Sustainable Aviation Fuels: A Canadian Perspective

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The Green Aviation Research and Development Network (GARDN) is a not-for-profit organization primarily funded by the Business-Led Network of Centres of Excellence (BL-NCE) of the Government of Canada and the Canadian aerospace industry. GARDN's mission is to increase the competitiveness of Canada's aerospace industry by reducing its environmental footprint. In 2018, a number of GARDN projects were also funded by the Government of Canada through Natural Resources Canada (NRCan) and Environment and Climate Change Canada (ECCC).

DISCLAIMER

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A4A: Airlines for America

AJF: Alternative Jet Fuel

ASCENT: Aviation Sustainability Center

ATAC: Air Transport Association of Canada

ATAG: Air Transport Action Group

ATJ-SPK: Alcohol-to-Jet Synthetic Paraffinic Kerosene

ATM Project: Assessment of likely Technology Maturation pathways project

BL-NCE: Business-Led Network of Centres of Excellence

CAAFI: Commercial Aviation Alternative Fuels Initiative

CAF: Conventional Aviation Fuel

CAPEX: Capital Expenditure

CARIC: Consortium for Aerospace Research and Innovation in Canada

CBSCI: Canada's Biojet Supply Chain Initiative

CFS: Clean Fuel Standard

CI: Carbon Intensity

CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation

CRIAQ: Consortium de Recherche et d'Innovation en Aérospatiale au Québec

CRIBIQ: Consortium de Recherche et Innovations en Bioprocédés Industriels au Québec

ECCC: Environment and Climate Change Canada

FRL: Fuel Readiness Level

FSRL: Feedstock Readiness Level

FT-SPK: Fischer-Tropsch Synthetic Paraffinic Kerosene

GARDN: Green Aviation Research and Development Network

GGPPA: Greenhouse Gas Pollution Pricing Act

GHG: Greenhouse Gas

HEFA: Hydroprocessed Esters and Fatty Acids

HFS-SIP: Hydroprocessing of Fermented Sugars – Synthetic Iso-Paraffinic Kerosene

HRJ: Hydroprocessed Renewable Jet Fuel

IATA: International Air Transport Association

ICAO: International Civil Aviation Organization

iLUC: Indirect Land Use Change

IP: Intellectual Property

IPCC: Intergovernmental Panel on Climate

Change

ISCC: International Sustainability and Carbon Certification

LCA: Life Cycle Analysis

LCCAF: Low-Carbon Conventional Aviation Fuel

LUC: Land Use Change

MFSP: Minimum Fuel Selling Price

MVR: Monitoring, Verification and Reporting

MSW: Municipal Solid Waste

N2N: Network to Network

NDC: Nationally Determined Contributions

NRCan: Natural Resources Canada

OBPS: Output-Based Pricing System

OEM: Original Equipment Manufacturer

PCF: Pan-Canadian Framework

PM: Particulate Matter

PPP: Public-Private Partnership

RD&D: Research, Development and Demonstration

RED: Renewable Energy Directive

RSB: Roundtable on Sustainable Biomaterials

SAF: Sustainable Aviation Fuel

SAFI: Pan-Canadian Sustainable Aviation Fuel Initiative

SDGs: UN's Sustainable Development Goals

TRL: Technology Readiness Level

WCI: Western Climate Initiative

EXECUTIVE SUMMARY

Nearly 15 years ago, Canada was among the first countries to voluntarily set environmental targets to reduce the carbon footprint of commercial aviation and to pioneer research into the development of sustainable aviation fuels (SAF). Ongoing efforts to reduce greenhouse gas (GHG) emissions from the air transport sector at the federal and provincial levels include a variety of regulatory and policy instruments to incentivize the production and uptake of SAF across Canada.

Since 2009, the Green Aviation Research and Development Network (GARDN) has played a pioneering role in the development of SAF through collaborative research projects where cross-sectoral industrial and academic partners have co-created less-environmentally-impactful ways to travel by air.

Whereas some of the proposed mechanisms analyzed in this white paper can contribute to the development of SAF supply chains from a regional perspective, they will not, by themselves, drive the transition toward commercial deployment of SAF.

Future efforts demand addressing current gaps and opportunities from a collaborative and integrated perspective throughout the following strategic areas: (1) research, development and demonstration (RD&D) and innovation, (2) financing and strategic partnerships, (3) policy and regulations, (4) technical and sustainability certifications, (5) outreach and knowledge transfer, and (6) consortia-building and regional initiatives.

These strategic areas form the basis of GARDN's vision of a Pan-Canadian Sustainable Aviation Fuels Initiative (SAFI Canada), a commercialization roadmap that builds on the principles of the circular economy, strategic eco-design and industrial symbiosis to advance the decarbonization of the Canadian air transport sector through the use of domestically produced SAF.

To operationalize the objectives pursued by SAFI Canada, this document encompasses a set of succinct recommendations for each of the analyzed strategic areas that require further work to bridge the "valley of death" while avoiding the introduction of competition distortions within the aviation sector.

CLIMATE CHANGE: WHAT ROLE FOR SAF?

In October 2018, the Intergovernmental Panel on Climate Change (IPCC) released the *Special report on the impacts of global warming of 1.5°C above pre-industrial levels*[1]. This report estimates an increase of 0.2°C in the average global temperature per decade, largely driven by past and ongoing anthropogenic emissions.

Climate change entails economy-wide risks and impacts for Canada that could overlap spatially and temporally, creating new and exacerbating hazards, exposures and vulnerabilities for Canadians, particularly in the Artic, where communities are at a disproportionately higher risk of the adverse consequences of global warming. This could lead to additional impacts that are difficult to value and monetize, such as the loss of cultural heritage, biodiversity and ecosystems services, among others.

At present, the Government of Canada's mitigation goal to cut national GHG emissions by 30% by 2030 compared to 2005 levels requires more efforts to effectively contribute to limit global warming to 1.5°C (IPCC, 2018). Pathways for Canada consistent with the targets of the Paris Agreement and the UN's Sustainable Development Goals (SDGs) demand prompt and far-reaching transitions of industrial, energy and infrastructure systems, including the transport sector.

Furthermore, the share of emissions from the Canadian aviation sector remains significantly larger than the average global share of 2% (Transport Canada, 2018). In part, this is due to the role

1 The report's full title is *Global Warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

of air transport in supporting Canada's domestic and international trade and to connecting people through its large landmass, particularly to remote communities that can only be accessed by air.

Since 2010, the demand for air transport services in Canada has continuously grown, and despite the annual fuel-efficiency gains from improved technologies, operations and navigation, the total GHG emissions have also increased. In 2017, GHG emissions from domestic and international flights increased by 7.7%—from 19.5 to 21.01 MtCO2e—as a result of a 7.7% increase in the demand for conventional aviation fuel[2] (CAF). This trend is expected to continue, leading to greater GHG emissions than the potential reductions from future fuel-efficiency gains (Transport Canada, 2018).

While transitions of unprecedented scale, predominantly through the electrification of road transport, are underway in several developed and developing countries around the world, the air transport sector will mostly be dependent on the use of SAF to decouple its absolute GHG emissions from the projected sectoral growth in the next few decades.

The International Civil Aviation Organization (ICAO) and the Air Transport Action Group (ATAG) define SAF as alternative jet fuels (AJF) that can be continually sourced in a manner consistent with the preservation of the earth's ecological balance and consistent with social and economic aims (ATAG, 2017). AJF are drop-in aviation fuels that can be produced from biomass (e.g. agronomic and dedicated bioenergy crops, agricultural and forestry residues, algae) and non-biomass feedstocks (e.g. municipal solid waste, coal, natural gas, industrial waste gases) by over 20 conversion pathways, of which five currently hold the ASTM D7566[3] certification for use in civil and military aircraft.

As of April 2018, ASTM also certified an additional conversion pathway under

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2 Fuel consumption by Canadian air carriers was 7.55 billion litres in 2016 and 8.14 billion in 2017.

3 ASTM D7566 *Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons*. Fuels certified under this standard are also compliant with equivalent international standards (e.g. GB 6537, GOST 10227).

standard D1655[4] to include the use of low-carbon conventional aviation fuel (LCCAF) from the co-processing of oil-based feedstocks in existing petroleum-refining infrastructure.

There are a number of reasons for the aviation sector to use SAF to achieve greater GHG reductions beyond those resulting from the implementation of technological and operational measures. First, the current technological barriers to powering aircraft with cleaner energy carriers[5] make air transport reliant exclusively on liquid fuels. Second, even if a technological breakthrough were to become commercially available before 2050, new technological developments in the aviation sector usually take up to a couple of decades before reaching maturity. Third, aircraft in service can only be phased out gradually as they reach the end of their service life, which is estimated between 20 and 25 years on average.

Canada has pioneered and supported ambitious initiatives to advance research and innovation for the production and use of SAF, some of which have been led by the GARDN programs. Overall, these initiatives have demonstrated that most of the technical barriers for the domestic production and scale-up of SAF have been overcome, but a number of economic and policy challenges remain before Canada can enter the commercial-deployment phase.

What are the objectives of this white paper?

The aim of this white paper is to envision a national sustainable-aviation-fuel roadmap that contributes to the efforts of the Government of Canada to reduce the environmental footprint of aviation through the commercial-scale production and uptake of SAF. The document has two main objectives:

The first one is to provide the reader with a comprehensive overview of the accomplishments, the ongoing efforts and the current gaps with regards to furthering the development of SAF in Canada. The analysis builds on a set of recommendations and international best practices that allowed for the identification of six strategic areas relevant to the Canadian context that require further development for SAF to move into the commercial phase.

The second objective of this document is to present GARDN's vision of the Pan-Canadian Sustainable Aviation Fuels Initiative (SAFI). This national roadmap was developed using the six identified strategic areas to advance the commercialization of Canadian-made SAF by integrating the principles of circularity, strategic eco-design and industrial symbiosis.

This white paper is divided into eight sections. The first six sections focus on each of the aforementioned strategic areas for SAF

4 ASTM D1655 *Standard Specification for Aviation Turbine Fuels*. This standard defines properties, specifications, performance characteristics, test and sampling methods, etc., of petroleum-based aviation turbine fuel for civil use (Jet A and Jet A-1).

5 The use of sustainably sourced hydrogen, natural gas and electricity has been proposed, but they require substantial changes to aircraft design and propulsion systems.

development identified by GARDN. These areas are: (1) RD&D and innovation, (2) financing and strategic partnerships, (3) policy and regulations, (4) technical and sustainability certifications, (5) outreach and knowledge transfer, and (6) consortia-building and regional initiatives. Each section briefly presents the reader with a background and the progress achieved as of 2019, then explores current gaps and areas of opportunity based on lessons drawn from GARDN's projects on SAF and from best practices elsewhere.

The seventh section presents Canada's Biojet Supply Chain Initiative Project (CBSCI), a case study that illustrates the successful integration of actions within the six strategic areas analyzed throughout this white paper into a demonstration project for SAF supply using the existing fuel supply infrastructure at Toronto's Lester B. Pearson International Airport.

The eighth section introduces GARDN's vision of the Pan-Canadian Sustainable Aviation Fuels Initiative (SAFI), a national roadmap to support and accelerate the production and uptake of SAF in Canada. In order to facilitate the operationalization of SAFI, this section compiles a set of succinct recommendations for policymakers for each of the six identified strategic areas.

Methodology

The information and data collected for the elaboration of this white paper were sourced from primary and secondary sources. Primary sources include surveys, external consultations and personal communications. Secondary sources include electronic media articles, reports and publications from authoritative international organizations, conference proceedings, etc., as well as a wide array of documents from GARDN's internal archives, including research project reports.

A survey consisting of 28 questions was distributed through GARDN's SAF Community online platform[6] (view *Annex 2*). The survey was made available in English and French, and responses were received between January 8 and 21, 2019. Participation was optional and responses could be submitted anonymously. The survey was sent to 650 individuals and organizations, from which GARDN received 61 responses.

Participating stakeholders include academia, airlines, airports, consulting firms, certification bodies, feedstock producers and suppliers, investors, financial institutions, original equipment manufacturers (OEMs), R&D centres, industrial associations, consortia, and provincial and federal government departments.

Data collection and analysis were followed by consultations with an advisory panel comprised of experts and stakeholders from each component of the supply chain of sustainable aviation fuels in Canada and abroad.

6 Refer to section 5 in this document for detailed information on the SAF Community platform.

1. RD&D AND INNOVATION

For nearly a decade, GARDN has supported Canada's efforts to reduce the air transport industry's carbon footprint through the development of technologies and processes for a quiet, clean and sustainable sector, including five projects on sustainable aviation fuels.

These projects have focused on innovations along the supply chain of SAF in Canada, where the creation of project-specific industrial research consortia has transformed ideas into economic value. It has gathered a community of interest, and, most importantly, it has paved the way toward commercial deployment of SAF.

Furthermore, the active role played by GARDN in the emerging SAF sector has provided us with a deeper understanding of the obstacles and the opportunities faced by stakeholders along each component of the supply chain. Despite the significant achievements in Canada and elsewhere that have been instrumental in accelerating the commercialization of SAF, the establishment of domestic SAF supply chains requires additional collaborative research and innovation.

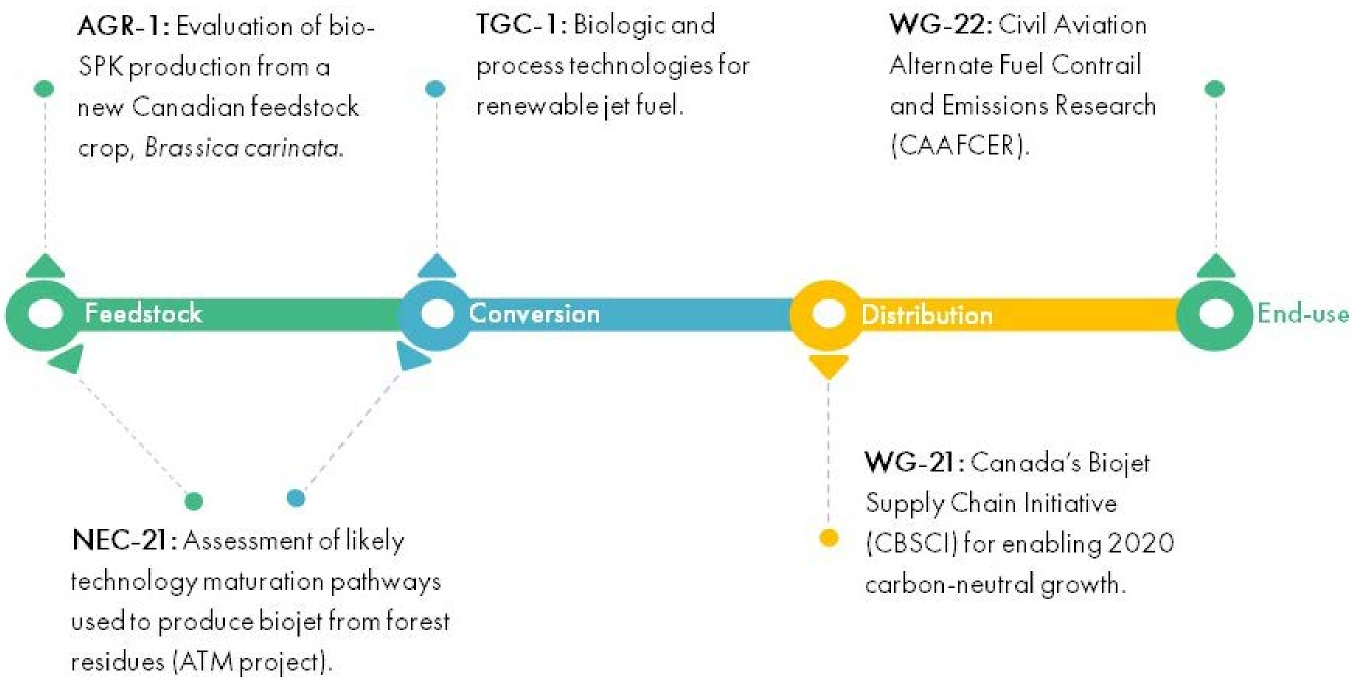
ESTABLISHING THE BASIS FOR A SUPPLY CHAIN

The SAF supply chain spans various sectors, including feedstock production and sourcing (e.g. agricultural and dedicated bioenergy crops, MSW, forestry, biomass), conversion technology, distribution, storage, and end users. The logistics

for the development of a Canadian SAF market demand great effort and coordination, and innovation, network creation and project collaboration among a wide array of stakeholders are essential for success.

GARDN has played a pioneering role in advancing research on SAF and consortia development. Our program has supported a total of five projects (Figure 1) that were intended to accelerate the production of SAF through technology innovation and research, development and demonstration (RD&D).

Figure 1: GARDN projects on SAF



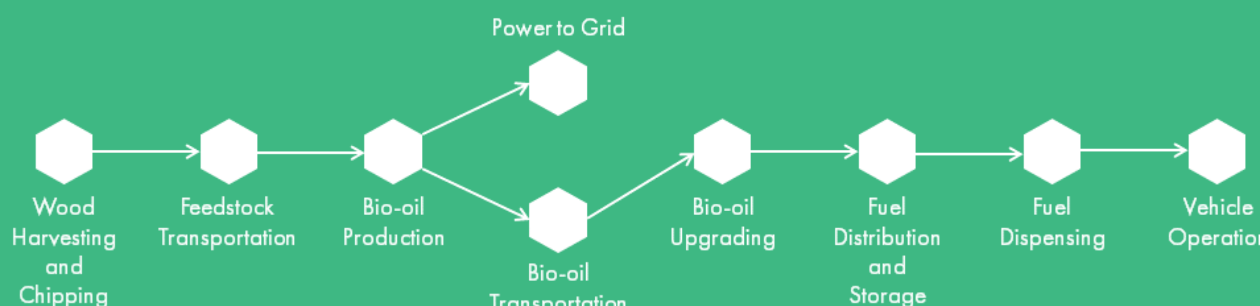
The first two projects undertaken by GARDN, AGR-1 and TGC-1 (Figure 1 and Table 1), aimed to analyze the viability of using SAF sourced from lignocellulosic biomass to power conventional aircraft. The successful demonstrations of those projects opened the way to further research on the conversion of forestry biomass into SAF (NEC-21) by assessing the likely technology maturation pathways. The utilization of lignocellulosic biomass such as forest residues is essential for securing a long-term supply of feedstock for SAF production (Van Dyk, 2019).

GET INSPIRED BY THE ATM PROJECT:

The preliminary results of this project accentuate the importance of an overall sustainability assessment of AJF with a cradle-to-cradle approach to analyzing the whole system's boundaries.

Elements highlighted as having an impact on the potential emission reductions are co-products, hydrogen use and feedstock source. Furthermore, avoided emissions from slash burning in BC could have a significant impact on the life cycle analysis (LCA), if included in the calculations.

The project has shown that "fast pyrolysis and dedicated hydrotreating pathways have produced the highest potential emission reductions of 74% below a fossil fuel baseline." That was achieved by reaching significant milestones in "advancing the knowledge and identifying key challenges of producing biojet fuels through thermochemical liquefaction technologies" pertaining to forestry biomass. Nonetheless, further research is still needed and "pathways evaluated are still being optimised. They don't represent a static state of technology, and therefore improvements can be expected into the future as development progresses" (Van Dyk, 2019).



Furthermore, the introduction of SAF into the existing airport infrastructure was demonstrated at Toronto's Lester B. Pearson International Airport (WG-21). Finally, an assessment of characteristics of persistent contrails formed from petroleum Jet-A1 fuel and a 43% HEFA/Jet-A1 was done under the WG-22 project.

Some of the most remarkable achievements resulting from the GARDN program include:

- The first alternative-jet-fuel-powered commercial flight in Canada (TGC-1)
- The first civilian jet in the world powered by 100% unblended SAF (AGR-1)
- The integration of SAF into the existing fuel-supply infrastructure at a Canadian airport (WG-21)

Table 1: GARDN AJF-related projects

		Partners	Objectives	Project outcomes	Contribution to SAF development
AGR-1	$634,000	Agrisoma, Transport Canada, Applied Research Association, Air Force Research Laboratory	• Conduct the world's first flight on 100% drop-in AJF	• Improvement of 1.5% in specific fuel consumption was noted during steady-state operation • Significant reduction in particulate matter (PM) (up to 25%) and black carbon (up to 49%)	Demonstrated the potential substitution of Jet A1 with AJF: • Commercial-scale production of Canadian-grown industrial oilseed crop *Brassica carinata* • Novel processing of oil feedstock into 100% drop-in AJF • Qualification of fuel performance through systematic evaluation on engines and airframe platforms • Demonstration of fuel performance through flight testing • Technology readiness level (TRL) 4 to 6

TGC-1	$500,000	Targeted Growth, Bombardier Aerospace, Pratt & Whitney Canada, Porter Airlines, Sustainable Oils	• Improve oil quality and yield of *Camelina sativa*
			• Develop technology for efficient conversion of camelina oil to hydroprocessed renewable jet fuel (HRJ)
			• Evaluate low-emission combustor technology with camelina HRJ
			• Evaluate the performance of camelina-derived AJF on-ground and in-flight
			• Progress from TRL 4 through TRL 7
				• 50% reduction in sulfur for 50/50 blend and 30-35% reduction in GHG for 50/50 blend
				• 20% improvement in camelina oil yield
					• Canada's first AJF-powered revenue flight with a Bombardier Q400 turboprop with one wing filled with a 50/50 fuel derived from 49% camelina oil and 1% carinata oil
					• Gained critical knowledge on the impact of fuel on gauging system; >10% improvement of crop yield; first IP submissions were filed for North-American-bred camelina
					• Progressed camelina from batch-scale AJF feedstock (TRL 5) to testing of the most promising varietals with improved processing techniques (TRL 5 to 6)
					• Optimized HRJ source with commercial-scale production capabilities (app. TRL 7)
					• BA and P&WC assessed the material compatibility and performance characteristics of AJF:
					  ○ material compatibility testing (TRL 4)
					  ○ combustion rig test (TRL4-5)
					  ○ engine ground performance, emission, operability (TRL 6)
					  ○ flight test (TRL 7)

WG-21	$1,179,380.8	Air Canada, CAAFI, ASCENT, IATA, National Research Council, Transport Canada, Boeing, SkyNRG, Waterfall Group	• To demonstrate the operational feasibility of AJF in the domestic jet-fuel- supply system using existing delivery infrastructure • Validate Canadian AJF supply chain elements • Catalyze the development of the domestic AJF sector	• AJF has successfully been entered in the co-mingled supply infrastructure of Toronto's Lester B. Pearson International Airport • Fuel sourced from AltAir supplied 22 domestic flights with a 30% blend	It was a first in Canada for AJF to be introduced in the hydrant system of an airport, opening the way for other airports to do the same with high confidence of efficiency without any performance risk. This project provides a major contribution for the Canadian supply chain as feasibility and safety were demonstrated.
NEC-21	$1,445,000	Boeing Canada, University of British Columbia, Bombardier Aerospace, WestJet, NORAM, SkyNRG	To demonstrate that thermochemical technologies (fast pyrolysis, catalytic pyrolysis and hydrothermal liquefaction) and upgrading through hydrotreatment is a feasible and suitable method for AJF production.	• Biocrudes produced through thermochemical liquefaction technologies, including fast pyrolysis, catalytic pyrolysis and hydrothermal liquefaction, can be successfully used to produce a significant volume of AJF • The ATM Project represents a significant achievement in advancing the knowledge and identifying key challenges of producing AJF through thermochemical liquefaction technologies	• The fuel fractions were analyzed with a specific focus on the jet fraction. The quality of the jet fractions met most of the general ASTM D7566 specifications and, with further optimization, all standards could likely be met. • A range of possible emission reductions was demonstrated, with the fast pyrolysis and dedicated hydrotreating pathway producing the highest potential emission reductions of 74% below a fossil fuel baseline. Avoided emissions from slash burning in BC could have a significant impact on the LCA if included in the calculations. • Engineering design for a 200bbl/day demonstration scale facility that could produce enough jet fuel, up to a 10% blend, for up to 10 medium-haul flights per day. • From an economic perspective: the greatest sensitivity of net present value analysis is feedstock cost (among biocrude CAPEX and hydrogen cost).
WG-22	$648,440	AC, Boeing, Waterfall Group, SkyNRG, University of Alberta, Argonaut, National Research Council	Compare the characteristics of persistent contrails formed from petroleum Jet A1 fuel and a 43% HEFA/JetA1 AJF blend.	For the 43% HEFA/Jet A1, the contrail ice-particle number correlated inversely with fuel hydrogen content and, to a much lesser extent, directly with fuel sulphur content.	AJF have higher hydrogen and lower sulfur contents, which leads to a reduced size of contrail ice particles. At a 43% HEFA blend, contrail ice particles were approximately 10% smaller than those in for 100% CAF contrails.

To quantify the emission reductions of those projects with an LCA approach, the environmental assessment of the entire GARDN II research portfolio was carried out by a third party named Groupe Agéco in collaboration with CIRAIG (International Reference Centre for the Life Cycle of Products, Processes and Services), both experts in the field.

The assessment concludes that "The overall contribution of GARDN II projects to reduce the environmental footprint of the Canadian aerospace industry is significant. [...] this study found that the technologies under study have the potential to contribute with 27% of the Canadian aviation GHG target of neutral growth in 2030. Approximately 98% of that reduction is attributed to SAFs." (Groupe Agéco; CIRAIG, 2019)[7]

Collaborative approach

The GARDN program uses a rigorous process for project selection and monitoring by a group of experts sitting on the GARDN Scientific Committee. The main responsibility of this committee is to provide scientific and managerial support on each project. Furthermore, the GARDN Integration Committee enables discussions of common issues and facilitates coordination between the overall portfolio of projects. GARDN's governance structure is an asset for network management given the complexities of establishing more ambitious innovation programs and managing cross-sectoral relationships.

The Canadian private sector, national research centres, universities and international organizations play an essential role in the GARDN network. Each of the stakeholders has a critical role in advancing the technology development toward more sustainable air travel. Together, they have a unique ability to strengthen the Canadian RD&D capability in the field of green aviation—one that is recognized worldwide. From our perspective, the collaborative cross-sectoral network approach to fostering the development of new technologies is necessary because no single company can meet the required environmental goals alone.

LONG-TERM VISION FOR INNOVATION AND RD&D

In the long term, innovation and RD&D efforts are one of the most important drivers in helping Canada decarbonize its activities and develop more sustainable products and services. Creating a carbon-neutral world is a highly ambitious and challenging goal, but we are convinced that with an integrated approach between private and public sectors, Canada could become a world leader in the low-carbon-energy transition.

Based on our experience, there are a few elements that should be taken into consideration when developing a national innovation strategy for newly emerging sectors like SAF. The assessment of the Canadian context and its stakeholders helps us to better understand the innovation gaps and what kind of business collaboration is needed to foster the RD&D efforts. We believe

7 For further information on the main findings, refer to Annex 1.

that non-conventional feedstock resources and feedstock-agnostic conversion technologies are the most promising areas to decrease emissions in the long run.

There is still a need to invest in ongoing feedstock research, such as non-food crops, municipal solid waste, forestry waste and lignocellulosic biomass. However, we believe that RD&D should include a broader range of feedstock sources to ensure the long-term sustainability of SAF production.

Feedstocks

The real and perceived risks around various types of feedstocks are some of the biggest challenges faced by the SAF sector. First, each conversion process has technical input specifications; a consistent quality of feedstocks is difficult to achieve (pre-treatment operations). Second, many sectors are shifting their strategies to integrate more sustainable raw materials into the production process, saturating the market rapidly and compromising the availability of low-carbon feedstocks.

Even though Canada is one of the best-positioned countries in terms of feedstock abundance from its agricultural and forestry sectors[8], affordability and quality of the feedstock supply are still likely to be the most severe limitations faced by Canadian SAF production in the long term. Hence, the industry cannot rely on a single feedstock. Some feedstocks are better suited to some climates and locations than others; for this reason, a wide portfolio of AJF sources and a variety of regional supply chains are ultimately expected to be developed (GARDN Conference, 2018).

With the ambition to build a long-term vision for Canadian innovation in this field, RD&D efforts should be focused on the feedstock sources for conventional and advanced alternative fuels that are the most environmentally and economically sustainable for achieving carbon neutrality.

Conventional and advanced alternative fuels are defined differently in different countries[9] and regions; however, two criteria are commonly used to distinguish them: (1) a ≥50%GHG reduction potential compared to their fossil counterpart (e.g. gasoline), and (2) the use of feedstocks that do not directly compete with food.

Several advanced alternative fuels remain at the demonstration stage and require additional funding for industry-led collaborative research. Let's consider algae: these are fast-growing organisms that do not require arable land, as agricultural and dedicated crops do. One of the examples of how the production of SAF along with seafood brings benefits to economy,

8 A little less than half of Canadian forest is independently certified as sustainably managed, representing close to 40% of the world's certified forests, far more than any other country. Canadian forest lands represent about 9% of the world's forest (NRCan, 2016).

9 The Canadian Renewable Fuels Regulations do not distinguish between conventional and advanced alternative fuels, but it provides a list of eligible feedstocks for fuels to be considered renewable that include food and non-food crops, dedicated bioenergy crops and biogenic and non-biogenic residual materials (Renewable Fuels Regulations, SOR/2010-189).

environment and food security is Abu Dhabi's ambitious Seawater Energy and Agriculture System (SEAS). Under this project, Etihad Airways successfully operated the first commercial flight partially fuelled by locally produced biofuel derived from plants grown in saltwater on January 15, 2019. Furthermore, some species of microalgae that contain oil suitable for SAF production—amounting to up to 80% of their dry body weigh—can be grown using waste waters (Schlagermann, 2012).

The production and quality of algae feedstocks could be more consistent if they were grown in more controlled environments, such as photobioreactors. These attributes make algae a suitable renewable source of alternative fuel production, despite the prevailing challenges of scaling this technology, including process contamination, intensive use of fertilizers and water, and high production costs. From our perspective, further RD&D on algae holds many opportunities as a long-term feedstock for a pan-Canadian SAF roadmap.

Other promising types of drop-in alternative fuels with potential to replace CAF include: electrofuels, photobiological solar fuels, carbon sequestration and densification. Of the latter, there is already a know-how and a developing infrastructure with strong potential for larger-scale production of synthetic fuels made from sequestered atmospheric carbon (Carbon Engineering, 2019). However, further funding is needed to scale these technologies.

The most common method for estimating the technology maturity of a fuel pathway is the technology readiness level (TRL). Based on the work undertaken by GARDN in SAF-related RD&D activities, the TRL method is not equipped to properly examine feedstocks and technology requirements. Based on the exemplary work done by the Commercial Aviation Alternative Fuels Initiative (CAAFI) in the US, more extensive use of various tools and methods specifically designed for SAF feedstocks in Canada is required. The examples of such tools are: feedstock readiness level (FSRL), fuel readiness level (FRL) and environmental progression (CAAFI, 2019).

Conversion technology

As mentioned earlier in this report, there are currently five AJF conversion pathways certified under ASTM D7566 for use in civil and military aircraft and one certified under ASTM D1655 that includes the use of LCCAF from the co-processing of oil-based feedstocks in existing petroleum-refining infrastructures. These conversion pathways are:

ASTM D7566 *Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons*:

1. FT-SPK (Fischer-Tropsch Synthetic Paraffinic Kerosene). Biomass is converted to synthetic gas and then into bio-based aviation fuel. Maximum blending ratio is 50%.
2. FT-SPK/A is a variation of FT-SPK, where alkylation of light aromatics creates a hydrocarbon blend that includes aromatic compounds. Maximum blending ratio is 50%.

3. HEFA-SPK (Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene). Lipid feedstocks, such as vegetable oils, used cooking oils and tallow, are converted using hydrogen into green diesel, and this can be further separated to obtain alternative aviation fuel. Maximum blending ratio is 50%.

4. HFS-SIP (Hydroprocessing of Fermented Sugars – Synthetic Iso-Paraffinic Kerosene). Using modified yeasts, sugars are converted into hydrocarbons. Maximum blending ratio is 10%.

5. ATJ-SPK (Alcohol-to-Jet Synthetic Paraffinic Kerosene). Dehydration, oligomerization and hydroprocessing are used to convert alcohols (currently ethanol and iso-butanol) into hydrocarbon. Maximum blending ratio is 50%.

ASTM D1655 *Standard Specification for Aviation Turbine Fuels.*:

- Co-processing. Feedstocks consisting of mono-, di- and triglycerides, free fatty acids and fatty acid esters, including hydroprocessed synthesized kerosene up to 5% by volume in conventional petroleum-refinery processes.

The fuel readiness level (FRL) depends on the RD&D efforts undertaken previously and may vary for each country. The following table gives an example of the maturity levels of different pathways in Europe. The TRL (method of estimating a technology maturity) and FRL (provides guidance on fuel technical development and certification testing) assessment of Canadian conversion technologies will be required to ensure the most efficient knowledge transfer to foster the development of SAF worldwide.

The quality and affordability of feedstock are perceived as huge risks by the technology developers. A conversion facility must have a long lifespan and if there is no guarantee on the availability and acceptability of feedstock used in the process, the business case for a commercial-scale facility of many conversion technologies would quickly become problematic and the developed technologies obsolete.

We believe that the best way to mitigate this risk is to focus on feedstock-agnostic conversion technologies. Is it possible to build a facility producing SAF from various sources of feedstock simultaneously? The answer is yes, it is possible, but it requires great effort and coordination across different stakeholders, including the public sector, to facilitate the development of such technologies. In the shorter and medium term, a feedstock-agnostic technology that is oriented to converting multiple sources within the same type of feedstock (e.g. multiple sources of lipids or multiple sources of grasses) is likely to be a better first approach in terms of development timelines and costs. However, in a long-term perspective, we envision the emergence of an innovative conversion technology that processes various types of feedstocks simultaneously (e.g. lipids and grasses). The main advantage of this concept is the resilience and flexibility of such conversion facilities. Its implementation would not depend on location, the type of feedstock available, or even the season, which would help decrease financial risks for the parties involved by providing a consistent and stable supply of feedstocks.

In terms of solid feedstocks, such as dry forest biomass, the GARDN ATM Project represents a significant achievement in advancing the knowledge and identifying key challenges of producing SAF through thermochemical liquefaction technologies.

From our perspective, developing and funding feedstock-agnostic conversion technologies is more sustainable and conveys less risks in the long-term than supporting feedstock-specific technologies. It's about building a shared vision, applying creative business innovation strategies and collaborating all together for a faster development.

Co-processing

Before realizing economies of scale, the costs of the SAF sector creation and establishment constitute a real barrier to its development. At the end-user segment of the aviation fuel market, SAF are in competition with conventional jet fuel, a 100-year-old industry with already amortized facilities.

The results of the SAF survey conducted by GARDN indicate that a means to introduce renewable content into Canadian conventional aviation fuels (CAF) prior to establishing a dedicated SAF capacity is the use of LCCAF from co-processing of up to 5% of lipid-based content. In co-processing, biologically derived lipids are refined with petroleum fractions to produce refinery products that include renewable content; middle distillates produced in this manner would partially contain renewable content (CBSCI, 2019c). This means using existing infrastructure from the petroleum-refining industry to produce and supply LCCAF.

This, in effect, allows further work on existing technologies that can be more easily developed in partnership with oil and gas companies and their established plant capacity. It is important to note that the fuel produced by co-processing is not an alternative jet fuel but a conventional aviation fuel with a lower carbon content due to the biogenic portion refined along with crude oil. However, further research has the potential to increase the renewable content in the fuel mix, progressively leading to greater carbon reductions.

Table 2: TRL and FRL of the six production pathways certified by ASTM for use in commercial flights (EASA, 2019)

Process	Acronym	Technology Readiness Level (TRL)	Fuel Readiness Level (FRL)
Fischer-Tropsch Synthetic Paraffinic Kerosene	FT-SPK	6-8	7*
Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics	FT-SPK/A	6-7	7
Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene	HEFA-SPK	9	9
Hydroprocessing of Fermented Sugars – Synthetic Iso-Paraffinic Kerosene	HFS-SIP	7-8	5-7
Alcohol-to-Jet Synthetic Paraffinic Kerosene	ATJ-SPK	6-7	7
Co-processing biocrude up to 5% by volume of lipidic feedstock in petroleum refinery processes	Co-processing	7-8	6-7

*FRL for coal is rated at 9.

2. FINANCING AND STRATEGIC PARTNERSHIPS

While creating strategies that make the most sense for the innovation and the development of the Canadian SAF industry, it is important to remain creative and apply diversified tools to finance the entire supply chain simultaneously. The establishment of a Canadian SAF supply chain cannot be accomplished without financial and strategic support from the public sector and the federal government.

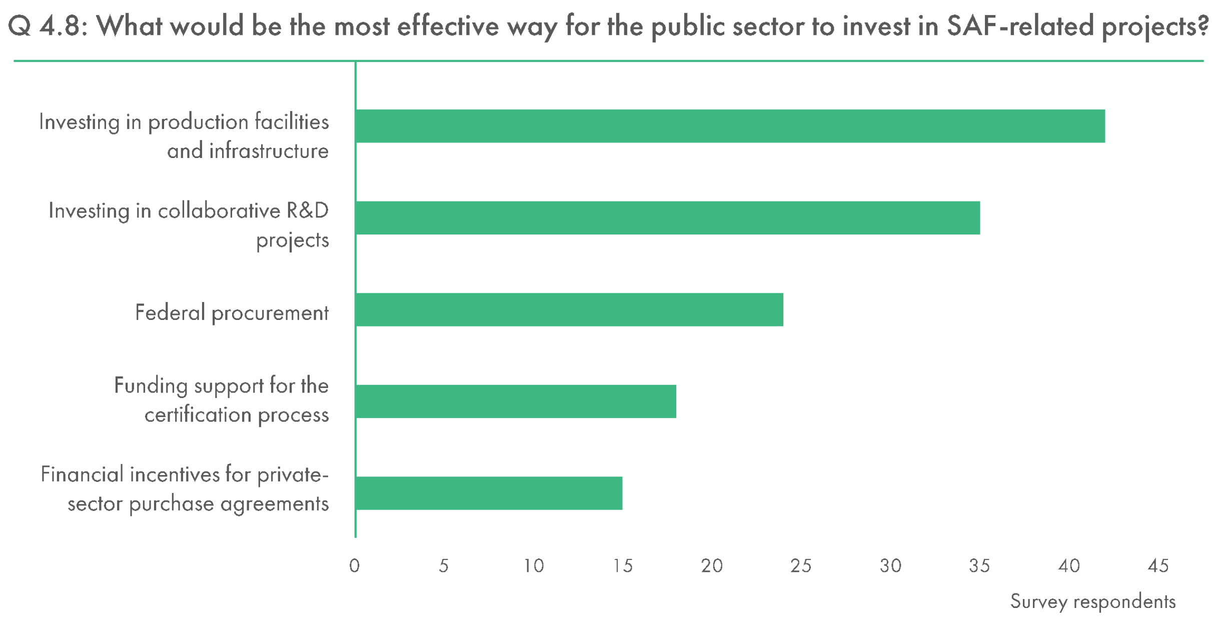
Furthermore, while GARDN's funding model was effective and its research projects reached their goals, other innovative models of financing, such as challenges, crowdfunding and offtake agreements, should be considered to welcome the participation of more stakeholders who are keen on contributing to this emerging Canadian sector.

PUBLIC SUPPORT

Financing the SAF industry is one of the main challenges and investors see many risks related to the scale-up of this sector. The complexity of the SAF industry requires a holistic approach to create an effective long-term financial strategy. Although the integrated national strategy for Canada to finance its SAF industry is yet to be developed, our community has already expressed a few ideas on how the public sector can further support the expansion of the SAF industry in Canada.

Based on the survey conducted by GARDN in January 2019, investing in production facilities and infrastructures, funding collaborative research and development projects, and federal

Figure 2: Survey results: how can public sector invest in SAF?



procurement would be the most effective ways for the public sector to strengthen the SAF industry in Canada. Additionally, to progress each of the business stages toward commercialization, the implementation of a framework to support the development of research laboratories, demonstration and pre-commercial facilities is imperative.

Providing financial support for the certification process and other incentives for private-sector purchase agreements were also identified as effective ways to enhance the SAF industry growth in Canada. One of the main conclusions that could be drawn from the community survey is the need for an integrated and holistic approach to public support for business innovation and financing.

Based on our experience and international successes in the field, the most promising policy and regulatory frameworks are those that create enabling conditions for strong public-private partnerships, the co-financing of collaborative projects and enhanced financial support.

STRATEGIC PUBLIC-PRIVATE PARTNERSHIPS (PPP)

Due to the prevailing policy uncertainty and the cost differential between CAF and SAF, the oil and gas sector still perceive the shift to low-carbon aviation fuels as too high a risk for the required level of investment without public support. Furthermore, the SAF sector is only starting to emerge in Canada, so it requires high levels of initial financing for RD&D, infrastructure, logistics, certification, etc. Based on the experience in other industrial sectors, public-private partnerships (PPPs) are essential to fostering the production and consumption of more sustainable products and services. There are various types of partnerships that could help develop the SAF sector in Canada.

The federal procurement mentioned previously is one example. Federal purchase agreements will both help the Canadian government to achieve its emission-reduction targets and create an important precedent, encouraging the production of the first significant volumes of SAF in Canada. The guarantee of first buyer will, as learned from international experience in Europe and the US, de-risk further private investments in this sector. Also, best practices worldwide suggest expanding the scope of PPPs to include the development of regional SAF production facilities, biohubs and bioports. The widespread application of industrial symbiosis principles—including the integration of renewable energies and the supply of SAF at the airport level—within the aviation sector increases chances of reducing the environmental footprint of air transport operations while driving local economic growth.

As the advantages of encouraging SAF regional supply chains accrue at multiple levels, it is appropriate and efficient to split the costs of initiatives of this kind among federal, provincial, and municipal governments as well as airport authorities, airlines and other relevant stakeholders.

The territorial commitment to the reduction of emissions on the aeronautic platform in Toulouse (DEMETER Project) is one example of a biohub

GET INSPIRED FROM OTHERS: KLM CORPORATE BIOFUEL PROGRAMME

The fuel cost represents the largest element of an airline's operating cost and, thus, is the single most important driver in purchase agreements for airlines. To finance the higher cost of SAF, the Dutch company KLM has come up with an inspirational approach. In 2012, to enable the use of SAF on a commercial scale, the company started the **KLM Corporate BioFuel Programme**, a 13-year initiative with two main objectives:

1. reduce GHG emissions from aviation
2. financially de-risk SAF investments

The program is designed for large companies with an ambition to reduce their environmental footprint from business travel. Under this program, business travellers from the private and public sectors would cover the SAF premium cost to allow KLM to purchase higher volumes of SAF. SkyNRG, certified by the Roundtable on Sustainable Biomaterials (RSB), partners with KLM on the logistics, purchase and distribution of SAF. Accenture, CBRE Global Investors, the City of Amsterdam, Heineken, Nike, Philips, the Dutch Ministry of Infrastructure and the Environment, the Schiphol Group and many others have joined the KLM Corporate BioFuel Programme to increase their environmental responsibility by paying the SAF premium cost.

Consequently, this initiative constitutes a win-win opportunity for every stakeholder:

- The airline can finance the purchase of higher volumes of SAF without impacting its razor-thin profit margin
- Fuel producers can scale up more comfortably by knowing beforehand what quantity is required by the airline
- The program users reduce the environmental impact of business travel and improve their corporate-responsibility profile.

and the resulting extended partnerships between local public and cross-supply-chain private partners, such as the Occitanie Region, the City of Toulouse, Airbus, the Regional and Local Chambers of Commerce, Toulouse Airport, Total, Suez, Safran and Air France (AIRBUS, 2017). The concept of establishing local biohub and bioport initiatives is gaining popularity in many other locations around the world, such as Oslo, Alabama, Rotterdam and Seattle. We believe there is an important opportunity for Canadian airports, especially those in remote communities, to consider these kinds of PPPs and the creation of local bioports. More information on bioports can be found in Chapter 6: Consortia building and regional initiatives.

Another example of PPPs aiming to foster the development and commercialization of SAF is the Farm-to-Fly and Farm-to-Fly 2.0 initiatives between the U.S. Department of Agriculture, Transportation Department's Federal Aviation Administration, aviation trade organisation Airlines for America (A4A), aircraft manufacturer Boeing and CAAFI. The main objective of these partnerships is to increase the nation's supply of SAF with the end goal of producing high volumes of drop-in sustainable aviation fuel by fostering the development of various state initiatives simultaneously. Both programs (Fly to Farm and Farm-to-Fly 2.0) are now wrapped up.

SKY'S THE LIMIT CHALLENGE[10]

The Sky's the Limit Challenge was created to stimulate the development of a SAF supply chain to further reduce the Canadian aviation industry's GHG emissions and lower its environmental footprint. This Challenge is part of Natural Resources Canada's $75-million initiative to launch five clean-tech challenges to drive innovation and accelerate the clean-growth economy under the Impact Canada Initiative. The Challenge consists of two competitions open to a range of innovators and includes significant prize money:

- First, the Green Aviation Fuels Innovation Competition provides $2 million apiece for four teams to develop the most innovative solutions, which, in turn, will support their next endeavour: an 18-month competition to produce the most economical and environmentally sustainable aviation fuel and win the $5 million grand prize.
- Second, the Cross-Canada Flight Competition, in which the first participant to fuel a Canadian commercial flight using a minimum 10% blend of made-in-Canada SAF will win $1 million.

NRCan has engaged a wide range of partners to support a SAF supply chain in Canada. Among those, WestJet and Air Canada will play key roles by serving as carriers for the Cross Canada Flight Competition. NRCan has also partnered with GARDN to promote the challenge, engage with its community and facilitate participation. The Challenge is expected to foster research into new feedstock sources and refining processes as well as de-risk public and private SAF investments in Canada.

A similar challenge initiated by Alberta Innovates and WestJet is focused on developing a provincial SAF supply chain in Alberta: the WestJet Aviation Biofuel Challenge. We believe that these challenges, with overlapping timelines, are complementary. To de-risk private and public investments, a coordinated approach between federal and provincial innovation programs is essential.

The Sky's the Limit Challenge has set into motion GARDN's online platform, SAF Community, by creating its first content elements and bringing together the potential applicants as platform users. Launching the community with a webinar presenting the Challenge was an obvious move to keep the great momentum and give substance to the incipient community online. The Challenge is also a great opportunity for GARDN to be in the front seat and participate in the creation of a Canadian SAF supply chain as the outcome of its community collaboration.

10 Detailed information about the Challenge can be found on the Impact Canada website: https://impact.canada.ca/en/challenges/green-aviation

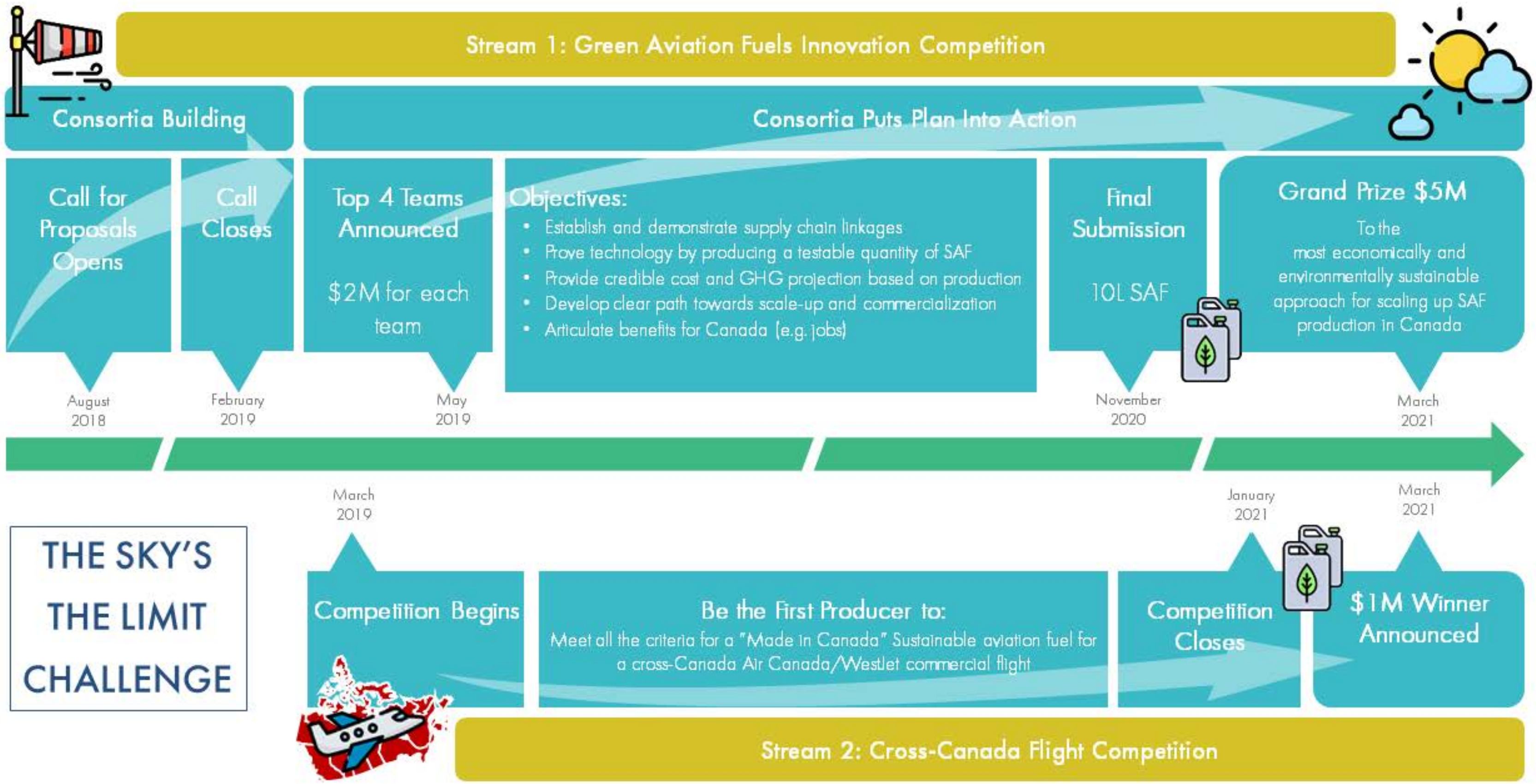
"This challenge will spur innovation to help the aviation industry reduce its carbon intensity in getting Canadians where they want to go."

— Geoffrey Tauvette, Westjet

"I am amazed to see the progress in the status of sustainable aviation fuels over these past few years and, in particular, the past year with the announcement of the Challenge."

— Ira Wolff, NORAM Engineering

Figure 3: Overview of the Sky's the Limit Challenge



3. POLICY AND REGULATIONS

The design and implementation of policies and regulations to support initiatives like The Sky's the Limit Challenge and the WestJet Aviation Biofuel Challenge are essential for the development of domestic SAF supply chains.

Canada's efforts to reduce its GHG emissions from the aviation sector date back to 2005, when Transport Canada and the Air Transport Association of Canada (ATAC) signed a voluntary agreement to annually improve by 1.1% increments through to 2020 the average fuel efficiency from domestic and international aviation compared to 1990 levels.

This agreement was followed by two major international landmarks: (1) the ratification of the Copenhagen Accord in 2009, in which Canada committed to reducing its national GHG emissions by 17% by 2020 compared to a 2005 baseline, and (2) also in 2009, the setting of carbon-emission-reduction targets for international aviation[11] by the International Air Transport Association (IATA), two of which were endorsed in 2010 by the International Civil Aviation Organization (ICAO) at its 37th Assembly.

These national and international commitments were later included in *Canada's Action Plan to Reduce Greenhouse Gas Emissions from Aviation*[12], a federal initiative submitted by Canada in 2012 in fulfillment of ICAO's 37th Assembly resolution A37-19. The Action Plan increased the original fuel efficiency target from 1.1% to 2% per year through 2020 compared to 2005 levels and incorporated a set of operational and technological measures to address carbon emissions for both domestic and international aviation activities.

Whereas GARDN had been conducting RD&D

11 The targets consist of: (1) increasing the annual average fuel efficiency by 1.5%, (2) achieving carbon-neutral growth by 2020 and (3) halving the sector's emissions by 2050 compared to 2005 levels.

12 From now on referred to as "the Action Plan".

on sustainable aviation fuels for nearly half a decade already, the Action Plan was the first policy document to acknowledge the role of SAF in cutting aviation's emissions and to financially support RD&D as part of several ongoing federal programs at the time, such as the ecoENERGY Innovation Initiative, the Program of Energy Research and Development, the SD Tech Fund™ and the NextGen Biofuels Fund™.

Following the signing of the Paris Agreement in 2015, the Government of Canada set a more ambitious national GHG reduction target of 30% by 2030 compared to the 2005 baseline as part of its nationally determined contributions (NDC) to limit global warming to 1.5°C above pre-industrial levels. This goal lies at the core of the Pan-Canadian Framework on Clean Growth and Climate Change, launched in 2016, a country-wide approach to transitioning to a low-carbon resilient economy.

CURRENT POLICY EFFORTS AND GAPS ON SAF

The Pan-Canadian Framework (PCF) recognizes the potential of SAF to achieve greater GHG emission reductions than other technological and operational measures undertaken by the aviation sector; however, there are currently no programs, incentives or regulations for SAF equivalent to those for alternative fuels in the road transport sector. This is a largely unrecognized factor despite the fact that domestic air travel, like road transport, falls within the category of domestic emissions for target-setting purposes.

This regulatory and policy uncertainty has been instrumental in deterring investment in SAF supply chains in Canada. Furthermore, most federal and provincial programs that support research and development of alternative fuels have either expired or are set to expire post-2020.

Public- and private-led commercialization initiatives such as NRCan's Sky's the Limit Challenge and WestJet's Aviation Biofuel Challenge will not, by themselves, drive the creation of SAF markets in Canada. This is also true of the Pan-Canadian approach of carbon pricing, as the proposed mechanisms do not individually provide a competitive advantage to SAF against other alternative fuels that can be used to comply with the existing federal and provincial mandates.

"The backstop": a pan-Canadian carbon levy

The Greenhouse Gas Pollution Pricing Act (GGPPA), enacted in 2018, introduced a carbon-pricing system ("the backstop") in provinces and territories that fall below the minimum federal requirements. The GGPPA covers GHG emissions from aviation in all the backstop provinces[13] but not the territories[14]. The carbon tax is scheduled to come into effect as of April 2019 in Saskatchewan, Manitoba, Ontario and New Brunswick, and it will be applicable to CAF used in intra-provincial

13 Pricing on CAF in Nova Scotia and Prince Edward Island is pending.

14 Due to the high cost of living, the existing challenges with food security and the high reliance on air transport, the Yukon, Nunavut and the Northwest Territories are exempt from the carbon levy on CAF.

Table 3: Carbon levy applicable to backstop provinces (Department of Finance Canada, 2019)

	2019	2020	2021	2022
Charging rate ($/tonne CO_2)	20	30	40	50
CAF charging rate ($/L)	0.0516	0.0775	0.1033	0.1291

flights. Table 3 presents the CAF charge rates applicable under the GGPPA:

Whereas British Columbia, Alberta and Quebec have their own carbon-pricing systems[15], the levy's rate and point of compliance on CAF differ between BC and AB, and Quebec's cap-and-trade entirely excludes emissions from aviation[16]. This presents a few issues:

First, the differences between the backstop provinces and those with existing carbon-pricing systems on CAF do not address the potential financial impacts of intra- and inter-provincial flights, which could disproportionately damage local air carriers and airports.

Second, SAF is not exempt from federal and provincial (BC and AB) carbon levies as ethanol, biodiesel and renewable diesel are when blended above the mandated levels. Although SAF would remain eligible to generate credits under the liquid stream of the Clean Fuel Standard[17] (CFS), the carbon tax would lead to an increase in the premium on CAF, which historically sells at a discount to other conventional fuels.

To exemplify this, the techno-economic analysis conducted as part of the NEC-21 project to assess the technology maturation pathways for AJF from forest residues in British Columbia (see Figure 1 and Table 1) showed a minimum fuel selling price (MFSP) between CAD$1,724 and $3,926 per metric tonne or CAD$1.37 and $3.11 per litre of alternative fuel[18] for the different conversion pathways. Based on the current average price in Canada of CAD$855.25/MT of CAF, a premium of CAD$963/MT would be required for the AFJ conversion pathway with the lowest MFSP (Van Dyk, 2019). Even if the premium is reduced to CAD$481/MT as a result of the credits generated under the BC Low-Carbon Fuel Regulations, the BC carbon levy would increase the premium on CAF by approximately CAD$98.65/MT[19] for intra-provincial flights.

15 Pricing on CAF in BC and AB will continue to raise up to $50/tonne CO2 to meet the federal requirements by 2022. Presently, Quebec does not have a carbon levy on CAF.

16 Quebec's emissions trading system has been linked to California's since 2014 as part of the Western Climate Initiative (WCI), which also excludes aviation fuels from the trading scheme.

17 The Clean Fuel Standard will allow compliance credits to be generated as of the date of publication of the final regulations in 2020.

18 Conversion factor of 1,260 litres of CAF per metric tonne.

19 As of March 2019, the BC carbon tax imposes CAD$0.0783 per litre of CAF on flights within the province. Inter-provincial and international flights are exempt from the levy.

Third, it is estimated that the federal carbon-pricing scheme could leverage from $133M in 2019 to up to $333M in 2022 (CBSCI, 2019d). However, the revenues generated are not expected to fund mitigation or adaptation measures in the aviation sector[20] despite the current financing needs to support SAF off-take agreements, RD&D, development of bioports and biohubs, etc.

Carbon intensiveness and the Clean Fuel Standard (CFS)

Under the current Regulatory Design Paper for the Clean Fuel Standard (CFS), lower-carbon-intensity liquid fuels are expected to contribute with 23 out of the proposed reduction goal of 30 $GtCO_2$ by 2030. This regulatory instrument aims to complement the PCF's approach to carbon pricing by reducing the carbon intensity (CI) of CAF on a life cycle basis. The liquid stream of the CFS should enter into force in 2022, but it will allow for compliance credits for SAF to be generated as of 2020 when the final regulations are published in the *Canada Gazette*, Part II.

Parties obligated to follow the CFS include producers and suppliers of national and imported CAF and SAF used for domestic operations who will operate within a compliance market system supported by credit generation and trading within the aviation sector and among other end-use sectors.

The CFS will require a reduction in the carbon intensity of CAF of at least 10g CO_2/MJ or 10-12% below the 2016 levels as determined by ECCC's Fuel Life Cycle Assessment Modelling Tool[21]. The proposed interim CI value for CAF is 83g CO_2/MJ, which is more ambitious than the 89g CO_2/MJ CI used by ICAO for the phased-in implementation in 2021 of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). However, a more ambitious CI reduction based on robust life-cycle data could incentivize SAF uptake in the absence of other policy and regulatory mechanisms, including blending mandates.

Furthermore, in SAF conversion processes that yield multiple co-products with already established markets (e.g. renewable diesel), the use of a multiplying factor for generating credits under the CFS could provide SAF with a competitive advantage and yield greater GHG reductions.

Although obligated parties under the CFS may not generate or use credits for compliance with other federal, provincial or territorial programs and regulations (e.g. the GGPPA's Output-Based Pricing System [OBPS]) and vice versa, the proposed CFS design has compliance flexibilities that will require appropriate monitoring, verification and reporting (MVR) systems to ensure the integrity of the scheme and avoid potential situations of double counting of credits generated or traded.

20 Approximately 90% of the federal revenues will be returned to residents of the backstop provinces through the Climate Action Incentive payments, whereas the remaining portion will support climate change adaptation strategies in colleges, universities, hospitals, nonprofits, Indigenous communities, etc.

21 Currently under development. It is important to note that the CI values will exclude the impacts of indirect land-use change (iLUC). Whereas measures will be adopted to protect against adverse environmental impacts, iLUC values could be incorporated in 2025 at the first CFS review.

Other regulatory and policy mechanisms

For over a decade, the international aviation community has expressed the need for long-term dedicated policies to create a level playing field and encourage commercial-scale production of SAF. Several countries have volumetric blending requirements in place for alternative fuels outside of the aviation industry, and SAF deployment has resulted mainly from a mix of multi-stakeholder initiatives and the use of carbon-pricing mechanisms.

In Europe, the revised Renewable Energy Directive (RED) establishes a favourable policy framework[22] for EU states to promote the adoption of SAF as part of their national policy frameworks . The proposed amendments to the RED allow for SAF to use a multiplier of 1.2 in contributing toward the REDII targets, while the EU Horizon 2020 research and innovation programme, plus several ongoing public-private initiatives, will continue to support the development of commercial-scale SAF production in Europe.

It is in this context that Spain and France are both to set national volumetric targets of 2% SAF by 2025 and up to 5% by 2030 in France. These "balanced commitment" targets were the result of regular consultations between governments and the industry toward the definition of national SAF roadmaps in both EU states, and thus are considered not to put the competitiveness of the aviation industry at risk nor introduce unfair competition distortions.

A similar approach could be adopted in Canada, where a progressive SAF volumetric target (<1%) that acknowledges the domestic market dynamics is supported by the CFS and a pan-Canadian carbon-pricing scheme that incorporates the recommendations made throughout this chapter. Additional policy mechanisms[23] to accelerate the commercial deployment of SAF in Canada include capital grants, loan guarantees, tax credits and exemptions, RD&D support programmes, etc.

BRIDGING THE "VALLEY OF DEATH"

In 2017, the second ICAO Conference on Aviation and Alternative Fuels (CAAF/2) adopted a vision for 2050 in which states ensure that a significant portion of CAF be substituted with SAF, with quantified targets to be agreed upon in 2025 at the next conference iteration. Also, CORSIA will be progressively phased in as of 2021, which means Canadian SAF and low-carbon CAF will be eligible to comply with aircraft operators' offsetting obligations if they meet the scheme's sustainability criteria.

In consequence, Canada faces a unique juncture for accelerating the commercial deployment of SAF through the implementation of a national

22 The original RED targets adopted in 2009 excluded aviation fuels, while an amendment from 2015 that acknowledged the possibility of member states to account for the use of SAF was only incorporated in the national regulations of the United Kingdom and the Netherlands.

23 An exhaustive analysis of additional mechanisms suitable to the Canadian context can be found at CBSCI (2019d), Policy Tools for Enabling Biojet. Retrievable at: https://cbsci.ca/reports/

SAF strategy[24] that leverages on: (1) the accomplishments and experience gained from the GARDN projects and the community of interest created thereof, (2) the international efforts on RD&D, financing and supply chain development over the past decade, (3) the entry into force in all Canadian provinces (backstop jurisdictions and provinces with existing carbon-pricing systems) of a carbon levy on CAF as of April 2019, (4) the entry into force of the liquid stream of the CFS in 2022, (5) the active engagement of stakeholders along the supply chain of SAF in Canada and abroad, and (6) the technological and business innovations brought about by the Sky's the Limit Challenge.

However, commercial deployment of SAF faces additional challenges compared to other types of alternative fuels that should be accounted for in policymaking. Sustainable aviation fuels are high-specification fuels that are costlier to produce than other alternative fuels (e.g. renewable diesel) due to the additional processing required for compliance with international standards (e.g. ASTM D7566, GB 6537, GOST 10227).

Also, current certified conversion processes are optimized for alternative fuels other than SAF that compete in established and financially advantaged markets. This is the case with renewable diesel, a high-value synthetic hydrocarbon eligible for incentives under current Canadian regulations on alternative fuels and, until recently, in the U.S. and other potential export markets, including the European Union.

The development of domestic SAF supply chains represents an enormous economic opportunity compared to the expected financial impacts of climate change on Canada and Canadians. Therefore, the entry into force of carbon-pricing regulations in the next half decade, if properly harmonized with other provincial and federal policy mechanisms, will be key to supporting the implementation of a Pan-Canadian SAF strategy.

This entails considering the following aspects:

i. A national strategy will be more likely to accelerate the domestic production and use of SAF if: (1) it sets quantified emission-reduction targets and (2) these are directly linked to the attainment of the national emission-reduction goals (e.g. Canada's NDC). In this regard, sustainability measurement and performance are essential for SAF development in Canada and as a means for decarbonizing the aviation sector.

ii. In conversion processes that yield multiple co-products with already established and financially advantaged markets (e.g. renewable diesel), SAF will require additional incentives to create a level playing field and encourage production. This equally applies to refining low-carbon CAF (e.g. through co-processing), where the use of a multiplying factor for generating credits under the CFS could provide SAF with a competitive advantage and yield greater GHG reductions.

iii. Until Canada has a more diversified and reliable pool of feedstock sources, policy has an important role in allocating competing feedstocks to SAF production that otherwise would be used in other bioenergy and/or industrial applications. This should only be applicable under the assumption that feedstock allocation for SAF leads to higher GHG reductions compared to other uses (e.g. local use of forestry residues versus exporting overseas for heat and power applications).

24 GARDN's vision of a Pan-Canadian Sustainable Aviation Fuels Initiative (SAFI) is presented in detail in Chapter 7.

iv. It is fundamental to assertively communicate to stakeholders and to the public that the value proposition of SAF transcends the environmental dimension (i.e. emission reductions) and has measurable direct, indirect, induced and catalytic contributions to other national priorities (e.g. health, mobility, local development) that are directly linked to Canada's progress in meeting the UN's Sustainable Development Goals (SDGs).

v. As international aviation moves toward and through its emission-reduction goal dates, international carriers will consider it advantageous to operate where SAF can be secured. This makes SAF, together with the technologies that deliver it, important potential export products. A Canadian international airport that offers SAF will constitute a commercial advantage for the country, the province, and the city where that airport is located.

4. TECHNICAL AND SUSTAINABILITY CERTIFICATIONS

Technical and sustainability certifications have been identified by our community as a major component in the development and use of SAF. Until now, GARDN's involvement with the certifications of SAF has remained limited. Therefore, to better assist our community, we aim to deepen our understanding and identify the areas requiring support.

TECHNICAL CERTIFICATION

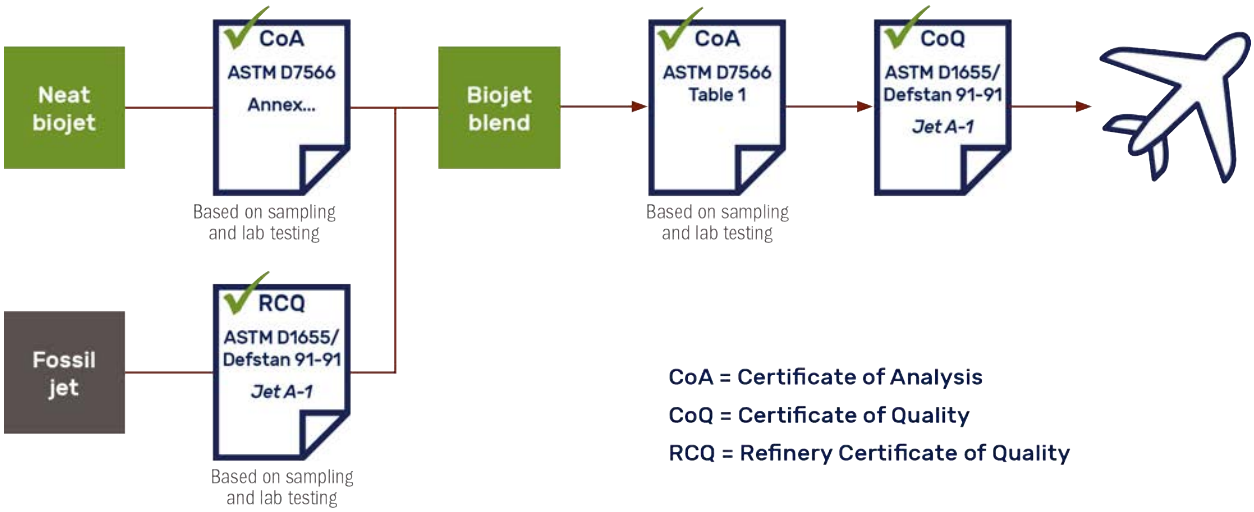
SAF must have the same qualities and characteristics as conventional jet fuel to be considered a drop-in fuel. As such, SAF can be mixed with existing jet fuel in gradually increasing proportions and can potentially become a 100% replacement for fossil-based fuel. This approach is seen as the most sustainable way to transition to low-carbon air travel because manufacturers do not have to redesign engines or aircraft, and fuel suppliers and airports do not have to build new fuel-delivery systems.

Fuel qualification

Any fuels used in an aircraft must pass a rigorous technical certification process. The ASTM D1655 standard covers petroleum-based fuels, so every blended batch of SAF and conventional aviation fuel must be certified under the ASTM D1655 standard as well. Before getting to this stage, the SAF component of the fuel must be certified under standard ASTM D7566 at two different stages: before and after the blending[25].

25 For more information about technical standards applied to the integration of SAF into the conventional fuel supply chain, please see the CBSCI project report available at https://cbsci.ca/wp-content/uploads/CBSCI-Operations-Report-Jan2019.pdf

Figure 4: Overview of blending and certification for SAF (CBSCI, 2019a)



Once the industry approves a production methodology for SAF through a detailed and comprehensive certification process, the conversion pathway is added as an annex to the aforementioned standard. There are currently five pathways that are approved by the ASTM D7566 standard, enabling them to be used at commercial scale with a maximum percentage of blending specified for each conversion technology. Additionally, the co-processing of fat and oil feedstocks within existing refineries to produce SAF at up to 5% renewable content is now approved under standard ASTM D1655 (CBSCI, 2019c).

The new pathways of emerging technologies need to go through a complex and expensive technical certification process that requires the involvement of many stakeholders, certification bodies, aircraft manufacturers (OEMs), fuel producers and airlines. Most of the time, fuel producers working independently do not have the required expertise and resources (in the range of US$10-15 million) to go through the certification process to approve a new AJF conversion pathway under standard ASTM D4054.

Our community has expressed the need for a Canadian SAF clearing house to conduct evaluations of new technologies and support fuel testing and review. The establishment of such a program aims to foster the commercialization of the most environmentally and economically promising technologies. The roles and responsibilities of a potential SAF clearing house are yet to be established with the Canadian SAF Community, but based on examples provided by CAAFI, these could include:

- Conduct in-house or arrange 3rd-party tier 1 and 2 testing and compile data
- Draft Phase ASTM Research Report and coordinate review and editing with the producer
- Review the submitted information and provide feedback to the producer regarding readiness for entry into the standard practice for approval
- Provide responses to any questions that the producer may have

Handling, storage and distribution certification

The downstream supply chain comprising the transport, storage and distribution of aviation fuels follows a variety of safety- and quality-assurance guidelines that, conversely to the fuel qualification process, are mostly done at the national level. In Canada, the API 1543 and API 1595 guidelines cover distribution logistics, while the CSA B836 guideline is used for airport operations.

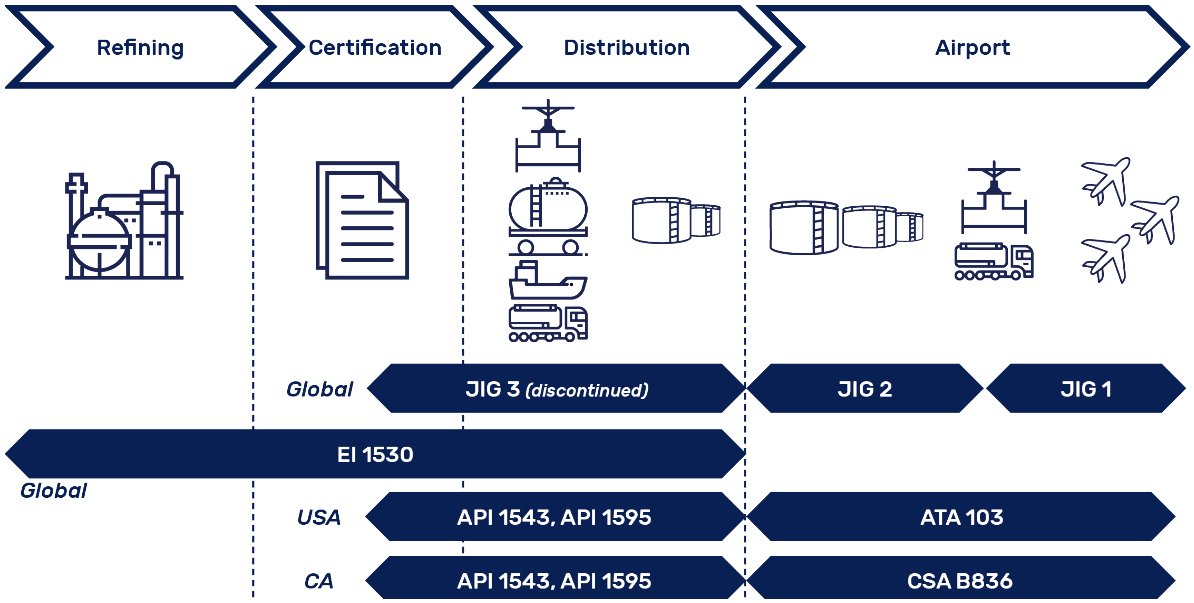
Based on CBSCI's experience with HEFA blends, the integration of SAF into the existing infrastructure require a revision and update of fuel-management and -handling guidelines (CBSCI, 2019b).

In Canada, the lack of dedicated blending infrastructure at existing storage or tank terminals means that blending SAF must take place at the site of production and the final product must be distributed to an airport by rail and/or tanker trucks. Although transportation of conventional aviation fuel by rail and/or bowser trucks is common practice for most Canadian airports, SAF remains at a competitive disadvantage compared to its fossil counterpart as a greater volume of fuel needs to travel longer distances at higher operative costs.

SUSTAINABILITY CERTIFICATION

International policy makers and leaders in the global aerospace industry recognize that noise, emissions, and sustainability are some of the main constraints on the growth of aviation over the medium and long term. A deep understanding of the overall life cycle of SAF, including a holistic

Figure 5: Overview of various conventional jet fuel quality assurance guidelines (CBSCI, 2019b)



assessment of the environmental and social impacts, is essential to ensure the long-term sustainability of air travel. Regarding the SAF sector, there are already several recognized organizations, such as the International Sustainability & Carbon Certification (ISCC) and the Roundtable on Sustainable Biomaterials (RSB), conducting sustainability certifications on various elements of the supply chain worldwide.

Moving forward with the aviation industry goal of reducing carbon intensity requires clear focus on sustainability throughout the entire life cycle of feedstock production, distribution, fuel refining and blending, and use by the airline. Sustainability and certification standards are constantly evolving as new environmental and social research is being done. From a life cycle perspective, the impact evaluation, which includes climate change, biodiversity loss or land use of each type of feedstock, conversion process or distribution, will differ for each region and depend on availability of specific impact inventories. Different criteria are studied based on the availability of regional data and the specification of each feedstock.

To ensure the consistency while comparing various types of SAF produced in Canada, it is necessary to leverage the LCA data available through GHGenius and ECCC's Fuel Life Cycle Assessment Modeling Tool (under development) to develop a robust methodology that incorporates and addresses regional and specific value chain issues by encompassing environmental, social and economic criteria that differ in nature and geography (CBSCI, 2019a).

As the sustainability performance is calibrated over time, feedstock producers will see more potential in the development of sustainable aviation fuels by having a clear path to sustainability certification beforehand. Therefore, not only will producers benefit from more accurate sustainability assessments, but all SAF stakeholders will have the certainty that the impact of air travel is in conformity with environmental, social and economic contexts.

According to ICAO, the sustainability of the production of alternative fuels requires the definition of:

- The different sustainability impacts and consequences of alternative-fuel production;
- Principles that will be used as a reference for what is and what is not acceptable against a detailed set of criteria;
- Targets and indicators to measure and monitor progress and compliance (CBSCI, 2019a).

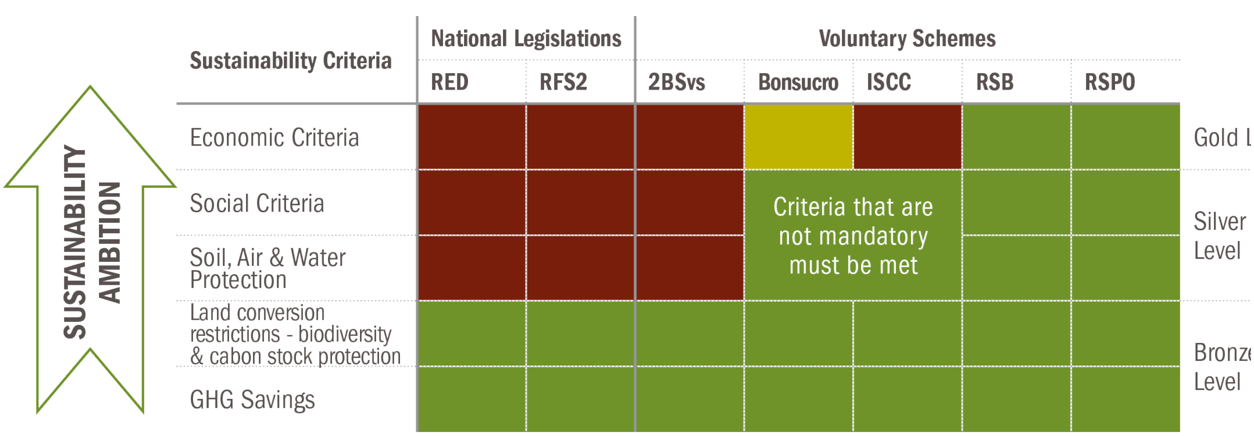
ICAO is currently preparing to launch the pilot phase of CORSIA in 2021, and in the meantime stakeholders have been using sustainability programs such as RSB to demonstrate sustainability compliance. Consequently, until CORSIA is fully phased in, by 2027, efforts to reduce emission will proceed on a voluntary basis for international aviation. It is important to note here that CORSIA will not have any legal ramifications against participants who do not comply by offsetting their emissions.

Despite these positive developments in international aviation to ensure the long-term sustainability of air travel, we strongly believe that Canada must adopt a more demanding sustainability compliance, the same way Canada has shown its excellence in other areas, like health compliance that are more stringent than the international requirements.

Nonetheless, a Canadian sustainability compliance scheme does not have to be written from scratch. The work already undertaken by IATA with its Meta Standard can be used to define the principles and criteria for sustainability that are directly applicable to the aviation sector and SAF. As shown in Figure 6, IATA's Meta Standard defines three levels of compliance: bronze, silver and gold.

The three levels account for a spectrum of compliance, and the more criteria considered, the higher the ranking. The EU developed its own certification legislation (REDcert for instance) in 2009 to promote the development of renewable energy and, notably, SAF. The legislation also provides a clear certification path for all stakeholders along the entire biomass value chain.

Figure 6: IATA Meta Standard approach to AJF sustainability (CBSCI, 2019a)



The REDcert scheme not only supports producers and economic operators with implementation, it also employs measures related to transparent scheme management to assure integrity and prevent misuse and fraud. Finally, it ensures the development, evaluation and modification of requirements to comply with legal and operational specifications put forward by the European legislators.

Because of the international scope of the aviation sector, what we see fit for the Canadian context is in compliance with worldwide recognised certification bodies that not only provide sustainability certifications for GHG savings but also include the criteria in Figure 6 to ensure the long-term viability and relevance of the certification as a tool. Schemes and approaches like the RSB or the IATA Meta Standard provide criteria for each step of the supply chain by assessing the level of GHG savings achieved. Besides the net carbon emission, these tools address the biodiversity and soil conservation, local air and water quality, human and labour rights, indirect land use change, etc.

In suggesting possible adoption of a standard, such as the RSB, we note that carbon reduction is currently certified to a certain level. Over the course of the next few decades, fuel carbon content must migrate toward zero or even to negative values.

While certifying each component of the supply chain separately can be justified from a life-cycle perspective, the added cost significantly increases the overall price of SAF. Thus, long-term partnerships are more likely to occur if the cost of certifications (technical and sustainability) is split among stakeholders.

5. OUTREACH AND KNOWLEDGE TRANSFER

By bringing national presence and visibility to its projects and initiatives, GARDN has brought down some barriers to facilitate collaboration and partnerships between stakeholders instead of working in silos. Although the consortium has been active in terms of visibility with its annual corporate reports and by participating in various national and international industry events and workshops, public awareness is a matter that has much room for improvement if the general public is going to see the benefits of SAF.

To help the development of the SAF sector in Canada, there is a need to create a better knowledge-transfer strategy to help the stakeholders all along the supply chain understand local growth opportunities. Many participants of the GARDN survey highlighted the poor communication efforts around SAF in Canada. There have been suggestions for more networking sessions, dedicated websites and partnership-building activities as well as more consultation and even a dedicated coordinating organization.

SAF Community and GARDN have the ambition to respond to some of those community requests to improve outreach through facilitating events and online communication, as well as collaborations with existing networks. The survey also pointed out the need to increase outreach and communication about SAF to the public and citizens. The perceived idea about alternative fuels in general is still tainted by the “food versus fuel” debate and the question of agricultural crops as feedstocks. Communication should pinpoint the sustainable aspects of SAF, spread information about certification possibilities, and put forward the efforts of the industry to go toward a fuel that would benefit both the environment and society.

Along with the CFS, a communication plan should be implemented to inform Canadians of SAF benefits. We also believe there is a need to encourage citizens, through public-awareness strategy and communication, to adopt more sustainable lifestyles by reducing non-essential air travel, promoting local tourism, and considering means of transportation with a lower environmental impact.

SAF COMMUNITY PLATFORM

A new virtual engagement platform

In October 2018, GARDN officially launched its online social platform, SAF Community, to gather stakeholders of the SAF sector and foster collaborations all along the supply chain, from the feedstock producer to the end user.

This tool aims to enable members of the community to get engaged in discussion groups, collaborative projects, events, etc. By enriching the platform's company and contact database, we hope to enable users to easily find the right expertise and collaborators. Although most of its users are located in Canada, SAF Community is open to players worldwide as a better global contribution will accelerate innovation and development in the sector. As an interactive tool, it encourages users to share their ideas, knowledge and opinions with the community, thereby increasing business opportunities and facilitating collaboration.

SAF Community has the ambition to evolve into a hub for all projects and SAF-related activities in Canada, as well as a knowledge base and reference on the subject, and to make information on SAF accessible to everyone. Admittedly, bringing together stakeholders from such a

OUTREACH LESSONS FROM OUR PROJECTS

One of GARDN's projects, titled **Greening the Aerospace Supply Chain (QC-21)**, defined a supply-chain management framework to provide industrials with the capacity to prioritize eco-responsible purchasing actions, define technologies' green specifications and efficiently treat environmental information. Although the scope of the project was mainly around the aerospace sector, many of the conclusions and recommendations are applicable to the SAF sector as well.

Conclusions and recommendations of the QC-21 project regarding green practices, products, processes, technologies and innovations include:

- The sector must better document and communicate the benefits and opportunities rather than mostly focusing on compliance regarding environmental management and green practices.
- The sector needs to address environmentally related challenges and opportunities from "a whole-supply-chain perspective." A network or collaborative approach to sharing best practices, developing a common language and transferring knowledge should be sought.
- Knowledge transfer between all members of the supply chain, universities and external experts will be a key success factor, as will the development of better business cases to demonstrate the benefits and returns on investment in green practices and products.
- Education and sensitization about the market demands for environmentally friendlier products and technologies, as well as new requirements and specifications (e.g. environmental regulations, new regulations, sustainability standards), should be part of a global strategy to further ecologize the Canadian SAF supply chain.

Based on those recommendations, additional efforts are needed to properly disseminate knowledge and raise awareness about the environmental benefits of more sustainable practices in the aviation sector. To play a more substantial role in this area, GARDN enlarged its outreach scope over the past few years with a diversified communication strategy and engagement tools.

broad and dispersed supply chain is not without challenges. More time will be required to meet a user registration level that allows more interactions and the community to engage and grow by itself.

The online platform also has an entire section dedicated to the Sky's the Limit Challenge, in accordance with GARDN's collaboration with NRCan. All information related to the challenge has been published (guides, FAQ, links, news) and participants in the Challenge have been invited to a live Q&A session before the submission of their projects.

Future vision

In order to become a reference in knowledge sharing and connecting SAF professionals, a clear strategy must define a roadmap of how we want the platform to evolve.

The first stage will be to grow the community by increasing the number of registered users and bringing together a representative panel of the Canadian SAF supply chain. Since the platform should be more than a simple directory, we want to develop the content and relay news from the SAF industry worldwide. Then we intend to create exclusive content to promote local SAF initiatives, such as RD&D and innovations, companies, consortia, etc. A dedicated space is also available to share documents such as reports, papers, presentation from conferences, webinars, workshops, etc.

SAF Community will also collaborate with other organizations and partners to develop content and webinars. To answer the demand from the industry for more events, SAF Community already has an Events page where we publicize SAF-related events worldwide. In order to have an exhaustive event calendar, users are encouraged to publish their own events, whether they've organized it or are just attending.

Finally, we mean to develop a SAF knowledge base by developing content with relevant organizations to create a "SAF 101" or "SAF for beginners" dynamic guide with regular updates to inform the general public and final consumers on the importance of SAF for a greener future for air transportation.

COMMUNITY-ENGAGEMENT ACTIVITIES AND EVENTS

GARDN is focusing more and more on the communication activities around the SAF industry, where improvement is currently demanded

WHAT WOULD BE OUR DREAM USER EXPERIENCE OF THE SAF COMMUNITY PLATFORM?

Eve Mustermann is a research associate at the University of Green-City. She has been working on a new revolutionary process to extract oil from invasive algae and wants to develop SAF. She needs more funds and expertise to apply and scale up her production, preferably on a regional level, so she registers in SAF Community to find potential collaborators.

After completing her profile and posting a message in the Forum to present herself and her project, she searches through the People directory and finds potential partners in the region. She decides to contact Sam Sample, who is working at We Finance Corp., a firm specializing in renewable-energy businesses. She sends him a direct message through the platform, inviting him to meet her someday to discuss her project. He answers, saying that he will be a panelist at the Green Flying Conference and that they should meet there.

Eve checks the Events page on SAF Community and registers for the conference. She also reads the latest news about SAF worldwide and some reports on green aviation from the Media Center. Meanwhile, Michel Michu, who wants to develop his algae-conversion plant, gets to see Eve's profile in the algae discussion group and sends her an email to invite her to discuss opportunities for collaboration.

At the conference, which takes place in another region, Eve uses the geolocation from the mobile app of the platform to see who is around and present at the event for networking sessions.

by the sector. To fill this gap, GARDN actively participated in many SAF-related events to raise awareness around biofuels in various sectors and fields of activities.

GARDN Conference — SAF-themed content

In November 2018, around 200 participants both from within and outside the aerospace and aviation sectors attended GARDN Conference in Ottawa. The event's primary focus was on clean, quiet and sustainable aviation. Specific to SAF, the conference had a dedicated forum to give participants an overview of the Sky's the Limit Challenge, followed by a panel discussion on key issues for applicants and the possibility to receive advice from producers, investors and financial experts.

Presentations included a number of stakeholders who introduced their current work and projects to be submitted to the challenge, identified their own strengths and capacities, and networked with potential partners. Informative sessions were dedicated to analyzing the GHG aviation trends in Canada and reduction scenarios using SAF and supply chain logistics and enabling policies and regulations.

A post-conference survey indicated that for 63% of the participants, the Sky's the Limit Challenge sessions were the main reason for their attendance, which makes us believe that more SAF-only-related events could be appealing and interesting for the industry and confirms that SAF is the key component of a greener aviation.

"There was optimism in the room around the potential to produce clean biojet fuel, attract investment and form lasting partnerships in Canada."

—Jason Gadoury, Natural Resoures Canada

CRIBIQ/CRIAQ Workshop

This workshop, held in Montreal on December 18, 2018, mobilized around 45 participants from Quebec to discuss the creation and challenges of a regional supply chain for SAF. The Sky's the Limit Challenge was also presented and promoted to encourage stakeholders from Quebec to submit their projects. Presentations and roundtable discussions covered the following topics:

- Current situation of SAF in Quebec
- The motorists' point of view and the technological challenges
- The airlines' point of view and the importance of regulations and standards

It has been clear from the start that there is a demand from attendees for more events gathering players from the whole supply chain, especially at the regional level. Besides the conclusions and recommendations drawn from the roundtables, the workshop also led to the submission of two projects to the Challenge.

Webinars and other communication initiatives

The first SAF-themed webinar was the Sky's the Limit Challenge post-launch presentation, which took place on October 22, 2018. It presented the Challenge and its conditions as well as the newly launched SAF Community platform and ended with a Q&A session. The speaking time was shared between GARDN, NRCan and Challenge partners Air Canada and WestJet. High participation rate at this webinar encouraged GARDN to use this communication tool for more events and knowledge transfer in the future. The second SAF-themed webinar was prepared by GARDN, the Roundtable on Sustainable Biomaterials (RSB), and the SAF Community with the objective of sharing information on SAF-sustainability certification. In the future, we expect to regularly host webinars to provide quality content to our community using mass-media platforms.

NRCan and Alberta Innovates also hosted a webinar in December 2018 to present the Sky's the Limit and the WestJet Aviation Biofuel challenges, on which GARDN made a small presentation of our organizational mandate, activities and SAF Community. We believe that through the use of digital tools and mass-media platforms, players in the SAF supply chain can foster collaboration between regional and national stakeholders to accelerate the consolidation of SAF clusters.

SOCIAL MEDIA (TWITTER, LINKEDIN) AND PUBLIC AWARENESS

GARDN has an online presence on social media through Twitter and LinkedIn to regularly connect to our community, communicating on events, news and updates on projects and collaborations.

GARDN's Twitter account (@GARDN_aero), created in October 2016, has close to 300 followers and relays corporate news, project information, events organized or attended by GARDN, and other green-aviation-related news. On LinkedIn, GARDN has close to 600 followers and publishes corporate news, events and HR-related information. Finally, a GARDN newsletter keeps about 900 registered professionals informed on the latest network news.

When it comes to SAF and the development of our SAF Community platform, we believe that GARDN should have an extended social-media presence. Public awareness and social media being inseparable, a stronger communication strategy that comes with a higher budget will be crucial. This strategy should include a dedicated Facebook page and a YouTube channel to reach a wider audience.

OUTCOMES AND FUTURE INITIATIVES

There is a clear demand for an annual meeting, like the GARDN Conference, dedicated to SAF in Canada. Though SAF-only events have mainly taken place abroad, a strong presence at the national level is desirable to increasingly gather the interest of stakeholders operating in Canada.

The industry should also be involved in more workshops and participative events from network to network (i.e. in collaboration with other networks and initiatives) to increase collaboration between local players along the supply chain and cross-sectoral stakeholders. These interactive events are easier to organize and coordinate on a regional level and require a much lower budget than stand-alone organization. Even though these events would be primarily tailored toward SAF stakeholders, it would be valuable to collect, compile and publish the outcomes, lessons and best practices in the form of short articles made accessible to everyone over the Internet.

Virtual meetings are also on the SAF Community agenda in order to share best practices and knowledge that could contribute to the development of the SAF sector. Also, we strongly encourage users to publish and advertise their events on the SAF Community platform for an increased visibility of the work being done on SAF in Canada and abroad.

GOING THE EXTRA MILE

The following are key subjects to be addressed by GARDN in the future:

- Contribution to the global framework: How the Canadian SAF industry is contributing to the UN's Sustainable Development Goals (SDGs) and what else could be done to make a greater contribution to these goals in the future.

- Building the vision 2050: Insight on the future of the SAF industry in Canada, creating the scenarios of development for long-term success.

- Supply-chain awareness and knowledge transfer: How to apply circular economy to the SAF industry (**A comprehensive guide about new business models that will increase the overall supply-chain effectiveness and foster the development of SAF**).

- Public awareness: Everything that everyone should know about climate change and air travel (A comprehensive guide about how passengers can contribute to the decarbonization of air travel).

6. CONSORTIA-BUILDING AND REGIONAL INITIATIVES

GARDN allows companies to build trusting and transparent relationships that otherwise would not exist and in so doing makes itself greater than the sum of its parts. These partnerships, between the private sector, the public sector and academia, make GARDN the "go-to" network for aviation environmental RD&D. As research programs deliver results, GARDN is taking advantage of its business leadership and connections through other networks and business associations to communicate opportunities for growth and future research avenues with potential Canadian and international partners.

There are many benefits to be gained from collaboration across the various stakeholder groups involved in all aspects of SAF production and use. Many of those benefits have been discussed throughout this white paper, such as the acceleration of the innovation process, more efficient knowledge transfer and simplification of certification processes. One of the main advantages is a better risk mitigation for all parties involved, which could lead, for example, to increased financing opportunities. For this reason, it is not surprising that most of the SAF initiatives around the world are done through consortia where various stakeholders work cooperatively on expanding the production and use of SAF.

Dedicated funding programs for collaborative RD&D projects to decarbonize air travel are essential, and our community has unanimously supported and advocated for the continuation of the GARDN program in the future. However, we believe that various strategies to finance the RD&D efforts and consortia-building are needed to create meaningful partnerships across all types of stakeholders.

FROM RD&D TO COMMERCIAL DEPLOYMENT

Partnership with NRCan

Over the past year, GARDN has had the opportunity to partner with Natural Resources Canada (NRCan) to explore and promote creative ways to stimulate the Canadian green technologies sector. Recognized for the achievements of its network, GARDN has provided key assistance to NRCan's Sky's the Limit Challenge. This collaboration has broadened GARDN's community of interest and has facilitated the first steps toward what could become the Pan-Canadian Sustainable Aviation Fuel Initiative (SAFI Canada), which draws inspiration from the Commercial Aviation Alternative Fuel Initiative (CAAFI) in the U.S. This has led to a better expertise and understanding of our stakeholders and their expectations, giving us the right foundation to support and respond to the sector's needs.

Through this collaboration, GARDN has been playing an active leadership role in the advancement of SAF for Canada by:

i. Facilitating and promoting new collaborations and connections across the different sectors and components of the SAF supply chain to broaden the SAF network and mobilize Canadian clusters as well as leverage existing programs;

ii. Engaging with green-aviation stakeholders in the form of events, meetings, teleconferences, webinars and workshops;

iii. Supporting participants during the Challenge by providing them with tools to share information and facilitating real-time interactions between them.

Our partnership with NRCan in the context of the Sky's the Limit Challenge has greatly expanded the SAF network in Canada and contributed to more cross-sectoral consortia building. One of the first projects we undertook under this partnership was the stakeholders map of the Canadian SAF industry to facilitate the identification of existing expertise and capacities for potential participants in the Challenge. From a sustainable-development perspective, geographical distance is one of the most important metrics to consider when establishing a new sector.

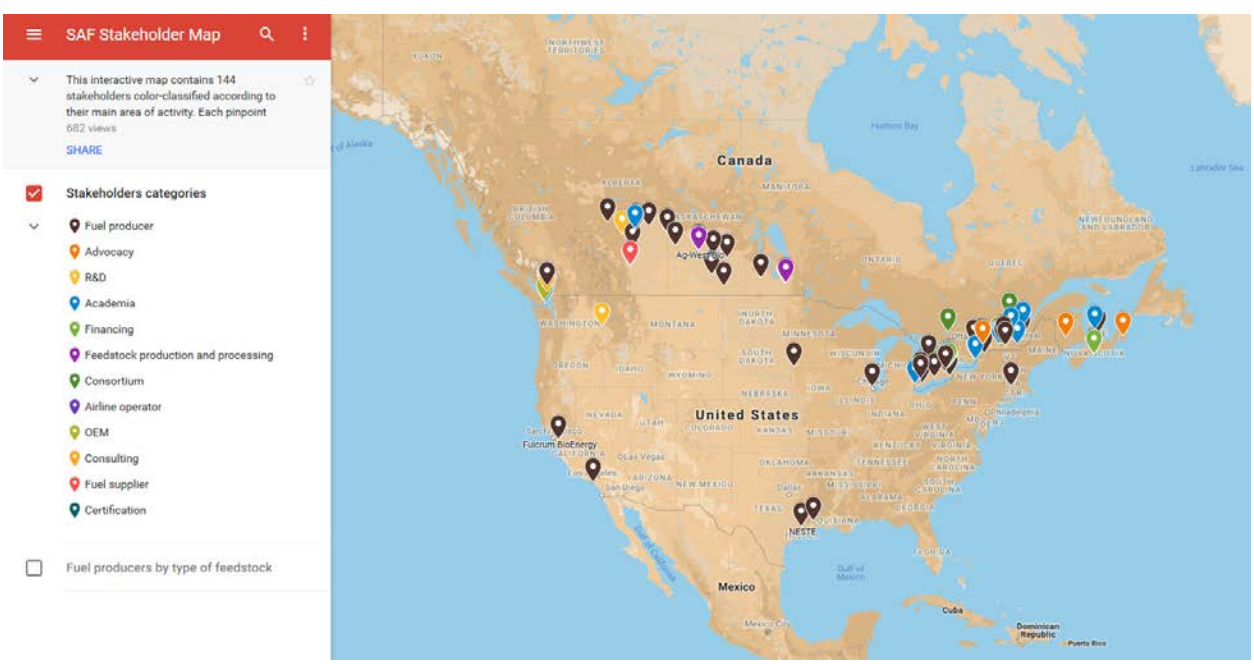
Building a Canadian SAF directory

The main purpose of the stakeholders map is to provide users with a visualization tool for identifying regions with the greatest potential for SAF project development and/or cluster formation. At the moment, the open-access software has limited capabilities for incorporating certain information layers (e.g. oil and gas infrastructure, agricultural and forestry growing regions), but these can be found on the departmental websites of the Government of Canada for further reference.

For example, it allows the identification of Quebec and Ontario as the provinces with the greatest diversity of stakeholders within the value chain of SAF compared to the rest of Canada since producers and users are strategically geolocated nearby to one another and connected through delivery and supply infrastructure that facilitates downstream logistics. Also, although Alberta has a much larger number of fuel producers compared to other types of in-province stakeholders, we can pinpoint Edmonton as a region with great potential for cluster formation along with Toronto and Sarnia since they are all well connected by rail, road and pipelines.

The stakeholders mapping report and the visual map are available to the users on the SAF

Figure 7: Stakeholders map



Community platform. Additionally, we have developed a platform feature called "Companies" where users can more easily identify SAF stakeholders of their interest and the people within those organizations. It is important to notice that the rapidly changing landscape of stakeholders requires an approach that allows information to be updated constantly and a tool for updating information in more centralised way.

FROM NETWORK TO NETWORK (N2N)

The world of innovation is a very organic and fast-growing environment, especially for newly emerging sectors like SAF. There are already various organizations in Canada that are specialized in specific parts of the supply chain and have unique expertise about the development and commercialization of SAF. The goal of a Network to Network (N2N) approach is to learn how to get those various organizations to collaborate and create a bigger added value to the private sector.

Based on our experience, collaboration with other organizations and networks like GARDN has a lot of benefits. Over the past few years, we have partnered with BioFuelNet[26] and with CARIC[27] to co-finance RD&D projects. These experiences helped us to better understand how to collaborate under different programs and facilitate the reporting process to research consortia. We have also collaborated on different events and brought communities together to make the knowledge transfer easier, innovation efforts faster and the benefits greater.

The holistic supply-chain approach, where various industries (agriculture, forestry, aerospace, aviation, etc.) collaborate, is key to fostering the development and use of SAF in Canada. Furthermore, the private-public-academia consortia building is essential to ensure the most ambitious environmental targets of the aviation sector are met.

Technology and business innovation cannot happen in Canada in isolation. Our SAF sector should take advantage of achieved progress in other locations around the world. For example, the U.S. and Europe have been working for several years on various bottlenecks of the low-carbon-fuel supply chain and have established sophisticated strategies to introduce SAF in daily airport operations in multiple locations around the world. Therefore, as part of a future vision, greater attention should be brought to the international collaboration efforts and worldwide knowledge transfer.

Based on the N2N concept, the collaboration efforts should be as open as possible, building on the existing expertise of various sectors and fields of activities. Today, it is not enough to

26 "BioFuelNet Canada mobilizes the Canadian biofuels research, industrial, governmental and investment communities to quickly address the challenges impeding the growth of an advanced biofuels industry, while focusing on non-food biomass as biofuel feedstock." (www.biofuelnet.ca)

27 The Consortium for Aerospace Research and Innovation in Canada is a non-profit organization with a mission to generate and foster dialogue and collaboration between players in the aerospace industry and provide financial support to R&D projects in partnership with these players. (www.caric.aero)

collaborate within a specific research community. The collaborations between various networks and associations are considered one of the most powerful tools of knowledge transfer. The cross-network collaborations inspire more creative problem solving and can achieve greater environmental and social benefits.

NEW APPROACHES

Circular economy

The concept of a circular economy is gaining momentum and becoming a cornerstone of transition strategies. That is because it's an economic system that limits waste as much as possible while making the most of finite resources. Climate change and material scarcity are the main drivers. One of the main goals of this model is to foster system effectiveness. To create economically and environmentally sustainable products and services, the circular economy focuses on areas such as design thinking, systems thinking and industrial ecology.

The implementation of circular business models requires a multi-sectoral approach and the engagement of various stakeholders. It is an enormous opportunity to leverage consortia created around SAF in Canada and facilitate their collaboration with national and regional authorities. Building the future of SAF based on innovative business models based on the principles of circular economy and industrial symbiosis seems like a natural next step for the Canadian industry.

Regional initiatives of SAF production and the establishment of bioports are examples of how those concepts inspire SAF development in various regions around the world.

Regional initiatives and biohubs

While pan-Canadian initiatives should be encouraged to develop a SAF supply chain, the question of local development should be emphasized to optimize the emission reductions and the efficiency of SAF supply. Geographical proximity and regional project development are key to fostering economies of scale. Although the use of existing production infrastructure is crucial to lowering the environmental impacts from an LCA perspective, the development of more local initiatives, such as biohubs, represent important potential for emission reductions and the de-risking of the entire SAF supply chain in the long term.

A biohub is a demand centre in the form of an airport and its airlines that are supplied by a dedicated regional supply chain. The feedstock refining, fuel blending and transportation to the surrounding airport offer the most effective way to stabilize the demand for SAF, while bringing the following interesting characteristics:

- Market growth and innovation stimulation
- Decrease in the lifecycle CO_2 emissions
- Creation of direct benefits for employment and regional development
- Securing of SAF supply at a stale price

This kind of infrastructure is one of the ways to reduce the aviation sector's dependency on CAF that makes the most sense for Canadian geography.

In the Netherlands in 2013, KLM, SkyNRG, Neste Oil, Schiphol Group, Port of Amsterdam and the Dutch government developed the Bioport Holland supply chain with the aim of boosting the SAF market in Europe. Today, this represents the largest renewable-industry cluster in the world, with five biofuel factories, five oil refineries, two biochemical companies and more than 45 chemical companies. This also brought growth opportunities due to the development of a new industrial zone in the port.

We strongly think that the government should facilitate the development of such multi-stakeholder regional projects because this approach considerably lowers risks, brings better social benefits and attracts greater investments.

7. CANADA'S BIOJET SUPPLY CHAIN INITIATIVE (CBSCI)

As we have seen in previous sections, to foster the development of SAF, a diversified basket of strategies is needed to address the challenges and grasp the most promising opportunities. It is most important that these strategies are part of a holistic approach integrated in a shared vision among all parties involved. From our perspective, every single initiative should address all the steps simultaneously: research and development, financing, knowledge transfer, certification process, enabling policy development and consortia building.

As an example, we would like to illustrate how one of the GARDN projects, Canada's Biojet Supply Chain Initiative (WG-21), is already paving the way with a holistic approach that contributes to all the previously discussed strategies.

RD&D and innovation

The project studied the feasibility of integrating SAF sourced from used cooking oil into the co-mingled hydrant system of an airport, along with developing operational best practices that can be implemented in Canadian airports to efficiently integrate SAF in blend levels for carbon-neutral growth.

Financing and strategic partnerships

The CBSCI project was financed by GARDN, with additional funding from BioFuelNet Canada and IATA and significant in-kind contribution (fuel purchase) from Air Canada. Also, the project assessed the feasibility for private-sector investment in commercial-scale SAF production in Canada.

Policy and regulations

The implementation of CBSCI allowed the identification of several policy and regulatory gaps needed to support the establishment of SAF supply chains, particularly for downstream logistics. The lessons drawn from this project were compiled in a dedicated report on policy instruments for Canada (*Policy Tools for Enabling Biojet*).

Technical and sustainability certification

The integration and use of a 30/70 HEFA blend with conventional Jet-A1 resulted in a saving of 161.66 tonnes of CO_2e. This was equivalent to 230,000 liters of SAF supplied to 22 commercial flights that departed for domestic destinations on Earth Day 2018.

The report (HEFA Production and Feedstock) brings elements related to the technical specifications for certification.

Communication and knowledge transfer

Understanding developed in CBSCI was captured and disseminated via four publicly available reports:

- Policy Tools for Enabling Biojet
- Considerations for the Application of a Biojet Sustainability Standard in the Aviation Sector
- HEFA Production and Feedstock
- Canada's Biojet Supply Chain Initiative Operations Report

A three-minute video was produced to illustrate, in a simplified way, the whole process of SAF importation and how it was integrated in the hydrant system. It explains succinctly why the project was undertaken, what was the process and what are the achieved results. This initiative helps to raise public awareness through an illustration that every viewer can understand without prior knowledge or expertise. The use of a social-media platform also helps spread the information in a more consistent manner as the video is accessible for free for anyone to watch.

Furthermore, the video has been uploaded to a website specifically dedicated to the project in order to centralize information and make it easily accessible by using the domain names biojet.ca and cbsci.ca

Consortia-building and regional initiatives

The CBSCI team includes experts from a variety of disciplines and sectors, including: biomass supply chain (BioFuelNet, ASCENT), biomass conversion to SAF (Queen's University), fuel procurement and distribution (SkyNRG), engines and combustion (University of Toronto, ASCENT), commercial end use (Air Canada, Boeing), policy (Transport Canada, NRC), lifecycle emissions (McGill University, Fraunhofer), and guidance materials and best practices (IATA, CAAFI). The project has brought together a total of 14 stakeholders, each bringing their expertise.

Collaborations with other projects were essential to the development of CBSCI. The main collaboration was with the WG-22 project (Civil Aviation Alternate Fuel Contrail and Emissions Research) as the same fuel logistics team was used for both projects. An association was also made with the NEC-21 project (Assessment of likely Technology Maturation pathways used to produce biojet from forest residues—the ATM Project). Internationally, WG-21 collaborated with ASCENT and was able to leverage the international reach of both IATA and CAAFI.

Figure 8: Canada's Biojet Supply Chain Initiative (WG-21)

Canada's Biojet Supply Chain Initiative (WG-21)

Outreach and knowledge transfer

3min. video illustrating the process in a simplified way to raise public awareness

Four policy papers on feedstock, sustainability operations and regulations available for free at a dedicated website: biojet.ca / cbsci.ca

Financing and strategic partnership

Feasibility assessment for private-sector investment in commercial-scale SAF production in Canada

Technical and sustainability certification

Report: HEFA production and feedstock selection

Blending of 230,000 litres of HEFA-SPK at 30% supplied to 22 commercial flights resulting in savings of 161.6 tonnes of CO_2

Stand-alone paper: *Considerations for the application of a biojet sustainability standard in the aviation sector*

Consortia building

Multidisciplinary and cross-sectoral team of experts strategically selected for their contributions to the SAF value chain:

Development of biomass production and conversion, fuel procurement and distribution, commercial end use, guidance materials and best practices

Policy and regulations

Identification of policy and regulatory gaps within the downstream logistics

Report: *Enabling policy for domestic biojet production*

R&D and innovation

Demonstration of the operational feasibility and safety of SAF in the domestic supply system using existing infrastructure

Development of Canadian-made SAF by using HEFA-SPK

8. THE PAN-CANADIAN SAF INITIATIVE (SAFI CANADA)

The need for a pan-Canadian sustainable aviation fuels initiative has been raised by many stakeholders over the past few years. What we have learned so far has inspired our team to draw our very first sketch of what the future could look like for GARDN. We strongly believe that a detailed strategy for building a Canadian SAF initiative should be co-created with the entire supply chain through a rigorous process and collaborative strategic planning. The shared vision and mandate of such an initiative are yet to be refined and discussed with the entire SAF community. Below we present what we consider should be the first steps and structure toward a pan-Canadian SAF initiative.

BUILDING THE FUTURE

Many countries around the world are making great progress in establishing national frameworks to facilitate the production and commercialization of SAF. Despite the fact that we live in a truly innovative country with an ambitious commitment to reducing its effects on climate change, we are currently behind in terms of properly establishing a supply chain for SAF production.

The production of domestic low-carbon fuels holds great social and environmental impacts. Plus, Canada already has many advantages for producing clean fuels, such as:

- notable infrastructures and capacities inventory
- well-established aviation, aerospace, oil and gas, forestry and agricultural industries
- strong community of researchers, innovators and entrepreneurs
- multitude of public programs for innovation and clean-tech R&D

- growing number of networks, innovation hubs, research consortia and other collaboration initiatives

We strongly believe that the establishment of a national roadmap to foster the development of a SAF industry will benefit Canada's economy and lower our emissions. The national innovation strategy should be built on a clear long-term vision, co-created and shared among all stakeholders. To continue its efforts in the transition to a low-carbon economy, Canada must facilitate the RD&D process and de-risk public and private investments for more radical innovations. The business relationships between different players at early stages of development facilitate the technology implementation at a commercial scale. Furthermore, a more extended and decentralized knowledge transfer will help with the establishment of multidisciplinary coalitions and the acceleration of certification and policy development.

INTEGRATED APPROACH

Imagine a network built on the multi-sectoral community of stakeholders with a shared goal to foster the production and use of sustainable aviation fuels in Canada. Let's call it Pan-Canadian Sustainable Aviation Fuel Initiative (SAFI). To accelerate the Canadian transition to a low-carbon economy and increase its contribution to the UN Sustainable Development Goals, the guiding principles of the future Pan-Canadian SAF Initiative are strategic eco-design, whole-system design, bio economy, circular economy and industrial symbiosis.

Now consider the six strategic areas described throughout this report as the building blocks or areas of interest of SAFI, whose main objectives could be summarized below:

Innovate

- Foster research into new feedstock sources and refining processes
- Support the technical and sustainability certification processes for SAF

Facilitate

- De-risk public and private investment in SAF
- Enable more robust cross-sectoral policy development

Connect

- Promote knowledge transfer and outreach
- Establish coalitions encompassing all parts of the supply chain

The diversified scope of such an organization calls for a new innovative business model where various types of public and private organizations are extensively represented. Moreover, the inclusion of currently under-represented groups of stakeholders is key to ensuring a global representation and a more systemic approach to the future development of the SAF sector.

To achieve this goal, the use of a full range of innovative and multi-disciplinary strategies is required. As outlined through this report, GARDN has already experimented with various tools and methods in each of the strategic areas. We believe that the experience gained by our community over the past few years sets the foundation for what could become the next Pan-Canadian Sustainable Aviation Fuel Initiative.

The following table identifies current gaps and challenges along each of the components of the SAF supply chain in Canada that need to be comprehensively addressed in a national SAF strategy:

Table 4: Gaps and challenges for SAF market development

Strategic area/component	Feedstock	Conversion	Distribution	End use
RD&D	Development and maturation of non-conventional feedstocks*	Development and maturation of feedstock-agnostic conversion technologies	Optimization and testing of SAF blending suitable for existing supply infrastructure	Demonstration of SAF supply using comingled fuel infrastructure in airports across Canada**
Financing	Wider access to loans, guarantees and insurance	Access to capital grants and producer-based incentives	Development of dedicated blending infrastructure at storage terminals and tank farms	PPP, government procurement through off-take agreements
Certification	Streamlined support for sustainability certification	Streamlined support for fuel qualification under ASTM D4054	Review of CSA B836 for blending infrastructure at airport tank farms	Monitoring, reporting and verification of compliance with the CFS and CORSIA (when applicable)
Outreach & knowledge transfer	Communicate the value proposition of SAF and actively engage stakeholders along the supply chain. Expand outreach by leveraging social-media resources			
Regional initiatives	Multi-stakeholder initiatives focused on commercial-scale production and supply of SAF at bioports and biohubs			

*Feedstocks that do not generate land use change (LUC) or indirect land use change (iLUC), such as capture and densification of atmospheric carbon dioxide, hydrogen produced using renewable energies, fungi, etc.

**Canada's Biojet Supply Chain Initiative (CBSCI) demonstrated SAF integration in the co-mingled fuel supply of Toronto's Lester B. Pearson International Airport.

Figure 9: Pan-Canadian Sustainable Aviation Fuel Initiative (SAFI)

RECOMMENDATIONS

The following recommendations are addressed to both the private and the public sectors. They summarize the main takeaways from each chapter. Some of them require specific guidance from the national and provincial governments and others straightforward leadership from the industry. The creation of a comprehensive and holistic long-term vision shared between all stakeholders is foundational to SAFI Canada and should be the essence of SAF development in Canada.

Strategic Area 1 — RD&D and innovation

- Facilitate cross-sectoral research for advanced and non-conventional feedstocks and conversion technologies for SAF production
- Facilitate public investment in collaborative RD&D projects at low TRL stages
- Set innovation strategy targets for SAF development
- Focus RD&D efforts on the feedstock sources that are the most environmentally and economically sustainable in the long term
- Encourage the development of feedstock-agnostic conversion technologies
- Explore Canadian opportunities for co-processing of low-carbon conventional aviation fuels

Strategic Area 2 — Financing and strategic partnerships

- Encourage federal procurement or other public incentives to finance the premium on SAF for government-related travelling
- De-risk private and public investments with a coordinated approach between federal and provincial financial-support programs
- Enhance access to capital grants, loan guarantees, tax credits, producer-based incentives, RD&D support programs, etc.
- Foster the production and consumption of more sustainable products and services through PPPs

Strategic Area 3 — Policy and regulations

- Design and implement a Pan-Canadian SAF roadmap to support the targets proposed by the CFS and the goals of the PCF
- Harmonize the carbon-pricing schemes among all Canadian provinces to address concerns of fair competition distortions

- Exempt SAF from federal and provincial carbon levies to reduce the price gap with CAF
- Re-invest CAF charge proceeds into mitigation and adaptation measures within the aviation sector
- Allow the use of a multiplying factor for SAF to generate credits under the CFS
- Incorporate iLUC values into the LCA Modelling Tool during the 2025 CFS review with the objective of minimizing the potential trade-offs from Canadian SAF commercial deployment
- Set "balance commitment" targets between the industry and regulators in support of national GHG-reduction goals
- Engage stakeholders through demonstration initiatives across Canada to facilitate SAF integration into the existing transport, storage and distribution infrastructure

Strategic Area 4 — Technical and sustainability certifications

Technical certification

- Ensure a coordinated approach to the certification of SAF from various federal departments such as the National Research Council of Canada, Transport Canada, Natural Resources Canada, National Defense, and Environment and Climate Change Canada
- Develop a fast-track approach to the certification of new conversion pathways in Canada under ASTM D4054
- Provide assistance to applicants throughout the certification process
- Provide incentives to support fuel testing and review process for fuel certification
- Review the existing guidelines for incorporating SAF into the downstream logistics of CAF (API 1543, API 1595 and CSA B836)

Sustainability certification

- Develop a comprehensive LCA database for the Canadian SAF sector and low-carbon CAF to ensure the data consistency throughout regulatory and policy frameworks at federal and provincial levels
- Develop a meta-sustainability framework that ensures compliance with the already established sustainability standards such as RSB and ISCC standards
- Create incentives to support the Canadian stakeholders going through the sustainability certification process

Strategic Area 5 — Outreach and knowledge transfer

- Implement a communication plan to inform Canadians of the benefits of a Clean Fuel Standard, carbon tax and other policy mechanisms

- Deploy a comprehensive outreach strategy to communicate the value proposition of SAF to stakeholders and Canadians
- Encourage citizens, through public-awareness strategies, to reduce non-essential air travel and consider other means of transportation with lower environmental impact
- Hold a dedicated SAF forum in Canada on an annual or biennial basis
- Encourage knowledge transfer between regional and national initiatives through workshops and webinars
- Increase online presence on social media and SAF Community virtual platform
- Have a dedicated organization to push forward knowledge transfer and public awareness

Strategic Area 6 — Consortia-building and regional initiatives

- Encourage the development of biohubs and other multi-stakeholder regional projects and initiatives
- Foster N2N approaches for more collaborations and extended knowledge transfer
- Enable and facilitate consortia-building based on the principles of circular economy and industrial symbiosis

CLOSING REMARKS

The use of sustainable aviation fuels is expected to help the Canadian commercial aviation sector to meet its domestic and international carbon-reduction targets; however, existing and proposed regulatory and policy instruments at the federal and provincial levels require complementary measures to successfully drive the production of SAF into the commercial phase.

Whereas initiatives such as the Sky's the Limit Challenge could facilitate consortia-building and Fuel Readiness Level (FRL) acceleration, the viability of a domestic SAF market will remain strongly tied to the regulatory framework resulting from the entry into force of the GGPPA's carbon tax and the Clean Fuel Standard.

Multi-stakeholder projects such as the CBCSI are useful to illustrate the approach envisioned by the Pan-Canadian Sustainable Aviation Fuels Initiative to advance the efforts to build a domestic SAF-production capacity. The deployment of comparable initiatives to address existing barriers for SAF in Canada will be more likely to succeed if approached from an integrated perspective, as per the recommendations presented in this white paper.

Canada is uniquely positioned with extensive natural, human and financial resources to successfully contribute to SAF volumes. The GARDN program is a unique opportunity for the public and private sectors to continue their efforts in strengthening the various supply-chain components required for the Canadian air transport sector to achieve greater GHG reductions. Our SAF Community is committed to supporting aviation to attain a more sustainable future.

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ANNEXES

ANNEX 1: GARDN II ENVIRONMENTAL ASSESSMENT

GREENER CANADIAN AEROSPACE A LOOK TOWARD 2030

ENVIRONMENTAL ASSESSMENT OF GARDN II RESEARCH PORTFOLIO

The Green Aviation Research and Development Network (GARDN) is a non-profit organization that aims to reduce the environmental footprint of the next generation of Canadian aircraft, engines, and avionics systems by funding collaborative and innovative projects. This study assessed the technologies' contribution to the development of cleaner, quieter, and more sustainable aircraft in Canada and abroad.

Evaluated technologies

To assess their environmental benefits, the technologies of the nineteen GARDN II projects were grouped in the following nine clusters. They were assessed using the environmental metrics described at the bottom of this page.

- **Greener commercial turbofan** equipped with optimized flight management systems and manufactured with low-waste processes
- 30% blend of **sustainable aviation fuel** (SAF) from renewable feedstock
- Self-launching **electric glider**
- **Unconventional aircraft configurations** that reduce drag and noise
- Other technology clusters
  - **Greener large turboprop** equipped with quieter and cleaner engines as well as quieter airframe features
  - **Greener small turboprop** equipped with a flight optimization tool
  - **Hybrid unmanned aerial vehicle** (UAV)
  - **Greener business jet** equipped with cleaner engines, quieter airframe features, and lighter landing gear
  - **Green supply chain management** (GSCM)

Key findings

The technologies of the GARDN II projects have the potential to:

- Contribute to **27% of the Canadian aviation's carbon neutral growth target in 2030** (0.7 of 2.6 Mt CO_2 eq.). The development of the **SAF** industry is a key component of success contributing to 98% of this effort.
- Address important environmental issues related to the aviation sector: **GHG**, **NO_x**, and **SO_x** emissions, non-renewable energy consumption, and noise, as well as emissions of other air contaminants, such as **PAH** and **lead**.
- Help the industry meet ICAO's **noise regulations**, which must be met for an aircraft to enter service, and therefore contribute to the competitiveness of the sector.
- Provide very high benefits per flight, especially for **electric gliders, greener small and large turboprops, and hybrid UAVs.** When benefits are scaled up to an entire fleet and extrapolated to 2030, the greatest benefits are from **greener commercial turbofans** and **SAF**.

Estimated environmental benefits at the flight level

For each technology cluster, the percentages below represent the reduction of the environmental metrics (i.e. the environmental benefits) of an aircraft flying with green technologies compared to a conventional aircraft.

	NRPEC	NO_x / PM / SO_x	Noise	GHG	
Greener commercial turbofan	3%	3%	NA	3% per flight	= 10 million passengers
SAF	13%	0-9%	NA	18% per flight	= 9 million passengers
Electric glider	93%	37-93%	65%	95% per flight	= 25,000 passengers
Unconventional configurations	13%	13%	16%	13% per flight	= 3 million* passengers
Other technology clusters	0.3-10%	0.3-31%	13-28%	0.3-10% per flight	= 1 million passengers

2018–2030 cumulative GHG benefits at the fleet level

Scaled up to the fleet level, the cumulative GHG reductions of all clusters by 2030 correspond to...

20 million passengers

...travelling between Toronto and Vancouver.
In 2016, Canada's air traffic GHG emissions were equivalent to 66 million passengers travelling this distance.

Environmental metrics:

- **NRPEC:** Non-renewable primary energy consumption (e.g. jet fuel) as opposed to renewable resources, such as plants
- **NO_x:** Nitrogen oxides formed during fuel combustion
- **PM:** Particulate matter smaller than 100 microns emitted to air during incomplete combustion
- **SO_x:** Sulphur oxides emitted to air when burning sulphur-containing fuels
- **Noise:** Depending on the technology cluster, either the change in air pressure due to sound waves or the perceived loudness of the sound
- **GHG:** Greenhouse gases (mostly CO_2 emitted by jet fuel combustion)

NA = not applicable
** Environmental benefits of unconventional configurations would occur from 2035. Therefore, they were estimated over a 2035–2047 period and were excluded from the total.*

GARDN GROUPE AGÉCO CIRAIG

March 2019

ANNEX 2: SAF COMMUNITY SURVEY

1. Background information

1.1. Your name and/or your organization

1.2. What are your main areas of activity/affiliation in the sector of SAF? (More than 1 answer is possible)

- ○ Academia
- ○ Advocacy
- ○ Airline operator
- ○ Airport
- ○ Certification
- ○ Consortium
- ○ Consulting
- ○ Feedstock production and processing
- ○ Financing
- ○ Fuel producer
- ○ Fuel supplier
- ○ OEM
- ○ R&D
- ○ Provincial government
- ○ Federal government
- ○ Other:

1.3. Where do most of your activities take place? (More than 1 answer is possible)

- ○ Ontario
- ○ Quebec
- ○ Nova Scotia
- ○ New Brunswick
- ○ Manitoba

- British Columbia
- Prince Edward Island
- Saskatchewan
- Alberta
- Newfoundland and Labrador
- Territories (Northwest Territories, Yukon, Nunavut)
- Canada
- International
- Other:

1.4. In your opinion, what feedstocks would make the most sense to use for SAF production in your region? (More than 1 answer is possible)

- Algae
- Lignocellulosic biomass
- Municipal solid waste (MSW)
- Oils and fats
- Other carbon sources
- Sugars and starches
- Other:

2. Innovation / R&D / Technology development

2.1. What are the main R&D or innovation gaps in Canada?

2.2. In your main field of activity, what would be the most "low-hanging fruit" activities to help the technology development in this sector in Canada? (Short term)

2.3. Economics aside, what solutions could be imagined with the best social and environmental impacts for this industry? (Long term)

3. Production / Scale-up / Commercialization

3.1. Have you encountered specific risks in the SAF supply chain and what could be done to minimize or eliminate those risks?

3.2. What are the main technical issues and difficulties in scaling up the production of SAF?

3.3. What would you suggest to facilitate the certification process of SAF?

3.4. How would you evaluate the potential scope of impact of the following stakeholders?

	Low impact	Medium impact	High impact
International Organizations (ICAO, IATA, etc.)	○	○	○
Federal government	○	○	○
Provincial governments	○	○	○
Feedstock providers	○	○	○
Technology developers	○	○	○
End users	○	○	○
Citizens	○	○	○

3.5. Please comment on your answers to the previous question.

3.6. What are the main commercial barriers to scaling up SAF in Canada? What would be the most effective (or creative) solutions to overcome those barriers?

4. Financing and funding

4.1. What are the main barriers to accessing the capital? What would help minimize those barriers?

4.2. What are the main financial risks (real or perceived) related to financing SAF projects? What could be done to minimize those risks?

4.3. What role can airlines and airports play in supporting and financing SAF projects?

4.4. What is your understanding of the price difference between SAF and conventional jet fuel?

4.5. In the context of a carbon tax, what price would be required for 1 tonne CO2 to close the gap and level prices between SAF and fossil jet fuel?

4.6. What would be the best way to close the price gap between conventional jet and SAF?

4.7. In your opinion, who should support the biggest share of the extra cost related to SAF? (1 answer only)

- ○ Federal government with off-take agreements
- ○ Private aviation (e.g. private jets, air shows, recreation)
- ○ Travel for business
- ○ Tourism / frequent flyers (the more you fly = the more you pay)
- ○ Other:

4.8. What would be the most effective way for the public sector to invest in SAF-related projects? (More than 1 answer is possible)

- ○ Investing in collaborative R&D projects
- ○ Investing in production facilities and infrastructure
- ○ Funding support for the certification process
- ○ Financial incentives for private-sector purchase agreements
- ○ Federal procurement
- ○ Other:

5. How can the public sector help?

5.1. What policy changes (or new policies) do you think would be most effective in helping the development of a Canadian SAF supply chain?

5.2. What regulation changes (or new regulations) do you think would be most effective in helping the development of a Canadian SAF supply chain?

5.3. What other initiatives could the public sector put in place to help the SAF sector in Canada?

5.4. What kinds of collaborations between private and public sectors could be imagined to help develop SAF?

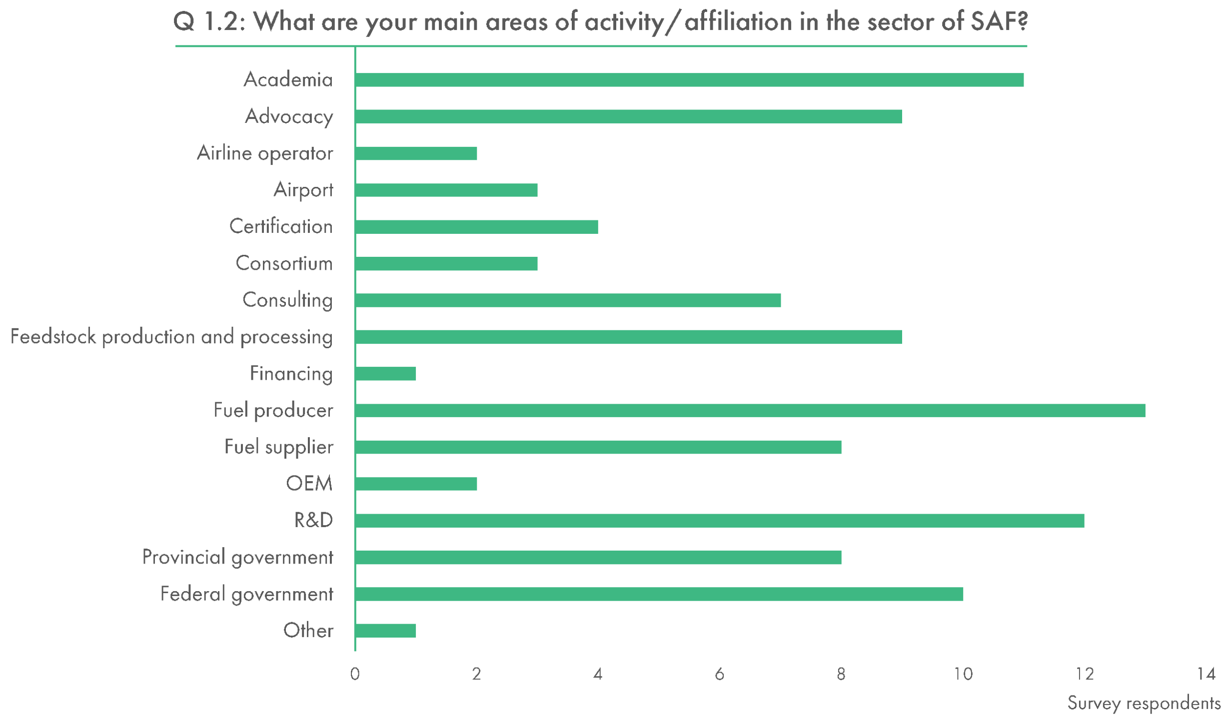
5.5 What kinds of collaborations between federal and provincial governments could be imagined to grow the SAF sector in Canada?

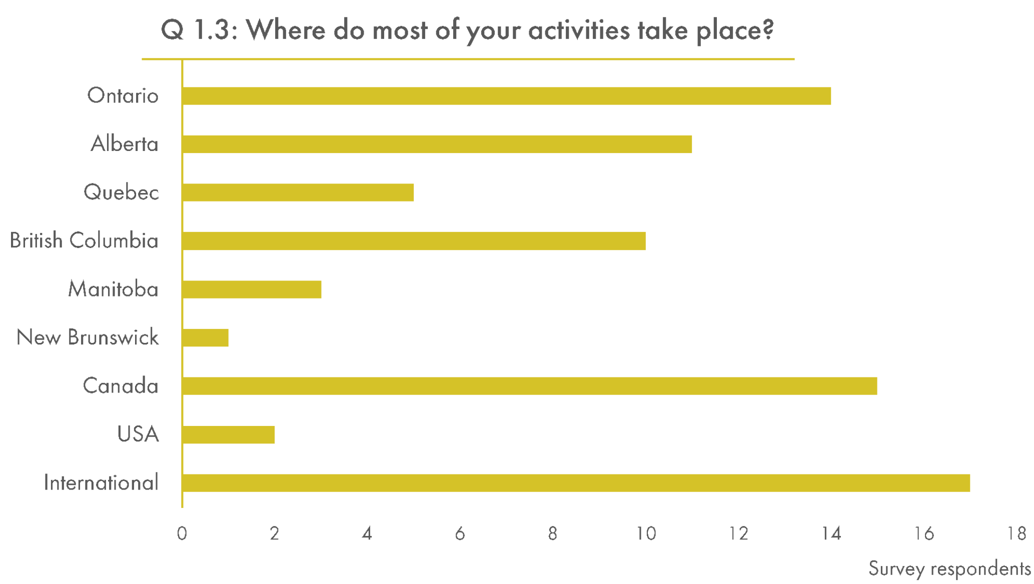
6. Other creative ideas...

6.1. What would be the best way to enhance collaboration and co-creation in this sector?

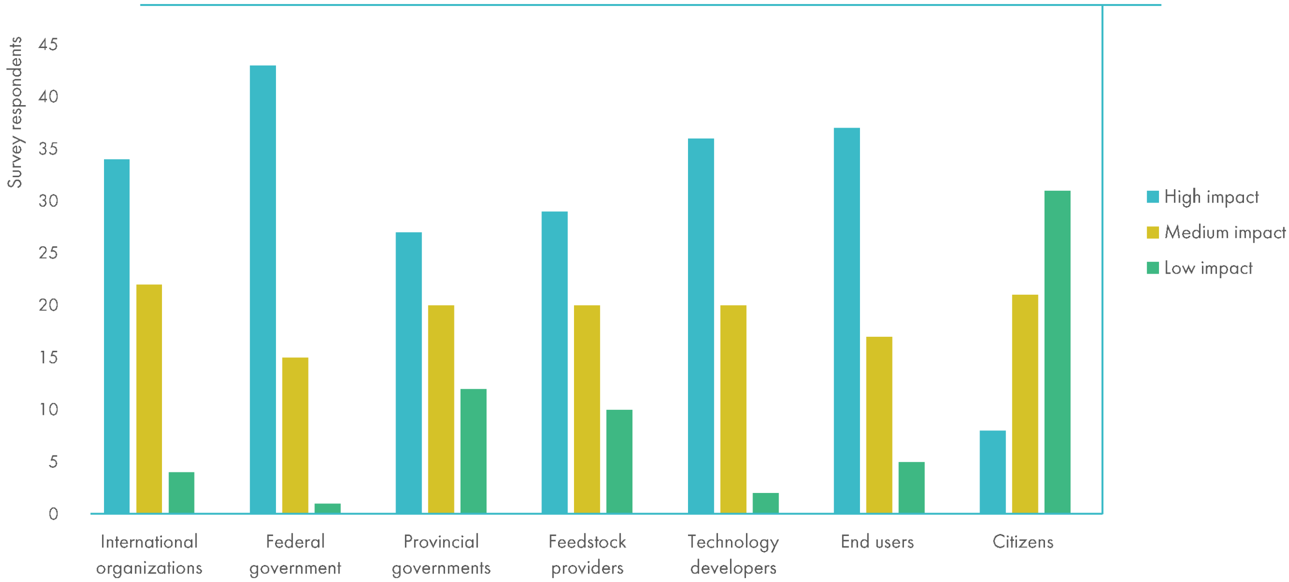
6.2. What other creative ideas and concrete solutions can you think of to help the Canadian SAF sector become the most successful and the most sustainable in the world?

ANNEX 3: OVERVIEW OF THE SAF COMMUNITY SURVEY RESULTS (2019)

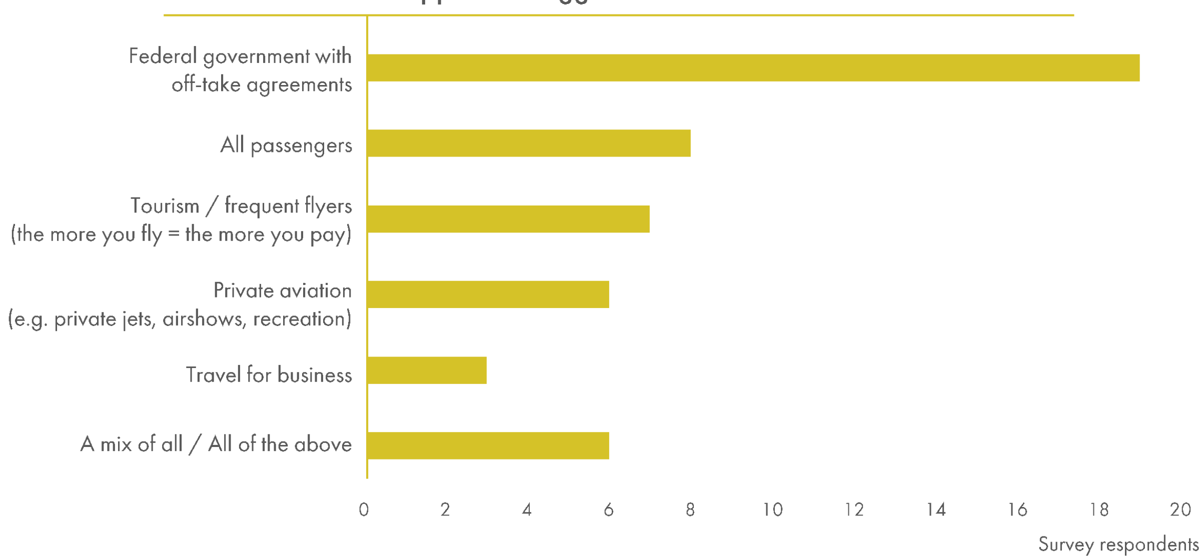




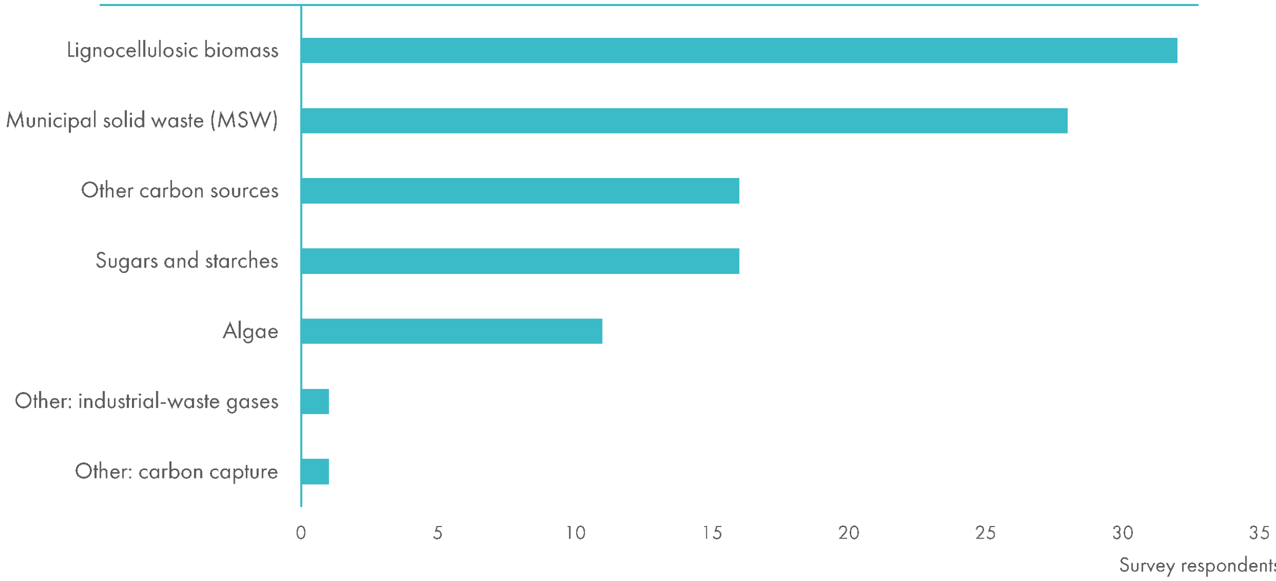
Q 3.4: How would you evaluate the potential scope of impact of the following stakeholders?



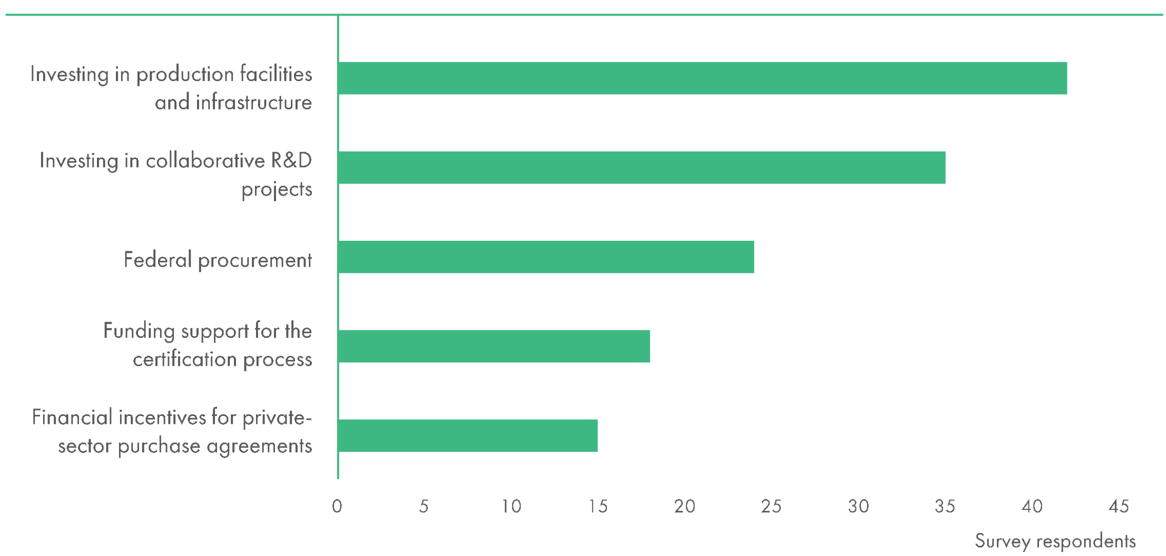
Q 4.7: Who should support the biggest share of the extra cost related to SAF?



Q 1.4: What feedstocks would make the most sense to use for SAF production in your region?



Q 4.8: What would be the most effective way for the public sector to invest in SAF-related projects?



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