The transition to sustainable aviation fuel (SAF), amidst geopolitical and economic turmoil

BY ROBERT V. PARSONS, MARYNA KLYMCHUK AND PAUL D. LARSON

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Abstract

There is a growing, global need to reduce greenhouse-gas (GHG) emissions, amidst emerging geopolitical and economic turmoil.

Since 2015, Canada has set reduction of emissions as a priority, but progress has been slow. Canada has also been facing trade barriers; from China starting in 2019, and recently from the United States, in the form of tariffs. Despite these obstacles, there are opportunities, such as using Canadian canola to produce sustainable aviation fuel (SAF) to reduce emissions from civil aviation. This article outlines and explores these obstacles and opportunities, in light of the energy transition.

Introduction

There is an urgent need to reduce greenhouse-gas (GHG) emissions and transition to a zero-emission global economy, in this time of war and other geopolitical disruptions. Since 2015, Canada set emission reduction as a priority, but progress has been slow. Concurrently, Canada faces trade barriers and tariffs from China, starting in 2019, and more recently from the new administration in the United States. Despite these ambitious goals amidst obstacles, there are opportunities for Canada to employ domestic oilseed canola crops to produce renewable drop-in fuels. Such fuels can help industries like aviation and heavy-duty trucking. This paper focuses specifically on sustainable aviation fuel (SAF), using the *three effects model*, i.e. by considering activity, structural and energy efficiency effects.

Impacts on Canola

One Canadian crop hit hard by trade barriers and tariffs is canola. Canola is a specialized oilseed crop developed from rapeseed. Canada is the largest producer and exporter in the world (FAS 2024). In Canada, canola accounts for $24.5 billion in direct economic activity, along with nearly 130,000 jobs (GlobalData 2024). Indeed, canola is larger than the Canadian automotive sector. Though more prominent in the media, automotive accounts for $16.5 billion in economic activity and job numbers similar to those of canola (CVMA n.d.).

Recently, canola has been subjected to periodic trade restrictions by China. Canada was once a major canola exporter to China; however, from 2019 through 2021, imports were restricted, in an apparent response to the detention of a Huawei executive based on an extradition request from the United States. One analysis estimated costs to the industry of between $1.5 and $2.4 billion from lost sales and lower prices (Left Field Commodity Research 2021). Canadian canola also involves genetically-modified organisms (GMO), which are not permitted by the European Union (EU) for human consumption, limiting alternative food markets. More recently, China imposed tariffs on canola in response to Canadian tariffs on Chinese-made electric cars.

Meanwhile, the U. S. tariff situation is volatile and uncertain. Tariff levels of 25% could be more damaging than even higher tariffs from China. Thus, Canada needs new markets and alternative ways to support its canola industry. Locally-produced canola can be used to produce drop-in renewable biofuels for aviation (i.e. SAF) and surface freight transportation (renewable diesel).

Canada's Emissions

Canada's Nationally Determined Contribution (NDC) under the 2015 Paris Agreement was set at reducing total emissions by 40% to 45% by 2030, vis-à-vis 2005 levels (Office of the Prime Minister 2021). However, the most recent National Inventory Report (NIR) from Environment and Climate Change Canada (ECCC 2025) reports 2023 emissions of 694 million tonnes, with updated reference for 2005 of 759 million tonnes. This reflects a reduction of only 8.5%. The Commissioner of Environment and Sustainable Development (2023) bluntly stated the country is not on track, and the

Robert Parsons holds a PhD in Engineering, University of Manitoba, and MBA, with Distinction, Schulich School of Business, York University. He earlier worked for 15 years as an advanced-energy technology consultant for government, and is currently a Sessional Instructor in the Department of Supply Chain Management, Asper School of Business, University of Manitoba. **Maryna Klymchuk** is an Instructor at the University of Manitoba. She holds a Doctor of Science (Economics) and a PhD in Economic Science from leading Ukrainian universities, where she previously served as Professor of Organization and Construction Management. Author of over 100 publications, her research spans supply chain management, business process management, AI in economics, sustainable development financing, energy efficiency, digitalization, innovation, green bonds, and sustainable aviation fuel. **Paul D. Larson, Ph.D.** is the CN Professor of Supply Chain Management at the University of Manitoba, where he was Head of the SCM Department and Director of the Transport Institute from 2005 to 2011. Dr. Larson earned graduate degrees at the University of Minnesota (MBA) and the University of Oklahoma (PhD). He is also a HUMLOG International Research Fellow at the Hanken School of Economics in Helsinki, Finland. Paul's research focuses on sustainability. Current interests include crude oil transportation, by railway vs. pipeline; zero-emission trucking technology; and sustainable aviation fuel (SAF).

United Nations Environment Program (2023) revealed that Canada had the largest implementation gap (27%), among G20 countries. NIR data shows that significant national reductions only occurred due to external factors, e.g. the 2008 recession and the 2020 COVID pandemic.

Emissions data by economic sector demonstrate that, in 2023, oil and gas was first in emissions, at 208 million tonnes or 30% of Canada's total (ECCC 2025, Table ES-2). Transportation came in second, at 157 million tonnes or 23% of total emissions. The smallest sector was electricity, with only 49 million tonnes (7% of total). These results contrast with the USA, where transportation was the largest emitting sector in 2022 (at 28%), followed by electricity (at 25%).

Canada's largest increase from 2005 was also the oil and gas sector, up 13 million tonnes or 7%, while the largest decline was electricity, down 67 million tonnes or 58%. Thus, Canada's overall reductions, 65 million tonnes since 2005, are overwhelmingly attributable to electricity, which fell from second largest to lowest major sector. In contrast, transportation emissions remained relatively unchanged since 2005 despite numerous reduction policies and programs. Emissions for all modes of domestic freight transportation, including air, ship, rail and truck, are itemized in the NIR – and remained largely unchanged since 2005 (ECCC 2025, Table 2-13).

Aviation, as well as the other freight modes, relies heavily on middle-distillate fuels, exhibiting relatively higher GHG intensities. Diesel accounts for the largest volume of such fuels, with turbine-based aviation fuel second. On-road diesel fuel consumption for 2023 increased by approximately 2.4% compared to pre-COVID levels in 2019 (Statistics Canada 2024a), to 18.3 billion Litres. Meanwhile aviation fuel consumption for 2023 totalled 8.0 billion Litres, 92% of pre-COVID levels. The importance of aviation fuel in Canada is downplayed since international passenger and cargo emissions are excluded from the NIR (Ferreira 2022). By 2023, emissions from civil aviation in Canada had increased 9% compared to 2005, reaching 98% of 2019 pre-COVID levels (ECCC 2025, Table 2-5).

End-use energy projections from Canada Energy Regulator's Energy Futures 2021 outlook (CER 2021) estimate that by 2030, overall diesel consumption will drop somewhat, while aviation fuel use will continue to rise, reaching nearly 10.6 billion Litres. Thus, a focus on transportation fuel consumption and emissions appears to be a worthwhile priority moving forward.

Reduction Policy Concerns

While the focus here is renewable drop-in fuels produced from canola, it is relevant to first outline other policies designed to reduce emissions – and their success in achieving reduction objectives.

Up until 2025, Canada's emission reduction plans focused on a commodity-based carbon tax, applied to a broad range of fossil fuels (ECCC n.d.) consumed in transportation, including civil aviation. After six years it was withdrawn, largely for political reasons. Instead of employing a Pigouvian approach, wherein adding a charge to cover externalities *might* inspire consumers to reduce their consumption (McKittrick 2016); it was promised that the tax *would* reduce fuel consumption and GHG emissions, i.e., "put a price on carbon, and reduce carbon pollution" (Liberal Party of Canada 2015). Environment and Climate Change Canada (ECCC 2018) suggested the tax would become Canada's largest single reduction measure and, by 2022, would result in a decline of 80 to 90 million tonnes of CO_2eq annually. As seen in the NIR data, the tax failed to achieve reductions as planned, especially in the transportation sector.

Since 2005, the electricity sector has enjoyed success with grid-decarbonization programs, but these were largely provincial rather than federal initiatives (Parsons 2021). By 2021, the federal government began to focus on electricity, after large reductions had already been realized. By 2023, federal tax incentives of around $33 billion were in place, mostly oriented to intermittent renewable sources, e.g. solar and wind (Finance Canada 2023). The major driver appears to have been alignment with directions of the Biden administration (DOE 2023), including the *Inflation Reduction Act* (IRA), rather than Canada's situation (EPA n.d.). Such an approach was more sensible for the United States, given their high electricity emissions compared to Canada.

Canada already had third lowest grid emissions within the G20 (IEA and KEEI 2025), with grid-intensity of about 30% that of the U.S., raising concerns about diminishing reduction returns compared to other sectors. Applications like light-duty electric vehicles and heat pumps are emphasized for electricity, and certainly growing, but still present in small numbers, only around 3% of all light-duty vehicles and home heating capacity (Statistics Canada 2024b, 2025a, NRCan 2023), requiring long lead-times to reach meaningful adoptions. As an exporter, Canada is not short of electrical energy (kWh), but needs to address more pressing concerns associated with grid-interconnections and electrical delivery (kW) capacity (Bowman et al. 2009, Economist 2023). Canada also relies overwhelmingly on imports, for technologies like solar panels, wind turbines, heat pumps and electric cars. The prospect of tariffs severely impacts economic viability. Expecting Canadians to purchase these imported products is not easy in the face of punishing tariffs and economic uncertainties.

More notably, civil aviation and long-haul trucking remain poor candidates for electrification. Electric-based aviation is still at early technology-readiness (Crownhart 2022), not expected to contribute much by 2050 (IATA 2024). In addition, the economic viability of electric long-haul trucking is constrained by multiple factors, and in some instances infeasible (Larson et al. 2024).

Focus on Aviation

The International Air Transport Association (IATA 2021), in response to growing environmental concerns and pressures, announced an ambitious goal of achieving "net-zero" by 2050. For this industry the *three effects model* is a useful analytical tool (SDTC 2009). The three

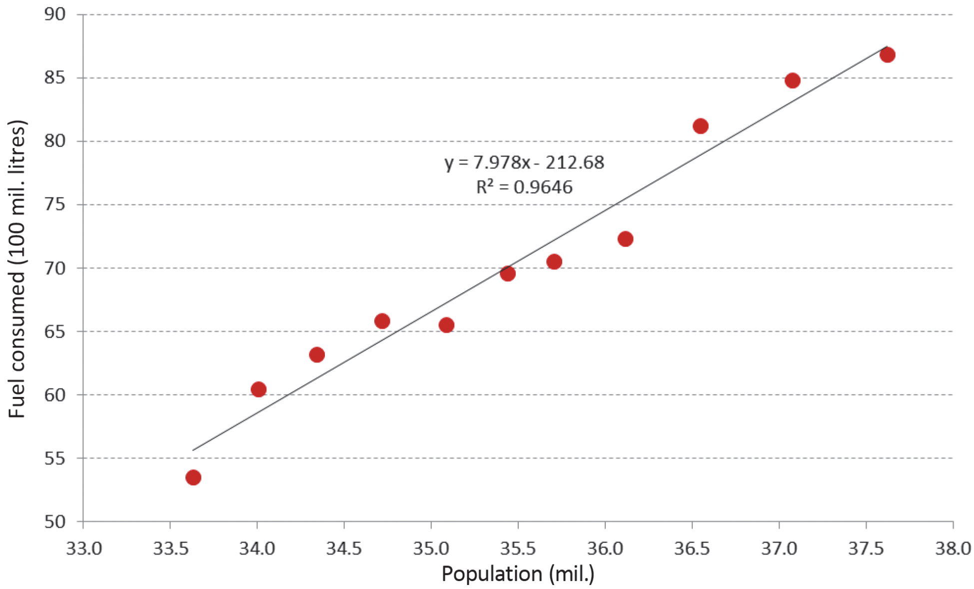

Figure 1: Canadian Aviation Fuel Consumption and Population, 2009-2019

effects are *activity*, driven largely by population; *structural*, e.g. shifts from air travel to travel by train or bus; and energy *efficiency*, i.e. use of technology or policy to reduce energy consumption – and emissions. Aviation sector emissions are strongly linked to activity, with demand expected to grow rapidly through 2030. Historically, activity growth has outpaced efficiency gains associated with new aircraft (IEA n.d.). The sector has been flying into a stiff headwind, yielding increases in energy consumption and GHG emissions, as seen in Canada.

Annual national population is an indicator of activity; more people, more air passenger travel and air cargo movement. Regression analysis of annual turbine-related aviation fuel use in Canada (Statistics Canada 2010, 2015, 2025b), as a function of population (Statistics Canada 2025c) over the eleven years leading up to the pandemic disruption (2009-2019), results in a highly significant relationship (see Figure 1). Note the R-square = 0.9646.

Additional analysis, from 2009 through 2023, excluding the COVID years of 2020 and 2021, yields a positive significant correlation ($F = 12.9$; $p = 0.004$). Using this correlation, along with population projections for the Energy Futures outlook (CER n.d.), yields estimated aviation fuel consumption by 2030 of roughly 10 billion Litres, close to previously projected fuel consumption of 10.6 billion Litres (CER 2023, Figure R4 data). Figure 2 depicts the collapse of civil aviation in Canada during the pandemic (2020-2021) and subsequent recovery, starting in 2022.

Given that improved fuel efficiencies associated with replacement aircraft are overwhelmed by increasing activity, SAF (an energy efficiency effect driver) becomes a good option for emission reduction. In 2022, Canada set an aspirational goal for 10% of aviation fuel to be SAF by 2030 (Transport Canada 2022). Based on conventional fuel projections, this requires about one billion Litres of SAF by 2030; an amount consistently noted by the Canadian Council for Sustainable Aviation Fuels or C-SAF (Allan *et al*. 2023). Currently, Canada is nowhere near this volume. The Rocky Mountain Institute suggests that by 2030 more than 85% of SAF will come via the hydrogenated esters and fatty acids (HEFA) pathway (Shams et al. 2024), which could include conversion of canola. These factors imply that SAF using canola can be a viable contributor to emission reductions in Canada.

Addressing Constraints

To achieve its ambitious goals, Canada needs to reduce GHG emissions. However, the country faces unprecedented trade threats and tariffs, which have eclipsed public concerns about the environment (Hussain 2025). This combination leads to consideration of liquid renewable fuels as an option, in particular SAF for aviation. To move forward with SAF produced from canola, two critical obstacles must be addressed: (1) current federal government incentive policies and (2) requirements of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Compared to SAF, renewable diesel is a more commonly available product, with relative price compared to conventional diesel varying regionally, either positive or negative, based on recent Department of Energy data from the U.S. (DOE 2025). The price of SAF, on the other hand, tends to be higher than conventional fuel. Information from Europe and North America suggests SAF costs are roughly twice that for conventional fuel, though mostly because production volumes are still very small (Airlines for America n.d., European Union Aviation Safety Agency 2025, Parolini et al. 2025). High costs and

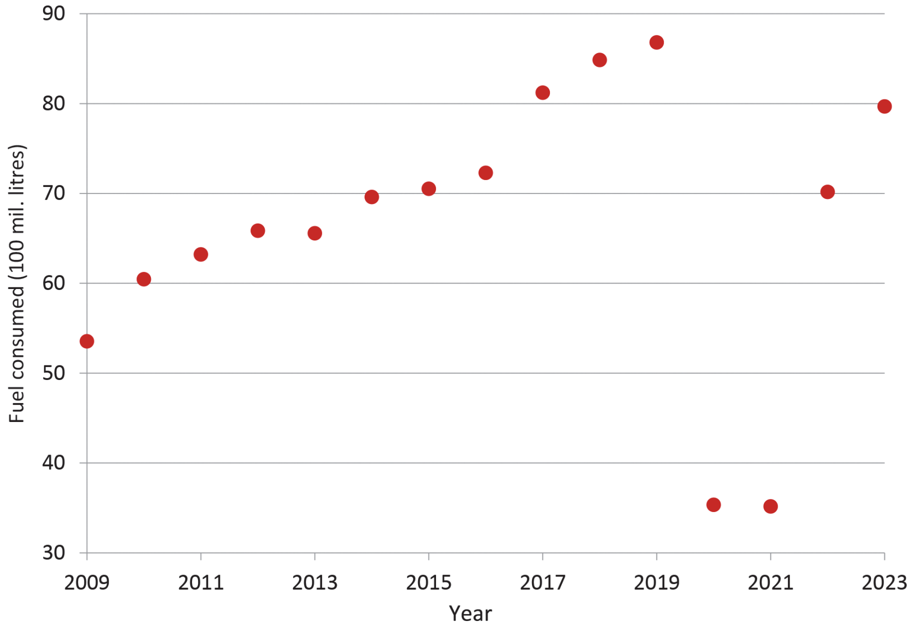

Figure 2: Canadian Civil Aviation – Pandemic Collapse and Recovery

market uncertainties imply that incentives are needed to address investment risks and encourage production.

However, incentives should to be tailored to suit projects. In the U.S. under the IRA, which seems to still be in place, production tax credits (PTC) are available for SAF and renewable diesel. Canada lacks comparable incentives. Incentives roughly matching those for renewable biofuels under the IRA translate to $100 to $170 per tonne (USD). These are within the range of $70 to $190 per tonne reduction (USD) identified by the Specific Mitigation Opportunities Working Group (2016) for middle-distillate fuel-related reductions. Thus, these incentive levels seem reasonable, and worth pursuing. Further work is underway to understand differences in incentives and their effects, as well as developing and proposing a suite of incentives.

Regarding the second obstacle, compliance with stringent CORSIA requirements, this system was initially established in 2016 under the International Civil Aviation Organization (Liao et al. 2022). The intent was to develop a global market-based set of practices for international aviation, which could include offsets, technologies, operational improvements and SAF to address carbon footprints. CORSIA includes a framework for evaluating SAF reduction potential, and confirming compliance for allocation of credit (Prussi et al. 2021). The CORSIA threshold requires demonstrating a minimum 10% reduction.

CORSIA evaluations are based on lifecycle analyses (LCA), expressed as g CO_2e per MJ energy content. A series of "default" LCA emissions values are provided, with oilseed crops assigned less-favorable reduction values, partly due to indirect land use change (ILUC) impact estimates. While the CORSIA process is complex, it allows proponents to submit detailed evaluations of LCA emissions, rather than relying on the defaults.

Addressing CORSIA is less important for fuels used domestically, since national inventories, such as Canada's NIR, do not involve LCA (EPA 2016). But CORSIA compliance is essential for export markets. Further work is underway to understand CORSIA and develop approaches relevant to SAF manufactured in Canada from canola.

Conclusions

Canada's changing circumstances, including slow progress on reducing emissions and emerging trade threats, suggest a need to revisit priorities and policies. One important opportunity is using canola, a major oilseed crop, as the feedstock to produce renewable drop-in fuels, e.g. SAF for aviation and renewable diesel. The benefits include: protecting a major and valuable Canadian agricultural sector; creating value-add and employment opportunities in Canada; and facilitating significant reductions in GHG emissions.

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