CAAFI® Alternative Jet Fuel Environmental Sustainability Overview

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Introduction/Background

Commercial airlines and the U.S. military are seeking commercially viable alternative jet fuels to augment fuel supply, diversify fuel sources to help address price volatility, and provide environmental benefits relative to petroleum-based jet fuel. The aviation community's interest is growing in step with global interest in alternatives to petroleum-based fuels, chemicals and materials. There is an increasing sense that the current path of energy usage by global society is socially, economically, and environmentally unsustainable, and that to a large degree this is due to our reliance on abundant and (relatively) inexpensive fossil fuel resources, specifically petroleum. Petroleum usage is associated with global environmental damages, including the release of greenhouse gases that are contributing to global climate change and its associated impacts, as well as local and regional impacts resulting from extraction and accidents such as oil spills during transport. A petroleum-based future is also questionable because petroleum is a finite resource.

While there are growing concerns regarding environmental and other risks associated with petroleum-based jet fuel, which might be addressed through the development and deployment of alternative jet fuels, the development of a new industry for alternative fuels also has its risks and challenges. Central among these are sustainability issues, and as one of the key drivers for adoption of alternative fuels is environmental benefit, the environmental sustainability challenges of alternative fuels have come under intense scrutiny.[2]

As the aviation community seeks to adapt to the changing energy landscape and facilitate the development and use of alternative jet fuels, the industry will need to ensure that the fuels into which it invests political and economic capital will provide the hoped-for benefits (environmental, economic, and otherwise). This document is intended to provide some common ground for discussing the

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[1] The information provided herein is based on work by CAAFI, the Federal Aviation Administration, and Volpe National Transportation Systems Center, Futurepast, and Life Cycle Associates and input from CAAFI Environment Team members. The work was sponsored by the FAA's Office of Environment and Energy.

[2] One of the challenges for alternative jet fuels is that the burden of proof of sustainability is generally on the feedstock or fuel producer, and the demonstration of sustainability through regulatory or voluntary programs can carry a cost to the feedstock or fuel producer that may be incorporated into the final cost of the fuel. As no such analyses are required or expected of petroleum-based fuel producers, this can create an inequity in production and management costs between alternative jet fuels and traditional jet fuels. To the extent there is interest in developing commercially viable alternative jet fuels, incentives may need to be put in place to help to mitigate the cost and resource burden of evaluating alternative fuels relative to conventional fuels.

environmental sustainability challenges associated with the development, deployment, and use of alternative jet fuels.

How is "sustainability" defined in this document?

The Oxford English Dictionary defines sustainability as something that can be "maintained at a certain rate or level", specifically something that conserves "an ecological balance by avoiding depletion of natural resources."[3] While the term "sustainability" encompasses environmental, social, and economic aspects according to many frameworks, this document focuses on environmental sustainability. Specifically, it focuses on the key environmental areas that are likely to be considered when evaluating sustainability, and explains how environmental performance can be monitored and improved to provide the data for sustainability evaluations of alternative jet fuels to facilitate purchasing agreements or other commitments. This is not intended to imply that other environmental, social, and economic indicators are not important, and other indicators may be added to this document over time.

How does environmental sustainability apply to alternative jet fuel?

Reducing air pollutant emissions: The aviation community has long had an interest in addressing air pollution impacts, and is looking to alternative jet fuels to assist in reducing aviation-related air pollutant emissions relative to petroleum-based jet fuel. The emissions benefits may come from reducing emissions that affect either air quality or global climate change, or both. In terms of air quality, for example, alternative fuels tend to have much lower fuel sulfur and aromatic compound content than petroleum-based fuel, and hence result in lower emissions of sulfur oxides and particulate matter. Production and combustion of alternative fuels may also have reduced greenhouse gas (GHG) emissions relative to petroleum-based fuels over the life cycle of the fuels, depending on the feedstocks and production processes employed.

Minimizing other environmental impacts: While the aviation industry seeks air pollutant emissions benefits from alternative jet fuels, it increasingly recognizes that the use of alternative jet fuels must not create environmental problems in other areas. In addition, political and social acceptance of alternative fuels increasingly depends on a sense that the production, transport and use of those fuels are not inducing new environmental issues. Thus, alternative jet fuels ultimately need to be produced in a fashion meeting all relevant environmental criteria, including land use, water management and the like. It may be the case that a particular alternative fuel may have better environmental performance than standard petroleum-based jet fuel in some areas (e.g., meeting a particular regulatory or voluntary threshold for GHGs) and not in others (e.g., water consumption). Therefore, full cost accounting to compare among fuels may involve an additional decision-making process regarding sustainability priorities. Such expanded evaluation may include ecosystem services analyses and/or a cost-benefit

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[3] http://oxforddictionaries.com/definition/english/sustainable

analysis to take into account potential tradeoffs among various aspects of sustainability (Committee on the Sustainable Development of Algal Biofuels 2012). These potential impacts must also be weighed against the potential increase in sustainability concerns for petroleum-based fuels as the baseline for petroleum continues to shift to more energy- and carbon-intensive sources.

How can CAAFI help stakeholders gain a better understanding of environmental sustainability?

Providing common ground for discussion among "deal-makers:" There are differing views on the criteria and thresholds that might be applied to demonstrate the production, transport and use of a particular fuel as "sustainable." It is important to understand that considered indicators of sustainability and the levels of attributes or services that can or will be sustained fundamentally involve human choice. This document is intended to augment the aviation community's understanding of environmental sustainability concerns by providing CAAFI stakeholders with basic information on select environmental sustainability indicators that may be used by individual fuel purchasers or producers and some common metrics and baselines that may be used for comparison.[4] This document is intended to provide information about environmental sustainability relevant to a fuel purchase/sale. Therefore, it focuses on environmental sustainability measures as they may apply to particular fuels or individual operators. Viewing environmental sustainability at the fuel-specific and/or individual operator level may be different than viewing environmental sustainability on regional, national, or industry-wide levels, where multiple fuels, industries, and/or broader geographic areas might be at issue, rather than a single product or operator.

Highlighting environmental indicators: CAAFI has selected a few key environmental indicators for discussion to provide an understanding of the potential impacts that may need to be evaluated, monitored, prevented, or mitigated. CAAFI does not set any specific threshold targets for individual sustainability indicators and is feedstock and process neutral, although improved environmental performance is a critical aspect of alternative jet fuel acceptance for certain regulatory and incentive programs and by many stakeholders in the aviation community. CAAFI stakeholders want to ensure that appropriate environmental analyses have been performed with respect to alternative jet fuels, in order to provide confidence in the suitability of such fuels for long-term purchase commitments.

Providing Environmental Progression to track evaluations: CAAFI has developed two detailed communication tools for evaluating the technical development of feedstocks and conversion processes: the Fuel Readiness Level (FRL) and Feedstock Readiness Level (FSRL) tools. Both acknowledge certain aspects of sustainability assessment. In addition, CAAFI has developed an "Environmental Progression" tool (see Appendix to this document) to parallel CAAFI's suite of existing communication tools, including the FRL and FSRL (for downloadable versions of all three tools, see www.caafi.org/information/fuelreadinesstools.html). The Environmental Progression reflects

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[4] This document is for informational purposes only and is not intended to be exhaustive or prescriptive, or to provide advice on legal requirements or permitting.

environmental issues identified in the FRL and FSRL in addition to the specific indicators outlined in this document.

The goal of the Environmental Progression is to provide guidance on when different environmental analyses might best be performed during the development of a new fuel production process. For example, aspects of environmental sustainability that are potentially difficult to mitigate or are irreversible (e.g., land use conversion and biodiversity impacts or invasive species introduction) need to be evaluated prior to facility establishment or feedstock introduction. Some of these (e.g., invasive species risks and/or impacts) also need to be evaluated both during scale up and during operations. Critical sustainability indicators such as GHG emissions may also be preliminarily evaluated prior to scale up (screening level GHG life cycle analysis (LCA)). Other evaluations may be done during scale up (e.g., study level GHG LCA). Other measures may not be possible until a commercial facility is in development (e.g., acquisition of permits) or established (e.g., compliance with permits, comprehensive GHG LCA). In many cases these evaluations should also be repeated over the course of development and/or process refinement, as the evaluation results may change substantially due to changes (including possible improvements) over time.

The CAAFI Environment Team intends to work with member organizations to produce case studies that describe the use of the Environmental Progression and other tools in order to identify gaps and enhance the tools' utility.

How might CAAFI Stakeholders use environmental sustainability evaluations?

Feedstock/process screening: For fuel purchasers and producers, measures of environmental performance are likely to be used to screen existing and new processes and/or feedstocks to determine whether to pursue (or continue) development. For example, a preliminary GHG screening may suggest that a new feedstock/process combination will emit more GHGs on a life cycle basis than is considered tolerable from an environmental standpoint or marketable from a societal standpoint. A preliminary feedstock screening for importation, cultivation, and release requirements may show that the feedstock is at high risk for becoming invasive and therefore may be a poor candidate. Novel bioenergy feedstock crops, as well as waste materials, have not been fully studied to the extent that current commodity materials such as soybean oil, corn starch, sugar cane have been. Therefore the uncertainties associated with sustainability evaluations of these feedstocks may be larger.

Comparison among fuels or operators: Assuming a new feedstock/process passes basic screenings, the most likely next step will be to compare environmental performance among alternative fuels and/or operators, as well as to compare the relative environmental performance between alternative fuels and petroleum-based options.

How is environmental sustainability measured?

Comparing among fuels: Fuels may differ in energy content per unit volume or mass. Therefore, to compare fuels on an apples-to-apples basis, one should consider using the energy available for aviation end use on a per unit of energy basis (for example, per megajoule[5] or MJ). Relative sustainability metrics indicate the consumption of resources required to produce a unit of fuel or the emissions/wastes/environmental impacts associated with that production. In other words, they represent resource use efficiency (e.g., water consumed per unit of fuel produced) or production efficiency in terms of releases (e.g., emissions per unit of fuel produced). Furthermore, the indicators may be measured in terms of their impacts over the total fuel production life cycle (i.e., from inception of feedstock production through processing to final fuel combustion, and related supply chain components) or in terms of impacts at specific stages of production or consumption (i.e., separating out impacts at the stages of production, transportation, combustion). While these are not mutually exclusive (stage-specific impacts feed into the life cycle impacts approach), consideration of life cycle impacts is specifically recommended when the impacts are not local in nature but are felt on a much larger scale. For example, carbon dioxide (CO2) emissions are typically measured in terms of their life cycle impact given their global contribution to climate change. Life cycle analyses of impacts would include allocation of those impacts among co-products, such as oilseed meal or multiple fuel products coming from the same production pathway. To effectively compare among jet fuel options, the analysis must use the same life cycle approach (boundary definitions, assumptions, allocation methods, etc.). When the impacts are relevant to a local area, such as when the impact is dependent on background conditions that vary geographically (i.e., water availability), stage-specific indicators may be more appropriate. For example, effects of emissions on local air quality should be measured close to where the emissions are generated because the local background emissions level will determine the impacts of additional emissions from a new emitter on local air quality and human health.

Comparisons among alternative fuels or between an alternative fuel and petroleum-based fuel require identification of relevant environmental parameters and assessment of relative impacts. When considering the sustainability of a fuel in terms of air quality, some of the key pollutants of interest are carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx) and particulate matter (PM), which, in the United States are deemed “criteria pollutants.” In the case of GHGs, it is generally accepted that GHGs from alternative fuels should be compared to a baseline of GHGs from standard petroleum-based fuels, and this indicator should be evaluated on a life cycle basis for both alternative and petroleum-based fuels. For other indicators, the goal is to minimize detrimental environmental impacts, but few explicit criteria exist. In the case of biodiversity, some programs, such as the EPA’s Renewable Fuel Standard, set threshold dates for land conversion to be grandfathered in or require biomass to be extracted from forestlands that are “not ecologically sensitive.” Fuels made from feedstocks grown on land converted after the specified dates would not qualify for certain programs and incentives. While such thresholds may not be driven by scientific data, but may instead be driven by the desire to

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[5] A megajoule is one million Joules. A joule is a measure of energy expended to achieve a certain amount of work per unit time and is written in standard units as $(kg*m^2)/s^2$

minimize the impacts of a particular regulatory program, they can be important from a fuel producer and/or purchaser's perspective because they indicate an aspect of acceptability of the proposed alternative fuel to regulatory agencies and/or voluntary sustainability frameworks.

Table 1 provides a summary of the ways in which each of the selected indicators discussed in this document can be measured, what an ideal baseline would be for assessing impacts (or departure from optimum) and possible thresholds for assessing environmental performance and/or acceptability of a particular fuel.

Table 1: Types of metrics used for common environmental indicators.

Indicators relating to:	**General metric form**	**Ideal baseline**	**Possible thresholds**	**Example metric**
Emissions (GHG emissions; emissions affecting water or air quality)	Mass emitted per unit of fuel energy (life cycle) or per unit operation (e.g., feedstock production, fuel facility)	Minimization of total acceptable for given economic operator, with acceptability based on local context	Permitted levels or comparison with accepted standard petroleum baseline (e.g., 2005 standard petroleum required by EISA)[6]	Grams CO2 equivalent per megaJoule of fuel (gCO2e/MJ)
Withdrawal / consumption (water use)	Volume per unit of fuel energy (life cycle) or per year per unit operation (e.g., feedstock production, fuel facility)	Sustainable renewable water available to operator considering source (i.e., rain, ground, waste water)	Local water permits, comparison with standard petroleum or other alternative fuels	Liters of water withdrawn per MJ of fuel (Lw/MJ), Liters of water consumed or produced[7] per MJ fuel (Lc/MJ), total liters of water consumed in reference to consideration of local water scarcity
Land use (land conversion, soil quality)	Area of land converted from other uses, erosion rate, nutrient loss	Dependent on the initial condition of the land	Minimization, comparison with other fuels	Hectares converted per unit of fuel produced; tons of soil lost per hectare

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[6] EISA is a reference to the Energy Independence & Security Act. Under Section 526 of this U.S. statute, U.S. federal agencies are prohibited from purchasing "an alternative or synthetic fuel" for any mobility-related use, other than for research or testing, unless it is demonstrated that the lifecycle greenhouse gas emissions associated with the production and combustion of the fuel supplied is "less than or equal to such emissions from the equivalent conventional fuel produced from conventional petroleum sources." 42 USC 17142. Section 201 of EISA establishes that the baseline for this determination shall be "the average lifecycle greenhouse gas emissions" of petroleum-based fuels sold or distributed as transportation fuel in 2005.

[7] i.e., by deoxygenation of renewable oils

Biodiversity	Change in species richness, area affected by introduced invasive species, endangered & threatened species affected	None	Minimization, comparison with other fuels, zero impact on endangered / threatened species	Acres affected (or potentially affected) by invasive species, # of species lost to local area due to facility / organization (Δspecies)

Evaluating operator sustainability in local context: Although comparisons among fuels require relative sustainability measures that address environmental performance on a per-unit-fuel or energy basis, to adequately address the sustainability of the fuel, one must also consider consumption or emissions in the context of local conditions in which the feedstock or fuel is produced, including water availability, land use history, and other local conditions of air and water quality (Efroymson et al. 2012). This context-based approach addresses total impact of a given facility or operator on the production or combustion location and can be referred to as an assessment of "operator" sustainability.

Operator sustainability metrics as defined in this document are aggregate annual measures of either inputs/consumption or outputs/emissions that would be compared to local or regional resource availability or emissions limits. Operator metrics are measured on a facility or economic operator (e.g., feedstock producer, blender) basis rather than on a fuel life cycle basis, as life cycle analyses could potentially aggregate information across regions (although certainly the facility/operator values could become inputs for a life cycle analysis of a given indicator). Since these metrics are for aggregate use or emissions, the measurements are generally in an amount per year rather than per unit of fuel. These metrics provide a measure of the performance of the facility and can be compared to desired environmental performance, regional requirements or comparable facilities to assess total impact.

Ideally, facility-level information would be compared to baseline conditions and/or to alternative scenarios without the facility/producer of interest, although these may be difficult to define (Efroymson et al. 2012). Since facilities will be located in various ecosystems, even fuels that have the same water use efficiency for fuel production (volume of water per unit of fuel) could have very different impacts on the ecosystem in which they are produced. For example, a facility may use very few gallons of water to produce a unit of fuel (which could be considered excellent efficiency on a per energy unit basis). However, if the facility that produces that fuel is in a water-stressed (i.e., dry) area and draws sufficient water from its surroundings to drain local aquifers or streams or damage water quality nearby, this would result in poor operator sustainability for the fuel producer. Such context-specific impacts will likely also change over time due to factors that will alter the local context in which a facility or operator functions.

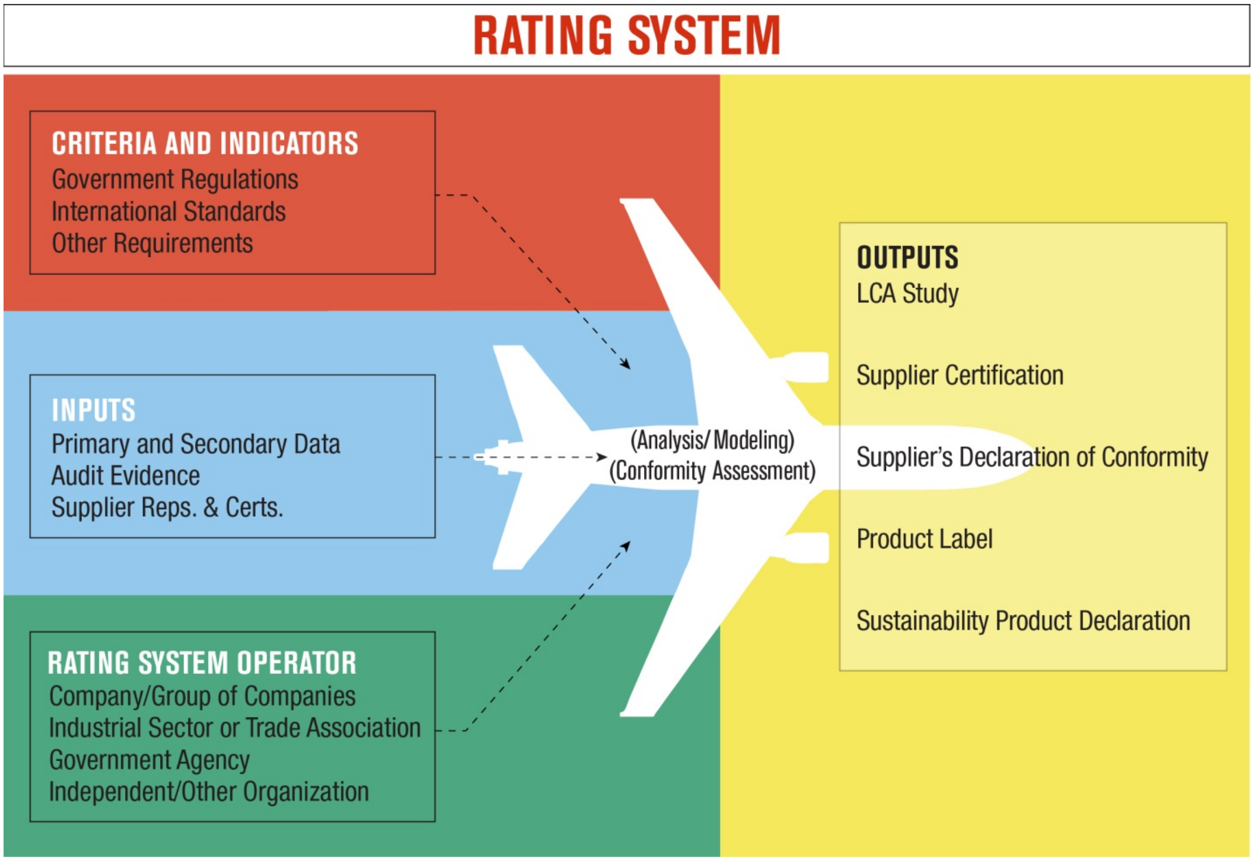
In some cases, permits are required for a facility reaching certain aggregate thresholds of emissions for a given pollutant or combination of pollutants. For example, facilities above a certain emissions threshold are required to secure permits to release air pollutant emissions. Compliance with a permit would suggest that the environmental authority (for example, EPA in the United States) has deemed the emissions level acceptable on a regional basis. Thus, the operator sustainability metrics can be used to provide an indication of whether emissions and/or resource consumption are within regulatory bounds that maintain regionally determined thresholds. It should be noted that conforming to legal requirements may not meet environmental sustainability goals in certain cases, although the existing emissions limits may currently be the most tractable approach to estimating a facility's fair share, or maximum acceptable emissions for indicators such as air and water quality. In cases where no regional targets have been set, the only available target may be to minimize impacts and comply with relevant laws or established best practices. For example, soil quality is not regulated on a regional level, and characteristics such as soil erosion may not be measured on a regular basis; therefore minimization of impacts through compliance with agricultural best practices such as those recommended by the United Nations Food and Agriculture Organization (UN FAO) or the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service may be the most reasonable methods for demonstrating sustainability for a feedstock producer (technical, and in some cases financial, assistance may be available to implement these practices: see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/). For a fuel producer, soil quality impacts are likely to be related to potential air, water or waste emissions or accidental releases and therefore are more likely to be covered under air and water quality impact minimization. Year-over-year improvement can be seen as an indicator of improved environmental performance and can be measured using an energy management system and/or an environmental management system (see best practices section below). Certain indicators are likely to be of greater concern to one economic operator class (e.g., feedstock producer, fuel producer) than another. For example, soil erosion is more likely to be a significant sustainability issue at a feedstock production location than a fuel conversion facility.

Who is measuring environmental sustainability of alternative jet fuels?

Alternative jet fuel sustainability may be evaluated by government agencies, companies, industries, end users, or independent organizations for the purposes of regulatory compliance, for compliance with voluntary standards, or for performance comparisons among fuel production pathways, companies, or economic operators (i.e., feedstock producers and fuel conversion facilities). One of the challenges for evaluating sustainability of alternative fuels is that there are many different sustainability frameworks, each with slightly different but overlapping values, indicators, methodologies (if addressed), and target audiences. The audience for the results of a sustainability evaluation may include standards developers, bioenergy industry participants, governmental policy makers, regulators, local communities, bioenergy industry workers, fuel users, and the general public (Futurepast 2012), and this may alter the level of detail, thresholds, or other aspects of interest that may direct the evaluation as well.

A generally acceptable sustainability evaluation will require verifiable data or well-justified assumptions in order to quantify environmental performance for various issues of concern. For an evaluation of environmental performance with regard to GHG emissions, an evaluator might require a life cycle GHG analysis that makes reasonable, transparent, justifiable assumptions (for processes that are not actually commercialized yet) and / or uses verifiable, high quality data (for aspects that already exist in the real world and are measurable). Figure 1 shows how data are incorporated into a variety of types of rating systems to provide reliable performance evaluations. To compare among fuels or operators, one would also need consistent criteria and metrics.

Figure 1: This schematic shows the various stakeholders involved in the use of a sustainability rating system and how data are fed into the system and audited to provide a rating or evaluation. Reproduced with permission from a report by Futurepast (2012) produced for the FAA.



Government regulations of alternative fuels that require the evaluation of some aspects of environmental performance include:

- The US Environmental Protection Agency's Renewable Fuel Standard (RFS2)
- The European Commission's Renewable Energy Directive (RED)
- The UK Renewable Transport Fuel Obligation (RTFO)
- The California Low Carbon Fuel Standard

In general, these programs require a specific volume or percentage of fuels used in their geographic region of interest to be renewable fuels (generally biofuels). For example, the RFS2 requires certain volumes of different kinds of fuels to be sold as transportation fuels in a given year, and provides specific thresholds for life cycle GHG emissions reductions that must be met. These regulatory programs may provide their own evaluations of individual processes, feedstocks or combinations or may rely upon voluntary frameworks developed by the private sector or non-governmental organizations (NGOs) to determine eligibility. The qualification for RFS2 inclusion, for example, depends on the EPA's evaluation of life cycle GHG emissions on a pathway-level basis and also on the qualification of the feedstock biomass as renewable based on statutory definitions. The RFS2 limits renewable biomass to materials harvested from land that was in agricultural or cleared condition prior to the law's enactment, or comes from non-Federal, non-imperiled forest lands, and forests that are not old growth or late successional, among other conditions (110 PL 140 §201). RED, on the other hand, specifically excludes fuels made from biomass grown on land converted from highly biodiverse[8] or carbon-storing lands, and relies on approved sustainability accounting methods developed by outside organizations, such as REDCert, The Roundtable on Sustainable Biomaterials (RSB)[9], or NTA RED, for qualification under the law.

A variety of voluntary frameworks and certification schemes have been developed both for feedstock production and for overall biofuel production (as well, of course, for companies and products in the more general sense). Each of these alternative fuels-related initiatives addresses different indicators of environmental sustainability (for an excellent summary of environmental factors addressed by various initiatives, see Table 2 in Scarlat and Dallemand 2011). In general, these programs rely on detailed data or assumptions that are usually audited by a third-party to ensure data quality and methodological consistency. Some also set specific thresholds that must be met to qualify the fuel as "sustainable" or "renewable" as defined by that particular initiative. Each targets a specific audience and use of the resulting evaluation. For example, the Global Bioenergy Partnership (GBEP) convened through the Food and Agriculture Organization of the United Nations, identifies 24 indicators of bioenergy sustainability, eight each in social, economic, and environmental areas or "pillars" (Global Bioenergy Partnership 2011). Because GBEP is intended for government policy makers, the target is sustainability of an entire bioenergy industry at the national level. This framework facilitates tracking of performance but does not set any criteria for expected performance level. Others, like the RSB certification scheme, focus on performance criteria and their measurement at the economic operator level, covering "Feedstock Producers, Feedstock Processors, Biofuel Producers and Biofuel Blenders" (Roundtable for Sustainable Biofuels 2010). RSB's certification scheme includes a specific threshold requirement with regard to GHG emissions in order to be certified as "sustainable" under the embodied value system. Still other programs, such as REDCert, are solely focused on meeting specific regulatory requirements. There are also product labeling approaches to compare environmental performance among products, such as Environmental Product Declarations based on Product Category Rules (ISO 2006) that do not necessarily correspond to any particular thresholds requirements. Therefore, it is critical to select an appropriate

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[8] Note that these requirements do not necessarily protect rare or vulnerable species that occur in less diverse or low-carbon storing habitats.

[9] Until March 2013, RSB was known as the "Roundtable on Sustainable Biofuels."

performance evaluation tool based on the objectives of the analysis. Voluntary frameworks that may be applicable to alternative fuel sustainability at various levels include:

- Governmental level
    - The Global BioEnergy Partnership (GBEP) Sustainability Indicators for Bioeneregy (agreed to by many governments as guiding sustainability principles) – available at / http://www.globalbioenergy.org/programmeofwork/sustainability/en/
- Facility/Operator Level
    - RSB Sustainability Criteria - accepted as European Union Renewable Energy Directive (EU-RED) compliant. (http://www.rsb.org)
    - ISO14025 - provides information on self-reporting of sustainability measures (http://www.iso.org/iso/catalogue_detail?csnumber=38131)
    - International Sustainability and Carbon Certification (ISCC) (http://www.iscc-system.org/en)
    - NTA 8080 and NTA RED (from the Netherlands Standardization Institute; http://www.sustainable-biomass.org/)
- Feedstock Oriented Frameworks
    - Council on Sustainable Biomass Production (CSBP; www.csbp.org)
    - Better Sugarcane Initiative (BSI or Bonsucro; www.bonsucro.com)
    - Roundtable for Sustainable Palm Oil (RSPO; www.rspo.org)
    - Forest Stewardship Council (FSC; https://ic.fsc.org/)
    - Programme for the Endorsement of Forest Certification (PEFC; www.pefc.org)
    - Sustainable Agriculture Network (SAN; http://sanstandards.org/sitio/)
    - International Federation of Organic Agriculture Movements (IFOAM; www.ifoam.org)
    - Fair Trade/Scientific Certification Systems
    - DLA Energy Indicators and Requirements (Alcorn et al. 2012)
- Forthcoming:
    - A new ISO standard on Sustainability Criteria for Bioenergy (TC248) is anticipated to be issued in 2015.

What parts of the alternative fuels supply chain are at the greatest risk relating to environmental sustainability issues?

The CAAFI Environment Team has worked with Futurepast and Life Cycle Associates to develop an impact matrix that identifies where in the supply chain potential sustainability impacts may be most likely to occur for a specific set of environmental indicators. The goal is to provide producers and purchasers with information so that greater attention may be paid to the components of the supply chain where best management practices and process refinement may have the greatest effect on improving sustainability, and conversely, where poor choices may increase risks. The "Impact Matrix" shown below (Table 2) suggests that for the selected indicators addressed by CAAFI, the overall greatest risk for impacts lies with feedstock and fuel producers rather than preliminary feedstock processing, distribution, or the final user. These results generally agree with a recent study by Efroymson et al. (2012) indicating major potential environmental effects are concentrated in the feedstock production and harvesting and biofuel conversion stages of fuel production. However, no steps in the supply chain are without their risks, and all economic operators in the supply chain are responsible for implementing appropriate best management practices.

Figure 2: Impact Matrix showing potential for direct environmental impacts across the alternative jet fuel supply chain for selected environmental sustainability indicators[10]

	Economic Operator				
Indicator	**Feedstock Producer**	**Feedstock Processor**	**Fuel Producer**	**Fuel Blender/ Distributor**	**Fuel End User**
Energy Use (Balance)	High	Medium	High	Low	High
Greenhouse Gases	High	Low	High	Low	High
Air quality	Medium	Low	High	Medium	High
Biodiversity	High	Medium	Medium	Low	Low
Land Use	High	Low	Medium	Low	Low
Water quality (Pollutants, Eutrophication)	High	Low	Medium	Low	Low
Freshwater use (Consumption)	High[+]	Low	High	Low	Low
Soil quality	High	Low	Low	Low	Low
	+ most likely related to irrigation for first generation biofuels, less likely for advanced biofuels				
Potential Impact Severity (color) →	Low	Medium	High		

What are the potential impacts?

This section describes the sustainability indicators highlighted in the Environmental Progression and the Impact Matrix. These indicators were selected based on their environmental implications, their current evaluation in the aviation community (e.g., air quality, GHGs) and/or their common consideration

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[10] This impact matrix is not restricted to sustainable/renewable alternative fuels but is also intended to reflect potential impacts from drop-in alternative fossil-based fuels (e.g., coal-to-liquid or natural-gas-to-liquid fuels).

among various frameworks such as the GBEP and RSB. Note that the order below follows of Figure 2 and it does not imply any hierarchy of importance. When tradeoffs arise among different sustainability indicators during the selection of different feedstocks, processing options, and other aspects of the alternative fuel value chain, the producer, purchaser, and public will need to make decisions about the relative importance of these environmental concerns as well as economic and social considerations, such as the relative economics of fuel production.

Energy Balance - The production of any fuel requires energy inputs. Efficient production systems provide a large energy return on energy invested (EROEI), which can be measured as energy yield over energy invested. The energy invested may include distinctions between self-generated (internal) energy that is applied to the process versus external energy sources, but for sustainability purposes evaluations are more likely to distinguish between fossil energy versus renewable energy invested, as fossil fuels are inherently not renewable. Therefore, a process that has a lower investment of fossil fuel energy per unit fuel production (either as a feedstock or as a process fuel) may be more sustainable than another that uses fossil fuels more heavily. Past controversy over the sustainability of early corn-based ethanol production were in part due to poor energy balance and reliance on fossil energy (as well as food-fuel concerns), although the energy efficiency of corn ethanol has risen over time to achieve a positive energy balance (Shapouri et al. 2002). It is likely that the aviation community will be concerned about ensuring a positive energy balance to avoid similar controversies.

Greenhouse gases – Greenhouse gases trap heat in the atmosphere. The current and ongoing change in climate, particularly global average temperature, is attributed to carbon dioxide (CO_2), methane, nitrous oxides, and other gases that are released from combustion of fossil fuels and other agricultural and industrial activities, including that resulting from the conversion of land to biofuel feedstock production. As hydrocarbons are fundamental to powering aircraft engines, the CO_2 generated upon combustion cannot be eliminated from drop-in alternative jet fuels, but the net greenhouse gas emissions associated with jet fuel use can be lowered by reducing the CO_2emissions elsewhere along the life cycle of the fuel. Alternative jet fuel purchasers will be looking for a GHG) LCA indicating that the use of an alternative jet fuel results in lower life cycle GHG emissions per unit of energy than conventional fuel made from petroleum. A fuel's GHG LCA should be performed according to a methodology that is appropriate for the regulation that is being met or, if for voluntary purposes, according to a widely accepted methodology that includes auditing of data and assumptions. While the boundaries for life cycle analyses can vary, the life cycle GHG evaluation should at a minimum include the GHG footprint that results from all inputs (energy, fertilizer/pesticides, etc.), direct land use change, transportation of feedstock and other materials used to produce the fuel, all inputs to fuel processing, the transportation of fuel products and co-products, and the fuel combustion.

In recent years, various standards-setting organizations have set forth the steps for performing life cycle analysis. The ISO Standard 14040 and its component parts, "Environmental Management – Life cycle assessment – Principles and Framework" and "Environmental Management – Life cycle assessment – Requirements and guidelines" (2006 versions) are fairly well accepted and commonly referenced in this regard. The United States Air Force, in collaboration with a number of aviation stakeholders including the U.S. Federal Aviation Administration, prepared a helpful document on how to perform life cycle analysis for jet fuel, “Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels (Final Report) (2009, AFRL-WP-TR-2009-2206).[11] This document, also colloquially referred to as the “Rules and Tools Document,” builds on ISO Standard 14040 and augments and applies the ISO Standard approach to life cycle analysis to jet fuel. It identifies the steps associated with life cycle analysis for jet fuel and makes recommendations for dealing with open issues.

While helpful resource documents such as these exist, there is no universally-agreed method for performing life cycle analysis for alternative jet fuels. Various regulatory and voluntary regimes specify methodologies to assess life cycle GHG emissions. Thus, there can be differences when various methods and guidance are applied. For example, some life cycle GHG accounting methodologies assume that combustion CO_2emissions from bio-based jet fuels in particular can be counted as zero because the emitted CO2 has all been recently fixed by the organisms from which the fuel is derived. Some accounting methods stop here and assume all bio-based fuels have zero GHG emissions, while others sum the remaining GHG emissions resulting from production activities (other than CO2 fixation) and processing to calculate the life cycle GHG emissions. Currently, the United Nations Framework Convention on Climate Change (UNFCCC) requires reporting of jet fuel combustion emissions only and does not require the inclusion of GHG emissions from jet fuel production. This contrasts with the methodology in the commonly used GREET model from Argonne National Lab and certain other well-accepted GHG LCA accounting methods. In actuality, all drop-in fuels will produce approximately the same amount of CO_2 emissions during combustion, but may vary in other compounds (e.g., black carbon, SO_x) that affect climate change. Furthermore, there are other contributors to climate change impacts (e.g., contrails) that are not offset by feedstock production credits, regardless of source. Given that aviation is an international enterprise, it likely will be important that criteria be adopted for recognition of GHG LCA results across the aviation supply chain and between countries.

A number of existing methodologies also attempt to estimate potential indirect land use change effects, but the estimation of indirect land use change in GHG LCAs is challenging and is not always included (see further discussion under “Land Use Change” below). The CAAFI Environment Team plans to convene a small working group to identify technical differences among existing GHG LCA calculation tools and accounting schemes, while continuing to work to broaden data and analysis availability.

Air quality – Air quality is affected by emissions of airborne pollutants such as carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM), which can have detrimental effects on human health. Unlike GHG emissions, most of these pollutant emissions are considered problematic on a local or regional basis rather than on a global basis. Because of their local to regional nature, pollutants that degrade air quality are generally regulated to maintain regional air quality at or above a certain threshold regional basis to limit health impacts. However, some pollutants are long-lived and can have impacts beyond the regional area. Also, ecological impacts (e.g., on wildlife, flora, or

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[11] The full title of this report is: “Propulsion and Power Rapid Response Research and Development (R&D) Support – Delivery Order 0011: Advanced Propulsion Fuels Research and Development Subtask: Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels (Final Report).” It can be downloaded from: http://www.caafi.org/information/reports.html

water quality) may not be prevented at the same thresholds used to limit human health impacts. Therefore, minimization of pollutant emissions is always considered desirable from the perspective of environmental management, again highlighting the distinction between regulatory requirements that identify a maximum allowable emissions level and environmental performance goals that target minimization of impacts. Background pollutant concentration is important relative to the impact of pollutants affecting air quality, and background emissions vary among the regions where the feedstock and fuel are produced and where the fuel is used. Therefore, it can be useful to examine the components of the fuel supply chain individually to address local air quality.

Biodiversity - Biodiversity is defined as the variability of living organisms on earth, encompassing the number of species of plants, animals, and microorganisms, the diversity within those species (genes, populations), as well as the wide variety of habitats and ecosystems of which they are a part, such as grasslands, rainforests, and coral reefs (Millenium Ecosystem Assessment 2005). Biodiversity can be affected by existing or alternative fuel production in several ways. Habitat loss may result if habitat that supported native species is converted into agricultural land, fossil feedstock extraction zones, or alternative fuel refinery facilities. This can be particularly important for rare or vulnerable species. There can also be effects on adjacent areas that are not cleared due to noise or other non-physical encroachment, pollutant emissions, or water withdrawals. The immediate effects of habitat loss due to feedstock or fuel production siting may also lead to broader effects in the area or region due to potential migration of species away from the site to other areas, or loss of an entire species from the region if the species on the site affected are rare, vulnerable, threatened, or endangered. Thus, context of the location and extent of impact is a critical consideration for identifying potentially undesirable changes (Efroymson et al. 2012). The introduction of novel biofuel crop species can further threaten biodiversity, since many of these species are selected for traits that are also indicative of potentially invasive species, although actual invasion depends on a variety of factors including local conditions. Even genetically engineered (GE) /genetically modified (GM) bioenergy crops that are not themselves invasive may facilitate gene introgression to weedy relatives, for example, by transferring herbicide or pest resistance genes, resulting in range expansion and invasion by those species. On the other hand, selecting feedstock production approaches that enhance biodiversity and provide habitat (e.g., by the use of mixed prairie grasses (Tilman et al. 2006, Fargione et al. 2009) or other diverse farming approaches (Kremen et al. 2012)) can increase the presence of beneficial insects and other organisms, enhance resilience, and decrease inputs such as fertilizer and pesticides (Dale et al. 2010, Kremen et al. 2012, Kremen and Miles 2012). Specific management practices can reduce negative and promote positive impacts on biodiversity within and around feedstock production sites (Buck et al. 2004, Scherr and McNeely 2008). Many conservation practices exist and are being developed that apply to different crops, landscapes, and specific issues (Bennett and Mulongoy 2006, Perrow and Davy 2008b, a) that can mitigate impacts.

As a proxy for the many levels of biodiversity that can exist, biodiversity is generally measured by species richness and evenness indices that take into account relative abundance of each species. However, even this simplified approach requires much baseline data and tracking of changes over time, by which point impacts may have already occurred. For this reason, current approaches to evaluate sustainability of biofuel production with regard to biodiversity for the purposes of regulatory or incentive programs (e.g., the EPA Renewable Fuel Standard or the European Renewable Energy Directive) tend to set specific limitations on when land must have been converted to agricultural purposes and/or exclude biodiverse[12] or high carbon stock vegetation or land types as sources of renewable biomass. These limitations are intended to minimize disturbance, destruction of native species and habitat, and GHG emissions. Voluntary certification schemes also recommend feedstock selection and cultivation techniques to reduce the risk of potential invasive species introduction, as well as the use of international and regional biodiversity mapping tools (Roundtable for Sustainable Biofuels 2010) such as the Integrated Biodiversity Assessment Tool (IBAT) and Natureserve's Surveyor tool (Matthew Rudolf, RSB, pers. comm. to KCL, 1/31/2013). In the U.S., government agencies such as EPA, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service use Ecological Risk Analysis (ERA) to evaluate potential impacts from exposure to a novel chemical (e.g., pesticides) or organisms on an ecosystem, including biodiversity components (e.g., EPA 1998). Recent work by the National Research Council of the National Academies (NRC NA) has attempted to synthesize and harmonize the ERA approaches of these agencies to provide a consistent approach through which to look at ecosystem impacts (National Research Council of the National Academies 2013). The NRC has identified four key elements to any ERA – problem formulation, evaluation of exposure and potential impacts of exposure, and then a risk assessment component that evaluates what the actual impacts would be given the overlap between potential for exposure and the impacts of exposure. This system of risk analysis may provide additional tools for alternative fuel producers looking to understand their potential ecological impacts.

Land Use - Land use change has implications for environmental performance in several ways. Conversion of land from natural vegetation to agricultural or industrial use can result in the emission of greenhouse gases due to the destruction of biomass and potential release of stored carbon in the soil. This is generally counted against the GHG emissions benefit (if any) of the alternative fuel. Land use change can result in soil erosion, which affects soil quality and nearby water quality. Land use change can also have significant effects on habitat availability for wildlife, affecting biodiversity and potentially rare, vulnerable, endangered and threatened species. Furthermore, where agricultural land is converted to bioenergy cropland, land use change can compete with and affect the availability and/or price of food or animal feed (and the resulting animal products). Finally, conversion of agricultural land for bioenergy production can result in compensatory land use change elsewhere to produce additional agricultural products as a result of the change in the price of agricultural products (i.e., indirect land use change effects). Estimating the impact of indirect land use change is challenging due to the many economic factors that must be modeled accurately; the regional and temporal variations in land use intensity, agricultural yields, and other agricultural factors; as well as the difficulty in attributing changes to the price of agricultural products to specific causes when many factors contribute simultaneously. However, indirect land use change concerns can be mitigated by using feedstocks that reduce the

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[12] These definitions do not necessarily protect threatened species if they occur in habitats that are not considered biodiverse or threatened. In this case, as discussed previously, the legal requirements are designed to set a maximum allowable amount of impact but do not necessarily accomplish the minimization of impact.

likelihood of compensatory land use being needed, such as by using cover crops or wastes. Land conversion is therefore both an indicator and the trigger of a variety of potential sustainability impacts. The magnitude of total land conversion from non-cultivated, natural condition is important because it strongly influences habitat availability and fragmentation, as well as potential local or regional impacts on water quality, soil quality, etc. The amount of carbon released and the impacts on biodiversity, water, and air quality depend on the prior use of the land (e.g., fallow field versus forestland versus natural grassland), and the conversion of different types of land may be governed by a variety of regulations and incentives (for example, qualification for RFS2 or enrollment in easement programs such as the USDA Farm Service Agency's Conservation Reserve Program). On the other hand, converting brownfields, degraded agricultural lands, or other low-carbon conditions to bioenergy crop production may be beneficial in terms of carbon sequestration and/or ecological function.

Water Quality - Alternative fuel production, whether from bio- or fossil feedstocks, can both directly and indirectly affect local and regional water quality, a key sustainability consideration. Unconventional extraction techniques for fossil fuels (e.g., hydraulic fracturing) may have water quality impacts greater than those associated with traditional extraction techniques due to potential releases of drilling fluids and additives into groundwater as well as surface water (Ramudo and Murphy 2010). Direct effects of fuel production facilities on water quality may include release of nitrogen and phosphorus, pollutants in effluent, accidental spillage, and release of cooling water into natural bodies of water, which causes thermal pollution. Agricultural activities may also result in runoff of pesticides and fertilizer (mainly nitrogen and phosphorus). Nutrient releases can cause plant and algal blooms and subsequently increased biochemical oxygen demand (BOD) as decomposing plant and algae deplete the dissolved oxygen, leading to hypoxic zones in waterbodies that cannot support aquatic life. Hypoxia is largely due to runoff from agriculture (Committee on Environment and Natural Resources 2010). Therefore, emissions of such pollutants are an important consideration for any agricultural or industrial process, including biofuel and feedstock production. The use of bioenergy crops that do not require substantial fertilizer inputs may reduce the potential runoff of nutrients compared to more fertilizer-intensive crops. Best management practices can be used to protect water quality, reduce erosion potential, and provide a mosaic of habitats on the landscape. Land use change, soil erosion and compaction, and runoff from impermeable surfaces that carries other types of contaminants (e.g., motor oil) can also affect water quality near croplands or industrial facilities and should be managed as part of the biofuel producers' sustainability efforts. Water quality evaluations should consider the nitrogen and phosphorus released by cropland and total suspended solids (TSS) released. One tool for evaluating potential water quality emissions due to agricultural land runoff is the USDA Natural Resource Conservation Service (NRCS) Water Quality Index (WQIag, available at http://199.133.175.81/WQIPublic/ in beta form). This tool allows a grower to input information about their location, soil type, slope, and management approaches to get information on likely water quality impacts, and also allows the producer to explore conservation techniques that might reduce water quality impacts.

Biofuel refinery performance comparisons could include impacts on biological oxygen demand (BOD) and chemical oxygen demand (COD) (concentration and total release per unit of fuel), and releases of oil and grease. Under the U.S. National Pollutant Discharge Elimination System (NPDES), permits are required for industrial entities to discharge effluent into surface waters. These permits take into account the technology available to control the pollutants, the affected watershed, and limits on the whole effluent toxicity to the water supply (EPA 2010) . Permitted amounts may be the best measure of maximum acceptable emissions for biorefineries and other industrial facilities, although they do not address the goal of minimization of emissions (and associated impacts). One of the challenges of using this approach, however, is that countries (or even states within countries) may not have permitting regulations or may have requirements that vary in rigor, stringency, and approach, and this may make it harder to use permit compliance as a "minimum test" for sustainability.

Water Use -

Water use can be broken down into withdrawal and consumption. It is important to be aware of the differences between water use and water consumption in these processes. Water withdrawal is the volume removed from a water source such as a lake or river, to which the water is returned and becomes available again. Consumption is the volume of water removed for use and not returned to its source (or returned at lower quality). Generally, concerns about water over-use focus on freshwater consumption (a.k.a., blue water from freshwater aquifers or surface sources) as opposed to rainwater consumption (a.k.a., green water). Grey water may be characterized as the amount of freshwater necessary to dilute released pollutants to acceptable levels given background conditions and existing standards, and is another form of water use (Hoekstra et al. 2011). In the U.S., agriculture, specifically crop irrigation, accounted for 37% of all freshwater withdrawals in 2005 (Kenny et al. 2009). Usage (as opposed to just withdrawal) for agricultural irrigation is also very high, accounting for 85% of total national consumptive use in 1995 (Solley et al. 1998). A distinction is also made between renewable and non-renewable water resources. Renewable water represents the long-term average annual flow of surface and groundwater, whereas non-renewable water resources include deep aquifers that negligibly recharge on the human time-scale once they are drawn. In many places in the U.S., unsustainable water use has depleted groundwater in the last 50 years, resulting in the water level dropping by several hundred to nearly 1000 feet in some areas (DOE 2006). Fossil groundwater is over-used in many other parts of the world, too.

The amount of total water withdrawal and consumption that is sustainable depends strongly on the context of the cropland and refinery locations, the local and regional water resources, and competing uses for the available renewable water. Withdrawal and consumption of a given quantity of renewable water in water-stressed Western states, for example, is not equivalent to the same consumption in a humid region with high water inflow. The timing of the water demand may also be important because of seasonal variations in the scarcity of water. Water scarcity metrics (e.g., total water use versus total water available) must therefore be used as the baseline to assess whether a given location can tolerate additional water consumption (e.g., Hoekstra et al. 2012).

A number of approaches are being developed for water "footprinting" to evaluate water use to take into account both use and local water availability. For example, the Water Footprint Network's approach to evaluating sustainable water use (www.waterfootprint.org) takes into account geographic and process sustainability. The first consideration addresses local and regional water scarcity – if a subcatchment or catchment in which the product supply chain is located is a “hot spot” in which water use exceeds availability annually or seasonally, then additional water use in that zone would be considered unsustainable. A recent study showed that of 405 river basins evaluated around the globe (accounting for 69% of global runoff and 65% of global population), 201 of them experienced severe water scarcity for at least one month per year even without considering the amount of water that may be polluted and therefore of limited uses (e.g., Hoekstra et al. 2012). Such analyses suggest that the temporal patterns of water use may also be important for sustainability. The second consideration under this approach is whether the water use is avoidable or can be reduced at reasonable societal cost. This water footprinting protocol considers it unsustainable to use water at a greater level than necessary, regardless of local water scarcity context (Hoekstra et al. 2011). A forthcoming ISO standard on water footprinting (ISO/DIS 14046 “Environmental management – Water footprint – Principles, requirements and guidelines”) will likely provide additional, internationally acceptable approaches to evaluating water use sustainability for products and processes, and is intended to be consistent with international LCA approaches (Margni 2010). However, it is likely that water footprinting will be as varied and contentious in approach as GHG LCA has been over the past few years. Points of contention among water footprinting approaches are likely to include the system boundaries (e.g., subcatchment, catchment, region), accounting for grey water, thresholds for “scarcity” designations, and resolution/scale of evaluation. Ridout and Pfister (Ridoutt and Pfister 2010) also identify concerns regarding standardization, comparability, and the ability to associate actual impacts with a given water footprint. As with GHG LCA, for water footprinting, a rigorous approach with thoroughly verifiable data and/or well-justified assumptions, as well as third party review, will be important for acceptance of any water footprint evaluation and results.

Past analyses have suggested that water use concerns may be exacerbated as alternative fuel production increases in the future (Berndes 2002). The concern about water overuse is related to the possible need for irrigation to produce feedstocks (DOE 2006) as well as the cooling requirements of conversion processes (Stratton et al. 2010).   Both crop type and processing technology contribute to water footprint of a fuel. In an analysis of water footprint of first generation biofuels (bioethanol and biodiesel) assuming the most water-efficient first-generation crop source, biodiesel was nearly three times more water intensive than bioethanol for surface transport purposes (Gerbens-Leenes and Hoekstra 2011), although this depends on both the crop and the country of production (Mekonnen and Hoekstra 2011). Recent research by Staples et al. (Submitted 2013) under the FAA sponsored PARTNER program estimates life cycle water consumption to be 4-8 liters of water per liter of conventional jet and diesel fuels. Other non-conventional extraction methods for fossil feedstocks (e.g., hydraulic fracturing, or “fracking”) may have higher life cycle water use per unit of fuel produced (lower water efficiency). According to Staples et al (Submitted 2013), advanced biofuels from non-irrigated feedstocks have life cycle water efficiencies on the same order of magnitude as conventional jet and diesel, but feedstock irrigation can lead to life cycle water use up to three orders of magnitude higher than conventional fuels. This water efficiency of fuel production is important, and must also be combined with evaluations of local water availability or scarcity to fully evaluate sustainability.

Soil Quality - The loss of soil fertility reduces land productivity, affecting the ability to grow crops, thereby requiring greater land areas to produce the same products and/or greater agricultural inputs such as fertilizers, which result in other environmental issues. Reduced land productivity can have indirect effects on land use change, biodiversity, and water quality. Soil quality issues are interrelated and therefore likely to occur together. For example, soil compaction reduces porosity, which decreases water infiltration; reduced infiltration can cause the soil to crust and become subject to erosion by wind. Most of the organic matter and nutrients are in topsoil and leave with it. Soil erosion and runoff also lead to other sustainability impacts such as degraded water quality and biodiversity in rivers and lakes. Biofuel feedstock production can affect soil quality in a variety of ways, including physical erosion of soil, the introduction of salt and other contaminants, loss of soil organic carbon (SOC), nutrient depletion, and compaction, all of which can jeopardize the fertility of the land and the sustainability of continued bioenergy crop growth. Biofuel feedstock production can also affect soil quality in a variety of positive ways, including maintaining soil cover, increasing soil carbon, and improving infiltration rates. Some studies have suggested that the use of bioenergy crops in rotation with traditional crops can enhance yields of the food crop due to enhanced uptake of soil nutrients (Angus et al. 2011). The sustainability of biofuels with regard to soil quality can be compared on the basis of annual soil quality test data from the land on which the crops are cultivated. Factors to consider include: changes in SOC and nutrients, salinization, erosion, and bulk density. Given the variability in soils, practices, and sampling costs, it is likely that repeated measurements at appropriate time intervals will be necessary to determine any relevant trends.

As discussed previously under water quality, one tool in the US for identifying potential soil conservation practices to reduce impacts on soil quality, runoff, and water quality is the NRCS WQIag, which allows user-specific inputs to estimate the potential releases from a specific location based on management practices and site characteristics, and can explore the effects of specific BMPs to address potential impacts. NRCS, and probably state agricultural extension programs, will also work directly with farmers and ranchers to identify BMPs that can reduce soil impacts for a particular location and activity.

What are some ways to prevent or mitigate impacts?

Pro-active environmental performance assessment: Proactive use of the available tools and compliance with existing requirements can go a long way toward preventing potential environmental impacts associated with alternative fuel production. In addition, risks can be reduced by assessing potential issues prior to implementing a project and taking corrective action. The CAAFI Environmental Progression is intended to provide a checklist to help identify what environmental analyses can be done and when they should be performed during alternative fuel/feedstock development and scale up. Performing (or, if you are a purchaser, requiring) rigorous, audited or peer-reviewed analyses of potential impacts in accordance with a well-accepted (or required) sustainability framework (for example, that of RSB or other voluntary programs) can facilitate acceptance of the fuel as sustainable and/or identify areas where production processes or feedstock options can be modified to improve environmental performance prior to fuel development.

Compliance with legal requirements: Many countries have existing laws that already regulate certain types of emissions or impacts related to the indicators discussed above. Thus, depending on the country, the acceptability of a particular facility or company's actions may in part be addressed through compliance with relevant domestic laws. For example, in the U.S., relevant laws include the Endangered Species Act, wetlands protections, noxious weed and seed laws, the Clean Air and Clean Water Acts, the National Environmental Policy Act (NEPA) and OSHA standards, among others. However, it should be noted that while compliance with laws and regulations is both expected and indicates acceptability, it does not necessarily indicate sustainability.

Minimization of emissions is always the sustainability target for pollutant emissions. Reporting of aggregated tons of a given pollutant emitted per year gives a clear understanding of the magnitude of the problem but there is no absolute threshold for determining individual facility sustainability. Currently, the best approach for evaluating the acceptability of a facility's emissions may be to rely on compliance with existing required permits regulated to limit regional air quality issues. For example, in the United States, CO, NOx, SOx, and PM are criteria pollutants that are regulated under the EPA's authority to implement the Clean Air Act through the promulgation of National Ambient Air Quality Standards (more info available at http://www.epa.gov/air/criteria.html). Refineries, production facilities, and aviation activities are required to apply for and comply with NAAQS permits if they meet certain emissions thresholds. Other pollutants, such as toluene, are regulated through EPA's National Emission Standard for Hazardous Air Pollutants (NESHAP; see http://www.epa.gov/apti/course422/apc4e.html for more information). These types of permits are specifically focused on managing regional air quality and therefore provide some basis for sustainability evaluation. In addition, frameworks such as RSB suggest continuing year-over-year improvement in such indicators as air quality emissions in order to fulfill sustainability criteria.

Implementation of Best Practices: In addition to compliance with laws and regulations, there are a variety of voluntary "best practices" that can enhance resource conservation and facilitate compliance with regulations. "Best practices" are broadly recognized approaches to managing quality-related issues. It is advisable that most facilities implement an energy management system (EnMS) and/or environmental management system (EMS) in accordance with an internationally recognized protocol (e.g., ISO 5001 and ISO 14001, respectively), as such systems allow the operator to track environmental and energy performance on a continual basis, including the effects of best practice implementation, and generate the data that would be used for sustainability evaluations, particularly for showing evidence of continuous improvement (e.g., as required by RSB Principle 2 and ISO 14001). Application of a voluntary sustainability framework that requires third-party auditing and continuous reporting and monitoring is one way to demonstrate environmental performance and improvement across the supply chain or by an individual operator.

For feedstock and fuel producers, general best practices that should be followed include compliance with national, regional and local laws, regulations, and permit requirements. In addition to these general best practices, there are specific best practices associated with individual sustainability criteria. An array of environmental sustainability-related best practices can be found in the ISO 14000 series; for example, ISO 14001 providing guidelines on environmental management system implementation, ISO 14020 series on environmental management, ISO 14031 on environmental impact evaluation, ISO 14040 series on life cycle assessment, and ISO 14064 on evaluating and reducing GHG emissions, among others. The Biomass Research and Development Board has put together an extensive summary of best management practices for different types of feedstock production (e.g., herbaceous annuals or perennials, woody species, algae) to minimize soil, water, and air quality impacts as well as water use and invasive species issues (Biomass Research and Development Board 2011). A similar document has been developed by the UN Food and Agriculture Organization emphasizing protection of food security in bioenergy production (FAO/BEFS 2012). In addition to these general documents about bioenergy production best practices, there are guidelines related to specific issues, such as best practices for reducing invasive species risk (IUCN 2009) and for limiting water use and quality impacts relating to biofuel feedstock production (National Research Council of the National Academies 2008).

For U.S. producers, a variety of U.S. Government agencies have developed best management practices (BMPs) to address invasive species, biofuel production, protection of soil quality, and others. For example, the NRCS not only provides information on BMPs that can be used to reduce impacts on soil quality, erosion, and water quality due to soil runoff, but will also work directly with feedstock producers to assist in identifying BMPs for a particular location and activity (see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/). Their WQIag tool can also be useful to producers to estimate potential impacts and how they would be reduced through various BMPs. State agricultural extension programs are likely to similarly assist with BMP implementation at a given site. The U.S. National Invasive Species Council (NISC) outlines BMPs for invasive species screening, monitoring, and control in both the National Invasive Species Management Plan (NISC 2008) and their guidance for Early Detection and Rapid Response programs (NISC 2003). The U.S. Forest Service (USFS) has developed BMPs to address non-native invasive species management in forested settings (U.S. Forest Service 2012).

In some cases, it may be beneficial to focus bioenergy cultivation on degraded land (e.g., salinized, overgrazed, nutrient depleted, or contaminated lands) (Kassam et al. 2012). High yielding feedstocks that produce a large amount of fuel energy per unit of converted land result in more efficient land use for a given amount of fuel, although they may require high inputs as well (e.g., water, fertilizer, pesticides) which can affect GHGs, biodiversity, water quality, etc. [1] It may also be possible to select feedstocks that facilitate phyto- or bioremediation (extraction and/or degradation of contaminants by plants or microbes), or accelerate vegetation renewal on salinized or nutrient-poor lands (Kassam et al. 2012), thus providing additional societal and agricultural benefits beyond feedstock production..

In closing

The objective of this document is to provide an overview of environmental concerns that may arise in connection with the sustainable production of alternative jet fuels. This document has provided discussion of some common environmental sustainability indicators that are being considered by the aviation community when evaluating alternative fuel purchases, as well as some of the frameworks and regulations that have been developed to quantify these indicators. Based on the work done to establish the Impact Matrix showing potential for direct environmental impacts across the alternative jet fuel supply chain, feedstock production and fuel production appear to be the two components of the alternative fuels supply chain most at risk for significant environmental impacts with respect to relevant indicators. This document also has provided an overview of the sources and brief summary of the many best practices that are in place to mitigate environmental impacts associated with fuel production. It was not the intent of the authors to be all-encompassing or to prescribe actions for those involved with alternative jet fuels.

It is important to note that in many cases, there will be tradeoffs amongst the individual environmental indicators. For example, jet fuel derived from conventional petroleum may have a smaller impact on land use and water consumption per unit of energy produced compared to fuels derived from renewable biomass, but at the same time biofuels and other alternative fuels may provide a GHG emissions reduction relative to today's jet fuel. Furthermore, individual alternative fuels may provide opportunities to reduce impacts in one area (e.g., GHG) without offering a reduction in other areas (e.g., water use). As such, one needs to be mindful that it is possible to set thresholds on some indicators that could inadvertently prevent the development of fuels that are more sustainable than what we are using today.

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APPENDIX: CAAFI® Environmental Progression (as of 6/26/13) – download at http://www.caafi.org/information/fuelreadinesstools.html

		Risk Assessment			**Risk Management**	
Scale	**Environmental Progression Description**	**(1) Feedstock**	**(2) Fuel Producer**	**(3) Life Cycle**	**(1) Feedstock**	**(2) Fuel Producer**
1	Basic Principles	Evaluate potential risks of feedstock introduction (e.g., Weed Risk Assessment) and potential impacts on biodiversity and land use.				
2	Concept Formulated	Evaluate feedstock for compliance with regulatory requirements for likely production environments Estimate production impacts on multiple resources concerns[‡] Formulate a plan including best practices to address regulatory requirements Comply with any feedstock pre-importation regulations				
3	Proof of Concept	Perform preliminary evaluation of water use and consumption (e.g., irrigation requirements) and potential soil impacts, as well as air and water quality impacts		Perform screening level analyses to identify lifecycle stages and issues relating to mass/energy balance, GHG emissions, and freshwater consumption using information gained from proof of concept	Identify appropriate best management practices to minimize environmental risks.	
4.1	Preliminary Technical Evaluation	Re-evaluate feedstock for potential invasiveness concerns,.	Preliminary evaluation of water use/consumption, potential air, water and soil impacts for processing technique	Perform preliminary GHG analysis in accepted GHG life cycle tool (e.g., GREET) using theoretical data for commercial scale production	Develop/refine weed risk management protocols	
		Consider "dry run" of sustainability evaluation under a well-accepted sustainability framework		Improve estimates of mass/energy balance, GHG emissions, and freshwater consumption using information gained from preliminary technical evaluation	Develop conservation plan and associated best management practices to address resource concerns for a feedstock production system. onsider an independent review of GHG LCA to identify any methodological issues or feedstockconcerns.	Consider an independent review of GHG LCA to identify any methodological issues or conversion process concerns
4.2				Consider approaching regulatory agencies to discuss pathway-level qualification steps for particular programs (e.g., RED, RFS2)	Develop soil conservation and feedstock production management plans	
5.1	Scale up Validation of Initial Assessments	Improve estimates of potential water use and consumption requirements, potential soil impacts	Evaluate potential water use and consumption, air, water and soil quality, land use change and biodiversity risks associated with fuel facility scale up	Improve estimates of mass/energy balance, GHG emissions, and freshwater consumption using information gained from scale-up	Draft NEPA (EA or EIS), if required, and other required permitting documents	
5.2					NEPA documents, conservation plan, and other required permit applications approved	
5.3		Evaluate land use change and biodiversity risks associated with feedstdock production scale up.			Ascertain that land under consideration for full-scale feedstock production complies with renewable definition under appropriate regulations (e.g., RFS2, RED) and other sustainability frameworks	NEPA documents, conservation plan, and other required permit applications approved
5.4						
6.1	Full-Scale Feedstock Impact Evaluation	Improve estimates of potential water use and consumption, air, water and soil quality, land use change and biodiversity risks associated with commercial feedstdock production.	Improve estimates of potential water use and consumption, air, water and soil quality, land use change and biodiversity risks associated with full-scale conversion/fuel production	Confirm pilot scale results on mass/energy balance, GHG emissions, and freshwater consumption and compare with original estimates; improve commercial-scale estimates of same using information gained from full-scale evaluation	Begin planning environmental management system components	
6.2					Feedstock producer approved for all relevant environmental permits, regulatory compliance is complete	
6.3				Confirm pathway mass/energy balance, GHG emissions and water consumption estimates for consideration by regulatory agencies (e.g., EC, EPA) and voluntary sustainability certification frameworks using actual data. Improve LCA for projected commercial scale production		
6.4					Environmental management system and best management practices implemented	
7	Full-Scale Fuel Producer Impact Evaluation		Improve estimates of water use and consumption, air, water and soil quality, land use change and biodiversity risks associated with commercial scale fuel facility	Finalize qualification for any incentive programs, and/or certification under voluntary sustainability frameworks		Fuel producer approved for all Federal, State and local permits, regulatory compliance is complete
8	Commercialization			If needed, perform facility-specific study-comprehensive analyses for mass/energy balance, GHG emissions, and freshwater consumption using information gained from scale-up, use for voluntary sustainability certification	Regulatory compliance is ongoing, environmental management system and best practices result in maintained or improved environmental performance, voluntary sustainability certification completed as needed	
9	Sustainable Feedsdtock and Fuel Supply Established			Continously monitor mass/energy balance, GHG emissions, freshwater consumption, etc. to validate LCA and identify process efficiency improvements.	Annual reporting of air and water pollutant emissions, water use, energy balance, GHGs, soil quality, biodiversity, land use, and invasive species impacts	

[‡] Multiple natural resources concerns include the USDA Natural Resources Conservation Service (NRCS) conservation planning framework SWAPAE+H (Soil, water, air, plant, animal, energy, plus human effects). Various decision tools are available to estimate feedstock production impacts on metrics of soil erosion, fuel use, pest risk assessment, and greenhouse gas emissions.