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REPORT

CLEANER SKIES ARE FRIENDLIER SKIES:

NRDC's 2016 Aviation Biofuel Scorecard

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Executive Summary

1: THE NEED TO ENSURE SUSTAINABILITY

The aviation industry is the transportation sector with the fastest growth in greenhouse gas (GHG) emissions, and it is under unprecedented regulatory scrutiny in national and international climate policy arenas. Therefore, the industry is making substantial efforts to develop alternative liquid fuels to meet two goals: capping its carbon emissions by 2020, and reducing emissions 50 percent from 2005 levels by 2050. NRDC's *Aviation Biofuel Scorecard* aims to encourage airline leadership to adopt truly sustainable biofuels through third-party certification standards. Now in its third year, the *Scorecard* has emerged as the premier global measure of airlines' progress toward this goal.

Unlike other transportation modes (e.g., light-duty vehicles), the aviation industry requires dense liquid fuels and faces some of the most stringent fuel replacement demands. New fuels must demonstrate reduced emissions across their entire life cycles, from production through use. The aviation industry is seeking fuels with quality, performance, and energy density matching petroleum equivalents that can be seamlessly integrated or "dropped into" current delivery systems and engines. For these replacement fuels to be broadly accepted by the environmental community and public, they must go beyond GHG reductions to include other sustainability standards. Fuel production must limit adverse impacts on food security, land, water, air, wildlife, and local communities while providing socioeconomic benefits for the latter.

Sustainability concerns, including threats to food security and biodiversity, have surrounded first-generation biofuels such as corn ethanol and palm oil–based biodiesel. In response, the Sustainable Aviation Fuel Users Group (SAFUG), with its 28 member airlines representing approximately 33 percent of commercial aviation fuel demand, has adopted a set of environmental, economic, and social sustainability criteria. In fact, SAFUG pledges to use sustainability criteria "consistent with and complementary to emerging internationally recognized standards such as those being developed by the Roundtable on Sustainable Biomaterials (RSB)."[1] RSB is widely regarded as the gold standard among an emerging set of certification systems. Third-party sustainability certification standards, such as those of RSB, provide assurance of sustainable performance.

Ultimately all biofuels should meet high sustainability standards, and the aviation industry can and should send market signals that shape the biofuels sector as a whole by committing to 100 percent sustainability-certified biofuels.

2: SURVEY RESULTS

For the 2016 *Scorecard*, we surveyed 29 airlines that have indicated a commitment to adopting aviation biofuels. We received responses from 19—an improvement of 2 over the number of 2015 responses. Because mergers among 2015 respondents reduced the overall number of airlines, the percentage response rate increased to 65.5 percent from last year's 53.1 percent.

In 2015 we ranked airlines individually, but airline respondents and industry players expressed concerns that individual rankings might create a false specificity since the gaps between scores were often narrow. So this year we grouped airlines into four categories: (1) Leading, (2) Advancing, (3) Basic, and (4) Nonresponsive. The categories were decided on the basis of commitments to sustainable fuel supply chain development, sustainable fuel use, and monitoring and disclosure. Airlines are listed below by category and, within each category, in alphabetical order.

Leading Airlines

These airlines are characterized by broad involvement in creating sustainable fuel supply chains, as well as solid commitments to use and purchase sustainable fuels and monitor and disclose performance. We found six Leading Airlines:

- Air France/Royal Dutch Airlines (KLM)
- British Airways
- Cathay Pacific Airways
- Scandinavian Airlines (SAS)
- South African Airways
- United Airlines

Advancing Airlines

Most Advancing Airlines are actively engaged in advancing supply chain development, but most have not yet established firm use or purchase commitments or made the same level of monitoring and disclosure commitments as seen in the Leading group. We found nine Advancing Airlines:

- Air New Zealand
- Alaska Airlines
- Etihad Airways
- GOL Airlines
- Japan Airlines
- Qantas Airways
- Thomson Airways
- Virgin Atlantic
- Virgin Australia Airlines

Basic Airlines

Airlines in this category are engaged in sustainable fuels development in some form, but at the time of the survey had not made the same level of commitments as those in the two above categories. We found four Basic Airlines:

- Aeromexico
- Finnair
- JetBlue Airways
- Singapore Airlines

Nonresponsive Airlines

Nine airlines did not respond to the survey, drawing a score of zero for this year's *Scorecard*. American Airlines and U.S. Airways were sent separate surveys but subsequently merged, so they were treated as a single non-respondent.

- Air China
- American Airlines (now includes U.S. Airways)
- All Nippon Airways
- Avianca Taca
- Cargolux
- FedEx Express Cargo Airline
- Gulf Air
- Lufthansa
- Southwest Airlines

This year, for the first time, we asked airlines about their public policy engagements. All respondents except one reported advocating for policies and supports for alternative fuels in their communications with government representatives. While we did not score this question, we used the information to evaluate the airlines that most explicitly incorporated the full range of sustainability criteria. Last year, we investigated efforts to address indirect land use change (ILUC) concerns. This year, we did so again, analyzing those responses and assigned a score to those with the best assurances of avoiding ILUC risk.

We also asked, for the first time, whether airlines have committed to not using fuels made from fossil natural gas or coal (where they can avoid them), which can generate more GHG emissions than petroleum fuels. We received positive responses from Air France/KLM, SAS, Qantas, Air New Zealand, and Singapore Airlines. NRDC applauds this crucial commitment and urges its adoption across the airline industry since the use of fossil fuels in liquid fuel replacements is inconsistent with the industry's GHG reduction goals.

In another departure from last year, we asked airlines for confidential responses regarding capacity to scale up biofuel production to meet the 2020 carbon-neutral goal. These responses were not a part of the scoring criteria. We found airlines are more optimistic about the future of biofuels production in their own home regions than across the globe. But we also found most airlines believe they need to offset their carbon outputs to meet the goal, and they are exploring prospects.

3: GLOBAL AVIATION BIOFUEL DEVELOPMENTS

This year's *Scorecard* surveyed the global landscape for aviation biofuel development, including regulatory processes and industry engagement in supply chain development.

A: REGULATORY PROCESSES

Aviation GHGs are facing unprecedented regulatory scrutiny.

The International Civil Aviation Organization (ICAO) is developing a global market-based measure (GMBM) aimed at capping GHGs from international flights by 2020. The policy design for this measure, which will be considered for adoption at the fall 2016 ICAO General Assembly, has ramifications for biofuels development. The design could include a carbon offset system under which airlines could gain credit for using aviation biofuels. The measure may also include an option to count all biofuels as GHG-neutral, rather than assessing actual life-cycle performance. This addition would introduce significant uncertainty about the measure's benefits, open it up to criticism, and discredit aviation biofuel development and infrastructure investment. The GHG performance of aviation biofuels varies considerably, depending on feedstock and production process.[2]

ICAO and the U.S. Environmental Protection Agency (EPA) are working on GHG emissions standards for aircraft engines. These standards will not directly impact biofuel use.

The Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) met in Paris for a major conference on climate change in December 2015. While the conference produced the Paris Agreement, the final document omitted the aviation and marine sectors. Global nongovernmental organizations (NGOs) focused on the process, such as World Wildlife Fund International, were hoping for a strong signal from the UNFCCC for an aviation target consistent with limiting global warming to 1.5 to 2 degrees Celsius, widely considered the absolute limit beyond which climate change impacts would overwhelm the adaptive capacities of society and nature. While no such direct signal was sent, the Paris Agreement set a global target of "well below" 2 degrees Celsius with an aim for 1.5 degrees Celsius. Either of those goals would require emissions reductions substantially greater than those targeted by the aviation industry, studies indicate. As climate change impacts intensify, the aviation industry is likely to face increasing policy demands for such reductions. Therefore, it is advisable to consider the implications now.

B: SUPPLY CHAIN DEVELOPMENT

The aviation industry is rethinking multiple stages of its supply chain. We interviewed industry experts not directly employed by airlines who indicated that this trend is motivated by regulatory pressures and fuel price volatility. In anticipation of fuel cost increases over the next several years, the industry is investing in its production chain to ensure security of supply. Airlines have been supporting new producers through fuel purchase agreements that guarantee an airline market for their product. Direct airline investments in fuel production facilities and development of alternative fuel feedstock sources listed later in this report represent two other major emerging trends.

Major recent supply chain developments supported by the industry include the following:

- Leading airlines in the United Kingdom, Japan, and Abu Dhabi have participated in multi-stakeholder processes to plan development of sustainable aviation fuel supply chains.
- In 2015, United Airlines announced a $30 million investment in Fulcrum BioEnergy, representing the largest airline equity stake in a biofuel producer to date, followed by Cathay Pacific's 2014 investment of more than $10 million in the same company.
- There have been novel nonfood feedstock development efforts, including energy tobacco by South African Airways and salt-tolerant halophyte plants by Etihad Airways.
- Beginning in Scandinavia, "bioport" delivery hubs have been developed; development is underway in the Netherlands and Australia.
- Supply chains based on regional feedstocks are being explored in Brazil.

ASTM approval of new fuel pathways is required for commercial airline use, and five such pathways have been approved. An alcohol-to-jet-fuel pathway was finalized in April 2016, and another process is underway to approve renewable diesel as an aviation fuel. Approval of renewable diesel could open the way to a large, competitively priced aviation biofuel supply. It is crucial that the oil feedstocks used are sustainable. Palm oil development, for example, is of special concern since it is closely associated with land clearance in tropical forests, resulting in high GHG emissions and threats to biodiversity. For this reason, NRDC does not support the use of palm oil for fuels.

Biomass feedstocks derived from forest materials are emerging as a target source for aviation biofuel supply chains in Scandinavia, New Zealand, British Columbia, and the western United States. Burning these types of feedstocks as a fuel can threaten forest ecosystems and produce higher GHG emissions than fossil fuels. Those increases can persist for 35 to 100 years or more, depending on regional variations in climate and forest type. Forest-derived biomass fuel must be limited and subject to full GHG accounting and rigorous sustainability analysis. Mill waste, such as sawdust, can produce fewer GHG emissions with limited impacts on forest sustainability. Likewise, short-rotation woody crops, such as poplar, are a viable option, but only if they do not cause natural forest replacement or displace food production. They also must be certified through credible sustainable forest management standards, such as those of the Forest Stewardship Council (FSC).

Later in this report, we further outline concerns about forest-derived biomass, particularly as it relates to whole trees and other large-diameter residues. We also evaluate the potential for scaling up aviation biofuels, much of which depends on sustainability validation of feedstocks and proven operation of new technologies.

4: RECOMMENDATIONS

Our *Scorecard* concludes with the following recommendations to ensure that the aviation biofuel sector will grow in the most sustainable way possible and that GHG emissions will decline as it expands:

1. Airlines should make public commitments to source only aviation biofuels that have been RSB-certified, and communicate this to fuel and feedstock producers.
2. Airlines that have not yet made a public commitment to using sustainable aviation biofuel—one that specifies volume, percentage, and timeline—should do so. Where possible, they should commit in all three areas.
3. Airlines that do not yet have a firm contract for delivery of RSB-certified biofuels should explore and secure a delivery contract at the earliest opportunity.
4. Airlines should strive for total transparency in aviation biofuel volumes, GHG emissions, and sustainability certification.

5. To meet the industry's GHG emissions reduction goals, SAFUG and the International Air Transport Association should firmly commit to using the RSB certification framework.
6. All airlines should establish a clear policy that prohibits the purchase of fuels from coal and fossil natural gas.
7. Airlines should limit their use of forest-derived biomass feedstocks to those that will demonstrably reduce carbon emissions in the near term (compared with fossil fuels) and will not threaten natural forest ecosystems. Examples include sawmill residues including sawdust and waste wood chips that would otherwise quickly decompose.
8. Any biofuel credits under the ICAO's GMBM should be based on validated life-cycle carbon performance. Credits should also account for ILUC and include sustainability requirements consistent with the RSB standard.

Airlines deserve credit for their substantial efforts to develop sustainable fuels. By fortifying their commitments to sustainability, airlines can advance even further and contribute to the growth of sustainable fuel supplies throughout the transportation sector.

Introduction: The Critical Role of Sustainability Certification in Aviation Biofuel Development

NRDC's *Aviation Biofuel Scorecard* aims to encourage airline leadership to adopt truly sustainable biofuels through third-party certification standards. Now in its third year, the *Scorecard* has emerged as the premier global measure of airlines' progress toward this goal.

The aviation industry now accounts for 2 percent of human-produced carbon dioxide. By 2050, this share is projected to grow to 3 percent—the fastest increase of any transportation sector.[3] Amid growing concern about climate disruption, the industry is taking steps to avoid that percentage increase. Airlines are motivated by the opportunity to distinguish themselves as leaders on sustainability and generate public goodwill, and by expected regulation of aviation GHG emissions. The aviation industry has committed to carbon-neutral growth starting in 2020, and to reducing emissions by 50 percent from 2005 levels by 2050.[4] To this end, airlines will combine more efficient aircraft, improved airspace management, and low-carbon fuels from non-petroleum sources. It is generally agreed that all three approaches will be required to meet the industry's goals. A fourth approach, a carbon market mechanism, is also broadly viewed as necessary to reach the 2020 goal.

While other transportation sectors can employ electrification, aviation requires the density of liquid fuels. Therefore, the aviation industry is actively creating alternative fuel supply chains, and this report highlights key developments in that arena. The industry is seeking to minimize the costs associated with infrastructure, fuel delivery systems, airframes, and jet engines. To achieve this, it is seeking replacement fuels equivalent to petroleum-based fuel in terms of quality, performance, and energy density. These fuels are termed "drop-in" fuels because they can enter existing systems seamlessly. Due to sustainability concerns associated with first-generation biofuel feedstocks such as corn starch and palm oil, the industry is aiming at sustainably produced nonfood feedstocks.

The aviation industry is leading the development of advanced biofuels, and its efforts have ramifications that are potentially important throughout the transportation sector. With 11 percent of global transportation fuel use and a 6 percent share of global oil consumption, aviation has market leverage that can drive development and adoption of comprehensivly sustainable biofuels throughout the transportation sector.[5] Full life-cycle analysis to determine net GHG emissions is one critical sustainability measure. However, for truly sustainable performance, fuels must meet other requirements to limit adverse impacts on food security, land, water, air, wildlife, and local communities while providing socioeconomic benefits for the latter.

The Sustainable Aviation Fuel Users Group (SAFUG), representing 28 airlines with 33 percent of world commercial aviation fuel demand, has adopted strong sustainability principles, listed in a subsequent section.[6]

Recognized certification standards based on third-party audits ensure that sustainability criteria will be met. A number of third-party fuel certification standards are now in place, including Bonsucro for sugarcane, Roundtable on Responsible Soy (RTRS), International Sustainability and Carbon Certification (ISCC), and Roundtable on Sustainable Palm Oil (RSPO). The Roundtable on Sustainable Biomaterials (RSB) certification is widely regarded as the gold standard. In fact, SAFUG has adopted RSB as its preferred standard. NRDC encourages airlines to leverage their market power by purchasing only biofuel certified by a recognized third-party standard, with strong preference for RSB, as reflected in the weighted scoring of our survey. (RSB's sustainability framework is shown in the accompanying text box.)

Airlines' market signals can play a critical role in driving adoption of sustainable practices throughout the supply chain. Biofuel operators are making long-term design, employment, and operational decisions to optimize production for their marketplace, and many are now focusing on aviation as a key market. Sending clear signals that production must comply with sustainability standards that are independently audited through credible certification programs will incentivize producers to proactively include this in their planning and operations.

If aviation is held to a higher sustainability standard, there is concern that fuel feedstock growers and producers will focus on the less demanding and rigorous ground transportation sector. However, we argue that all biofuels should be held to high sustainability standards. For example, NRDC is advocating for a broader range of sustainability requirements in California's Low Carbon Fuel Standard. By driving high sustainability standards in their own industry, airlines are setting a standard for the biofuel sector as a whole. The *Scorecard* outlines the industry's commitment to high sustainability standards and encourages other transportation sectors to follow suit.

ROUNDTABLE ON SUSTAINABLE BIOMATERIALS (RSB) FRAMEWORK

The RSB's comprehensive sustainability framework consists of 12 principles:[7]

1. Biofuel operations shall follow all applicable laws and regulations.
2. Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent, and consultative impact statement and management process and an economic viability analysis.
3. Biofuels shall contribute to climate change mitigation by significantly reducing life-cycle greenhouse gas emissions as compared with fossil fuels.
4. Biofuel operations shall not violate human rights or labor rights and shall promote decent work and the well-being of workers.
5. In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural, and indigenous people and communities.
6. Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions.
7. Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and other conservation values.
8. Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health.
9. Biofuel operations shall maintain or enhance the quality and quantity of surface and groundwater resources and respect prior formal or customary water rights.
10. Air pollution from biofuel operations shall be minimized along the supply chain.
11. The use of technologies in biofuel operations shall seek to maximize production efficiency and social and environmental performance, and minimize the risk of damages to the environment and people.
12. Biofuel operations shall respect land rights and land-use rights.

Section I: 2016 *Aviation Biofuel Scorecard* Survey Results

I: AIRLINES RANKED IN FOUR GROUPS

For this year's *Scorecard*, we surveyed 29 airlines that have indicated a commitment to adopting aviation biofuels. We received responses from 19—an improvement of 2 over the number of responses in 2015. Since mergers among 2015 respondents reduced the overall number of airlines, the percentage response rate increased to 65.5 percent from last year's 53.1 percent.

In 2015, we ranked airlines individually, but in many cases the scoring differences between airlines were narrow. Since there are many ways to earn points, individual rankings can create an impression that the efforts of one airline are superior to those of another, when in reality they are focusing on different areas. So this year we opted to group airlines into four categories: (1) Leading, (2) Advancing, (3) Basic, and (4) Nonresponsive, based on a scoring system described below. The highest-scoring airline earned 31 points out of a possible 38, or 81.57 percent of the potential total. Next year's report will include a Gold category for airlines that achieve more than 90 percent of the potential total points.

We found natural break points among the groups based on the depth of their commitments to develop and purchase certifiably sustainable fuels and to monitor and disclose usage and sustainability performance. (Our scoring methodology is detailed in Appendix B.)

- **Six Leading Airlines:** These are characterized by broad involvement in creating sustainable fuel supply chains; strong contracts to use and purchase sustainable fuels; targets for volume, percentage of use, and/or dates for use; and systems to monitor and disclose performance. (20 to 38 points)
- **Nine Advancing Airlines:** Most are actively engaged in furthering supply chain development, but most have not established a strong contract or targets for volume, percentage of use, and/or dates for use, nor have they matched the depth of monitoring and disclosure commitments of the Leading Airlines. American Airlines and U.S. Airways were sent separate surveys but subsequently merged, so they were treated as a single non-respondent. (10 to 19 points)
- **Four Basic Airlines:** These are engaged in sustainable fuels development in some form. At the time of the survey, however, they had not made the same level of commitments as Leading or Advancing Airlines. (1 to 10 points)
- **Nine Nonresponsive Airlines:** These airlines did not respond to the survey and thus scored zero points on this year's *Scorecard*.

Airlines are listed alphabetically within each category, rather than by scoring rank.

A: LEADING AIRLINES

- Air France/Royal Dutch Airlines (KLM)
- British Airways
- Cathay Pacific Airways
- Scandinavian Airlines (SAS)
- South African Airways
- United Airlines

Key supply chain development trends clustered among the Leading Airlines:

- All six Leading Airlines have contracts for delivering RSB-certified aviation biofuels. Five had also affirmed in our 2015 *Scorecard* that they had a contract for the future delivery of sustainable biofuel.
- All Leading Airlines, except one, have made direct supply chain investments to produce certifiably sustainable fuels. Three have publicly announced research and development investments. These findings are the results of new questions in this year's survey and reflect increasing airline investments over the past two years.
- All Leading Airlines have set firm targets for volume, percentage of use, and/or dates for use of aviation biofuel, as discovered by another new question this year. (See Table III for commitments.)
- Four Leading Airlines are engaged in the ASTM processes necessary to approve fuel production chains for commercial flights. This was another new question in 2016.

TABLE I: LEADING AIRLINES' ENGAGEMENT IN SUPPLY CHAIN DEVELOPMENT

	RSB-Certified Contract Placed	Firm targets	Supply chain/ Research & Development investment	ASTM process
Air France/KLM	yes	yes	yes	yes
Scandinavian Airlines (SAS)	yes	yes		
British Airways	yes	yes	yes[8]	yes
South African Airways	yes	yes	yes	
United Airlines	yes	yes	yes	yes
Cathay Pacific Airways	yes	yes	yes	yes

TABLE II: ADVANCING AIRLINES ENGAGEMENT IN SUPPLY CHAIN DEVELOPMENT

	RSB-certified contract placed	Firm targets	Supply chain/ R&D investment	ASTM process
Air New Zealand			yes	
Alaska Airlines		yes	yes	yes
Etihad Airways			yes	
Qantas Airways			yes	
Thomson Airways		yes		
Virgin Atlantic Airways	yes			yes
Virgin Australia Airlines		yes	yes	

B: ADVANCING AIRLINES

- Air New Zealand
- Alaska Airlines
- Etihad Airways
- GOL Airlines
- Japan Air Lines
- Qantas Airways
- Thomson Airways
- Virgin Atlantic Airways
- Virgin Australia Airlines

Most Advancing Airlines are engaged in some aspects of supply chain development, including the following examples:

- This group includes one airline with a contract for RSB-certified fuels. (All others with contracts are Leading Airlines.)
- Three Advancing Airlines have set firm timeline, volume, and/or percentage targets for sustainable biofuel use.
- Four Advancing Airlines have invested in research and development, actually exceeding the Leading Airlines by one. One has also directly invested in a feasibility study for an airport biofuel delivery system.
- Two Advancing Airlines have participated in ASTM approval processes.

TABLE III: AIRLINES WITH FIRM COMMITMENTS TO AVIATION BIOFUEL USE

Airline	Date	Percentage	Volume
Air France/Royal Dutch Airlines (KLM)	2017	1% if economic viability is achieved	2,000 tonnes in 2015; 3,000 tonnes in 2016; 30,000 tonnes in 2017; 100,000–300,000 tonnes in 2020
Alaska Airlines	2020	Not established	Not established
British Airways	2017	~2% of Heathrow demand	50,000 tonnes
Cathay Pacific Airways	2020	3–5%	Dependent on total fleet use at that time
Scandinavian Airlines (SAS)	2020	>1%	Not given
South African Airways	2023	5% Johannesburg uplift	50 million liters
Thomson Airways	2020	1%	Not given
United Airlines	2015		5 million gallons/ year
Virgin Australia Airlines	2020	5%	5% of fuel used by 2020

Some further explanation is required:

- Alaska Airlines is the only Advancing Airline active in three supply chain development areas. Alaska Airlines is a proven, consistent innovator in aviation biofuel, but, rather than a firm contract, it has only a memorandum of understanding with a fuel producer with “certification significantly consistent with RSB criteria.” An RSB-certified contract would appreciably improve Alaska Airlines’ score.
- GOL Airlines did not respond affirmatively to any of the questions reflected in Table II and is, therefore, not included in the table. But GOL Airlines is active in multiple feedstock development partnerships and is one of only two airlines to report aviation biofuel use in scheduled flights over the past year.
- Japan Airlines is also not included because it is not engaged in the four categories shown in the table. However, the airline did report a solid set of sustainability commitments, including recent road-mapping engagements and chairing a focus group on producing fuels from municipal solid waste. (See Section 3: Multi-Stakeholder Processes Road Map Supply Chains.)
- At $2 million, Etihad Airways has by far made the largest disclosed research and development investment, through a novel desert agriculture system discussed in the “See Section 4: Multiple Approaches Taken To Develop Supply Chains” section.

C: BASIC AIRLINES

- Aeromexico
- Finnair
- JetBlue Airways
- Singapore Airlines

Common themes among the four Basic Airlines:

- Three of the four—Aeromexico, JetBlue, and Singapore—scored in the Basic category by virtue of their SAFUG membership, which extends a commitment to the RSB standard. Thus, these airlines have established a basic commitment to ensure aviation biofuel sustainability, putting them ahead of much of the global airline industry.
- In addition to its SAFUG membership, JetBlue became the first U.S. airline to directly join RSB, on February 25, 2016.[9] (This year's scoring criteria do not give additional credit for direct membership, but we will add this next year.) In 2017, JetBlue plans to publicly commit to adding sustainable fuels to its fuel mix, bringing it in line with all other survey respondents, all of which have publicly committed to sustainable fuels. NRDC views these developments as indications that JetBlue is building toward a more active role in advancing aviation biofuel.
- Finnair is the only respondent that is not a member of SAFUG and the only respondent that did not report use of a recognized third-party biofuel sustainability certification system. We urge Finnair to correct these shortcomings. Finnair is, however, the only Basic Airline to invest in supply chain/research and development.
- After the survey was completed, on February 24, 2016, Aeromexico and Mexican government agencies announced a research and development partnership to investigate supply chains based on Mexican feedstocks.

D: NONRESPONSIVE AIRLINES

- Air China
- American Airlines (now includes U.S. Airways)
- All Nippon Airways
- Avianca Taca
- Cargolux
- FedEx Express Cargo Airline
- Gulf Air
- Lufthansa
- Southwest

Some Nonresponsive Airlines have publicly announced alternative fuels development, but without transparency we cannot rate their sustainability performance. In the process of developing aviation biofuels, transparency will be crucial for maintaining public goodwill and the "social license to grow" cited by many aviation industry leaders. We urge the Nonresponsive Airlines to embrace transparency by participating in next year's survey.

2: MOST RESPONDENTS COMMITTED TO HIGH SUSTAINABILITY CERTIFICATION STANDARDS

Participating airlines reported a broad commitment to sustainability certification standards. At the time of the survey, all but one of the 19 respondents (JetBlue) affirmed that they had publicly committed to using certifiably sustainable biofuels. All except one (Finnair) have committed to the high sustainability certification standards set by SAFUG or RSB. (SAFUG standards are not strictly the same as RSB; SAFUG has pledged to use "criteria . . . consistent with and complementary to emerging internationally recognized standards such as those being developed by the Roundtable on Sustainable Biomaterials."[10]) All airlines except Finnair indicated membership in SAFUG, and in RSB indirectly (for the most part) via SAFUG membership. JetBlue, a SAFUG member at the time of the survey, has since also become a direct RSB member and has promised a 2017 biofuel plan. South African Airways is also a direct RSB member as well as a SAFUG member. These results are substantially consistent with the 2015 *Scorecard*, where 16 of 17 respondents reported SAFUG and RSB membership. Air France/KLM was the only airline to report participation in additional standards and processes; it is also a member of Bonsucro.

SAFUG airlines commit to the following sustainability criteria for aviation biofuel:

- Jet fuel feedstock source development should not jeopardize food or water supplies or biodiversity.
- Total GHG emissions from feedstock growth, harvesting, processing, and end use should be significantly reduced compared with those associated with fossil fuels.
- In developing economies, projects should improve socioeconomic conditions for small-scale sustenance farmers and avoid involuntary displacement of local populations.
- High-conservation-value areas and native ecosystems should not be cleared to make way for jet fuel feedstock source development.[11]

As detailed in the next section, SAFUG has also developed principles to avoid ILUC as a result of biofuel feedstock production.

3: FIVE AIRLINES STAND OUT IN THEIR COMMITMENTS TO ELIMINATING LIQUID FUELS DERIVED FROM COAL OR FOSSIL NATURAL GAS

The aviation industry is seeking new fuels not only to reduce GHG emissions but to hedge against oil price volatility and supply shocks. Therefore, unfortunately, some alternative aviation fuel initiatives have included fossil fuels such as coal and natural gas. Coal-based jet fuel is an approved ASTM pathway and has been delivered at South Africa's Johannesburg Airport. Jet fuels derived from unconventional sources, including tar sands and oil shale, are already widespread throughout conventional fuel supply chains.

Aviation biofuels that meet sustainability requirements are environmentally preferable to coal and gas alternatives. Coal-derived fuels produce far higher GHG emissions than petroleum. Natural gas–based liquid fuels may provide a small GHG emissions decrease at best, but pose high risk of increasing emissions.[12] Fossil fuel production is also associated with other significant negative environmental impacts, including land disturbance, water pollution, and health consequences for workers and surrounding communities.

This year was the first time the *Scorecard* investigated whether airlines have publicly committed to eliminating fuels made from coal or natural gas when other options are available. Air France/KLM, SAS, Qantas Airways, Air New Zealand, and Singapore Airlines answered affirmatively. NRDC applauds this crucial commitment and urges the industry to adopt it generally. Fossil-derived jet fuels are not consistent with the industry's GHG emissions reduction goals.

4: ENSURING TRANSPARENCY THROUGH MONITORING AND DISCLOSURE

In order to achieve transparency, biofuel use, certification, and GHG emissions need to be monitored, and the information gathered needs to be made public. To evaluate performance in these areas, we asked the following questions:

- Does your airline publicly disclose the total volume of biofuels it uses in a year (whether or not it has used biofuels in the past year)?
- Does your airline publicly disclose whether the biofuels it sources are sustainable-certified, and the system(s) by which they are certified?
- Does your airline monitor the full life-cycle greenhouse gas emissions of biofuels it uses employing third-party life-cycle analysis (LCA)?
- Are these figures disclosed publicly now?
- If you aren't currently disclosing these figures now, do you intend to publicly disclose these numbers by 2020?

The responses illuminated some distinguishing points among the categories:

- While most airlines disclose biofuel volumes, certification disclosure is universal only among the Leading Airlines. Six of nine Advancing Airlines and one Basic Airline provide that information.
- Similarly, monitoring of GHG emissions is heavily concentrated among the Leading Airlines. Only two other airlines—both Advancing—do such monitoring.
- Two of the three airlines disclosing their GHG emissions performance, SAS and United Airlines, are Leading Airlines. The other, Advancing Airline Qantas, has the most extensive monitoring and disclosure commitments

TABLE IV: MONITORING AND DISCLOSURE COMMITMENTS

	Volume	Certification	GHG monitor	Disclose now	Disclose 2020
British Airways	yes	yes	yes	yes	yes
Qantas Airlines	yes	yes	yes	yes	yes
Cathay Pacific Airways	yes	yes	yes		yes
SAS	yes	yes	yes		yes
South African Airways		yes	yes		yes
United Airlines		yes	yes	yes	yes
Japan Airlines	yes	yes			yes
Air New Zealand	yes	yes			yes
Virgin Atlantic Airways		yes	yes		yes
Virgin Australia Airlines	yes	yes			yes
Finnair	yes	yes			yes
Air France/ KLM	yes	yes			
Alaska Airlines	yes				yes
GOL Airways	yes				yes
Aeromexico	yes				yes
JetBlue	yes				yes
Etihad Airways					yes
Thomson Airways		yes			

Table shows commitments ranked by level. Overall ranking is reflected by the colors—green for Leading, purple for Advancing, blue for Basic. The table reveals that Leading Airlines tend to have the deepest monitoring and disclosure commitments, but not always. Some Advancing and even Basic Airlines are competitive in this area. One of the airlines, Singapore, reported no commitments in this area and is therefore not shown on this chart. (It is assumed that airlines currently disclosing GHG performance will continue to do so through 2020.)

beyond the Leading Airlines. In fact, Qantas's commitments surpass all Leading Airlines except British Airways.

- All airlines except three are committed to disclosing GHG emissions performance immediately or by 2020.
- These results are influenced by the level of biofuel adoption to date. Virgin Australia Airlines noted, "[W]e have not used aviation biofuel yet so it would be a misrepresentation to suggest independent assessment had occurred. However, Virgin Australia reports its emissions from our operations to the Australian government annually and through the GRI [Global Reporting Initiative] reporting process and the fuel and emissions data are certified by independent third parties. Were we using biofuels, then we would continue this third-party assessment and a full independent LCA [Life-Cycle Analysis] would be a relevant consideration prior to any biofuel offtake agreement."

5: PEOPLE POWER: STAFF DEVOTED TO BIOFUELS ADOPTION

This year, for the first time, we credited airlines for the number of staff devoted to biofuel adoption. Some highlights:

- All respondents except one have assigned staff to biofuel adoption.
- The total number of full-time equivalent (FTE) staff working on aviation biofuel adoption at respondent airlines is 24.83 to 26.83. (The number ranges because United Airlines fluctuates between 4 and 6 FTE staff, depending on project demands.)
- Biofuel-devoted staff members are concentrated among the Leading Airlines, with 14 to 16 FTE staff.
- Advancing Airlines had a total of 9 FTE staff, and Basic Airlines had 1.83.
- Ten airlines have at least 1 full-time staff person focused on biofuel adoption: Air France/KLM, British Airways, Cathay Pacific, South African Airways, Virgin Australia Airlines, Virgin Atlantic Airways, Qantas Airways, Japan Airlines, United Airlines, and GOL Airways.
- With 6 FTE positions, Air France/KLM has the most employees consistently working on biofuel adoption.

6: THREE AIRLINES REPORT BIOFUEL USE ON COMMERCIAL FLIGHTS

Three airlines reported purchasing more than 1 metric ton of aviation biofuels. All were used on scheduled commercial flights in 2014. (Our survey was conducted in summer 2015.)[13]

Air France/KLM: The airline sourced 196 tons of hydrogenated esters and fatty acids (HEFA) made from used cooking oil (UCO) for 20 flights totaling 90,820 nautical miles from Amsterdam to Aruba and Bonaire. The fuel was RSB-certified. In addition, KLM sourced 60 tons of sugarcane-based Amyris synthesized iso-paraffins (SIP) fuel in late 2014 that was not used, except on one flight. The Amyris production process is certified by RSB. The sugarcane feedstock is now undergoing certification procedures and assessments of sustainability risks through third-party evaluation by Bonsucro and RSB. Air France sourced four tons of this fuel to operate 11 flights between Toulouse and Paris totaling 3,420 nautical miles.

GOL Airways: During the 2014 World Cup, 69 tons of UCO-derived HEFA were used on 365 flights from Rio de Janeiro. Sustainability certification is pending. RSB has certified several UCO-based biofuel producers.[14] GOL also sourced 1 ton of Amyris SIP for the first commercial and international SIP flight, which took place on July 31, 2014, from Orlando to Sao Paulo. Flights totaled 245,638 miles.

SAS Airways: Less than 5 tons of UCO-derived HEFA were used on two November flights in Sweden and Norway. The fuel was RSB-certified.

7: AIRLINES AND INDIRECT LAND USE CHANGE

One of the most challenging biofuel sustainability issues is ILUC resulting from feedstock cultivation. Transforming natural ecosystems, such as grasslands and forests, to croplands releases stored natural carbon.[15] Even though biofuel may produce fewer direct emissions than petroleum, repaying the land disturbance "carbon debt" can take decades.

It is relatively simple to measure GHG emissions from direct land-use changes to create biofuel feedstock cropland. However, demand for biofuel feedstock can also cause *indirect* land use change (ILUC) impacts that are more challenging to calculate. For example, using palm oil–derived fuel can disrupt palm oil for food supply, prompting the development of new palm plantations in tropical forests. Since ILUC became a prominent issue in the mid-2000s, it has been a key biofuel sustainability concern. The U.S. Renewable Fuel Standard requires specific GHG emissions reductions for biofuels compared with petroleum fuels, and ILUC is factored into the equation. California's Low Carbon Fuel Standard also mandates ILUC calculations. These measurements require computer-based scenario modeling, which can produce widely varied results depending on initial assumptions.[16]

SAFUG has adopted a position that "government policies should only incentivize the development and use of fuels that meet strong sustainability criteria, which actively protect against ILUC and other social and environmental risks. . . . (ILUC) must be addressed in government policies promoting the production of sustainable fuels, and decision-makers should consider mechanisms to lower the contribution of high ILUC risk biofuels and create incentives for sustainable fuels that have been certified as [posing a] low risk of ILUC."[17]

SAFUG recommended that policymakers adopt protections such as the Low Indirect Impact Biofuels (LIIB) module developed by World Wildlife Fund International, École

Polytechnique Fédérale de Lausanne, and Ecofys and launched in 2015 by RSB. Since its purpose is to certify individual land holdings, RSB does not currently calculate ILUC impacts into its GHG emissions reduction criteria. LIIB certifies low risk of ILUC for specific feedstocks. Practices that minimize the risk of biofuel production changing land use elsewhere include using wastes and residues as feedstocks, increasing yields, employing degraded and/or unused lands, and growing biofuel feedstocks in conjunction with other products on the same land.

This year, we asked airlines whether they were developing measures to evaluate and avoid ILUC. Nine airlines answered affirmatively, but we could credit only four. British Airways, United Airlines, and Qantas Airways were credited because they are focusing on waste feedstocks from municipalities and agriculture. British Airways reported that it "is committed to the development of Low Indirect Impact Biofuels." Etihad Airways was credited because it is focusing feedstock development efforts on a novel desert agriculture system that does not use traditionally arable lands. More information on these efforts can be found in the Supply Chain Development section of this report. We found the measures reported by the remaining five airlines insufficient to avoid ILUC risk.

Cathay Pacific Airways reported that it places "primary focus on waste and residues for feedstock" but is also considering energy crops that must be certified by the RSB or another recognized system. While Cathay Pacific's response did not fully address ILUC risk, it did indicate steps in the right direction. RSB certification is not sufficient without LIIB screening. Because Virgin Atlantic Airways, South Africa Airways, and Air France/KLM also responded that they will use the RSB but did not specify that they will also use LIIB, we again could not assign credit. Air France/KLM answered that it is advised on ILUC by SkyNRG's Sustainability Board, which "is assessing strategically all relevant aspects including ILUC." The airline will take LIIB "into account if feasible, to be decided together with the relevant supply chain partners."

Air New Zealand reported that it is "promoting the use of forestry residues and wood processing waste as a sustainable feedstock in New Zealand." Some waste pathways have the potential to avoid ILUC, but forest residue pathways may not meet GHG emissions and sustainability requirements. We discuss this further in the "Forest-Derived Biomass Sustainability Requirements" section later in this report.

Jet Blue and Finnair responded affirmatively, but Jet Blue did not describe its measures and Finnair described them as "a part of the cooperation with organizations [and] fuel suppliers." These responses were not sufficient to gain credit.

8: AIRLINES ADVOCATE FOR PUBLIC POLICY

All but one of the respondents affirmed that their airline is "engaged in public policy advocacy to further development and adoption of sustainable aviation fuels."[18]

While reducing GHG emissions is a key goal of all aviation biofuel advocacy, we found the following reported efforts most explicitly associated with a broad range of sustainability requirements:

- Eighteen of the 19 responding airlines are engaged in efforts with multi-stakeholder groups to road-map aviation biofuel pathways. These processes acknowledge the need to address the full range of sustainability concerns. Notable recent processes include efforts by SAS and Finnair with the Nordic Initiative for Sustainable Aviation; United Airlines with the Midwest Aviation Sustainable Biofuel Initiative; Etihad Airways with BIOjet Abu Dhabi; and British Airways, Thomson Airways, and Virgin Atlantic Airways through Sustainable Aviation (see Road Mapping section).
- Air France/KLM, SAS, Cathay Pacific Airways, Virgin Australia Airlines, United Airlines, and Thomson Airways highlight their SAFUG membership as an element of their public policy engagement.
- GOL Airways cites a set of regional initiatives through the Brazilian Biojetfuel Platform (discussed in the Supply Chain Development section), a partnership of a number of organizations actively developing aviation biofuels. RSB certification is one of three pillars of fuel development for GOL, on par with economic competitiveness and ASTM approval of fuel processes.[19]
- Air France/KLM, British Airways, and Lufthansa are founding members of the European Advanced Biofuels Flight Path, which was launched in 2011 to bring two million tons of aviation biofuel to European commercial aviation by 2020. Its agenda includes "concrete actions to inform the European citizen of the benefits of replacing kerosene by certified sustainable biofuels."[20]
- Air New Zealand reports its "advocacy of a regional biofuel industry at selected symposia and workshops. . . . We always state our support for the strictest sustainability standards such as those represented by the RSB and explain why those are so important to airlines and how biofuel producers should aim to satisfy their or equivalent criteria."[21]

Some airlines reported policy advocacy that includes sustainability criteria beyond GHG emissions:

- In 2015, United Airlines took a leading role in FARM Illinois, a multi-stakeholder collaborative, to help create the state's food and agriculture road map. United participated to promote farm residue feedstocks that do not compete with food. Among other recommendations, the report called for improved soil conservation practices.[22]

- Japan Airlines noted, "As part of an all-Japan team of industry, government, and academia, we are promoting a project to produce aviation biofuel from municipal waste, which we aim to realize by around 2020 (the year of the Tokyo Olympics). The project will also contribute to the creation of a recycling-based society."[23]

Qantas Airways and Virgin Australia Airlines reported a phased approach. In collaboration with Boeing and Airbus since 2014, the two airlines have advocated national and state adoption of a coordinated policy to build an Australian aviation biofuel industry. We queried them on the role of sustainability principles, such as those embodied in SAFUG and RSB, in their processes. Virgin Australia Airlines responded, "A lot of the discussions have been back to basics on the importance of this fuel and dispelling misunderstandings about how it is produced (including sustainability issues)." Qantas Airways said, "The policy conversation in Australia isn't that mature yet, so a lot of what we've done to date is around getting the opportunity back on the agenda with government. As we go forward, SAFUG/RSB will no doubt become a more important part of the conversation."

United Airlines and Alaska Airlines supported Airlines for America's advocacy to have aviation biofuel credited under California's and Oregon's Low Carbon Fuel Standards. These standards focus on GHG emissions, however, and do not reflect a full range of sustainability requirements. NRDC is encouraging states to incorporate such requirements into their standards.

9: AIRLINES ASSESS INDUSTRY SCALE-UP POTENTIAL

For the first time, this year we asked for confidential assessments of whether aviation biofuel production will ramp up in time to meet the industry goal for carbon-neutral growth from 2020. We received 17 responses, and they varied widely. Interestingly, they indicate a higher level of optimism for scale-up in airlines' respective home regions than globally. Below is a list of our questions and the range of responses.

- *Rate the probability that aviation biofuel production will scale to levels that allow the aviation industry to reach its 2020 carbon-neutral-growth goals in conjunction with more efficient fleets and improved airspace management.*
  - Less than 10 percent: 2 airlines
  - 10 to 30 percent: 6 airlines
  - 30 to 60 percent: 2 airlines
  - 60 to 90 percent: 7 airlines
- *Rate the difficulty of scaling sustainable feedstocks and aviation biofuels production to reach 2020 carbon-neutral growth in your home region.*
  - Challenging but likely to happen: 10 airlines
  - Unlikely and so will have to access fuels from beyond region: 7 airlines

We asked airlines to assess the need for carbon offsets to reach the 2020 goal, and whether they themselves are considering offset purchases. The results indicated less optimism that the above assessments. The International Civil Aviation Organization is considering offsets as a way to meet the goal. (This is discussed in the Regulatory Process section.) Sixteen airlines responded to this question.

- *Do you believe airlines can meet 2020 carbon-neutral-growth goals without purchasing carbon offsets?*
  - Yes: 4 airlines
  - No: 12 airlines
- *Is your airline considering offsets as a means to achieve carbon neutrality goals?*
  - Yes: 13 airlines
  - No: 3 airlines

Section II: Global Aviation Biofuel Developments

I: REGULATORY PROCESSES FOCUS ON AVIATION'S GHG EMISSIONS

The aviation industry's GHG emissions are under unprecedented regulatory scrutiny, with action focused in four institutions:

- United Nations Framework Convention on Climate Change
- European Union Emissions Trading System
- International Civil Aviation Organization (ICAO)
- U.S. Environmental Protection Agency

A: UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The Conference of the Parties (COP) to the UNFCCC met for a major conference on climate change in Paris in December 2015, but the final agreement (known as the Paris Agreement) omitted the aviation and marine sectors. Global nongovernmental organizations (NGOs) that focused on the process, such as the World Wildlife Fund, were hoping for a strong signal from the UNFCCC for an aviation target consistent with limiting global warming to 1.5 to 2 degrees Celsius. These are widely considered the absolute limits beyond which climate change impacts would overwhelm the adaptive capacities of society and nature. While no direct signal was sent regarding aviation, the Paris Agreement set a global target of "well below" 2 degrees Celsius, with an aim for 1.5 degrees Celsius.[24]

The aviation industry's aspirational target, set through the International Air Transport Association, is to reduce carbon emissions by 50 percent relative to 2005 levels by 2050. However, this goal is not consistent with the 1.5 to 2 degrees Celsius limit. A Tyndall Centre report projects that the aviation and marine sectors will need to cut their GHG emissions more in the area of 80 percent below 2005 levels by 2050.[25] ICAO, the current center of work on a global aviation carbon cap, still has not set a long-term target. This is despite the fact that its 2013 Assembly tasked the Council "to explore the feasibility of a long-term global aspirational goal for international aviation."[26] As climate change impacts intensify, however, the aviation industry is likely to face increasing policy demands for such reductions. Therefore, it is advisable to consider the implications now.

B: EUROPEAN UNION EMISSIONS TRADING SYSTEM

At the beginning of 2012, the European Union (EU) began including aviation in its Emissions Trading System (EU ETS). The system was intended to cover all flights within, to, and from Europe. Due to resistance from nations including the United States, China, and Russia, in 2013 it narrowed its focus to cover only flights within Europe and its economic area.[27] The suspension is scheduled through 2016, in expectation that ICAO will adopt a system to cover international flights by 2016 (see below). If ICAO does not follow through, the EU intends to resume enforcing carbon pricing of international flights in its system.

C: ICAO GLOBAL MARKET-BASED MECHANISM (GMBM)

ICAO'S Committee on Aviation Environmental Protection is developing a GMBM to cover GHG emissions on international flights, which account for about two-thirds of global aviation carbon emissions.[28] The GMBM is meant to help the aviation industry meet its goals for carbon-neutral growth from 2020. Given that the alternative is a patchwork of inconsistent regulatory schemes around the world, the aviation industry has strong incentives for GMBM success. The global aviation GHG cap would be mandatory and could be limited by various potential exemptions (addressed below). A proposal is expected to go before ICAO's General Assembly in the fall of 2016.

The GMBM faces obstacles consistent with global climate negotiations across the board. Developing nations with fast-growing aviation sectors want special consideration vis-à-vis nations with established sectors, the argument being that developed nations have already taken a large share of global carbon "airspace." Developing nations want their space to grow. ICAO is considering options such as looser regulations for certain routes, or goals for each airline based on previous emissions. This issue has emerged as critical and could well sink the GMBM when it is considered at the General Assembly.

According to the International Coalition for Sustainable Aviation (ICSA), a market-based measure will be essential for the aviation industry's emissions goals. ICSA cites a 2013 Manchester Metropolitan University study indicating that even with new fuels, more efficient airplanes, and better airspace management, additional economic measures will be required.29 While options for the GMBM such as a global levy or an emissions trading system have been on the table, the mechanism is expected to take shape as a GHG credits market. Our survey results showed a strong preference for offsets to meet the 2020 goal.

D: NEED FOR LIFE-CYCLE ACCOUNTING

An emissions credits market would allow airlines to offset their emissions growth by buying offsets in other sectors, such as forestry and energy. This system might also credit airlines for their use of biofuel. Assessment of GHG reductions from biofuel is a significant concern. The carbon performance of aviation biofuels varies considerably, depending on feedstock and production process and impacts, including ILUC.[30]

One option is simply to count all biofuel as GHG-neutral. However, biofuel life-cycles include significant carbon emissions, including ILUC impacts, that in some cases are greater than their fossil fuel equivalents.[31] To count all biofuels as equal poses significant disincentives to the development of truly sustainable options and could well discredit the whole process, thus undermining adoption. It is also crucial that credited biofuels meet the range of sustainability requirements as set out by the RSB. Rather than blanket-labeling biofuel as carbon-neutral, assessing actual life-cycle performance would allow for proper accounting of GHG emissions.

ICSA is calling on ICAO to build "a solid foundation of transparency through . . . robust life-cycle emissions accounting for all alternative fuels, whether they result in emissions savings or increases relative to conventional fuel. The (GMBM) should only 'credit' biofuels that reduce net life-cycle emissions beyond set thresholds and that meet environmental, social, and economic sustainability requirements, including low indirect land use change."[32]

Overall, it is uncertain how effectively a crediting system will drive biofuel growth. Offsets would provide low-cost options to reduce GHG emissions and biofuel would have a tough time competing. Airlines will still have an incentive to distinguish their brand as a leader in sustainability by meeting GHG goals in their own operations rather than through credits, but relative costs alone will not tip the balance for biofuel. A small levy on global aviation GHG emissions to fund fuels development would be more effective for promoting biofuel growth, but this appears off the table at the moment.

E: EPA/ICAO ENGINE STANDARDS

Two related regulatory processes by the EPA and ICAO focus on setting GHG emissions standards for aircraft engines. ICAO released draft engine standards in February 2016.[33] Beginning in 2023, they call for engine modifications on new planes to reduce fuel consumption by 4 percent below 2016 levels by 2028. The rule goes before ICAO's General Assembly in October 2016.

Environmental NGOs were critical of ICAO's modest goal.[34] Drew Kodjak, executive director of the International Center for Clean Transportation, noted that "the proposal will only require [carbon dioxide] reductions from new aircraft of 4 percent over 12 years, when market forces alone are predicted to achieve more than a 10 percent efficiency gain in the same timeframe."[35]

The EPA is expected to harmonize its standard with ICAO's. In June 2015, the EPA agreed that GHG emissions from aviation endanger human health and welfare and therefore are subject to regulation under the Clean Air Act.[36] This decision was a result of a 2007 petition by Friends of the Earth, Oceana, the Center for Biological Diversity, and Earthjustice and a subsequent successful lawsuit. While this decision is similar to the EPA's decision to regulate GHG emissions from power plants, it is based on a different section of the law. In fact, it is the same section of the law the EPA used in 2009 to designate GHG emissions from cars and light trucks a health danger. As with the 2009 ruling, the EPA's aviation decision is focused on improved engine efficiency rather than fuels, so it is not a direct driver of biofuel adoption. The new standard is not expected to be implemented until the next presidential administration. On April 12, 2016, Earthjustice filed a new lawsuit on behalf of the Center for Biological Diversity and Friends of the Earth alleging that the EPA has unreasonably delayed regulation of aviation GHG emissions.

2: AIRLINES MOVE UPSTREAM INTO SUPPLY CHAINS

In interviews with aviation industry experts who are not directly employed by airlines, we found a consistent theme: Airlines are moving up the supply chain.

"The most major development is the willingness of the airlines to really take a strong position in their upstream energy future . . . to put capital on the table," one expert said. "Beyond announcements of offtake [purchase] contracts, there is a growing wave of what looks to be serious investment, serious deployment of airline resources in this space. The caveat is these are all announcements, and product is not yet moving."

"There are two dynamics there," said another expert. "In the early days it was thought what airlines could bring is an offtake agreement. You are seeing offtake agreements. With a few of those deals, you are seeing investment actually in the producer. In some ways it is more entrepreneurial than originally envisioned. This is partially enabled by a stronger airline industry that was hurt during the recession." This is happening despite low oil prices, that expert noted.

"Nobody believes those oil prices are going to stay lower forever," said one observer. "They are hedging against future expected volatility. I think in the near term, it is probably having an effect on some of the offtake deals that were in the works. I don't think it's going to reverse the trend."

Low oil prices contributed to the cancellation of one high-profile sustainable aviation fuel development project. In November 2015, British Airways announced the termination of its agreement with Solena Fuels, which would have produced fuels from urban wastes in a London-area plant. The entire project was scrapped in January 2016. The airline cited the lack of public policy support from the British government as a large contributing factor.

"The government needs to support innovative aviation biofuels projects such as this if they are to progress," airline spokesperson Cathy West commented. "Aviation fuels are not eligible for incentives that road transport fuels receive, making it difficult to build a business case to invest in U.K. aviation fuels projects. This affects investor confidence."[37]

Price volatility can work both ways. Darrin Morgan, who leads Boeing's biofuel efforts, noted that many airlines have bought fuel ahead in hedging deals that lock in prices. But this can tie them to higher-than-market costs in times when fuel prices decline. That uncertainty is a driver for biofuel development. "If they can vertically integrate and eliminate volatility, that is a very big deal. This is why a lot of them are doing this."

CIT Aerospace Outlook reported in fall 2015 that "44 percent of global airline fleet and finance executives cite volatile fuel prices as a top challenge for the industry over the next two years. Fifty percent of them expect prices to rise in the next 18 months, and 80 percent expect fuel prices to rise in the next three years."[38]

"Airlines are more deeply involved for security of supply," Morgan said. They are also facing increased regulatory pressure on aviation GHG emissions through ICAO and other processes, he noted. "All of these things are coalescing. Industry needs to find a solution. Nobody debates anymore that changing the fuel is one thing we need to focus on. The past decade of work is bearing fruit."

The airline industry has a strong incentive to demonstrate GHG emissions reductions, a biofuel industry observer noted. "They will have to have an international standard. They are not happy about the prospect of 192 different ways to measure carbon. They have to deliver. By 2020, they have to show some meaningful progress. What the airlines don't want is 2021 or 2022 emissions higher."

3: MULTI-STAKEHOLDER PROCESSES ROAD-MAP SUPPLY CHAINS

All airlines except one reported participation in multi-stakeholder processes to develop road maps for aviation biofuel supply chains.[39] Road maps have been developed in regions including Australasia, Mexico, and Brazil, as well as the U.S. Pacific Northwest and Midwest.

Three road maps have been released recently:

BIOjet Abu Dhabi: Led by Etihad Airways, Boeing, and Masdar Institute, this road map was issued in June 2015. Because arable lands and freshwater are at a premium in Abu Dhabi, one of the United Arab Emirates (UAE), the road map focuses on three feedstocks beyond traditional agriculture. One feedstock, the Integrated Seawater Agriculture Energy System (ISEAS), is a novel arrangement that employs seawater irrigation of salt-tolerant plants on desert lands. This system is focused on the supply chain development section. The second feedstock is the Emirates' rapidly growing municipal solid waste stream. The third feedstock is improved management of human-created plantation forests that were originally developed for recreational purposes. The addition of commercial species as potential feedstock sources could promote water use efficiency and add a fuel industry revenue stream to support the forests. The road map promotes SAFUG and RSB principles and outlines a series of steps for Abu Dhabi and UAE public agencies to take in order to develop a supply chain.[40]

Sustainable Fuels U.K. Road Map: This report was issued in December 2014 by Sustainable Aviation (SA), a 37-member British aviation industry coalition that includes TUI Travel (the parent company of Thomson Airways), British Airways, and Virgin Atlantic Airways. British Airways chairs SA's Sustainable Fuels Working Group. The road map calls for aviation biofuel incentives on a level playing field with the ground transportation sector, as well as public financing, research and development support, and a public-private partnership to advance aviation biofuel. The report projects slow but steady growth to around 0.64 million tons per year by 2030, 1.5 million tons by 2040, and 4.5 million tons by 2050. Biofuel will provide a 15 to 24 percent reduction from 2005 aviation carbon emission levels by 2050. The U.K. could have 12 of the 90 to 160 sustainable fuel biorefineries projected to be in operation by 2030. It could also gain up to £265 million in economic benefits ($399 million at approximate time of report release in November 2015), and 4,400 jobs. The road map notes that SA "members are committed to the development of sustainable fuels that offer significantly reduced life-cycle GHG emissions over fossil fuels, including fuels that are produced from wastes, residues, and nonfood crops grown on degraded lands. These fuels must:

- "Meet stringent sustainability standards with respect to land, water, and energy use;
- Avoid direct and indirect land use change (ILUC) impacts, e.g., tropical deforestation;
- Not displace or compete with food crops;
- Provide a positive socio-economic impact; and
- Exhibit minimal impact on biodiversity."[41]

Initiatives for Next-Generation Aviation Fuels: This Japan road map, released in July 2015, aims for a supply chain to be operational by the 2020 Tokyo Olympics. The 46-member stakeholder process included Japan Airlines (JAL), All Nippon Airways, Nippon Cargo Airlines, and Boeing. The report focuses on municipal waste, microalgae, natural oils, waste food oil, nonedible biomass, and woody biomass. In our survey, JAL reported that it "serves as the secretariat for the subcommittee on producing aviation biofuel from municipal waste. We have seen promising results from several manufacturing processes using municipal waste, which offers a significant cost advantage in terms of procuring raw material. We are convinced that using resources that are otherwise discarded as waste, by recycling them into fuel, also represents a major step toward realizing a zero-waste society, a common goal of many countries." The report's sustainability section focuses only on reducing GHG emissions and avoiding competition with food markets.[42]

From 2013 through 2014, Singapore Airlines partnered with the Civil Aviation Authority of Singapore to examine the technical and economic feasibility of aviation biofuels and to outline a Singapore supply chain. The study engaged government agencies, airlines, infrastructure and airport operators, feedstock suppliers, biofuel producers, and research institutions. The study was for internal use by the company and not for public release.

4: MULTIPLE APPROACHES TAKEN TO DEVELOP SUPPLY CHAINS

Continuing a trend set with the start of aviation biofuel supply chains in the last decade, today's biofuel development plans emphasize waste streams. Much of the early fuel stream was derived from used cooking oil. New initiatives are focused on municipal solid waste (MSW) and forestry residues. Landfilled MSW emits methane, a GHG 28 to 36 times more potent than carbon dioxide.[43] Though there are methane capture operations, they do not prevent all releases. Fuel conversion thus presents a sustainable alternative, especially if waste streams are reduced and recycled to the greatest extent possible and if diverted MSW comes only from the remaining portion. The MSW projects covered in this section are from post-recycled streams.

Advanced aviation biofuel initiatives around the world are converging on forest-derived biomass. Wood and other cellulose-based materials hold great promise as a substantial, sustainable feedstock source. Using forest materials, however, raises important concerns and must be done within sustainability requirements (detailed later in this report). Forest-derived fuels release as much carbon dioxide during combustion as petroleum. But when the full production cycle is taken into account, use of whole trees and larger forest materials can potentially emit more GHGs than petroleum equivalents. In addition, the time it takes to regrow trees between the initial release of carbon dioxide into the atmosphere and its reabsorption creates a warming impact known as carbon debt.[44] The ecosystem impacts of logging, such as effects on wildlife and stream flow, are also a concern.

A: DIRECT AIRLINE SUPPLY CHAIN INVESTMENT

Fulcrum BioEnergy

Fulcrum BioEnergy plans to deploy Fischer-Tropsch (FT) technology to convert heat-gasified MSW into synthetic crude oil, which can then be upgraded to jet fuel. The company projects annual production of 10 million gallons from 200,000 tons of MSW diverted from landfills. The company has contracts for a 20-year feedstock supply. Fulcrum announced that its first waste-to-fuel biorefinery, the Sierra BioFuels Plant near Reno, Nevada, will deliver fuels in 2018. This is one of eight plants with a cumulative annual capacity of 300 million gallons under development by Fulcrum.[45] It is being built by an engineering company, Abengoa, which received a $200 million fixed-cost contract to build the plant and is a biofuels player itself.

United Airlines announced the signature airline supply chain investment of the year on June 30, 2015, with a $30 million equity stake in Fulcrum BioEnergy. It was the largest single investment in alternative aviation fuels from a U.S. airline. In conjunction, United Airlines announced a purchase agreement for up to 90 million gallons annually.[46] That announcement followed Cathay Pacific Airways' August 2014 announcement that it had become Fulcrum's first airline investor. The amount of that investment was undisclosed, but the airline revealed in our survey that it exceeded $10 million.[47] The plant has also received $70 million in funding from three federal departments—Agriculture, Energy, and Defense. The military, for example, is funding plants under the Defense Production Act to serve energy security objectives.

European Supply Chain: Air France/KLM

Air France/KLM reported supply chain investments of €10 million ($13.3 million, at the average 2013 to 2014 conversion rate, when most investments were made), placing it among the top three respondents that disclosed investment amounts. The figure included bioport and corporate fuel program activities discussed later in this report. Other funding went to:

- Biobased Industries Consortium, a public-private partnership to further the bioeconomy in the EU.
- Initiative Towards sustAinable Kerosene for Aviation (ITAKA), a collaborative EU project to develop a full HEFA supply chain based on camelina, an oilseed crop. The initiative has sponsored crop trials to improve productivity and aims to grow crops on degraded lands that reduce ILUC risk. Supply chain sustainability is assessed according to RSB requirements.[48]
- Climate KIC Renewable Jet Fuel project, the EU's major climate innovation initiative. It is working with KLM and SkyNRG (the KLM spinoff dedicated to advancing aviation biofuel) on a supply chain project for Amsterdam's Schiphol Airport.[49]
- BioRefly, a European project to build a demonstration biorefinery that converts 2,000 tons of lignin, a component of plant matter, into jet fuel each year.

B: AIRLINE FEEDSTOCK DEVELOPMENT

Solaris Energy Tobacco

South African Airways, Boeing, SkyNRG, and RSB are engaged in a project to provide South African smallholder tobacco farmers an alternative through Solaris. Developed by Italian company Sunchem, Solaris is a non-genetically-modified, nicotine-free, hybrid tobacco with high oil content. The oil is a feedstock for jet fuel that the partners claim could reduce GHG emissions by 50 to 70 percent. In September 2014, 123 acres (50 hectares) of Solaris were planted in Limpopo Province, the "breadbasket" of South Africa. This is the first operational feedstock development project for SkyNRG, a KLM spinoff marketing aviation biofuel that had previously been mostly UCO-based.[50]

The project was RSB-certified in September 2015. "Developing a biofuel crop in South Africa's breadbasket province has, of course, drawn us into the center of the food versus fuel debate," said Joost van Lier, managing director of Sunchem South Africa. "Having to undergo a systematic process of evaluating the social and environmental ramifications of this development as prescribed by the RSB has allowed us to feel confident in promoting Solaris, not only as a financially viable crop for farmers in the region, but also [as] one that will not affect food security or lead to environmental degradation." As of this writing, a South African test flight was planned for mid-2016. For processing into HEFA fuel, tobacco oils will be shipped to AltAir's Los Angeles–area plant, currently the world's only commercial-scale HEFA facility. If AltAir receives RSB certification for its plant by then, it would be the first fully RSB-certified test flight.[51]

Integrated Energy Seawater Agriculture System (ISEAS)

Etihad Airways, Boeing, and Masdar Institute are members of the Sustainable Bioenergy Research Consortium, which is piloting the aforementioned novel feedstock production system in Abu Dhabi based on salt-tolerant halophyte plants. Employing seawater irrigation on desert lands, ISEAS avoids competition with Abu Dhabi's limited supplies of freshwater and arable lands. Etihad's $2 million investment is the largest research and development expenditure reported in our survey.

ISEAS is a combination of three synergistic production systems working in coastal environments: aquaculture, halophyte cultivation, and mangroves. Aquaculture ponds set inland from coasts raise shrimp and/or finfish. Nutrient-rich discharge water from aquaculture pools, which would pose eutrophication and red tide hazards if released directly into coastal waters, is channeled to halophyte fields on traditionally nonarable desert lands. The plants produce fuel feedstocks in the form of oils and cellulosic plant matter as well as high-value chemicals and fish feed. Finally, human-made mangroves clean waters of remaining nutrients to allow discharge to coastal waters. Mangroves provide carbon storage and wildlife habitat, and may also supply cellulosic feedstocks. A Masdar study projects a 50 percent or more reduction in carbon emissions.[52] A five-hectare pilot at Masdar City is largely complete, with operations ramping up from spring through summer of 2016.

C: FULL SUPPLY CHAIN DEVELOPMENT

Bioports

SkyNRG is developing a network of bioports, systems to link airports that provide a continuous supply of aviation biofuel with regional supply chains. The company has partnered with Statoil Aviation to open the world's first bioports in Scandinavia. On June 26, 2015, deliveries from the world's first airport aviation biofuel tank began at Karlstad Airport in Sweden.[53] The effort was aligned with FiberJet, which engages paper and forestry interests in sustainable fuel production. On January 22, 2016, the new bioport at Oslo Gardermoen Airport in Norway made the world's first biofuel hydrant system deliveries.[54] Lufthansa contracted supplies of a 5 percent blend sufficient to power more than 5,000 flights, and KLM and SAS also signed up for fuel deliveries.[55] Annual deliveries of 2.5 million liters are projected. The early source is camelina-based fuel from the aforementioned ITAKA project. Woody biomass from Norway's forest industry is viewed as a long-term feedstock source.

In August 2015, the Fly Green Fund was launched to support these efforts. This Scandinavian initiative allows airlines' corporate clients to pay a premium to support supply chain development. It is similar to a corporate program launched by SkyNRG and KLM in 2012 but involves multiple airlines. Currently, partners include survey respondents SAS and KLM plus Swedavia, Braathens, and European Flight Service, as well as the Nordic Initiative on Sustainable Aviation.[56]

SkyNRG is developing BioPort Holland through a partnership announced in 2013 among the Dutch government, KLM, the Port of Rotterdam, Neste Oil, and Amsterdam's Schiphol Airport. SkyNRG is also working toward a Brisbane BioPort. Virgin Australia Airlines has made an undisclosed investment to support a supply chain feasibility study.

A Helsinki "Green Hub" is being developed as part of the Finnish government's effort to expand renewable fuels to 40 percent of the transportation market by 2030. Forest-derived biomass is the target feedstock.[57] Forty percent of aviation fuel used at the airport is delivered by Neste, which has powered its eight delivery trucks with its renewable diesel product since 2013. Eventually, the company wants to deliver its fuel to planes.[58] Finnair reported a €15,000 investment ($18,600 at approximate time of investment in December 2014).

In the United States, Seattle-Tacoma International Airport is the first to undertake an extensive feasibility study on delivering aviation biofuel through its tank and hydrant system. This $250,000 study was announced in December 2015 by the Port of Seattle, Boeing, and Alaska Airlines, which has its hub at the Seattle-Tacoma Airport.[59]

(A delivery hub under development at Los Angeles International Airport is covered in the "AltAir Fuels" section, below.)

Brazil Biojetfuel Platform

GOL Airways is a member of the airline steering committee of the Brazil Biojetfuel Platform, which was formally convened in 2013 as "an open, collaborative platform to bring together key stakeholders to promote the implementation of a highly integrated biojet fuel and renewable value chain, 'from R&D to the wing.'"[60] From 2013 through 2014, the national platform launched regional initiatives to address continental logistical optimization and integration to local biodiversity and infrastructure in several states. In Minas Gerais, more than 20 organizations are involved. One project, in which RSB is engaged, is working on the gathering of oil from macaúba (Acrocomia aculeata), a naturally occurring palm species in Brazil, by smallholder farmers.

"GOL is looking for regional highly integrated and optimized solutions, respecting each area's value chain vocation," the airline reports. "For example, sugarcane in São Paulo, macaúba oil in Minas Gerais, macaúba and sugarcane in [the] northeast region, seed oil (such as soya) in [the] south region. We are also supporting technologies that allow for small- to medium-sized modular refining facilities that could optimize the benefits of local biomass production and local airport consumption. In the next 10 to 15 years, we do not need large solutions, we need solutions that are optimized for each local market and size of operation."

Commercial Aviation Alternative Fuels Initiative (CAAFI)

The Commercial Aviation Alternative Fuels Initiative (CAAFI) was formed in 2006 to bring together aviation and energy industry players, researchers, and public agencies to advance petroleum jet fuel alternatives. CAAFI published a "Pathway to Alternative Fuels Readiness" document that includes a fuel readiness tool to measure technical and certification progress, a feedstock readiness tool to measure availability, a guide to selling alternative fuels to airlines, and an environmental checklist to assess sustainability.[61]

D: AIRLINE FUEL PURCHASE AGREEMENTS

AltAir Fuels

AltAir has repurposed part of an Alon Energy USA oil refinery in Paramount, California, to produce HEFA fuel and renewable diesel. Total production is projected at around 40 million gallons per year and will be sourced from agricultural residues and beef tallow. They will be run through a pyrolysis process that uses heat to extract oils from biomass in an oxygen-starved environment. Oils are then upgraded to jet fuel and diesel. AltAir has applied for RSB certification for this plant.[62] In 2013, AltAir Fuels and United Airlines announced an offtake agreement for 15 million gallons of aviation biofuel over three years, to be uplifted from the airline's hub at Los Angeles International Airport. World Fuel Services agreed to purchase an additional 15 million gallons within the same timeframe. KLM will gain fuel from that purchase. Deliveries started in early February 2016.

Red Rock Biofuels

Red Rock Biofuels is developing a biorefinery in Lakeview, Oregon, to process forest residues into aviation fuel, diesel, and naphtha. As of this writing, construction has not yet started, and deliveries are slated for 2017. The refinery is projected to produce up to 15 million gallons of fuel annually through gasification and Fisher-Tropsch processing of 140,000 dry tons of residues. In September 2014, Southwest Airlines announced an offtake agreement for deliveries to San Francisco in the area of 3 million gallons annually. In July 2015, FedEx followed suit with an agreement to purchase 3 million gallons each year from 2017 to 2024.[63] The plant received $70 million in federal funding to go toward the $200 million total cost, sourced from the same Defense Production Act pool that funded Fulcrum.

Red Rock cofounder and CEO Terry Kulesa said the company was started in response to two trends—the increase in wildfires in the western United States and increasing demand for renewable fuels. "By removing and repurposing the excess biomass that fuels destructive fires, we see great potential in the 'waste to value' sector, creating cleaner fuels, healthier forests, and delivering sustainable biofuels," Kulesa commented.[64]

Such forest-thinning operations cause significant sustainability concerns, which are discussed in the "Forest-Derived Biomass Sustainability Requirements" section.

LanzaTech

Virgin Atlantic Airways and New Zealand–based LanzaTech have an offtake agreement for fuels sourced from waste carbon monoxide gases produced by heavy industrial facilities such as steel plants. The process may be applicable in 65 percent of steel plants worldwide.[65] The company has developed a patented microbe that converts gases into alcohols via a fermentation-like process. Next, a chemical process developed by Swedish Biofuels converts the alcohol into jet fuel. The new fuel was RSB-certified in November 2013, and the company claims it could reduce GHG emissions by 60 percent compared with petroleum fuels. LanzaTech has successfully commissioned and run two pre-commercial plants in China. The original deal was announced in 2011. HSBC joined as a partner in October 2014 to finance scale-up to demonstration scale. "This is the first development of its kind, so getting it just right takes a bit of time," Virgin Atlantic Airlines said in its survey response. LanzaTech plans to take one plant to scale to supply jet fuel to Virgin Atlantic Airways at Shanghai Pu Dong International Airport.

E: OTHER RESEARCH AND DEVELOPMENT

Airline initiatives

Other research and development engagements in our survey include these:

- Along with Airbus and the Cooperative Research Centre for Future Farm Industries, Virgin Australia Airlines participated in the 2014 Sustainable Mallee Jet Fuel Project to document that mallee trees could provide a source of RSB-certified jet fuel to Perth Airport. The investment amount was not disclosed.[66]
- Qantas Airways provided AU$500,000 ($456,350 at June 2013 conversion rates) to support a June 2013 Australian Renewable Energy Agency study to examine the country's capacity to produce aviation biofuel. It looked into both HEFA and Fischer-Tropsch pathways and found potential public policy allies. This is one of the foundations for policy advocacy reported in the earlier "Airlines Advocate for Public Policy" section.[67]
- United Airlines joined with Honeywell UOP and Boeing to provide an undisclosed investment for Purdue University to examine conversion of corn stover to jet fuel. The funding supports existing research and development funded by the Indiana Corn Marketing Council and the Iowa Corn Growers Association.[68]
- Alaska Airlines is a member of the advisory council of the FAA's Center of Excellence for Alternative Jet Fuels &

Environment (ASCENT), which was established in 2013. This joint project of Washington State University and the Massachusetts Institute of Technology brings together 16 research universities and 60 private-sector organizations. Other aviation advisory council members include Cathay Pacific Airways, Delta Airlines, Boeing, and Airbus.[69]

Boeing initiatives

In addition to its aforementioned engagements, Boeing recently announced several other feedstock development initiatives:

- In September 2015, Chinese President Xi Jinping visited Boeing's Everett, Washington, factory. In conjunction with the visit, Boeing announced that it would partner with China's National Development Reform Commission on a number of aviation projects, including converting agricultural residues such as corn stover and wheat stalks into jet fuel.[70]
- Boeing is lined up with SkyNRG and the University of British Columbia in a Forest-to-Fuel Technology Maturation Platform aimed at developing technologies to produce aviation biofuel from low-value forest resources in western Canada. The objective is to use analysis, research, and technology development to overcome challenges in techno-economic scale-up, biomass processing, and coproduct development.[71]
- On February 24, 2016, Aeromexico and Mexican government agencies announced a research and development partnership. The effort links 17 institutions that will research supply chains based on Mexican feedstocks including jatropha, halophytes, and sewage sludge.[72]

5: FOREST-DERIVED BIOMASS SUSTAINABILITY REQUIREMENTS

Forest-derived biomass is emerging as a target feedstock for a number of aviation biofuel supply chains. This *Scorecard* has documented the role of forest-derived biomass in Scandinavia, New Zealand, British Columbia, and the western United States. However, there are complex and controversial issues surrounding forest-derived biomass, and its use—particularly of whole trees—is coming under increasing criticism from environmental groups and scientists due to its potential to increase GHG emissions and negatively impact forested ecosystems.

There is a growing body of peer-reviewed science showing that some forms of biomass fuel, such as whole trees and other large-diameter wood, emits more GHGs than fossil fuels. Those increases can persist for 35 to 100 years or even more, depending on regional variations in climate and forest type. Forest-derived biomass would, therefore, make climate change worse.[73] On the other hand, some forms of forest-derived biomass, such as sawdust and waste wood chips from sawmills that would otherwise be burned or quickly decompose, can potentially reduce GHG emissions compared with fossil fuels. Likewise, very short-rotation woody crops—such as poplar—grown on nonforested, degraded land present a viable low-carbon option, but only if they do not replace natural forests or displace food production. Such crops should be certified by credible sustainable forest management standards, such as those of the Forest Stewardship Council.

Evidence on the ground, however, shows that the bioenergy sector is focused on using whole trees, the more GHG-intensive feedstocks. In the southeastern United States, this source feeds a rapidly expanding pellet market and threatens a host of ecosystem values in sensitive forests, such as habitat for critical species, water quality, and flood control.[74] Europe, which is seeking alternatives to coal and other fossil fuels, is the epicenter of demand for biomass. U.S. wood pellet exports doubled from 1.6 million tons per year in 2012 to 3.2 million tons in 2013. From 2013 to 2014, they increased again, by nearly 40 percent, and they are expected to reach 5.7 million tons in 2015.[75] Wood pellet manufacturing in the southeastern United States is expected to continue to skyrocket, with estimated production as high as 70 million metric tons per year by 2020.[76]

Some proponents of forest-derived biomass claim that thinning forests aimed at reducing wildfire dangers—particularly in the western United States—will decrease GHG emissions, but studies cast doubts on these projections. Because wildfires largely burn tree surfaces, even large wildfires leave the bulk of carbon unreleased. One study finds that "high-severity wildfires burn only 10 percent more of the standing biomass than do the low-severity fires that fuel treatment (thinning) is intended to promote."[77]

The authors conclude, "Although fuel-reduction treatments may be necessary to restore historical functionality to fire-suppressed ecosystems, we found little credible evidence that such efforts have the added benefit of increasing terrestrial [carbon] stocks. . . . Carbon losses incurred with fuel removal generally exceed what is protected from combustion should the treated area burn. Even among fire-prone forests, one must treat about 10 locations to influence future fire behavior in a single location."[78]

Another study examined the effect of using forest thinnings for bioenergy. It found that "fire prevention measures and large-scale bioenergy harvest in U.S. West Coast forests lead to 2–14% (46–405 Teragrams C) higher emissions compared with current management practices over the next 20 years. We studied 80 forest types in 19 ecoregions, and found that the current carbon sink in 16 of these ecoregions is sufficiently strong that it cannot be matched or exceeded through substitution of fossil fuels by forest bioenergy."[79]

In light of the emerging science and these concerns, NRDC strongly recommends using only forest-derived biomass feedstocks that will demonstrably reduce GHG emissions in the near term (as compared with fossil fuels) and do not threaten natural forest ecosystems—e.g., sawdust and waste wood chips from sawmills that would otherwise quickly decompose.

6: ANALYSIS: WHEN WILL AVIATION BIOFUEL TAKE OFF?

This *Scorecard* documents an impressive array of commitments on the part of the aviation industry to develop aviation biofuel supply chains:

- Airlines are making substantial investments in advanced biofuel producers and supporting research into novel feedstock opportunities.
- Aviation industry organizations are beginning to develop full aviation biofuel supply chains linked to airport delivery hubs.
- Airlines are providing market certainty through offtake agreements, enabling producers to secure financing. (An important caveat is that many of these agreements specify market-competitive pricing, which presents a challenge.)
- Aviation entities, including airframe manufacturers and airlines, are supporting a broad range of research and development efforts.

At the same time, aviation biofuel use in commercial flights to this point has been minimal. Biofuel remains far more expensive than petroleum jet fuels, and the price disparity presents a significant competitive challenge for producers of new fuels. The industry expects oil prices to increase and would like to reduce impacts from price volatility. These factors will continue to incentivize new fuels development. Development will also be driven by the need to meet the industry's 2020 GHG emissions goals, public goodwill concerns, public image benefits, corporate sustainability goals, and movement toward international emissions regulation.

ASTM approval of a HEFA Plus version of renewable diesel for aviation could open a large new source of cost-competitive alternative fuel. However, supplies of UCO and other waste oils that feed renewable diesel plants are limited, so oil crops will ultimately be required to meet growing demand. Nonfood oils, such as camelina and carinata, are being researched.[80] Palm oil is both the most productive oil crop per acre and the most controversial. Palm development is closely associated with tropical forest clearance, which emits high levels of GHGs and threatens biodiversity. Because of these threats, NRDC does not support palm oil as a fuel source.

Beyond feedstock challenges, the industry is still developing production technology for commercial-scale advanced biofuel plants. As noted in the above section, delivery on signed contracts has been slow and, in some cases, has missed original deadlines. Advanced biofuel plants have faced engineering challenges in their journeys from pilot to commercial-scale. This is not unique to aviation biofuel production.

For example, Abengoa's Hugoton, Kansas, facility is one of the world's first commercial-scale plants to produce ethanol from cellulosic plant matter—in this case, agricultural residues. After its March 2015 production start, the facility was reported operating at less than its capacity of 25 million gallons per year, and engineering challenges were reported. In an August 2015 investor call, the company said it aimed "to continue working on improving the process with the objective of ramping up to something close to full capacity next year."[81]

Fischer-Tropsch (FT) technology is at the center of key aviation biofuel development. The FT process employs catalysts to reshape gases into a paraffin, which is then processed into liquid fuel.[82] FT faces economic and technological questions.

The extremely high up-front capitalization cost attached to large-scale FT plants presents an economic challenge, as illustrated by two recent projects. At Qatar's Pearl gas-to-liquids (GTL) plant developed by Shell—the world's largest such facility—costs escalated to $19 billion from an original estimate of $4 billion.[83] Likewise, in 2014, costs of Chevron's Escravos GTL plant in Nigeria multiplied by at least a factor of four from original projections to reach $10 billion.[84] SASOL has produced jet fuel from coal in South Africa using Fischer-Tropsch. However, this investment is a legacy of apartheid-era boycotts, which prompted government subsidies to develop an alternative fuel supply. In Europe, several FT projects have been discontinued due to cost and technology issues. In an effort to cut down on capitalization overhead, Fulcrum and Red Rock plan to use micro-FT technology developed by Velocys with a $300 million investment over 15 years.[85] The $200 million price tag for the Fulcrum and Red Rock plants indicates that micro-FT might resolve capitalization challenges.

The technology itself raises challenges, as evidenced by FT's feedstock issues. When solid materials (e.g., coal and biomass) are used, FT is preceded by a gasification stage. Contaminants from inadequately cleaned gases can clog catalysts and cause maintenance problems. This has been a major FT stumbling block that could be particularly challenging in the processing of mixed feedstocks such as MSW and forest residues, as is intended at aviation biofuel plants. The next two years will tell whether the micro-FT technology slated for use will be effective in these plants.

"From our point of view, however, we have a hard time believing the FT promise," a biofuel development expert told us. "The fact that in the past 70 years no single company has actually been able to make the business case work for [Fischer-Tropsch] is not so reassuring. There are too many examples of failure across the globe, especially with more difficult feedstock."

In November 2015, British Airways announced termination of its partnership with Solena Fuels, which started in 2010 with the announcement of the GreenSky Project to convert MSW to fuels. British Airways was an equity investor in Solena and was providing capital for construction. The airline committed to purchasing 50,000 tons per year under the assumption that prices would be competitive with conventional jet fuel. But the partnership ended due to a combination of low oil prices and Solena's failure to raise needed capital. The airline then scrapped the entire project in January 2016, citing lack of public support from the British government. In fact, Solena has filed for bankruptcy in the United States.

Manufacturing fuels from biological sources is rife with unique challenges, including collecting and transporting low-density biomass, removing oxygen, and processing materials that are difficult to break down, such as cellulose. All these stages add costs. In conjunction with biofuel industry partners, the aviation industry is making significant efforts to overcome economic and technology challenges. Coming years will show whether these challenges can be met in a manner that is environmentally, economically, and socially sustainable. If so, the benefits will be widespread across the transportation sector.

FUEL APPROVAL PROCESSES

Alternative aviation fuels need production pathway approval through ASTM, the international standards-setting body in this arena. ASTM International D7566 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons spells out the requirements. Once a pathway is approved under D7566, it is considered to meet the D1655 Standard Specification for Aviation Turbine Fuels. Five pathways are approved: Fischer-Tropsch-synthesized paraffinic kerosene (SPK), Fischer-Tropsch synthetic kerosene with aromatics (FT-SKA), HEFA SPK, SIP, and alcohol-to-jet.

Alcohol-to-jet was approved in April 2016. The process was led by Gevo, which has developed a process to convert isobutanol to jet fuel. So far, Gevo has employed corn starch. The company is working with the Northwest Advanced Renewables Alliance, a USDA-funded project in the Pacific Northwest, to expand its isobutanol sources to include forest residuals (the slash that remains after logging operations). With ASTM approval, Alaska Airlines will launch the first test flight with alcohol-to-jet fuel. Alaska was one of the key partners in Sustainable Aviation Fuels Northwest, a multi-stakeholder process in 2010 and 2011 that identified forest residuals as a potentially sustainable feedstock for aviation biofuel.[86] Also in 2011, Alaska Airlines flew 75 commercial flights on aviation biofuel.

As of this writing, one additional fuel approval pathway was in process, with approval expected in 2016: HEFA Plus fuel, which refers to renewable diesel used in aviation. In 2014, Boeing experts identified renewable diesel, also known as green diesel, as a feasible aviation fuel. Diesel is closely related to kerosene, which is used as jet fuel. Renewable diesel, unlike biodiesel, is chemically very similar to its petroleum equivalent. Its energy density and freeze point characteristics allow it to be blended with jet fuel. That makes it a “drop-in” fuel, meaning it can be used in fueling systems and engines with no modifications. On December 11, 2014, Boeing flew a test flight with a 15 percent renewable diesel blend. The freeze point performance of renewable diesel might allow use of significantly higher percentages.

Approval opens a significant, competitively priced aviation biofuel supply. Production capacity and markets are growing robustly in the United States, Europe, and Singapore. In July 2015, United Parcel Service (UPS) announced that it will buy up to 46 million gallons of renewable diesel over the coming three years to power its ground fleet.[87] In some places, renewable diesel is actually cheaper than petroleum diesel, partly due to incentives from the U.S. Renewable Fuel Standard. Boeing maintains that existing capacity could provide around 600 million gallons of aviation fuel, or 1 percent of global demand.[88]

Conclusions and Recommendations

The 2016 NRDC *Aviation Biofuel Scorecard* documents airlines' substantial commitments to sustainable fuels. Nearly all of the airlines we surveyed reported membership in SAFUG and RSB, representing a credible commitment to developing aviation biofuels with high sustainability standards.

We carefully evaluated the responses to our survey and classified the airlines into four categories: (1) Leading, (2) Advancing, (3) Basic, and (4) Nonresponsive. Leading Airlines are following through with firm commitments for use and contracts for delivery of RSB-certified biofuel while engaging in a broad set of supply chain development actions. Advancing Airlines are mostly taking significant steps to develop supply chains but have not made commitments as strong as their Leading counterparts. Basic Airlines have not made commitments at the level of the two higher categories, but are all engaged in developing sustainable fuels at some level, putting them ahead of much of the global aviation industry.

The aviation industry is engaging with a wide range of stakeholders through road-mapping processes and public policy advocacy. Many efforts are advancing the full spectrum of sustainability requirements. Some airlines are evolving strategies to substantially reduce risks of ILUC. Several have committed to avoiding GHG-intensive fuels made from coal and natural gas.

Airlines are also investing in producers and novel feedstock development, signifying the growing commitment to sustainable fuels. Despite low oil prices, the development of aviation biofuels is motivated by the need to maintain recognition as a sustainability leader in the face of increased concern over climate disruption, regulatory pressure on aviation GHG emissions, and oil price volatility.

NRDC recommends the following actions to ensure that the aviation biofuel sector grows in the most sustainable manner possible:

1. Airlines should make public commitments to source only aviation biofuels that have been RSB-certified, and communicate this to fuel and feedstock producers.
2. Airlines that have not yet publicly committed to using sustainable aviation biofuel—one that specifies volume, percentage, and timeline—should do so. Where possible, they should commit in all three areas.
3. Airlines that do not yet have a firm contract for delivery of RSB-certified biofuels should explore and secure a delivery contract at the earliest opportunity.
4. Airlines should strive for total transparency in aviation biofuel volumes, GHG emissions, and sustainability certification.
5. To meet the industry's GHG emissions reduction goals, SAFUG and the International Air Transport Association should firmly commit to using the RSB certification framework.
6. All airlines should establish a clear policy that prohibits the purchase of fuels made from coal and fossil natural gas.
7. Airlines should limit their use of forest-derived biomass feedstocks to those that will demonstrably reduce carbon emissions in the near term (compared with fossil fuels) and will not threaten natural forest ecosystems. Examples include sawmill residues including sawdust and waste wood chips that would otherwise quickly decompose.
8. Any biofuel credits under the ICAO's GMBM should be based on validated life-cycle carbon performance. Credits should also account for ILUC and include sustainability requirements consistent with the RSB standard.

Aviation is leading the development of new fuel supplies that meet the demand for low-carbon performance, while ensuring sustainability across the entire production chain. These efforts are substantial and deserving of credit. By fortifying their commitments to sustainability, airlines can further the process and contribute to the growth of sustainable fuel supplies throughout the transportation sector.

Appendix A: NRDC 2016 *Aviation Biofuel Scorecard* Survey

IDENTITY

1. What is the name of your Airline?
2. What is your first name?
3. What is your last name?
4. What is your position?
5. What is your email address?
6. What is your phone number?

MEMBERSHIP

7. Is your airline a member of any recognized sustainability certification system such as (but not limited to) the Roundtable on Sustainable Biomaterials, Bonsucro, or Roundtable on Responsible Soy? YES NO
8. If so, which one?
9. Is your airline a member of the Sustainable Aviation Fuel Users Group? YES NO

PUBLIC COMMITMENTS

10. Has your airline made a public commitment to use aviation biofuels certified as sustainable? YES NO
11. By what certification system or systems?
12. If so, has your airline set firm targets for volume, percentage of overall use, and/or date?
13. If so, what is the volume?
14. Percentage?
15. Target date?
16. Does your airline have a contract in place for delivery of biofuels certified as sustainable? YES NO
17. If so, by what date?
18. If so, by what certification system? (e.g., RSB, Bonsucro, RSPO, RTRS, ISCC, etc.)
19. Has your airline made a public commitment to not use fuels made from coal or natural gas when the airport fuel supply provides other options? YES NO
20. Has your airline made a commitment to not use biofuels from feedstocks grown on lands deforested for feedstock production by 2020? YES NO

BIOFUEL VOLUMES

21. Does your airline publicly disclose the total volume of biofuels it uses in a year (whether or not it has used biofuels in the past year)? YES NO
22. If so, what is the amount used in the past year, or the most recent year when aviation biofuels were used?
23. Does your airline publicly disclose whether the biofuels it sources are sustainable-certified, and by which certification systems? YES NO
24. If any biofuel was sourced last year, what percentage was certified as sustainable?
25. By what certification systems?
26. If sustainable-certified aviation biofuels were sourced last year, how many air miles were flown on regularly scheduled flights that employed these fuels?

SUPPLY CHAIN DEVELOPMENT

27. Has your airline participated in multi-stakeholder road-mapping efforts?
28. Has your airline participated in ASTM certification processes for aviation biofuel process pathways? (1.0—Y/0—N)
29. Has your airline made a publicly announced investment in aviation biofuels research? YES NO
30. If so, how much?
31. Has your airline made a publicly announced investment in commercial supply chain development for fuels that are to be certified as sustainable? (Can include feedstocks or biorefineries.) YES NO
32. If so, how much?
33. If so, by what certification system?
34. Is your airline engaged in public policy advocacy to further development and adoption of sustainable aviation fuels? YES NO
35. If so, please describe your engagement.
36. Please describe any additional information and/or projects your airline is currently working on related to your efforts to identify and implement aviation biofuels.

GREENHOUSE GAS ASSESSMENTS

37. Does your airline monitor the full life-cycle greenhouse gas emissions of biofuels it uses employing third-party life-cycle analysis? YES NO
38. Are these figures disclosed publicly now? YES NO
39. If you aren't currently disclosing these figures now, do you intend to publicly disclose these numbers by 2020? YES NO

LAND USE

40. Is your airline developing measures to evaluate and avoid indirect land use change such as use of waste products as feedstocks or RSB Low Indirect Impact Biofuel (LIIB) certification? YES NO

41. If yes, please describe these measures.

AIRLINE STAFF DEDICATED TO AVIATION BIOFUELS

42. How many of your airline's staff, if any, devote full time to aviation biofuels?

43. Estimate the full-time employee equivalent of all staff time devoted to aviation biofuels.

ADDITIONAL CONSIDERATIONS

44. Are there any additional issues that you would like to highlight, or information that you would like to share, related to your company's commitments to use aviation biofuels and validate their sustainability?

INDUSTRY STATUS

These questions will be used not to score your individual airline, but to help us assess the progress of your airline industry as a whole in meeting sustainability commitments. Individual airline responses will be held in confidence and not reported publicly, but instead aggregated as an industry-wide evaluation.

45. Rate the probability that aviation biofuels production will scale to levels that allow your airline industry to reach 2020 GHG-neutral growth goals in conjunction with more efficient fleets and improved airspace management:
    1. Highly likely: >90 percent probability
    2. Somewhat likely: 60 to 90 percent
    3. Potentially likely: 30 to 60 percent
    4. Low likelihood: 10 to 30 percent
    5. Probably won't happen: <10 percent

46. Rate the difficulty of scaling sustainable feedstocks and aviation biofuels production to reach 2020 GHG-neutral growth in your home region:
    1. On course to meet goal
    2. Challenging but likely to happen
    3. Unlikely and so will have to access fuels from beyond region

47. Do you believe airlines can meet 2020 GHG-neutral growth goals without purchasing GHG offsets? YES NO

48. Is your airline considering offsets as a means to achieve GHG-neutrality goals? YES NO

Appendix B: Scoring Methodology

Membership

Membership in any recognized sustainability certification system, such as the Roundtable on Sustainable Biomaterials (RSB), Bonsucro, Roundtable on Responsible Soy (RTRS), Roundtable on Sustainable Palm Oil (RSPO), or ISCC, merited one point, as did membership in the Sustainable Aviation Fuel Users Group (SAFUG).

Public Commitments

A public commitment to using certified-sustainable aviation biofuels merited one point. Additional points were allotted based on the certification system's effectiveness. RSB certification merited three points, Bonsucro merited two, RSPO merited one, RTRS merited one, and ISCC merited one.

We asked airlines if they had set firm targets for biofuel use.

- Targets of twenty-five percent and under received one point. All airlines that set a percentage target received one point, because all reported targets were 25 percent and under. We would have provided two points for 25 to 75 percent and three for 75 to 100 percent.
- Airlines earned two points if they set a firm target for biofuel use by 2020. Those with targets before 2020 earned three. We allotted one point to an airline with a 2023 goal.

Airlines also earned points if they had a contract in place for delivery of biofuels certified as sustainable. Three points were allotted if the system was RSB, two if Bonsucro, and one for all others. All airlines with such contracts reported using RSB.

Airlines earned one point if they had a public commitment to not employ fuels made from coal or natural gas when the airport fuel supply provides other options.

We asked airlines if they had committed to not employing biofuels from feedstocks that necessitate deforestation for production by 2020. Positive answers were credited with one point. SAFUG membership also earned one point, since this is part of the SAFUG commitment.

Biofuel Volumes

Airlines that publicly disclose their annual biofuel volume drew one point, regardless of whether they used biofuels in the past year. Airlines that publicly disclose whether they source certified sustainable biofuels, as well as the certification system used, drew one point.

We asked whether any biofuel was sourced in the past year, and what percentage was certified as sustainable. The question was scored:

- RSB: seven points for 100 percent, five for 25 to 75 percent, and three for 1 to 25 percent
- Bonsucro: five points for 100 percent, three for 25 to 75 percent, and one and a half for 1 to 25 percent
- Others: four points for 100 percent, two for 25 to 75 percent, and one for 1 to 25 percent

We asked whether certified-sustainable aviation biofuels were sourced last year, and how many air miles were flown on regularly scheduled flights using these fuels. Only two airlines responded positively, while a third reported flying on fuels not yet certified. Therefore, we opted not to score this question, but the results are reported in this document.

Supply Chain Development

Airlines that participated in multi-stakeholder road-mapping efforts or that participated in ASTM certification processes received one point for each. We did not award points for publicly announced investment in aviation biofuels research, but reported the results in this document.

Points were allotted for publicly announced investments in commercial supply chain development for fuels that are to be certified as sustainable—three points for RSB, two for Bonsucro, and one for other systems. We evaluated engagement in public policy advocacy to further development and adoption of sustainable aviation fuels but did not score the question.

Greenhouse Gas Assessments

We awarded two points to airlines that monitor the biofuels they use for full life-cycle GHG emissions through third-party life-cycle analysis. If the analysis was publicly disclosed, we awarded another two points. We awarded one point for airlines that do not currently disclose these figures but intend to do so by 2020.

Land Use

If reported measures were deemed adequate, we awarded one point for airlines developing measures to evaluate and avoid ILUC.

Airline Staff Dedicated to Aviation Biofuels

We awarded one point for airlines with one employee devoted full time to aviation biofuels. Airlines gained one-half point for each full-time-equivalent employee dedicated to aviation biofuels, with a top score of three points.

Industry Status

Industry status questions assessing biofuel readiness and offsets requirements were not scored by individual airline. Instead, they were aggregated as an industry-wide evaluation to help us assess the overall progress of the airline industry toward its sustainability commitments. Individual airline responses will not be made public.

Appendix C: Glossary of Acronyms

ASTM
Proper name of group formerly known as the American Society for Testing and Materials

ATAG
Air Transport Action Group

COP
Conference of the Parties to the United Nations Framework Convention on Climate Change

EPA
Environmental Protection Agency

EU
European Union

EU ETS
European Union Emissions Trading System

FTE
Full-Time Equivalent

GHG
Greenhouse Gas

GMBM
Global Market-Based Mechanism

GRI
Global Reporting Initiative

HEFA
Hydrogenated Esters and Fatty Acids

ICAO
International Civil Aviation Organization

ILUC
Indirect Land Use Change

ICSA
International Coalition on Sustainable Aviation

ISEAS
Integrated Seawater Agriculture Energy System

ISCC
International Sustainability and Carbon Certification

LCA
Life-Cycle Analysis

LIIB
Low Indirect Impact Biofuels

MSW
Municipal Solid Waste

NRDC
Natural Resources Defense Council

RSB
Roundtable on Sustainable Biomaterials

RSPO
Roundtable on Sustainable Palm Oil

RTRS
Round Table on Responsible Soy

SA
Sustainable Aviation

SAFUG
Sustainable Aviation Fuel Users Group

SIP
Synthesized Iso-Paraffins

UAE
United Arab Emirates

UNFCCC
United Nations Framework Convention on Climate Change

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