POLICY BRIEF

FLYING GREEN

POLICY RECOMMENDATIONS FOR DEVELOPMENT OF PRODUCTION AND CONSUMPTION OF BIOJET FUELS IN CANADA

S. VAN DYK, J. SADDLER

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SUSAN VAN DYK
University of
British Columbia

JACK SADDLER
University of
British Columbia

HIGHLIGHTS

- The aviation industry is responsible for over 2% of global greenhouse gas (GHG) emissions and this percentage will rise significantly as air travel increases in continents such as Asia, Africa and South America.
- To address this problem, the industry has set aspirational goals to reduce emissions to achieve carbon neutral growth by 2020 (from 2005 levels) and a 50% reduction in emissions by 2050.
- Initial measures that have, and are being, implemented to reduce emissions, include improvement of the fuel efficiency of aircraft and operations, such as reducing aircraft weight, optimizing air traffic management systems, and modernising airport facilities. However, these activities will not be sufficient to reduce emissions significantly in the mid-to-long term.
- It is recognised that the use of sustainable aviation biofuels (biojet fuel), *which are functionally equivalent to petrochemical jet fuel and fully compatible with existing infrastructure,* will be the only way to meet these commitments. Substituting fossil-based jet fuels with sustainable biojet fuels can offer significant emission reductions of up to 80%.
- Since the first demonstration flight using biojet fuel in 2008 by Virgin Airlines, there have been more than 2,000 demonstration and commercial biojet-fuelled flights by 21 airlines. However, global production and consumption of biojet fuel is still less than 1% of total jet fuel use and only four technology pathways have been certified under ASTM for biojet production.

- A variety of conversion technologies can be used to make biojet, including oleochemical, thermochemical and biochemical methods. However, >95% of biojet is produced through the oleochemical route, the upgrading of oils and fats. Other technologies are still at different stages of maturity.

- Several challenges remain before large commercial volumes of biojet fuel will be produced and consumed, including: technology maturity; certification of more conversion pathways; high cost of biojet fuel; scale-up and commercialisation.

- The biggest barrier, however, is the lack of policies at national level to support the development of the biojet industry. Policies such as mandates, producer or blender credits, consumption incentives, and capital loan guarantees were essential for the development of biofuels such as ethanol and biodiesel and similar policies will be required for the development of biojet fuels. In October 2016, an international agreement was reached on emission reductions through a global carbon offsetting scheme. This will allow the aviation sector to reduce emissions through purchase of offsets from other industries, but it is unlikely to lead to the significant expansion of biojet fuel production and consumption.

- The current production cost of biojet fuel, as a highly specialised product, is more expensive than jet fuel from fossil fuels and financial incentives to bridge this price parity gap will be essential to drive the consumption of biojet fuel while maintaining competitiveness, particularly for airlines that operate at an international level.

- Production of biojet fuel will compete with road transportation biofuels for the same feedstocks and policy incentives will be needed to preferentially drive the allocation of feedstocks towards biojet fuels. This may be desirable as road transportation has other alternatives to biofuels for emission reduction, while aviation has no other option.

BACKGROUND

The aviation sector has set voluntary, aspirational goals as a way of reducing the industry's emissions and it is accepted that biojet fuels will need to play a significant role to achieve these goals. Unlike road transportation, where biofuels such as ethanol and biodiesel can be used (or where electric vehicles offer an alternative), aviation has no option other than using sustainable biojet fuels that are functionally equivalent to fossil jet fuel and completely compatible with existing infrastructure (drop-in biofuels) (Karatzos et al. 2014). No alternative aircraft propulsion systems are expected to reach commercial stage until well after 2050.

While biofuels, such as ethanol, have been produced for decades, production of biojet fuel is still in its infancy and development has been slow. Globally, limited volumes (~200-300 million litres) of biojet fuels have been produced when compared to the ~120 billion litres of conventional biofuels that are produced and used annually in road transport (IEA, 2015). Any biojet fuels that are produced through a specific technology have to meet the high specifications required by the aviation industry and requires certification through a body such as the American Society for Testing and Materials (ASTM), a process that takes many years and costs tens of millions of dollars. Without this certification, biojet fuels cannot be used on a commercial basis and this process is therefore essential for market access. While many conversion technologies can produce biojet fuel, only four pathways have been certified under ASTM for commercial use, and only one technology pathway for biojet production has reached full commercial stage. This is the so-called conventional biojet or 'oleochemical route' that involves the production of biojet fuel through hydrotreatment of oils and fats. More than 95% of commercial biojet flights have used oleochemical biojet fuels with other technologies supplying small quantities.

ASTM CERTIFIED CONVERSION TECHNOLOGY PATHWAYS FOR PRODUCTION OF BIOJET FUELS

As of May 2016, four different technology pathways to produce biojet fuels (synthetic paraffinic kerosene, with or without aromatics) have been certified by the American Society for Testing and Materials (ASTM) (only ASTM certified fuels can be used in commercial flights):

1. **HYDROPROCESSED ESTERS AND FATTY ACIDS (HEFA BIOJET),** using oleochemical feedstocks such as oil and fats. This is the foundation technology, and was certified in 2011.
2. **GASIFICATION AND SYNTHESIS THROUGH THE FISCHER-TROPSCH METHOD (FT),** certified in 2009. It uses municipal solid waste (MSW) or woody biomass as feedstock.
3. **SYNTHESIZED ISO-PARAFFINIC FUELS (SIP),** formerly known as the direct sugars-to-hydrocarbon route (farnesane), was certified in 2014.
4. **ALCOHOL-TO-JET BASED ON ISOBUTANOL (ATJ),** was certified in 2016.

Many other technology pathways exist, including aqueous phase reforming of sugars, pyrolysis and upgrading of bio-oils, hydrothermal liquefaction and upgrading of biocrudes. Several pathways are undergoing certification at ASTM level.

RECENT PROGRESS IN BIOJET FUEL EXPANSION

Recent developments in biojet fuel expansion has been promising. In 2016, AltAir Fuels, the first biofuels facility with integrated biojet fuel production, opened in Paramount, California (http://altairfuels.com/), with biofuel produced from the hydrotreatment of non-edible oils. It should be noted that biojet fuel is not the sole product, and a blend of biofuels is produced (total 40 million gallons per year), of which renewable diesel is the highest-volume component. Biojet fuel from AltAir is supplied to United Airlines under a 3-year offtake agreement for commercial flights between LAX and San Francisco and was also used to fuel the launch of the US Navy Great Green Fleet initiative[1]. In parallel, a pioneering project that will supply biojet as part of the regular hydrant fuel supply system at an airport has been established at Gardermoen airport, Oslo, Norway[2]. In addition, many other conversion technology pathways are close to ASTM certification, which will expand the potential supply of biojet fuels. Further biojet production facilities are under construction, with Fulcrum Bioenergy set to produce biojet fuel from the gasification of municipal solid waste, while Red Rock Biofuels proposes to use the gasification of wood for biojet fuel production. Several airlines have also made investments in biofuel companies, including United Airlines, Cathay Pacific; or entered into long-term offtake agreements, such as Southwest Airlines and FedEx.

However, progress is still slow when taking into account that several hundred billion litres of biojet fuel will be required annually by 2050 to meet long-term GHG emission reductions in the industry. This policy brief examines the development of the biojet sector and reviews the potential barriers and challenges to the widespread production and consumption of biojet fuels. The lack of long-term supporting policies are considered the biggest challenge to biojet development and this brief will focus on the policies that will be required for biojet production and consumption globally and in Canada, and the role that academia might play in supporting development of a domestic biojet industry.

POTENTIAL GHG EMISSIONS REDUCTIONS FROM USE OF BIOJET FUELS

Limiting or reducing GHG emissions from aviation can be achieved through the consumption of biojet fuels derived from sustainably sourced biomass. The extent of reduction depends on the specific feedstock and conversion technology used. The reduction can be quantified using lifecycle analysis (LCA), which is used to calculate all the emissions and environmental impacts associated with biojet production and use and can be compared to equivalent petrochemical jet (e.g., Jet A-1). Although Elogowainy et al. (2012) indicated that LCA reductions of between 55-85% can be achieved by switching from Jet A-1 to biojet, many biojet technologies have not yet reached commercial scale and thus limited industrial data is available for accurate calculation of GHG reduction potentials. Most studies to date are based on theoretical or research-based factors. It should also be noted that different jurisdictions use different models to calculate GHG emissions, with Canada using GHGenius, the United States using GREET, and Europe using BioGrace[3]. The models are designed differently and often produce different results from the same input data. This presents a challenge to accurately quantifying the GHG reductions obtained from utilization of biojet fuels. Parameters that can have a significant effect on LCA model results include, but are not limited to, co-product allocation, source of hydrogen for upgrading, and source of electricity. This underscores how the use of specific LCAs and the input assumptions/values to the model can significantly influence the results.

BARRIERS AND CHALLENGES TO BIOJET PRODUCTION AND CONSUMPTION

There are a number of barriers and challenges that influence biojet production and use. These include the slow maturity of the technologies, with only the oleochemical pathway, which involves hydrotreating of oils and fats, being fully commercial.

Another challenge is the cost of biojet fuel production, which is not competitive with the price of oil-derived kerosene (jet fuel), which itself is largely due to the current low price of oil. Currently, estimates on cost difference for biojet range from 200-700% above Jet A-1 (IATA 2015). Given their generally low profit margins, airlines are not in a position to pay a premium for fuel and reduce their competitiveness. Thus, policies will play an important role in both bridging this price gap and facilitating the production and consumption of biojet fuels. Currently, the predominant route to making biojet is the oleochemical route. However, these oil and fat feedstocks are generally more expensive than finished Jet A-1 fuel, making their conversion to biojet, and all the costs associated with conversion, prohibitive. Prices of vegetable oils generally track the price of crude oil, which means it will always be economically difficult to make price-competitive biojet fuel via this route. Other conversion technologies that are based on lower cost feedstocks, such as wood residues or municipal solid waste, have not yet been commercialized. While some demonstration facilities are nearing construction, these pioneer facilities are likely to be far more expensive to build than subsequent large commercial 'nth' (not pioneer or first-of-kind) facilities. Thus, the initial production cost of biojet will likely be high and many published techno-economic assessments, based on nth facilities, are likely to be overly optimistic about the potential minimum fuel selling price.

One of the biggest barriers to biojet development is the lack of specific national policies or international agreements to facilitate its production and consumption. Incentives will be required to bridge the price parity gap between conventional jet fuel and biojet. As a high specification fuel, biojet requires additional processing for its production, making it more costly to produce than, for example, biodiesel. If biojet is to compete with other advanced biofuels, additional incentives will have to be implemented that specifically target biojet fuels and not just transportation biofuels in general. Carbon pricing has become the most prominent policy for climate change mitigation, but is unlikely to result in any adoption of biojet fuel by itself.

Another barrier to greater biojet fuel development is the international nature of aviation and the fact that regulation of international air travel falls under the jurisdiction of the International Civil Aviation Organisation (ICAO). This has resulted in delayed national policy development as countries have waited for international consensus to be reached on emissions mitigation. In October 2016, after many years of discussion, an international agreement was reached on a global market based measure (GMBM) in the form of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to address any annual increase in total CO_2 emissions from international civil aviation. Implementation of the CORSIA will begin with a pilot phase from 2021 through 2023, followed by a first phase, from 2024 through 2026. A global scheme ensures a sector-wide approach and maintains the competitiveness of airlines, but is unlikely to have an impact on biojet fuel development unless the price of carbon is very high (>$100 per tonne CO_2). Although biojet fuel use can reduce emissions from aviation, it is anticipated that reductions will likely be met with low-cost carbon offsets (GHG reductions in other projects/industries). It should also be noted that Canada has agreed to voluntary participation of the ICAO carbon offsetting scheme (CORSIA) commencing from the pilot stage in 2021.

POLICIES THAT COULD BE USED TO PROMOTE BIOJET FUEL PRODUCTION AND CONSUMPTION

Policies that have been essential to the development of conventional road transportation biofuels include mandates, producer or blender credits, consumption incentives, and capital loan guarantees. Policy incentives have been successfully used to develop road transportation biofuels production and use in many jurisdiction around the world (the US and Brazil in particular). Similar policies should be developed for biojet. More recently, policies such as a low carbon fuel standard have been effective in promoting biofuel development, while carbon pricing measures such as carbon taxes and emissions cap-and-trade policies have been used for climate mitigation, but with limited effect on biofuels development.

While road transportation biofuels are typically regulated at a national or regional level, the development of a biojet supply chain will require both an international and a national approach. Fuel for international aviation cannot be taxed at a national level, so domestic carbon taxes will only apply to fuel for domestic flights (such as currently happening in BC), while the ICAO CORSIA agreement as a market based measure sets a price on emissions, but only applies to emissions from international aviation. Different policies may therefore exist at national and international level and it is important that they are harmonised to maintain the competitiveness of airlines.

Policies such as mandates and financial incentives for production and consumption of biojet are not restricted by international law and will be the key to promotion of biojet development. Currently, two jurisdictions have policies that provide financial incentives for biojet production and consumption: the USA and The Netherlands. In the US, biojet fuel production has been able to qualify for tradable credits, Renewable Identification Numbers (RINs), under the Renewable Fuel Standard (RFS) legislation since 2013. A similar policy instrument in the Netherlands allows biojet to earn an incentive in the form of a bioticket. For each litre of biofuel sold, a company receives a bioticket which can be traded between companies to fulfil their obligations under the Renewable Energy Directive (RED) or Fuel Quality Directive (FQD). At a local level, a policy of reduced landing fees to promote biojet consumption has been used at Gardermoen airport in Norway.

Biofuel mandates have been the driving force behind development and expansion of biofuels, requiring fuel suppliers to blend a certain volume or percentage of biofuels into fossil-based transportation fuels. While it is worth considering establishment of a biojet mandate in Canada, establishing this type of policy would be premature until a regular supply of biojet can be guaranteed.

Policies such as loan guarantees are used effectively in the USA for the development, construction, and retrofitting of commercial-scale biorefineries, with a focus on production of advanced biofuels. Grants are made available for construction of demonstration scale biorefineries. Such policies are crucial for de-risking investment into new technologies and facilitating scale-up, allowing commercialisation to bridge the "valley of death". Pioneer or first-of-kind plants have been demonstrated to have higher capital costs than subsequent or nth facilities. In addition, the technologies for production of advanced biofuels in general, and biojet fuels in particular, are more expensive than conventional biofuels, and often require high temperatures and pressures, expensive catalysts and specialised equipment. This has to be considered when developing policy.

As emphasised earlier, policies to bridge the price parity gap between biojet and conventional jet fuel will be essential as biojet is likely to be more expensive than fossil jet fuel for many years to come. As the technology develops, it is likely that cost of production will improve and biojet may become more competitive with fossil jet. Production costs of other biofuels have been substantially reduced over time. However, the price of oil will have a significant impact on the competitiveness of biojet. Until the price of biojet becomes competitive, strong policy support will be required for a prolonged period, to both bridge the price parity gap and allow various technologies to mature and become more competitive.

It is important to note that biojet-specific policy incentives will be needed to avoid competition with road transportation biofuels, as feedstocks are likely be diverted towards lower-specification and potentially lower-cost biofuel production. In the absence of policies promoting biojet fuels, a biofuel blend will most likely be sold as road transportation fuel as there are already several policies promoting and incentivising use of biofuel in the road sector. In addition, the use of a blender credit rather than a producer credit will likely favour imports as opposed to development of a domestic production industry.

THE EXISTING FRAMEWORK IN CANADA AND POTENTIAL FOR BIOJET FUEL DEVELOPMENT

The aviation sector in Canada is committed to addressing GHG emissions from the industry. In 2005, Transport Canada signed a voluntary agreement with the Air Transport Association of Canada (ATAC) members to address GHG emissions from both domestic and international aviation operations. This was followed by the 2012 Transport Canada report "Canada's Action Plan to Reduce Greenhouse Gas Emissions from Aviation". The 2012 Action Plan strategy identified three priorities that should be tackled to address emissions: increased fuel efficiency, improved air management efficiency, and modernization of airport facilities. Biojet fuels were not identified as a strategic priority in this action plan, although a recommendation was made to increase funding for research and development into biojet fuels.

In 2014, Transport Canada funded a study which examined the feasibility of establishing a biojet supply chain in Canada over the short-term (2020) and long-term (2025). The project was coordinated by the Waterfall Group, in association with the BioFuelNet Network Centre of Excellence (NCE), and University of British Columbia (UBC) members of BioFuelNet were tasked with delivering the major research components; specifically Dr. Jack Saddler, Dr. Shahab Sokhansanj, Dr. Mahmood Ebadian and Dr. Susan van Dyk. This report critically analyzed the entire biojet supply chain, including an assessment of feedstock availability, conversion technologies, identification of potential sites, as well as a techno-economic and life cycle analysis (LCA) of potential supply chains. The key conclusions of the report were that the supply chain for biojet in the short-term will be based on oils and fats while the longer-term supply chain will be based on lignocellulose feedstock and thermochemical technologies. An earlier, complementary report on the feasibility of biojet production in Canada, with an emphasis on feedstock supply, was completed by BioFuelNet/TorchLight Bioresources for Air Canada and Airbus. The Transport Canada report formed the basis for two subsequent biojet projects that are supported by the Green Aviation Research and Development Network (GARDN), another Canadian NCE. The ATM Project ("Assessment of likely Technology Maturation pathways for biojet production") is based on the technology challenges associated with upgrading of pyrolysis and hydrothermally-produced bio-oils/biocrudes to biojet fuel. UBC is the lead research institution on this project with the focus on technology challenges, policy, life cycle assessment and feedstock sustainability certification. Dr. Jack Saddler and Dr. Susan van Dyk are joint project managers on this project and leading the research component.

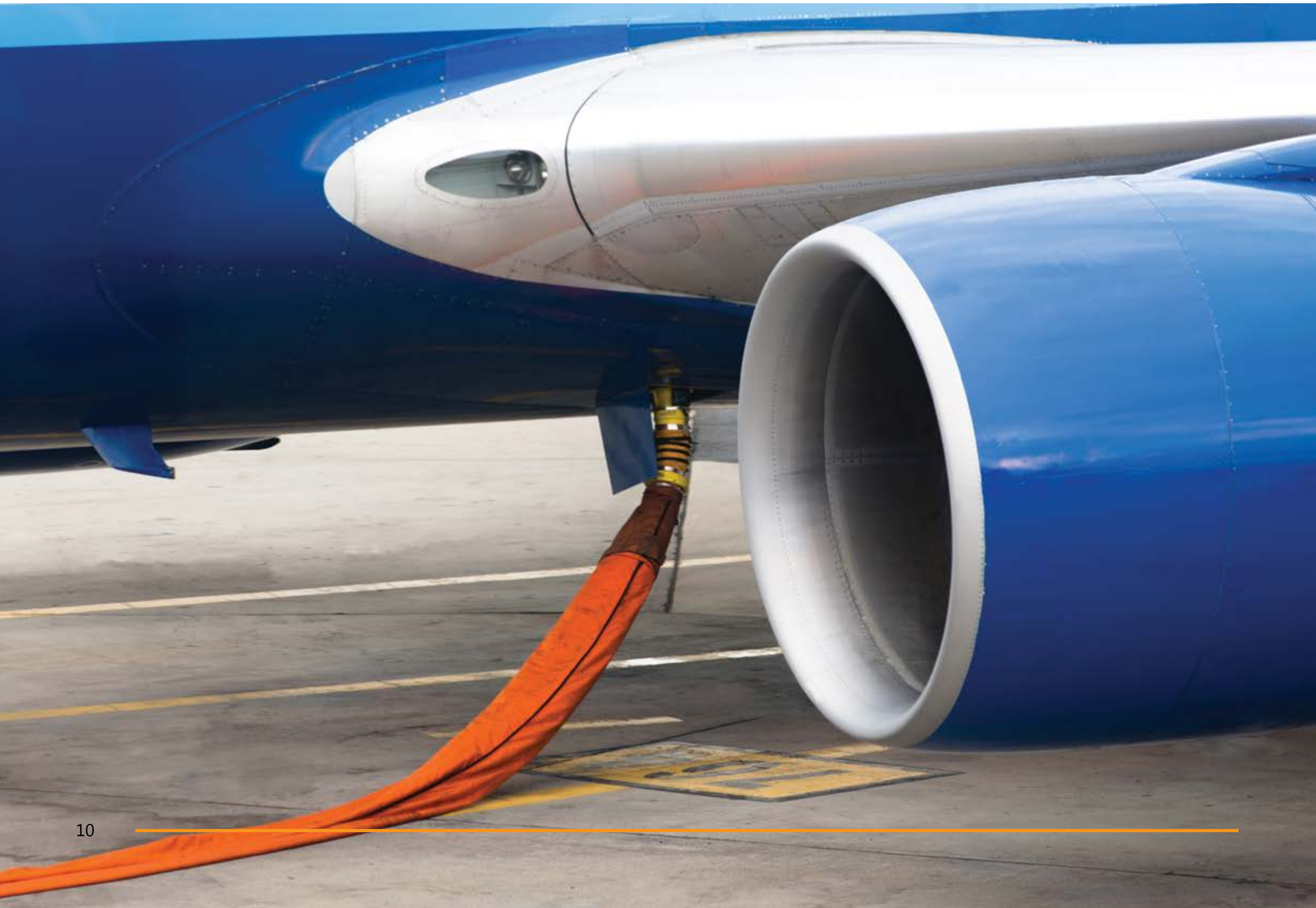
The complementary project is entitled "Canada's Biojet Supply Chain Initiative: Enabling 2020 Carbon Neutral Growth" and is led by the Waterfall Group. This project has the objective of establishing an oleochemical biojet supply chain at a Canadian international airport. BioFuelNet is the primary research partner for this project and several BioFuelNet researchers, including Dr. Warren Mabee and Dr. Pascale Champagne at Queen's University, are playing key roles.

However, prospects for Canada becoming a biojet fuel producer in the near-term are limited. Current policy supports conventional biofuels for road transportation through mandates, but policies supporting advanced biofuel production are insignificant. Funding to stimulate biofuel production and use has been provided through two main programmes: ecoENERGY which is a producer incentive (but the program has not accepted new applications since 2010); and, the SDTC NextGen Biofuels Fund for construction of first-of-kind facilities, (also not accepting new applications, although most of the money set aside has not been spent). The SD Tech Fund is still active and has been funding smaller projects in biofuels development, although it is not limited to biofuels. Apart from funding for research and development, there are no policies targeting biojet fuel production and consumption.

CONCLUSIONS AND RECOMMENDATIONS

The development and expansion of biojet production and consumption will be essential if the aviation sector is to meet its GHG reduction goals. However, significant challenges remain; industry development has been slow, biojet supply is limited and biojet fuel is likely to be significantly more expensive than fossil jet fuel for quite some time to come. Although progress is being made in developing technology to make advanced (biomass/algae-derived) biojet fuels, policy will likely play the most important role in advancing biojet industry development, production capacity, and fuel supply. The United States is currently the only jurisdiction offering significant policy support for biojet production and consumption as part of the Renewable Fuel Standard. However, due to competition with road transportation, these types of incentives have a limited impact on development of the biojet fuel industry and typically favour biofuels to displace gasoline or diesel fuel. Specific policies will have to be developed and implemented to achieve much greater production and consumption of biojet.

While it is worth considering the establishment of a biojet mandate in Canada as mandates have been critical to the development of domestic and foreign conventional biofuels industries, until a regular supply of biojet can be guaranteed, establishing this type of policy would be premature. Other policies such as loan guarantees and funding for commercialisation to bridge the “valley of death” must play an important role in bringing biojet to Canadian markets. Financial incentives targeting biojet fuels will be essential to bridge the price parity gap and allow development of the industry.



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