MASBI
Midwest Aviation
Sustainable Biofuels Initiative

Fueling a Sustainable Future for Aviation

2013

The U.S. military and commercial aviation industry together consume more than 20 billion gallons of jet fuel a year. Nearly three billion gallons are consumed by airlines in the Midwest. The cost of jet fuel has more than tripled since 2000, and jet fuel demand in the Midwest is expected to increase by 9% by 2020. For every 5% of Midwestern petroleum jet fuel that can be replaced by biofuels, approximately 3,600 jobs will be created and an estimated 700,000 tons of carbon dioxide on average will be avoided annually.

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FOREWORD

We are proud to release our final report of the Midwest Aviation Sustainable Biofuels Initiative (MASBI). This has been a year-long collaboration that brought together experts representing the entire aviation biofuels value chain from over 40 different public, private, and non-profit organizations. This report highlights an action plan to accelerate the commercialization of biofuels for aviation.

The journey to develop an aviation biofuels industry began in 2006. Aviation is interested in the development of alternatives to petroleum-based jet fuels to address its largest operating cost and most significant impact on the environment. Progress has been achieved in certifying conversion technologies, proving advanced biofuels use in aircraft, and developing sustainability standards. However, significant challenges remain in achieving commercial-scale production of aviation biofuels at prices that airlines can afford to pay.

The benefits of building this industry extend beyond aviation. Developing a commercial market for aviation biofuels has the potential to create jobs, generate economic growth, further contribute to U.S. innovation, and fulfill the nation's energy security needs.

Commercial aviation in the Midwest consumes three billion gallons of jet fuel per year and has an established infrastructure in place for the efficient delivery of aviation fuels. The Midwest boasts a rich history in agricultural development, clean technology innovation, research institutions, and a vibrant investment community. Midwest governments and policymakers have recognized the importance of the advancement of the biofuels industry. These factors combined highlight the region's potential.

The recommendations of the MASBI report, if enacted, will accelerate the development of this industry.

Sincerely,

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FUELING A SUSTAINABLE FUTURE FOR AVIATION

THE CHALLENGE AND THE OPPORTUNITY

Each year, over 20 billion gallons of jet fuel are required to support both the U.S. commercial aviation industry and the U.S. military. From 2001 to 2012, the price of crude oil increased by 262%, now accounting for nearly 40% of an airline's total operating costs. On a global level, aviation produces only 2% of man-made carbon dioxide. Forecasted growth in demand for air services globally is expected to increase over the next 20 years. The aviation industry is relying on improvements in aircraft and engines, infrastructure, and biofuels to achieve sustainable growth. Commercial aviation has proactively established industry commitments on climate change and is actively engaged with the United Nation's International Civil Aviation Organization (ICAO).

To reduce both its largest operating cost and its most significant impact on the environment, the aviation industry is interested in the development of alternatives to petroleum-based jet fuels. Since work began in 2006 to develop a sustainable biofuels industry for aviation, significant progress has been made. Today, challenges remain in achieving commercial-scale production of aviation biofuels at prices that airlines can afford to pay.

The Midwest presents a promising opportunity and is uniquely positioned to develop this industry through its rich history in agricultural development, research institutions, clean technology innovation, and vibrant investment community. Commercial aviation in the Midwest consumes nearly 3 billion gallons of jet fuel per year and has a robust infrastructure for the efficient delivery of aviation fuels. Midwest governments and policymakers have recognized the importance of the advancement of the biofuels industry. These factors combined highlight the region's potential to be instrumental in the development of the aviation biofuels industry.

The benefits of building this industry extend beyond aviation. A robust commercial, advanced biofuels industry presents an opportunity to provide substantial benefits to the region, country, and the aviation industry as a whole. Developing a commercial market for aviation biofuels has the potential to reduce global carbon emissions, create green jobs, generate economic growth, drive innovation in clean technology, improve U.S. energy security, and power a sustainable future for aviation.

INTRODUCTION: INNOVATION IN AVIATION

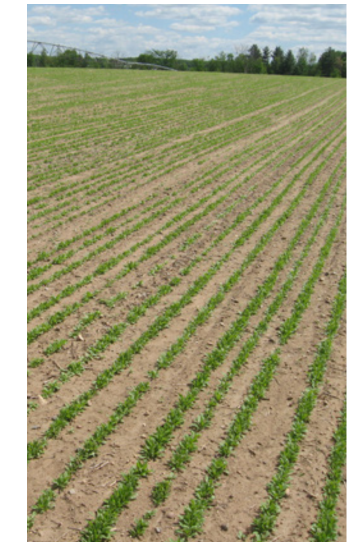
The Midwest Aviation Sustainable Biofuels Initiative (MASBI) is a collaboration of 40-plus public and private organizations that came together in 2012, led by United Airlines, Boeing, Honeywell's UOP, the Chicago Department of Aviation, and the Clean Energy Trust. The group convened to formulate an action plan detailing how commercial aviation might achieve its goals of diversifying energy supply, managing its largest operating cost, reducing industry-wide greenhouse gas emissions, generating job growth, and leveraging the Midwest's agricultural resources to accelerate the development of the aviation biofuels industry.

In addition, Argonne National Laboratory chaired an Advisory Council, which included government agencies and non-profit institutions. (For a full list of MASBI participants, see inside the back cover). The year-long initiative culminated in a comprehensive report, drawing from the experience and shared findings of MASBI stakeholders such as feedstock researchers and growers, sustainability experts, aviation fuel producers, biofuels producers, technology developers, biomass experts, state and federal government agencies, non-governmental organizations, academics, airlines, airports, aircraft and engine manufacturers, logistics providers, and investors.

MASBI's collaboration evaluated aviation biofuels conversion technologies, feedstock options, commercialization considerations, fuel logistics, infrastructure needs, regional and national policy measures, economic impact, and scalability. The analysis was organized along the value chain and engaged dedicated research groups assessing investment and policy with an integrated focus on long-term sustainability.

MASBI stakeholders working on aviation biofuels have proven that numerous sources of naturally produced hydrocarbons can be repurposed into renewable jet fuel, including plant and animal oils, sugars/starches, and cellulose. Several types of waste streams (agricultural residues and processing waste, industrial flue gases, and municipal waste) can also be used for fuel production.

As a consumer of aviation biofuels, the aviation industry has much to gain by encouraging progress in the field of renewable fuels, particularly in the Midwest, where airlines enjoy a significant presence and attributes that make them an ideal first adopter.



With the aim of addressing regulatory and environmental goals while mitigating the impact of the price volatility of fossil fuels – which account for more than one-third of airlines' total annual costs – MASBI is looking to biofuels as a cost-effective and sustainable alternative to petroleum-based fuel that will benefit the entire country.

It should be noted that demand for renewable jet fuel is large enough to dwarf the supply available for the foreseeable future. With that in mind, the aviation industry is looking to take a leadership role in spurring growth in the aviation biofuels industry to meet the demands of tomorrow, broadening its fuel options while also minimizing its carbon footprints.

The utilization of biofuels in commercial flights in recent years has become a reality: More than 1,500 passenger biofuels flights have been successfully completed worldwide.

Indeed, the case for renewable jet fuels is in their prospects for commercial viability. While demonstration flights have proven to be an essential part of the way forward, commercialization is a market-based indicator of how successfully all necessary steps have been taken in the process. This includes the cultivation of sustainable feedstocks, their innovative conversion into "drop-in" fuels, and their delivery to real markets, with practical policies that encourage competitive prices.

Accordingly, it is the shared objective of the authors of this report to convey the promise, progress, and optimism of this industry in the frankest terms possible with the intention of laying the groundwork for the commercialization of renewable jet fuels in the Midwest – serving not just as a model for the industry, but for the nation as a whole.

AVIATION BIOFUELS: STEADY PROGRESS SINCE 2006

In 2005, U.S. commercial aviation identified a need to focus on the development of alternatives to petroleum-based jet fuels due to their increasing price volatility and concerns about the environmental impact and emissions. At commercial scale, sustainable aviation biofuels present an enormous opportunity for airlines. In 2006, U.S. airlines, aircraft manufacturers, and the U.S. Federal Government began a partnership known as the Commercial Aviation Alternative Fuels Initiative (CAAFI) to identify and promote sustainability criteria and the development of alternative jet fuel options that would be safe, fungible, and cost-effective compared with petroleum-based jet fuels. CAAFI supports the development of alternative fuels that offer carbon emissions reductions on a life-cycle basis and enhance the security of energy supply for aviation. Since CAAFI was formed, biofuels have advanced significantly. Selected milestones include:

- Fuel approval by ASTM International (formerly known as the American Society for Testing and Materials)
- Environmental Protection Agency (EPA) certification of a jet fuel pathway for renewable identification numbers (RINs)
- First test flights using biofuels, such as the U.S. Navy's flight of the Green Hornet
- Construction of pilot and demonstration-scale plants
- Commercial off-take agreements

The utilization of biofuels in flights has proven to be safe and indicates that drop-in alternatives can be produced with properties that are functionally identical to conventional, petroleum-based fuels. The opportunity for scheduled, commercial travel using aviation biofuels is near and achieving commercial-scale production will enable sufficient supply of biomass-derived jet fuels that are cost-competitive with conventional jet fuel.

These advancements through 2012 are significant, and they have built a strong foundation. Even so, continued progress in 2013 and beyond is not without its challenges. The aviation industry is mindful of maintaining a realistic perspective on the future development of this industry and encouraging of the factors that will contribute to its success. Many of these important factors are outlined in the pages ahead.

THE MIDWEST: A CATALYST FOR COMMERCIALIZATION

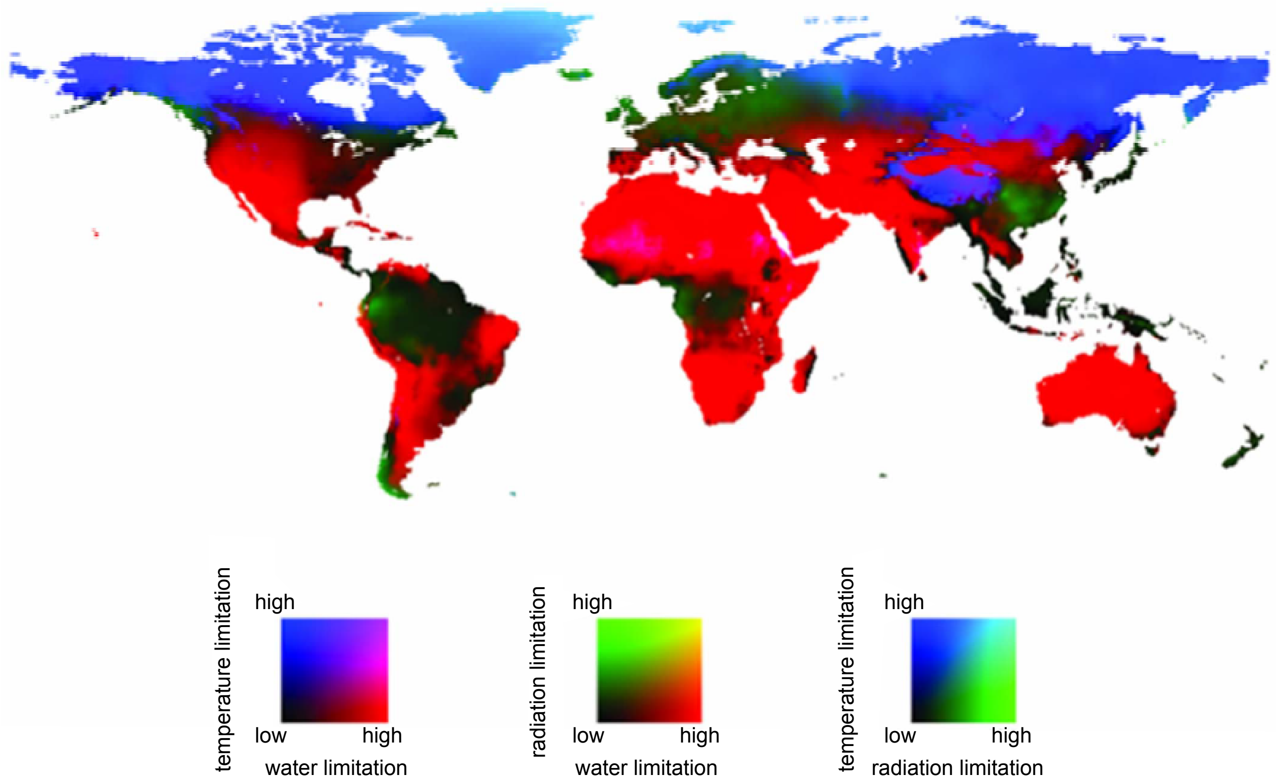
In the Midwest, commercial airlines require nearly 3 billion gallons of jet fuel a year. Against the backdrop of the region's world-leading agricultural assets, this presents an attractive opportunity for the nascent aviation biofuels industry and the Midwest as a proving ground. The Midwest has a unique opportunity to take a leadership role in boosting energy security and paving the way for advances in sustainability, including significant reductions in greenhouse gas emissions. As illustrated in the chart on page 7, the Midwest has a unique set of natural attributes which lend itself to the leveraging of agriculture for the creation of biofuels.

United Airlines and AltAir Fuels to Bring Commercial-Scale, Cost-Competitive Biofuels to Aviation

On June 4, 2013, United Airlines signed a definitive purchase agreement with AltAir Fuels for cost-competitive, sustainable, advanced biofuels on a commercial scale, representing a historic milestone for industry.

With United's strategic partnership, AltAir Fuels will retrofit part of an existing petroleum refinery to become a 30 million gallon, advanced biofuels refinery near Los Angeles, California.

Through process technology developed by Honeywell's UOP, AltAir is retrofitting the existing refinery to produce renewable biofuels. Utilizing this technology, licensed from UOP, the AltAir facility will be the first refinery internationally to be capable of in-line production of both renewable jet and diesel fuels. The facility will convert non-edible natural oils and agricultural wastes into approximately 30 million gallons of low-carbon, advanced biofuels and chemicals per year. United has collaborated with AltAir Fuels since 2009 and has agreed to buy 15 million gallons of lower-carbon, renewable jet fuel over a three-year period, with the option to purchase more. The airline is purchasing the advanced biofuels at a price competitive with traditional, petroleum-based jet fuel, and AltAir expects to begin delivering five million gallons of renewable jet fuel per year to United starting in 2014. United will use the biofuels on flights operating out of its Los Angeles hub (LAX).



Source: Chris Somerville Energy Biosciences Institute UC Berkeley, LBL, University of Illinois

For successful and productive agriculture and biofuels production, sunlight, water, and a temperate climate are necessary. This chart shows the range of each of those climate attributes across the world. Red areas indicate a lack of water, blue areas indicate colder climates, and green indicates areas with lower sunlight due to higher cloud cover. Those regions which are darkest indicate the highest potential for agriculture and biofuels development.

MASBI believes the development of integrated renewable jet fuel refineries in the Midwest that take advantage of synergies vertically across the supply chain would be an important way the nation might move the industry forward. With coordinated action by aviation, aviation biofuels stakeholders, and government policymakers, the Midwest can address gaps and rapidly scale up biofuels for production. By doing this, there is real potential to provide airlines with a steady stream of sustainable and cost-competitive alternative energy supplies.

The challenges that must be addressed to realize the full-scale commercialization of biofuels is a normal part of the development of all energy resources. Throughout history, similar growing pains have emerged across the energy complex – including with petroleum, which continues to receive heavy government funding and subsidies to this day.

MASBI believes the commercialization of aviation biofuels will be realized through vertically coordinated actions across the supply chain. In addition, there is increasing agreement among stakeholders that the prospective value created by developing the aviation biofuels industry vastly outweighs the risks and upfront costs.

LARGE-SCALE PLANS, SMALL BEGINNINGS

Building regional refineries that take full advantage of the Midwest's resources and expertise would serve as an ideal means to connect an agricultural system with processing technology, delivering drop-in fuel at meaningful quantities and making biofuels more cost-competitive with fossil fuels.

Regional development will serve to expedite and focus progress while minimizing capital at risk. In MASBI's view, it is of paramount importance to establish a local system that drives sustainable processes and procedures for creating a market for biomass feedstocks.

Opportunities exist for renewable jet fuel to claim a piece of the energy pie as the supply chain grows, from access to cost-effective sustainably produced feedstock to financing biorefineries. By starting in local markets, and leveraging regional assets, the aviation biofuels industry can leverage its successes to strengthen its market presence and expand to larger-scale, renewable jet fuel refineries.

Building a successful aviation biofuels industry for aviation requires the reduction of fuel production costs in the long run. As fuel producers and technology developers gain commercial operating and distribution expertise, costs will decline as efficiencies are incorporated into future operations. Public-private partnerships focused on integrated refining strategies also have the potential to attract the attention of regional economic development offices, aligning themselves for broader federal and institutional financing.

Significant advances have been made and will continue to be made in converting biomass to aviation biofuels, but the industry has not yet proven its viability on a commercial basis without market and government incentives. Accelerating the learning curve toward commercial scale production would give the Midwest a chance to nurture an environment where a competitive aviation biofuels and aviation industry would have room to grow.

Orchestrating a new market structure and supply chain will take commitment, resources, and time from the airlines, producers, and other stakeholders. But building, financing, and supplying a limited number of renewable jet fuel plants and tangible quantities of drop-in fuel can be achieved in the near term.

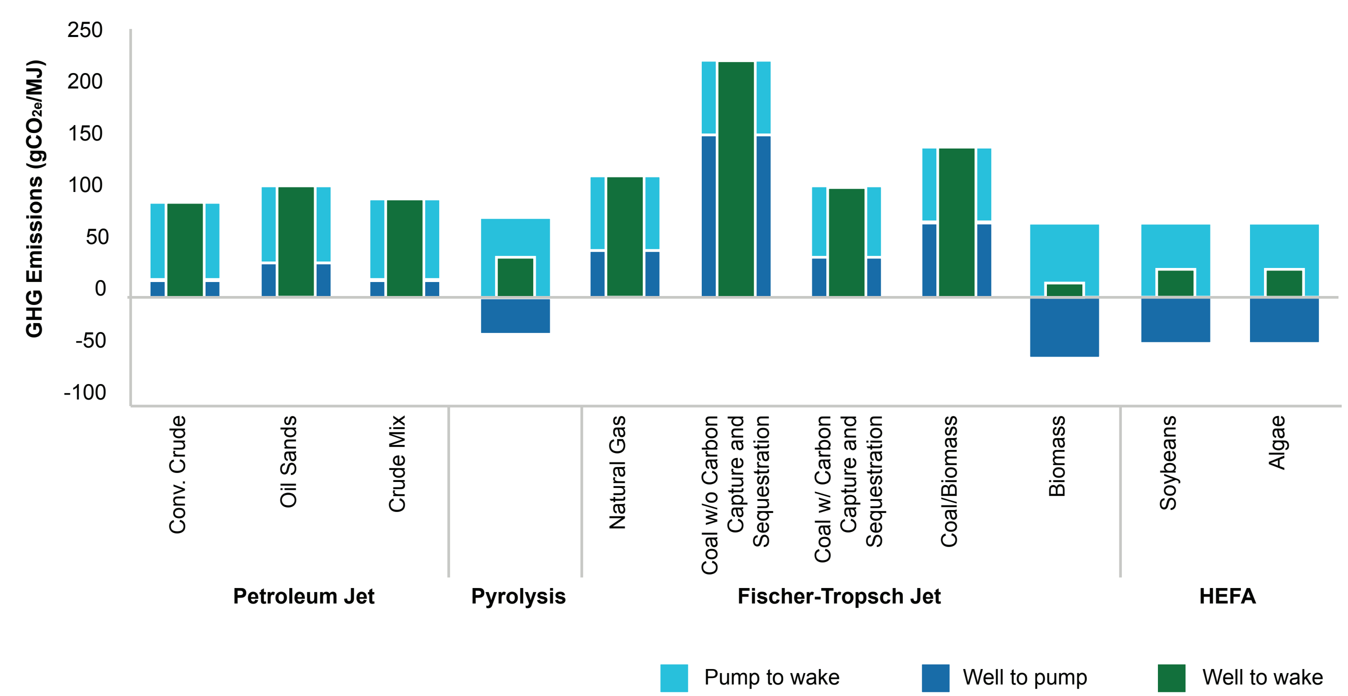
BEYOND ECONOMICS: SUSTAINABILITY BENEFITS

Aviation biofuels that produce measurable environmental, social, and economic benefits are vital to the aviation industry's long-term strategy to diversify fuel supply. This has the potential to contribute to price stability and cost reduction, while also reducing aviation's environmental footprint. A number of renewable jet fuel pathways have the potential to contribute fewer greenhouse gas (GHG) emissions than petroleum-based jet fuels, and will need to have a net life cycle improvement of 50% or greater to qualify for credit under the EPA's Renewable Fuel Standard.

The aviation industry has acknowledged the need to take additional steps to address GHG emissions from its operations. Accordingly, in 2009, Airlines for America (A4A) joined with the International Air Transport Association (IATA) in adopting an ambitious set of targets to mitigate GHG emissions using a global and sectoral approach, including collective industry commitments to:

- Continue industry fuel (and, hence, CO_2) efficiency improvements, resulting in an average annual CO_2 efficiency improvement of 1.5 percent per year on a revenue ton-mile basis through 2020;
- Carbon neutral growth from 2020 (CNG2020) as a cap on aviation emissions, subject to critical aviation infrastructure and technology advances achieved by the industry and government. Market-based measures may serve as an interim approach to addressing CO_2 emissions exceeding the baseline;
- Contribute to an industry-wide goal of reducing CO_2 emissions by 50 percent by 2050, relative to 2005 levels.

EXHIBIT 1: WELL TO WAKE GHG EMISSIONS BY ALTERNATIVE JET FUELS PRODUCTION PATHWAYS



Note: gC02e/MJ equals units of greenhouse gas per units of energy.

Source: "Life-cycle Analysis of Alternative Aviation Fuels in GREET," A. Elgowainy 1, J. Han 1, M. Wang 1, N. Carter 2, R. Stratton 2, J. Hielman 3, A. Malwitz 4, S. Balasubramaian 4; 1-Energy Systems Division, Argonne National Laboratory, 2-Massachusetts Institute of Technology, 3-Massachusetts Institute of Technology; currently with the FAA, 4-John A. Volpe National Transportation Systems Center.

This approach in principle has been adopted by the United Nations (UN) International Civil Aviation Organization (ICAO) in an Assembly Resolution in 2010. On June 3, 2013, the International Air Transport Association (IATA) 69th Annual General Meeting (AGM) endorsed a resolution on "Implementation of the Aviation Carbon-Neutral Growth (CNG2020) Strategy." The resolution provides governments with a set of principles on how governments could establish procedures for a single market-based measure (MBM) and integrate a single MBM as part of an overall package of measures to achieve CNG2020. United Airlines is a member of both A4A and IATA, and an active airline participant in the global negotiations for designing the Global Sectoral Approach and CNG2020. The 2013 ICAO General Assembly is expected to build on the initial resolution and continue progress toward the Carbon Neutral Growth 2020 goal.

GOVERNMENT: INSTRUMENTAL IN ADVANCING NEW ENERGY

Government has historically played a critical role in the development of energy resources. From fossil fuels to nuclear energy, federal, state, and local governments were critical in providing resources for technologies to develop and become economical. As with previous energy transformations, the development of an aviation biofuels industry will require coordinated and stable policies among local, state, and federal entities.

There is no single policy mechanism that will immediately transform the aviation biofuels industry into a highly competitive component of the energy complex. Like many renewable energy alternatives, biofuels will take time to develop and compete against a mature fossil fuel industry. Based on the collective efforts of MASBI researchers across the supply chain, this report will lay out the most expedient routes to the rapid incubation of the biofuels industry.

Support for biofuels is strong at the executive level of government, but budget uncertainty is an impediment to development. The U.S. Department of Agriculture (USDA) last year supported advanced feedstocks to produce 10 million gallons of aviation biofuels and the USDA has spearheaded public-private partnerships that support renewable jet fuel, such as its recently renewed Farm to Fly program.

The U.S. Department of Energy (DOE) has a strong track record of supporting research, development, and deployment through the Bioenergy Technologies Office (BETO), the Bioenergy Science Centers (BESCs) and the Biomass Research and Development Initiative (BRDI). Other agencies, including the Federal Aviation Administration (FAA), the Environmental Protection Agency (EPA), and the U.S. Navy (USN) have also supported renewable jet fuel.

GROWTH PROSPECTS: TARGETING FIVE KEY AREAS

MASBI addresses critical factors as a coalition. The Midwest is a hub of vibrant financial, academic, and agricultural sectors. It is well-positioned to lead in clean energy development through strategic coalition-building. Seeking to capitalize on the Midwest's unique position, MASBI assembled representatives from across the aviation biofuels value chain to define an actionable blueprint for the development of aviation biofuels in the region.

Taking into account the particular strengths and conditions in the Midwest, MASBI outlined actions required to advance the development of aviation biofuels in five key areas:

- Research and development
- Production and commercialization
- Financing and investment
- Policy and economic development
- Sustainability

This report provides actionable information in each of these categories to policymakers, stakeholders, and investors to understand the benefits of long-term planning and the requirements to fully commercialize aviation biofuels.

MASBI researchers developed a list of high-level recommendations for both industry leaders and policy makers. These recommendations provide guidance and insight into the most promising pathways for the short to medium term development of the biofuels industry.

RESEARCH AND DEVELOPMENT

The Midwest region is home to an expanding industry for the production of both conventional and alternative fuels and technology that is being harnessed to bring promising new products to market. Leveraging the Midwest's industrial base will require a highly strategic approach to both the development of feedstocks and the refining technology that converts them into biofuels.

MASBI analyzed eight technology pathways that include feedstock requirements, capital expenditures, and the cost of obtaining approval from the ASTM International. As part of this analysis, MASBI researchers also considered the maturity of each technology, expected time to commercialization, and sustainability criteria, including energy, water, land, and GHG emissions associated with the production and utilization of aviation biofuels.

MASBI chose four pathways, examined below in detail, based on the expectation that these four might have greater prospects for commercialization by 2020. These pathways have either already been approved through ASTM or are expected to be approved in 2014. Therefore the fuels derived from these pathways have, or are about to, overcome a major market entry barrier – approval – and it is reasonable to assume these fuels may be commercially available in the next five years. It is important to note that MASBI stakeholders recognize that other viable technology pathways beyond the four discussed here in greater depth certainly have the potential to be commercialized as well. Indeed, given the appropriate technology, business plan, and market dynamics, game-changing innovations or unanticipated breakthroughs are not out of the question for the emerging family of renewable jet fuels and biochemicals.

For more on all pathways considered in the MASBI study, refer to "Selection Methodology and Technology Pathway Comparisons," in the appendix.

While each pathway has its share of challenges, MASBI classifies the four technologies as nearest to commercialization. Some of these technologies are still in early research and development stages and lack complete data, but all have been determined by MASBI researchers to hold a strong degree of promise over the course of the next decade.

Alcohol to jet (ATJ) is a technology that produces fuel from fermented plant sugar or industrial synthesis or syngas. MASBI researchers evaluated various pathways as part of this process. The technology is at the qualification stage and must undergo the approval process by ASTM, which is expected to be completed in 2014.

Fischer-Tropsch synthesized paraffinic kerosene (FT) is a product derived from converting carbon-rich materials, including biomass, such as wood, into synthesis gas, or syngas, and turning the syngas into fuel. Significant upfront capital costs present the biggest challenge for this technology. Commercial FT facilities typically use coal and process 10,000 to 50,000 tons-per-day to be economical. For biomass, FT would require a large collection area, which increases transport costs and storage costs.

Hydroprocessed ester and fatty acids (HEFA) is produced from animal fats or plant oils. More than 800 million gallons of global commercial capacity will be up and running in 2013 for production of surface transportation fuels. HEFA is co-produced with renewable diesel from these commercial units.

Hydrotreated depolymerized cellulosic jet (HDCJ), creates fuels out of biomass, such as wood or corn stover. This direct liquefaction pyrolysis process can use a variety of lignocellulosic feedstocks, thus limiting land use impacts and navigating concerns about potential competition between energy and food crops.

List of technologies analyzed by MASBI stakeholders

Technology Process	Advantages	Challenges
Alcohol to Jet (ATJ)	Feedstock flexibility and availability in Midwest	Still at developmental stage Need to go through costly ASTM approval process
Catalytic Conversion of Oil to Jet (CCOTJ)	Low capex Commercial unit to make biodeisel	Best suited to produce products other than jet fuel Needs to be further processed to make jet fuel
Catalytic Conversion of Sugar to Jet (CCSTJ)	Feedstock availability	Still being developed Need to go through costly ASTM approval process
Catalytic Hydrothermolysis, Hydroprocessing to Jet (CH-HRJ)	Potential for no blending requirement	Early stage of development Need to go through costly ASTM approval process
Direct Fermentation of Sugar to Jet (DFSTJ)	Good feedstock supply potential	Low yield → high cost Concern of product properties for jet fuel application
Fischer-Tropsch synthesized paraffinic kerosene (FT-SPK)	ASTM approved	High capex requirements
Hydrotreated Depolymerized Cellulosic Jet (HDCJ)	Feedstock flexibility Attractive cost structure	Early stage of development Need to go through costly ASTM approval process
Hydroprocessed Esters & Fatty Acids (HEFA)	ASTM approved Commercialized technology	Limited feedstock availability (non-food) and high cost of feedstock Renewable diesel has better yield/return

For a deeper description of each pathway and how it was analyzed for purposes of this study, refer to "Selection Frameworks and Metrics," in the appendix.

Feedstock Supply

MASBI researchers analyzed 26 potential feedstocks for renewable jet fuel and created a shortlist that includes nine of the most promising ones.

Candidates were added to the shortlist of feedstocks based on environmental factors, including greenhouse gas emissions and potential land use changes required to produce the feedstock; social factors, such as food prices and farm income; and economic factors, such as productivity per acre and scale of processing in the Midwest. The goal is to develop supplies of sustainable feedstocks that can eventually lower biofuels production costs.

For more on the range of factors MASBI considered in evaluating feedstocks, see the fifth and final section of this report on Sustainability.

Successful industry development could grow from creative scenarios where local policy and feedstock availability provide viable economic conditions for biofuels production. While current yields of targeted crops may be relatively low, past experience and data suggest there is potential to attain sizable yield improvements. A case in point is corn, which has received more research and development than any other feedstock post-WWII and, as a consequence, has seen continued sustained growth of 1.8 bushel per acre per year over the past 30 years. These yield improvements have been driven by improved equipment, agronomic practices, biotechnology, breeding, and increased utilization of technology. These yield improvements have also decreased fertilizer and water requirements per unit of product.

Local successes are not automatically expected to be replicable across regions. However, a portfolio of diverse and regionally-specific markets together can serve as the bedrock for a robust and successful industry. The feedstocks on the shortlist have enough positive characteristics to potentially meet the economic and sustainability targets highlighted in this report.

Camelina: In addition to its rotational value, this feedstock can be grown on unproductive or marginal agricultural land unsuitable for food production due to soil quality, annual rainfall, poor past farming practices, or other issues. Camelina and energy cane are the only non-food crop, non-residue feedstocks approved by the EPA for aviation biofuels production.

Corn: In the United States, over 80 million acres of corn are typically planted annually and offer highly advanced production and transportation infrastructure. This makes corn highly accessible, however concerns over competition with food remain. MASBI only considered corn a bridging feedstock, when it is grown under more sustainable practices such as integration with livestock production, no-till farming, and reduction in fertilizer use.

Corn stover: The part of the corn plant remaining in the field after grain harvesting. Corn stover represents an opportunity to make use of a residue stream to produce fuel while also supporting food production, provided enough is left in the field to protect soil quality. Corn stover has potential be used as animal feed.

Municipal waste, industrial residues, and inedible oil processing from corn: The use of wastes, industrial waste gases, or byproducts (inedible corn oil) does not impact the food basket or land use. Inedible corn oil is utilized in animal feed and biodiesel industries.

Pennycress: This is a winter oil seed crop, with the potential to be inserted into a crop rotation with crops such as corn or soybeans, providing a potential opportunity for the production of a dedicated fuel crop without interrupting food production.

Wood residues: There are around 90 million acres of forest in the Midwest, which could produce substantial amounts of logging residues for biofuels production. Notably, the upper Midwest has an established wood collection infrastructure that was built to support the now declining pulp and paper industry.

The table below lists the set of feedstocks analyzed by MASBI. Those in blue indicate an environmental, social, and economic profile was undertaken. The rest were not profiled because they were not deemed to have met the required characteristics for near-term potential success.

Oils	Camelina	**Lignocellulosic based**	Miscanthus
	Soy		Switch grass
	Used cooking oil (1/2)		Energy sorghum
	Field pennycress		Renewable/farmed trees
	Mustard/winter		Corn stover
	Canola/rapeseed		Wood residues/byproducts
	Corn (inedible oil processing)		
	Animal-processed based		
	Rapeseed (Ethiopian mustard, Brassica carinata L)		
	Sunlight grown algae (1/2)		
	Heterotropic algae		
Sugars and starches	Corn and cornstarch	**Industrial byproducts**	Ag residues (corn stover)
	Sugar beet		Waste industrial gases
	Sweet sorghum		Municipal solid waste (MSW)
	Energy cane		Farm waste
			Landfill recovery
			Waste water sludge

Scalability & Risk

Achieving sufficient feedstock scale to justify capital investments in large refineries is challenging. To reduce risk, investors desire a large volume of available feedstock before committing capital.

It is important to reduce the risk to farmers, waste producers, and handlers to ensure that they produce a targeted feedstock. For existing feedstocks, this is achieved through a combination of crop breeding, crop insurance, best practice guidelines, experience, and utilization of technology. The risk is inherently higher during initial adoption, as producers gain familiarity with growing a new crop. Also certain perennial crops will not reach maximum productivity for several years. Specific programs, such as the Biomass Crop Assistance Program, can help produce a greater supply of promising biofuels feedstocks by incentivizing farmers.

Farmers are reluctant to grow novel energy crops on highly productive agricultural land, because risk-adjusted returns may be less than those for established food crops. Farmers will readily adopt technologies and crops when risk-adjusted returns are established. For well-developed crops, time from introduction to near complete market penetration can be as little as five years. Market penetration can be limited by the availability of sufficient supplies of seed to plant, as well as best practice knowledge in how to use the technology. In the case of crops that lack sufficient local demand or distribution infrastructure, adoption will take much longer. For dedicated energy crops, farmers will require a crop insurance program similar to those for established food crops.

Farmers are more likely to change their practices if the market for a prospective crop is guaranteed and diverse. It can be helpful to piggyback on an existing market, though the downside is that other uses for a feedstock may make it more expensive in a competitive marketplace.

The animal feed market plays a very important role in the economics of biofuels crops. Feedlots may directly compete with biofuels for some feedstock supply. However, feed markets also offer an additional diverse revenue stream by increasing overall product value from feedstocks with protein, oil, fiber, cellulose, and starch fractions. Additionally, the feed market allows refiners to diversify their product offering, and service a diverse set of customers and industries.

Biorefiners also face economic decisions when considering producing aviation biofuels. Products with higher margins than jet fuel, such as cosmetics, specialty chemicals, plastics and renewable diesel, command a higher return and profit per pound of input feedstock. Biorefiners will focus on higher-margin products other than renewable jet and capture initial available feedstock until they achieve market saturation. Government support specifically for aviation biofuels could help overcome market competition for feedstocks. Also, depending on the process, coproduction of higher-value products and renewable diesel can be economically attractive and help bolster business propositions.

For further information on MASBI-endorsed government action in support of biofuels research, processing and financial incentives, see in the appendix

Additionally, airlines also could foster the industry by supporting co-product development, while signing long-term off-take agreements for defined volumes from refineries producing renewable jet fuel. As refinery operators improve performance, they could offer additional product to the airlines or expand their portfolio. While current economics may suggest producers optimizing alternative fuel refineries for renewable diesel, securing even small amounts of renewable jet fuel as part of a broader mix can stimulate the industry.

Market Pricing of Feedstocks

Biofuels can and do compete with petroleum, however there is an economic gap that is currently bridged with government subsidies and market mechanisms, resulting from mandates that amount to approximately $2 per gallon.

For the HEFA pathway, feedstocks are priced at a premium when compared with diesel and jet fuel prices. See, for example, Exhibit 2. The cost of the feedstock is higher than the cost of the finished product.

To overcome the feedstock price challenge, MASBI examined ways to acquire feedstocks at cost-competitive prices, which would be below spot market prices. Feedstock producers provided the following recommendations:

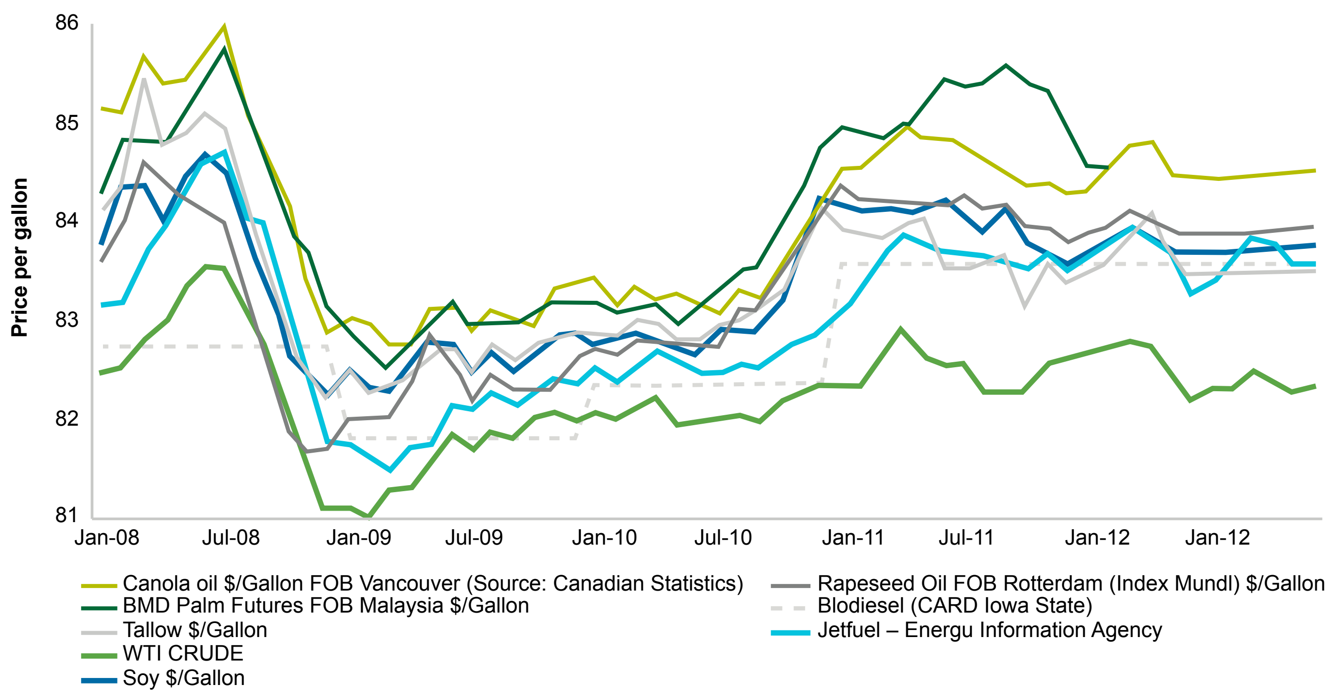
Cost pricing: Create mechanisms (for example, long-term contracts) that allow refineries to buy feedstock at a lower cost, essentially exchanging reduced risk for lower price.

Vertical integration: Aviation biofuels stakeholders could directly invest in the biofuels value chain or commit to long-term off-takes, allowing reduced prices in return for security of supply.

Waste: Focus on waste stream feedstocks such as corn stover, woody biomass, and industrial residues. Corn stover, the part of the plant remaining in the field after grain harvesting, offers an opportunity to make fuel, while supporting, rather than competing with, human food production. Feedstocks such as woody waste logging residues and waste industrial gases, which are not linked to human food, could also be a competitive.

For many technology pathways, the market price of feedstocks is too high for biofuels to compete with petroleum on cost.

EXHIBIT 2: PRICE OF OIL FEEDSTOCK PER GALLON



Source: Global Clean Energy Holdings

MASBI RECOMMENDATIONS

Research and Development (R&D)

1. Improve feedstock production capacity through agricultural innovation. Identify and promote potential additional biofuels production capacity generated by increased yield due to breeding and innovative planting such as crop rotations, and double and cover cropping with crops such as camelina, which can be produced between food crop rotations.
2. Tailor feedstocks to jet fuel. Develop advanced feedstocks tailored for jet fuel production, including the development of an oil seed crop with chemical properties predisposed for jet fuel production.
3. Investigate the impacts of uncertainty on production. Investigate the effects of uncertain conditions, such as changing policy, weather, seasonal intermittency, and co-products on the techno-economic performance of conversion technologies.
4. Advance technologies to convert lignocellulosic biomass. Biomass made up of lignin, cellulose, and hemicellulose (wood, residue biomass such as corn stover) is a very large-volume sustainable feedstock source. Increase investment in bio/catalytic pathways to produce jet fuels from depolymerized biomass, cellulosic sugars, or simple alcohols.

> "The Midwest is a vital contributor to the nation's economy and the global air transport system. Developing sustainable new energy sources for aviation provides economic opportunities and builds on the region's legacy of leadership."
>
> *– Bill Glover, Boeing*

PRODUCTION AND COMMERCIALIZATION

Large-scale commercialization must consider feedstocks, logistics, and conversion technologies, as well as the system challenges of certification, production scale-up, downstream market viability, and policy. MASBI believes that we can and will succeed and the potential reward for both the aviation industry and the nation justify the effort.

The amount of feedstock required to reach scale differs by feedstock and conversion technology. In the short term, feedstock volume from dedicated energy crops is limited, as net profit to farmers for energy crops is less than that for food. This means the conversion of farmland from food production to energy crops is unlikely. The sustainable collection of residue streams such as corn stover and forest residue has the potential to provide large volumes of low-cost feedstocks more quickly.

Because jet fuel currently trades at lower prices than distillate (diesel) transportation fuel, feedstock and production volume is likely to target diesel as well as higher-valued chemicals. Partly economics and partly chemistry, the properties of feedstocks such as camelina and other oils are chemically closer to diesel than jet, and so are more amenable and economic to producing diesel.

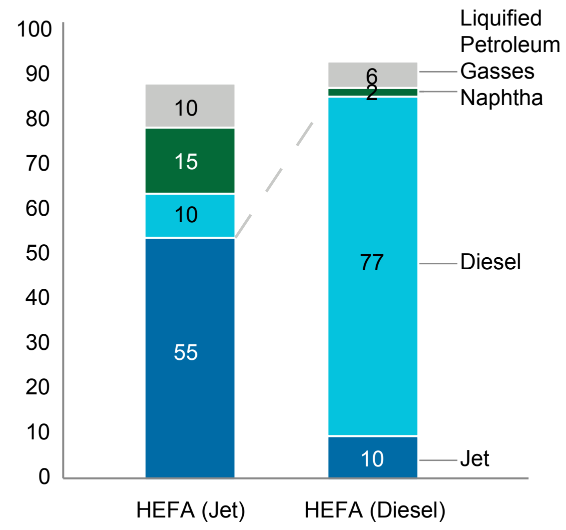
The premium of diesel over jet fuel in the marketplace has several implications for the biofuels industry. Because renewable diesel can be sold at a higher price than renewable jet fuel, it has a higher potential of improving biorefinery profitability. A HEFA facility can therefore reach profitability faster if it initially maximizes renewable diesel production. Similarly, other technologies might initially focus on other alternative products, such as specialty chemicals. This pattern has been observed in the marketplace, with several announcements of initial production of chemicals at biorefineries. These examples show that renewable diesel and alternative products can drive the economics of new technology adoption by maximizing profits before feedstock and technology learning is able to reduce costs and boost volume.

Lipids – which include oils, fats and waxes – are attractive technically because of the ease of their conversion to fuels, and the lower associated capital costs, but the current value of the feedstock oil for other uses makes it challenging as an aviation biofuels feedstock. We should not try to predict future markets.

Under current economics, MASBI researchers found the cost to produce HEFA renewable jet fuel ranges from $4 to $6 a gallon and is driven by the price of feedstocks. However with a variety of incentives, the price per gallon can be under $3, which is cost competitive with today's refined fossil fuel products.

Considering technology investments, the Midwest has the potential to meet feedstock requirements to produce meaningful quantities of renewable jet fuel, even when considering the overall maturity of the sector and the lack of underutilized capacity.

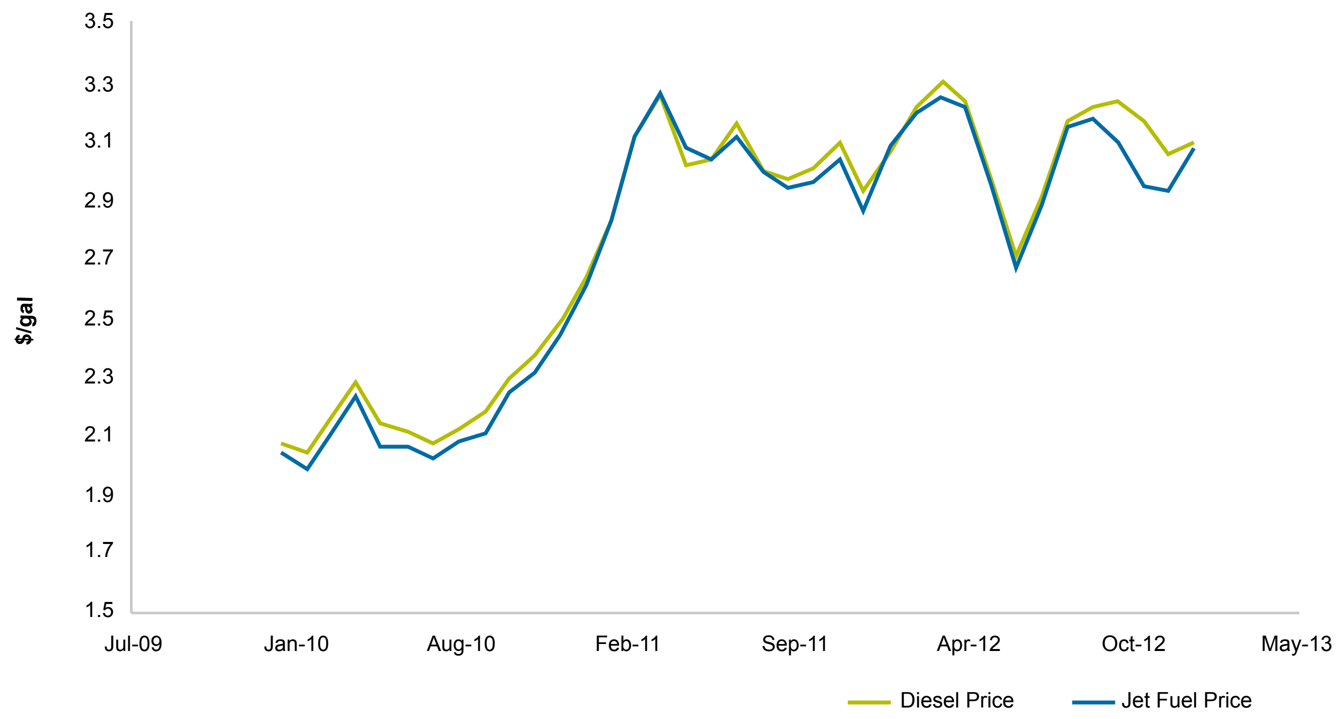
EXHIBIT 3: HEFA PRODUCT EFFICIENCY AND PRODUCT OUTPUT
Output as a % of input weight



Source: A Techno-Economic and Environmental Assessment of Hydroprocessed Renewable Distillate Fuels. Matthew Pearlson, Massachusetts Institute of Technology, June 2011

Bio oils are chemically predisposed to favor diesel production. If jet is favored, the output of higher value distillate fuels drops, resulting in a $0.25–$0.30 gal premium. This is tied to the natural chain length of the oils and cannot be addressed by modifying the conversion process.

EXHIBIT 5: JET FUEL VS. DIESEL



Source: Honeywell UOP

EXHIBIT 6: HEFA COST STRUCTURE

Source: A Techno-Economic and Environmental Assessment of Hydroprocessed Renewable Distillate Fuels. Matthew Pearlson, Massachusetts Institute of Technology, June 2011

Current returns indicate farming for energy crops is likely to be limited to idle/unused land (only about 3% of Midwest farmland) or innovative planting such as cover and double cropping.

Feedstock used for renewable jet fuel, including biomass, waste gas, and oil seeds, comes with additional logistical requirements related to transport that reduce economic viability.

Feedstock, often of low bulk density, must move from the farm or waste generator to the refinery; finished renewable jet fuel must move from refinery to airport. The viability of the local supply chain can determine the viability of feedstock logistics.

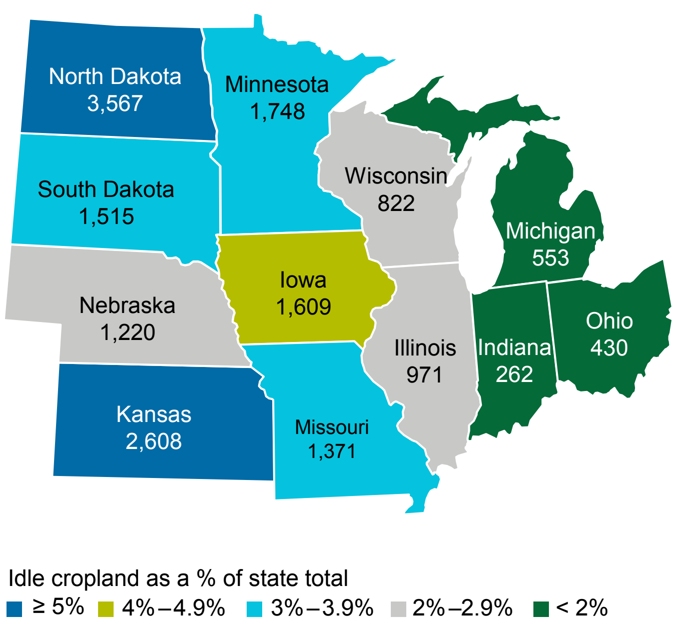
For example, waste gases, used in a gas fermentation process to produce biofuels, are waste residues of industrial facilities such as iron and steel production, petroleum refining, and petrochemical processes. The fermentation facilities, co-located with the gas producer, could share infrastructure and utilities, reducing capital requirements.

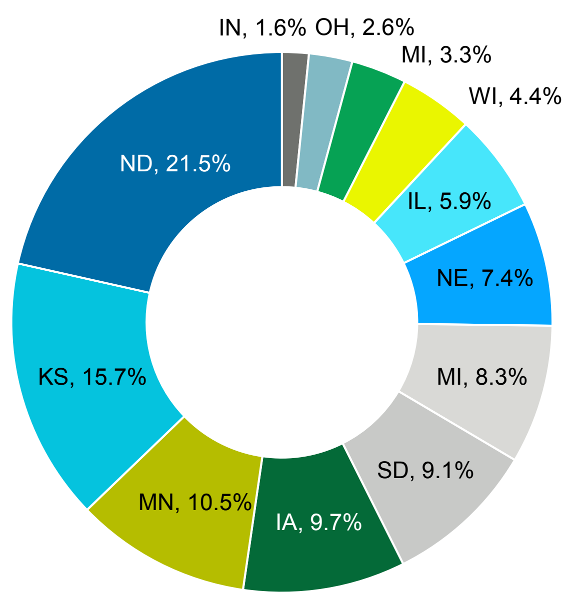
Meanwhile, oil seed feedstocks require special handling, including proper moisture and temperature conditions for storage and cleaning, drying, and de-hulling before the extraction process and removal of impurities. Biological

by nature, feedstock stability or shelf-life must be considering in coordinating harvest with delivery, storage, and conversion.

Transporting finished “neat” renewable jet fuel from the refinery to the blender requires special transport and storage as current specifications only allow for blended product to be certified for transport in existing pipelines and other logistics infrastructure. However, as initial volumes of “neat” product will be relatively modest, this does not represent a barrier to commercialization.

EXHIBIT 6: ACREAGE AND DISTRIBUTION OF MIDWEST CROPLAND
Thousands of Acres/Distribution





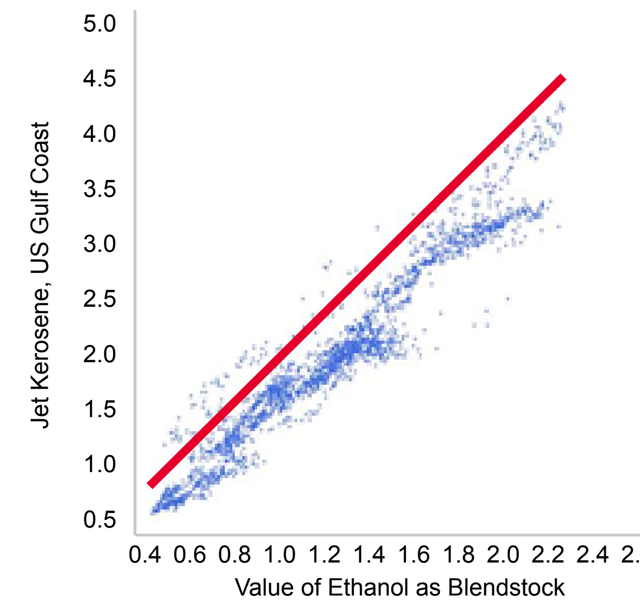
Source: Purdue University

Currently, only renewable fuels produced with the HEFA and FT technology pathways are approved for blending and use with conventional fuels.

The maximum blending ratio of aviation biofuel to petroleum fuel currently allowed by ASTM specifications is 50%. Blending renewable fuel may present minor growing pains, but it is not expected to be difficult for the industry to handle. Depending on supply chain participants, blending can be accomplished at several stages, including at the refinery, at a storage terminal, or at the airport. To reduce logistics, MASBI members recommend blending renewable jet fuel with traditional jet fuel as far upstream as possible. Upstream blending avoids the need and costs for duplicative infrastructure for handling neat biofuels and petroleum fuels. In general infrastructure per gallon costs will decline with increasing jet fuel volumes.

How tracking of alternative fuel will work is still an open question. Once the alternative jet fuel is blended and the fuel enters co-mingled storage, batch traceability is lost and it is not possible to determine the alternative fuel content without additional testing. Therefore, a tracking system based on a “book and claim” approach is considered to be more practical and cost effective than having to rely on physical segregation of the product.

EXHIBIT 7: SURFACE FUEL VS. JET FEEDSTOCK
Value on BTU Basis; $ per Gallon



Source: Honeywell UOP

In the majority of circumstances, ethanol has a higher value when blended with gasoline rather than as a feedstock for jet production. With export, ethanol is an unsaturated market.

ASTM International

Before any jet fuel, conventional or renewable, can enter the supply chain, it must be certified as meeting the applicable standard specification. The specifications for jet fuel in the United States and around the world are established by standard setting organizations such as the ASTM International (formerly known as American Society for Testing and Materials, www.astm.org) and the United Kingdom’s Ministry of Defence Standard 91-91(DEFSTAN, www.dstan.mod.uk).

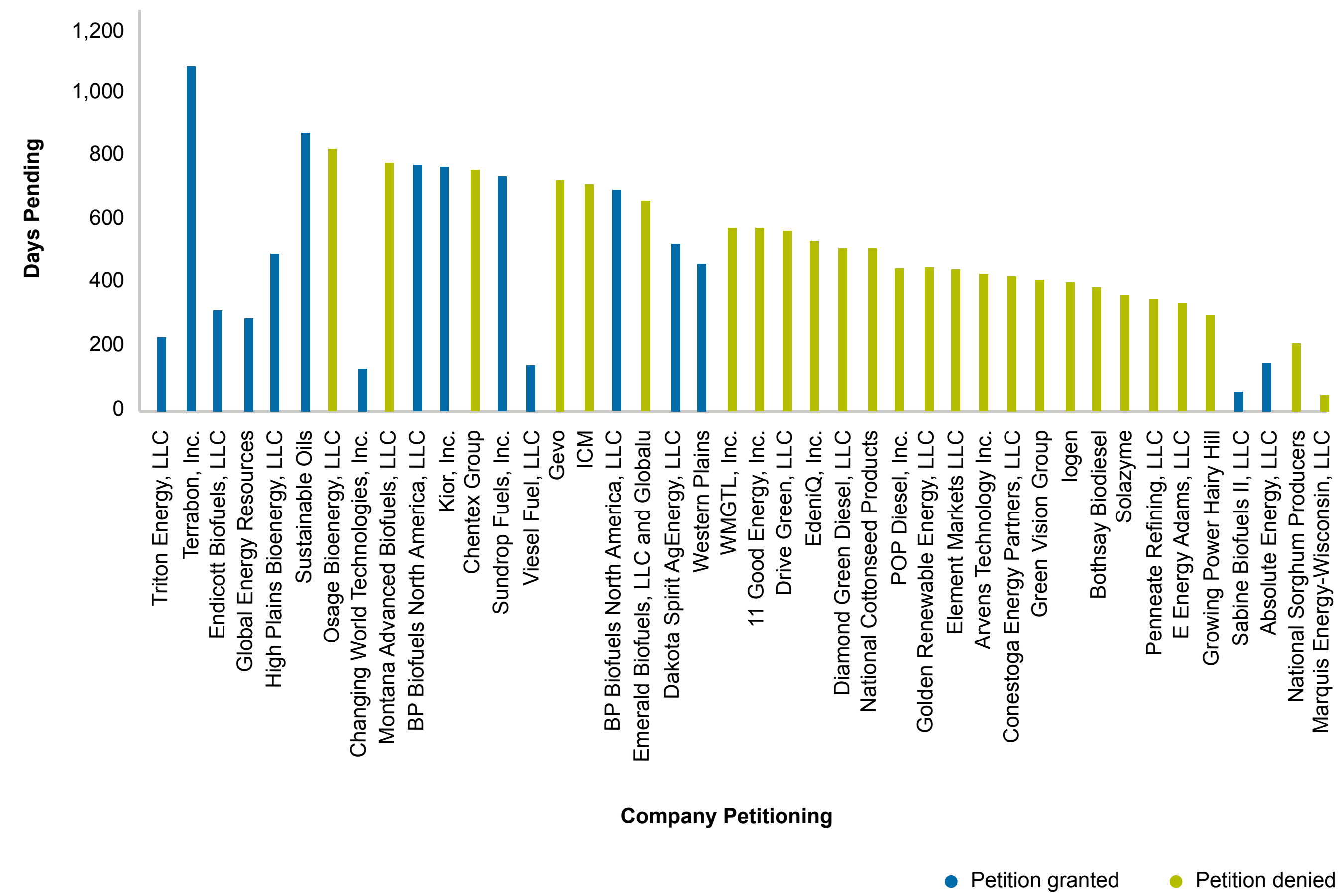
The ASTM D1655 standard defines the specifications for conventional jet fuels for commercial use, such as Jet A and Jet A1. The standards for jet fuels from non-petroleum sources, such as those under discussion here, are identified under ASTM standard D7566. Fuels complying with ASTM D7566 are currently approved for blending with conventional jet fuel up to a maximum 50/50 blend ratio.

The existing ASTM process is both lengthy and costly, taking up to three years and costing producers upwards of $30 million.

EXHIBIT 8: RFS2 BIOFUELS PATHWAY PETITION DATES

Source: http://farmdocdaily.illinois.edu/2013/05/epa-biofuels-pathways-petitions.html

EXHIBIT 9: PATHWAY PETITION WAITING PERIODS



Source: http://farmdocdaily.illinois.edu/2013/05/epa-biofuels-pathways-petitions.html

Expediting Approvals

The competitive advantage of "drop-in" fuels is that they avoid the need for significant equipment and infrastructure changes, thus reducing potential capital investment. Drop-ins require approval of both feedstock and conversion process. Approvals can represent a significant barrier to bringing new feedstock/conversion processes to market. The critical approval processes include chemical, physical, and engine tests which require large fuel volumes, beyond the capacity of pilot facilities. Producing the fuel for testing is an economic barrier.

The ASTM process can take over two years and require investments of tens of millions of dollars. Both alcohol to jet and HDCJ technologies, highlighted as high-potential technological pathways, are expected to gain ASTM certification by 2015, but other promising technologies still face years until approval.

Reforming the EPA Approval Process

Currently, each specific combination of fuel type, feedstock, and production process must be approved by the EPA as a "pathway." This requires a two-part application process: the determination of meeting qualifications of the Energy Independence and Security Act (EISA), including meeting the definition of "renewable biomass"; and compliance with a greenhouse gas threshold that includes greenhouse gas assessments (direct and significant indirect emissions from land-use changes) related to the full lifecycle, including all stages of fuel and feedstock production, distribution, and use by the end-user. The process can take two years or more.

Because of the number of pathways currently under consideration and the speed of technology innovation, the approval process has proven cumbersome, causing a backlog of petitions, concerns about transparency in the process, and questions of bias for some crops.

The long and uncertain timeline for EPA approval impedes commercial development and business certainty for a growing number of biofuels producers.

To overcome the development challenge, the EPA should provide clear guidance on criteria, including templates on how petitions should be structured. Additionally, the EPA should streamline and accelerate the process by which feedstocks are evaluated and approved.

MASBI RECOMMENDATIONS

Production and Commercialization

5. Identify means to expedite approvals by the ASTM International and the Environmental Protection Agency. In the former, identify means to speed up the process in critical areas such as generation of test data to evaluate the performance of proposed fuels and engine testing. Expediting this can speed up time to market of new conversion technologies.

6. Allow producers to optimize product portfolios. The production of renewable diesel as part of the refiner's product portfolio should be fully supported, allowing for improved renewable jet fuel supply and improved overall economics of biofuels production.

> "Advanced biofuels are important to the aviation industry's sustainability, both as a way to diversify our fuel supply and lower our carbon footprint. Development of this new, clean energy industry drives innovation in the American economy, benefits the environment, creates jobs, and strengthens the communities we serve."
>
> *– Jimmy Samartzis, United Airlines*

FINANCING AND INVESTMENT

Investment in biofuels has been largely influenced by steep fluctuations and record-breaking spikes in the price of fossil fuels, which have become exceedingly volatile during the past decade. Although clean-tech and biofuels investment rose sharply in 2008 with petroleum price shocks, in 2012 clean-tech investment decreased 33%.

This was largely attributed to the decline in fossil fuel prices stemming from the boom in hydraulic fracturing (more colloquially known as “fracking”) in the U.S. and the weak financial performance of clean-tech investments during the past several years.

Institutional investors such as venture-capital and private-equity firms have indicated they would be more interested in biofuels projects if aviation industry stakeholders were willing to take a leadership role in the financial commitments or direct investments involved.

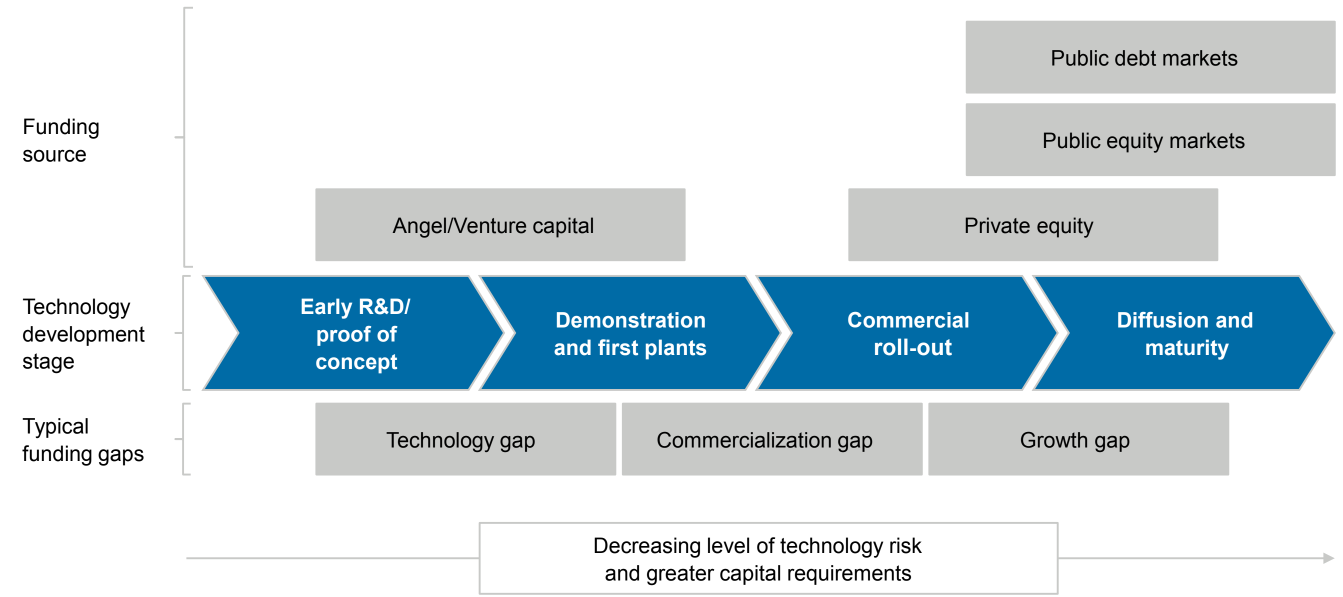
Notwithstanding variations among conversion technologies, the biggest contributor to the cost of biofuels is the feedstocks of raw material that make biofuels sustainable.

At current market prices, feedstocks for approved production technologies are frequently uneconomical without accounting for government incentives.

Amid current political uncertainty, investors discount the value created by those government incentives when calculating prospective returns (as they are not sure how long those policies will last). The industry requires incentives such as subsidies and market mechanisms that result from mandates to further develop. At the same time, government support tends to be subject to political and budget cycles. Some of the most promising biofuels technologies are still in development, so the time to market and potential returns remain uncertain. As a result, the biofuels industry is perceived as higher-risk than other sectors of the energy complex, which can be rectified. As of now, investors demand greater returns on their investments to offset the risk.

With the understanding that laying the groundwork for the renewable jet fuel industry will pay off in the long run, aviation biofuels stakeholders, investment banks, biofuels funds, and consortiums will want to consider drawing on public and private resources to finance renewable fuel technology, while also taking steps to share the risk.

EXHIBIT 10: TECHNOLOGY DEVELOPMENT STAGES



Source: Brookings Institute

Overview of Industry Stage, Lifecycle, and Financing Steps

The funding process that biofuels must undergo to achieve large-scale commercialization is not unique to the industry. It is a fundamental process most companies in the tech sector and similar industries must confront. The additional challenge with biofuels is that they must compete and penetrate a mature, established industry.

As shown in Exhibit 10, there are four sequential technology development stages: early R&D/proof of concept; technology demonstration and initial plant development; commercial rollout of the product, and product diffusion and maturity.

A technology attracts different types of investors depending on the product’s development stage. This usually begins with angel investors and moves to venture capitalists, and then to private equity, to project-finance vehicles, such as public debt and equity funds.

As a point of reference, the solar industry in a broad sense is largely assumed to be at the diffusion and maturity phase, though some experts say solar is at the point between commercial roll out and diffusion/maturity.

As with biofuels, solar technologies are facing steep investment challenges which have stalled diffusion of the technology.

In contrast, biofuels technologies lie in different parts of this value chain.

Some are in the research and development or proof of concept phase, while others are constructing their first commercial facility. This is why the investment community intersects this value chain at multiple points.

Many upstart biofuels firms are between commercial roll out and diffusion maturity. This is a particularly precarious spot in the value chain, identified in the chart as the growth gap. This is traditionally the hardest funding gap

Potential Funding Sources

Angel investor: An investor who provides capital at the earliest stage of a technology’s development. An angel investor usually funds the early R&D and proof of concept stage. This investor usually provides the smallest amount of capital, focusing on helping the business succeed early and grow.

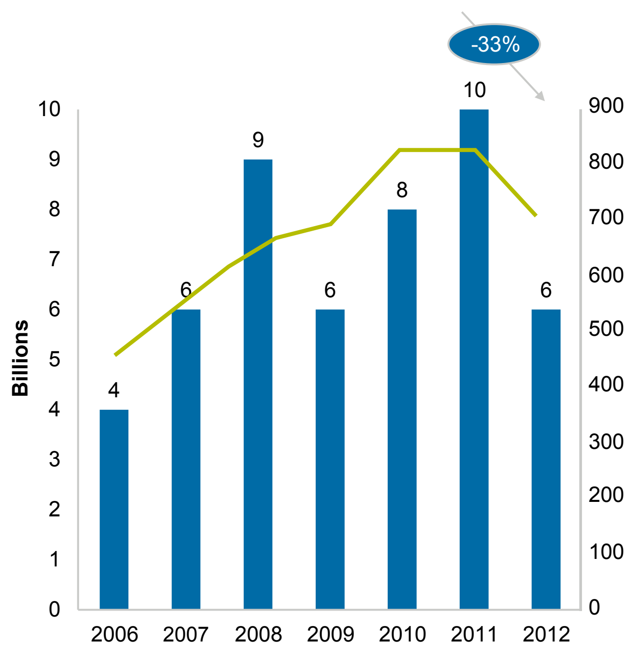
Venture capital: This early-stage investor helps companies traverse the technology valley of death noted in the chart by providing financing to get though the demonstration and first plant stage. The venture capitalist then exits, sometimes with an initial public offering. VCs typically invest more capital than angel investors but less than private equity or project finance. Venture capitalists have a high tolerance for the risks associated with technology development, but not for policy risks or market volatility. Most venture capital comes from private wealth, investment banks, or other financial institutions that pool such investments or partnerships. VCs are often granted some operational oversight and an equity stake in the company.

Private equity: Private equity firms invest in private companies, usually on behalf of institutional or high net-worth investors. PE firms usually invest in industry sectors where they have expertise. Thus, they usually put in capital after a technology is proven, or in the commercial rollout phase. PEs have a higher tolerance for market risk than angel investors or venture capitalists, but a lower tolerance for technology or market risk. They typically have more access to funds than VCs and they use this capital to drive a proven technology closer toward a diffuse state and wider-scale commercialization.

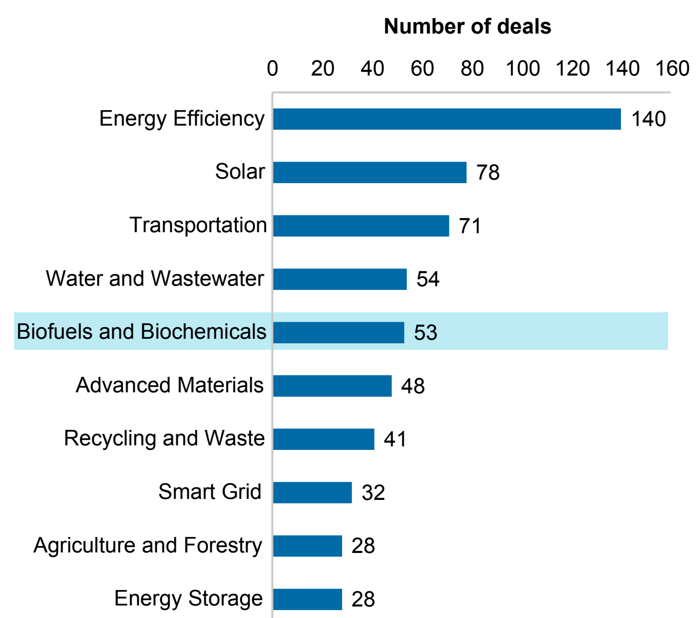
Project finance: Project finance entails investing in long-term infrastructure, industrial projects, and public services based upon a non-recourse or limited recourse financial structure. Project debt and equity are paid back from the cash flow generated by the project. Most commercial facilities are financed with publicly-traded debt and equity. The funding arrives at the final diffusion and maturity stage and typically provides the most capital.

EXHIBIT 11: INVESTOR ANALYSIS: VENTURE INVESTMENT TRENDS AND SECTORS

Global VC investment in cleantech, by year



Top ten cleantech sectors by VC deal count



Source: Sheeraz Haji, CEO, Cleantech Group

to bridge, because companies at this stage need large amounts of capital at affordable rates to meet project requirements and achieve maturity.

Current Barriers and Incentives to Investment

MASBI conducted an industry survey of venture investment trends within clean-tech segments, which include aviation biofuels. The charts in Exhibit 11 illustrate the major findings.

As the first chart shows, clean tech funding declined by 33% in 2012 compared with 2011. The largest category of clean-tech investment is in energy efficiency. In particular, biofuels are considered risky investments because of large capital requirements, uncertain time to market, uncertain policy support, and the overall political landscape.

Each segment of the investment community identified specific risks that negatively impact their view of the biofuels market space.

- Angel investor/venture capital: They see the technology risks as too high. This concern arises from the previously noted large capital expenditures and uncertain time to return on investment.
- Private equity: These investors view the political risk as unmanageable, with no opportunity to hedge. PEs said positive economic outlooks on biofuels projects require massive government subsidies and these can change significantly over the time horizon of such an investment portfolio.
- Public funds (publicly-traded debt and equity markets): Debt ratings agencies typically grade biofuels projects as a single B (according to Standard and Poor's, this means they're seen as "more vulnerable to adverse business conditions" but currently able to meet financial obligations). Thus the required interest on debt ranges from 15% to around 25%.

Financiers said the cost of debt in biofuels projects is approximately 17%, with cost of equity more than 20% and a capital structure that requires greater than 50% equity. That investment profile does not compare favorably with ethanol and biodiesel investments, which often compete for project-financing dollars.

Because of these factors, the investment community is concerned with the long-term economic viability of renewable jet fuel production without long-term and stable government policies (on the order of 10-plus years). According to investors, large-scale movement in the institutional investor community is unlikely until stakeholders in the aviation value chain themselves make direct investments. Commitment will signal a reduction in risk to financiers, which will incentivize investment.

Institutional investment in biofuels is stagnant under current policy and market conditions. This is not unusual in the history of energy innovation, which has always entailed taking on outsized risk, but it is uncommon for institutional investors to get involved with an industry until it reaches a higher level of industry maturity. However, this highlights the need for a stable and consistent energy policy surrounding aviation biofuels.

Investors face four fundamental risks: oil price risk, agricultural feedstock supply and price risk, technology risk associated with cost and conversion yield, and government policy risk.

That said, an oil price shock, a technological breakthrough, or a geopolitical event could offer an opportunity for well-positioned biofuels investors to make a substantial return. There are strong public benefits to avoiding energy shocks, which can be used for government support for nurturing the industry.

Long-term strategic planning for clean energy investment, and energy/climate policy has proven complicated in recent years. Yet, many MASBI stakeholders agree that reaction responses or inordinate focus on near-term trends do not provide consumers, investors, or policy makers with the stability and security they ultimately desire.

Among its recommendations, MASBI suggests supporting the development of investment banks that tap into public and private resources to finance renewable fuel technologies. The advancement of mechanisms for sharing risk, such as consortiums or biofuels funds, also would foster the industry.

Another consideration is that the aviation industry could create a consortium to advance the biofuels industry and engage in supportive commercial activities with producers.

Investment community research suggests that more direct involvement by the aviation community as a strategic partner in commercial opportunities would demonstrate its interest and accelerate investor inflows into aviation biofuels production opportunities.

Correlation of Feedstock Price to Petroleum

Price volatility of aviation biofuels feedstocks should, over time, match that of petroleum, although – as with all fuels across the U.S. – localized factors will also play a role in the outright price.

It is generally accepted that over long time horizons (relative to market scalability), the price of certain feedstocks designated for fuel production will begin to track the price of petroleum. While that means the feedstock price will closely correlate with the petroleum price, with each having similar price volatility, it also will mean more diversity of supply for the aviation industry, not to mention more renewable fuel for all.

An example of this market phenomenon is biodiesel. Before the biodiesel market was established and mandates were put in place by the federal government, the price of oil such as soy oil was not tightly correlated to the price of petroleum. This was due to the lack of a linking mechanism between the two commodity markets. Also with the addition of RINs into the marketplace, the price of feedstocks increased; it is expected that if RINs were to expire, feedstock prices would fall.

Once the biodiesel market matured and consumers could choose between either diesel or biodiesel, their prices began to track each other.

This type of correlation would not exist initially in a Midwestern aviation biofuels market, but it would develop over time as more plants processing feedstock came online.

It should be noted that even in a mature market, the feedstock to petroleum correlation will not be 100% as a rule. This is due to the fact that the petroleum market may respond to broader geopolitics or global supply disruptions, while Midwest feedstock would be sensitive to global agricultural market conditions and be more responsive to highly localized fundamentals, such as regional weather patterns. Still, as production expands, the correlation will become tighter.

MASBI RECOMMENDATIONS

Financing and Investment

7. Balance risk and reward for early adopters of technology. Aviation biofuels is technically ready to scale commercially. At this early stage of development, stakeholders should consider entering agreements with the aim to balance risks with partners, thereby accelerating the rate of industry growth. For example, airlines could consider innovative pricing structures and long-term off take agreements, investors could require lower cost of capital on investments, feedstock providers could enter into long-term supply agreements with better than market pricing, fuel producers could consider alternative margins, and refiners could consider slightly higher volumes of jet fuel. If all stakeholders are willing to compromise and consider the needs of partners, the industry will reach its potential sooner.

8. Demonstrate industry demand with aviation jet fuel purchase guidelines. Aviation stakeholders operate within a constrained operational and economic environment. Likewise, producers have their own sets of constraints. Each side is frequently unaware of the limitations of the other. Aviation industry stakeholders could articulate a series of guidelines to initiate and inform discussions that would result in both sides setting respective parameters and identifying places of overlap where their commercial needs meet.

9. Create a pool of capital to invest in biofuels. Private financiers are either reluctant to finance biofuels projects or require rates of return that are too high. Aviation industry stakeholders could collaborate with other aviation biofuels consumers, including government or commercial entities, to develop structures allowing for efficient capital raising and vertical integration such as investment in the biofuels supply chain.

> "We are fortunate to have the engagement of commercial leaders interested in building a supply chain for sustainable jet fuel. This is an important emerging industry for the Midwest that can be a significant economic driver for decades to come."
>
> *– Amy Francetic, CEO, Clean Energy Trust*

POLICY AND ECONOMIC DEVELOPMENT

Reliable and long-term policy will help aviation biofuels develop into an established industry. If aviation stakeholders and policy makers in the Midwest and Washington take coordinated action, the aviation biofuels industry will be capable of meeting growing demand, providing economic benefits to the region, country, and the aviation industry.

MASBI has identified specific policy measures focusing on the industry's strongest needs to mitigate risk across the value chain and usher in incremental advances.

MASBI evaluated state and federal level measures that incentivize the development of an aviation biofuels industry in the Midwest. This exercise considered the inputs and needs expressed by both internal MASBI members and a broader commercial audience throughout the United States.

Current Political Outlook

The political outlook at the federal level is mixed, with both strong support and resistance complicating the industry landscape. At the executive level, the Obama Administration strongly supports the reduction of GHG emissions, calling on agencies to work together to achieve this goal. In his 2013 State of the Union address, the President said we can make meaningful progress to mitigate climate change while driving strong economic growth. As well, the President urged coordination among federal agencies to find solutions to climate change.

"I will direct my cabinet to come up with executive actions we can take, now and in the future, to reduce pollution, prepare our communities for the consequences of climate change, and speed the transition to more sustainable sources of energy."

Other federal agencies with oversight responsibilities in the biofuels sector have indicated strong support. In April 2013, Secretary of Agriculture Tom Vilsack and Secretary of Transportation Ray LaHood signed a five-year agreement with members of the aviation industry to continue to develop aviation biofuels. With that agreement, the Federal Government and its partners hope to support the annual production of 1 billion gallons of drop-in aviation biofuels by 2018. The renewed agreement follows the initial success of the 2010-2012 Farm-to-Fly initiative, a public-private program involving the USDA and aviation industry stakeholders. The initiative is designed to accelerate the availability of a commercially viable and sustainable aviation biofuels industry in the U.S. and would improve domestic energy security, establish regional supply chains for aviation biofuels, and support rural development.

Other federal agencies such as the FAA, the EPA, and the U.S. Department of State have shown support by implementing strategic initiatives and facilitating interagency progress.

For more information on this, refer to "Provide robust support for aviation biofuels under RFS," in the appendix.

Legislators are showing less interest in one-off tax credits and subsidies that could fuel biofuels industry growth. The energy security debate has shifted somewhat from renewable fuels to domestic oil and gas with the boom in shale drilling. In addition, general budget turmoil, the ongoing sequester, and other Capitol Hill distractions leave government policy for biofuels uncertain.

Current biofuels policy measures are often short term and don't address fundamental inequities in the treatment of fossil fuels and biofuels. Biofuels production relies on long-term, capital-intensive investment. Government policy must complement this private investment by providing long-term, reliable market signals as the industry grows to commercial scale. This investment will help meet important government priorities, such as energy security and diversification, rural economic development, and a low-carbon economy. The public risk of future energy or oil shocks as exhibited in the post-war period is sufficient justification for public investment. Finally, as policy leaders contemplate policies to promote aviation biofuels, rigorous sustainability and environmental standards should also be included to ensure government support is targeted at truly sustainable fuels.

Policy Analysis

Five overarching themes and objectives led to MASBI's recommendations listed below.

1. SUPPORT SUSTAINABLE AVIATION BIOFUELS AS A STRATEGIC NATIONAL SECURITY PRIORITY

Increasingly, the U.S. includes endemic industrial or technological shortfalls as national security risks. This makes it worthwhile for government agencies to ensure productive capacity to meet strategic military and domestic needs. There is an established track record of successful DOD investments in critical national industries, many of these energy related. Such programs share costs with the private sector by investing capital in areas such as facility retrofits or wholesale construction or supporting manufacturing innovation. This public-military-private partnership can promote industrial production that would meet essential government requirements and helps establish commercial viability for key industries, such as the developing aviation biofuels market.

The Defense Production Act Title III Program

The DPA Title III Program plays an important role in the development of domestic production capabilities for a wide range of cutting-edge technologies necessary to strengthen national security. The Act provides financial incentives for companies to make investments in production capabilities and resources; executes projects ranging from process improvement to production plant construction; and targets the most important elements of production as they relate to both the nation's needs and the industry business model.

The mission of the DPA Title III Program is to create assured, affordable, and commercially viable production capabilities and capacities for items essential to the nation's defense. This crucial mission can be accomplished by supporting these program objectives:

- Create, maintain, expand, protect, or restore the production capabilities of domestic suppliers whose technologies and products are critical to the nation's energy security
- Increase the supply/improve the quality/reduce the cost of advanced materials and technologies
- Reduce U.S. dependency on foreign sources of supply for vital materials and technologies
- Strengthen the economic and technological competitiveness of the U.S. defense industry

The joint DOD-, DOE-, and USDA-sponsored DPA Title III initiative is designed to promote new commercial production of military specification jet and diesel biofuels. The program's goal is to provide funding to support feedstock production and logistics (from USDA Commodity Credit Corporation funds) and grant funds to support engineering and construction (from DOE and USN funds) of integrated biorefinery projects specifically capable of producing military grade biofuels.

The Title III initiative has a phased approach, with Phase 1 covering completion of planning and preliminary design. Phase 2 covers facility construction, commissioning, and performance testing as well as delivery of biofuels, and assumes that awardees would be under contract in early 2014. On May 27, 2013, DOD awarded three contracts totaling $16 million to Emerald Biofuels, Natures BioReserve, and Fulcrum Biofuels as part of Phase I. Under these contracts, the three companies will develop plans for biorefineries capable of producing up to 150 million gallons of drop-in biofuels from oil seed crops and waste residues at a cost of less than $4 per gallon. The DOD grants will be matched by a $17 million investment from the companies, and the facilities are expected to produce aviation and marine diesel fuel.

Authorize the use of longer-term government purchase contracts

It is important to note that the Defense Logistics Agency (DLA) may only execute fuel contracts up to five years in duration. Longer-term (10- to 15-year) biofuels purchase contracts would provide greater economic surety for biorefinery development. This has the potential to be a powerful investment incentive, especially if coupled with additional off-take agreements from commercial users such as airlines, trucking companies, and railroads.

2. PROVIDE RISK MITIGATION FOR INVESTORS, PRODUCERS, AND CUSTOMERS

Support for the following programs would create greater economic investment opportunities and mitigate risk for all industry stakeholders.

Extend refinery assistance in the Farm Bill

The Biorefinery Assistance Program is administered by USDA Rural Development and is part of the Farm Bill, which supports the development of biorefineries and R&D through loan guarantees. The program assists farmers, ranchers, and rural small businesses to purchase renewable energy systems.

Proposed language in the Senate would expand eligibility to include renewable chemicals, increasing the ability of these biorefinery projects to compete with petroleum across a broad spectrum of hydrocarbon products.

The purpose of the Biorefinery Assistance Program is to provide guaranteed loans for the development and construction of commercial-scale biorefineries or for the retrofitting of existing facilities using eligible technology for the development of aviation biofuels. The maximum guaranteed loan is $250 million.

Extend tax incentives

Support is needed for provisions of the Family and Business Tax Cut Certainty Act of 2012, which amends and extends tax policies for bioenergy systems and extends them through the end of 2013. It would extend the investment tax credit in lieu of a production tax credit, the cellulosic biofuels producer tax credit (including algae-based fuels), incentives for biodiesel and renewable diesel, and cellulosic biofuels bonus depreciation.

Extend and coordinate local, state, and federal policy for regional facilities

Smaller demonstration facilities are an important step in proving new processes while accessing smaller amounts of feedstock available locally. State and local governments often have mechanisms in place such as financing vehicles, bond authorities, grants, and tax relief that can be packaged together to help site a facility regionally. For example, in Washington State, legislators recently authorized the Washington State Housing Finance commission to issue bonds and enter into other financial arrangements for the purpose of financing biofuels facilities.

Continue support through the US Renewable Fuel Standard

The US Renewable Fuel Standards requires oil refiners and importers to blend 36 billion gallons of biofuels into the transport fuel pool by 2022. It provides significant market-based incentives for advanced aviation biofuels without enforcing mandates for jet fuel end users. Aviation fuel's access to the incentives offered by the RFS is pivotal to the scale up of this industry in the United States. Regulatory support such as the RFS complements commercial commitments and investments made by end users and industry participants. Confidence in RFS incentives improves the business cases for biorefineries as they supply the next generation of sustainable aviation biofuels.

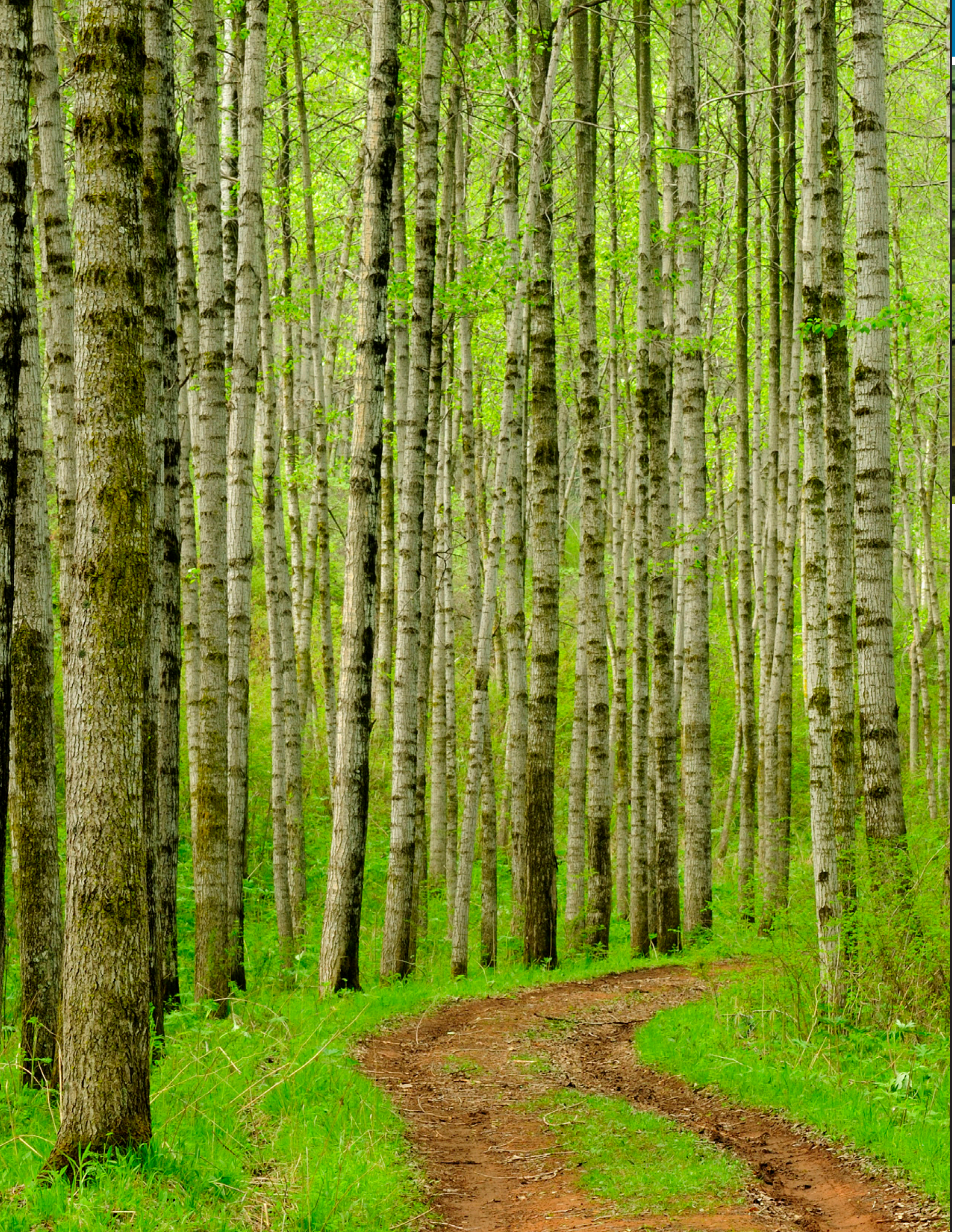
3. ENSURE A LEVEL PLAYING FIELD FOR AVIATION BIOFUELS

Address inequities in government policies regarding different energy sources

Governments should ensure that sustainable aviation fuels have a level playing field relative to traditional petroleum fuel and other forms of ground-based fuels. There are many policies at the state and federal level that advantage fossil fuels. Aviation biofuels are at an early stage of development and should not face additional barriers from preferential treatment of fossil fuels. One recent example of this is the master limited partnership (MLP) corporate structure. An MLP is a business structure that is taxed as a partnership, but whose ownership interests are traded like corporate stock on a market. By statute, MLPs have only been available to investors in energy portfolios for oil, natural gas, coal extraction, and pipeline projects. These projects get access to capital at a lower cost and are more liquid than traditional financing approaches to energy projects, making them highly effective at attracting private investment.

R&D

Research and development along all areas of the value chain are critical to the success of this industry. State and federal government can play a transformative role in funding research. R&D is also an effective tool governments can use to spur industry development without giving preferential treatment to particular technologies or feedstocks. While several federal agencies are already funding research and development, additional funding for aviation-relevant fuels research is needed to address various commercialization hurdles outlined in this report.



MASBI RECOMMENDATIONS

Policy and Economic Development

10. Create longer-term policies that enable investment and production. Create a stable long-term policy environment, which is critical for the development of the renewable jet fuel industry and encouraging investment.

11. Level the playing field. The fossil fuels industry has relied on and continues to receive government subsidies, policies, and support which foster growth. The aviation biofuels industry should be afforded similar opportunities for growth. For example, allow master limited partnerships (MLP) for renewable jet fuel, which are currently limited to the conventional petroleum industry.

12. Fully fund the Defense Production Act Title III for the production of biofuels. Government action to develop new sources of energy has historically been an effective approach. The U.S. government and in particular the U.S. Navy has been instrumental throughout its history in transitioning from wind to coal to nuclear energy. The U.S. Government's efforts to support aviation and marine aviation biofuels is important and the Defense Production Act Title III program sponsored by the U.S. Departments of Agriculture, Energy, and Navy should be fully funded.

13. Build regional demonstration facilities supported by municipal and state policy. In the short term, focus biofuels development on smaller facilities that will not exhaust local feedstock supply. Simultaneously, leverage coordinated municipal, state, and national policies to maximize opportunity. For example, allow state bonds to be sold to support the construction of production facilities.

"As the aviation industry plans for future growth, sustainability must be considered every step of the way. Advances in aircraft technology and sustainable biofuels will position our industry to reduce emissions while maintaining a competitive advantage."

– Rosemarie S. Andolino, Chicago Department of Aviation

SUSTAINABILITY AND THE ROAD AHEAD

By 2020, the Midwest's total demand for jet fuel is expected to reach approximately 3% of total U.S. aviation demand. At the same time, the aviation industry seeks to improve its environmental footprint. How the region chooses to develop the biofuels industry will be critical to achieveing sustainable carbon-neutral growth of the aviation industry.

Sustainability

Sustainability, or meeting present needs without compromising the ability of future generations to meet their own needs, is important to the development of a Midwest aviation biofuels market. The Midwest is an agriculturally rich region of the country and preserving its continued development with sustainability in mind will positively impact its future growth and the lifecycle benefits of aviation biofuels. The production of alternative aviation fuels therefore must be done with consideration given to social, economic, and environmental sustainability. MASBI regards sustainable development as a fundamental aspect of a sound business case for the market examined in this report.

Demonstrating its commitment to the environment, MASBI reviewed the sustainability factors that would be instrumental in determining sources of biofuels for both the near-term and long-term and the broader parameters of its blueprint for the Midwest biofuels industry. Below are the findings of its assessment.

Land Use

The land area needed to cultivate biofuels feedstocks at commercial scale and the necessary site pre-processing facilities are potentially significant issues. Some biomass and intermediate feedstock materials would require little-to-no additional land use (waste grease, crop and forest residues, and municipal solid waste). Certain feedstocks could be integrated into existing cropping systems (cover crops, co-products) or require significant conversion of existing or fallow cropping areas.

Direct land use change (DLUC) is the conversion of land directly to biomass production. Indirect land use change (ILUC) is attributed to biofuels feedstock demand displacing existing products and prompting shifts in land use in other regions to compensate. Section 201 of the Energy Independence and Security Act (EISA) cites the need to consider both "direct emissions and significant indirect emissions such as those from land use change." There are more potential risks for ILUC with dedicated energy crops. The potential impact of ILUC is tied to converting rainforest or native lands to row agriculture, which releases soil carbon and reduces future carbon sequestration in the soil.

EISA restricts certain types of land use conversion for "renewable biomass." More broadly, it's critical to avoid the conversion of native ecosystems when boosting biomass production, because of potential impacts on biodiversity.

Water Impact

Fresh water is a requisite natural resource for human sustenance, agricultural production, industrial processes, natural system sustainment, and provision of ecological services. Irrigation is the single largest consumer of underground water resources. Depending on the region, these water resources can take centuries to recharge.

Federal and state laws cover and regulate two aspects of water use: quality and quantity. The government regulates activities that affect water quality under several federal statutes, such as the Clean Water Act of 1972 and state and local regulations.

Agricultural and industrial activities are permitted, managed, and monitored to help maintain human and ecosystem health standards. Water allocations are managed by regional authorities with significant policy differences in the more water-rich East and the more arid West.

Water consumption for agriculture has been a focus of concern during the past decade. Failure to consider the water requirements of a biofuels pathway and local water availability can greatly compromise feedstock availability and a facility's economic viability and negatively impact the health of local communities.

Sustained water overdraw can damage aquatic ecosystems and even aquifer water resources in extreme cases.

Soil Impact

Agricultural production of any crop for food, feed, fiber, or fuel requires sufficient and healthy soil. Good soil provides structural stability, regulates water retention, stores nutrients, filters harmful substances, and serves as habitat. Soil health can be quickly damaged by mismanagement. For example, over-grazing, slash-and-burn land clearing, intensive tillage cropping methods, or overuse of agricultural chemicals can break down organic matter, expose soils to rain and wind, and damage beneficial soil organisms. Direct loss of topsoil through erosion is often a result of mismanagement. However, a loss of nutrients, fertility, and soil ecosystem health can just as quickly undermine sustainable production. Biomass production ventures should promote best practices that build soil quantity, minimize degradation, and proactively manage soil health to maintain productive and economic viability and reduce impacts on water quality and biodiversity.

Biodiversity

Conservation of species diversity, native habitats, and the broader terrestrial, aquatic, and marine ecosystems is a core sustainability factor. Greater diversity and habitat preservation directly equates to healthier, more productive, and resilient biological resources. Existing statutes, such as the National Environmental Policy Act of 1969, the Endangered Species Act of 1974; and numerous other federal policies, emphasize the importance of conserving biodiversity.

The imperative to maintain biodiversity is not limited to protecting endangered and threatened species or preventing the introduction of invasive species. Managing and protecting native habitats and their inherent biodiversity ensure their resilience, such as from drought or pests, and the continued provision of ecosystem services, such as water filtration, fisheries commodity production, carbon sequestration, etc.

Greenhouse Gas Emissions

Reducing life cycle greenhouse gas emissions involves using best practices to increase yield, reduce soil carbon depletion, maintain or enhance soil organic matter, reduce nitrogen inputs (with precision applications and nutrient testing), integrate livestock and crop systems, utilize perennial crops, and avoid the conversion of natural forests, wetlands, and native grasslands. Improvement in biorefinery performance will improve energy efficiency and reduce GHG emissions. Using renewable or low-carbon fuels to power the biorefinery will reduce GHG emissions. Meeting or exceeding 50 % GHG emissions will enable aviation biofuels to qualify for RINs and provide a direct economic benefit.

MASBI RECOMMENDATIONS

Sustainability and the Road Ahead

14. Incorporate sustainability standards and advance certification. Ensuring sustainable production of biofuels is critical to the integrity of this industry and incorporating sustainability criteria and standards is the responsibility of all its participants, from feedstock providers and fuel producers, to airlines and government. These criteria should be consistent with, and complementary to emerging internationally-recognized standards, such as those being developed by the Roundtable on Sustainable Biomaterials. Third-party certification also could help ensure that greenhouse gases, land use, water use, and other sustainability criteria are appropriately considered.

MASBI participants are diverse and cover the entire value chain.

Steering Committee

United
Boeing
Chicago Department of Aviation (CDA)
UOP – A Honeywell Company
Clean Energy Trust

Program Manager

Oliver Wyman

Advisory Council

Argonne National Laboratory *Chair

- Algal Biomass Organization
- Carbon War Room
- Clean Air Task Force
- Civic Consulting Alliance
- Commercial Aviation Alternative Fuels Initiative
- Consumer Energy Alliance
- Environmental Law and Policy Center
- Federal Aviation Administration
- Illinois Farm Bureau Federation
- Iowa Farm Bureau Federation
- Midwestern Governors Association
- National Wildlife Federation
- Natural Resources Defense Council
- Ohio Aerospace Institute
- U.S. Department of Agriculture
- U.S. Department of the Navy
- World Wildlife Federation

Stakeholders

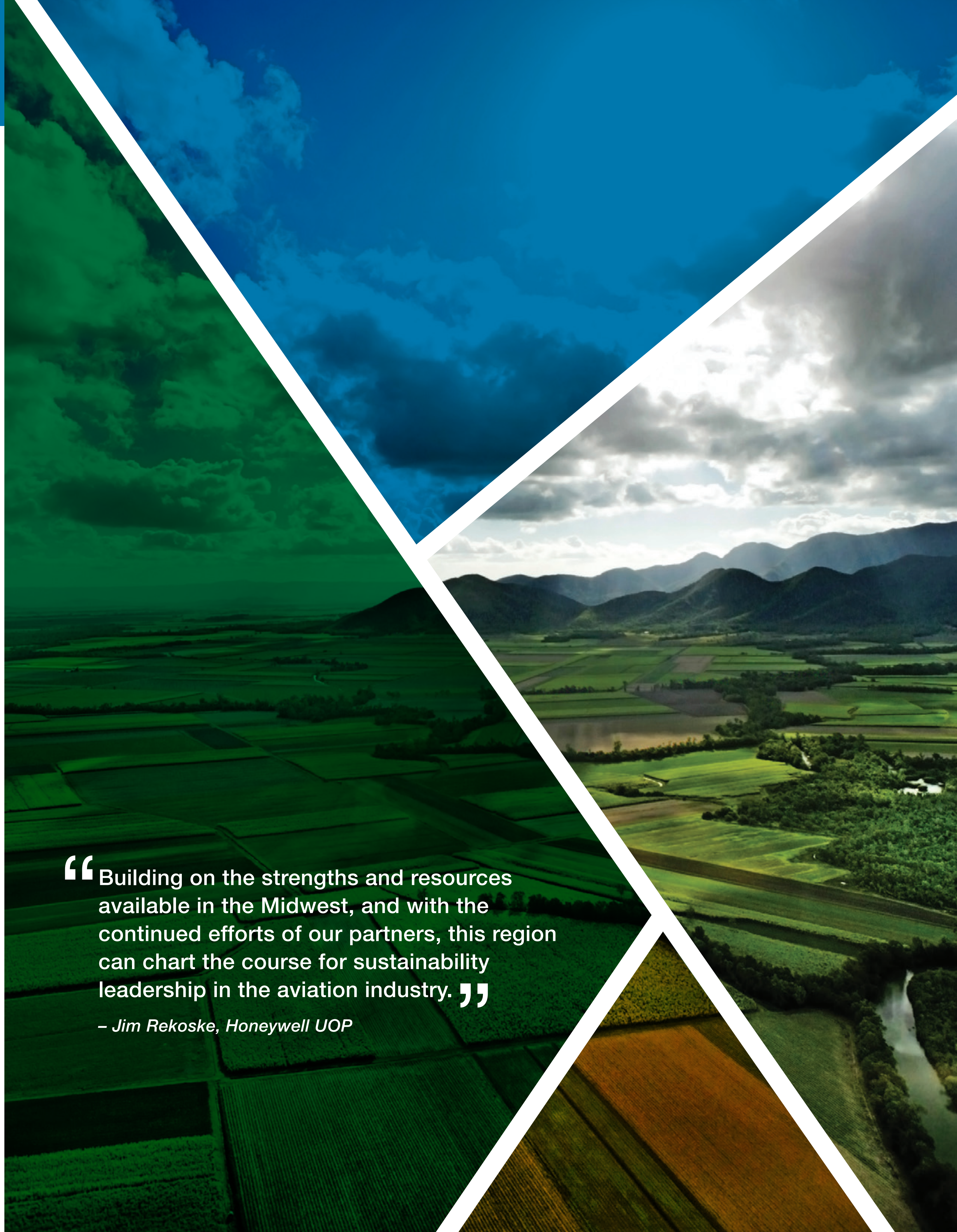
- Air BP
- Airlines for America
- Buckeye Partners
- Cleveland Airport
- Elevance
- Fredrickson & Byron P.A.
- Gas Technology Institute
- GE Aviation
- Gevo
- Global Clean Energy Holdings
- Iowa State University
- Kansas Alliance for Bioenergy
- Kansas State University
- LanzaTech
- Magellan Pipeline
- Metron Aviation
- Monsanto
- Northwestern University
- Paradigm BioAviation LLC
- Purdue University
- Renewable Energy Group
- SkyNRG
- Solazyme
- Sun Grant Initiative/SDSU
- University of Illinois
- University of Nebraska-Lincoln
- Virent
- Western Illinois University

Observers

- Illinois Department of Commerce
- Illinois Governor's Office
- Stern Brothers

* Advisory Council members advised and informed the Steering Committee and Stakeholders on, among other things, existing policy, funding options, and environmental topics related to MASBI. Their involvement does not represent their explicit support of the recommendations, nor their advocacy of specific policy recommendations. All participants are dedicated to and fully supportive of the development of a sustainable commercial aviation biofuels industry in the Midwest.

* Stakeholders participated in the workshops and contributed their high-level knowledge, including their particular expertise, in at least one MASBI Work Group, and contributed to the development of findings and recommendations included in the MASBI final report.



"Building on the strengths and resources available in the Midwest, and with the continued efforts of our partners, this region can chart the course for sustainability leadership in the aviation industry."

– Jim Rekoske, Honeywell UOP

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Midwest Aviation
Sustainable Biofuels Initiative

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