

Assessing Opportunities for Alternative Fuel Distribution Programs

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 83

**Assessing Opportunities
for Alternative Fuel
Distribution Programs**

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AIRPORT COOPERATIVE RESEARCH PROGRAM

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

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

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

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

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

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FOREWORD

By Theresia H. Schatz

Staff Officer

Transportation Research Board

ACRP Report 83: Assessing Opportunities for Alternative Fuel Distribution Programs provides a guidebook and toolkit for airports to introduce and market alternative fuels to their airport community that includes tenants and consumers off airport. Alternative fuels considered include alternative jet fuel, green diesel, biodiesel, ethanol, compressed natural gas (CNG), liquefied petroleum gas (LPG), and electricity. The guidebook identifies a variety of economic, environmental, and policy issues that need to be addressed to help make alternative fuel programs a success. This guidebook includes a step-by-step process to evaluate opportunities and constraints for alternative fuel distribution programs. The toolkit on the accompanying CD-ROM consists of two spreadsheets that help airport decision makers evaluate alternative fuels marketing and distribution programs.

Increasingly, airports and their tenants are examining the potential to introduce alternative fuels, including alternative jet fuel, at their facilities. Airports, however, may lack the information and analytical tools to evaluate the business case for implementing alternative fuel distribution programs. Many projects are under consideration around the country for production of alternative jet fuels. For example, there is an ongoing effort to bring alternative jet fuel production and distribution to the northwest region. The production of alternative jet fuel results in a variety of co-products such as green diesel, which raises an additional desire to find markets for these co-products. Given the concentrated demand for fuel products at or near airports, airports may have the potential to become distribution centers for the co-products of alternative jet fuel production as well as other alternative fuels. Optimizing the potential for alternative fuel use from a broad business view can offer airports a new sustainable business and environmental opportunity, can promote aviation growth, and can create jobs at airports and in the region.

This research was conducted under ACRP Project 02-36 by Metron Aviation in association with ACA Associates; Barnard Dunkelberg Corp. (now part of Mead & Hunt, Inc.); Integration Strategy, Inc.; Ricardo-AEA; PPC; and RCB Altman Associates, LLC. *ACRP Report 83* expands the foundation provided in *ACRP Report 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting* to cover other alternative fuels in addition to alternative jet fuel.

A separate final report, which provides background to the research conducted in support of this guidebook, has been posted on the ACRP Project 02-36 web page at <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3036>.



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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.



Purpose of This Guidebook

Alternative fuels have the potential to provide significant economic and environmental benefits to airports and their communities. These fuels can lead to improvements in local air quality emissions and reductions in life-cycle greenhouse gases. In addition, alternative fuels offer the possibility to diversify away from imported conventional petroleum-derived fuels and enhance energy security. Furthermore, alternative fuel distribution programs offer airports additional business opportunities to generate revenue through the operation of such facilities or leasing of land to third-party operators.

Airports are natural nodes for multi-modal demand and are ideally situated to become distribution centers for a variety of alternative fuels for aircraft and surface transportation. Producers and marketers of alternative fuels can take advantage of this concentrated demand to strengthen their business case as they can cater to a wide spectrum of potential clients, including airlines, airports, and third-party operators such as rental car facilities, courtesy shuttles, taxis, buses, freight trucks, and other fleets that may operate nearby. This is especially the case for facilities that produce alternative jet fuel because, in addition to jet fuel, they also produce co-products such as green diesel, which can be used by some passenger and most cargo vehicles.

This guidebook and associated toolkit provide airport management with planning and evaluation tools for assessing commercial opportunities involving the distribution of alternative fuels. The alternative fuels considered here include alternative jet fuel, green diesel, biodiesel, ethanol, compressed natural gas, liquefied petroleum gas, and electricity. This guidebook identifies economic, environmental, and policy issues that need to be addressed to make alternative fuels a success. It is designed to remain relevant in spite of the anticipated changes in the economics and technology of alternative fuels. Thus, the content is focused on the critical issues that need to be considered to arrive at a comprehensive picture of an airport-based alternative fuel distribution program. While the guidebook is targeted primarily at airport leadership and their staff, it is also helpful to other parties, such as users and producers of alternative fuels. Lastly, this guidebook provides airports with a framework for identifying factors that are unique to their situation and provides toolkits for evaluating business opportunities and metrics to support quantitative assessments of the benefits and costs of becoming involved in an alternative fuel distribution program. The guidebook and toolkit provide information and resources to allow readers to reach their own conclusions about deploying distribution infrastructure according to what is most appropriate to their local circumstances.

This guidebook is a continuation of the work presented in *ACRP Report 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting*. This guidebook expands the foundation laid out in *ACRP Report 60* to cover other alternative fuels in addition to alternative jet fuel.



How to Use This Guidebook

This guidebook and associated materials are intended to be used by a wide audience with varying degrees of familiarity with alternative fuels. Therefore, depending on the reader's level of expertise with alternative fuels, different sections will be more or less relevant.

For readers not familiar with alternative fuels, Sections 1 and 2 are a good starting point. Section 1 presents the motivation for using alternative fuels and the role that airports can play in their deployment. Section 2 discusses the main characteristics of alternative fuels, including environmental characteristics, infrastructure requirements, and user profiles.

Sections 3 through 8 are intended for readers comfortable with alternative fuels. In Section 3, a framework for evaluating alternative fuel distribution programs is introduced. This framework is explained in detail in Sections 4, 5, and 6. In Section 7, four representative case studies that illustrate a number of analyses and questions that can be addressed with this guidebook and associated toolkit are presented. Section 8 briefly discusses suggested next steps; Section 9 answers some frequently asked questions. The printed guidebook ends with some supporting material: a glossary, acronym list, and bibliography.

The toolkit associated with this guidebook consists of two separate spreadsheets that help the reader implement the elements of the evaluation framework introduced in Section 3. The spreadsheets can be found on the accompanying CD-ROM or downloaded from the TRB website (<http://www.trb.org>; search for Toolkit for Alternative Fuel Distribution Programs).

The following appendixes to the guidebook are also on the CD-ROM: the User Guide for the toolkit, a detailed explanation of the forecasting methodology developed here, and more information on environmental characteristics of alternative fuels and environmental permitting guidelines.

Introduction

1.1 What Are Alternative Fuels?

For the purposes of this guidebook, alternative fuels are defined as fuels that can be used to replace today’s petroleum-based fuels—such as Jet A, diesel, and gasoline—and that have the potential for providing environmental, energy security, and supply reliability benefits. Alternative fuels can be produced with a variety of technologies and from a number of different feedstocks, both renewable and non-renewable. Renewable feedstocks include plant oils, animal fats, and biomass (e.g., crop residues, wood chips, and prairie grasses); non-renewable feedstocks include coal and natural gas. Depending on the feedstock and technology process utilized, alternative fuels have different environmental and economic characteristics.

Alternative fuels for use at airports can be divided in two large groups: alternative jet fuels and alternative fuels for surface use. With respect to alternative jet fuels, this guidebook considers the two pathways that have been approved for use on aircraft at the time of writing and three other pathways that are being considered for approval for use on aircraft in the short to medium term:

- Alternative jet fuels (currently approved):
 - Fischer-Tropsch (FT) process
 - Hydroprocessed esters and fatty acids (HEFA)
- Alternative jet fuels (expecting approval):
 - Alcohols to jet (ATJ)
 - Fermentation renewable jet (FRJ)
 - Pyrolysis renewable jet (PRJ)

With respect to alternative fuels for surface use, there are many different types currently available for use on ground transportation or other surface applications, such as power generation. This guidebook concentrates on those alternative fuels that have the most potential for being utilized in the airport setting. This selection was made based on current maturity of the production technology as well as current or expected uses at airports across the United States, as explained further in the guidebook. The selected alternative fuels for surface use include the following:

- Biodiesel blended at 20% with conventional diesel (B20)
- Ethanol blended at 85% with conventional gasoline (E85)
- Compressed natural gas (CNG)
- Liquefied petroleum gas (LPG)
- Electricity

2 Assessing Opportunities for Alternative Fuel Distribution Programs

The U.S. Department of Energy (DOE) also considers liquefied hydrogen as a potential alternative fuel. However, the vehicle technology and refueling infrastructure does not appear to be as advanced as that for the other alternative fuels mentioned. In fact, most hydrogen refueling stations in the United States have been constructed to support demonstration projects (EIA 2011b). Therefore, it is not expected that hydrogen will be adopted for use at airports in the short to medium term and is excluded from this report.

1.2 What Is Driving the Interest in Alternative Fuels?

A diverse group of stakeholders—including airports, airlines, the military, federal and local governments, and end users—wants alternative fuels for a series of economic, operational, and environmental reasons. These reasons include the following:

- **To diversify sources of conventional fuel:** Alternative fuels offer the potential to reduce the dependence on petroleum-derived fuels. This is especially important for the air transportation sector because virtually all of the jet fuel currently used in aviation operations is derived from petroleum. Given current technology, there are no practical options to power aircraft engines other than with liquid fuels. For surface applications, alternative fuels offer the chance to shift away from petroleum-based fuels and create a portfolio of options to meet the demands of the transportation and other energy-intensive sectors.
- **To improve reliability and security of supply:** Alternative fuels can incrementally secure the supply of energy for the economy in general and of liquid fuel to the airline industry in particular. The United States is the largest net importer of petroleum. These import supplies are subject to disruption because of regional or international conflicts. Major users of petroleum-based fuels, such as U.S. airlines and the military, would like to develop domestic alternatives to lessen the dependence on foreign sources. The production of alternative fuels using feedstocks that are available in the United States can help meet that goal. Furthermore, alternative fuel production facilities need not be located in the same places where conventional refineries are located. This alternative location would allow the geographic diversification of production away from sites prone to natural disasters, such as the U.S. Gulf Coast.
- **To reduce the volatility of the price of jet fuel:** Alternative fuels may contribute to reducing the volatility of the price of fuel. By diversifying the supply of fuel and making fuel less dependent on unstable foreign sources and more immune from the vagaries of financial flows in the futures markets, alternative fuels may lead to less variability in the price of fuel. Furthermore, as the alternative jet fuel industry develops, airlines may have the ability to enter into long-term supply contracts with potential producers that would specify a certain price or price band over time.
- **To provide regional economic benefits:** Alternative fuels have the potential to generate new jobs and spur economic activity, especially in rural areas where feedstocks can be grown. In addition, the growth of a domestic alternative fuels industry would help reduce U.S. imports of foreign crude oil and, thus, those resources that would otherwise be spent abroad could be re-invested domestically. Alternative fuels can also mitigate the economic impact of carbon taxes or other charges under consideration for conventional fuel.
- **To provide potential environmental benefits:** All users of petroleum-based fuels generate carbon dioxide (CO₂), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM) emissions. The use of alternative fuels can potentially help to reduce emissions of these

pollutants, providing environmental benefits to the airports, their surrounding communities, and the airlines they serve.

1.3 Why Are Airports Interested in Alternative Fuels?

Airports can specifically benefit from alternative fuels for the following reasons:

- **Incremental business opportunities:** Alternative fuel distribution facilities offer airports another means of diversifying and augmenting business opportunities. Airports can benefit by, for example, leasing land to third parties to develop and manage alternative fuel refueling stations.
- **Improvements to local air quality:** As mentioned in Section 1.2, alternative fuels have the potential to reduce emissions of local air quality pollutants. This is of particular interest to airports that operate in air quality “non-attainment” areas, which means that they are operating or trying to build something in an area where air quality does not conform to federal or state standards of acceptability with respect to various pollutants.
- **Good citizenship:** Airports are vital members of the communities they serve and are important players in local economies. Airports are already environmentally conscious by, for example, introducing electric-powered vehicles, building more energy-efficient buildings, and modernizing firefighting training facilities. The introduction of alternative fuels offers airports an opportunity to expand their economic and environmental activities and other efforts to create a positive impact.
- **Serving of their airlines’ needs:** Airports may have an opportunity to play an enabling role for sourcing and distributing alternative fuels, in particular, alternative jet fuels to interested airlines. For example, the International Air Transport Association (IATA) has set a target of carbon-neutral growth starting in 2020 and a reduction in CO₂ emissions of 50% by 2050 relative to a 2005 baseline (IATA 2009a, 2009b). The availability of alternative fuels will be fundamental for the industry to achieve these targets. Furthermore, the availability of alternative jet fuel at an airport may attract additional air service from parts of the world that are particularly sensitive to environmental issues. This may lead to incremental business for the airports and contribute to regional economic development.

1.4 What Roles Do Airports Already Play in Fuel Distribution?

Airports are currently involved in the distribution and sourcing of conventional fuel. In the case of jet fuel, airports ensure that safety and regulatory requirements of fuel handling and storage are met but are not typically involved with commercial aspects of jet fuel sourcing. The supply of jet fuel at airports is typically the responsibility of airlines that enter into contracts with oil companies, third-party suppliers, or fixed-based operators (FBOs). Furthermore, the jet fuel infrastructure at airports is typically managed and maintained by third-party vendors on behalf of the airports or the airlines. Thus, the sourcing and handling of jet fuel is not usually part of an airport’s core business.

With respect to alternative fuels for surface use, there are many different ways in which airports are involved. In some cases, just as with jet fuel, third parties manage refueling stations and the fuel distribution facilities. In other cases, the airports themselves have facilities and staff with direct responsibility for sourcing and managing some or all of the fuel.

4 Assessing Opportunities for Alternative Fuel Distribution Programs

1.5 What Roles Can Airports Play in Alternative Fuel Programs?

There are many opportunities for airports to get involved and be supportive of alternative fuel distribution programs—even for cases in which airports are not expected to be the main program developer. For example, airports can:

- Bring together local stakeholders, such as airlines, local fleet owners, fuel producers, feedstock providers, and government entities;
- Conduct studies to identify the feasibility of introducing alternative fuels;
- Help stakeholders understand program risks and develop business cases;
- Include alternative fuels as part of the airport's sustainability plan;
- Provide direct support such as the use of airport property for construction of storage and other infrastructure that may be required; and
- Support program funding through the use of bonding capability and assistance with federal or state funding programs.

The roles that a specific airport adopts will depend greatly on its specific conditions and governing structure. In general, an airport may consider adopting those roles that support new business development, enhance existing business, foster good citizenship, and support sustainability efforts.

1.6 Limitations of This Guidebook

The field of alternative fuels, especially alternative jet fuel, is advancing very rapidly. The information contained in this guidebook about the technologies and feedstocks to produce alternative fuels reflects the best knowledge as of the date of writing and are expected to be relevant in the short term. New technologies and feedstocks are expected to become available in the medium to long term; however, given the large uncertainties surrounding these developments, it is not practical to attempt to summarize them in this guidebook.

In addition, many of the factors addressed in this guidebook are complex and their interrelationships are also complex. The tools and approach set forth in this guidebook can provide only a basic framework for conducting a preliminary assessment of the viability of introducing alternative fuel programs at an airport. For example, this guidebook cannot be used to determine definitively the greenhouse gas life-cycle emissions or the relative water impacts of any particular fuel produced at any particular facility. This guidebook also cannot be used to determine how potentially competing costs and benefits should be weighed. Ultimately, the critical evaluation of the environmental, economic, social, and institutional impacts of any given program will be complex and likely require the assistance of experts.

1.7 Resources for Further Information

The latest information about the development of alternative jet fuels and alternative fuel for ground use can be obtained from a number of resources, including the following:

- Alternative Fuels Data Center (<http://www.afdc.energy.gov/afdc/>), a comprehensive clearinghouse of information related to advanced transportation technologies provided by the DOE.

- The *Sustainable Airport Manual* (<http://www.airportgoinggreen.org/SAM>) published by the City of Chicago offers insights into best practices and strategies for encouraging alternative fuels in the airport setting.
- Clean Cities (<http://www1.eere.energy.gov/cleancities/index.html>), the DOE's flagship alternative transportation deployment initiative.
- Airport Cooperative Research Program (<http://www.trb.org/ACRP/ACRP.aspx>), which supports a portfolio of programs on alternative fuels.
- 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, www.airlines.org), the leading trade association for U.S. airlines.
- The International Air Transport Association (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 (www.safug.org), a coalition of airlines, manufacturers, and other organizations involved with alternative jet fuel.
- The Midwest Aviation Sustainable Biofuels Initiative (www.masbi.org) and Sustainable Aviation Fuels Northwest (www.safn.com), two examples of multi-stakeholder initiatives focused on introducing alternative fuels in specific geographic regions.



SECTION 2

What Are the Main Characteristics of Alternative Fuels?

This section discusses the main characteristics of the alternative fuels considered in this study:

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

Each characteristic is covered to some extent within Sections 2.1 through 2.4. Potential user groups and an overview of the current status of fueling infrastructure for alternative fuels in the United States are discussed in more detail in Sections 2.5 and 2.6, respectively.

2.1 Alternative Jet Fuels

The emphasis of Section 2.1 is on the two pathways for alternative jet fuel that have been approved for use on aircraft at the time of writing, namely FT and HEFA. A significant portion of this information is taken from a previous study, documented in *ACRP Report 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting* (Miller et al. 2011). Readers interested in in-depth information regarding alternative jet fuels are encouraged to consult this report.

Alternative jet fuels include those fuels from non-petroleum sources that are approved for use on aircraft. These fuels meet the specifications established by standard-setting organizations such as ASTM International (ASTM) and the United Kingdom's Defense Ministry (DEFSTAN). The certification requirements for these fuels are specified in ASTM D7566, Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons (ASTM 2011); guidance is also provided by the Federal Aviation Administration (FAA 2010a). Once the fuel is certified, it is considered to meet ASTM D1655, Standard Specification for Aviation Turbine Fuels (ASTM 2010), which is the specification that applies to conventional jet fuel made from crude oil.

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. Currently, there are only two processes for producing alternative jet fuels that have been certified by ASTM: FT and HEFA (described in Sections 2.1.1 and 2.1.2). 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 discussed in Section 2.2.

Are alternative jet fuels compatible with existing fuel delivery infrastructure?

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 (ASTM 2010), it can be distributed, handled, stored, and used without modifications to existing infrastructure or equipment.

What are the blending requirements for alternative jet fuels?

The ASTM D7566 specification requires that alternative jet fuels produced through the FT or HEFA process 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 available for blending prior to certification.

Some of the new processes for producing alternative jet fuel under investigation have the potential to meet the ASTM specification without the need of being blended with conventional jet fuel. Once these fuels are certified for use on aircraft, the blending requirement will not apply to them.

2.1.1 Fischer-Tropsch Process

The 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 and 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 developing technologies may use a variation of the FT process that holds the promise of cost effectiveness on a much smaller scale. These more modest capital costs are essential to jet fuel production facilities being able to use municipal waste such as is been proposed for a number of alternative jet fuel programs that are in the planning stage in Australia, the United States, 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 2009b).

What is the status of the technology behind the FT process?

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.

What new infrastructure and equipment will be required to store and distribute alternative jet fuels manufactured by the FT process?

No changes to existing (1) storage and distribution infrastructure at the airport or (2) equipment, including aircraft and engines, are required, because, once blended, the fuel is drop-in.

What are the potential environmental considerations of utilizing the FT process to manufacture alternative jet fuels?

FT fuels are chemically very similar to their petroleum equivalents; however, the low sulfur contents are likely to result in lower secondary PM emissions as well as sulfur emissions (e.g., SO_x). NO_x emissions are more dependent on the temperature at which the fuel is burned and not the fuel formulation itself; therefore, they 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).

FT's water impact is driven primarily by the feedstock. Although cooling in FT uses more water relative to traditional oil and gas refining, this water is largely recaptured, which reduces net impact. Therefore, the relative water impact is driven by the feedstock. Conventional natural gas feedstock uses less water than any other transportation fuel (DOE 2006). However, the potential water consumption and pollution impact of natural gas extracted by relatively recently commercialized hydraulic fracturing of shale is the subject of debate and uncertain. Agricultural feedstocks are much more water consumptive than hydrocarbon-based feedstocks. Therefore, producers of FT alternative feedstocks that use water directly or indirectly (e.g., in the form of agricultural waste) will have a higher impact on the water cycle than producers of hydrocarbon-based FT feedstocks.

Under what conditions is the FT process cost competitive?

FT is competitive when the price of the feedstock, relative to the energy content, is significantly less than that of a barrel of oil. Price anomalies occur where feedstocks have limited uses or its supply exceeds its demand. Municipal solid waste is a feedstock that has limited alternative uses, and, in the United States, the supply of natural gas 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 that covers volume and price
- High demand for co-products, such as green diesel or green naphtha
- Availability of low-cost financing
- Governmental tax credits available for fuel produced from the proposed feedstock

What challenges are associated with utilizing the FT process to manufacture alternative jet fuels?

Some challenges associated with FT include the following:

- 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).
- Water impact is heavily dependent on the feedstock (see the discussion on the water-energy-food nexus in Section 5.5.3.2).

Who are the potential users of FT alternative jet fuels and co-products?

Because the FT process produces a range of products (e.g., green diesel, jet fuel, naphtha), the potential users are diverse:

- Commercial airlines, military aircraft, and general aviation will use alternative jet fuel.
- Surface transportation will use green diesel (i.e., diesel produced from feedstocks other than conventional petroleum; see Section 2.4.1 for more information), for example, taxis, cargo trucks, buses, and rail.
- Airport ground support equipment will use green diesel.
- Airport facilities or rail/light rail mass transportation will use excess heat and electricity generated by the FT process.

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

2.1.2 Hydroprocessed Esters and Fatty Acids Process

The HEFA process converts fatty acids that originate from either plants or animals into a combination of jet fuel, 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). ASTM certified HEFA-produced jet fuels in July 2011 (ASTM 2011).

While there are only a limited number of HEFA refineries producing jet fuel at the time of writing this guidebook, there are commercial-scale refineries that employ substantially similar technology to produce green diesel. Commercial-scale HEFA refineries are expected to produce approximately 80 million to 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 such 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% to 70% diesel, 15% to 45% jet fuel, and the remainder naphtha, LPG, and other by-products (Pearlson 2011). By-products of the HEFA process can be used to produce renewable de-icing fluid, which would provide another potential revenue stream to a HEFA production facility.

What is the status of the technology behind the HEFA process?

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.

What new infrastructure and equipment will be required to store and distribute alternative jet fuels manufactured by the HEFA process?

No changes to existing (1) storage and distribution infrastructure at the airport or (2) equipment, including aircraft and engines, are required since, once blended, the fuel is drop-in. Blending can be done both at the point of manufacture, if there is a suitable supply of conventional fuel available, or, more commonly, at the point of sale. This blending is normally accomplished by mixing the contents of two separate tanks into one common tank.

Generally, conventional gasoline stations in the United States have two or three tanks used for the delivery of fuel—one for regular gasoline, one for premium, and sometimes one for mid-grade. It is more common for modern refueling stations to have only two tanks and to use a blend of those two tanks to create mid-grade gasoline. The additional cost associated with blending HEFA fuels and others is primarily associated with the cost of cleaning and converting an existing tank to make it suitable for alternative fuels, or the cost of buying a new tank to use as the blending tank. New tanks, including installation, are priced at \$35,000 for a 2,000-gallon tank, and about \$70,000 for a 10,000-gallon tank. The cost to clean and convert an existing tank is significantly less (Lemas 2012).

What are the potential environmental considerations of utilizing the HEFA process to manufacture alternative jet fuels?

As with FT fuels, the combustion of HEFA fuels is expected to produce lower sulfur and PM emissions, with similar NO_x 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.

The computation of a crop-based feedstock's water impact is highly complex and varies widely depending on what, where, and how it is grown. Nevertheless, this computation must be done because the impact may be substantial, particularly due to the increasing visibility of the water-energy-food nexus. HEFA's water impact is driven primarily by the need for water to grow the feedstock rather than the HEFA process itself. In general, first-generation feedstocks, particularly when irrigated, consume substantially more water per British thermal unit (BTU) of energy content than traditional hydrocarbon-based fuels (DOE 2006). Some second- and third-generation feedstocks may consume less water. However their impact on local water resources where they are grown must be evaluated, especially if they are in arid or water-stressed environments and/or if they draw upon water systems that are used to grow food elsewhere. The pollution impact of pesticides, biocides, and fertilizers along with runoff resulting from agricultural practices must also be evaluated.

Under what conditions is the HEFA process cost competitive?

The HEFA process is cost competitive when there is:

- 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; and
- Substantial demand for co-products.

What challenges are associated with utilizing the HEFA process to manufacture alternative jet fuels?

Some challenges associated with this technology include the following:

- HEFA refineries that use 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 the discussion on food versus fuel in Section 5.5.3.1).
- The impact of crop-based feedstock on water availability and pollution may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).

Who are the potential users of HEFA alternative jet fuels and co-products?

The HEFA process produces a range of products; therefore, 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 trucks, buses, and rail.
- Airport ground support equipment will use green diesel.
- Airport facilities or rail/light rail mass transportation will use excess heat and electricity generated by the HEFA process.

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

2.2 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. (Because the field of alternative jet fuel is very dynamic, some of the terms used to describe processes such as “alcohols to jet,” “fermentation renewable jet,” and “pyrolysis renewable jet” may change over time.)

2.2.1 Alcohols to Jet

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.

What is the status of ATJ technology?

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

What additional storage or distribution infrastructure is required for ATJ fuels?

No changes to existing (1) storage and distribution infrastructure at the airport or (2) equipment, including aircraft and engines, are required, because the certified fuel will be drop-in.

What are the potential environmental considerations of utilizing ATJ fuels?

It is 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, NO_x 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 feedstock 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 composed of agricultural waste, it is expected to have a relatively low life-cycle GHG footprint.

Potential water impact is substantial, and the increasing visibility of the water-energy-food nexus makes it critical to evaluate. To the extent that most current ATJ technologies under development utilize crops as the source of the alcohol feedstock, ATJ's water impact is driven primarily by the need for water to grow the feedstock. In general, first-generation feedstocks, particularly when irrigated, consume substantially more water per BTU of energy content than traditional hydrocarbon-based fuels (DOE 2006). Some second- and third-generation feedstocks may consume less water. However, their impact on local water resources where they are grown must be evaluated, especially if they are in arid or water-stressed environments and/or if they draw upon water systems that are used to grow food elsewhere. Pollution impact of pesticides, biocides, and fertilizers along with runoff resulting from agricultural practices must also be evaluated. Computation of a crop-based feedstock's water impact is highly complex and varies widely depending on what, where, and how it is grown. Some contemplated ATJ technologies may bypass the need for crop-derived alcohols, which could potentially reduce water impact.

Under what conditions are ATJ fuels cost competitive?

The ATJ process is cost competitive when there is:

- Inexpensive feedstock,
- Minimal feedstock transportation costs, or
- Adequate demand for co-products.

What are some challenges associated with ATJ fuels?

Some challenges associated with this technology include the following:

- The technology is young.
- Some feedstocks may compete with food.

- The impact of crop-based ATJ feedstocks on water availability and pollution may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).

Who are the potential users of ATJ fuels?

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.

2.2.2 Fermentation Renewable Jet

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. Certification efforts are under way but there is no firm target certification date as of the writing of this report.

What is the status of FRJ technology?

FRJ is young and unproven at commercial scale.

What additional storage and delivery infrastructure is necessary to support FRJ fuels?

No changes to existing (1) storage and distribution infrastructure at the airport or (2) equipment, including aircraft and engines, are required, because the certified fuel will be drop-in.

What are potential environmental considerations associated with FRJ fuels?

The environmental considerations for FRJ fuels are the same as ATJ for local air quality and GHGs (see Section 2.2.1). As for water impact, this can be substantial, and the increasing visibility of the water-energy-food nexus makes it critical to evaluate. To the extent that most current FTJ technologies under development utilize crops as the source of the sugar feedstock, FTJ's water impact is driven primarily by the need for water to grow the feedstock. In general, first-generation feedstocks, particularly when irrigated, consume substantially more water per BTU of energy content than traditional hydrocarbon-based fuels (DOE 2006). Some second- and third-generation feedstocks may consume less water. However, their impact on local water resources where they are grown must be evaluated, especially if they are in arid or water-stressed environments and/or if they draw upon water systems that are used to grow food elsewhere. Pollution impact of pesticides, biocides, and fertilizers along with runoff resulting from agricultural practices must also be evaluated. Computation of a crop-based feedstock's water impact is highly complex and varies widely depending on what, where, and how it is grown.

Under what conditions are FRJ fuels cost competitive?

The FRJ process is cost competitive when there is:

- Inexpensive feedstock,
- Minimal feedstock transportation costs, or
- Adequate demand for co-products.

What are some challenges associated with utilizing FRJ fuels?

Some challenges associated with this technology include the following:

- The technology is young.
- Some feedstocks compete with food.
- The impact of crop-based FRJ feedstocks on water availability and pollution may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).

Who are the potential users of FRJ fuels?

The potential user groups are those for aviation alternative 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.

2.2.3 Pyrolysis Renewable Jet

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. Certification efforts are under way but there is no firm target certification date as of the writing of this report.

What is the status of PRJ technology?

PRJ technology is young and unproven at commercial scale.

What additional storage and delivery infrastructure is required to support PRJ fuels?

No changes to existing (1) storage and distribution infrastructure at the airport or (2) equipment, including aircraft and engines, are required, because the certified fuel will be drop-in.

What are the potential environmental considerations of PRJ fuels?

The environmental considerations for PRJ fuels are the same as ATJ for local air quality and GHGs (see Section 2.2.1). As for water impact, this can be substantial and the increasing visibility of the water-energy-food nexus makes it critical to evaluate. PRJ's water impact is largely driven by underlying sewage sludge feedstock. Similar to FT, PRJ requires incrementally more water than traditional oil or gas for cooling/BTU; however, this water is largely recaptured, which reduces net water impact. Computation of the feedstock's water impact is highly complex and varies widely depending on assumptions about its composition.

Under what conditions is PRJ cost competitive with conventional fuels?

The PRJ process is cost competitive when there is:

- Inexpensive feedstock, as feedstock is likely to account for a significant portion of the cost of the alternative fuel;

- Minimal feedstock transportation costs; or
- Adequate demand for co-products.

What are some potential challenges of utilizing PRJ fuels?

Some challenges associated with this technology include the following:

- The technology is young.
- The impact of PRJ feedstocks on water availability and pollution may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).

Who are the potential users of PRJ fuels?

The potential user groups are those for aviation alternative 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 Aviation Gasoline

Aviation gasoline (avgas) is used on piston aircraft for general aviation (GA). It is one of the few remaining leaded fuels in the United States. The FAA is currently looking at options for making unleaded aviation gasoline available to the GA fleet by 2018; however, there is currently no drop-in alternative fuel available and the agency is investigating its options (FAA 2012). For the purposes of this guidebook, conventional avgas is included because it constitutes a significant part of the energy mix at many airports, in particular small airports with large GA operations; however, since “alternative avgas” is not currently commercially available, only conventional avgas is considered throughout the guidebook and toolkit.

2.4 Alternative Fuels for Surface Applications

In contrast to alternative jet fuels, some alternative fuels for surface transportation have been commercially available in the United States 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 the most commonly available for current and future use at airports in the United States.

2.4.1 Green Diesel

The term “green diesel” is used here to describe diesel fuels produced from feedstocks other than conventional petroleum, for example, through an FT or HEFA process, 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.

It is important to make a distinction between green diesel as a co-product from an FT or HEFA process and “biodiesel.” See Section 2.4.2 for a discussion of the latter.

What is the status of technology for green diesel?

Green diesel production through the FT and HEFA processes are understood but enjoy limited commercial availability. This will change as additional refineries come on-line.

What are the additional infrastructure requirements for the delivery and storage of green diesel?

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.

What are the potential environmental considerations associated with green diesel?

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 PM emissions as well as lower sulfur emissions. In contrast, the levels of carbonaceous PM are unlikely to be substantially different. Emissions of NO_x are more dependent on the temperature at which the fuel is burned and not the fuel formulation, so NO_x 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.

Potential water impact is substantial and the increasing visibility of the water-energy-food nexus makes it critical to evaluate. Green diesel’s water impact is driven primarily by the need for water to grow the feedstock rather than the manufacturing process. In general, first-generation feedstocks, particularly when irrigated, consume substantially more water per BTU of energy content than traditional hydrocarbon-based fuels (DOE 2006). Some second- and third-generation feedstocks may consume less water. However, their impact on local water resources where they are grown must be evaluated, especially if they are in arid or water-stressed environments and/or if they draw upon water systems that are used to grow food elsewhere. The pollution impact of pesticides, biocides, and fertilizers along with runoff resulting from agricultural practices must also be evaluated. Computation of the crop-based feedstock’s water impact is highly complex and varies widely depending on what, where, and how it is grown.

Under what conditions is green diesel cost competitive?

Green diesel is cost competitive under these conditions:

- Green diesel is fully interchangeable with conventional diesel and can be typically cost competitive when the cost of crude petroleum oil is high.
- Some jurisdictions mandate the use of alternative diesel, but few require green diesel because of its limited availability. Mandates affect the cost equation.
- Federal regulations and incentives have affected the economics of both green and biodiesel. However, these regulations and incentives are subject to legislative changes.
- 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.

What potential challenges are associated with green diesel?

Some challenges associated with this technology include the following:

- 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.
- The impact of crop-based green diesel feedstocks on water availability and pollution may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).

Who are the potential users of green diesel?

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

- Airport authorities and their tenants operating airside and groundside equipment.
- Taxi drivers, cargo truck operators, and 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 alternative fuel is provided in Section 2.5.

2.4.2 Biodiesel

The term “biodiesel” refers to fuels produced through esterification. Biodiesel is generally made from vegetable oils such as palm, soy, rape seed, and used cooking oil; technically, pure vegetable oils (PVO) and lightly processed fatty acid methyl esters (FAME) are also biodiesels. Vehicle and engine manufacturers for road transport and GSE 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, the focus is on biodiesel as a 20% mix with conventional diesel (i.e., B20). Other blend ratios are possible, but B20 is the most common blend in the United States (DOE 2011d).

What is the status of biodiesel technology?

Biodiesel technology is relatively mature. There are many production routes ranging from very small-scale production using a mechanism known as phase separation to large-scale production using distillation. However, while the technology is sound, biodiesel will solidify at low temperatures and has other properties that are not as suitable for existing applications as are the properties of petroleum-based diesel. This is the reason why biodiesel is generally sold as B20.

What new infrastructure is required to support biodiesel storage and delivery?

In terms of pipelines and storage infrastructure, there is little that needs to be changed at the airport setting to support B20; however, FAME is considered a pollutant in jet fuel, so care must be taken with storage and handling infrastructure so that jet fuel does not come into contact with FAME. While B20 is an acceptable direct substitute to conventional diesel in many applications,

pure biodiesel (B100) or high-concentration biodiesel blends are not for several reasons. Pure biodiesel is an attractant of water, meaning that when held in tanks for long periods of time, water will collect at the bottom of tanks and cause corrosion, fuel filter clogging, and possible engine failure (CDM Federal Programs Corporation et al. 2012). Additionally, biodiesel stored over time can react with oxygen and gel. Biodiesel tends to gel at temperatures higher than conventional diesel, so its use in cold climates is not recommended. Adding storage-enhancing additives or using a dry, semi-sealed, cool container can mitigate some of the storage issues associated with biodiesel.

There are restrictions on the types of diesel engines that can use biodiesel, and at what blend strength. B20 is currently the most popular blend because many existing diesel engines can use it with minor or no modifications, but concentrations higher than that have potential to degrade the rubber and other internal engine components. This characteristic impacts GSE, buses, trucks, and other vehicles common in the airport setting. There are over 600 biodiesel refueling stations in the United States (DOE 2011c).

What are the potential environmental considerations of biodiesel?

Changes in PM and NO_x emissions depend on blend strength and vehicle technology, particularly fuel delivery systems and combustion chamber design. A 2002 U.S. Environmental Protection Agency (EPA) summary suggests that using B20 may increase NO_x emissions by around 2% (EPA 2002). A more recent study (AEA 2008) suggests that using B15 leads to changes in NO_x emissions of +1% for heavy-duty vehicles, and no change for passenger cars.

Biodiesel is affected by the water-energy-food nexus, though not in the same context as green diesel. While the pertinent component of the nexus for green diesel is water and water utilization in evaluating the suitability of that fuel, food serves as the pertinent component of the nexus with respect to biodiesel. The spectrum of feedstock that can be used to create biodiesel includes culinary oils such as vegetable oil and sunflower oil. Competition for the use of these oils between the food and energy industries would likely result in higher prices for the feedstock and thus higher prices for resultant products in both industries, an unappealing outcome. Therefore, significant research to focus on feedstocks that are not heavily used in other industries, such as *Jatropha* and *Camelina*, would assist in mitigating this issue.

Under what conditions is biodiesel cost competitive?

B20 is typically cost competitive with conventional diesel (DOE 2011c). Historically, government incentives have helped to support the price competitiveness of biodiesel. As of January 2012, a gallon of B20 cost \$3.95 compared to \$3.86 for conventional diesel. When normalizing for energy content, a gallon of B20 costs \$4.02 (DOE 2012b).

What are some challenges associated with biodiesel?

Some challenges associated with this fuel include the following:

- Biodiesel 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. Microbes growing in the fuel can block fuel filters or injectors.

- Diesel engine warranties often restrict the concentration of biodiesel permitted in the fuel.
- There is the potential problem of fuel deteriorating, or even polymerizing, in the tanks of vehicles or equipment left standing, e.g., standby generators.
- The impact of crop-based biodiesel feedstocks on water availability and pollution may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).
- Biodiesel produced by first-generation feedstocks are at the core of the world's food-versus-fuel debate.

Who are the potential users of biodiesel?

Potential users of biodiesel include the following:

- Road transport—Biodiesel can be blended with petroleum diesel (up to 7% in Europe; based on ASTM D975 (ASTM 2008), up to 5% in the United States), or used in higher proportions in dedicated fleets without engine modifications.
- Rail—Biodiesel is not generally used in the United States; however, a study in the UK indicates a blend of up to 20% (i.e., B20) can be used (RSSB 2006).
- Water transportation—Biodiesel is not used for main engines but 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 fuel is discussed in Section 2.5.

2.4.3 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 typically blended at 10% with gasoline in all of the United States. This guidebook focuses on mixtures with 85% ethanol (i.e., E85), which is considered an alternative fuel by the EPA (DOE 2011e). Flex-fuel vehicles (FFVs) can use both gasoline and E85 for propulsion. FFVs are widely available—there were over 8 million of them on U.S. roads as of August 2010 (DOE 2011c).

What is the status of ethanol technology?

Commercial-scale production of ethanol has been available for decades; ethanol has been added in low concentrations to gasoline for about the same time. Ethanol has been blended with conventional gasoline, currently limited to 10% (E10) in the United States, for around the last 30 years. However, in November 2010 the EPA announced it would allow up to 15% ethanol blend (E15) 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 United States, with one source suggesting E85 is available from approximately 2,650 stations in the United States in

January 2011 (though this is still a small fraction of the approximately 140,000 publicly accessible gasoline stations in the United States). Price and availability of E85 are available from e85prices.com.

What additional infrastructure is required for the storage and delivery of ethanol?

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 E85 used in FFVs, require modifications to a vehicle's fuel distribution system and dedicated storage tanks. E85 tends to freeze at a higher temperature than does conventional gasoline or lower concentration ethanol blends (CDM Federal Programs Corporation et al. 2012). As a result, cold weather climates may find that they have to switch to a lower ethanol blend or use additives during the winter months in order to maintain engine starting integrity. This shelf life can be lengthened to several years if the ethanol is stored in sealed tanks. Ethanol absorbs more water than gasoline, and when this water evaporates, valuable components of the ethanol are lost. Ideally, an on-airport E85 facility would be sized correctly to avoid fuel sitting in tanks for long periods of time. For those facilities at risk of having fuel inventories for long periods of time, sealed storage tanks are available to mitigate the problem of spoilage or evaporation.

What are the potential environmental considerations of ethanol?

Generally, research has shown that for ethanol blends up to 25% (E25), PM shows a clear reduction, whereas NO_x and hydrocarbon emissions results are mixed—some show significant reductions and others show significant increases (AEA 2008). For the E85 blend, the review of available data indicated no change in the emission factors of NO_x 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.

Potential water impact is substantial and the increasing visibility of the water-energy-food nexus makes it critical to evaluate. Ethanol's water impact is driven primarily by the need for water to grow the feedstock, especially in the case of corn-based ethanol. In general, first-generation feedstocks, particularly when irrigated, consume substantially more water per BTU of energy content than traditional hydrocarbon-based fuels (DOE 2006). Some second- and third-generation feedstocks may consume less water. However their impact on local water resources where they are grown must be evaluated, especially if they are in arid or water-stressed environments and/or if they draw upon water systems that are used to grow food elsewhere. The pollution impact of pesticides, biocides, and fertilizers along with runoff resulting from agricultural practices must also be evaluated. Computation of a crop-based feedstock's water impact is highly complex and varies widely depending on what, where, and how it is grown.

Under what conditions is ethanol cost competitive?

Generally, ethanol is cost competitive only when it is blended with gasoline. However, because its energy density is around two-thirds that of gasoline, vehicles require more fuel to travel the same distance; hence, its cost needs 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.

As of January 2012, a gallon of E85 cost \$3.14, compared to \$3.37 for a gallon of conventional gasoline. Taking into account the energy differential between the two fuels, an energy-equivalent gallon of E85 cost \$4.44 (DOE 2012b).

What are some challenges associated with ethanol?

Some challenges associated with this fuel include the following:

- 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 corrosion.
- There are materials compatibility challenges for ethanol blends higher than E15 that affect fuel lines, seals, and other equipment.
- Ethanol has 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 capable of using a blend of up to 85% ethanol (E85). Therefore, more sophisticated fuel management systems must be used, which leads to additional vehicle purchase costs.
- Ethanol also has challenges regarding fuel costing, especially if tax is charged on a volume basis because of the low energy density.
- Ethanol produced by first-generation feedstocks is at the core of the world's food-versus-fuel debate.
- The impact of crop-based ethanol feedstocks on water availability and pollution may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).

Who are the potential users of ethanol?

The potential users are all those who currently use gasoline. Regarding the airport setting, there is some potential for airside use on, for example, some airport vehicles and some GSE. However, for landside use the majority of fuel burned is gasoline.

Two primary factors affect 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. To achieve parity, the price differential needs to be 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 fuel is provided in Section 2.5.

2.4.4 Compressed Natural Gas

Natural gas is an important fossil fuel, most commonly used for heaters, boilers, and electricity generation. Natural gas is prevalent and burns cleaner than conventional gasoline. Though natural gas is responsible for around a quarter of all energy used in the United States, only 0.1% of that amount is used for transportation fuel. CNG is increasingly being used for surface transportation applications, most notably for buses, dump trucks, and other heavy vehicles.

What is the status of CNG technology?

CNG is available in commercial scale because a wide-ranging, extensive network of pipelines exists in the United States for natural gas transport and delivery. The technology for distribution, storage, and road vehicles is also available. As mentioned above, CNG is common in heavy vehicle fleets but not as commonly seen as a fuel for conventional vehicles. This is because the containers that must be used to hold the fuel are extremely heavy and add significant weight to any vehicle. While this extra weight is problematic in terms of both weight and mass needed to support the storage tanks in the context of light-duty vehicles, it is not as much of an issue in heavy vehicles. Conversions of both heavy and light vehicles to run on CNG are common.

What additional infrastructure is required to support CNG?

There is an extensive low-pressure natural gas infrastructure already in place, such as that reaching into many residential and commercial buildings in the United States and a number of airports that have CNG stations (Clean Energy Fuels 2012). 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.

What are the potential environmental considerations of CNG?

If CNG is used to replace diesel in appropriate vehicles, NO_x and PM emissions would be reduced. 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.

The water impact of CNG depends on the way the gas was extracted. Natural gas extracted via conventional drilling methods consumes the least amount of water/BTU relative to any other transportation fuel (DOE 2006). Widespread natural gas extraction via hydraulic fracturing of shale rock is a relatively new technique that has been used at commercial scale only within the last 10 years. Its pollution impact and relative water consumption and withdrawal impact are a present subject of debate by the public.

Under what conditions is CNG cost competitive?

Natural gas is a fossil fuel whose price fluctuates somewhat similarly to the cost of crude oil but is 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 very low in the United States in recent years. As of January 2012, the energy-equivalent price of CNG compared to a gallon of gasoline was \$2.13. The price of CNG containing the same amount of energy as a gallon of diesel was \$2.38 (DOE 2012b).

What are some challenges associated with CNG?

Some challenges associated with this fuel include the following:

- The principal challenge of CNG is its low energy density compared to diesel or gasoline coupled with 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 United States (Chevron 2006).
- The impact of natural gas extracted via hydraulic fracturing of shale rock on water availability and pollution is a present subject of debate by the public (see the discussion on the water-energy-food nexus in Section 5.5.3.2).

Who are the potential users of CNG?

Potential users of CNG include the following:

- Fleets of buses or shuttles with a significant number of units can 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 fuel is provided in Section 2.5.

2.4.5 Liquefied Petroleum Gas

LPG is a fossil fuel comprising principally propane but sometimes containing small quantities of butane and is manufactured as part of both the petroleum-refining and natural gas-refining processes. 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 the liquid form.

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 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-fueled equivalents. LPG is also widely used on certain types of equipment operating in enclosed facilities, such as forklifts.

What is the status of LPG technology?

LPG has been available as an on-road fuel source for more than 80 years. The technology associated with it is well understood. New-build LPG vehicles are available as are bi-fuel vehicles that can use conventional gasoline as well as LPG. These bi-fuel vehicles maintain separate fuel systems as gasoline and LPG cannot use a shared system. In terms of infrastructure, LPG production and refueling is commercially available but not nearly as widespread as gasoline.

What new infrastructure is required to support LPG?

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 United States is almost triple that of CNG—around 2,600 compared to 900 for CNG (DOE 2011b).

What are the potential environmental considerations of LPG?

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

The water impact of LPG depends on the way it was extracted. Hydrocarbons extracted via conventional drilling methods consume the least water/BTU relative to other transportation fuels (DOE 2006). Widespread extraction of hydrocarbon liquids via a method called hydraulic fracturing of shale rock is a relatively new technique that has been used at commercial scale only within the last 10 years. Its pollution impact and relative water consumption and withdrawal impact are a present subject of debate and uncertain.

Under what conditions is LPG 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. As of January 2012, a gallon of LPG cost \$3.08, compared to \$3.37 for a gallon of gasoline and \$3.86 for a gallon of diesel. On an energy-equivalent basis, however, LPG cost \$4.16 per gallon compared to gasoline and \$4.75 per gallon compared to diesel.

What are some challenges associated with LPG?

LPG has few challenges. However, the impact of hydrocarbons extracted via hydraulic fracturing of shale rock on water availability and pollution is a present subject of debate by the public (see the discussion on the water-energy-food nexus in Section 5.5.3.2).

Who are the potential user groups of LPG?

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 United States (DOT 2011). This implies that the number of potential consumers for LPG is very significant.

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

2.4.6 Electricity

Electricity is increasingly being used in airports around the world to power 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 used for off-airport surface transportation, such as buses, shuttle fleets, and taxis.

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 million and 3 million gallons of liquid fuel per megawatt of electricity generated (Swanson et al. 2010; Liu et al. 2011).

What is the status of electricity technology?

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

What additional infrastructure is required for electricity delivery and storage?

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 require the current infrastructure at airports (e.g., substations, 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 for siting. Additional GSE vehicles may also need to be purchased to cover charging downtime.

What are the potential environmental benefits of utilizing electricity in lieu of other fuels in an airport setting?

Electric vehicles generate zero NO_x and significantly less PM emissions than gasoline or diesel engines at the point of use (all vehicles, including electric vehicles, generate some PM associated with brake and tire wear). In addition, the use of electrified gates reduces fuel burn on aircraft engines or APUs while parked at the gate. Life-cycle GHG emissions depend greatly on how the electricity is generated.

Similarly, potential water impact depends on how the electricity is generated—thermoelectric plants (coal, natural gas, or nuclear) and hydroelectric-, solar thermal-, solar photovoltaic-, wind-, and biomass-generated electricity all have widely different impacts on water availability and pollution.

Under what conditions is electricity cost competitive?

Electricity rates and the market are well understood and vary based on certain factors related to how it is generated and distributed, and market conditions. Access to cheaper electricity than what is provided by the grid will have a positive impact on the program 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.

What are the potential challenges associated with electricity?

Electricity has relatively few challenges. The 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; more expensive batteries will need to be used (i.e., not lead acid batteries) when required, and lead acid batteries will need to be kept above freezing temperatures when not in use.

The impact of electricity production on pollution depends on the source of the energy used to generate the electricity and may be controversial because of the increasingly visible water-energy-food nexus (see the discussion in Section 5.5.3.2).

Who are the potential user groups of 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 uses—as fixed electrical ground power and for generation of preconditioned 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 fuel is provided in Section 2.5.

2.5 Potential User Groups and Their Motivations

Potential users can be divided into two groups depending on their use of alternative jet fuel or other alternative fuels.

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 following list identifies the key potential user groups for alternative fuels and their motivations:

- **Airport operators**—Airports of all sizes have their own fleets 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.
- **Bus and shuttle operators**—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 alternatively fueled vehicles when vehicle replacement is an option.

- **Taxi and limousine operators**—Similar to buses and shuttles, taxis and limousines could be encouraged to use alternative fuels by the airport granting preferential vehicle treatment. 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 alternatively 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 potentially 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**—Private vehicles constitute a large percentage of the traffic to and from U.S. airports, representing 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)**—Ferries and small passenger boats generally use gasoline or diesel engines comparable to those in automobiles and so are ideal candidates to utilize alternative fuels. In an airport setting, joint purchases of biodiesel and green diesel could lower costs and increase efficiency by utilizing economies of scale inherent in purchase agreements. However, it is exceedingly rare that an airport utilizes ferries or boats as a primary method of public transportation to and from the facility. In fact, Boston Logan International Airport is unique among major U.S. airports in offering scheduled ferry service from the airport to destinations in downtown Boston. As maritime modes are not a normal part of the mix of surface transportation options at most airports, they are not a focus of this report.
- **Off-airport users**—The unique role that the airport plays within a community offers an opportunity for the airport itself to take a lead role in the provision of alternative fuels for airport operations as well as for off-airport operations undertaken by the general public. Given their physical characteristics, airports can use alternative fuels to expand their businesses. Storing and distributing drop-in alternative fuels requires no significant new investment in infrastructure on the airport's part, which lessens the cost of providing the fuel to the community. Most new investment would be focused on expansion of facilities and infrastructure, the cost of which could be borne by a combination of user groups. Alternatively, if airports do not wish to directly manage fuel storage and delivery of alternative fuels, they could lease land out to a third party and still have the potential to capture value. The provision of alternative

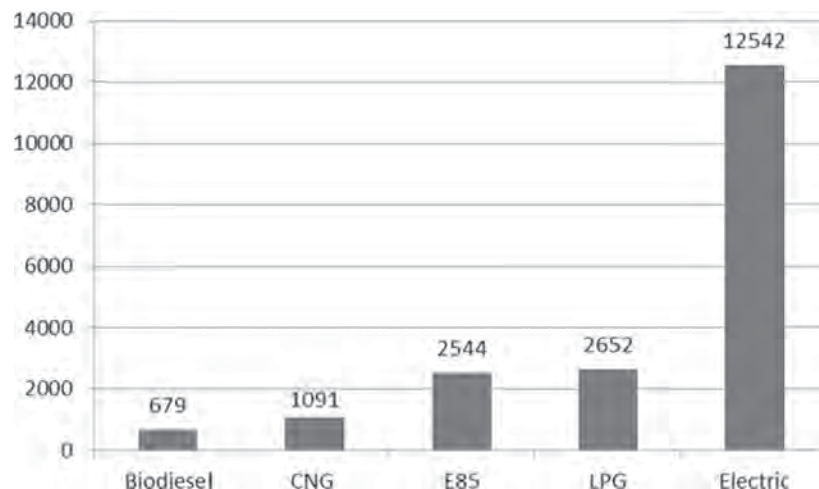
fuels to off-airport customers has the potential to strengthen the financial position of airports that choose to explore it.

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 can also play 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.

2.6 Current Status of Fueling Infrastructure for Alternative Fuels in the United States

The number of refueling stations for a number of alternative fuels in the United States is shown in Figure 1. Electricity has the highest number of refueling points with 12,542, while biodiesel has the least with 679.



Note: Biodiesel includes B20 and above; electric charging units are counted once for each outlet.

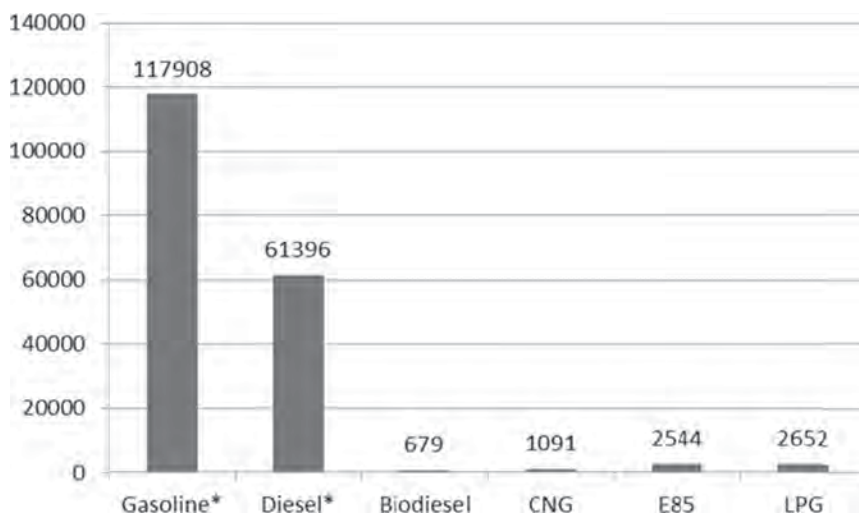
Figure 1. Number of U.S. alternative fuel refueling stations, January 2012 (DOE 2011b).

For illustration purposes, it is useful to compare the penetration of alternative fuel infrastructure to that of conventional fuel. As can be seen in Figure 2, the number of gasoline stations and diesel stations are orders of magnitude higher than that for alternative fuels. Note that gasoline and diesel station counts are 2010 estimates from Hart Energy Consulting using data from the 2007 U.S. Economic Census, while alternative fuel station counts are updated monthly by the Alternative Fuels Data Center. Given the long-term steady decline in the number of conventional gasoline stations in the United States, it is likely that the current number of stations in the country is lower than the estimates provided. However, the number of conventional gasoline stations offering diesel has steadily increased from 35% in 1997 to 52% in 2007 (Hart Energy Consulting 2010) and has likely continued to climb as remaining owners of conventional gasoline stations seek ways to diversify their revenue streams in the current economic environment.

The United States has seen a decrease in the number of traditional gasoline refueling stations in the last two decades while all other fuels have seen growth. This corresponds to decreasing gasoline usage per capita for U.S. residents primarily due to rising passenger vehicle fleet efficiency, among other factors. Diesel is the second most prevalent liquid fuel used for motor vehicles and, unlike gasoline, has been increasingly offered at refueling stations nationwide. It is currently available in about half of all U.S. stations (Hart Energy Consulting 2010). This is positive for the commercialization of green diesel, which is a drop-in fuel that can work effectively with existing infrastructure.

Biodiesel, on the other hand, must have dedicated fueling and storage infrastructure because it is not a drop-in fuel and requires separate facilities from regular diesel. Therefore, the number of stations that have invested in infrastructure to serve biodiesel blends (particularly blends higher than B20) has been relatively slow. However, automobile manufacturers are beginning to support the use of low-blend biodiesel in traditional diesel engines with only very minor modifications. As the supply of biodiesel increases and the price decreases, more manufacturers will likely follow this lead.

In the United States, CNG has been utilized primarily as a fuel for large commercial vehicles such as buses, because of the heavy weight of CNG tanks; for vehicles that were not originally designed for CNG, a conversion involves using empty space for tank storage. This often results in the CNG tanks being located in the trunks for converted cars and in the beds for converted



*Estimates using data from the 2007 U.S. Economic Census

Figure 2. Number of U.S. refueling stations, 2010 (Hart Energy Consulting 2010; DOE 2011b).

trucks. These disadvantages have, in the past, held down demand for what is a viable alternative fuel. However, CNG-specific vehicles often have tanks installed under the vehicle, which saves space and increases the appeal of CNG as a fuel. Refueling stations for CNG, while plentiful in some other parts of the world, are still quite rare in the United States for passenger vehicle use.

Ethanol (E85) has significant fueling infrastructure in the United States, largely as a result of government efforts to use it as a primary alternative fuel for passenger vehicles. Only five states (Alaska, Maine, New Hampshire, Rhode Island, and Vermont) have no E85 refueling stations, and many states, primarily in the Midwest, have hundreds of E85 stations (Chevron 2006). However, the growth of E85 as an alternative fuel is constrained by the amount of feedstock available to manufacture it. These constraints have been seen in the past in Brazil, a country that has the world's largest fleet of ethanol-powered vehicles and more than 35,000 refueling stations that offer the fuel. Sugarcane is the primary feedstock for Brazilian-produced ethanol. Though sugarcane is widely cultivated in Brazil, supply disruptions and shortages have periodically been seen as a result of poor harvests and increasing internal and external demand (McConnell et al. 2010).

Electricity, used as a substitute for traditional fuel, has shown promise as an alternative. Though not a liquid fuel, advancing battery technologies have resulted in production of all-electric vehicles that have enough range to cover a typical commute. The fueling infrastructure related to all-electric vehicles has begun to accelerate in recent years, and the widespread availability of electricity indicates that its utilization will continue to climb. The airport setting offers a greater advantage to electric-powered vehicles than does the market for powered vehicles as a whole, as the decreased range of electric vehicles relative to vehicles powered by gasoline or diesel is less of an issue.

How Can Alternative Fuel Distribution Programs at Airports Be Evaluated?

3.1 Introduction to the Evaluation Framework

The evaluation framework in this section guides the reader through a series of steps to identify and evaluate different options for alternative fuel distribution programs. The distribution options are defined in terms of the types of alternative fuels and associated quantities that are intended to be used at the airport. This framework is shown in Figure 3.

The first step is to define the distribution options to be evaluated. This step is divided into three substeps: (A1) identify the current energy mix at the airport including a forecast of energy demand, (A2) forecast projected energy use based on measures of airport activity as well as policy choices with respect to what alternative fuels should be introduced and promoted, and (A3) define the required infrastructure to store and handle the fuels at the airport. Step A is explained in Section 4. Step B is to evaluate the options identified in Step A using different parameters, including environmental, economic, social, financial, and regulatory. This is explained in Section 5. Finally, in Step C, siting requirements for the alternative fuel distribution programs are considered. Step C is discussed in Section 6.

Notice that a number of iterations may be required in this process, as indicated by the arrows looping back from Steps B and C into Step A. There are two fundamental questions that the

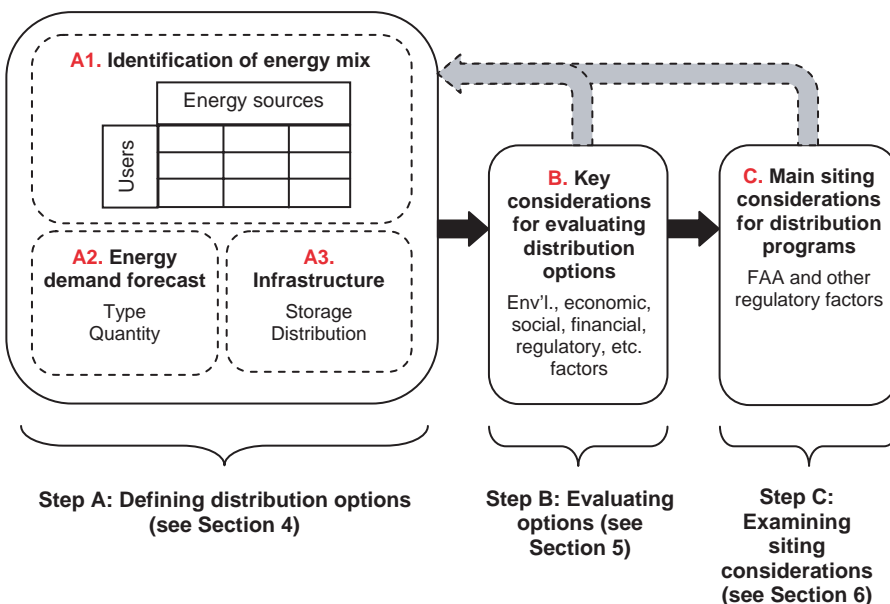


Figure 3. Schematic of evaluation framework.

airport needs to consider, namely, what types of alternative fuel to use and how much. In many cases, it will not be obvious which alternative fuels to select without knowing how much will be needed, and vice versa. To facilitate this process, the recommendation is to start with existing information on current energy use at the airport and to project possible future use based on that knowledge. The projection of future use includes considering fuels other than the ones currently used. This allows an initial screening of potential options that can then be evaluated using the considerations indicated in Steps B and C.

3.2 Introduction to the Toolkit and User Guide

A toolkit and associated User Guide have been developed to help readers apply the framework. The toolkit consists of two separate spreadsheets that accompany this guidebook. These files can be found on the accompanying CD-ROM and on the TRB website where the guidebook can be downloaded (<http://www.trb.org/Main/Blurbs/168378.aspx>):

- The energy mix spreadsheet includes worksheets to identify current and future energy use. This spreadsheet helps the reader apply Step A in the evaluation framework by enabling the identification of the current energy use and energy mix at the airport by user type and energy type (Step A1). In addition, the spreadsheet can be used to project future energy use and energy mix at the airport (Step A2). It also facilitates the examination of “opportunities” for exchanging conventional fuel use for alternative fuels. Finally, the spreadsheet also helps the reader identify storage and distribution infrastructure for the different fuels (Step A3). The spreadsheet allows the information to be displayed graphically.
- The workbook spreadsheet helps the reader apply Steps B and C in the evaluation framework. The worksheets correspond to each of the considerations for evaluating alternative fuel distribution programs: benefits, costs, financial, legal, community, and siting. This guidebook contains information to assist the user in filling out the worksheets.

The User Guide for the spreadsheets, included on the CD-ROM, explains the functionality of the spreadsheets and gives a step-by-step explanation of how to use them.

Evaluation Framework Step A: How Can Distribution Options Be Defined?

The alternative fuel distribution options are defined in terms of three main elements:

- Type of alternative fuel
- Quantity of alternative fuel
- Required storage and distribution infrastructure for handling the alternative fuel

Start by understanding the existing energy mix at the airports, i.e., the types and amounts of energy by user type. This knowledge is used to project future energy use by fuel and user type. These projections can include both fuels currently in use at the airport and other fuels that the airport may want. Finally, use these estimates of projected use of the different types of fuels to estimate the storage and distribution requirements.

4.1 Step A1: Identification of Energy Mix at Airports

The first substep is to understand current energy use at the airport. A matrix similar to that in Table 1 is provided to guide the analysis. This matrix is found on the “MatrixCurrent” worksheet in the energy mix spreadsheet. The categories on the left indicate the major areas where energy is used at airports: aircraft, vehicles, and buildings. The subcategories of energy users may vary depending on local conditions.

The matrix differentiates between passengers and airport employees for some groundside modes, such as private vehicles, scheduled buses/vans, and courtesy vans. The distinction is driven by the availability of data (see Appendix B on the accompanying CD-ROM for more details). This difference can be significant at airports with separate parking facilities for employees and passengers. At airports where parking and other transportation facilities are used jointly by employees and passengers, this distinction is not as important.

Airports that have their own systems for tracking energy demand for items such as airport vehicles and buildings can use that information in the appropriate rows in Table 1. When an airport lacks internal data, outside sources of data may be available (e.g., from third-party operators) or the row can be left blank. The matrix is not representative of the conditions at all airports because there is much variability from one facility to another. Depending on the scope of the analysis and the availability of data, the user can opt to use all or just some of the rows in the energy matrix. The energy matrix is intended to include the largest users of energy at the airport to facilitate an understanding of the major energy options whether or not the airport controls the energy use. The evaluation framework limits energy sources to those shown in Table 1. The “Custom” headings are placeholders for other fuels that are of interest to the airport because of local conditions.

Table 1. Current energy mix at airports.

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	* Passenger GSE																
	Cargo GSE																
	Military GSE																
	Airport Vehicles																
	Groundside	* Passenger Vehicle															
		Employee Vehicle															
		* Rental Cars															
		* Taxis															
		* On-Demand (Limos)															
	* Passenger Bus/Van																
	Employee Bus/Van																
	* Passenger Courtesy Vans																
	Employee Courtesy Vans																
	Passenger Rail																
	Employee Rail																
Off-airport	Water Shuttle																
	Water Freight																
	Rail Freight																
	Truck Freight																
Buildings / Other	Airport Buildings																
	Military Buildings																
	Other Buildings																
	Systems																
	Concessions																
	Military Other																
	Custom																

4.2 Step A2: Energy Demand Forecast

When the current energy matrix is completed, the next step is to forecast energy demand. This matrix includes the same energy use categories as the current energy mix illustrated in Table 1 and presents a forecast for a particular year of interest defined by the user (see Table 2). In addition, the future energy mix matrix allows the user to input growth in aviation activity (passenger, cargo, military, and GA) in the top left corner.

As in the case of the current energy mix, there are two ways to provide the information for the future energy matrix shown in Table 2. Some airports may already have a means of forecasting demand for different fuels and can input their own data directly. For those that do not, a spreadsheet-based model has been developed to provide rough estimates of potential fuel use for the following users (shown with an asterisk in Tables 1 and 2):

- Passenger and cargo aircraft
- Passenger GSE
- Light-duty passenger vehicles: private passenger cars, rental cars, taxis, and on-demand (limousines)
- Scheduled passenger vans and courtesy passenger shuttles

This forecasting model is included in the “MatrixFuture” worksheet in the energy mix spreadsheet. For more details regarding the forecasting methodology, please see Appendix B.

This step is organized to facilitate fueling options based on the nature of the relationship of the airport to the key stakeholder. For example, an airport may want to provide specific fueling options for its own vehicles and buildings, which will only involve a few rows in the matrix. The airport may also consider partnering with passenger airlines to provide alternative jet fuel and green diesel for aircraft, airline GSE, and airport vehicles, which will also involve a few rows in the matrix. Another option could be partnering with transit vehicles (buses and vans) to adopt CNG. For each scenario, the user completes a separate matrix. Again, not all rows of the matrix need to be filled to proceed to the next step. The user is free to set the scope of the analysis in terms of which energy users and energy sources to include.

4.3 Step A3: Storage and Distribution Infrastructure

The final part of Step A is to determine the storage and distribution requirements for the fuels identified in Steps A1 and A2, as explained below. The “Infrastructure” worksheet of the energy mix spreadsheet can be used to facilitate this process.

4.3.1 Storage Infrastructure

Storage is a significant consideration. The use of existing storage infrastructure has many benefits, including the avoidance of building new infrastructure and experience with operation and maintenance; however, it may not be possible to use existing storage. 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. The key issues in site selection for each alternative fuel can be captured in a table as shown in Table 3.

Table 2. Future energy mix at airports.

Growth from 2011 to 2015		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		
Pass	Override																		
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																
			* Rental Cars																
		Passenger Light-Duty (Fleet)	* Taxis																
			* On-Demand (Limos)																
			* Passenger																
	Scheduled Bus/Van	Employee																	
		* Passenger																	
Employee																			
Courtesy Vans	* Passenger																		
	Employee																		
	Passenger																		
Rail	Employee																		
	Employee																		
Off-airport		Water Shuttle																	
		Water Freight																	
		Rail Freight																	
		Truck Freight																	
Buildings / Other		Airport Buildings																	
		Military Buildings																	
		Other Buildings																	
		Systems																	
		Concessions																	
		Military Other																	
		Custom																	

Table 3. Storage requirements for distribution option.

Storage requirements (total maximum capacity)		Jet Fuel (Conv + Alt) (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)
Aircraft	Current													
	Future													
	% Chg													
Vehicles	Current													
	Future													
	% Chg													
	Current													
	Future													
	% Chg													
	Current													
	Future													
	% Chg													
Buildings	Current													
	Future													
	% Chg													

4.3.2 Distribution of Alternative Fuels

The next consideration is how the alternative fuels will be made available to final users. Similar to storage, using the existing infrastructure has many benefits when feasible. New distribution points may be required if the current infrastructure is not able to handle the anticipated volumes. In addition, the location of the distribution points may require new infrastructure depending on existing user access. These variables can be captured in a table as shown in Table 4.

Table 4. Distribution requirements for distribution option.

Distribution requirements (total maximum throughput)		Jet Fuel (Conv + Alt) (gal/hr)	AVGAS (gal/hr)	Gasoline (gal/hr)	E85 (gal/hr)	Diesel (gal/hr)	Green diesel (gal/hr)	Biodiesel B20 (gal/hr)	CNG (gal/hr)	LPG (gal/hr)	Electricity (kWh/hr)	Custom 1 (000 gal/hr)	Custom 2 (000 gal/hr)	Custom 3 (000 gal/hr)
Aircraft	Current													
	Future													
	% Chg													
Vehicles	Current													
	Future													
	% Chg													
	Current													
	Future													
	% Chg													
	Current													
	Future													
	% Chg													
Buildings	Current													
	Future													
	% Chg													



SECTION 5

Evaluation Framework Step B: What Are the Key Considerations for Evaluating Distribution Options?

The objective of this section is to help airports identify the costs, benefits, and other key considerations associated with alternative fuel distribution programs. The workbook spreadsheet has templates to help with this evaluation. This section provides a methodology for evaluating the strengths and weaknesses of each option. This step also highlights those items that warrant more detailed analysis. Table 5 lists the items that the researchers considered to be most important.

The first two categories, environmental and economic, vary significantly for each alternative fuel and should be reviewed accordingly. For the remaining categories, the discussion is not divided by alternative fuel, because the observations apply, in general, to all of them.

Water impact (increasingly referred to as the “water-energy-food nexus”) is rapidly emerging as an important criterion due to water’s importance for agriculture, numerous industrial processes, and life itself. However, it is difficult to evaluate due to the limited information on water impacts. Although water is not specifically addressed in the following sections, the impact of a fuel on the availability of water is of increasing importance and should be kept in mind. Please refer to the discussion in Section 5.5.3.2 for a summary of currently available information.

Each airport is unique, and some of these differences, such as size and governance structure, 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 influence their applicability.

Table 5. Main considerations for comparative evaluation of alternative fuel distribution programs.

Category	Subcategory	See Section
Environmental	Local air quality (e.g., PM, NO _x)	5.1
	Greenhouse gases	5.1
Economic	Fuel cost	5.1
	Vehicle cost	5.1
	Infrastructure cost	5.1
	Additional jobs	5.1
Social and Community		5.2
Financial and Commercial		5.3
Legal and Regulatory	FAA regulations	5.4
	Local, state, and federal regulations	5.4
Stakeholder Engagement and Community Acceptance	Stakeholder engagement	5.5
	Community outreach	5.5

5.1 Environmental and Economic Considerations

The evaluation of environmental and economic considerations associated with alternative fuels and their distribution are discussed in this section. The following categories are included:

- Environmental considerations
 - Potential change in PM and NO_x emissions
 - Potential change in life-cycle GHG emissions
- Economic considerations
 - Relative cost of fuel
 - Relative cost of vehicle/plant
 - Relative cost to upgrade existing vehicle/plant
 - Additional infrastructure storage cost
 - Additional facilities cost (e.g., refueling station)
 - Additional jobs

The criteria for this discussion were based on the team's expert knowledge and professional judgment and information gained from related studies (AEA 2008; AEA 2009; DfT 2010), a key study being ACRP Project 02-23, documented in *ACRP Web-Only Document 13: Alternative Fuels as a Means to Reduce PM_{2.5} Emissions at Airports* (Peace et al. 2012). ACRP 02-23 developed a mechanism for evaluating alternative fuels based on their capacity to reduce PM_{2.5}, their capacity to reduce other pollutants' emissions, and potential issues regarding use of those alternative fuels such as their associated costs. Most of the criteria listed above were developed in ACRP 02-23, with the exception of "additional jobs." Information related to emissions from ethanol was largely obtained from a literature review (AEA 2008); data pertaining to LPG and CNG were obtained from sources cited in the text or the FAA's Emissions Dispersion Modeling System (EDMS) databases; and information on green diesel and other biodiesels was primarily obtained from EPA sources (EPA 2002). Other data, such as the cost of fuel and the availability of alternatively fueled vehicles and buildings, were obtained from studies previously cited. The comparison of fuel costs is on an energy-equivalent per-gallon basis. Other references are also listed where appropriate.

A resource for estimating emissions is the Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (ANL 2011). The GREET model estimates emission data for a number of different fuels based on specific assumptions about feedstocks, supply chains, vehicles, and other pertinent information. The GREET model allows the estimation of both tailpipe or wake emissions and life-cycle emissions. Tailpipe or wake emissions are those that occur where the fuel is burned by the final users (e.g., cars, truck, aircraft), while life-cycle emissions include all the emissions associated with the feedstock, production, handling, and use of the fuel. Thus, tailpipe emissions may be essentially the same for different fuels, while life-cycle emissions may be very different. For example, there are no tailpipe emissions associated with the use of electricity to power vehicles, but life-cycle CO₂ emissions can be very different depending on how the electricity is generated (e.g., hydroelectric vs. coal-fired power plants). Readers are encouraged to use GREET and modify its assumptions, as needed, for estimates applicable to their local conditions.

5.1.1 Alternative Jet Fuel

5.1.1.1 Relative Change in PM and NO_x Emissions

Alternative jet fuels have the potential to significantly reduce emissions of SO_x and PM. This reduction is primarily because alternative jet fuels are virtually sulfur free and have a lower

aromatic content. SO_x and hydrocarbon aromatics are precursors and indicators of the formation of $\text{PM}_{2.5}$. Tests by the U.S. Air Force (USAF) indicate that $\text{PM}_{2.5}$ is significantly lower in alternative fuels compared to conventional jet fuel (Miller et al. 2011).

NO_x emissions attributable to aviation activities are widely variable by aircraft type. This variability is because NO_x production is closely tied to the temperature of combustion and the technologies associated with a particular engine (Starik 2008). Therefore improvements in engine and aircraft technology are likely to reduce future NO_x emissions.

5.1.1.2 Relative Change in Life-Cycle GHG Emissions

Life-cycle GHG emissions for conventional jet fuel using traditional crude sources are estimated at 87.5 grams of CO_2 equivalent per megajoule (MJ) of energy (Stratton et al. 2010). The life-cycle emissions for alternative jet fuels vary significantly and depend on how the fuel is generated and what degree of land use change is required to support the cultivation of feedstocks. Figure 4 shows the ranges of estimated GHG emissions of alternative jet fuels based on different feedstocks. Note that the life-cycle analysis for GHG for both FT and HEFA fuels are shown as a range. This range is primarily caused by variations in land use necessary to make an area suitable for cultivation. Changes in land use affect the life-cycle emissions of plant-based fuels more than any other single factor. A greater change in land use to support a given feedstock would result in greater life-cycle GHG emissions.

5.1.1.3 Relative Cost of Fuel

While the cost of alternative jet fuel will vary significantly, it is currently more expensive than conventional jet fuel. This high cost is due to a variety of factors, including the new state of the technology, high upfront capital costs for alternative fuel production facilities, and the challenge of securing feedstock that can meet performance and financial benchmarks.

The challenges associated with feedstocks for alternative jet fuel are numerous. Some feedstocks compete with food and others are expensive due to their current tight and highly competitive markets. Many of the new feedstocks are still experimental. Others are produced in limited volumes. Still others have supply chain inefficiencies that must be solved. All of these factors contribute to the present high cost of alternative jet fuel. However, as the technology matures and feedstock supplies develop, the cost is expected to decrease.

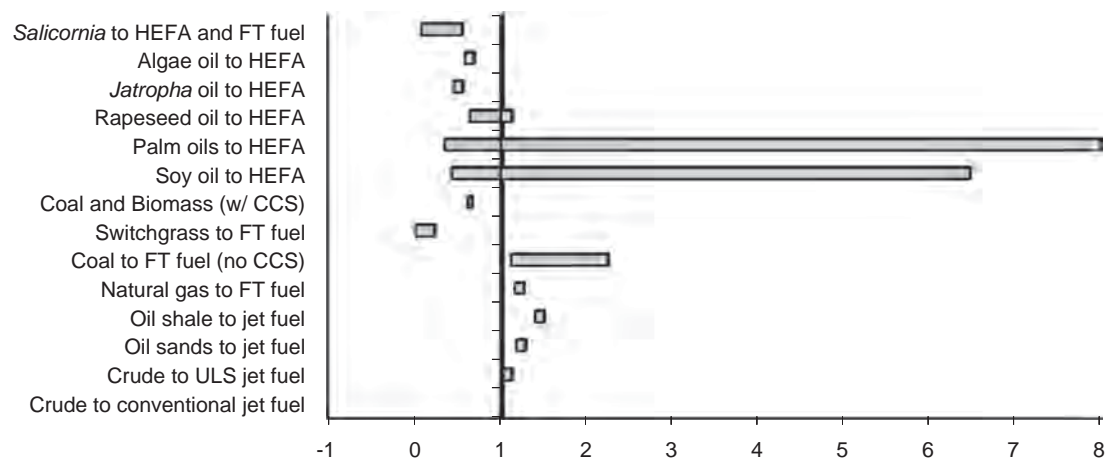


Figure 4. Relative life-cycle GHG emissions of several pathways for alternative jet fuels (conventional jet fuel = 1.0; adapted from Stratton et al. 2010).

5.1.1.4 Relative 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 is required.

5.1.1.5 Relative Cost to Upgrade Existing Vehicle/Plant

Minimal because alternative jet fuel is drop-in.

5.1.1.6 Additional Infrastructure Storage Cost

Minimal because alternative jet fuel is drop-in.

5.1.1.7 Additional Facilities Cost (e.g., Refueling Station)

Minimal because alternative jet fuel is drop-in.

5.1.1.8 Additional Jobs

The use of alternative jet fuel is likely to create few airport-related jobs.

5.1.2 Green Diesel

5.1.2.1 Relative Change in PM and NO_x Emissions

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 PM emissions as well as lower sulfur emissions. In contrast, the levels of carbonaceous PM are unlikely to be substantially different. Emissions of NO_x are more dependent on the temperature at which the fuel is burned and not the fuel formulation, so NO_x emissions are unlikely to be affected.

5.1.2.2 Relative Change in Life-Cycle GHG Emissions

The life-cycle emissions for green diesel vary significantly. They depend on how the fuel is generated and what degree of land use change is required to support the cultivation of feedstocks.

5.1.2.3 Relative Cost of Fuel

Green diesel is fully interchangeable with petroleum-derived diesel. Production of green diesel is not yet widespread so prices tend to be higher than conventional diesel; however, as in the case of alternative jet fuel, as the industry matures and more processing capacity is installed, the price of the fuel is expected to decrease.

5.1.2.4 Relative Cost of Vehicle/Plant

Green diesel is fully interchangeable with petroleum-derived diesel, and no modifications are required for diesel engines to use green diesel. Some additional maintenance may be required, such as changing filters, due to green diesel's lower aromatic content.

5.1.2.5 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. Some additional maintenance may be required, such as changing filters, due to its lower aromatic content.

5.1.2.6 Additional Infrastructure Storage Cost

No additional infrastructure is required beyond what already exists for petroleum-derived diesel. This is because the two fuels are so chemically similar and can be used in conventional vehicles.

5.1.2.7 Additional Facilities Cost (e.g., Refueling Station)

The similarity of green diesel to petroleum-derived diesel, as discussed in previous sections, means that no additional facilities are required.

5.1.2.8 Additional Jobs

Changing from petroleum-derived diesel to blends containing green diesel will not create any additional on-airport jobs.

5.1.3 Biodiesel

5.1.3.1 Relative Change in PM and NO_x Emissions

Changes in PM and NO_x emissions depend on blend strength and vehicle technology, particularly fuel delivery systems and combustion chamber design. A 2002 EPA summary suggests that using B20 may increase NO_x emissions by around 2% (EPA 2002). A more recent study (AEA 2008) suggests that using B15 leads to changes in NO_x emissions of +1% for heavy-duty vehicles, and no change for passenger cars.

5.1.3.2 Relative Change in Life-Cycle GHG Emissions

The life-cycle emissions savings depend on the production and transportation emissions that come from the growing and processing of the crops, in addition to the tank-to-wheel technology.

5.1.3.3 Relative Cost of Fuel

B20 is typically competitive with conventional diesel. As of January 2012, a gallon of B20 cost \$3.95 compared to \$3.86 for conventional diesel. When normalizing for energy content, a gallon of B20 cost \$4.02 (DOE 2012b).

5.1.3.4 Relative Cost of Vehicle/Plant

Most new vehicles can use blends up to about 20%, thereby avoiding incremental cost. However, older vehicles using higher blends require modifications.

5.1.3.5 Relative Cost to Upgrade Existing Vehicle/Plant

Because most new vehicles can use blends up to 20%, any upgrade cost would be purely to support blends higher than this. The upgrade costs should be nominal since they usually result from changing internal engine parts, such as filters.

5.1.3.6 Additional Infrastructure Storage Cost

For blends up to 20%, 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 as both standard diesel and biodiesel blends would need to be offered separately.

5.1.3.7 Additional Facilities Cost (e.g., Refueling Station)

Potentially there is the need to install additional pumps for high blends; however, this depends on current pump availability.

5.1.3.8 Additional Jobs

No additional on-airport jobs are likely, other than during the construction of the infrastructure.

5.1.4 Ethanol

5.1.4.1 Relative Change in PM, NO_x and GHG Emissions

Most research has shown that for ethanol blends up to 25% (E25), there is a meaningful reduction in PM relative to gasoline. There is less consensus on ethanol's impact on NO_x and hydrocarbon emissions (AEA 2008). For the E85 blend, the review of available data indicated no change in the emission factors of NO_x or hydrocarbons, but a 20% reduction in PM emissions.

5.1.4.2 Relative Change in Life-Cycle GHG Emissions

The life-cycle GHG emissions depend on the production and transportation emissions that come from the growing and processing of the crops, in addition to transportation to the refueling station.

5.1.4.3 Relative Cost of Fuel

Ethanol is generally blended with gasoline. Based on the discussion in Section 2.4.3, E85 has a fuel economy penalty that is constant at around 30%. In addition, the price differential between E85 and gasoline fluctuates and, at the time of writing, favored E85 by about 10%. To achieve parity, the price differential needs to be at around 30%. As of January 2012, a gallon of E85 cost \$3.14, compared to \$3.37 for a gallon of conventional gasoline. Taking into account the energy differential between the two fuels, an energy-equivalent gallon of E85 cost \$4.44 (DOE 2012b).

5.1.4.4 Relative Cost of Vehicle/Plant

A variety of vehicles are currently available as E85 or FFVs for blends above 10%. They generally cost approximately the same as a gasoline vehicle. Blends of 10% or less can be used in gasoline vehicles without any modifications.

5.1.4.5 Relative Cost to Upgrade Existing Vehicle/Plant

Nearly all gasoline vehicles are capable of using ethanol blends of up to 10%, but higher blends require an FFV or dedicated E85-fueled engine.

5.1.4.6 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 because it attracts water. It is blended with gasoline just before delivery to retailers or to industrial customers. Therefore the additional infrastructure cost can range from \$40,000 to \$200,000 (Loveday 2011). Of this total cost, \$35,000 to \$70,000 is associated with the cost of the tanks themselves, while the rest is associated with other parts of the system (Lemas 2012). To partially offset this, the current administration is offering incentives for installing E85 pumps.

5.1.4.7 Additional Facilities Cost (e.g., Refueling 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.

5.1.4.8 Additional Jobs

Few, if any, additional jobs will be created at the airport because most fuel pumps are operated by the customer and most high ethanol blend pumps will be placed at an existing refueling station. 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.

5.1.5 CNG

5.1.5.1 Relative Change in PM and NO_x Emissions

If CNG is used to replace diesel in appropriate vehicles, there would be reductions in NO_x and PM emissions. If CNG is used to replace gasoline, then there is likely to be a moderate reduction in PM.

5.1.5.2 Relative Change in Life-Cycle GHG 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.

5.1.5.3 Relative Cost of Fuel

Cost competitiveness and availability are CNG's main strengths. As of January 2012, the price of CNG with energy equivalent to a gallon of gasoline was only \$2.13 compared to \$3.37 for an actual gallon of gasoline and \$3.86 for a gallon of diesel. The price of CNG containing the same amount of energy as a gallon of diesel was \$2.38 (DOE 2012b).

5.1.5.4 Relative Cost of Vehicle/Plant

Currently, there is only one CNG-powered light-duty vehicle that is sold in the United States—the Honda Civic GX. This automobile has a retail price of \$25,000, which is \$6,000 to \$8,000 more than the gasoline-powered Honda Civics (Honda 2012).

5.1.5.5 Relative Cost to Upgrade Existing Vehicle/Plant

The average cost of CNG conversions of gasoline vehicles is \$12,000 to \$18,000 (DOE 2011f). This relatively high cost is primarily due to the expense associated with the high-pressure storage system.

5.1.5.6 Additional Infrastructure Storage Cost

There is a relatively extensive low-pressure natural gas infrastructure already in place. Therefore, the additional infrastructure storage cost is low.

5.1.5.7 Additional Facilities Cost (e.g., Refueling 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, including a small compressor connected to a main gas supply, or low-pressure storage tank, and 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).

5.1.5.8 Additional Jobs

Few additional jobs are likely to be created at an airport. For routine operation, the number of jobs is assumed to be low, because it is assumed that the additional CNG filling points will be placed on the same site as the liquid fuel pumps at an existing refueling station. It is anticipated that a few additional filling points will not require further staff to be employed. However, there would be temporary additional jobs created to install the new capacity prior to the filling points becoming available for routine filling of vehicles.

5.1.6 LPG

5.1.6.1 Relative Change in PM and NO_x Emissions

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

5.1.6.2 Relative Change in Life-Cycle GHG 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.

5.1.6.3 Relative Cost of Fuel

A gallon of LPG has around 75% of the energy of a gallon of gasoline, so price per gallon must be lower in order for the fuel to be economically competitive. As of January 2012, a gallon of LPG cost \$3.08, compared to \$3.37 for a gallon of gasoline and \$3.86 for a gallon of diesel. On an energy-equivalent basis, however, LPG cost \$4.26 per gallon compared to gasoline and \$4.75 per gallon compared to diesel.

5.1.6.4 Relative Cost of Vehicle/Plant

There are currently no light-duty LPG vehicles on the market in the United States.

5.1.6.5 Relative Cost to Upgrade Existing Vehicle/Plant

The cost to convert a vehicle from gasoline to LPG is estimated at \$4,000 to \$12,000 (DOE 2011f).

5.1.6.6 Additional Infrastructure Storage Cost

Approximately 2,600 existing vehicle refueling 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 \$40,000 to \$200,000 for E85 (see Section 5.1.4), and it is assumed a similar figure applies to the addition of LPG to an existing refueling station. According to CleanFUEL USA, a company that markets LPG fueling systems, the cost of a typical 2,000-gallon LPG fueling system with a single pump is approximately \$100,000, 35% of which is associated with the tank itself. For a larger, 10,000-gallon system, that cost is approximately \$150,000 as of March 2012, with half of the total cost attributed to the cost of the tank alone (Lemas 2012).

5.1.6.7 Additional Facilities Cost (e.g., Refueling Station)

As demand for LPG increases, additional pumps may need to be added, as well as advanced fuel control systems for operators with multiple fuel systems. These pumps generally cost approximately \$5,000 each, while adding an advanced fuel control system to a base LPG installation will add \$15,000 to \$20,000 to the price (Lemas 2012).

5.1.6.8 Additional Jobs

The use of LPG will produce few additional jobs at the airport.

5.1.7 Electricity

5.1.7.1 Relative Change in PM and NO_x Emissions

Electric vehicles generate zero NO_x and significantly fewer PM emissions than gasoline or diesel engines at the point of use. (All vehicles, including electric vehicles, generate some PM associated with brake and tire wear.)

5.1.7.2 Relative Change in Life-Cycle GHG Emissions

Potential life-cycle GHG reductions depend on how the electricity is generated.

5.1.7.3 Relative Cost of Fuel

In terms of cents per kilowatt-hour, the cost of electricity is highly variable and typically ranges from 4.07 to 28.10, with the average price being 9.83 cents per kilowatt-hour in 2010

(EIA 2011a). This compares with the average price of \$26.67 per million BTU (DOE 2012b) (equivalent to 9.10 cents per kilowatt-hour) for gasoline. However, the cost of fuel does not tell the entire story, as electric engines are significantly more efficient at converting potential energy to useful work than are conventional gasoline internal combustion engines. DOE estimates that 75% of the potential energy from an electric motor will be used to power the wheels, while only 20% of the potential energy from an internal combustion engine will be used (DOE 2012d). This disparity means that, when accounting for differences in engine efficiency, the effective average cost for electricity will generally be less than that of gasoline.

5.1.7.4 Relative Cost of Vehicle/Plant

The capital costs of electric vehicles are generally higher than their gasoline or diesel equivalents. Two examples of light-duty electric vehicles currently on the U.S. market are the Nissan Leaf (Nissan 2012), which sells for more than \$32,000 and the Chevrolet Volt, which sells for just over \$40,000 (GM 2012). Both of these subcompact cars are \$15,000 to \$20,000 more expensive than their closest gasoline-powered competitors. These high upfront costs can be offset by lower operating costs (e.g., fuel, maintenance, and repair) of equivalent gasoline or diesel equivalents.

5.1.7.5 Relative Cost to Upgrade Existing Vehicle/Plant

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

5.1.7.6 Additional Infrastructure Storage Cost

See next section.

5.1.7.7 Additional Facilities Cost (e.g., Refueling Station)

For recharging of electric vehicles, assuming that trickle charging can be used and spare capacity already exists, little additional infrastructure development is needed. However, issues may arise from parking vehicles or equipment for long periods during recharging, implying some mix of mobile and stationary charging stations. Single-port, level 2 charging stations start at approximately \$2,000 each, and a DC fast charge station starts at about \$50,000 (McKuen 2011). Finding adequate space for the charging stations and vehicles can be an issue and needs to be investigated. Additionally, if an airport's peak power capacity is insufficient for the anticipated level of usage, then further costs will be incurred via the necessary expansion of the power infrastructure. Gate electricity and PCA supply for reducing APU usage are likely to require more infrastructure development than smaller-vehicle recharging points.

5.1.7.8 Additional Jobs

There would be temporary additional jobs created to meet the infrastructure requirements prior to this energy source coming on-line. In the long term, the use of electricity is unlikely to create any airport-related jobs.

5.1.8 General Observations

A number of observations can be seen from the information presented in this section:

- Alternative fuels have the potential to provide environmental benefits. 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, have the cost advantage of not requiring any changes to the existing storage and distribution infrastructure and equipment (e.g., aircraft, engines, GSE). 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 significant quantities. Current projections indicate that their initial price will be higher and decrease over time as more capacity comes on-line. Other alternative fuels (e.g., E85, B20, LPG, electricity) have been available at commercial scale for many years and their price histories are well documented.
- Few additional jobs, other than construction, are expected from the operation of alternative fuel distribution programs at airports.

5.1.9 Life-Cycle Evaluation

There are important trade-offs to consider when evaluating alternative fuels. Some alternative fuels are cheaper than conventional fuels, but the infrastructure requirements are more costly, as is the case of CNG. As a result, it is important to conduct a life-cycle evaluation of the program's costs and benefits. A detailed discussion of life-cycle evaluation for all the fuels included in this document is not within the scope of the program. However, the following case studies and tools offer information on life-cycle cost-benefit evaluations:

- Vehicle and Infrastructure Cash-Flow Evaluation Model (DOE 2012c)
- *Business Case for Compressed Natural Gas in Municipal Fleets* (Johnson 2010)
- *E85 Retail Business Case: When and Why to Sell E85* (Johnson and Melendez 2007)
- *Cost Benefit Analysis Modeling Tool for Electric vs. ICE Airport Ground Support Equipment—Development and Results* (Morrow et al. 2007)
- *Technical Support for Development of Airport GSE Emissions Reductions* (EPA 1999)
- *ACRP Report 78: Airport Ground Support Equipment (GSE): Emission Reduction Strategies, Inventory, and Tutorial* (CDM Federal Programs Corporation et al. 2012)

5.2 Social and Community Benefits

In addition to the environmental and economic benefits highlighted in the previous section, there are other social and community benefits associated with alternative fuel distribution programs. These benefits include diversification away from conventional petroleum-based fuels, improved reliability and security of supply, support of energy independence as imports of foreign petroleum decrease, and reduced volatility of the price of fuel. These benefits are described in more detail in Section 1.2.

5.3 Financial and Commercial Considerations

This section provides guidelines for evaluating financial and commercial considerations of alternative fuels distribution programs. These guidelines are intended to be sufficiently general to apply to all alternative fuels. However, it is important to note that some alternative fuels have higher risks than others and that these distinctions matter when evaluating financing decisions.

The financial risk associated with an alternative fuel decreases significantly when it has been proven at commercial scale. As a result, fuels are divided in two broad categories:

- **Commercial scale**—fuels that are already being produced in commercial quantities, with known costs and developed markets and distribution infrastructure:
 - Electricity
 - CNG

- LPG
- Biodiesel (B20)
- Ethanol (E85)
- **Pre-commercial scale**—next-generation transportation fuels that are not yet commercially available:
 - Alternative jet fuel
 - Green diesel

This section also presents information on public programs that are designed to finance alternative fuel distribution programs. These programs include ones administered by the USDA, DOE, and FAA.

5.3.1 Financial Considerations for Attracting Financing

For a program to attract financing, the promoters must demonstrate that they understand the program's risks and have a means of eliminating them. These risks can be characterized as technology, management, financial, policy, feedstock, engineering, and construction:

- **Technology**—This is likely to be the most significant risk of a next-generation fuel. For a fuel to be economically competitive with traditional fuels, it must be produced profitably at commercial scale and, at the time of the publication of this document, few next-generation fuels have been produced at a commercial scale. As a result, the technology is considered unproven by the financial community, and a financier will require a guarantee from an entity that has the resources to repay the loan if the technology has problems.
- **Management**—Exceptional management is essential to the successful implementation of new technology programs, and this skill is usually demonstrated via a history of successfully implementing new programs which have similar risks.
- **Financial**—Alternative fuel programs will typically require significant amounts of capital (tens or perhaps hundreds of millions of dollars) to be realized. Securing the necessary funds for a program of this size is a challenging task, especially for small or start-up companies.
- **Policy**—Governmental policy has a major impact on the likely profitability of a refinery and the cost of most alternative fuels. Because a fuel refinery has an economic life of over 20 years, the policies that are important to the program's success should have stability for a comparable period.
- **Feedstock**—For some alternative fuels, feedstocks account for the majority of the cost of the final product. As a result, it is important to be confident that there will be sufficient feedstock to supply the refinery at competitive prices for the refinery's life.
- **Engineering**—The firm that designs the infrastructure must have the skills appropriate for the technology and the site and also have the financial strength to guarantee its work.
- **Construction**—Similarly, the construction firm must have the skill to convert the engineering design into a plant within the contracted timeframe and have the financial strength to guarantee its work.

In addition to the seven risks mentioned above, an airport should review the following items when considering alternative fuel distribution programs:

- Are customers willing to enter into binding purchase agreements to reduce the financial risks and improve a program's financial viability? Do 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 program share the risks?

- Which stakeholders have the greatest interest in the program, and does that interest translate into their willingness to take a greater share of the risk?
- Which of the seven risks (technology, management, financial, policy, feedstock, engineering, and construction) are significant and how will they be mitigated?
- What is the availability of feedstocks, is its supply reliable, and is its future cost known?
- Are new technologies for production of alternative fuels likely to impact the program's economic viability? 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 program's overall environmental sustainability, including water use, land use, and life-cycle GHG benefits? Is the program likely to face local or national opposition that could increase its risk?
- 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 program's economic viability, can the policy be changed during the program's life, and how would that affect the program's viability?
- What is the quality and depth of the team that will manage this program?
- Can the required financing be found?

5.3.2 Public Financial Support for Alternative Fuel Programs

To date, developers for alternative fuel programs have looked to government programs for both grants and loan guarantees to help reduce risks. Public sources of financing include local, regional, and federal governments. Diverse local and regional initiatives exist 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 USDA and DOE, is providing incentives such as grants, loans, loan guarantees, subsidies, and tax credits. Some of these programs are outlined in the following paragraphs (Miller et al. 2011):

5.3.2.1 EPA Renewable Fuel Standards

The EPA'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 identification 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 alternative jet fuel. The value of RINs is largely determined 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.

5.3.2.2 USDA Programs

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. The Biorefinery Assistance Loan Guarantee Program in Section 9003 of the 2008 Farm Bill is of particular relevance to a developer of an alternative 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 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 obtaining financing easier by reducing the risks a banker would have to assume.

The Bioenergy Program for Advanced Biofuels in Section 9005 of the 2008 Farm Bill 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. The researcher’s 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 sources of biorefinery equity or debt are not expected to take these payments into account because they will change over time depending on how much bioenergy is produced.

The Biomass Crop Assistance Program in Section 9011 of the 2008 Farm Bill provides owners with dollar-for-dollar matching payments for the sale and delivery of eligible material to a biomass conversion facility (USDA 2009). 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 alternative fuel production, which could reduce the cost of the alternative fuel.

5.3.2.3 Carbon Markets

One approach to encouraging a reduction in GHG emissions is “cap-and-trade,” whereby a carbon market is created by “capping” the amount of CO₂ that regulated industries are allowed to emit and requiring them to obtain permits for the CO₂ they do emit. Over time, the cap on CO₂ is incrementally reduced, requiring regulated entities to obtain (“trade” for) an increasing amount of permits to cover their CO₂ emissions. 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 CO₂ from others if that is cheaper than investing in the technology to reduce their own emissions. Because renewable fuels generally are expected to have lower GHG emissions (measured on a life-cycle basis), it is anticipated that users will be able to reduce their carbon emissions. Thus, under a “cap-and-trade” regulatory regime, alternative fuels may have a cost advantage over traditional petroleum-based fuels if they have a lower GHG footprint.

Such a market—the European Union Emissions Trading System—has been in operation for carbon-intensive industries in the European Union since 2005 and is being expanded to include aviation in 2012. Many airlines and governments throughout the world have voiced their opposition to the system and its ultimate viability remains in doubt. In the United States, 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 United States 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 emissions 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.

5.3.2.4 Biofuel Tax Incentives

The federal government, through the Internal Revenue Service, has provided price support in the past to encourage development of ethanol and diesel from agricultural sources. The pro-

grams introduced in 2005 (in the American Jobs Creation Act of 2004 and Energy Policy Act of 2005; apart from the Small Ethanol Producer Credit, which was introduced in 1990 in the Omnibus Budget Reconciliation Act of 1990) provided as much as \$1.00 per gallon tax credits for road transportation fuels. They have now expired, causing disruptions in the marketplace for these products. The 2008 farm bill contains provisions that extend and modify tax credits on cellulosic ethanol, which is intended to spur investment in ethanol produced from cellulosic feedstocks rather than from corn starch.

5.3.3 Funding Overview of the Airport Improvement Program

FAA grant funding opportunities for fuel storage and dispensing systems 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 5100.38C, *Airport Improvement Program Handbook*, that allows for certain revenue-producing aeronautical support facilities at non-primary airports to obtain AIP grant funding (FAA 2005a). AIP funds can be used for fuel facilities serving aeronautical users, but alternative fuel systems are not eligible. 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. Non-primary commercial service airports are defined as airports that have fewer than 10,000 annual enplanements. Additionally, airports participating in the Military Airport Program are eligible to receive federal funding to support fuel facilities, regardless of whether they are primary or non-primary airports. Refer to FAA Order 5100.38C, *Airport Improvement Program Handbook* (http://www.faa.gov/airports/aip/aip_handbook/), for specifics on eligibility of fuel storage and dispensing systems.

The FAA's VALE program is a separate component of AIP. VALE funds projects that reduce ground emissions at commercial service airports located in areas that are in non-attainment or maintenance status with National Ambient Air Quality Standards (NAAQS) when converting from conventional fuels to certain eligible alternative fuels. The VALE program can fund eligible alternative fuel vehicles, equipment, and infrastructure when there is a demonstrated emissions benefit. For example, VALE could fund projects such as electric vehicles and rechargers, CNG buses, and CNG refueling facilities. Refer to the *VALE Technical Report* (<http://www.faa.gov/airports/environmental/vale/>) for specifics on program eligibility and application requirements.

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 GA 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 safely 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 may 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. Refer to FAA Order 5190.6, *Airport Compliance Manual* (http://www.faa.gov/airports/resources/publications/orders/compliance_5190_6/), for more specifics on grant assurances.

For more information on AIP grant funding and grant assurances, airports are encouraged to contact their local FAA office. Contact information for the FAA regional offices is available at http://www.faa.gov/about/office_org/headquarters_offices/arp/regional_offices/.

5.3.4 Clean Cities

Clean Cities is a government-industry partnership sponsored by the DOE to promote means to reduce the use of petroleum-derived fuels in the transportation sector (DOE 2012a). Clean Cities has nearly 100 coalitions all over the United States working on bringing together government agencies and private companies to develop plans to promote advanced transportation alternative fuels. 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 the DOE (2012a).

5.4 Legal and Regulatory Considerations

5.4.1 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 6 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 programs.

5.4.2 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 has several programs to promote alternative jet fuels. These programs include collaboration between the U.S. Navy and the USDA and DOE to invest up to \$510 million over 3 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 United States supporting the development of alternative jet fuels. Other recommended sources for the latest information about alternative jet fuels were listed in Section 1.7.

5.4.3 Regulatory and Policy Framework on Other Alternative Fuels

The regulatory and policy framework for other alternative fuels is complex, 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 6).

Table 6. Number of incentives and laws related to alternative fuels by jurisdiction (DOE 2011a).

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

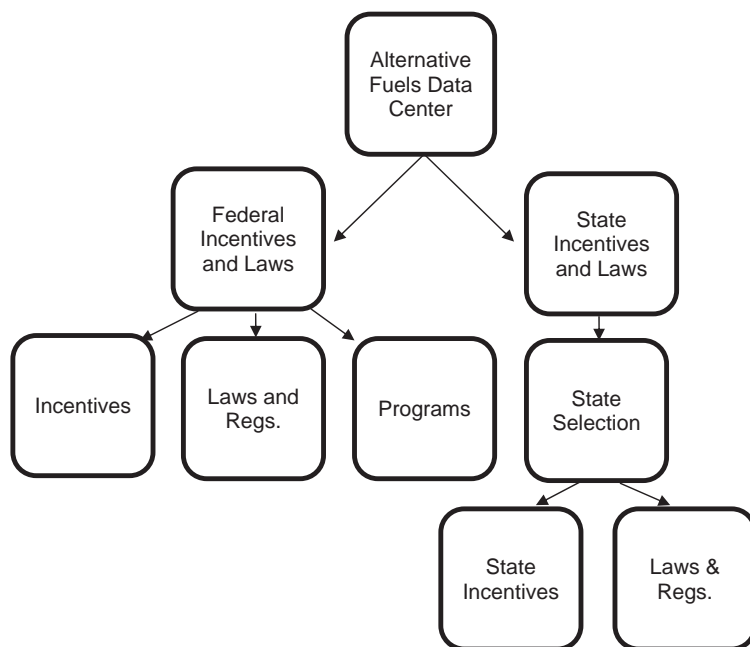


Figure 5. Organization of Laws and Incentives web pages on Alternative Fuels Data Center website (<http://www.afdc.energy.gov/afdc/>).

The DOE's Alternative Fuels Data Center (AFDC; <http://www.afdc.energy.gov/afdc/>) is an excellent resource for identifying and tracking federal and state incentives and laws that apply to alternative fuels and vehicles. This website has an entire section dedicated to incentives and laws that can be searched by technology and fuel, incentive, and state. It also has information that will help find incentives and laws at the local level. The organization of the portion of the AFDC website dedicated to incentives, laws, and regulations is given in Figure 5. Airports are encouraged to use this website as their first step in identifying incentives and laws applicable to them.

5.5 Stakeholder Engagement and Community Acceptance

5.5.1 Stakeholder Engagement

Stakeholder support is very important when evaluating alternative fuel distribution programs. An airport must have a clear picture of what its customers and other constituents need before allocating scarce resources. It is also helpful to understand institutional barriers and motivations of all stakeholders that may contribute to the program's success.

Many stakeholders are likely to become involved in alternative fuel distribution programs and can contribute to the airport's knowledge. Airports will benefit from identifying all the stakeholders and understanding their needs. Following is a list of stakeholders along the entire supply chain, from feedstock suppliers to end users, who are likely to be important to most programs, but airports are encouraged to consider unique local circumstances:

- Feedstock suppliers
- Fuel producers
- Fuel handlers

- Third-party concession operators
- Airports
- End users
- Vehicle and equipment manufacturers
- Unions
- Government entities
 - Municipalities
 - Metropolitan Planning Organizations
 - Counties
 - States
 - Federal government
- Funding sources
 - Public
 - Private
- Non-governmental organizations
- Community groups

Alternative fuel distribution programs need active stakeholders' support. Stakeholders have different motivations and needs for participating in an alternative fuel program. A "motivation" is defined as a reason for pursuing alternative fuels, and "need" is defined as the required outcome to enable support of the idea. The following list provides examples of motivations and needs by type of stakeholder.

- **Feedstock suppliers**
 - Motivations: market diversification for existing production, new market opportunities.
 - Needs: higher financial returns than available from supplying traditional feedstock to existing customers, mechanisms to protect financial returns (e.g., crop insurance).
- **Fuel producers**
 - Motivations: support of 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 appropriate to the program's risk.
- **Fuel handlers**
 - Motivations: support of existing customers, new market opportunities.
 - Needs: partnership with producers and end users.
- **Third-party concession operators**
 - Motivations: support of 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 program.
- **Airports**
 - Motivation: support of existing customers, diversification of revenue streams, achievement of environmental goals, community outreach.
 - Needs: ability to demonstrate economic and environmental benefits, minimization of infrastructure and fleet costs, long-term financial viability of the program.
- **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 of existing customers, new market opportunities.
 - Needs: partnerships with airports, end users, and third-party providers.

- **Unions**
 - Motivations: support of environmental targets and 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, counties, states, federal government)**
 - Motivations: meet policy objectives, respond to constituents' needs.
 - Needs: understanding of quantifiable and non-quantifiable economic and political benefits.
- **Funding sources (private sector)**
 - Motivations: diversification, new market opportunities.
 - Needs: guaranteed rates of return appropriate to the program's risks.
- **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.
- **Non-governmental organizations**
 - 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 motivations and needs of stakeholders can be identified and documented using Table 7. This table provides a detailed template that can be useful to understand the needs of each stakeholder, to determine whether or not the program meets those needs, and to identify exactly what specific actions must be taken to ensure the stakeholder actively and energetically supports the program.

5.5.2 Addressing Particular Concerns of Airport Leadership

Given the dynamic nature of the alternative fuel landscape, airport leaders should progress cautiously when considering significant changes in fuel sources. The following paragraphs briefly discuss relevant items that need to be addressed when considering an alternative fuel program.

5.5.2.1 *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 low. There is the risk that confusion about the benefits and challenges of different alternative fuels may make it difficult to obtain support for them. Addressing these concerns requires thoughtful explanations from sources that airport executives deem credible.

5.5.2.2 *Need for Solid Political and Economic Support*

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

Table 7. Stakeholder needs analysis.

Stakeholder Information	Response
Stakeholder (Name of entity):	
Role in program: (e.g., airport, airline, feedstock supplier, fuel producer, municipality/local government, public/private sector funder)	
Stakeholder mission	
Economic	
Non-economic	
Is program consistent with mission? (yes, maybe/not sure, no)	
Explanation	
“Hurdle rate”—specific minimum requirements that program must meet to obtain stakeholder’s participation	
Economic	
Non-economic	
Does program 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)	
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	

5.5.2.3 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.

Of particular importance is to recognize the organizational structure of the airport as there are many different alternatives. These can range from an airport being run by independent authorities to airports being part of a city or regional government. How the organizational structure affects priorities and decision making is important to understand as airport leaders can strengthen their proposals for alternative fuel programs by extending them to, or being part of, wider initiatives that may be undertaken by other city, local, or regional entities.

5.5.3 Community Acceptance

Alternative fuel distribution programs can provide many benefits to the airport and surrounding communities; however, some programs may create concerns. A recommended course of action is to acknowledge these concerns and to provide sufficient information to the community to discuss them. The assistance of outside experts may be required to resolve many of these complex questions.

5.5.3.1 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% of the domestic corn crop is used for ethanol production, which has caused 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 was the result of high energy costs, not corn ethanol production. The issue has become very political and there is little consensus regarding the impact of alternative fuel production on food production and prices.

To avoid the controversy surrounding the food-versus-fuel debate, some organizations and user groups, such as the 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). Nevertheless, these non-edible feedstocks can have direct and indirect impacts on the food supply. For further discussion of this complex topic, see Miller et al. (2011).

5.5.3.2 Water-Energy-Food Nexus

The “water-energy-food nexus” refers to the inextricable links between water, energy, and food. Although GHG impact has been the primary environmental focus of fuels to date, the importance of water scarcity, energy-based water consumption, and their impact on the world’s food supply have emerged as critical issues. 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 (McGuire 2001). Expected global population growth, coupled with increasing wealth and its corresponding impact on energy and food demand, will further stress already-strained global 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 the following issues: food versus fuel, hydraulic fracturing of shale rock formations to release oil and gas, and current and potential energy shortages due to lack of water to cool power plants.

Therefore, evaluations of alternative fuel programs must consider the program’s impact on water resources associated with that fuel’s complete supply chain. In particular, consideration should be given to water as (1) a production constraint, (2) a risk to business continuity and cost, (3) a critical environmental resource, and (4) potential source of political and public scrutiny. In addition, alternative fuel program 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 call for future researchers to systematically explore data weaknesses including in areas such as non-irrigated and second- and third-generation bio-fuels, 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.

There are no recent cross-cutting studies that systematically evaluate the water impact of various forms of conventional and emerging fuels. The following discussion is therefore based on emerging areas of consensus and identified unresolved issues based on the patchy and frequently outdated information available to date; it should therefore be revised as additional research is conducted.

The most useful way to consider the impact of the water-energy-food nexus on the fuels within the scope of this guidebook is to group the fuels into three categories:

- Hydrocarbon-based fuels, including CNG, LPG, natural gas, oil, or coal to fuel via FT
- Crop-based fuels, including biodiesel and ethanol
- Electricity, including thermoelectric (nuclear, coal, gas, oil), hydroelectric, solar thermal, solar photovoltaic, and wind

From there, the framework systematically addresses the impact of each category on water consumption, water withdrawal, and water quality; it also identifies key unanswered questions. Summary-level highlights are indicated in the following sections.

Hydrocarbon-Based Fuels. Water consumption of natural gas and petroleum serve as the reference point against which alternative fuels are compared. According to the DOE (2006), natural gas is the most water-efficient of any transportation fuel. The extraction and production of natural gas consumes approximately 2 gallons of water per million BTUs of energy content. By comparison, petroleum consumes approximately 12 gallons per million BTUs. This information is based on traditional production methods.

However the lowest-cost and most easily accessible oil and gas reserves have been depleted, which is forcing oil and gas companies to use increasingly prevalent “unconventional” methods of extracting oil and gas that are buried deeper in the earth, further offshore, or trapped in rocks such as shale that do not as easily release their hydrocarbons. For oil, these methods include mining and refining a tar-like oil mixed with sand such as in the Canadian oil sands and “enhanced oil recovery” techniques that involve injecting water, CO₂, and other solvents to move the petroleum into a well that lifts it to the surface. Technological advances and cost reductions in another unconventional technique called “hydraulic fracturing” have led to dramatic increases in both oil and gas production from very dense shale rock formations that were previously unprofitable to drill. Hydraulic fracturing involves injecting water under very high pressure to fracture the shale rock, which releases the oil and gas trapped within. It is clear that all these unconventional techniques are more water consumptive than traditional oil and gas extraction methods, and some forms of enhanced oil recovery are particularly so (Mielke et al. 2010). The water intensity

of hydraulic fracturing per BTU is unresolved, and its pollution impact is a particularly heated area of public debate.

For hydrocarbons, water impact is largely driven by extraction. Converting natural gas to CNG; producing LPG from molecules of propane and butane, which are closely related to natural gas; or converting hydrocarbons to alternative aviation fuel are not believed to materially impact water consumption per BTU. Incremental FT water consumption relative to traditional oil and gas is driven by cooling; however, this water is largely recaptured, which reduces net impact.

Crop-Based Fuels. As cited by the DOE (2006), agriculture and meat production are responsible for more than 80% of freshwater consumption, primarily via evaporation and irrigation. In arid or water-stressed environments, weather patterns can carry water vapor away; the amount that falls back to its source is insufficient to replace what was removed. To the extent possible, users should probe where energy crops are grown and attempt to understand the impact of the incremental energy crop on both local freshwater resources and the broader water systems of which they are a part.

In 2006, the National Labs concluded that the best available data at that time indicated that first-generation irrigated corn and soy-based biofuels consume thousands of times more freshwater than petroleum or natural gas per BTU of energy produced (DOE 2006). In addition, irrigation generally consumes large amounts of energy and emits ancillary carbon emissions. Most corn- and soy-based biofuels are not irrigated. Nonetheless evaporation drives consumption, and non-irrigated biofuels remain substantially more water intensive than traditional oil and gas. Crops grown in water-abundant regions could potentially constitute a net transfer of water to more water-stressed areas because of the water embedded in the crop, whereas the reverse could be true if crops are grown in water-stressed areas. There are also important pollution and health concerns regarding the impact of pesticides, biocides, fertilizers, and runoff resulting from agricultural practices.

Substantial effort is under way to develop second- and third-generation biofuels that require less water. However, it is important to recognize that even if they do not directly compete with food, they may utilize the same water resources or impact the same water systems that food crops draw upon. Even if contemplated energy crops grown on marginal land do not divert land from food production, they could nonetheless potentially impact local freshwater resources and systems. For example, if grown inappropriately in sensitive areas there is a potential as with any crop to contribute to accelerated rates of desertification; on the other hand, there may be opportunities to stabilize and strengthen local soils.

Some parties are concerned that energy crops that are not believed to compete with food may still indirectly divert arable land from food production and drive deforestation. Forests are a primary source of fresh water so their clearance constitutes an additional impact. The extent of this impact from these potential land use changes is an unresolved issue.

Evaluating the water impact of feedstock derived from agricultural waste products involves considering the water impact of the underlying crop. To the extent that MSW feedstock is composed of food, its water impact also reflects the underlying crops or meat.

For crop-based fuels, water impact is largely driven by agricultural production. The conversion of crops to fuels, including via HEFA, is not believed to materially impact water consumption per BTU—even including the water it consumes as part of the process. Similarly for emerging production pathways such as ATJ and FTJ, water consumption is driven by the agricultural products from which alcohol and sugar feedstocks, respectively, are primarily derived; technological efforts to develop non-agriculture-based feedstocks could potentially lower water impact. PRJ's water impact is largely driven by underlying sewage sludge feedstock; similar to FT, PRJ requires incrementally more water per BTU than traditional oil or gas for cooling; however, this water is largely recaptured, which reduces net water impact.

Electricity. As cited by the DOE (2006), electricity production consumes roughly 20% of freshwater that is not consumed by agriculture and meat. The water impact of electricity depends on how the electricity was produced. The vast majority of electricity production is from thermoelectric power generation such as by burning coal, gas, or oil or via nuclear reaction. Water consumption is largely driven by the need to cool the hot turbines in these thermoelectric power plants. According to the World Policy Institute, “natural gas-fired power plants are the most water-efficient conventional electricity generators. Coal and nuclear consume two and three times, respectively, more water per unit of electricity” (Glassman et al. 2011).

The water impact of renewable electricity varies widely. The installed base of solar-thermal electricity is five times more water consumptive per megawatt-hour than electricity from a natural gas-fired power plant. Solar photovoltaic and wind-powered electricity consume minimal amounts of water. From a life-cycle perspective, photovoltaic solar cell production is highly toxic and can lead to significant water pollution in countries without stringent environmental policies or enforcement. The water impact of biomass-derived electricity must consider the water impact of the feedstock.

Hydroelectric water consumption is driven by evaporation from the large artificial reservoirs they require. Depending on the methodology used to allocate the reservoir to alternative uses such as irrigation, fishing, recreation, etc., water impact varies widely—from zero water consumption to thousands of times more water consumption than natural gas per megawatt-hour.

Evaluation Framework Step C: What Are the Main Siting Considerations for Alternative Fuel Distribution Programs?

This section corresponds to Step C in the evaluation framework presented in Figure 3. 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. The workbook spreadsheet has templates to help with this evaluation.

6.1 Introduction to Siting Considerations

FAA policies and regulations largely control what can or cannot be done in the airport setting. The construction and operation of alternative fuel infrastructure is no exception. The FAA compiles and maintains a number of documents, including Advisory Circulars (ACs), Orders, and references to other documents that should be considered when evaluating the feasibility of placing alternative fuel infrastructure in the airport setting. In addition, given the complex technical issues surrounding fueling system and airfield design, engaging an aviation engineer familiar with these topics may be advisable to assist with locating a processing facility.

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 Airport Sponsor Grant Assurances (http://www.faa.gov/airports/aip/grant_assurances/)
- FAAAC 150/5300-13, Airport Design (http://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5300-13)
- Federal Aviation Regulations (FAR) Part 77, Subpart C: Standards for Determining Obstructions to Air Navigation or Navigational Aids or Facilities (<http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=2d79c95db81aec2c906f2211aa809a28&rgn=div5&view=text&node=14:2.0.1.2.9&idno=14#14:2.0.1.2.9.3>)
- FAA Order 1050.1E, Environmental Impacts: Policies and Procedures (http://www.faa.gov/documentLibrary/media/order/energy_orders/1050-1E.pdf)
- FAA Order 5050.4B, National Environmental Policy Act (NEPA) Implementing Instructions for Airport Projects (http://www.faa.gov/airports/resources/publications/orders/environmental_5050_4/)
- FAA AC 150/5070-6B, Airport Master Plans (http://www.faa.gov/documentLibrary/media/advisory_circular/150-5070-6B/150_5070_6b_chg1.pdf)
- FAA AC 150/5200-33, Hazardous Wildlife Attractants on or Near Airports (http://www.faa.gov/documentLibrary/media/advisory_circular/150-5200-33B/150_5200_33b.pdf)

- FAA AC 150/5210-20, Ground Vehicle Operations on Airports (http://www.faa.gov/documentLibrary/media/advisory_circular/150-5210-20/150_5210_20.pdf)
- FAA AC 150/5230-4A, Aircraft Fuel Storage, Handling, and Dispensing on Airports (http://www.faa.gov/documentLibrary/media/advisory_circular/150-5230-4A/150_5230_4a.pdf)
- FAA Order 5190.6B, Appendix R, Airport Layout Plan, *Airport Compliance Manual* (http://www.faa.gov/airports/resources/publications/orders/compliance_5190_6/media/5190_6b_appR.pdf)
- FAA Order 5190.7, Minimum Standards for Commercial Aeronautical Activities (http://www.faa.gov/documentLibrary/media/advisory_circular/150-5190-7/150_5190_7.pdf)
- National Fire Protection Association (NFPA) 407, Standard for Aircraft Fuel Servicing
- 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 415, Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways, 2008 Edition (if applicable)
- Title 14 of the Code of Federal Regulations (CFR) Part 139, Certification of Airports (http://www.faa.gov/airports/airport_safety/part139_cert/)
- Transportation Security Administration, *Recommended Security Guidelines for Airport Planning, Design and Construction*, May 2011 (http://www.tsa.gov/assets/pdf/airport_security_design_guidelines.pdf)
- Title 40 CFR Part 112, Oil Pollution Prevention (http://www.epa.gov/osweroe1/docs/oil/cfr/0703_40cfr112.pdf)
- Applicable Fire Code regulations (i.e., International Fire Code, Uniform Fire Code, NFPA 1 Fire Code, or other)
- FAA Best Practices for Environmental Impact Statement (EIS) Management (http://www.faa.gov/airports/environmental/eis_best_practices/)
- FAA Environmental Desk Reference for Airport Actions (http://www.faa.gov/airports/environmental/environmental_desk_ref/)

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 generalized siting plan is presented in Table 8.

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. The flowchart shown in Figure 6 illustrates these steps graphically.

6.2 Steps for Siting Alternative Fuels

6.2.1 Step 1: Inventory Airport Fuel Storage Facilities/Distribution Systems

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

Table 8. General considerations for siting alternative fuel distribution programs at airports.

Step	Key Considerations
1. Inventory existing airport fuel storage facilities and distribution systems, and 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 can accommodate the future alternative airport fuel storage requirements
3. Identify long-term goals and objectives for the alternative airport fuel storage facility and distribution system	Determine which alternative airport fuel storage facilities and distribution systems should be considered and identify the appropriate planning track for evaluation (see Figure 6)
4. Identify preliminary alternative fuel storage facility development sites	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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

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 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. Also, many

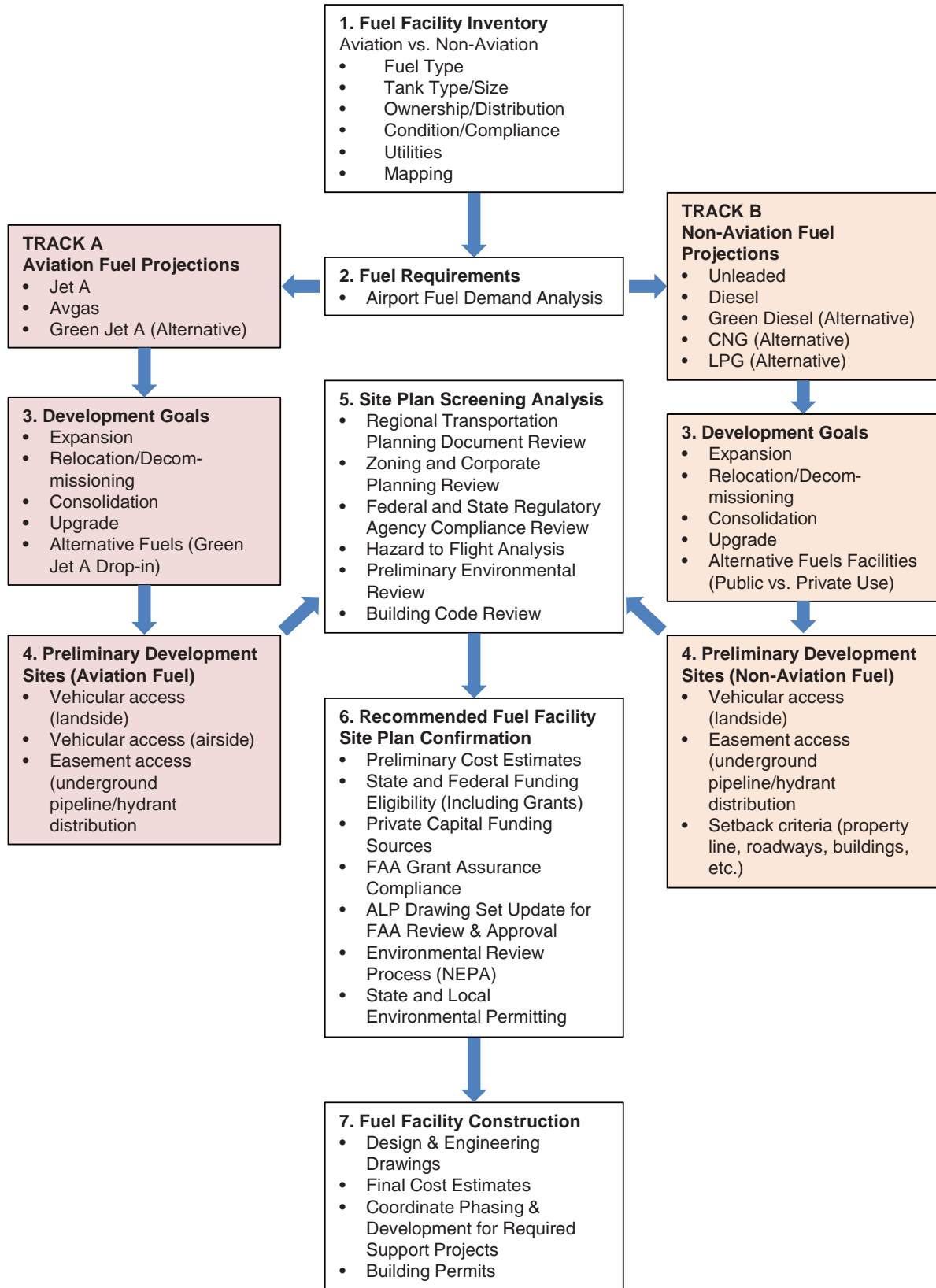


Figure 6. Planning process for siting alternative fuel storage and distribution facilities at airports.

airports likely have a Storm Water Pollution Prevention Plan or a Spill Prevention, Control, and Countermeasure Plan that details 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 (e.g., maintenance and aircraft rescue and fire fighting), 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. Once the inventory is complete, the airport should evaluate each item 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

6.2.2 Step 2: Identify Fuel Storage and Distribution System 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 distribution system 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 the case of non-aviation-related fuels, an analysis of related fuel storage requirements will also be necessary. The land footprint of a typical off-airport refueling station should be utilized as a reference to determine airport land requirements for the siting of any new refueling stations for non-aviation. Traditional gasoline refueling stations vary significantly in size and required land footprint. While plots of land hosting gasoline stations range from as small as 0.3 acres to 5 acres or more, the average size is about 1 acre (Xerxes Corporation 2012). Because underground fuel tanks can range from 7 feet in length (600-gallon tank) to nearly 75 feet in length (50,000-gallon tank), airports should ensure that they allow enough room for adequate underground storage to meet foreseeable demand for the selected stocked fuels. An overview of infrastructure requirements is shown in Table 9.

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

Table 9. Summary of infrastructure requirements for alternative fuels distribution systems (FAA 2010b, Xerxes Corporation 2012).

Fuel	Land Requirements	Infrastructure & Storage Requirements	Delivery System to Fueling Site	Storage System	Distribution System
Alternative jet fuel	Same as conventional jet fuel	Same as conventional jet fuel	Same as conventional jet fuel	Same as conventional jet fuel	Same as conventional jet fuel
Gasoline	0.3–5 acres	Storage tanks, pumps, control system, piping system	Pipeline, truck	Underground tanks	Fuel pump
Diesel	0.3–5 acres	Storage tanks, pumps, control system, piping system	Pipeline, truck	Underground tanks	Fuel pump with diesel-only connector
LPG	Similar to gasoline/diesel	Storage tanks, pumps, control system, piping system	Pipeline, truck	Underground or aboveground tanks	Fuel pump with LPG connector
CNG	Larger than gasoline/diesel	Compression system, pressurized storage tanks	Pipeline	Underground tanks, line packing	CNG dispensing system, fast fill nozzles
E85	Similar to gasoline/diesel	E85-compatible dispensers, pumps, pipes, and tanks	Truck	Underground tanks	Fuel pump with E85-specific markings
Biodiesel	Similar to gasoline/diesel	Dedicated tanks recommended for higher blends (above B20). Existing diesel tanks can be used, but filter clogging is likely to occur	Truck	Underground or aboveground tanks	Fuel pump with diesel-only connector (also specific markings to differentiate from ULS diesel)
Green diesel	Similar to gasoline/diesel	None, if there is existing diesel infrastructure present	Truck	Underground or aboveground tanks	Fuel pump with diesel-only connector
Electricity	Smaller than gasoline/diesel	Electric utility point of service, individual parking spaces, charging stations, utility branch accounting system (to separate electricity used by site from that used by charging vehicles)	Electric distribution system	None	Electric distribution system

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 to 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).

6.2.3 Step 3: Identify Alternative Fuel Storage and Distribution Goals

The third 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.

The following list presents possible development scenarios that may arise relative to the future provision of alternative fuels on the airport:

- Non-aviation fuels
 - Develop new public-use fuel-dispensing facilities for alternative vehicles on airport property (facilities would serve private vehicles that operate on alternative fuels).
 - Develop new private-use fuel-dispensing facilities for alternative vehicles on airport property (facilities would serve airport operation and maintenance vehicles, airline ground service vehicles, rental car facilities, etc.).
- Aviation fuels
 - Expand existing airport fuel storage facility to accommodate increased demand.
 - Relocate or decommission existing airport fuel storage facility due to environmental compliance or development and expansion constraints.
 - Consolidate multiple existing fuel storage facilities.
 - 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 is practical.

As with any airport facility, fuel storage and distribution facilities must comply with FAA AC 150/5300-13 (FAA 1989), which contains definitions for runway protection zones (RPZs) and runway object free areas (ROFAs) (see Figures 7 and 8). This AC prohibits objects non-essential to air navigation or ground maneuvering purposes in ROFAs and states that fuel storage facilities may not be located in the RPZ. FAA Order 5190.6B (FAA 2009) reiterates that fuel storage facilities are a prohibited RPZ land use. Additionally, 14 CFR Part 77 (FAA 1993) establishes standards for determining obstructions to air navigation by defining criteria for imaginary surfaces that

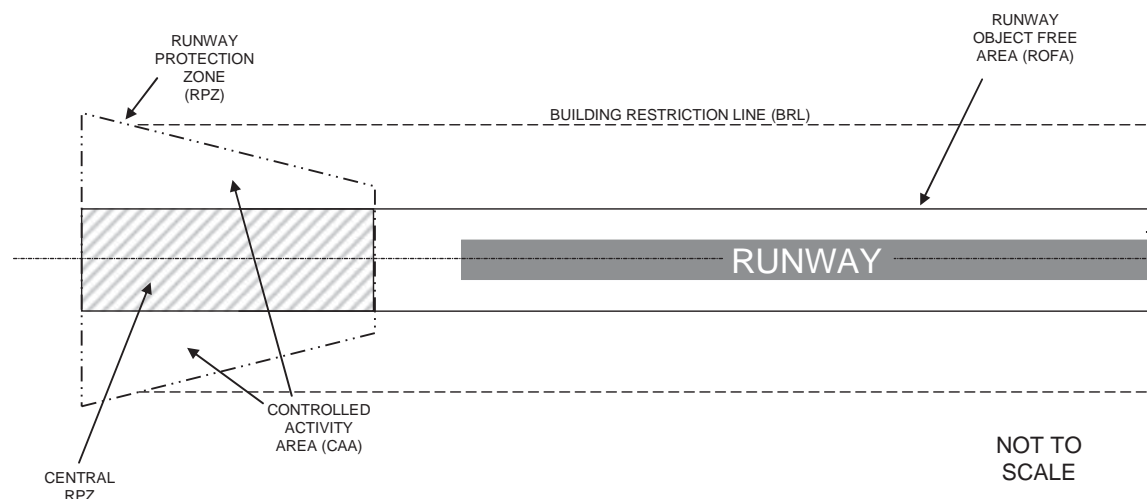


Figure 7. Controlled activity area [Figure 2-3 (FAA 1989)].

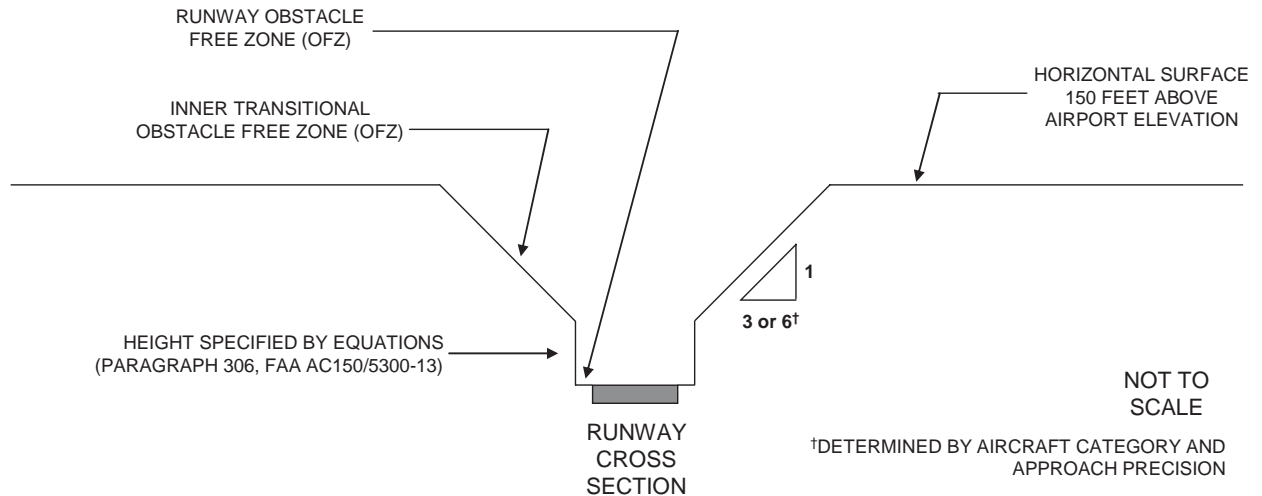


Figure 8. Obstacle free zones around runways [Figure 3-5 (FAA 1989)].

must not be pierced by any structure, including fuel production and storage facilities. Another consideration is that the proposed project must be shown on the ALP, as indicated in FAA Order 5190.6B (FAA 2009).

FAA AC 150/5230-4A (FAA 2004) states that NFPA 407 (NFPA 2007) lists specifications for the design, operation, maintenance, and location of fuel storage areas and aircraft fueling devices. Generally, it requires that fuel pumps, storage tanks, and related facilities be at or below ground level. However, NFPA 407 itself does not give many specifics on the design and siting requirements of fuel facilities. NFPA 407 allows the authority having jurisdiction to establish these requirements. The authority having jurisdiction may be a federal, state, local, or other regional department or individual.

The construction of alternative fuel facilities on or proximate to an airport will require an environmental review to adequately assess and disclose the potential for impacts to the environment from such a facility. FAA Order 5050.4B (FAA 2006b) provides information relative to the environmental review process that may be required. A NEPA determination is required for an obligated airport. FAA Order 5050.4B specifies three types of reviews: categorical exclusions (CATEXs), environmental assessments (EAs), and environmental impact statements (EISs). The type of review required will be determined by the responsible FAA official with jurisdiction over the program.

The type of review will also depend on the estimated significance of the impact of the program on the environment. A governmental agency's involvement expands depending on the circumstances that are likely to be highly controversial on environmental grounds. FAA Orders 1050.1E and 5050.4B both stress the importance of early contact with the FAA to avoid delays in the NEPA process.

Alternative fuel facilities located outside of the airport limits are not subject to the FAA policies and regulations governing on-airport facilities; however, near-airport and off-airport facilities must still comply with 14 CFR Part 77. For example, objects such as light poles, trees, construction cranes, and even tall buildings (sometimes miles away from the airport) can be in violation of 14 CFR Part 77 and would, therefore, present a potential hazard to aircraft operating in the area. Form 7460-1, Notice of Proposed Construction or Alteration, needs to be completed and filed with the FAA prior to construction for an airspace analysis and determination for on- or off-airport programs.

In addition to the FAA documents discussed in the previous paragraphs, it is important to indicate other resources available to jet fuel handlers. For example, A4A (formerly known as Air Transport Association or ATA) publishes the *ATA Specification 103: Standard for Jet Fuel Quality Control at Airports* (ATA 2009). This document includes recommended specifications that have been developed to provide guidance for safe storage and handling of jet fuel at commercial airports. While these recommendations are not mandatory, they are very closely followed by all major airlines and airports in the United States.

6.2.4 Step 4: Identify 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 (1) the provision of vehicular access, (2) the method of fuel distribution, and (3) 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 the fuel delivery tankers that use the regional roadway transportation system as well as airside access to the refueler trucks that use a combination of internal non-licensed vehicle roads and airfield pavement to serve individual aircraft. These criteria include adherence to local roadway engineering design standards (lane dimensions, curb radii, outside radius, roadway cul-de-sac dimensions, etc.) for tanker trailer maneuvering and emergency vehicle response. Ideally, fuel storage facilities allow both off-airport and on-airport vehicles to access the site conveniently. Therefore, a design solution should be sought that accomplishes the following:

- Minimizes travel times to and from the designated aircraft fueling areas
- Minimizes or avoids the crossing of aircraft movement areas by refueler trucks
- Does not interfere with future airport development or the expansion of aeronautical services, both airside and landside
- Allows for off-airport vehicles that are unfamiliar with airport operations to safely and intuitively utilize the facilities

It is important to highlight the need to separate ground vehicle access and aircraft operational areas for safety and security reasons, as indicated in 14 CFR Part 139 and AC 150/5215-20, Ground Vehicle Operations on Airports. In addition, the location of fuel facilities should be outside the secure aircraft operational areas and in places that do not require vehicles to cross aircraft apron areas. This is particularly important if the fuel distribution system includes users not familiar with airport operations, such as private vehicles and taxis.

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 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 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 the following:

- 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 AC 150/5300-13 prohibits the siting of fuel storage facilities within RPZs, 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, closed-circuit television 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.

6.2.5 Step 5: Screen Sites and Prepare Preliminary Fuel Storage Facility Site Plans

The fifth 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
- Supplemental hazard to flight analysis (e.g., FAA airport design criteria and FAR Part 77)
- 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.

6.2.6 Step 6: Select One of the 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 program 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: review for potential CATEX for proposed action, or determine the need for environmental analysis based on potential for extraordinary circumstances. Review program for the potential need to conduct 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

6.2.7 Step 7: Construct Alternative Fuel Storage Facility

The seventh step in the process is to implement construction of the alternative fuel storage and distribution 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 facility (such as access road, gates, etc.) and obtain local building or construction permits. This process has numerous steps and requires more detailed instructions than can be given in this guidebook. Readers are encouraged to engage outside experts for further guidance.

6.3 Environmental Reviews and Permitting

Environmental reviews and permitting will be requisite activities in the planning process for any alternative fuel distribution program. Jurisdictions at the federal, state, and local levels require permits for those activities or facilities that they view as affecting the environment, safety, or equity of the surrounding population. Alternative fuel distribution programs affect each of these three components. In general terms, the main categories of interest in the environmental review and permitting process tend to be the following:

- Water quality, including environmental impact on drinking and ground water, wastewater, and surface waters including storm water, coastal areas, wetlands, or floodplains
- Air quality, including environmental impact of gaseous and other emissions
- Impacts to historic landmarks, coastal regions, endangered species, or other environmental resources by facility construction, operation, maintenance, or access
- Land quality, including solid waste disposal, hazardous waste handling and disposal, and spill prevention, reporting, and cleanup
- Land use planning and zoning, including impacts to shared infrastructure such as roads and railways

6.3.1 Environmental Review

At the federal level, alternative fuel programs need to comply with the NEPA and applicable laws protecting sensitive environmental resources. NEPA outlines a process by which agencies are required to determine if their proposed actions have significant environmental effects. Depending on a number of factors, including the severity of the environmental effects, a CATEX, EA, or EIS may be required (see FAA Order 1050.1E for more information). Environmental effects that should be analyzed may include growth-inducing effects related to changes in land use and population density, and related effects on air and water and other natural systems, including potential impacts to ecosystems that an action may cause. In particular, the environmental issues addressed in the *Environmental Desk Reference for Airport Actions* (FAA 2007), or Appendix A of Order 1050.1E, should be investigated during the NEPA process. This must occur thoroughly before the FAA makes a decision on approving an alternative fuel facility.

At the state and local level, environmental review and permitting requirements and regulations vary to a high degree. Many states are developing review processes and integrated guidance materials on environmental review and permitting activities relative to infrastructure that may be applicable to alternative fuel programs (see Appendix C). Furthermore, the EPA maintains a database of state-specific regulatory information at <http://www.epa.gov/lawsregs/states/index.html#state>. Readers should consult this resource for guidance specific to their local conditions.

6.3.2 Environmental Permitting

This section provides an overview of federal, state, and local permitting processes to identify the breadth of permitting requirements that might be expected in developing alternative fuel production, storage, and distribution infrastructure. This is not intended to be a comprehensive review as requirements and processes vary from jurisdiction to jurisdiction.

There are various motivations for permitting, primarily to ensure protection of public health, safety, and environmental quality. Permitting requirements vary from state to state and have local nuances with respect to county, city, and other jurisdictional requirements—and they apply to the production of alternative fuels as they do to any other facility.

Most of the existing guidance issued by jurisdictions pertains to biodiesel facilities. For example, the State of Washington has two publications pertaining to biodiesel permitting. One of them is a fact sheet that lists the permits, regulations, and tax benefits associated with a biodiesel plant (State of Washington 2010a). The other publication appears on the State of Washington's Department of Ecology website (State of Washington 2010b). Table 10, taken from that website, lists the permits that a biodiesel manufacturer should consider; furthermore, the department notes that while these are “commonly required permits,” considerations “are not limited to” those listed in Table 10. The permitting process for biodiesel should be a reasonable approximation for that of other alternative fuels.

6.3.3 Land Use and Zoning in the Vicinity of Airports

Being a good neighbor is often a principle that airports adopt, as it fosters a mutually beneficial relationship between airport operators and surrounding developments and avoids potentially costly litigation. To avoid conflict with airport surroundings, land use zoning must be done carefully.

Zoning rules and regulations vary considerably from one jurisdiction to another, and it is not practical to summarize them in this document. Airports should consult *ACRP Report 27: Enhancing Airport Land Use Compatibility, Volume 1* (Ward et al. 2010) and the FAA *Land Use*

Table 10. Examples of commonly required permits (State of Washington 2010b).

Jurisdiction	Type of Permit
City and county	<ul style="list-style-type: none"> • Building • Preliminary/final plat • Grading • Water system • Shoreline • Right of way • Utility • Site plan review • Septic system • Floodplain development • Variance (e.g., zoning, shoreline) • Outdoor burning
State	<ul style="list-style-type: none"> • Department of Fish and Wildlife <ul style="list-style-type: none"> – Hydraulic project approval – Bald eagle management – Grass carp – Shooting preserve • Department of Natural Resources <ul style="list-style-type: none"> – Forest practices – Aquatic lease – Burning (forest slash) – Reclamation • Department of Ecology <ul style="list-style-type: none"> – Water rights – Well drilling – National Pollutant Discharge Elimination System (NPDES) – Water quality certification – Storm water – Underground storage tank certification – Dangerous waste • Air Authority/Department of Ecology <ul style="list-style-type: none"> – New source review, for a business or industry – Notice of intent, for demolition projects
Federal	<ul style="list-style-type: none"> • U.S. Army Corp of Engineers <ul style="list-style-type: none"> – Section 10 (navigable waters) – Section 404 (fill in waters) • U.S. Coast Guard <ul style="list-style-type: none"> – Section 9 (bridges) • National Marine Fisheries/U.S. Fish and Wildlife • Endangered Species Act consultation

Compatibility and Airports report (FAA 2001) for a deeper discussion of this topic. Nevertheless, there are a few general observations that can help airports evaluate alternative fuel programs with respect to zoning:

- **Obstacles to air navigation:** The FAA requires that there be no object, man-made or natural outgrowth, that is 200 feet from the ground level of the airport and within a 3-nautical-mile radius of the established reference point of the airport. Other requirements are listed in FAR Part 77.
- **Noise assessment:** If construction of alternative fuel facilities requires modifications to existing airspace procedures, a proper EIS may be needed before the FAA can approve route changes when there is a significant noise impact on the affected population. A NEPA determination is needed at obligated airports. See Section 6.3.1 for more information.

- **Agricultural land near airports:** The FAA recommends against using airport property for agricultural production because agricultural crops can attract wildlife during some phases of production (FAA 1997). If the airport requires agricultural crops as a means to produce income necessary for the viability of the airport, it needs to follow the crops distance guidelines established in AC 150/5300-13, Appendix 17. Airports should be advised that the FAA may require a Wildlife Hazard Assessment (WHA) or a Wildlife Hazard Management Plan when specific triggering events occur on or near an airport, as specified in 14 CFR Part 139. Such events include an aircraft ingesting or striking wildlife or observation of wildlife of a size or in numbers capable of causing an aircraft strike or engine ingestion. The WHA must be conducted by biologists with the appropriate training and education as specified in AC 150/5200-36A. Agricultural land use is compatible with airport operations from a noise sensitivity perspective (FAA 2001).

6.3.4 Additional Notes on Permitting

One significant risk with the permitting process is that it can stall a program's implementation or scuttle it entirely. Because of this risk, incorporating adequate lead time is absolutely necessary to meet all permitting requirements and to avoid delays in program coordination, planning, design, engineering, site preparation, and construction necessary for the development of alternative fuel infrastructure. Front-end planning with appropriate time buffers provides flexibility in schedule adherence.

This section has emphasized the motivation, complexity, and uncertainty associated with permitting. Because each alternative fuel facility carries its own risks, the permitting process should be customized to each situation. Therefore, airports are advised to utilize a consultant with expertise in this matter.

Representative Case Studies

Four case studies have been prepared to illustrate a number of analyses and questions that can be addressed with this guidebook and associated toolkit:

- **Analysis of energy demand from a subset of users:** Many airports are interested in introducing alternative fuels for only a subset of users (e.g., only airport-owned vehicles) and would like to use the toolkit to investigate options. Using Charleston International Airport in South Carolina as an example, this case study illustrates how an airport can use the toolkit to analyze a subset of the potential energy users and alternative fuels without the need to fill out the entire energy matrix.
- **Analysis of total energy demand at the airport:** In contrast to the Charleston case study, some airports want to produce a demand profile for all the users at the airport to make informed strategic planning decisions with respect to future energy use. Using Seattle-Tacoma International Airport as an example, this case study illustrates the advantages and disadvantages of using the energy matrix to capture this projected demand.
- **Support business plan for alternative fuel use at airports:** Using Hartsfield-Jackson Atlanta International Airport, this case study demonstrates how the guidebook and toolkit can be used to help airports and potential producers evaluate business opportunities at the airport.
- **Siting considerations:** To illustrate the framework for evaluating siting considerations presented in Section 6, an analysis is performed using Tulsa International Airport in Oklahoma as a hypothetical example. This case study provides a summary description of the application of the steps in the siting evaluation framework.

These case studies are short and focus on specific applications of these tools. They were chosen to be illustrative and not comprehensive.

7.1 Analysis of Energy Demand from a Subset of Users

7.1.1 Overview of Charleston International Airport

Charleston International Airport (CHS) is the busiest airport in South Carolina and serves as both a commercial and military field. CHS is a unique airport for a variety of reasons. The airport is the largest joint commercial/military air facility in the nation and it is in a high-growth area for marine, air, and rail transportation. Additionally, Boeing is in the process of expanding its Charleston factory, which currently houses the 787 Dreamliner assembly line. On the other hand, unlike many large commercial airports, the airport does not have access to a dedicated fuel delivery pipeline. This lack of access to a pipeline makes

CHS susceptible to occasional supply disruptions. Thus, by pooling the combined needs of the commercial and military users at CHS, the airport represents a significant node for multi-modal fuel demand. At the same time, the potential for supplying the airport with alternative fuels that may be produced locally would contribute to the supply reliability on the airfield.

7.1.2 Case Study Objective

CHS is interested in understanding its energy use and investigating alternative fuel distribution options. In particular, CHS wants to get a better understanding of the energy used by its largest clients (commercial air carriers and general aviation) and by its own vehicles. Like many other airports, CHS keeps track of only a limited set of energy users at the airport. CHS has data for the consumption of unleaded gasoline and conventional diesel by its own fleet of vehicles and GSE, and for the jet fuel dispensed to commercial aircraft on the airfield. However, the airport does not have information on fuel use by many other users such as the military and ground access vehicles (e.g., shuttles, taxis, private vehicles). This case study illustrates how the energy mix spreadsheet can be used to understand current energy use and investigate future options for alternative fuels even if information for possible users is not readily available.

7.1.3 Current Energy Use for Selected Users

The first step in the analysis of alternative fuel distribution options is to understand the current energy use at the airport. The energy mix spreadsheet provides rough estimates based on very simple statistics of airport operations; however, if more accurate information is available, it should be used instead. In the case of CHS, the airport had actual fuel use data as shown in Table 11.

Notice that information for military, groundside vehicles, off-airport users, and buildings was not available from the airport; however, since the airport is interested primarily in fuel use by commercial carriers and GA aircraft and its own vehicles, the information provided is sufficient to perform an analysis. The information shown in Table 11 was used to populate the “MatrixCurrent” worksheet in the energy mix spreadsheet. The results are shown in Table 12.

Table 11. Fuel consumption for selected users at CHS (Source: CHS airport).

User		Fuel Type	Fuel Use in 2011 (000 gal)
Aircraft	Passenger jet aircraft*	Jet A	17,300
	GA jet aircraft	Jet A	2,800
	GA piston aircraft	Avgas	152
Airside vehicles	Passenger GSE*	Unleaded gasoline	8
		Diesel	49
	Airport vehicles	Unleaded gasoline	24
		Diesel	3

*Note: The information provided regarding jet fuel and GSE fuel does not differentiate between passenger and cargo operations. For simplicity, it is assumed that all this fuel was used on passenger aircraft and passenger GSE.

Table 12. Energy demand screenshot with fuel use numbers from 2011 as provided by CHS.

		Energy Demand in 2011 at CHS															
		Conventional jet (000 gal)	Alternative jet (000 gal)	AVGAS (000 gal)	Gasoline (000 gal)	EB5 (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	
Current energy demand																	
Aircraft	* Passenger jet aircraft	100%														100%	
		17,300															
	* Cargo jet aircraft																
	Military jet aircraft																
	GA jet aircraft	100%														100%	
	GA piston aircraft			100%												100%	
				152													
Airside	* Passenger GSE				14%		86%									100%	
					8		49										
	Cargo GSE																
	Military GSE																
	Airport Vehicles				89%		11%									100%	
					24		3										
Vehicles	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																

Table 13. Energy demand screenshot showing total usage with fuel use numbers from 2011 as provided by CHS.

See Guidebook Section 4.1		Energy Demand in 2011 at CHS									
Current 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)
Total Usage	20,100	152	32			52					
Subtotals	Aircraft	20,100	152								
	Airside Vehicles			32		52					
	Private Vehicle										
	Passenger Light (Fleet)										
	Scheduled Bus/Van										
	Courtesy Van										
	Rail										
	Off-Airport Vehicles										
	Buildings/Other										

Total use for each type of fuel and a breakdown by major user is shown in Table 13. In summary, fuel use in 2011 at CHS included about 20 million gallons of Jet A, 152,000 gallons of avgas, 32,000 gallons of gasoline, and 52,000 gallons of diesel.

7.1.4 Baseline 2015 Projected Energy Consumption for Selected Users

For planning purposes, it is assumed that the airport is interested in projected fuel use by 2015. Based on the FAA’s Terminal Area Forecast, enplanements at CHS are expected to grow about 13% in that time period. Assuming the fuel mix used by aircraft, GSE, and airport vehicles remains the same as in 2011, the projected use by 2015 is as shown in Table 14. A comparison of the 2011 fuel use and the baseline projections for 2015 are shown in Table 15.

7.1.5 Scenario 1: Projected Energy Use with a Moderate Switch to Alternative Fuels

The airport is interested in understanding the fuel volume requirements associated with a moderate switch to alternative fuels. To explore this scenario, the airport can use the “Matrix-Future” worksheet in the energy mix spreadsheet with different mix percentages for passenger aircraft, GA jet aircraft, passenger GSE, and airport vehicles. For example, the airport could consider the following fuel mix:

- Passenger and GA jet aircraft: 98% Jet A, 2% alternative jet fuel
- Passenger GSE: 10% gasoline, 60% green diesel, 30% CNG
- Airport vehicles: 50% gasoline, 10% diesel, 40% biodiesel

The fuel volumes associated with this fuel mix are shown in Table 16. A comparison of the fuel volume of this scenario and the baseline 2015 scenario is shown in Table 17. The main changes relative to the baseline 2015 projections are the need for 450,000 gallons of alternative jet fuel; the reduction in projected gasoline and diesel consumption from 32,000 to 23,000 gallons and 52,000 to 3,000 gallons, respectively; and the consumption of 38,000 gallons of green diesel, 11,000 gallons of biodiesel, and 81,000 gallons of CNG.

Table 14. Baseline 2015 projected energy demand assuming constant energy mix.

		Energy Demand in 2015 at CHS														
		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
Growth from 2011 to 2015 Pass 17% Cargo 13% Military GA 3.5% Override		See Guidebook Section 4.2														
Future energy demand																
Aircraft	* Passenger jet aircraft	100%														100%
		19,614														
	* Cargo jet aircraft															
	Military jet aircraft															
	GA jet aircraft	100%														100%
	GA piston aircraft			100%												100%
				157												
Airside	* Passenger GSE				14%		86%									100%
					10		55									
	Cargo GSE															
	Military GSE															
	Airport Vehicles				89%		11%									100%
					28		3									
Vehicles	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															

Table 15. Comparison of 2011 and baseline 2015 projected energy demand.

Energy demand		Energy use (per year)													
		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)
Aircraft	Current	20,100		152											
	Future	22,512		157											
Airsides Vehicles	Current				32		52								
	Future				38		58								
Private Vehicle	Current														
	Future														
Passenger Light (Fleet)	Current														
	Future														
Scheduled Bus/Van	Current														
	Future														
Courtesy Van	Current														
	Future														
Rail	Current														
	Future														
Off-Airport Vehicles	Current														
	Future														
Buildings/Other	Current														
	Future														

Table 16. Projected 2015 energy demand assuming a moderate switch to alternative fuels (Scenario 1).

Growth from 2011 to 2015		Energy Demand in 2015 at CHS															
		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	
Pass	13%	<div style="border: 1px solid black; padding: 2px;"> See Guidebook Section 4.2 Future energy demand </div>															
Cargo	12%																
Military	35%																
GA																	
Aircraft	* Passenger jet aircraft	98%	2%													100%	
		19,222	392														
	* Cargo jet aircraft																
	Military jet aircraft																
	GA jet aircraft	98%	2%													100%	
	2,840	58															
	GA piston aircraft			100%												100%	
				157													
Airside	* Passenger GSE				10%			60%		30%						100%	
					7			38		81							
	Cargo GSE																
	Military GSE																
	Airport Vehicles				50%		10%		40%							100%	
					16		3		11								
Vehicles	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																

Table 17. Comparison of 2011 and projected 2015 energy demand assuming a moderate switch to alternative fuels (Scenario 1).

Energy demand		Energy use (per year)													
		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)
Aircraft	Current	20,100		152											
	Future	22,062	450	157											
Airsides Vehicles	Current				32		52								
	Future				23		3	38	11	81					
Private Vehicle	Current														
	Future														
Passenger Light (Fleet)	Current														
	Future														
Scheduled Bus/Van	Current														
	Future														
Courtesy Van	Current														
	Future														
Rail	Current														
	Future														
Off-Airport Vehicles	Current														
	Future														
Buildings/Other	Current														
	Future														

7.1.6 Scenario 2: Projected Energy Use with an Aggressive Switch to Alternative Fuels

In this scenario, the airport wants to explore a what-if scenario with a more aggressive switch to alternative fuels. The following fuel mix is now being analyzed:

- Passenger and GA jet aircraft: 90% Jet A, 10% alternative jet fuel
- Passenger GSE: 30% green diesel, 30% CNG, 40% electricity
- Airport vehicles: 20% gasoline, 10% diesel, 40% biodiesel, 30% electricity

The fuel volumes associated with this fuel mix are shown in Table 18. A comparison of the fuel volumes of this scenario and the baseline scenario is shown in Table 19. The main changes relative to the baseline projections are the need for approximately 2.2 million gallons of alternative jet fuel; the reduction in projected gasoline and diesel consumption from 32,000 to 6,000 gallons and 52,000 to 3,000 gallons, respectively; and the consumption of 19,000 gallons of green diesel, 11,000 gallons of biodiesel, 81,000 gallons of CNG, and approximately 1.3 megawatt-hours of electric power.

7.1.7 Summary of Results

A summary of projected fuel consumption for the 2015 baseline, moderate, and aggressive scenarios is shown in Table 20.

Even though this is a very high-level analysis, there are a number of observations that can be helpful for CHS as the airport considers strategic options for future fuel procurement. For example:

- Jet fuel consumption is projected to increase by about 13%. Since alternative jet fuel is assumed to be drop-in, no additional infrastructure will be necessary as long as there are enough storage and handling facilities to handle the increase in jet fuel consumption.
- Use of gasoline and diesel would decrease; therefore, no additional infrastructure would be required for either one. Some of the existing gasoline facilities could be removed or re-purposed, especially in the aggressive scenario, since usage would fall to less than 25% of the projected baseline. As for diesel, since a significant amount of green diesel use is expected, the existing diesel infrastructure could be used. Additional infrastructure for handling biodiesel may be required.
- New infrastructure for CNG would be necessary.
- Depending on current electric use and provision at the airport, additional infrastructure may be required to support an extra 1.3 megawatt-hours of power consumption.

With the information gathered for this case study, the airport can also start investigating other questions of interest such as how a potential switch to alternative fuels could affect the total cost of fuel or reduce emissions. To do so, the airport can use the information contained in the guidebook regarding price and emissions characteristics of the different alternative fuels to create a cost and emissions profile for the baseline and alternative scenarios.

If the airport is interested in expanding the scope of the analysis to include other potential users, a logical extension would be the inclusion of military users. The airport could request information from the military base with respect to their current and projected fuel needs and use that information to populate the energy mix spreadsheet. Since military activity at CHS is very significant, the addition of military users would result in much higher volumes of projected fuel use for both conventional and alternative fuels. Large potential demand for alternative fuels

Table 18. Projected 2015 energy demand assuming an aggressive switch to alternative fuels (Scenario 2).

		Energy Demand in 2015 at CHS															
		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	
Growth from 2011 to 2015 Pass 1.7% Cargo 7.3% Military GA 1.9% Override		See Guidebook Section 4.2															
Future energy demand																	
Aircraft	* Passenger jet aircraft	90%	10%													100%	
		17,653	1,961														
	* Cargo jet aircraft																
	Military jet aircraft																
	GA jet aircraft	90%	10%													100%	
	GA piston aircraft			100%												100%	
				157													
Airside	* Passenger GSE							30%		30%		40%				100%	
								19		81		971					
	Cargo GSE																
	Military GSE																
	Airport Vehicles				20%		10%		40%		30%					100%	
					6		3		11		311						
Vehicles	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																

Table 19. Comparison of 2011 and projected 2015 energy demand assuming an aggressive switch to alternative fuels (Scenario 2).

Energy demand		Energy use (per year)													
		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)
Aircraft	Current	20,100		152											
	Future	20,261	2,251	157											
Airside Vehicles	Current				32		52								
	Future				6		3	19	11	81	1,282				
Private Vehicle	Current														
	Future														
Passenger Light (Fleet)	Current														
	Future														
Scheduled Bus/Van	Current														
	Future														
Courtesy Van	Current														
	Future														
Rail	Current														
	Future														
Off-Airport Vehicles	Current														
	Future														
Buildings/Other	Current														
	Future														

Table 20. Summary of projected fuel consumption depending on alternative fuel insertion scenario.

Scenario	Conv. Jet A (000 gal)	Alt. Jet Fuel (000 gal)	Avgas (000 gal)	Gasoline (000 gal)	Diesel (000 gal)	Green diesel (000 gal)	Biodiesel (000 gal)	CNG (000 gal)	Electricity (kWh)
Baseline	22,512	–	157	38	58	–	–	–	–
Moderate	22,120	392	157	23	3	38	11	81	–
Aggressive	20,261	2,251	157	6	3	19	11	81	1,282

would be an important selling point for CHS to attract potential producers and distributors of alternative fuels to the field.

7.1.8 Conclusion

This case study illustrated how the energy mix spreadsheet can be used to explore possible alternative fuel use scenarios. Using data provided by the airport, the spreadsheet allows the user to investigate different mixes of alternative fuel use. Even though the airport had information for a limited set of users, the tool is still helpful as it does not require that all data be available to provide insights into possible alternative fuel uses. However, once additional data become available, the spreadsheet can be updated to investigate current and projected fuel use.

7.2 Comprehensive Analysis of Energy Demand

7.2.1 Overview of Seattle-Tacoma International Airport

Seattle-Tacoma International Airport (Sea-Tac) is one of the busiest airports in the United States and is the primary air transportation hub in Washington State and the Northwestern United States. Sea-Tac is one of the world's leading airports in addressing sustainability and environmental concerns and has developed a long-term strategic plan to move people and goods efficiently, manage natural resources wisely, and promote sustainable communities. Sea-Tac and the Port of Seattle have set measurable goals in the areas of air quality and climate change, energy use and conservation, buildings and infrastructure, materials use and recycling, water resources and wildlife, noise, and education to track and reduce its environmental impact (Port of Seattle 2012).

In terms of energy use at and in airport-controlled facilities and vehicles, the main fuels currently used include natural gas, electricity, diesel, and gasoline. Natural gas is the largest energy source, with nearly 3 million therms used for facility heating and hot water each year. Sea-Tac currently provides electric service to 67 businesses with over 170 metered sites. Total annual electric utility operating expenses are in excess of \$14 million, with an average annual load of 18.3 megawatts. The airport's vehicle fleet uses an estimated 100,000 gallons of gasoline and 12,000 gallons of diesel annually. In addition, approximately 150,000 gallons of CNG are used annually for specialized vehicles.

Sea-Tac tenants and service providers have adopted alternative fuels and energy to various degrees. For example, Alaska Airlines has used alternative jet fuel on a trial basis and many of the ground transportation service providers are using electricity, CNG, or propane to fuel their fleets.

7.2.2 Case Study Objective

The objective of the case study is to evaluate how the energy mix spreadsheet can be used to help airports do a comprehensive analysis of energy demand as the basis for an energy use strategy. The purpose is to indicate the strengths and limitations of the toolkit and stimulate its usage by other airports. Since Sea-Tac has ample experience evaluating, planning, and implementing energy and alternative fuel use strategies, it is uniquely positioned to evaluate the toolkit and how it can be applied to support the introduction of alternative fuels in the airport setting.

7.2.3 Research Approach

Sea-Tac entered current year data and assumptions from the airport's projected growth into the energy mix spreadsheet and let it forecast future energy mix. As part of the development of its environmental impact reduction strategy, Sea-Tac had previously produced energy use forecasts using other means, enabling it to provide a practical evaluation of the spreadsheet's utility.

7.2.4 Results and Discussion

Over the next 5 years, the increase in projected fuel and energy estimated by the spreadsheet was 18%, which is an acceptable estimate in a business-as-usual assessment; however, based on energy conservation initiatives and increases in energy efficiency targeted by Sea-Tac, over the same time frame the airport is projecting a 30% decrease in vehicle fuel use and, pending the implementation of several facility-based energy conservation measures, a 14% decrease in electrical use.

Overall, Sea-Tac found the energy mix spreadsheet to be a great way of showing a business-as-usual scenario that an organization can use to plan infrastructure improvements and an easy way to evaluate alternative scenarios. It may even help determine what, if any, mode shifts could help reduce the need for facility or roadway build-outs.

Given all the work already done at the airport with respect to alternative fuels, the energy mix spreadsheet may not play a prominent role in determining what alternative fuels are used at Sea-Tac. If, however, the spreadsheet's calculations suggest the airport may not be able to reach its emission reduction goals over the next 5 to 20 years, it will spur delving deeper into analyses and strategic planning. If, on the other hand, the spreadsheet's assessment suggests the goals are readily reachable, it might be time to develop new, more aggressive, goals.

The results from the spreadsheet and, just as important, working through the data entry can help facilitate conversations between the different departments and interests at an airport. Any effort to facilitate a discussion on the different aspects of future fuels, environment, infrastructure, and need is welcomed. The energy mix spreadsheet is a convenient way to display current airport fuel usage and allows for estimating airport service provider usage as well.

Sea-Tac is expected to soon see a significant change in the use of alternative transportation fuels, so having knowledge of regulations regarding alternative fuel use would help the user better understand how to populate the energy matrix. For example, if there is a rule that all government vehicles must use alternative fuels by 2018, the assumptions for that section can focus on forecasting trends to meet that rule. These assumptions can be tracked using the workbook spreadsheet of the toolkit. There, the user can keep track of regulatory considerations by specific fuel, which would help when putting data into the energy mix spreadsheet.

There are certain aspects in which the toolkit can be strengthened. For example, the energy mix spreadsheet has some limitations with respect to anticipating improvements in aircraft and surface vehicle fuel efficiency, air traffic management system improvements, and energy

conservation efforts that will be key components for reducing demand for energy use in the future. The energy mix spreadsheet does not assume improvements in energy efficiency or conservation explicitly. To capture these effects, the user can adjust the growth rate in air traffic activity (passenger, cargo, military, and GA) to reflect the gains in efficiency. For example, if air travel is projected to grow by 15% in 5 years, and energy efficiency is expected to reduce fuel consumption by 3% over the same time period, the adjusted projected growth rate would be $15\% - 3\% = 12\%$.

Furthermore, the energy mix spreadsheet identifies infrastructure needs in terms of volume changes but does not account for requirements based on special circumstances or the ability to modify existing facilities. These types of considerations have to be accounted for by the user outside of the energy mix spreadsheet. If these special circumstances result in the need for additional storage or distribution infrastructure, this information can be included in the “Infrastructure” worksheet of the energy mix spreadsheet.

7.2.5 Conclusions

Sea-Tac believes this toolkit is most useful for medium-range forecasting, the span of 5 to 20 years out, where knowledge of fuels and technology is relatively certain. Anything that happens in the next 5 years to radically change fuel mix will likely be less of a traditional planning effort and more of a reaction to some new initiative; beyond 20 years the energy mix becomes too speculative.

In summary, absent an airport’s specific knowledge of goals for its future energy mix and needs, the energy mix spreadsheet can be useful in developing a conversation about energy and fuel. As mentioned previously, any way to facilitate a discussion on the different aspects of future fuels, environment, infrastructure and need, by the multiple parties involved at an airport, is much appreciated. In addition, since industry data is the basis for calculating forecasts, the results can readily be used to truth check other airport analyses and environmental goal setting related to energy and fuel.

It is likely that the more time is put into using the toolkit, beyond the initial evaluation, the more valuable it will become. The abilities to track progress in meeting goals and to customize fuel and energy types give the tool a dynamic feel.

7.3 Support of Business Plan for Alternative Fuel Use and Production

7.3.1 Overview of Hartsfield-Jackson Atlanta International Airport

Hartsfield-Jackson Atlanta International Airport (ATL) is the busiest airport in the United States and the world. The airport is a major hub for Delta and Southwest airlines, serving a significant amount of domestic and foreign destinations. ATL has many unique characteristics with respect to the potential use of alternative fuels. It is one of the largest airports in the United States in terms of aircraft operations and, consequently, jet fuel consumption. The large number of aircraft operations also translates into strong demand for ground transportation fuels for both airside and groundside vehicles. ATL is also an important air cargo facility, with the associated significant traffic of heavy-duty trucks and potential demand for diesel and other fuels suitable for large trucks, such as CNG. In addition, ATL has long-term goals associated with reducing its use of electric power from the grid as well as the need to dispose of significant amounts of MSW, which could be used as feedstock for a number of alternative fuel production processes. Finally, as of 2012, the airport is scoping potential uses for a 39-acre parcel on the airport’s property

that has been set aside and could be used, for example, to house an “Energy Park” (Hartsfield-Jackson 2011).

7.3.2 Case Study Objective

The objective of this case study is to illustrate how this guidebook and toolkit can be used to support an airport in the identification of strategic opportunities to promote the use of alternative fuels. First, these materials can be used by the airport to understand its total energy demand (from both on- and off-airport users) and to create scenarios of possible future use. Second, the airport can use the output of this demand profile characterization to inform the business case for potential alternative fuel producers who may be interested in supplying the airport.

7.3.3 Information-Gathering Approach

To understand its energy use profile, the airport needs to gather information from a variety of sources. This process will require effort because an airport is not expected to have access to energy use information outside the activities that it directly controls. Examples of data that may not be readily available to an airport include fuel use by airline GSE, ground transportation vehicles, and private vehicles. Thus, the airport is encouraged to follow a tiered approach. The first step is to gather as much information as is available from airport-owned energy uses, such as airport vehicles and buildings. In the case of ATL, the airport has gathered a fair amount of this information in Appendix E of its annual *Sustainable Management Plan* (Hartsfield-Jackson 2011). Relevant data that can be extracted from this document includes fuel consumption by airport vehicles and buildings in 2010, as shown in Table 21.

A second step is to contact the main energy users at the airport. At the very least, the airport should be able to obtain jet fuel consumption data from the fuel farm operator or the airlines. This data may also include fuel dispensed for GSE. The airport should also contact rental car operators, fleet vehicle operators, and cargo truck operators for information that would enable an estimate of fuel consumption. Third, depending on resource availability, the airport could also survey energy users. This survey would be particularly helpful to estimate fuel use by private vehicles and employees. All this information can be organized and input into the energy mix spreadsheet to generate both a baseline and projected scenarios (note that the energy mix spreadsheet can generate high-level estimates of fuel consumption for many users; however, to the extent that the airport can gather the information from the primary energy users, the energy values will be more accurate).

With respect to supporting the business case for potential alternative fuel producers who may be interested in supplying the airport, several steps are recommended. First, the airport should engage alternative fuel companies that may benefit from the location of the airport or from the availability of particular types of feedstock in the proximity of the airport. The airport should also indicate if there are any facilities or land available for use by any interested producers. Second, the airport can demonstrate the potential for multi-modal energy demand by exercising the energy mix spreadsheet and showing the results to interested fuel producers. The parameters

Table 21. Example of energy use at ATL in 2010
(Source: Hartsfield-Jackson 2011).

User Type	Gasoline (000 gal)	Diesel (000 gal)	CNG (000 gal)	Electricity (GWh)
Airport vehicles	138	97	4	0
Airport buildings	0	32	0	288

that the airport can explore include changes in the growth rate of aviation activity, changes in the fuel mix for both aircraft and surface vehicles, and the time horizon. These scenarios can be combined with information gathered from the potential fuel producers to match their projected fuel production. Thus, the energy matrix can be used to specify targets in terms of volume for different fuels at a certain point in the future. At the same time, the data from the fuel producers can be fed back into the energy matrix to indicate how close they might be in fulfilling the projected demand. This information can give potential producers a high-level estimate of the size of the market for different products at the airport. This can be especially important for processes that result in a number of co-products, such as alternative jet fuel and green diesel.

In the case of ATL, three companies representing various process types were approached to gauge their interest in producing alternative fuels for delivery at the airport. These companies included an ATJ company, a thermochemical-and-MSW-to-liquids producer, and an HEFA company. The companies were interested in engaging with the airport because of the availability of infrastructure and feedstock in the proximity of the airport that fit their business needs and the significant demand for fuel at the airport not only from aircraft but also from ground transportation, among other reasons. In addition, the availability of airport land for a potential energy park was of interest to two of them. Each company was asked to provide information that would support subsequent, more in-depth analysis, including proposed size of facility and infrastructure requirements, production volume, feedstock utilization and supply, and an initial environmental assessment of the production process.

As of the writing of this guidebook, the airport and the alternative fuel companies were still in the exploratory phase. The energy mix spreadsheet was exercised in a limited capacity to demonstrate its applicability. A next step in this process is to extend the formal analysis of the proposals submitted by the potential fuel producers to perform a detailed study of costs and benefits for each proposed facility. The workbook spreadsheet can be used to help in the assessment of the costs, benefits, regulatory, and siting considerations for each one. All this information can then be used by the airport to evaluate the different alternatives and by the fuel producers to strengthen their business case.

7.3.4 Conclusion

The process described above demonstrates how the thought process behind the guidebook and toolkit can be useful in scoping the benefits and costs of having an alternative fuels facility on or near an airport. These materials can help airports where the question is not only should the option for alternative fuels supply be investigated but also how should the opportunities be evaluated. As of the writing of this guidebook, conversations between ATL and a number of alternative fuel producers are ongoing with the help of the guidebook and toolkit.

7.4 Review of Siting Considerations

7.4.1 Overview of Tulsa International Airport

Tulsa International Airport (TUL) is the second busiest commercial airport in Oklahoma and the primary gateway for residents of the northern and eastern parts of the state. It is the primary maintenance base for American Airlines, handling the maintenance for the company's Boeing 737, 757, 767, and 777 aircraft as well as for its sizable fleet of McDonnell Douglas MD-80s. It serves as a major regional airport, a GA gateway, and economic engine for the state of Oklahoma.

Determining the necessary future capacity of airport fuel facilities is critical to the ability of an airport to continue to adequately serve its various users and customers and to correctly size any new facilities to allow for future growth in demand. Tulsa is anticipated to see growth in passen-

ger enplanements of approximately 7% between 2011 and 2015, 17% between 2011 and 2020, and 42% between 2011 and 2030 (FAA 2011b). Prudent planning for infrastructure can mitigate the difficulties associated with providing increased infrastructure to support this growth.

The future provision for alternative fuels at the airport is another purpose of undertaking this step in the site planning process. Though construction and other regulations associated with tank storage on an airport are similar regardless of the type of fuel contained in those tanks, some logistical differences, particularly in the area of fuel delivery, are to be expected. For example, a lack of pipeline access may have consequences as to the ideal location of a potential new alternative jet fuel storage tank. Furthermore, depending on how aggressive an airport may be in introducing alternative fuels, it is possible that the required storage of conventional fuels could stabilize or decrease in future years as alternative fuels compose a larger share of total fuel use. This could have an effect on the level and direction of future infrastructure investment, possibly steering it toward providing solutions to expand alternative fuel storage rather than conventional fuel storage. However, some alternative fuels are drop-in, lessening the necessary changes that must be made to fueling infrastructure in those situations.

7.4.2 Case Study Objective

The objective of this case study is to illustrate the process for identifying the main siting considerations for alternative fuel distribution programs discussed in Section 6. This process is illustrated using TUL as an example. Tulsa was selected because of its mix of commercial and GA traffic and ground transportation refueling facilities that are common to many other locations. At the same time, Tulsa has very unique characteristics, such as hosting a major aircraft maintenance operation, which are not commonly found on other airports. Therefore, the general approach described here can be applied at other airports but the specific observations are only valid for TUL.

7.4.3 Approach

This case study follows the process shown in Figure 9, which reproduces Figure 6 from Section 6.1.

7.4.3.1 Step 1: Fuel Facility Inventory

An initial fuel facility inventory of TUL is shown in Figure 10 and Table 22. For each storage facility, this inventory includes the distributor, tank owner, type, size, and content. Overall, total fuel storage capacity at the airport consists of the following:

- 520,000 gallons of Jet A
- 42,000 gallons of avgas
- 110,000 gallons of unleaded gasoline
- 17,000 gallons of diesel

7.4.3.2 Step 2: Fuel Requirements

Fuel infrastructure requirements for existing and future operations can be derived from an assessment of current and projected fuel use. These estimates need to be done for both aviation fuels (Track A in Figure 9) and non-aviation fuels (Track B in Figure 9). The assessments may be included on an Airport Master Plan or from other independent analysis. For example, the energy mix toolkit can be used to estimate approximate values for current and future fuel use. As a hypothetical example, TUL may be interested in having 10% alternative jet fuel on the airfield by 2017, while at the same time replacing 50% of its diesel-powered trucks with CNG-fueled equipment and converting all diesel-powered GSE to electricity.

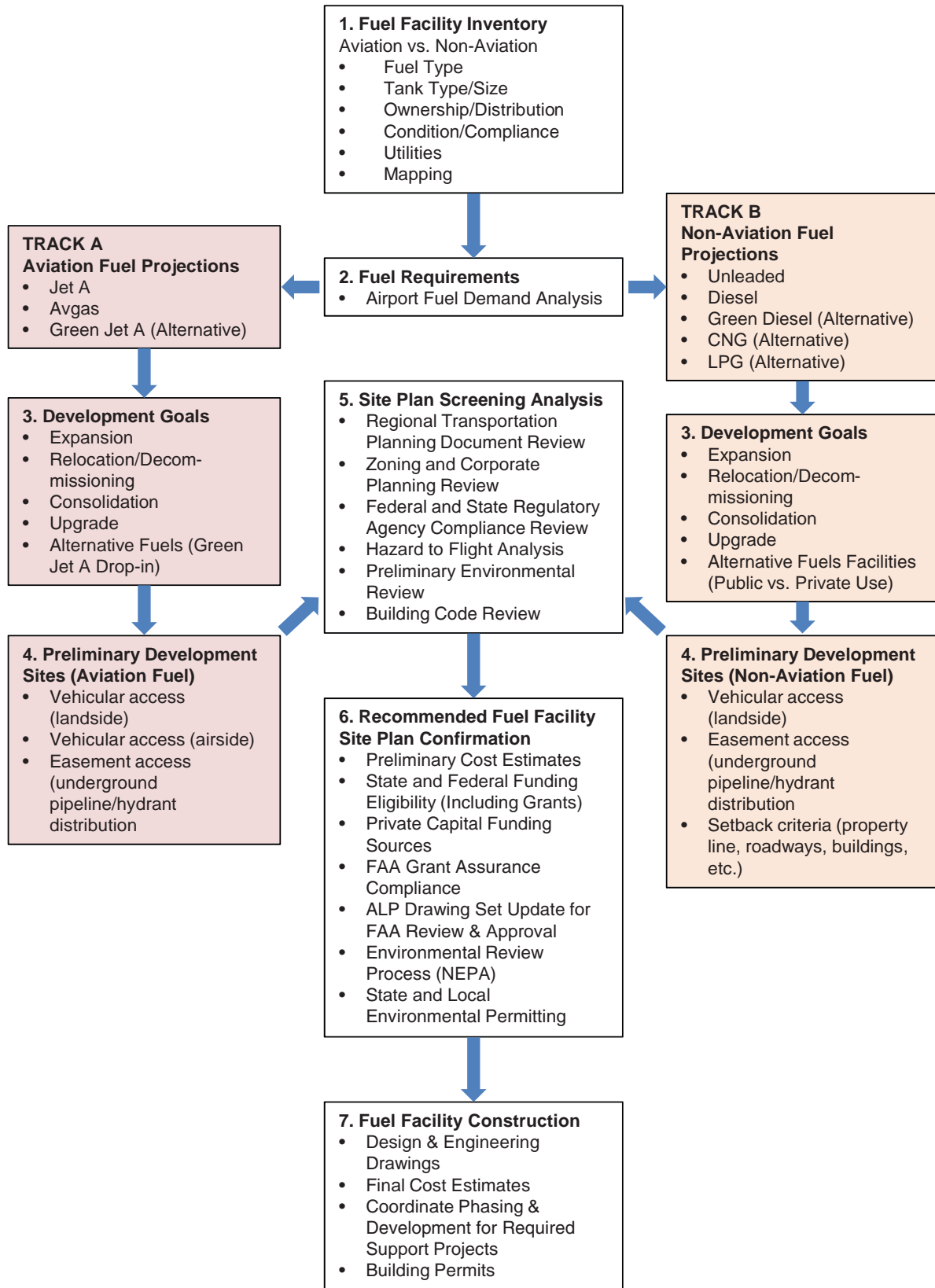
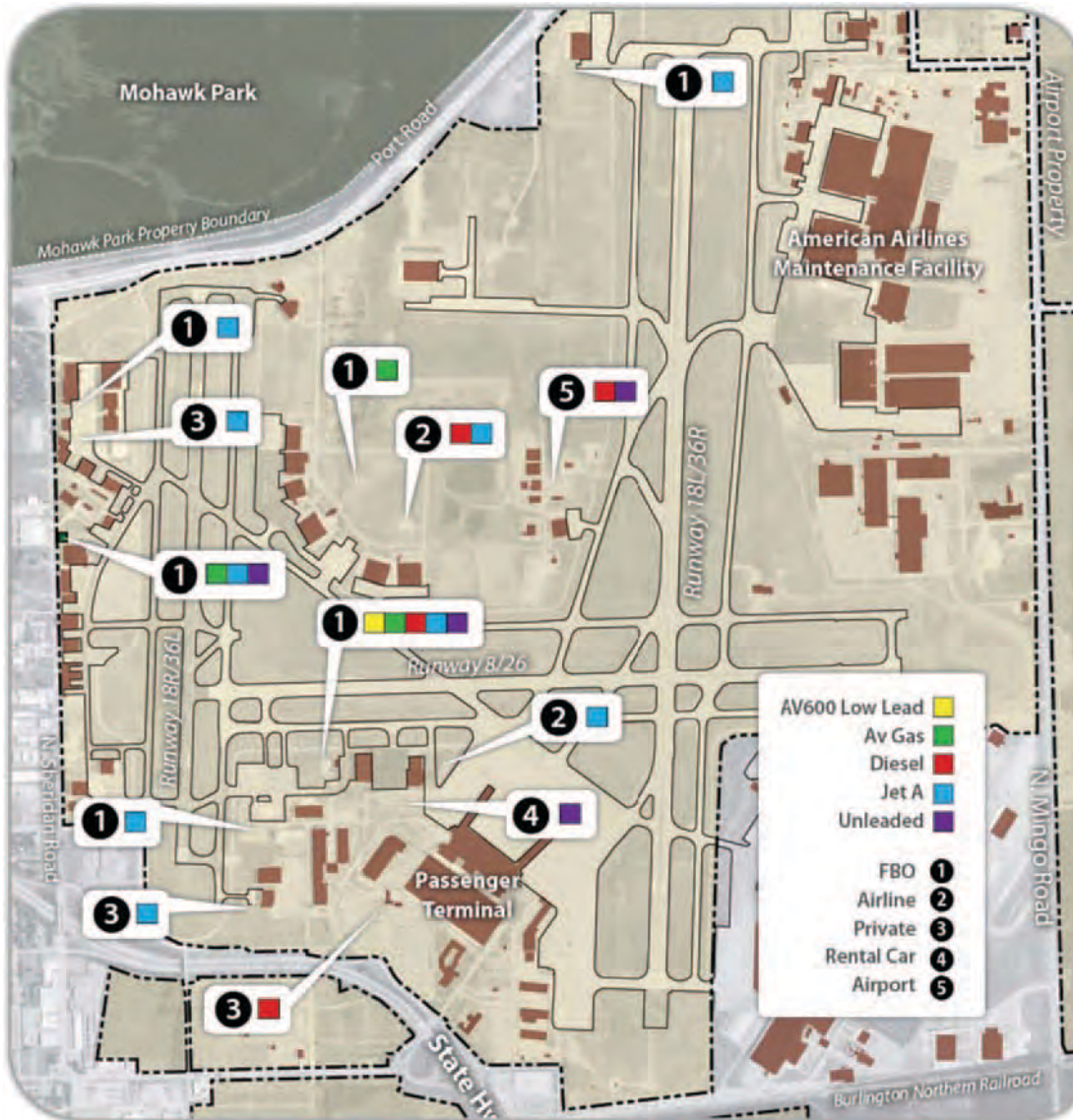


Figure 9. Planning process for siting alternative fuel storage and distribution facilities at airports (reproduced from Section 6.1)



Background image © 2011 Google Earth

Note: Some of the figures and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org/Main/Blurbs/168378.aspx) retains the color versions.

Figure 10. Fuel storage facilities at TUL.

7.4.3.3 Step 3: Development Goals

The main task is to determine whether additional infrastructure is required to support alternative fuel storage and distribution facilities. In the hypothetical example in Step 2, since alternative jet fuel is drop-in, no additional jet fuel infrastructure would need to be provided, assuming that the combined volume of conventional and alternative jet fuel can be handled with existing facilities. With respect to diesel, since the goal is to replace 50% diesel of trucks with CNG trucks and convert all diesel-powered GSE to electricity, there would be no need for additional infrastructure to handle diesel. In fact, it may be possible that existing diesel-related infrastructure would be redundant and, thus, could be removed. The introduction of CNG would require the provision of new infrastructure, including storage, handling, and refueling facilities. With respect to electric GSE, recharging stations would be required and an analysis of current and

Table 22. Fuel storage inventory at TUL.

Distributor	Tank Owner	Type*	Size	Content
FBO	Atlantic Aviation	UST	30,000	Jet A
		UST	8,000	Avgas
		UST	10,000	Diesel
		UST	10,000	Unleaded
		UST	30,000	Jet A
		UST	8,000	Avgas
		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/Sparrowhawk	UST	12,000	Avgas
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	Avgas
		AST	500	Unleaded
		UST	20,000	Jet A
		Truck	1,200	Avgas
		Truck	2,200	Jet A
		Truck	2,200	Jet A
		Truck	3,000	Jet A
		Truck	1,200	Avgas
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
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

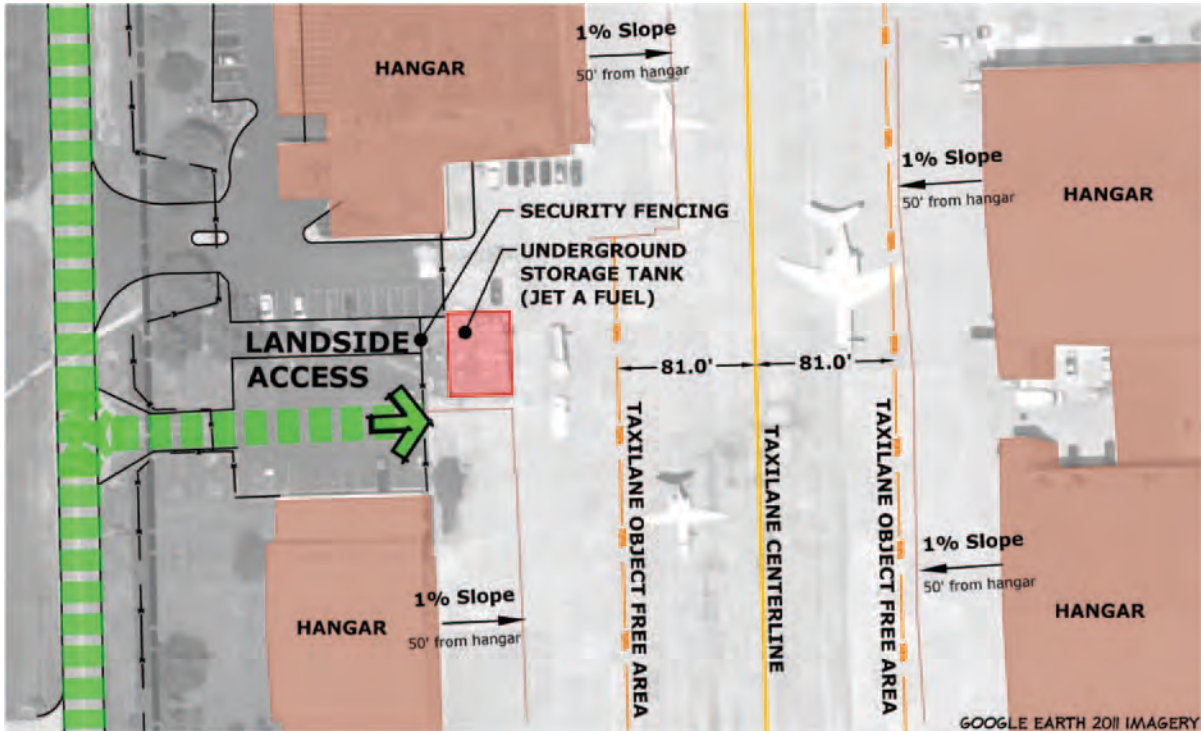
*UST – underground storage tank; AST – aboveground storage tank

projected electricity use should be performed to determine if the current electricity distribution infrastructure is sufficient to handle the anticipated loads.

7.4.3.4 Step 4: Preliminary Development Sites

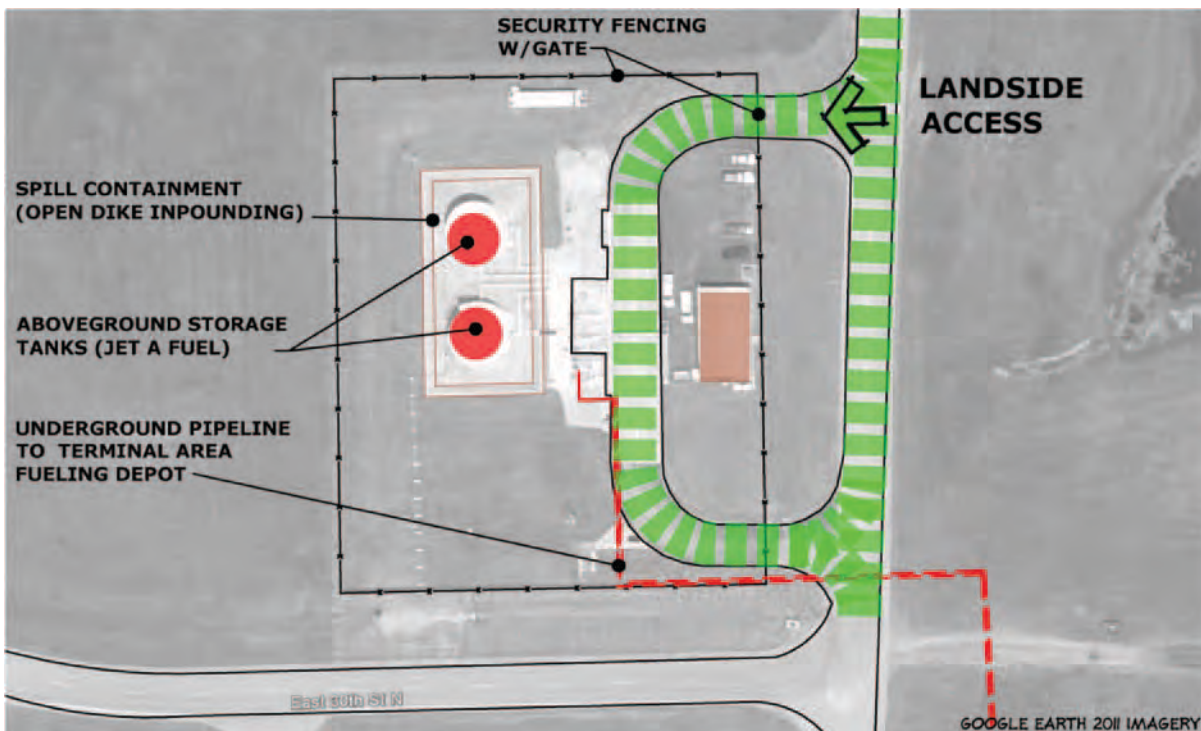
Once the development goals are identified, the next step is to do a preliminary identification of potential sites for additional infrastructure that may be required. A number of key planning considerations in the siting of fuel storage facilities on the airport must be taken into account when looking for potential sites. The type of siting considerations and associated regulations that planners need to observe are illustrated in Figures 11, 12, and 13.

Figure 11 shows the GA ramp at TUL and its primary Jet A storage tank. This graphic shows in detail how this area conforms to both regulatory and practical constraints. For



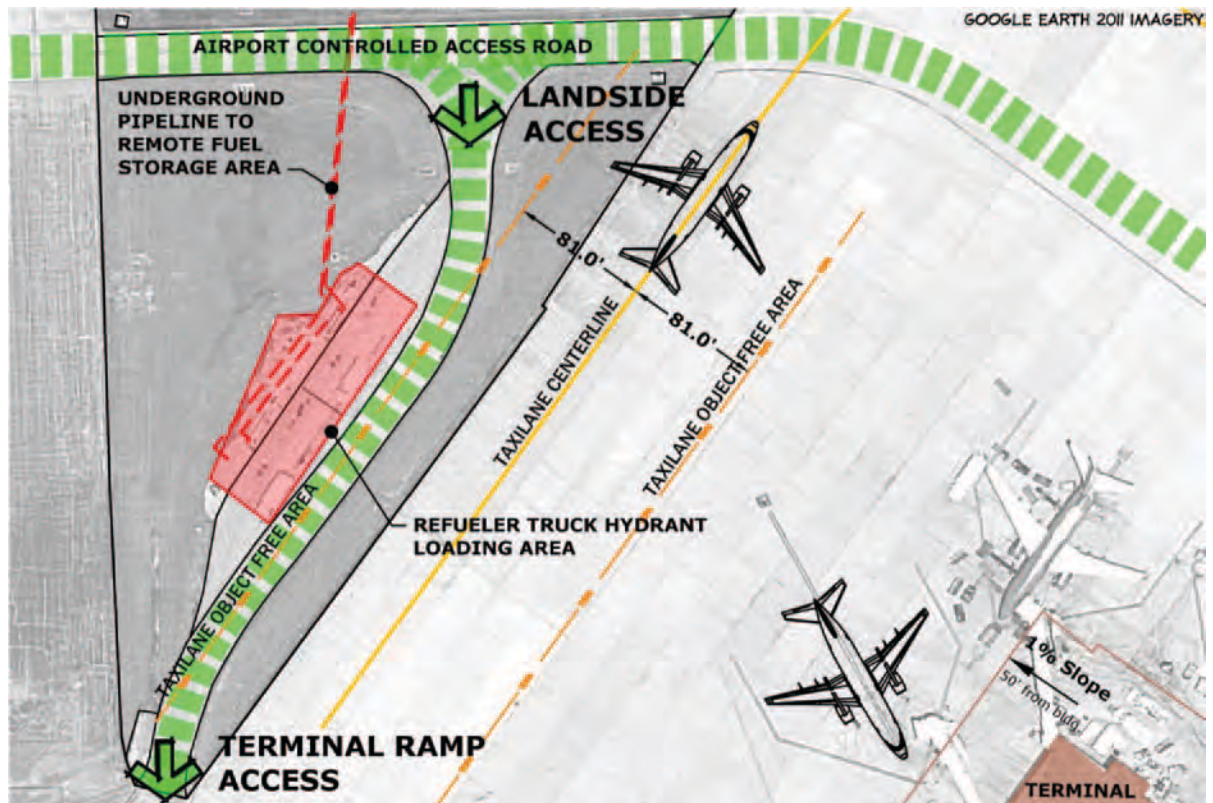
Background image © 2011 Google Earth

Figure 11. A GA fuel storage area at TUL.



Background image © 2011 Google Earth

Figure 12. Remote aviation fuel storage with pipeline to terminal area fueling depot at TUL.



Background image © 2011 Google Earth

Figure 13. Terminal area refueler truck depot at TUL.

example, the figure shows the extent of the security fencing, which is required by the Transportation Security Agency, and how it relates to the landside access to the storage tank. Additionally it shows the 50-foot clearance line from each hangar for two primary reasons. The first is to show that any refueling vehicles parked near the storage tank are at least 50 feet from all other buildings, vehicles, and aircraft, an NFPA statute. The second is to show that the storage tank (and its associated fencing) is not creating an obstacle or safety hazard near a designated aircraft moving area, also an NFPA rule. That designated aircraft movement area is highlighted by the taxiway centerline on the chart. Some reference documents pertinent to this illustration include the following:

- 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).
- NFPA 30, Chapter 22, for Aboveground Storage Tank (AST) location and separation criteria.
- NFPA 30, Chapter 23, for Underground Storage Tank (UST) location and separation criteria.
- NFPA 30, Chapter 5, for loading requirements of aircraft fuel servicing tank vehicles.
- Taxilane Object Free Area standards based on FAA AC 150/5300-13 for Group III Aircraft (aircraft with wingspans up to but not including 118 feet).

Figure 12 presents an example of a remote aviation fuel storage area with efficient landside access and a pipeline to the terminal area. The illustration shows the spill containment facilities surrounding the ASTs. For security reasons, a perimeter fence is required, as shown in the figure. Some reference documents pertinent to this illustration include the following:

- NFPA 30, Chapter 22, for AST location and separation criteria.
- NFPA 30, Chapter 22, for control of spills from ASTs (i.e., remote impounding, impounding around tanks by open diking, impounding around tanks by closed-top diking, or secondary containment-type ASTs).
- See local roadway engineering design standards for tanker trailer and emergency vehicle response maneuvering (e.g., typical outside turning radius of 60 feet and curb radii at corners of 30 to 40 feet).

Figure 13 presents an example of a terminal area refueler truck depot located in proximity to the commercial aircraft parking areas and gates. The figure shows how the refueling area is fed by pipeline from the remote storage area and the road access to trucks to come and refuel. Some reference documents pertinent to this illustration include the following:

- NFPA 30, Chapter 5, for loading requirements of aircraft fuel servicing tank vehicles.
- NFPA 415, Annex A, Apron Drainage at 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 of 60 feet and curb radii at corners of 30 to 40 feet).
- NFPA 30, Chapter 21, for detection of leakage from USTs (e.g., maintain accurate inventory records and/or implement a leak detection program).
- Taxilane Object Free Area standards based on FAA AC 150/5300-13 for Group III Aircraft (aircraft with wingspans up to but not including 118 feet).

7.4.3.5 Step 5: Screening Analysis and Preliminary Fuel Facility Site Plans

Once the preliminary development sites have been identified, the next step is to develop a draft schematic plan and perform a more systematic screening of the potential sites for compliance with applicable design criteria, NFPA codes and standards, and local fire codes. This review should also check for consistency with existing zoning and regional transportation planning documents, a supplemental hazard flight analysis, and a preliminary environmental review of the draft schematic site plans. When all this information is obtained, careful review and comparison should be undertaken to identify the preferred or recommended one(s).

7.4.3.6 Step 6: Recommended Fuel Facility Site Plans

With the preferred site(s) identified, the next step is to start working on preliminary design and engineering drawings with cost estimates for the proposed facilities. It would also be important to identify those portions of the project that may be eligible for state or federal funding and to confirm FAA grant assurances. The permitting process as well as a NEPA review should also be started in this step.

7.4.3.7 Step 7: Fuel Facility Construction

With a final site selection and design and engineering drawings with cost estimates completed, construction of the fuel facility can begin.

7.4.4 Conclusion

This case study illustrated the suggested process for analyzing siting considerations associated with alternative fuel facilities using TUL as an example. While every airport will have its own set of unique local characteristics and conditions, the process presented here is intended to be general enough to apply to most circumstances and to be helpful to airports of any size, operations profile, and geographic location.



SECTION 8

Suggested Next Steps

After applying the evaluation framework discussed in this guidebook, readers are encouraged to proceed with the implementation process of alternative fuel distribution programs. Suggested next steps include the following:

- Thorough analysis of the regulatory aspects, including detailed descriptions of how the option complies with each applicable regulation and policy.
- Thorough analysis of the environmental aspects, including assessment of life-cycle GHG intensity as provided by the responsible external agency (e.g., EPA), or as developed following procedures provided by that agency. Similar analysis applies to environmental benefits associated with local air quality.
- Thorough analysis of the logistical aspects, including an end-to-end engineering plan quantitatively addressing each stage in the handling, storage, and distribution of the alternative fuel.
- Thorough analysis of the financial aspects, including an investment-quality business plan that specifies capitalization, revenue, costs, and risks at appropriate intervals over the lifetime of the program.

Frequently Asked Questions

9.1 Potential Community Concerns around Alternative Fuel

Q: What is the food-versus-fuel debate and what is the implication for alternative fuel?

A: The food-versus-fuel debate arises from questions related to the use of agricultural food commodities for the production of alternative fuels. The debate stems from a spike in animal feed costs and food prices in 2008 and the rapid development and expansion of the corn ethanol industry. Currently, 30% of the domestic corn crop is used for ethanol production. Some people fear 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 was the result of high energy costs not corn ethanol production. The issue has become very politically charged. There is little consensus on the role of alternative fuel production on food production and prices.

To avoid the controversy surrounding the food-versus-fuel debate, the Commercial Aviation Alternative Fuels Initiative (CAAFI) and other stakeholders in the U.S. airline industry support the use of feedstocks that do not compromise food availability. Therefore, these entities are interested in 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 agriculture residues (e.g., wheat straw, corn stover), dedicated energy crops (switchgrass), woody biomass, MSW, alternative oilseed feedstocks (e.g., algae, *Jatropha*), and non-food oilseeds (e.g., mustard seed, *Camelina*).

Q: What does the concept of the energy-water-food nexus mean and why is it important to alternative fuels?

A: The energy-water-food nexus is a prominent issue among senior business, finance, policy, military, and non-governmental organization leaders. It refers to the links between energy, water, and food. Because these issues are so closely intertwined, credible analysis of one part of the nexus requires evaluating implications on the other parts of the nexus. For example, evaluation of crops for energy requires consideration of food-versus-fuel concerns and agriculture's impact on increasingly scarce water resources, including in marginal land such as in arid environments that may not be fit for other types of agriculture. In addition, the evaluation of natural gas requires consideration of extraction techniques on water quality.

Q: What does “land use” mean and why is it important to the future of alternative fuel?

A: Land use is an important component of the water-energy-food nexus. The term “land use” refers to unresolved concerns about whether increasing demand for agricultural products in one part of the world, for food or energy crops, drives conversion of forests

into agricultural land in other parts of the world such as in Brazil, Indonesia, and Africa. This issue is of importance for several reasons. First, deforestation is one of the world's largest sources of carbon emissions and has many other social, environmental, and economic impacts. In addition, overturning topsoil for planting, especially the first time once the land is deforested, also releases significant carbon. Land use implications are difficult to prove, disprove, or quantify. Despite this uncertainty, correctly gauging the impact of alternative jet fuels on land use will be critical to their long-term acceptance.

Q: How may the production of alternative fuel impact water resources?

A: Water utilization is a topic that frequently comes up during the discussion of any kind of alternative fuels. Depending on the specific way in which feedstocks are recovered and processed, water consumption for the production of alternative fuels may be comparable to or larger than that required for conventional fuel production. The water impact of alternative fuels should be evaluated by considering the feedstocks and conversion technologies separately. There are two components pertaining to feedstocks. In terms of water *consumption*, traditional feedstock crops, such as soybeans, require large amounts of fresh water. In contrast, new bio-derived crops, such as switchgrass, do not need irrigation, and algae can grow in brackish or sea water. In terms of water *pollution*, fossil feedstocks and traditional feedstock crops contribute runoff from fertilizers and pesticides.

Regarding conversion technologies, the need for cooling drives water impact. The impact varies widely from extensive to minimal with the type of cooling and conversion technology. Fischer-Tropsch requires substantial cooling and is generally more water intensive than hydroprocessing per unit of energy produced.

It should be noted that the United States has extensive laws and regulations governing water, as indicated in Section 6.3.2. Compliance with these laws and regulations should be considered sufficient to meet any concerns about impacts to water resources.

Q: Are there sustainability criteria for alternative fuels?

A: Production of alternative fuels may affect the environment in several ways, as noted previously. In the United States, there are no mandatory sustainability criteria for alternative fuels. The United States has a full suite of detailed environmental laws and a legal system to enforce compliance with those laws and regulations—demonstration of compliance with the law should be considered sufficient to establish sustainability according to existing laws and regulations.

There are efforts to develop sustainability standards applicable to development of alternative fuels in general (not only alternative jet fuel). One example is the Roundtable on Sustainable Biofuels (<http://rsb.epfl.ch/>). These standards aim to include a number of factors including food security, land and water rights, and fair labor laws. The development of these standards has been difficult because of the complexities and sensitivities around the main issues that need to be considered.

9.2 Potential Concerns Regarding Production of Alternative Fuel

Q: Who can I turn to for help in finding out more about particular production methods or feedstocks?

A: Contact the CAAFI through its website (www.caafi.org) or Airlines for America (A4A) at info@airlines.org. These organizations are knowledgeable in the application of feedstocks

and processes to alternative jet fuels. Renewable fuel trade associations (e.g., Advanced Biofuels Association, Algal Biomass Organization, BIO) can introduce airports to their members. *Biofuels Digest* and other trade publications are also excellent sources of this information. Increasingly fuel suppliers are now present at major air shows and can be contacted at those venues.

Q: What is the biggest challenge in finding the best option for producing alternative fuel in my region?

A: The main challenge for alternative fuel production is finding the appropriate feedstock. For processing plants using biomass feedstocks, local availability of feedstocks is likely the most important factor. For processing plants using fossil fuels, such as coal or natural gas, easy access to existing transportation infrastructure is the main concern.

Q: We have identified a possible production technology and have plenty of local feedstock; how can we find a company to produce the fuel?

A: Contact CAAFI or A4A. The CAAFI website (www.caafi.org) contains links to many companies that are among its stakeholders. A4A can help identify a fuel expert from one of the airlines that serve your airport. Other sources are the Advanced Biofuels Association, BIO, and the Algal Biomass Organization. In addition, several trade publications (e.g., *Biofuels Digest*) contain lists of qualified producers.

Q: Can more than one feedstock be utilized in an HEFA facility?

A: Yes, in fact most producers will not want to rely on a single feedstock. Multiple plant oils can grow in the capture radius of an HEFA facility.

Q: Can the percentage of alternative jet fuel and other products from an alternative fuel processing facility be altered during the life of the facility?

A: Yes. Alternative jet fuel requires more hydroprocessing capacity than diesel. Once a facility is built for alternative jet fuel it can always produce more alternative (green) diesel. Typically, the maximum amount of alternative jet fuel production is up to 60%.

Q: How much more will alternative jet fuels cost compared to conventional jet fuel? How will the cost differential change with time?

A: According to most pricing scenarios, alternative jet fuels produced from new energy feedstocks and bought only in small quantities will cost more than conventional jet fuel. These initial costs are mitigated by both congressional subsidies (\$1 per gallon in recent years) and the USDA Biomass Crop Assistance Program. Considering the history of food crops, in which the yield per acre has improved over time, it is reasonable to expect that the yield per acre of bio-feedstocks will also increase, resulting in a reduction in their price.

Q: Are there public funding sources that can support feasibility studies for a biofuel facility at or near an airport?

A: Yes. USDA Rural Development has a series of programs to fund these types of studies. State agriculture departments are a source of programs as well. Contact CAAFI for more information.

Q: What constitutes a “rural” alternative jet fuel program that can be supported by USDA?

A: In new rules published in February 2011, the definition of “rural” is greatly expanded. For example, a program constructed in a more densely populated location using feedstocks from historically rural locations can be eligible. Airports, their clients, and stakeholders should consult with local and national USDA rural development authorities to establish how these new rules are applied in the local area.

Q: Are there limitations on the sources of foreign funding that can be supported by the USDA loan guarantee program?

A: In new rules issued by USDA in February 2011, foreign sources of investment in United States-based project developments are now eligible for support through certain USDA programs, including loan guarantees to develop alternative jet fuel projects. While this policy has been executed, regulations on specific USDA programs may be required to capture its intent. Airports and their clients should consult with CAAFI or local or national USDA Rural Development authorities to establish which projects are eligible. Once this is known, consultation with the U.S. Department of Commerce programs, such as Invest in America (<http://www.investamerica.gov/>), may be useful.

9.3 Potential Concerns around the Storage, Handling, and Use of Alternative Jet Fuel

Q: Do airlines support the use of alternative jet fuel?

A: Yes, the U.S. airlines' interest in alternative jet fuel is being coordinated by A4A. A4A supports alternative jet fuels as long as they are safe, environmentally friendly, reliable, and economically feasible. Airlines are committed to supporting alternative jet fuel facilities by signing long-term purchase agreements, but their willingness to pay a premium over the cost of conventional fuel will depend on the amount and duration of the premium.

Q: Does alternative jet fuel need any special airport-related infrastructure?

A: No, alternative jet fuel will not be qualified if it cannot be handled by existing airport fueling equipment.

Q: Will alternative fuels require duplicate storage or distribution systems at my airport?

A: No, by definition, drop-in fuels do not require duplicate storage or distribution. However, if the fuel is delivered through infrastructure not currently in use, then hookups will be necessary. For example, if an airport currently receives conventional jet fuel through a pipeline from a refinery and starts to receive alternative jet fuel by railroad, then a hookup between the railroad car and the pipeline is required.

Q: Is alternative jet fuel really safe to use in all aircraft, including older models?

A: Yes, alternative jet fuel will be thoroughly tested and will not receive certification unless it is safe in all existing gas turbine engines.

Q: Is alternative jet fuel safe to mix with conventional jet fuel in our existing tanks?

A: Yes, alternative jet fuel will be thoroughly tested and will not receive qualification approval from ASTM unless it is safe to mix with conventional jet fuel.

Q: How can I know jet fuel produced by a particular process has been qualified as safe?

A: Alternative jet fuels that are safe are listed under annexes to the alternative fuels specification ASTM D7566. CAAFI can be consulted if there are questions in this regard.

Q: We always test jet fuel before we accept delivery and add it to our fuel tanks. Can we use the same testing methods on regular Jet A and alternative jet fuels?

A: Yes, the same testing procedures will be used for regular Jet A and alternative jet fuel per current plans.

Q: Does alternative jet fuel have more quality control problems than regular fuel?

A: There is no current evidence to indicate that alternative jet fuels have more quality control problems than conventional jet fuel. One concern, however, will be the proliferation of many new fuel providers. This issue is being studied by the FAA and has been highlighted by CAAFI.

9.4 Potential Community Concerns around Alternative Surface Fuels

Q: What safety concerns can be associated with alternative surface fuels?

A: Vehicles powered by alternative surface fuels are at least as safe as current gasoline-powered vehicles. There is a perception that CNG-powered vehicles carry an increased risk of explosion or fire due to the high pressures at which CNG is stored. However, CNG is very safe due to high ignition temperatures and a narrow range of flammability in air. These two components make an uncontrolled, accidental explosion of CNG unlikely.

Q: How would potential customers know if they have a flex-fuel vehicle?

A: Flex-fuel vehicles are denoted by various types of badging near the rear of the vehicle as well as at the refueling point. Newer FFVs have bright yellow fuel tank caps to indicate the ability to use both gasoline and E85.

Q: What are the costs of alternative surface fuels relative to gasoline or diesel?

A: Though these costs vary due to market and other forces, most of today's alternative fuels are competitive with conventional gasoline and diesel. CNG tends to be priced, on an energy-equivalent basis, significantly lower than gasoline and diesel. LPG is priced competitively with conventional fuels. Costs of electricity can be dramatically different depending on location. In 2010, average electricity prices in the United States ranged from as high as 25.1 cents per kilowatt-hour in Hawaii to as low as 6.2 cents per kilowatt-hour in Wyoming (EIA 2011a). Though high electricity prices hurt the competitiveness of electric vehicles when compared with gasoline vehicles, the top three most expensive states for electricity (Hawaii, Connecticut, and New York) also generally have gasoline prices that are higher than the national average. Biodiesel and green diesel can also be competitive with conventional diesel depending on the prices of both oil and green/biodiesel feedstocks.

Q: Are there any incentives available to encourage airport operators to invest in alternative surface fuel systems?

A: There are multiple incentives and programs available on both the state and federal levels. Additionally, other miscellaneous entities, such as utilities and fuel companies, offer incentives to support the development of alternative fuels. Visit the Alternative Fuels Data Center website (<http://www.afdc.energy.gov/afdc/laws/>) for more information.



Glossary

Airlines for America (A4A). The oldest and largest airline trade association in the United States. More information at www.airlines.org.

Alternative jet fuel. Combustible liquid fuel made from non-petroleum sources that have the same performance characteristics in aircraft as today's commercial and military jet fuels.

ASTM International. Formerly known as the American Society for Testing and Materials (ASTM), this organization is a globally recognized leader in the development and delivery of international voluntary consensus standards. More information at www.astm.org.

ASTM D1655. Standard specification for aviation turbine fuels according to ASTM International.

ASTM D7566. Standard specification for aviation turbine fuel containing synthesized hydrocarbons according to ASTM International. This was the first specification for alternative jet fuels approved by ASTM.

Biodiesel. Biodiesel is an alternative fuel made via the esterification process and often made using palm, soy, rapeseed, and vegetable oil. It is normally blended with conventional diesel at up to a 20% concentration.

Biomass. Any material produced by living or recently living organisms, such as wood, leaves, seeds, and algae.

Commercial Aviation Alternative Fuels Initiative (CAAFI). A coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants, and U.S. government agencies working to enhance energy security and environmental sustainability for aviation through alternative jet fuels. More information at www.caafi.org.

Compressed natural gas (CNG). Natural gas is an alternative fuel that is extracted from the earth through various processes. It is used as a vehicular fuel via a system of high-pressure tanks.

Defense Logistics Agency (DLA). The procurement arm of the U.S. Armed Services, responsible for securing weapons, fuel, and other material. More information at <http://www.dla.mil>.

Emissions Dispersion Modeling System (EDMS). An FAA model utilized to assess the air quality impacts of proposed airport development projects. More information at http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/edms_model/.

European Union Emissions Trading System. A “cap-and-trade” program to limit the total amount of certain greenhouse gases that can be emitted by different sources, including aircraft. More information at http://ec.europa.eu/clima/policies/ets/index_en.htm.

Fatty acid methyl ester (FAME). A type of biofuel produced by exposing fatty acids to methanol or another type of catalyst.

Fischer-Tropsch (FT) process. A series of chemical reactions used to transform a carbon-rich feedstock, such as coal, natural gas, or biomass, into a hydrocarbon fuel such as jet fuel.

Fermentation renewable jet (FRJ). Process that uses biological organisms that turn feedstocks directly into finished products such as alternative jet fuel.

Green diesel. Diesel created as a result of the Fischer-Tropsch or HEFA processes, and is a drop-in fuel, though it can be blended with conventional diesel if desired.

Greenhouse gases (GHG). Gases in the atmosphere that absorb heat in the atmosphere. The primary greenhouse gases are water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (NO_x), and ozone (O₃).

Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET). A model created by Argonne National Laboratory that aims to quantify life-cycle well-to-wheels emissions across a wide variety of vehicle types, fuel systems, and fuel pathways. GREET models over 100 different fuel pathways and over 80 vehicle/fuel combinations. More information at <http://greet.es.anl.gov/main>.

Hydroprocessed esters and fatty acids (HEFA). Alternative fuel made by hydrotreating plant oils or animal fats. This process yields biofuel as well as multiple co-products.

International Air Transport Association (IATA). A leading airline trade association comprised of over 240 airlines and representing 84% of world air traffic. More information at <http://www.iata.org/Pages/default.aspx>.

International Civil Aviation Organization (ICAO). A specialized United Nations agency, ICAO's role is to standardize many aspects of international air travel, increasing consistency and, thus, safety. More information at <http://www.icao.int/Pages/icao-in-brief.aspx>.

Life-cycle analysis. An analysis technique for assessing environmental impacts associated with all the stages of a product's life. Life-cycle analysis as it applies to aviation fuel consists of estimating the amounts of various substances produced (or consumed) during the complete process of obtaining and using the fuel.

Life-cycle carbon footprint. Estimated carbon released during the life cycle (i.e., extraction of raw materials, processing, combustion, disposal) of a given material such as jet fuel.

Liquefied petroleum gas (LPG). Liquefied petroleum gas (propane) is an alternative fuel manufactured via the same processes as conventional gasoline and diesel. It is easily liquefied at low pressures and a nearly direct replacement or substitute for gasoline.

National Ambient Air Quality Standards (NAAQS). Emissions standards, covering seven criteria pollutants, and created by the Environmental Protection Agency under authority of the Clean Air Act. More information at <http://www.epa.gov/air/criteria.html>.

National Environmental Policy Act (NEPA). A law, enacted in 1970, that mandates the use of Environmental Assessments and Environmental Impact Statements when the federal government intends to take action that has the potential to cause environmental change.

Pyrolysis renewable jet (PRJ). Process that converts cellulosic feedstocks into a bio-crude that can be used to produce alternative jet fuel.

Renewable Fuel Standard (RFS). Standards created under the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007. These standards establish renewable fuel volume mandates in the United States. More information at <http://www.epa.gov/otaq/fuels/renewablefuels/index.htm>.

Renewable Identification Number (RIN). A central component of the RFS program representing units of renewable fuel that can be used for credits and trading and that demonstrate compliance with renewable fuel mandates.

Voluntary Airport Low Emissions Program (VALE). An FAA program created in 2004 that provides financial assistance to airports located in non-attainment areas for the purchase of various low-emissions assets in the pursuit of meeting NAAQS.

Water-energy-food nexus. Refers to the inextricable links between water, energy, and food production.



Acronyms

Acronym	Definition
A4A	Airlines for America
AC	Advisory Circular
ACRP	Airport Cooperative Research Program
AFDC	Alternative Fuels Data Center
AIP	Airport Improvement Program
ALP	Airport Layout Plan
ANL	Argonne National Laboratory
APU	Auxiliary power unit
ASM	Available seat miles
ASTM International	Formerly known as the American Society for Testing and Materials
ATAG	Air Transport Action Group
ATJ	Alcohol to jet
B20	Biodiesel, 20% blend
B100	Pure biodiesel
BTU	British thermal unit
CAAFI	Commercial Aviation Alternative Fuels Initiative
CATEX	Categorical Exclusion
CNG	Compressed natural gas
DEFSTAN	United Kingdom Defense Standard
DGE	Diesel-gallon equivalent
DLA	Defense Logistics Agency (formerly DESC)
DOE	U.S. Department of Energy
E15	Blend of ethanol (15%) and conventional gasoline (85%)
E85	Blend of ethanol (85%) and conventional gasoline (15%)
EA	Environmental Assessment
EDMS	Emissions Dispersion Modeling System
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FAA	U.S. Federal Aviation Administration
FAME	Fatty acid methyl ester
FAR	Federal Aviation Regulations
FBO	Fixed-base operator
FFV	Flex-fuel vehicle
FRJ	Fermentation Renewable Jet
FT	Fischer-Tropsch
FTJ	Fermentation to jet

GA	General aviation
gCO ₂ e	Grams of CO ₂ equivalent
GGE	Gasoline-gallon equivalent
GHG	Greenhouse gas
REET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
GSE	Ground support equipment
HEFA	Hydroprocessed esters and fatty acids
HRJ	Hydrotreated renewable jet
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
LPG	Liquefied petroleum gas (propane)
MSW	Municipal solid waste
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
PCA	Preconditioned air
PM	Particulate matter
PM _{2.5}	Particulate matter smaller than 2.5 microns
PM ₁₀	Particulate matter smaller than 10 microns
PRJ	Pyrolysis Renewable Jet
PTJ	Pyrolysis to jet
PVO	Pure vegetable oils
RFS	Renewable Fuel Standard
RIN	Renewable identification number
ROFA	Runway Object Free Area
RPZ	Runway Protection Zone
ULS	Ultra low sulfur
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
VALE	Voluntary Airport Low Emissions Program
WHA	Wildlife Hazard Assessment



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Appendixes

The following appendixes are available on the attached CD-ROM and from the TRB website (<http://www.trb.org>; search for “Assessing Opportunities for Alternative Fuel Distribution Programs”):

- Appendix A. User Guide for Toolkit
- Appendix B. Fuel Demand Forecasting Methodology
- Appendix C. References to Environmental Permitting Guides

Abbreviations and acronyms used without definitions in TRB publications:

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