SUMMARY

The C-SAF Roadmap

Building a feedstocks-to-fuels SAF supply chain in Canada

in partnership with

C-SAF™

The Transition Accelerator | L'Accélérateur de transition

energyfutureslab

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Acknowledgments

The team would like to thank Juliana Lisi and Emily Blocksom for their work throughout the roadmap process. The authors would like to thank the C-SAF Board, Steering Council, and Technical Committee for their critical inputs to the roadmap. In particular, we would like to acknowledge the contributions of Chris Vervaet, Marion Town, Jack Saddler, Dave Schick, Devin O'Grady, Fred Ghatala, Teresa Ehman, Candice Paton, Aaron Robinson, Rob van Diepen, Mike Manshanden, Keith Lawless, David Lynch, Ursula Rivero, Scott Goobie, Dale Smith, Lana van Marter, Ryan Bowen, Jenna Anand, David Poisson, Nick Andrews, Alex Menotti, Anna Stukas, Patrice Mangan, Patrice Bergeron, and Benny Wong.

Cover images:
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About us

C-SAF Canadian Council for Sustainable Aviation Fuels

The Canadian Council for Sustainable Aviation Fuels (C-SAF) is a not-for-profit organization that aims to accelerate the commercial production and deployment of SAF in Canada by catalyzing the ecosystem and value chains, promoting public policy, strategies and a roadmap, acting as a neutral and balanced technical expert, and serving as the voice of its members to government and non-government stakeholders on SAF issues. C-SAF was created by a consortium of 60 domestic, international and cargo airlines operating in Canada who own and operate aviation fuel storage and distribution facilities at 11 international airports across Canada. C-SAF is comprised of 110 members who represent key industry leaders that are committed to advancing SAF production and use in Canada.

c-saf.ca

The Transition Accelerator / L'Accélérateur de transition

The Transition Accelerator exists to support Canada's transition to a net-zero future while solving societal challenges. The Transition Accelerator works with innovative groups to create visions of what a socially and economically desirable net zero future will look like and build out transition pathways that will enable Canada to get there. The Accelerator's role is that of an enabler, facilitator, and force multiplier that forms coalitions to take steps down these pathways and get change moving on the ground.

transitionaccelerator.ca

energyfutureslab

The Energy Futures Lab was created to address a growing sense of polarization in Canada. Since its inception in 2015, the EFL has brought together stakeholders from across the energy system to collaboratively develop solutions for a low-emissions energy future. This approach has highlighted the importance of drawing on diverse perspectives to address complex, system-level challenges.

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Summary

Sustainable aviation fuel (SAF) is an essential part of decarbonizing aviation.[1] Compared with other sectors which have multiple technology options, SAF is the only viable pathway for long haul aviation (which comprises the majority of sector emissions) in the coming decades. SAF is a critical piece of Canada's Aviation Action Plan, which lays out a 2050 net-zero vision for the industry.[2]

Canada has enormous opportunities in the SAF supply chain: bountiful sustainable feedstock, existing refining capacity, innovative technology providers, and domestic and international airlines seeking to decarbonize.[3] Building the whole supply chain would add value to the Canadian economy. In particular, adding manufacturing capacity to rural communities would create skilled jobs and help to build innovation economies in these important regions.

SAF is a critical piece of Canada's Aviation Action Plan, which lays out a 2050 net-zero vision for the aviation industry.

SAF provides an opportunity to strengthen the Canadian economy by building new future proof economic opportunities and decarbonizing the aviation sector while enhancing energy security. The Russian invasion of Ukraine has illustrated the importance of creating supply chains that are resilient to geopolitical shocks.

How can these opportunities be converted into a large and healthy SAF ecosystem that delivers long-term economic value-added across Canada?

This roadmap charts a pathway and a strategy to produce truly sustainable and affordable SAF in Canada with Canadian feedstock and clean energy, using made-in-Canada solutions that aim to promote Canadian technology.

Targets

Canada's Aviation Action Plan lays out a clear and ambitious goal: by 2030, SAF should be 10% of projected Canadian jet fuel use.[4] Based on this goal and the total market for jet fuel in Canada, C-SAF has established a target of 1 billion litres of SAF production by 2030. This SAF should achieve a minimum 50% reduction in life cycle greenhouse gas emissions compared to conventional jet fuel which would represent a reduction of about 1.6 million tonnes of GHG emissions[5].

There is no SAF being produced today in Canada. The good news is that several companies have announced biofuels facilities that could produce at least 500 million litres of SAF in Canada by 2030.

However, it is important to note that most of these announced facilities have not yet reached final investment decision, and there is no guarantee that the facilities would use Canadian feedstocks or that any biofuels they produce end up in the Canadian market. Moreover, many of these facilities are planning to produce renewable diesel and, without proper incentives, may not include any SAF capacity at all. Even if they include SAF capacity, the SAF fraction they produce will depend on the economics and the ability to meet SAF sustainability criteria. So, the 500 million litres we bank on here is an optimistic scenario.

How can we meet the targets and build regional supply chains that benefit all of Canada while decarbonizing aviation?

Canada's opportunity and strategy

We need to seize Canada's opportunities in the SAF supply chain. With the right economic environment, Canada can build resilient, innovative SAF value chains with the goal of meeting demand and emissions reduction requirements for all airlines flying in and out of Canada and generating exports.

An original analysis for this roadmap concludes that **Canada has sustainable biomass for 7–10 billion litres of SAF a year.**[6] This amount, if prioritized for aviation, is about what Canada would need to meet total aviation fuel demand in 2030. But Canada also has the potential to use abundant clean electricity and low carbon hydrogen to produce sustainable jet fuel. So, while in the short-run Canadian SAF should remain available for use in Canada, Canada has the potential to produce additional SAF for export, if the strategy is managed and executed properly.

Canada's opportunity is unique because it has firms that are positioned in all parts of the renewable fuels value chain. Every region of the country can build efficient, homegrown feedstocks-to-fuels value chains that could support the production of SAF and the creation of low-carbon aviation hubs at the airports.

In feedstocks, Canada has opportunities across all SAF pathways. In the short-run, commercial volumes will be dominated by HEFA-based SAF from oilseeds. But to scale SAF to meet the 1 billion litres SAF target in 2030 and beyond, we need technologies and projects that

activate Canada's strengths in forest and agriculture residues, municipal solid waste, ethanol, and power-to-liquids. All feedstocks and potential value chains must be activated to meet these targets and realize the potential. Furthermore, Canada must evaluate and demonstrate the environmental and socioeconomic impacts of SAF production in Canada and strive to ensure that life cycle methodologies are standardized for use across jurisdictions including the eligible fuel sustainability requirements under CORSIA[7].

In refining, Canada has world-leading expertise in hydrocarbons and green chemistry. Canadian refiners such as Parkland, Tidewater, Shell, Imperial Oil, Irving Oil and Suncor to name a few are all exploring how they might convert their expertise and facilities to produce SAF.

In technology, Canada has a wide range of technology providers leveraging the country's expertise such as Enerkem, Forge, Steeper, Ensyn, Expander, Carbon Engineering, and SAF+. Positioning these firms as world-leading technology providers would add economic value and create the basis for an innovation ecosystem that produces benefits over the whole energy transition.

However, the key global players are gearing up to produce SAF at scale. The EU has a hard SAF blending mandate that is driving investment in SAF

production. *The Inflation Reduction Act* ("IRA") creates incentives that make the US biofuels and SAF production investment climate more attractive than Canada's. This creates a real danger: Canadian feedstocks will be pulled into the US to make SAF and Canada will lose the economic value-added of fuel production. And if the refining and conversion moves to the US, then so too will the innovation ecosystem. The IRA is a serious problem for Canadian competitiveness and threatens to reduce Canada's contribution to a friendly provider of raw feedstock.

Canada has neither clear supply-side production incentives nor a mandate to help build the SAF market—just a nascent voluntary credit market under the Clean Fuels Regulation. From an investor perspective, it is simply impossible to bank a project with completely unknown credit values or uncertain regulations.

In the absence of Canadian-produced SAF supply, most of the SAF required by the aviation sector to meet their decarbonization objectives will need to be imported. But relying solely on imports is unstable and cost uncompetitive given that SAF production is limited even on a global scale and other jurisdictions are adopting positive supply incentives that support production and uptake of SAF production locally.

The strategy underlying this roadmap is to activate all sustainable feedstocks and pathways to build SAF regional value chains that create long-term economic value and innovation capacity.

Canada needs to respond with a clear strategy and concrete action plan. Canada must do three things to compete and capture SAF economic value-add:

- incentivize the production and use of SAF in Canada;
- prioritize sustainable feedstocks for SAF production and ensure demand-pull to develop the supply chains in key areas of competitive strength;
- position its technology providers in global markets with programs that support the scaling of Canadian firms.

Without doing all three, Canada could end up with a thin SAF industry that does not take advantage of Canada's opportunity to strengthen its economy while building an industry that is critical to achieving net-zero aviation.

The strategy underlying this roadmap is to activate all sustainable feedstocks and pathways to build SAF regional value chains that create long-term economic value and innovation capacity. In practical terms, Canada can make the most of Canada's existing HEFA-based renewable diesel capacity to produce SAF now. At the same time, we need to deploy feedstocks and technologies today so that forestry and agricultural residues can produce SAF at scale during the 2030s. We also need to advance power-to-liquids pathways, that produce SAF from low carbon energy and hydrogen, so they can scale in the 2030s.

This strategy depends on two key pieces: a Policy Package and a Flight Plan for SAF outlining a potential project portfolio that balances the goals of producing volumes now while developing innovative pathways for the future.

A Policy Package for SAF

It is beyond the scope of this report to specify a complete policy package, but it is clear that to seize the considerable opportunities for Canada, we must incentivize SAF production with a multi-pronged policy package and explore how federal and provincial measures can be further leveraged to enable and accelerate a SAF market in Canada:

	OBJECTIVE	ACTIONS TO DATE
1	SAF to generate credits in low carbon fuel standards as a voluntary opt-in	Canada Clean Fuel Regulations in force since June 20, 2022, include provisions for SAF to generate credits[8]
2	Provide SAF-specific production incentives (at a higher level than renewable diesel), such as the SAF producers tax credit in the *Inflation Reduction Act*	The federal government has indicated intentions to engage with industry in 2023 to explore opportunities to promote the growth of biofuels in Canada[9]
3	Waive all federal and provincial carbon tax on SAF that meets a certain minimum carbon intensity standard	Draft regulations amending the federal Fuel Charge Regulations[10] to exempt SAF
4	Federal procurement of SAF for federal fleets to support increasing market demand	Treasury Board Canada was awarded $228 million over 8 years to implement a low-carbon fuel procurement program for the federal air and marine fleets[11]

Our feedstock projections rely on fuel production processes that generate high SAF fractions: 40–77% depending on the pathway.[12] That is only going to happen if there is a strong incentive to produce SAF over and above regular renewable diesel.

The key is to kickstart the market now, in order to drive the technology deployments that will bring down costs. A market can be kickstarted by supply-side incentives or by demand-side regulations and mandates.

A mandate will drive up costs unless supply chains are incented and developed enough to scale with the mandate.

> *The key is to kickstart the market now, in order to drive the technology deployments that will bring down the cost of SAF.*

In the absence of a volumetric mandate, supply-side incentives can deliver volumes if they enable the production of SAF at prices on par with regular jet fuel, or a small premium.[13] The US Department of Energy's SAF Grand Challenge makes this bet. It is premised on the idea that existing incentives plus the *Inflation Reduction Act* can drive the production and uptake of SAF.

Canada needs incentives to create a level playing field with the United States. But part of the Canadian package will include credits from the CFR and carbon market. These have uncertain values. But in the 2022 Fall Economic Statement, the Government of Canada announced that the Canada Growth Fund will be able to write contracts for difference at the project level and in Budget 2023, the government will consult on the development of a broad-based approach to carbon contracts for difference that aims to make carbon pricing even more predictable. This means that projects will be able to negotiate contracts that guarantee a certain credit level for the project. If the credit level rises above the agreed strike price, then the government would keep the proceeds. If the credit level goes below the strike price, the government would pay the difference. This could be a key tool to get projects to final investment decision now.

The four-part policy framework must be supported by a robust and science-based sustainability framework. Incentives must be indexed to carbon intensity scores to encourage carbon reductions. But we also have to meet criteria for ecosystem productivity, erosion, biodiversity, and other sustainability standards as considered by CORSIA. This is key to Canada's competitiveness in global markets, which will reward low-carbon and ecologically robust practices up and down the supply chain.

Production Facility For Ethanol Biofuel.

A Flight Plan for SAF: Projects and timelines

This roadmap is premised on a target of 1 billion litres of SAF by 2030 with a minimum 50% reduction in lifecycle GHG emissions compared to conventional fossil-based jet fuel in accordance with an approved lifecycle GHG methodology such as ICAO or equivalent. But this target, which represents 10% of all jet fuel use in Canada is just a waypoint on the way to net-zero. By 2035, Canada should be ready to produce SAF to meet 25%

This roadmap is premised on a target of 1 billion litres of SAF by 2030 with a minimum 50% reduction in lifecycle GHG emissions.

of total jet fuel demand which would reduce emissions by 15–20% for departures from Canada[14].

In order to decarbonize Canadian aviation while seizing the considerable economic opportunities in the supply chain, Canada has to meet that 2030 target by building an ecosystem that is ready to scale. That ecosystem will only be ready to scale if we create demand-pull on nascent supply chains for the Canadian feedstocks that will be critical for long-term goals: oilseeds and waste fats, forest residues, agricultural residues, and the hydrogen and carbon dioxide streams needed for power-to-liquids. Projects in each of these areas are needed to prime supply.

The Flight Plan to 2030 is to produce real SAF volumes while creating the conditions for lift-off after 2030. Moreover, since the global SAF value chain will be highly competitive over a long transition, innovation capacity must be built in from the beginning. That innovation capacity will ensure Canadian production is competitive over time.

There are then three objectives to balance:

1 Decarbonize now

Maximize SAF now from commercial ready pathway

2 Feedstock activation

Establish commercial pathways for all Canada's feedstocks

3 Innovation drive

Launch demonstrations with homegrown technology in multiple pathways

The key is to realize each of these objectives at the project level. We could construct pathways that maximize each individual goal. A strategy emphasizing decarbonization now would focus on the HEFA pathway, because it is an already proven commercial technology, while advancing gasification with Fischer-Tropsch on wood residues, which is a key emerging pathway. To activate feedstocks, commercial scale projects for agricultural residues and power-to-liquids are needed. An innovation drive would involve building multiple demonstrations to advance other feedstocks and pathways such as hydrothermal liquefaction and alcohol-to-jet.

A project pipeline ready for take-off after 2030 needs to do all three. The **SAF take-off portfolio** proposed here points to the concrete projects necessary to achieve all these goals and articulates the priority actions needed to incentivize these projects. In short, Canada must push for as much HEFA-based SAF as possible now, site as many new commercial pathways as possible that use advanced feedstocks, and seed demonstrations in next generation areas with Canadian technology providers where feasible.

SAF TAKE-OFF PORTFOLIO:

Advance decarbonization, feedstock, and innovation goals

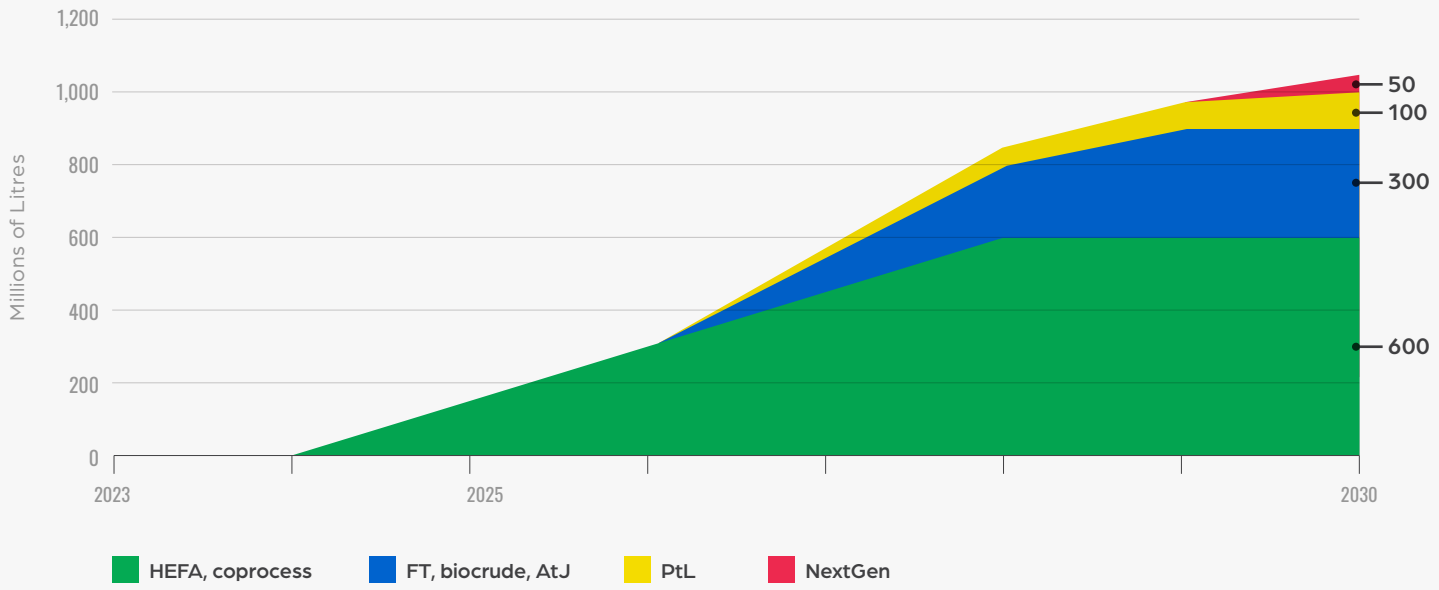
HEFA	600 ML
Forestry (FT)	200 ML
Ag residue (FT)	100 ML
PtL	100 ML
Next Gen Demonstrations	50 ML
2030 SAF Production	**1,050 ML**

PRIORITY ACTIONS:

- Ensure policies and programs support final investment decision and maximum SAF fraction for proposed facilities.
- Validate the sustainability of Canadian oilseed HEFA to meet CORSIA Eligible Fuel criteria
- Build upstream collection and delivery logistics for forestry and agricultural residues.
- Secure demonstration funds.
- Create long-term industrial and innovation strategy.

Notes: HEFA—SAF from oilseeds, tallow, used cooking oils, fats and greases; Forestry (FT)—wood residues via gasification and Fischer-Tropsch; Ag residue (FT)—agricultural residues (straw and stover) via gasification and Fischer-Tropsch; PtL—power-to-liquids using CO_2 and hydrogen. Next generation demonstrations include: Forestry (HTL)—wood residues via hydrothermal liquefaction; Cellulosic (AtJ)— biomass residues via alcohol-to-jet; and CO_2 (AtJ)—CO_2 via alcohol-to-jet.

FIGURE 1. SAF TAKE-OFF PORTFOLIO – POTENTIAL SAF VOLUMES FROM PATHWAYS



Action Plan and Next Steps

It is time to get to work. With this roadmap, C-SAF and its partners in government, industry, and civil society can build the regional value chains that will activate Canadian feedstocks, incentivize Canadian refining, and boost Canadian technology providers while producing the SAF needed to start decarbonizing aviation now.

In short, Canada must push for as much HEFA-based SAF as possible now, site as many new commercial pathways as possible that use advanced feedstocks, and seed demonstrations in next generation areas with Canadian technology providers where feasible.

This report highlights concrete actions in five SAF Action Areas: feedstock, SAF production, technology and innovation, sustainability, and policy and programs. These actions require collaboration among all members of the ecosystem. The long-term success of the Canadian ecosystem depends on building strategic collaborations that go beyond this roadmap. Best practices from other jurisdictions suggest that public-private partnerships independent from both government and industry are needed to ensure success.[15]

C-SAF is well positioned to bring together the broad coalitions necessary to deliver on these priorities. To do this, C-SAF will create implementation Task Forces that bring together government, industry, indigenous communities, and experts to work together to advance policy and programs, articulate the sustainability case, build SAF supply chains, and advance a long-term industrial strategy for the aviation sector.

The following C-SAF 2 year Action Plan sets out the priorities that each Task Force will focus on to progress the five SAF Action Areas.

C-SAF 2 year Action Plan (from June 2023 to May 2025)	
POLICY AND PROGRAMS	» Advance a policy package that will incentivize the investment needed to meet 2030 and longer-term SAF targets. » Ensure that federal and provincial funding programs take an active role in supporting innovative SAF production here in Canada, including final investment decisions and maximum SAF fractions for proposed facilities. » Build the strategic collaborations necessary to advance a successful long-term industrial policy for SAF and aerospace development in Canada. » Develop a Canadian SAF registry (book and claim SAF accounting system).
SUSTAINABILITY	» Map the GHG emissions footprint from all steps of cultivation, collection and production of biomass and CO_2 derived SAF. » Conduct rigorous analysis of the sustainability of Canadian feedstocks for ecosystem productivity, biodiversity, and other environmental benefits. » Ensure clarity on the differences between Canadian and international sustainability requirements (i.e. CORSIA), lifecycle analysis methodologies, and consumer preferences and work to facilitate and standardize SAF accounting and certification methodologies. » Articulate sustainability case for Canadian feedstocks, including oilseeds.
FEEDSTOCKS	» Build the infrastructure and policy frameworks needed to bring all feedstocks into SAF regional supply chains. » Build upstream collection and delivery logistics for forestry and agriculture residues.
SAF PRODUCTION CAPACITY	» Create an active project pipeline with first commercial, demonstrations, and pilots in critical SAF production pathways. » Ensure proposed HEFA projects reach final investment decision. » Seed projects in emerging commercial pathways such as gasification with Fisher-Tropsch and alcohol-to-jet.
TECHNOLOGY AND INNOVATION	» Canada to establish a national centre of excellence for the future of aviation in a net-zero world to ensure that SAF and aerospace decarbonization priorities are aligned and complimentary. » Canada to create a national industrial and innovation strategy with two clear streams: – Create clear technology development plans for SAF pathways that activate Canadian feedstocks. – Create clear technology development plans for new propulsion technologies. » Secure demonstration funds for SAF. » Coordinate R&D with leading universities and international partners.

Endnotes

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4 CBSCI 2019; Deloitte 2022.

5 Transport Canada. 2022. Canada's Aviation Climate Action Plan 2022-2030. https://tc.canada.ca/en/corporate-services/policies/canada-s-aviation-climate-action-plan

6 1 billion L SAF x (50% * 89 g CO2e/MJ) x 37.4 MJ/L x 10^{-6} = 1.664 million tonnes of GHG emissions

7 For further details, please see the technical appendix.

8 https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

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10 https://www.budget.canada.ca/2023/report-rapport/chap3-en.html#a7

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13 McKinsey. 2020. Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation. Insight Report, p. 19. https://www.weforum.org/reports/clean-skies-for-tomorrow-sustainable-aviation-fuels-as-a-pathway-to-net-zero-aviation/

14 The analysis for Bioport YVR suggests that for oilseed pathways, the policy package suggested here could achieve this. Bioport YVR. 2020. https://www.budget.canada.ca/2023/report-rapport/chap3-en.html#a7

15 In line with Canada's Aviation Climate Action Plan and SAF carbon intensities between 60 and 90% lower than conventional jet fuel.

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