Carbon Pricing and GHG Reductions in Aviation

National Airlines Council of Canada

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Delphi Group

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Executive Summary

The National Airline Council of Canada (NACC) commissioned The Delphi Group to provide an analysis of potential Canadian carbon policy scenarios and their impact on the aviation sector. The analysis was conducted through the lens that carbon policy should encourage decoupling of economic growth and environmental impact while maintaining a globally competitive aviation industry in Canada.

The policy scenarios considered were:

- A federal offset mechanism for aviation that continues the CNG 2020 agreement through the International Civil Aviation Authority (ICAO)
- An economy-wide federal Cap and Trade system that integrates with existing provincial regulation
- A carbon tax that integrates with existing provincial regulation

Analysis focused on how a cost of compliance would impact the sector, and also included a consideration of policy complexity and the potential for competitive distortions. Conclusions from the analysis were drawn as follows:

1. A federal offsetting mechanism has the highest probability of reducing the administrative burden of compliance and ensuring a level cost of compliance playing field for carriers. Inclusion of aviation in a patchwork of provincial and federal policies and regulations is likely to create onerous and complex compliance obligations that may also create competitive distortions unless specific effort is made to ensure a streamlined and consistent approach to the sector.
2. Carbon prices in the range currently discussed in Canada ($15-$40/tCO2e) will not incent the decoupling of economic growth from environmental impact in the aviation sector. Instead, compliance costs will flow money out of the sector, possibly also shrinking the sector at the same time.
3. Long-term decarbonisation of the sector is most dependent on the next generation of efficient aircraft and the development of a biojet industry. Of these two technology pathways, biojet represents the nearer term opportunity, as well as the opportunity to generate the deepest long-term reductions.

4. In and of themselves, none of these policy scenarios will support the decoupling of economic growth and environmental impact in the sector because the price signal is unlikely to be strong enough in the short and medium terms. In order to achieve this outcome, the policy scenarios need to be augmented by industry action, further regulation and/or direct government support in technology development.

Based on the key findings of the analysis, the near-term activity with the greatest potential to ultimately benefit the sector is the acceleration of a biojet fuel supply that is either cost competitive with jet fuel, or cost competitive after integrating cost of compliance. Canada is well positioned to be a leader in biojet fuel development, with significant potential for economic growth both in domestic and export markets. As a next step, NACC is working on a roadmap for biojet development which will outline the path to broad market adoption for biojet fuel in Canada.

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1 Introduction

Climate change policy, carbon pricing and efforts to drive towards a low-carbon economy are at the forefront of many political and economic discussions – with Canada being no exception. As with all other industries, there are expectations on aviation to contribute to climate change goals in Canada, including through achieving reductions as a sector.

In context, domestic aviation represents a relatively small portion of overall emissions in Canada – contributing 1% of the total[i]. Nonetheless, aviation is an emissions intensive and highly visible activity. The sector's global footprint continues to grow, with global fuel consumption expected to increase by 3-3.5% per year[ii].

As a leading voice in Canada's aviation sector, the mandate of the National Airlines Council of Canada (NACC) is to advocate for safe, environmentally responsible and competitive air travel through the development of sound public policy and engaging with government and industry stakeholders. The NACC is the trade association representing Canada's largest passenger air carriers: Air Canada, Air Transat, Jazz Aviation LP and WestJet.

The NACC commissioned The Delphi Group to provide an analysis of potential Canadian carbon policy scenarios and their impact on the aviation sector. The analysis is conducted through the lens that carbon policy should encourage decoupling of economic growth and environmental impact while maintaining a globally competitive aviation industry in Canada.

The policy scenarios considered are:

- A federal offset mechanism for aviation that aligns with the CNG 2020 agreement through the International Civil Aviation Authority (ICAO)
- An economy-wide federal Cap and Trade system that integrates with existing provincial regulation
- A carbon tax that integrates with existing provincial regulation

The policy scenarios are first defined in Section 2, followed by a brief overview of relevant background for the analysis in Section 3 and the analysis itself in Section 4. Key findings are outlined in Section 5, with a discussion on biojet fuel in Section 6.

2 Policy Scenarios

2.1 Policy Context

Domestically, the federal government must choose how to augment, complement or override existing provincial policy. Internationally, countries are looking to arrest the growth in emissions from international flights, and it is likely that Canadian carriers will have compliance obligations under an international agreement. These two contexts, expanded on below, create an existing framework to which emerging federal policy will be attached – and these points of attachment will influence how the high-level policy scenarios explored in this analysis could be implemented.

2.1.1 Domestic Policy Context

In the absence of federal policy in recent years, all provinces have set climate goals and many have developed robust climate policies and regulations to help achieve them. This has led to a patch-work approach across Canada, with aviation being implicated by varying policies, regulations and carbon prices. These include:

- **British Columbia:** The province's carbon of tax of $30 per tonne is applied to aviation fuels on intra-provincial flights.
  Equates to 7.83 cents per litre of jet fuel.
- **Alberta:** It is the expectation that aviation jet fuel (for intra-provincial flights) will be covered by the incoming carbon levy beginning January 1, 2017.
  Expected rate of 5.17 cents per litre in 2017 and 7.75 cents per litre in 2018.
- **Ontario and Quebec:** Aviation fuels are not directly covered under cap and trade, but operationally the sector sees flow-through costs on utilities and other fleet fuels under the carbon price.

2.1.2 International Policy Context

Globally, the aviation sector has been actively engaged in climate change discussions for the past several years. Under the auspices of the United Nations International Civil Aviation Organization (ICAO), a framework for climate action has been developed aimed at stabilizing emissions from international air travel at 2020 levels. The Carbon Neutral Growth 2020 (CNG 2020) approach includes the development of a global market-based measure (GMBM) for international air travel.

ICAO members have agreed that the GMBM is to be based on several principles, including:

- Should only be considered as part of a broader package of measures to address aviation emissions that cannot otherwise be achieved through cost-effective, in-sector reductions;
- Should not be designed to raise general revenues or suppress demand for air travel;
- Must maximize environmental integrity and take into account the circumstances and capacity of individual states while minimizing competitive and market distortions as well as administrative complexity;
- Ideally implemented through a single mandatory offsetting scheme for global aviation rather than with alternative (i.e. state-level) schemes.
- Meets criteria for fair and equitable distribution of CNG2020 commitment among all carriers.

ICAO intends to sign-off on the design framework of the GMBM at its upcoming Assembly meeting in October 2016. Key building blocks to be clarified include monitoring, reporting and verification (MRV) requirements, and quality of offsets that can be used under the scheme. Early indications suggest a phased-in approach beginning in 2021, with voluntary participation ultimately replaced by mandatory participation. Canada, the U.S., 44 States of the European Union, and China among others have indicated early voluntary participation.

2.2 Policy Scenarios

This section describes the policy scenarios in more detail to establish a common understanding prior to analysis. These policy scenarios are very broad, and there are many ways in which scope, exemptions, changes to the point of regulation and complementary policies (e.g. fuel standards) could create different policy impacts. That said, many of these implementation details would simply make one policy scenario adopt some of the characteristics and impacts of one of the other policy scenarios, and hence this analysis should be remain applicable.

2.2.1 Federal Offsetting Mechanism for Aviation (ICAO Model)

Scenario definition: The CNG 2020 agreement for international air travel being developed through ICAO would be adapted to Canadian domestic flights. Airlines would be required to offset their growth in emissions beyond the established baseline.

Treatment of aviation: This approach would equate to a federal sector-specific approach, with direct regulation of the carriers, who would be exempted from provincial regulations. Individual carriers would be given the option to demonstrate internal reductions, or purchase offsets on a domestic or international market (e.g. as outlined in the GMBM) to meet targets.

Domestic alignment: The federal government would override existing provincial policy. Jet fuel would be exempted from the BC carbon tax and Alberta carbon levy (it is already excluded from the Ontario and Quebec cap and trade systems).

International alignment: Carriers would face the same compliance domestically as internationally.

2.2.2 Federal Economy-Wide Cap and Trade

Under this option, the federal government would establish a national cap and trade system without a separate provision for aviation. This would involve the development of a carbon market likely covering all major sectors of the economy (i.e. oil and gas, industry, buildings and transportation [via fuels]). The government would set a 'cap' of allowable emissions and allocate emission permits (called 'allowances') either by *sector* or *province*.

Compliance entities could then have a number of options to procure emissions units equivalent to their emissions for a given period. These may include:

- Receive free emissions allowances from government
- Purchase of allowances from government auction
- Achieve internal reductions
- Trading between emitters and/other registered market participants
- Purchase of offset credits
- Obtaining early reduction credits

These various options produce emissions units at various price points, in theory providing flexibility to achieve reductions in a more cost effective manner than under a carbon tax.

Treatment of Aviation: The 'point of regulation' under cap and trade would be fuel distributors, utilities and large point sources of GHGs (i.e. industrial facilities). In this case, carriers would not be directly responsible for compliance and would see flow-through costs on fuels and utilities. This means the sector would have little direct ability to manage carbon costs or access flexibility mechanisms such as offsets.

Domestic alignment: The federal government would augment and complement existing provincial regulations.

International alignment: Carriers would be impacted by regulations based on deeper reduction targets domestically than they would be for international flights.

2.2.3 Carbon Tax

The federal government would set a federal carbon tax on fossil fuels. This could be done in a number of ways including:

- A flat price per tonne across all jurisdictions
- A 'floor price' that provinces must either demonstrate they meet through their own pricing system, or else the price (or differential) is applied.

Treatment of Aviation: The tax would be applied on the consumption of fossil fuels, at a differentiated rate depending on the carbon intensity of a given fuel. Aviation would therefore be subject to the tax in a similar way that the BC carbon tax is applied, but on a national scale applied to all intra and inter-provincial flights.

Domestic alignment: The federal government would augment and complement existing provincial regulations.

International alignment: Carriers would be impacted by regulations based on deeper reduction targets domestically than they would for international flights.

3 Background for the Policy Analysis

Two questions are first explored to understand how the three policy scenarios could impact the sector:

1. How will air travel be impacted by an increase in ticket prices arising from sector compliance costs?
2. How can the sector reduce emissions internally, and at what cost?

Exploring these questions provides an understanding of how the sector can ultimately transition to a low-carbon future, and how this could be incented, or dis-incented, by climate change policy and resulting compliance costs.

3.1 How Air Travel Demand Reacts to Price

In order to understand how air travel demand reacts to air travel price, two elasticity studies were examined: Gillen et al. (2002)[iii], a literature review of elasticities calculated during the 1980s and 1990s available through the Department of Finance, and a report commissioned by IATA (2007)[iv] containing both literature review and original analysis using air traffic databases. The full analysis can be found in Appendix A.

In synthesizing the results of both studies, the following broad conclusions are made:

- Leisure travel is more elastic than business travel.
- Short-haul travel is more elastic than long-haul travel, with short-haul leisure travel having the highest elasticity.
- Long-haul travel, either business or leisure, is expected to be inelastic to moderately elastic, with long-haul business travel being the most inelastic.
- Individual routes show elastic responses if price changes are not applied to other route options. If a price change is implemented at a national level, then demand is moderately inelastic.

3.2 Carbon Price and the Cost of Internal Reductions

Sectors typically use marginal abatement cost curves (MACCs) to estimate the costs and sizes of potential reductions achievable at various projected times in the future. Groups in the UK and EU have published several MACCs for the airline sector, but there has been less work focusing on the North American industry. Schafer et al. (2015) [v] published a recent study in Nature Climate Change of carbon reduction costs and timing in the U.S. airline industry. They considered a broad scope of mitigation options, including air traffic management (ATM), operational strategies, new aircraft technology and biofuels. Important results from the work include:

- The U.S. airline fleet can likely reduce intensity of fuel use by approximately 2% per year at zero marginal cost[1].
- In 2050, it is estimated that ~50% of reductions will come from aircraft technology, 20% from air traffic management, 20% from operational strategies and 10% from biofuels (assuming a 15% penetration rate)
- Near-term reductions are achieved through ATM[2], retrofits and normal fleet turnover to more efficient aircraft. The reductions achievable at additional

[1] The authors make multiple assumptions on equipment costs, lifetimes and the price of fuel.
[2] The study assumes full implementation of all identified ATMs by 2020

cost are mainly dominated by early replacement of 25-30 year-old stock, the majority of these reductions costing above $100/t$CO_{2e}$. Other operational strategies become implementable in the medium term but mainly remain additional costs until 2040.

- Two significant sensitivities in terms of achievable reductions are the timing of new 30% more efficient aircraft reaching market by 2035 and the degree of market adoption of biofuels[3], assumed to start in 2030.

The study implies that there are limited levers to accelerate fuel-use intensity reductions within the sector beyond 2%/year without incurring significant cost. A carbon price below $100 will have limited impact prior to the introduction of biofuels, whereupon biofuels can act somewhat as a flexibility mechanism for the sector to achieve more or less reductions depending on market uptake.

3.3 Summary: How a Carbon Price Will Impact the Sector

Firstly, if ticket prices increase, it can be expected that the sector will contract, though the degree of contraction may be small as national-level demand is moderately inelastic. Secondly, only a high carbon price would actually lead to short-term reductions within the sector. Given uncertainty with the actual sector elasticity, two possible outcomes of a low-mid carbon price could then be envisioned:

1. While increased ticket prices cause short and medium-haul leisure travellers to consider driving, the low overall elasticity of air travel at a national level means that sector emissions are only slightly impacted since the sector is not incented to achieve internal reductions.
2. Canadian air travel is on the elastic end of the ranges presented by Gillen et al. and increased ticket prices cause a significant contraction in the sector. Airlines do not have access to internal reductions at a cost below the carbon price, and hence they do not have a short-term mechanism to help control the contraction.

The commonality between these two rather different outcomes is the limited movement of the sector towards decoupling economic growth from sector impacts at

[3] The study considers cellulosic biofuels.

a low-medium price signal. Instead, these outcomes demonstrate that a low-medium price signal would either have limited impact on the sector in terms of reductions achieved, or if it did, would decrease carrier revenues while still not incenting fuel-use efficiency.

4 Policy Analysis

The policy analysis is conducted through the lens that carbon policy should encourage decoupling of economic growth and environmental impact while maintaining a globally competitive aviation industry in Canada. Four criteria have been developed to test the scenarios:

- **Cost impact**: Costs in the expected short-term range of $15 to $40 / tCO_{2e} are likely to achieve some degree of sector contraction without incenting long-term decarbonisation. Sector contraction is considered to be in contradiction to the goals of a carbon policy.
- **Technology enabling**: To decouple economic growth from environmental impact, there has to be a significant shift in technology for the sector. Air traffic measures and ongoing fleet renewal present short-term opportunities to achieve moderate reductions in fuel-use intensity, but the long term play for the sector is in new efficient aircraft and low-carbon biofuels. The most important question from a policy design perspective is how this technology shift will be incented and/or supported.
- **Complexity**: In general, an aim of carbon policy should be to minimize the degree to which compliance is either onerous or complex.
- **Competitiveness**: Canadian carriers compete with each other on domestic and international routes and international carriers on international routes. Inconsistent carbon prices, both within Canada and globally have the potential to lend competitive advantage to carriers that operate mainly where compliance costs are non-existent or lower.

4.1 Federal Offsetting Model for Aviation (ICAO Model)

4.1.1 Cost Impact

Cost of compliance would be expected to be low when compared to the other two policy scenarios for two reasons:

- Offsets are only purchased for emissions that exceed the target – emissions up to the target would not have a cost associated.
- The ICAO model relies on an international offset system which is likely to have lower costs than a domestic offset system.

Therefore, under this scenario, the risk of sector contraction would be considered to be lowest.

4.1.2 Technology Enabling

With a projected lower cost of compliance, this scenario creates a low price signal for internal reductions. The flip side of this lower cost is that the industry is arguably best positioned to support the technology development required to achieve these reductions. Support could be enabled through industry-government partnership, possibly similar to the existing *Canada's Action Plan to Reduce Greenhouse Gas Emissions from Aviation.*

4.1.3 Complexity

This would be the simplest system from the perspective of individual carriers as it would involve extending monitoring, reporting and compliance practices that are already expected to be implemented for international business. In addition, this scenario would remove the onerous requirement of being in compliance with multiple jurisdictions with different regulations across the country.

4.1.4 Competitiveness

With a single policy regime across the country, carriers would not be exposed to competitiveness issues arising from inconsistent treatment of aviation in provincial jurisdictions. From the perspective of harmonization with other jurisdictions, there has been discussion in the U.S. aviation sector related to potential domestic carbon

policy, on adopting a domestic model similar to ICAO, so this option may minimize carbon price exposure differences between Canadian and U.S. carriers.

4.2 Federal Cap and Trade

4.2.1 Cost Impact

In the likely event that fuel would be regulated at the distributor, carriers would pay flow-through costs from distributor compliance obligations. The cap and trade models implemented in Ontario and Quebec require that allowances or offsets be purchased for the entire carbon content of the fuel distributed (though as mentioned, aviation fuels are currently excluded). Under this model, flow-through costs would be very sensitive to the floor price of allowances, leading to potentially higher cost impacts. There could be room to mitigate flow-through costs if distributors either receive a portion of free allowances or have access to lower-cost compliance credit markets.

Given the range of potential compliance costs, the risk of sector contraction could be either higher or lower.

4.2.2 Technology Enabling

An economy-wide cap and trade system does not include incentives to enable technology beyond the price signal, which would be expected to be too low in the short to medium term. In a scenario where compliance costs are kept lower, technology enabling could be industry-led, similar to the CNG 2020 scenario. Where compliance costs are higher, there would be an increasing role for government to recycle revenue to support technology development.

4.2.3 Complexity

While a national cap and trade system in theory provides a way to create an effective market for carbon reductions and balancing of trade-offs between sectors, in practice it is likely to be much less elegant. This is largely due to the need to overlay a federal system on the varying provincial systems, rather than have it replace them. It may be more straightforward to align a federal cap and trade with provincial cap and trade systems (i.e Quebec, expected Ontario), but less so for carbon tax jurisdictions. Equivalency is difficult to demonstrate between the two, and therefore creates challenges for understanding what the federal 'top up' of any provincial tax would be vis a vis cap and trade. It could also create significant market inefficiencies if overlapping systems are in place. Compliance for individual carriers has the potential to be both onerous and complex if carriers must duplicate compliance reporting or secure compliance mechanisms within multiple regimes at the provincial and federal levels.

4.2.4 Competitiveness

Inconsistent carbon policy with respect to aviation across the country would have the potential to create lower-cost jurisdictions and higher-cost jurisdictions resulting in possible competitive distortions depending on carrier operational distributions. With a higher cost of compliance domestically than internationally, there could also be competitive distortions between domestic and international carriers who compete on the same international routes. The concern here would be that international carriers could use higher profits from within their domestic markets to lower costs on international travel. The degree to which this would manifest requires further work, but it should be remembered that many passengers purchase the cheapest tickets available on a given route, regardless of how small the price differential.

4.3 Carbon Tax

4.3.1 Cost of Compliance

The cost of compliance under a carbon tax would be expected to be higher. Carriers will be taxed based on the carbon content of all fuel consumed, with no alternative means of compliance other than avoided tax through fuel-use efficiency improvements.

The higher cost of compliance would result in a higher risk of contraction for the sector.

4.3.2 Technology Enabling

A carbon tax does not include incentives to enable technology beyond the price signal, which would be expected to be too low in the short to medium term. In fact, a carbon tax could act as a disincentive if it covers the carbon content of biofuel (as it does in BC, and is being contemplated in Alberta). In this type of carbon tax regime, biofuels would not reduce a carrier's cost of compliance, and hence there would be little reason for carriers to support the development of the technology or purchase the product.

Given the relatively high cost of compliance and the potential for the sector to contract, there would be an important role for government to recycle revenue towards supporting technology development.

4.3.3 Complexity

This approach would be relatively easy to align with existing tax jurisdiction (i.e. BC and expected Alberta), but it would be more difficult to show equivalency or determine federal 'top up' in cap and trade jurisdictions. Similar to cap and trade, compliance for individual carriers has the potential to be both onerous and complex if carriers must be compliant within multiple regimes at the provincial and federal levels.

4.3.4 Competitiveness

A potential for competitiveness issues would exist between Canadian carriers and international carriers on international routes as laid out in Section 4.2.4.

4.4 Summary

The outcomes of the policy analysis are summarized in Table 1.

Table 1: Comparison summary of policy scenarios

	Federal Offsetting Mechanism	Economy-wide Cap and Trade	Carbon Tax
Point of regulation	Carriers	Fuel distributors	Carriers
Reduction target	Specific to aviation (CNG 2020)	In-line with Canada	In-line with Canada
Risk of sector contraction	Lower	Lower – Higher	Higher
Complexity	Lower	Higher	Higher
Enabling of in-sector reductions	No direct enabling	No direct enabling	No direct enabling
Competitiveness	Lowest sector impact	Inter-provincial and international distortions possible	International distortions possible

5 Key Findings

Conclusions from the analysis are drawn as follows:

1. A federal offsetting mechanism has the highest probability of reducing the administrative burden of compliance and ensuring a level cost of compliance playing field for carriers. Inclusion of aviation in a patchwork of provincial and federal policies and regulations is likely to create onerous and complex compliance obligations that may also create competitive distortions unless

specific effort is made to ensure a streamlined and consistent approach to the sector.

2. Carbon prices in the range currently discussed in Canada ($15-$40/tCO2e) will not incent the decoupling of economic growth from environmental impact in the aviation sector. Instead, compliance costs will flow money out of the sector, possibly also shrinking the sector at the same time.
3. Long-term decarbonisation of the sector is most dependent on the next generation of efficient aircraft and the development of a biojet industry. Of these two technology pathways, biojet represents the nearer term opportunity, as well as the opportunity to generate the deepest long-term reductions.
4. In and of themselves, none of these policy scenarios will support the decoupling of economic growth and environmental impact in the sector because the price signal is unlikely to be strong enough in the short and medium terms. In order to achieve this outcome, the policy scenarios need to be augmented by industry action, further regulation and/or direct government support in technology development.

6 Enabling a Biojet Industry

Based on the key findings of the analysis, the near-term activity with the greatest potential to ultimately benefit the sector is the acceleration of a biojet fuel supply that is either cost competitive with jet fuel, or cost competitive after integrating cost of compliance. The idea here is that upfront investment will take an early stage technology that is too expensive for market uptake and help it transition to a viable solution that can even become cost competitive with the incumbent technology. An important caveat to this finding is that while lifecycle GHG reductions of 80-90% are possible, not all biojet fuel will have the same environmental benefits depending on the production pathway. Future policy should include a consideration of the lifecycle GHG impacts of the pathways in order to retain environmental integrity.

Based on work conducted by The Waterfall Group, Canada has a number of advantages for biojet fuel development, including:

- readily accessible, significant commercial quantities of sustainably grown and harvested biomass
- existing refining capacity, distribution infrastructure (storage, blending, pipelines, rail, barge systems) with local scale advantages from industry concentration around refining centres.
- scale – advantaged agricultural and forestry industries with harvest and processing systems in place, and established sustainability certification schemes
- regulatory systems for energy infrastructure development, including policy measures in place to enhance environmental performance of operations (e.g. emissions, water use, etc.)
- established networks of academic, government and private research/development expertise in advanced biofuels
- provincial and federal ministries with histories of enabling the development and commercialization of advanced biofuels

Given that countries around the world will be looking for emission reduction opportunities in aviation, there is a significant potential economic benefit for Canada to become a centre for biojet fuel technology.

At present there are multiple technology platforms able to convert biomass into biojet fuel. Each platform uses specific feedstock types. Typically, biojet is co-produced with other liquid and gaseous biofuel products used for other energy markets such as road or maritime transport, refining, heat and power. Many technology platforms for biojet production are not available at commercial scale today, requiring significant additional investment in research and development.

The table below gives a high level overview of the main pathways for biojet production:

Table 2: Biojet pathways

Pathway	Certification	Process Description	Feedstock
Fischer-Tropsch(FT)	Approved (up to 50%)	Converts carbon-rich material (e.g. biomass) into syngas, then catalytically converted to jet fuel	All biomass & MSW
Hydroprocessed Esters and Fatty Acids (HEFA)	Approved (up to 50%)	Converts oleochemicals to jet fuel via deoxygenation with hydrogen and cracking	Oils and fats
Direct Sugars to Hydrocarbons (DSHC)	Approved (Farnesene-based up to 10%)	Ferments plant sugars and starches to hydrocarbons which are subsequently thermo-chemically upgraded to jet fuel	Sugars (incl. C6 cellulosic sugars)
Alcohol to Jet (AtJ)	Approved (up to 30%)	Converts sugar/ starch derived alcohols to jet fuel via dehydration, oligomerization and hydrogenation	Alcohols (potentially derived from biomass, or waste)
Hydrotreated Depolymerized Cellulosic Jet (HDCJ)	Expected 2017	Converts any carbon-rich material into a bio-crude oil via thermochemical depolymerization which can then be upgraded to jet	All biomass & MSW

Analysis completed for Transport Canada in 2015 by The Waterfall Group proposed that the HEFA and HDCJ pathways hold the most promise for Canadian biojet production. HEFA would utilize the vast oleochemical feedstock supplies available in Canada while the HDCJ pathway would be able to process lignocelluslosic feedstocks from agriculture and forestry residues. At present, the HEFA pathway is commercially available whereas the HDCJ pathway has yet to commercially materialize and scale up to the volumes required for consistent blending in commercial aviation.

As a next step, NACC is working on a roadmap for biojet development which will outline the path to broad market adoption for biojet fuel in Canada. The roadmap

will include an exploration of how biojet fuel could contribute to both 2030 and 2050 GHG reduction targets for the domestic aviation sector. It is estimated that accelerated deployment of biojet fuel could contribute to GHG reductions in excess of 10% compared to 2005 levels, depending on the growth rate of domestic air travel.

Appendix A: Price Elasticity of Air Travel

In order to understand how air travel demand reacts to air travel price, two elasticity studies were examined: Gillen et al. (2002), a literature review of elasticities calculated during the 1980s and 1990s available through the Department of Finance, and a report commissioned by IATA (2007) containing both literature review and original analysis using air traffic databases. It should be noted that the IATA study references the work conducted by Gillen et al., but it is useful to consider both works separately as they offer different ways of categorizing elasticities. Elasticities from the Gillen et al. study are shown in Table 3.

Table 3: Air travel elasticities as presented in Gillen et al. (2002) [4]

Market Sector	Median	1st quartile	3rd quartile
Long-haul international business	-0.265	-0.475	-0.198
Long-haul international leisure	-1.040	-1.7	-0.560
Long-haul domestic business	-1.150	-1.428	-0.836
Long-haul domestic leisure	-1.104	-1.228	-0.787
Short/medium-haul leisure	-1.520	-1.743	-1.288
Short/medium-haul business	-0.783	-1.140	-0.595

It should be noted that the authors recommend looking at the median value, but also at the range of possible elasticities. This is important for two reasons:

[4] Data presented is from the higher-rated subset of studies included in the paper

- Elasticities presented in the different studies do not group around a normal distribution, with some categories such as long-haul international leisure showing distribution peaks at lower and higher elasticities.
- Analyses in the various studies were conducted on different geographic regions. Given the paucity of Canadian data, it is impossible to determine where Canada might be with respect to the median.

In taking into consideration the above, the following conclusions are then drawn:

- Business travel is likely less elastic than leisure travel
- Increased airfares will likely impact short/medium-haul leisure flights the most and international business flights the least.
- Short/medium-haul business flights are also expected to be inelastic.
- The elasticities of long-haul international leisure, long-haul domestic business and long-haul domestic leisure are less clear. These types of travel may prove to be either moderately elastic or moderately inelastic in Canada.

The IATA study looks at elasticities somewhat differently, differentiating between price fluctuations at the route/market level, the national level and the pan-national level. These levels are defined as follows:

Route/market level: All travel between a discrete origin and destination. In response to a price increase, travellers can choose to change their route (e.g. an alternative airport in the same area), change their destination, travel by another mode or not travel.

National level: All air travel within and from a country is impacted in the same way. In response to a price increase, travellers could use another mode or avoid travelling.

Pan-national level: All air travel within a region of countries is impacted in the same way. The options to respond to a price increase are mainly limited to avoiding travel.

Table 4: Air travel elasticities as presented by IATA (2007)

	Route/Market Level		National Level		Pan-National Level	
	Short-haul	Long-haul	Short-haul	Long-haul	Short-haul	Long-haul
Intra North America	-1.54	-1.40	-0.88	-0.80	-0.66	-0.60
Trans Atlantic (North America – Europe)	-1.85	-1.68	-1.06	-0.96	-0.79	-0.72
Trans Pacific (North America – Asia)	-0.92	-0.84	-0.53	-0.48	-0.4	-0.36

The conclusions that can be drawn from this study are as follows:

- Travel at the route/market level is the most elastic. However, it is noted that this category includes the use of alternative airports close to the same origins and destinations, so the degree to which this elasticity is impacted by modal shift and alternative destinations is unclear.
- Other air travel is moderately elastic or inelastic.

In synthesizing the results of both studies, the following broad conclusions are made:

- Leisure travel is more elastic than business travel.
- Short-haul travel is more elastic than long-haul travel.
- Long-haul travel, either business or leisure is expected to be inelastic to moderately elastic.

Increasing coverage of a price change (i.e. broadening geographic applicability) dampens elasticity.

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