%	3%	4%	3%
Other	3%	2%	2%	2%	5%	3%
Rail					3%	1%
Total	100%	100%	100%	100%	100%	100%

Vehicle_tripsMode: number of vehicle trips per originating passenger by transportation mode. Estimates based on

- Table 13Table 14:

Table 14: Mode trips per one-way passenger trips (Source: DOT 1996)

Mode	Mode trips per one-way passenger trip
Private vehicle	2.03
Rental Car	0.69
Taxicab	1.09
Other on-demand	0.165

Mode	Mode trips per one-way passenger trip
Scheduled bus/van	0.1
Courtesy vans	0.165
Other	
Rail	0

- Avg_trip_{Mode}: average vehicle trip length by mode. Estimates used shown in Table 15:

Table 15: Average vehicle trip length for ground-side passenger vehicles

Mode	Mapped to	Average vehicle trip length (miles)	Source
Private vehicle	Private vehicle	9.7	DOE 2001c
Rental Car	Private vehicle	9.7	DOE 2001c
Taxicab	Private vehicle	9.7	DOE 2001c
Other on-demand	Paratransit bus/shuttle	7.4	APTA 2010
Scheduled bus/van	Transit bus	3.9	APTA 2010
Courtesy vans	Paratransit bus/shuttle	7.4	APTA 2010
Other	N/A	N/A	N/A
Rail	Rail	10.9	APTA 2010

- $Fuel\_eff_{Fuel}$: fuel efficiency by mode and fuel type. Estimates shown in Table 16:

Table 16: Fuel efficiency estimates by mode and fuel type (Sources: ANL 2011 and DOE 2011c)

Mode split	Mapped to	Fuel efficiency (mpg)					
		Gasoline	Diesel	Biodiesel	E85	CNG	LPG
Private vehicle	Private vehicle	22.6	25.0	22.9	16.3	5.1	16.7
Rental Car	Private vehicle	22.6	25.0	22.9	16.3	5.1	16.7
Taxicab	Private vehicle	22.6	25.0	22.9	16.3	5.1	16.7
Other on-demand	Paratransit bus/shuttle	7.0	9.2	8.1	5.0	1.6	5.2
Scheduled bus/van	Transit bus	2.5	3.4	3.0	1.8	0.6	1.9
Courtesy vans	Paratransit bus/shuttle	7.0	9.2	8.1	5.0	1.6	5.2

12 Appendix B: Questionnaire for early consultations with airports

The main output of the ACRP 02 136 project is a Guidebook for *Assessing Opportunities for Alternative Fuel Distribution Programs*. There is also a *Toolkit* consisting of two spreadsheets to help users implement the recommendations in the *Guidebook*. Below are a series of questions to guide the review of these documents; however, the research team would of welcome any other feedback beyond these questions.

1. Format and writing style

- How is the level of information provided in the Guidebook and in the Toolkit (too technical, just right, too general)?
- Is the writing style of the Guidebook and Toolkit easy to follow and understand?
- What aspects of the writing style and format of the Guidebook and Toolkit did you like? What aspects should be improved? If so, how?

2. Content

- Are all relevant topics covered in the Guidebook and Toolkit?
- Are there other topics or information that should be included?
- Is the content structured logically and is it easy to follow?
- Do you have any suggestions for how to ensure that these documents stay current as the field of alternative jet fuels develop?

3. Usefulness

- Would the Guidebook and Toolkit be useful to your airport or to other airports?
- What aspects of these documents did you think were helpful? What aspects of these documents could be improved?
- If you were already considering alternative fuels, would these documents be useful?
- If you were not considering alternative fuel projects, would these documents help in your decision to perhaps do so?
- Would you recommend these documents to your peers, staff, or other airports?

4. General

- Are you considering alternative fuel projects at your airport?
- What can airports do to support alternative fuels?
- What could be your role in supporting alternative fuel projects?
- What other support do you think would be helpful for your airport to consider getting involved in alternative fuel projects?

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