November 5, 2025

Department of Ecology
Shorelands and Environmental Assistance Program
P.O. Box 47709
Olympia, WA 98504-7709

Submitted via: https://sea.ecology.commentinput.com/?id=8pM3Hf7QK

Re: Scoping for Sustainable Aviation Fuel Programmatic Environmental Impact Statement

Dear Ecology:

Thank you for your recent public meetings regarding the programmatic environmental impact statement (PEIS) for aviation fuel in Washington. Columbia Riverkeeper submitted oral testimony during the hearing on October 21, 2025. Columbia Riverkeeper and Oregon Physicians for Social Responsibility urge Ecology to consider the impacts to rivers, estuaries, clean air, and climate stability from increased refining, processing, and transportation of aviation fuel, as well as its combustion. Specifically, we offer the following comments:

- The geographic scope of the PEIS must involve the Columbia River Estuary, including identifying the tremendous harm that would come to the Estuary from storing toxic, liquid fuel on unstable soil near fisheries vital to the health of the entire region, particularly the Tribes who rely on the Columbia River.

  Please see the attached comments of Columbia Riverkeeper and separate comments filed by the Columbia River Inter-Tribal Fish Commission, who commented regarding a proposed Clean Water Act certification for a proposed aviation fuel and diesel refinery in the Columbia River Estuary at Port Westward. NEXT Renewable Fuels proposes to build a 50,000-barrel-per-day facility in the Columbia River Estuary across the River from Cowlitz County, Washington, upstream from Wahkiakum and Pacific Counties.

  This proposal would impact both sides of the River. The Columbia River Inter-Tribal Fish Commission urged Oregon to deny the Clean Water Act certification for the NEXT project, stating

  > The direct impacts to water quality and salmon rearing habitat from this project are substantial. The Columbia River is listed under §303(d) as limited and impaired by several water quality parameters, including temperature and toxics. Near this project, the river is listed as impaired from PCBs and DDE, and limited

> for temperature, dioxin, and dissolved gasses. The project's proposed refining process will include contaminants that would be present in all stages of production. The project's Biological Assessment does not define the name or concentrations of the "various contaminants in the waste stream" nor the efficacy of the proposed tertiary filter treatment at removing them…The sloughs and wetlands that will be impacted by the construction and operations of this facility are critical habitat for ESA-listed salmon and steelhead stocks, many of which are essential tribal treaty resources.

Please consider how increasing reliance on toxic, liquid, carbon-intensive aviation fuel could impact communities in the vicinity of major production and fuel shipping locations, such as Port Westward, Oregon - right on the border with Washington. The potential for increased reliance on toxic, flammable, liquid aviation fuel production, storage and handling close to aquatic resources, sensitive wetlands, estuaries, and streams must factor heavily in how the PEIS assesses the overall cost of expanding feedstocks and processes for making jet fuel.

- Feedstocks for the proposed expansion of aviation fuel are uncertain, causing a wide range in possible carbon intensity value for the aviation fuel produced. Recent studies show that most "true waste," lowest-carbon sources (such as used cooking oil) are spoken for. Their supplies are limited. Therefore, there will be a major lack of true waste feedstocks, like UCO. The industry is trying to hide this fact by relaxing standards, blending fuels, and labeling fuel that is largely fossil-fuel based, soybean-based, and very carbon-intensive as "sustainable" or "renewable" when it is, by volume, mostly fossil fuel and clearly not sustainable.

  The PEIS' analysis must include the potential likelihood that a turn to "sustainable" aviation fuel would require a huge increase in the production of purpose-grown feedstocks, such as soybean oil, and that these feedstock production efforts would have a tremendous and deleterious impact. Proponents of the NEXT project in Oregon wrote in a document filed with the SEC in 2023 that their "projections assumed that NXTCLEAN will increase the use of low carbon intensity feedstock and decrease the use of soybean oil as a feedstock gradually, which will increase the LCFS value for NXTCLEAN's products. Soybean oil has the highest carbon intensities ("CI") in the mix <u>and it is most accessible feedstock in the market</u>." (emphasis added)

  NEXT included this table, which shows that the facility would require huge amounts of soybean oil feedstock at the outset of production.

	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Soybean oil-Midwest	60.0%	60.0%	50.0%	40.0%	35.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Other Vegetable oil-foreign	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Used cooking oil (UCO)	5.0%	5.0%	10.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Animal tallows-high energy	7.5%	7.5%	10.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
White/Yellow Greases	7.5%	7.5%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
U.S. Distillers Corn oil	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Other (emerging oils)	0.0%	0.0%	0.0%	5.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%

If Washington expands use of aviation fuel based on soybean oil or other unsustainable feedstocks, the carbon consequences will be enormous and potentially deleterious to achieving reductions in carbon emissions required by law.

- The production of aviation fuel requires hydrogen. Hydrogen is required as an input to create aviation fuel. Aviation fuel refineries have hydrogen production units, and these hydrogen production facilities require huge amounts of fracked gas. The PEIS must consider the climate implications of all of the fracked gas required to produce hydrogen to refine and produce aviation fuel. Additionally, the refineries themselves require huge amounts of power, often supplied from fracked gas. This is an additional impact that should be considered when evaluating whether expanded aviation fuel use is a sustainable trajectory for Washington.

- The production, storage, handling, and use of aviation fuel in planes, trains, ships and trucks each pose hazards throughout the lifecycle of fossil fuels, with harms to community health and safety. As noted in the recent report from Physicians for Social Responsibility,

> Pipeline leaks and ruptures happen and contaminate soil and water and can cause explosions. Transport by rail and truck increases risks of accidents, spills and community exposure to harmful pollutants. Port communities near shipping hubs also face high concentrations of diesel exhaust, which is classified as a known carcinogen and linked to asthma, heart disease and premature death.

These impacts are a burden on communities where jet fuel is present.

A recently released study, Sustainable Aviation Fuel (SAF): A Critical Analysis, with a Focus on Agriculture, Land, and Food, by Darrin Qualman with the National Farmers Union, states

> Producing even a small fraction of the huge SAFs demand from grains and oilseeds (and another larger fraction from energy crops grown on farmland) will exert upward pressure

on food prices (especially as we simultaneously add two billion people to our global population). These foodprice impacts will hit the poorest and hungriest hardest, but will also have negative impacts on nearly every family on Earth.

In conclusion, we urge Ecology to evaluate how and where a massive increase in aviation fuel storage, transportation, and handling would occur, recognizing that this burden will likely fall on communities near estuaries that already bear a toxic burden from existing fuel industries. Washington's Environmental Health Disparities Map should be a helpful tool in developing the PEIS and considering how the impacts of aviation fuel production, storage, transport, and use are focused on vulnerable communities already over-burdened by pollution.

Thank you for your consideration of these issues.

Sincerely,

Dan Serres, Advocacy Director, Columbia Riverkeeper

Samantha Hernandez, Healthy Climate Program Director, Oregon Physicians for Social Responsibility

Attachments:

Comments of Columbia Riverkeeper on NEXT Renewable Fuels Refinery in Oregon.

Physicians for Social Responsibility. "Fueling Sickness: The Hidden Health Costs of Fossil Fuel Pollution." November 2025. https://psr.org/wp-content/uploads/2025/11/fueling-sickness.pdf

Comments of Columbia River Inter-Tribal Fish Commission on NEXT Renewable Fuels Refinery in Oregon.

Sustainable Aviation Fuel (SAF): A Critical Analysis, with a Focus on Agriculture, Land, and Food. A Report by the National Farmers Union Written by Darrin Qualman November 2024. https://www.nfu.ca/wp-content/uploads/2024/11/Sustainable-Aviation-Fuel-NFU-for-website.pdf

October 25, 2024

Leah Feldon, Director
Oregon Department of Environmental Quality
700 NE Multnomah St., Suite 600
Portland, OR 97232

Re: Comments on NEXT Renewable Fuels Oregon, LLC's Application for Clean Water Act § 401 Certification, U.S. Army Corps of Engineers No. NWP-2020-393, Oregon Department of State Lands No. 63036.

Dear Oregon § 401 Coordinator,

The Northwest Environmental Defense Center ("NEDC") and Columbia Riverkeeper ("CRK"), collectively, Commenters, submit the following comments on NEXT Renewable Fuels Oregon's ("NEXT" or "Applicant") application for Clean Water Act ("CWA") § 401 Certification ("Certification" or "401") for the construction and operation of a non-conventional diesel refinery capable of producing 50,000 barrels per day of renewable diesel and other fuel products. Commenters urge DEQ to deny NEXT's 401 because of the project's unacceptable impacts to water quality.

NEDC is an independent, nonprofit environmental organization established in 1969 by a group of professors, law students, and attorney alumni at Lewis & Clark Law School. The organization's members include citizens, attorneys, law students, and scientists. NEDC's mission is to protect the environment and the natural resources of the Pacific Northwest by providing legal support to individuals and grassroots organizations with environmental concerns, and by engaging in education, advocacy, and litigation independently and in conjunction with other groups. NEDC's membership includes individuals who live and recreate on the Columbia River, including the Columbia Estuary, and attribute great environmental, economic, and cultural value to the quality of the river basin and its ability to support various aquatic species, including federally listed salmon and steelhead populations.

Columbia Riverkeeper's mission is to protect and restore the water quality of the Columbia River and all life connected to it, from the headwaters to the Pacific Ocean. Columbia Riverkeeper has over 16,000 members and supporters in Oregon and Washington. Columbia Riverkeeper has members and supporters who live and work in the Port Westward region, as well as many members who work, boat, fish, and swim in the Columbia River nearby and downstream from the proposed refinery site and the Beaver Dock. Columbia Riverkeeper regularly comments on decisions impacting water quality, climate, and salmon habitat in the Columbia River. At Port Westward specifically, Columbia Riverkeeper has successfully opposed two proposed coal export terminals and a methanol refinery, as well as the planned expansion of an oil-by-rail export terminal and the rezone of hundreds of acres of agricultural land and wetlands for industrial use. Columbia Riverkeeper's experiences with NEXT's backers—in the context of this proposal and their past, failed proposals[1] elsewhere in the Columbia River watershed—shows NEXT to be untrustworthy, lawless, and wholly unqualified to build and run a project of this magnitude.

I. Impacted Water Bodies and Summary of Likely Water Quality Violations

NEXT's chosen site contains extensive potential for water quality violations due to its proximity to and direct interaction with several bodies of water. DEQ's draft permit correctly identifies the Columbia River, McLean Slough, and the Clatskanie River as affected waters of the state, but fails to identify and account for potential water quality violations in Bradbury Slough, Beaver Slough, and smaller waterways within and near the project site. NEXT's refinery will add pollutants to the smaller waterways and drainage ditches on the property. By definition, these drainage ditches transport water—and pollutants—to waterways within the levee system that DEQ has not considered. And, the Beaver Drainage Improvement Company ("BDIC") actively pumps water from inside the levee system into Bradbury Slough and Beaver Slough. NEXT does not provide adequate information about impacts to these waterways and improperly assumes that water within the site is contained.[2] As a result, DEQ fails to identify all of the water bodies potentially impacted by the project, undermining the conclusion that the project will not result in water quality violations.

The relevant segment of the Columbia River is impaired for a number of parameters, including pH, temperature, DDE 4,4, Polychlorinated Biphenyls ("PCBs"), dioxin, and dissolved gases.[3] These pollutants hinder the Columbia River's ability to support a number of beneficial uses, including supporting drinking water uses, aquatic life uses, and fish and shellfish consumption uses. However, the Applicant has not provided the requisite analysis to demonstrate

[1] Shick & Wilson, Businessmen Who Abandoned Toxic Mess Now Want To Build Refinery In Washington, KLCC (Feb. 2, 2016), https://www.klcc.org/2016-02-02/environmental-cleanup-unpaid-bills-in-refinery-backers-last-venture; US EPA, Odessa Biodiesel Site, https://response.epa.gov/site/site_profile.aspx?site_id=9819.
[2] *See infra*, Section VI.A.1.
[3] *See* Oregon DEQ, *EPA Approved Integrated Report: Water Quality*, available here: https://geo.maps.arcgis.com/apps/instant/sidebar/index.html?appid=7d13b19e01a44f1dbfd12903576e6d29

that the proposed activity will not cause further degradation of water quality for the aforementioned parameters and beneficial uses. Moreover, the facility's Biological Assessment ("BA"), prepared pursuant to the Endangered Species Act, is the Applicant's only attempt of substantive analysis of the myriad of water quality-related impacts from the facility's entire operation.[4] In this BA, discussed in full *infra* Section V.B.1., consultants determined that there are various avenues that will result in aquatic species' exposure to contaminants, which will adversely affect the species, water quality, and their critical habitat.[5] This analysis is highly relevant to protecting the beneficial uses of the Columbia River and its tributaries. Yet, DEQ does not engage in the requisite analysis, mandated by OAR 340, Division 41, to assure that the activity will comply with water quality standards.

II. Project Overview

NEXT proposes what would be one of the largest refineries of its kind, in a liquefaction zone next to the Columbia River Estuary, at a time when the US is on track to overproduce "renewable" diesel.[6] Throughout its five-year conception, NEXT's proposal has undergone dizzying, fundamental site design changes, adding to its fraught history and building mistrust in Port Westward's agricultural community.[7] To this day, NEXT's permits authorize inconsistent plans that demonstrate regulators' unwillingness to take a holistic view of the project and protect the surrounding environment and communities from obvious, substantial harms.

The risks posed by NEXT's ill-conceived project are numerous. Despite its "renewable" label, the core refinery infrastructure and activities will carry environmental impacts well beyond any marginal end-use benefits. For example, NEXT is permitted to produce over 1 million tons of greenhouse gas emissions each year, using the same amount of fracked gas as the City of Eugene on an annual basis to power the refinery.[8] These numbers do not count emissions from mobile sources: significant increased vessel and rail traffic from transporting feedstocks and finished product. Not only will these pollutants burden the local and regional airshed—these new

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[4] *NEXT Renewable Fuels Oregon, LLC: Biological Assessment for Renewable Green Fuel Facility* (Mar. 30, 2023) (hereinafter "NEXT BA").
[5] *See e.g.,* NEXT BA at 51.
[6] Shariq Khan and Nicole Jao, Renewable diesel glut hits US refiner profits, threatens nascent industry, Reuters (May 14, 2024), https://www.reuters.com/markets/commodities/renewable-diesel-glut-hits-us-refiner-profits-threatens-nascent-industry-2024-05-13/.
[7] Audrey Leonard, Greenwashing on the Columbia, Columbia Riverkeeper (Feb. 2024), https://www.columbiariverkeeper.org/2024/greenwashing-on-the-columbia/.
[8] Oregon Department of Environmental Quality, Air Contaminant Discharge Permit for NEXT Renewable Fuels LLC (2022) at 26, https://www.oregon.gov/deq/Programs/Documents/NEXT-ACDP-permit.pdf.

emissions are the antithesis of Oregon's stated climate targets and will hinder our state's ability to meet them.

The lifecycle emissions of NEXT's product's feedstocks are key to understanding the project's overall impacts. While renewable diesel *can* be produced from truly waste feedstocks like "fish grease" and used cooking oil, the vast majority of these low-carbon feedstocks are spoken for on the market—a direct result of California's Low Carbon Fuel Standard that prioritizes these feedstocks. In actuality, NEXT's product will be made primarily from carbon-intensive, purpose-grown feedstocks like corn and soybean oil, shipped from the midwest on long trains.[9] Regulators must take into account the lifecycle emissions of a product labeled as "renewable" before buying into greenwashed selling points and authorizing a massive refinery in a sensitive area.

The refinery's day-to-day operations pose major threats to the surrounding area: the Columbia River Estuary and vibrant farmland situated in an intricate drainage system. First, NEXT's operations would greatly increase vessel traffic in the estuary, with an estimated 115 vessels per year carrying feedstocks and 56 larger fuel vessels transporting finished product. Each new vessel causes pollution just by operating, and increases the risk of a catastrophic fuel spill in a part of the estuary known for difficult navigation.[10] Operations at the refinery itself are poorly suited for the area's notoriously soggy landscape, high water table, and diking system. Regular flooding and the interconnectedness of the diking district's drainage ditches mean that stormwater at the facility cannot be properly contained. In the event of spills—large or small—from feedstock or finished product, pollutants will easily move through the water and put local farms in danger. Spill risk and stormwater runoff are amplified by the extensive rail facility NEXT proposes. Finally, all of the infrastructure and fuel storage tanks would sit in a liquefaction zone. No amount of on-site management of pollutants can remedy the disaster of over 50 million gallons of fuel and feedstock that would leak as a result of the Cascadia Subduction Zone earthquake.[11]

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[9] Industrial Tech Acquisitions II, Inc., Amendment No. 1 to Form S-4, as filed with the U.S. Securities and Exchange Commission (Oct. 17, 2023), p. 106 (showing 60% of feedstocks as "Soybean oil-Midwest," which would arrive via rail).

[10] Last November, a vessel crashed into the Port of Columbia County dock, narrowly avoiding a major fuel spill. Will Lohre, *Incident at Beaver Dock narrowly avoids oil spill into Columbia*, The Chief (Nov. 23, 2023), https://www.waheagle.com/story/2023/11/23/news/incident-at-beaver-dock-narrowly-avoids-oil-spill-into-columbia/22985.html.

[11] NEXT's Application refers to "ten large product and feedstock tanks (125,000 to 225,000 barrels each)." This will exceed *50 million gallons* of storage of fuel and feedstock storage, when full.

NEXT chose to site its refinery in an untenable location, near sensitive waterways. DEQ's conclusion on water quality impacts in the draft certification is unfounded and does not align with the administrative record. For the reasons explained below, NEXT fails to demonstrate that the project, and associated discharges to federal- and state-jurisdictional waters, will comply with water quality standards.

III. DEQ's Authority to Deny NEXT's 401 Certification

NEXT has not provided sufficient information in its application materials for DEQ to support a 401 Certification. The Applicant carries the burden of demonstrating that a proposed project will comply with water quality standards. Here, NEXT has provided virtually no information as to how the project—including discharges from construction and future operation at the site—will impact water quality in the Columbia River, Bradbury Slough, McLean Slough, or associated wetlands. Before Certification may be issued for this proposed project, DEQ must require, at minimum, sufficient information as to how the project will comply with state and basin standards for individual criteria, Oregon's Antidegradation standard, and statewide narrative criteria.

The State has both a right and a responsibility to deny an application requesting a 401 Certification when the applicant fails to meet the burden of demonstrating compliance with applicable water quality standards. Other states have exercised this authority under Section 401 of the Clean Water Act to safeguard their water resources, setting a precedent for Oregon to follow suit.

For example, the State of Washington denied, *with prejudice,* Millennium Bulk Terminals-Longview's application for a 401 Certification in 2017.[12] After review of both the Application and the Environmental Impact Statement, the State found that there would be irreparable and unavoidable harm to the Columbia River. This harm stemmed from the installation of 537 pilings into the riverbed, the destruction of 24 acres of wetlands, the elimination of five acres of aquatic habitat, the increase of ship traffic on the Columbia by 1,680 trips a year and the impairment of tribal access to protected fishing sites.[13] Indeed, the State even noted that the facility's stormwater plan, to be regulated by a separate permit, did not provide "detailed information and analyses necessary to understand, evaluate, and condition wastewater and stormwater discharges" in order to assure compliance with Washington State water quality.[14]

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[12] Washington State Dep't of Ecology, *Millennium Bulk Terminals Longview,* https://ecology.wa.gov/regulations-permits/sepa/environmental-review/sepa-at-ecology/millennium.

[13] *Id.*

[14] *See* Washington State Dep't of Ecology, *Order # 15417, In the Matter of Denying Section 401 Water Quality Certification to Millennium Bulk Terminals-Longview, LLC in Accordance with 33 U.S.C. § 1341*, at 13-17.

Moreover, the State questioned the efficacy of the mitigation plan, and condemned Millennium's failure to include a detailed analysis for process wastewater and stormwater as it pertained to evaluating the project's potential to cause measurable degradation of water quality.[15] As such, the project could not demonstrate compliance with the State's Antidegradation Policy.[16] Millenium appealed this decision to the Cowlitz County Superior Court and the Pollution Control Hearings Board.[17] The Cowlitz County Superior Court dismissed the petition for review while the Pollution Control Hearings Board upheld Ecology's decision to deny the 401 permit.[18]

The State of New York has also exercised its 401 denial authority for proposed pipeline projects on three occasions. Of most relevance to this Application, is the New York State Department of Environmental Conservation's ("NYSDEC") denial of the 401 Certification for the Constitution Pipeline, a 124 mile intrastate pipeline proposal. NYSDEC required a draft EIS from the Federal Energy Regulatory Commission analyzing the environmental impacts of the proposal, prior to issuing a 401 Certification. NYSDEC, in 2016, then denied the 401 Certification request, noting that the applicant "fail[ed] in a meaningful way to address the significant water resource impacts that could occur from this Project and has failed to provide sufficient information to demonstrate" compliance with water quality standards.[19] In noting that the application, including supplemental materials, contemplated the disturbance of 251 streams, 87 of which support trout or trout spawning, the "cumulative construction would disrupt a total of 3,161 linear feet of streams and result in a total of 5.09 acres of temporary stream disturbance impacts."[20] The Second Circuit affirmed NYSDEC's decision to deny the application, holding that it was not arbitrary and capricious for NYSDEC to evaluate the environmental impacts in light of the State's water quality standards.[21] Indeed, the Second Circuit noted that NYSDEC "is responsible" for evaluating the environmental impacts of a proposed pipeline on water bodies, given the relevance of NYSDEC's considerations of impacts to water quality compliance.[22]

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[15] Cowlitz County Hearing Examiner, *Findings of Fact, Conclusions of Law and Decision Denying Permits*, File No. 12-04-0375, available at https://earthjustice.org/wp-content/uploads/millenium-bulk-terminals_findings-facts.pdf (finding that the denial of the 401 Certification, based on "unavoidable significant environmental impacts" identified in the EIS was reasonable).
[16] It is important to note that the denial also contemplates unavoidable impacts from "vehicle "transportation," "air quality," "rail transportation," "vessel transportation, "and "noise and vibration" as relevant to the water quality certification denial. *Id.* at 4-13.
[17] Washington State Dep't of Ecology, *Millennium Bulk Terminals Longview,* https://ecology.wa.gov/regulations-permits/sepa/environmental-review/sepa-at-ecology/millennium.
[18] *Id.*
[19] *Const. Pipeline Co., LLC v. New York State Dep't of Env't Conservation,* 868 F.3d 87, 96 (2d Cir. 2017).
[20] *Id.*
[21] *Id.* at 103.
[22] *Id.*

Here, NEXT has not provided substantial evidence to assure DEQ of compliance with the applicable standards. NEXT's application contains many of the fundamental flaws that served as the basis for denials from the State of Washington and the State of New York. As such, NEXT is not entitled to receive this Certification and the state must assert its authority—as Washington and New York have—to deny the application to protect Oregon's water quality and public health.

Given that the water quality impacts from biofuel production have not been studied extensively, DEQ must critically analyze the wealth of impacts that will affect water quality, both directly and indirectly. Despite NEXT's unsupported claims that there will be no pollutant loading to the Columbia, it is documented that biodiesel refining, regardless of process and feedstocks, produces wastewater that has high levels of COD, BOD, nitrogen, oil and grease, and has a considerably high pH, amongst other impacts.[23] The Application does not even contemplate what kind of pollutant load will result from the construction and operation of the large refining facility, much less provide the requisite information to assure that its pollutant load will not further degrade water quality. While biodiesel refining is a relatively new process, DEQ cannot blindly accept NEXT's unsupported conclusion that there will be no impacts to water quality. Moreover, the Applicant continues to evade any substantive water quality impacts analysis by stating that process wastewater will be transported to the Port of Columbia County for further treatment, in compliance with NPDES Permit No. 102650, and stormwater runoff will be analyzed pursuant to the 1200-Z permit. However, this conclusion does not analyze the quantity or quality of process wastewater that will be generated onsite. This is a concerted attempt to evade any substantive, cumulative, and meaningful analysis of the impacts to water quality that are sure to follow from this operation. DEQ cannot accept this segmentation for a facility of this magnitude, especially in light of the documented water quality concerns. NEXT's habitual bifurcation and segmentation of project descriptions—which renders submissions void of any substantive and meaningful analyses—mirrors that of the Constitution Pipeline and Millennium Bulk Terminals' playbook. DEQ cannot reward this behavior and should follow the precedent set by Washington and New York State.

A. DEQ's Public Notice is Fatally Flawed

DEQ's public notice for NEXT's draft 401 is flawed because it improperly authorizes work from the original 2021 Joint Permit Application ("JPA"), misrepresents basic project information, and does not reference the most recent, accurate Stormwater Management Plan. Improper notice frustrates the public participation process *and* undermines the assumption that DEQ has sufficiently accurate information about the project to be reasonably assured of compliance with water quality standards. DEQ is required to provide a notice that describes

[23] *See* I.M. Atadashi, et. al., *The effects of water on biodiesel production and refining technologies: A review,* Renewable and Sustainable Energy Reviews, 3466 (Mar. 2012).

public participation opportunities, identifies the proposed certification decision and is to properly identifies related documents as available for public inspection and copying.[24] DEQ has, in multiple instances, relied on documents that are not included as part of the most recent Certification, in conflict with the Public Participation obligations set forth in OAR 340-048-0027(1). These flaws are significant because this information goes to the core of the public's review and input on the draft 401, and forms the basis of DEQ's approval.

First, DEQ's draft 401 authorizes an exceptionally broad range of work that includes former, current, and potentially future unknown site designs:

> **Work Authorized:** Work authorized by this Order is limited to the work described in the Joint Permit Application signed on January 10, 2021 and additional application materials (hereafter "the permit application materials"), unless otherwise authorized by DEQ. If the project is operated in a manner that's not consistent with the project description contained in the permit application materials, the Applicant is not in compliance with this Order and may be subject to enforcement.[25]

NEXT has made numerous, substantive revisions to its site design since the original application in 2021. It is understandable that a project of this magnitude and complexity would experience design revisions. However, "[t]o ensure the project will comply with water quality standards, DEQ must understand all work involved in the construction and operation of the project."[26] DEQ's reference to the original application and "additional application materials," generally, does not demonstrate an understanding of the work involved.[27] Worse, this condition goes further to *authorize* work described in outdated site designs without clarifying the specific site design DEQ understands as the final, permitted activity. As written, this condition authorizes any number of site plans since January 2021. This characterization also deprives the public of a meaningful understanding of the project. A reasonable person would interpret this condition to mean the draft 401 authorizes the work described in the 2021 JPA—an inaccurate conclusion that lacks complete information about the site design and DEQ's authorization.

Second, the draft 401 contains errors in the project description regarding storage tanks and information about transportation of feedstocks and finished fuel products. The draft 401 project description notes the facility will have "twenty-two feedstock tanks." This is incorrect:

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[24] OAR 340-048-0027(1).
[25] Draft Certification at 2, General Condition 2.
[26] *Id.* (citing OAR 340-048-0015).
[27] When Columbia Riverkeeper raised this issue with DEQ at the start of the comment period, DEQ stated that it is certifying "the most recent/current valid request for a 401 water quality certification, which was sent to DEQ on January 13, 2024." Sept. 12, 2024 email from Haley Teach. While this is helpful for clarifying what work DEQ intends to permit, it does not cure the inadequacy of the public notice, which is intended to inform public comment on the draft 401.

the application describes ten large product and feedstock tanks (125,000 to 225,000 barrels each) and eleven smaller feedstock and process tanks (10,000 to 50,000 barrels each). While this may seem like an insubstantial error, it demonstrates a concerning lack of specificity and inaccuracy.[28] Again, failing to provide complete and accurate information results in two failures: first, DEQ has frustrated the purpose of the public notice obligations, and second, DEQ cannot demonstrate that it is "reasonably assured" that the project will not violate water quality standards, because the basis of information used to support those conclusions is inaccurate.

Has DEQ grappled with important questions regarding the quantities and types of product (fuel, feedstocks, and process materials) stored on site? The draft 401 project description goes on to state, "[f]eedstocks will primarily be received via barge and vessels to [the Port of Columbia County]." This is inaccurate. In 2023, NEXT's investors' SEC filings show that the majority of NEXT's feedstocks will be delivered by rail.[29]

- The projections assumed the following compositions of feedstock for the applicable production years:

	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Soybean oil-Midwest	60.0%	60.0%	50.0%	40.0%	35.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Other Vegetable oil-foreign	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Used cooking oil (UCO)	5.0%	5.0%	10.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Animal tallows-high energy	7.5%	7.5%	10.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
White/Yellow Greases	7.5%	7.5%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
U.S. Distillers Corn oil	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Other (emerging oils)	0.0%	0.0%	0.0%	5.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

- The projections assumed that BP will supply 100% of NXTCLEAN's feedstock supply on substantially the terms of NXT's previous feedstock supply agreement with BP, which has since been terminated.

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Additionally, the project description fails to mention that finished fuel products will be shipped via barge from the Port of Columbia County. Both of these details are essential to DEQ's review of the refinery's operation and its impacts to water quality. These substantive shortcomings also violate OAR 340-048-0042(5)(g), which requires that the Director articulate conditions necessary to assure compliance with the applicable water quality standards set forth in OAR 340-048-0042(2) (considerations DEQ should take into account when determining if the

[28] When DEQ was asked how much fuel and feedstock would be stored at the facility, DEQ provided a misleading answer that gives the impression that the volume is more than an order of magnitude too low. DEQ's Q&A states, "How many fuel tanks? How many gallons of flammable, toxic fuel?" DEQ answers: "The proposed plan at full capacity is 50,000 barrels per day, or 1.58 million gallons." The storage capacity far exceeds 1.58 million gallons. This misleading information undermines the public process for this permit.

[29] Industrial Tech Acquisitions II, Inc., Amendment No. 1 to Form S-4, as filed with the U.S. Securities and Exchange Commission (Oct. 17, 2023), p. 106 (showing 60% of feedstocks as "Soybean oil-Midwest," which would arrive via rail).

project can comply with requisite CWA sections and the water quality standards set forth in OAR Chapter 340, Division 41).

Third, the draft 401 references an outdated post-construction stormwater management report, dated January 30, 2023. Records request documents demonstrate that the most recent stormwater management plan for the facility is from August 2023. When Columbia Riverkeeper raised this issue with DEQ at the start of the comment period, DEQ confirmed that it "received an updated technical memo,"[30] but the full report that the draft certification is based on is from January 30, 2023. However, records request documents show a memo and an entire revised stormwater management plan—a revised version of the January 2023 report—dated August 3, 2023. We understand that DEQ often receives updated information from applicants while evaluating applications. However, when dealing with a site this complex, it is extremely important that references to specific documents underlying the decision are accurate and up to date. The stormwater management plan is the core document upon which the draft 401 is based, and it is essential for DEQ and the public to know which version is relied upon for the certification.

Again, these flaws indicate both a procedural failure to provide the requisite information integrated into the Certification, as required by OAR 340-048-0027, as well as a substantive failure to consider the relevant information, as mandated by OAR 340-048-0042(2). These flaws in the public notice undermine the purpose and function of notice and comment on the draft 401, as well as DEQ's conclusion that it is reasonably assured that the activity will comply with water quality standards.

B. DEQ's Analysis Fails to Ensure Activity's Construction and Operation Will Comply with Water Quality Standards

DEQ must deny the 401 Certification because it cannot comply with the obligations of 33 U.S.C. 1341 and the implementing regulations set forth in Part 41.[31] Pursuant to Section 401 of the Clean Water Act, an agency may not issue a permit or license to an applicant that seeks to conduct an activity that may result in a discharge to navigable waters of the United States unless a state or authorized tribe provides a water quality certification.[32]

The purpose of § 401 is to give states a measure of control over federally permitted projects within their jurisdiction that may harm water quality.[33] Because NEXT's project involves

[30] Sept. 11, 2024 email from Haley Teach.
[31] *See* 40 C.F.R. 121.1-121.11 (effective November 27, 2023).
[32] 33 U.S.C. § 1341.
[33] S.D. Warren Co., 547 U.S. at 380 (citing S. Rep. No. 92-414, p. 69 (1971) (provision must have "a broad reach" if it is to realize the Senate's goal: to give states the authority to "deny a

dredging and filling wetlands and waters, it requires a CWA Section 404 permit from the U.S. Army Corps of Engineers, and such permit cannot be issued without the required water quality certification from DEQ.

To facilitate this statutory mandate, EPA has promulgated rules to administer Section 401 of the Act, codified in Title 40, Part 121 of the Code of Federal Regulations. The rules remained largely in effect as they were originally written in 1971. Then, in 2020, the Trump Administration sought to severely limit the scope of the regulations that had been in effect for the better part of 50 years. The Trump Regulations ("2020 Rule") substantially narrowed the scope of the Certification—requiring that certifications could now only cover a discharge *from* a point source and that discharge needed only to comply with "water quality requirements."

As the 2020 Rule was challenged in federal court for about two years, the legal status of the Trump Rules and obligation of the 401 process was largely a mystery to even the most sophisticated regulators and Clean Water Act practitioners nationwide.[34] However, in recognition of the severely narrow scope of the 2020 Rule, the Biden Administration enacted the 2023 Clean Water Act Section 401 Rule, ("2023 Rule") which largely restored the regulations to their pre-2020 language.[35] Most relevant to this Certification, the 2023 Rule restored the more expansive requirement that a Certification assure water quality standard compliance for the proposed activity's construction *and* operations.[36]

The more expansive 2023 Rule, along with settled case law which endorses the expansive call of the 401 Certification process, it is clear that DEQ must consider the Application's direct and indirect water quality impacts which stem from both the construction of the facility—which in this case requires the removal of 105 acres of wetlands and addition of 76 acres of impervious surfaces—as well as future operations of the facility. These future operations include the continued use of a new main access road, a new rail yard, four new pipelines, 10 large feedstock

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permit and thereby prevent a Federal license or permit from issuing to a discharge within such State.").

[34] *See e.g., In re Clean Water Act Rulemaking,* 568 F. Supp. 3d 1013 (N.D. Cal. 2021), *rev'd and remanded,* 60 F.4th 583 (9th Cir. 2023).

[35] *See* 88 Fed. Reg. 66,558 (Sept. 27, 2023).

[36] 40 C.F.R. 121.3 ("When a certifying authority reviews a request for certification, the certifying authority shall evaluate whether the activity will comply with applicable water quality requirements. The certifying authority's evaluation is limited to the water quality-related impacts from the activity subject to the Federal license or permit, *including the activity's construction and operation.*") (emphasis added); *See also, PUD. No. 1 of Jefferson County v. Washington Dep't of Ecology,* 511 U.S. 700 (1994) (holding that "water quality limitations" need not be specifically tied to a discharge, but that a state may impose conditions necessary to enforce all aspects of a State's water quality rules, including beneficial uses and water quality standards.).

tanks, 11 feedstock and process tanks, a pre-treatment plant, hydrogen facility, "Eco-fining" units, a storm and process water system, and administrative and lab buildings.[37]

DEQ is required to account for the aforementioned facilities and their operations when issuing the certification, as the 2023 Rules went into effect before the Applicant requested, for the third time, a water quality certification. Given that this application was submitted in January of 2024 *and* EPA's Federal Register notice emphasizes that other aspects of implementation of Part 121 start with the "receipt" of a "request for certification," January of 2024 is the date for which DEQ must use to determine *which rule*—the 2020 or 2023—applies.[38] As such, DEQ must apply the new, more expansive, 2023 Rules to this project. DEQ's draft permit unfortunately shows a willingness to leave major parts of this extensive authority on the table, issuing a draft permit with boilerplate language for a massive, novel refinery that presents a wealth of threats to water quality.

1. EPA's Reasoning and Examples for the 2023 Rule

EPA's analysis of the 2023 Rule in the Federal Register is instructive for how agencies should apply their 401 authority: "In order to assure—as it must under section 401(d)—that the 'applicant' will comply with all applicable water quality requirements, the certifying authority must be able to evaluate water quality-related impacts from the activity made possibly [sic] by the applicant's license or permit beyond those related to its triggering discharge(s)."[39] This includes direct, indirect, short- and long-term impacts from the activity's construction and operation.[40] Indeed, DEQ affirmed its support for this broad authority in its own comments on the 2023 Rule.[41]

EPA's analysis of the 2023 Rule offers insight into the legislative history that supports the authority to consider impacts from an activity's operation.

> The legislative history reveals Congress's intent to ensure federally licensed or permitted activities are not considered in a piecemeal fashion; rather, Congress recognized the importance of considering the effects of subsequent operations during site selection see S. Rep. No. 91–351, at 8 (August 7, 1969) ("Site location is integral to effective implementation of the Nation's water quality program. There are sites where no facility should be constructed, because pollution control technology is not adequate to assure

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[37] *See* Joint Permit Application No. 2020-393 at 4.
[38] *See e.g.,* 88 Fed. Reg. 66,581(Sept. 27, 2023).
[39] *Id.* at 66,594.
[40] *Id.* at 66,599.
[41] "DEQ strongly supports a definition of 'activity' that includes all activities that might affect water quality both directly and indirectly." Oregon DEQ Comments on 2023 Rule (Aug. 8, 2022).

> maintenance and enhancement of water quality. Those who make the decision on site location should be aware of this prior to making any investment in new facilities.''), and of early planning to avoid later adverse effects, see H.R. Rep. 91–127, at 6 (March 25, 1969) (''The purpose of subsection 11(b) is to provide reasonable assurance . . . that no license or permit will be issued by a Federal agency for an activity that through inadequate planning or otherwise could in fact become a source of pollution.'') [42]

Because of NEXT's choice to site its project in such a complex and sensitive area, DEQ must make sure it has as much information as possible before issuing a 401. NEXT's inadequate planning and poor site choice is a burden that NEXT carries—DEQ does not have the requisite information to ensure the facility will not impact water quality. DEQ can and should require additional information about water quality impacts, including the draft Environmental Impact Statement for the facility to inform its analysis. For example, DEQ should, at minimum, require analysis on water quality impacts of vessel traffic (i.e. increased vessel traffic's impacts on bank erosion, turbidity) to beneficial uses; water quality impacts of pesticide use at the mitigation site; and the potential for leaking infrastructure and/or spills to result in additions of toxic pollutants to receiving waters.

EPA goes on to give an instructive example of impacts beyond an activity's dredging discharge that should be considered: A 401 for a section 404 permit

> may consider both the construction associated with the dredging (*e.g.*, removing sediment from the waterbody to place dock pilings) as well as the subsequent operation associated with the completion of the dredging (*e.g.*, increased vessel pollution in the water associated with increased vessel traffic due to the construction of the dock).[43]

DEQ's draft Certification stops short of considering these same types of impacts, even though NEXT's operation will directly increase vessel traffic. In order to be assured that NEXT's operation will not affect water quality, DEQ must go a step further. But again, DEQ has full authority to determine that water quality impacts from operation are too great. In fact, "if the certifying authority determines that no conditions could assure that the activity, including post-expiration aspects of the activity, will comply with water quality requirements, denial of certification would be appropriate."[44] The increased[45] vessel pollution from NEXT's operation, in the sensitive Columbia River Estuary, and associated water quality violations, are too

[42] 88 Fed. Reg. 66,599.
[43] *Id.* at 66,600.
[44] *Id.*
[45] EPA makes clear that this consideration includes water quality impacts *caused by* and *contributed to* by the activity, meaning DEQ can consider NEXT's increased vessel pollution in the context of existing vessel pollution in this segment of the Columbia River. *Id.*

great[46]—DEQ can determine that no conditions can assure that NEXT can comply with water quality requirements and deny the 401.

2. DEQ's Implementing Regulations

DEQ's 401 Certification implementing regulations are found in Chapter 340, Division 48.[47] A Certification is the written determination by the Director that the activity subject to Section 401 of the Clean Water Act will comply with several provisions of the Act, including water quality standards set forth in OAR 340, Division 41, and other state water quality requirements.[48]

DEQ "must" evaluate whether the activity will comply with applicable CWA provisions, the water quality standards set forth in OAR 340 Division 41, and other appropriate requirements of state law.[49] In making this evaluation, DEQ may consider, *among other things*, potential alterations to water quality that would either contribute to or cause violations of water quality standards; existing and potential designated beneficial uses that might be affected by the activity; potential water quality impacts from the activity's use, generation, storage, or disposal of hazardous substances, waste chemicals, or sludges; potential water quality impacts from wastewater discharges; and potential water quality impacts from the construction of intake, outfall, or other structures associated with the activity.[50] Given the broad scope of considerations expressly articulated in OAR 340-048-0042, DEQ's own implementing regulations contemplate a broad scope of considerations, which allows DEQ to condition or deny a Certification based on the myriad of potential water quality impacts that stem from construction, operation, and even basic handling of potentially hazardous substances and waste chemicals.

When a Certification is approved, the conditions incorporated therein are the conditions which the Director deems necessary to *assure* compliance with applicable water quality standards.[51] Given the wealth of concerns associated with the Facility's operations, DEQ cannot condition a project of this magnitude, in this location, with this proximity to such sensitive and compromised aquatic habitat, in a manner that would bring the facility within compliance with the Clean Water Act. Even if it were possible to condition this project to assure compliance with water quality standards, NEXT has not provided the requisite information and analysis to enable DEQ to meet its own obligations. As such, Commenters urge DEQ to deny this Application as the complexities of the project are not conducive to maintaining, much less *enhancing*, water quality.

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[46] *See* discussion of vessel traffic impacts, *infra* Section VII.
[47] *See generally* OAR 340-048.
[48] OAR 340-048-0010(1).
[49] OAR 340-048-0042(2).
[50] OAR 340-048-0042(2).
[51] OAR 340-048-0042(5).

IV. NEXT Has Not Met its Burden of Demonstrating Compliance With All Water Quality Standards

When issuing a 401 Certification, DEQ must support its decision with materials and analysis submitted by the applicant. The applicant carries the burden of proof to demonstrate that its discharge of pollutants will comply with all state water quality standards. This includes the burden of presenting sufficient evidence to satisfy Certification requirements, and persuading DEQ that Certification is justified.[52]

Before DEQ can accept a 401 Certification as complete and begin to review it, an applicant must supply adequate information as required by OAR 340-048-0020(2). That Rule makes clear that an application "must contain, *at minimum*":

> g)...environmental information submitted to the federal licensing or permitting agency and other environmental information and evaluations as necessary to demonstrate that the activity will comply with applicable provisions of Sections 301, 302, 303, 306, and 307 of the Clean Water Act, including water quality standards set forth in OAR chapter 340, Division 041 and other appropriate requirements of state law; . . .
>
> j) an exhibit that identifies and describes the other requirements of state law applicable to the activity that have any relationship to water quality . . . . [53]

Failure to provide a complete application is grounds for denial of Certification. [54]

DEQ must also evaluate the short-term *and long-term* compliance with applicable provisions of the CWA, state water quality standards, and appropriate requirements of law for the construction *and* operation.[55] For the purposes of Certifying a Section 404 permit to be issued by the Corps, DEQ's 401 Certification operates as verification of compliance for both proposed construction discharges, post-construction discharges, and for the operations of the facility.[56]

NEXT has submitted a JPA to the U.S. Army Corps of Engineers ("Corps") and the Oregon Department of State Lands ("DSL").[57] This application describes the proposed project

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[52] *See* OAR 340-041-0020(2) and OAR 340-041-0032(1).
[53] OAR 340-048-0020(2) (emphasis added).
[54] OAR 340-048-0020(3).
[55] *See* OAR 340-048-0042(2).
[56] *See* 1341(a)(3) ("[t]he certification obtained…with respect to the construction of any facility shall fulfill the . . . certification . . . . for the operation of such facility").
[57] Joint Permit Application, NEXT Renewable Fuels Oregon, LLC (Aug. 29, 2023) (hereinafter "JPA" or "Application").

and requests approval to engage in removal-fill activities in the waters of the United States. NEXT submitted its Request for Certification to DEQ in January 2024.[58] The present 401 Certification comment opportunity made available, by request, the JPA and appears to serve as the main document submitted by NEXT to support a 401 Certification. Additionally, NEXT provided a letter and memo answering questions from DEQ in May 2024.[59]

The May 2024 document contains NEXT's "analysis" of water quality impacts, but merely provides conclusory statements that the facility will treat wastewater and stormwater in a manner that will not pose any threats to water quality. However, this memo does not offer the kind of technical specifications necessary to ensure that these methods will be sufficient, nor do these documents refute the literature[60] that illustrates that even the most sophisticated treatment does not prevent the inevitable pollutant loading that comes from a facility of this kind and scale. Moreover, the benefit of hindsight allows DEQ and the public to understand that these facilities spill, their infrastructure leaks, and even the most stringent of management plans habitually fail to completely eradicate pollutant loading to waterways.[61] While not all pollution is necessarily a violation of water quality standards, Applicant's materials demonstrate a potential to add pollutants which further degrade water quality of an already-impaired waterbody, and hinder compliance with protection of beneficial uses. As such, DEQ must provide the requisite analysis to demonstrate that it has reasonable assurance that such pollution will not violate water quality standards.

In short, NEXT invites DEQ to accept its assertion that it will not further degrade water quality, simply because it says it will not.[62] DEQ cannot accept this premise and cannot facilitate the risk of water quality degradation that is virtually inevitable for a facility of this kind, size, and proximity. That is especially so given NEXT's fraught history in the region. Bolstering DEQ's outright authority to deny the Certification is the authority set forth in ORS 468.070, which gives DEQ clear authority to deny a request for Certification based on prior behavior.[63] Thus, DEQ is not required to issue a Certification when it receives an application. Rather, the statutory language above sensibly authorizes DEQ to consider the history of past noncompliance with environmental statutes, rules or standards. While Commenters acknowledge that this would

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[58] Oregon DEQ Request for Certification, NEXT Clean Fuels, Inc (Jan. 13, 2024).
[59] Stewardship Solutions, Response to DEQ 401 Water Quality Certification Review Questions for NEXT Renewable Fuels Oregon Application (2020-383) (May 22, 2024) (hereinafter "May 2024 Response").
[60] *See e.g.,* NEXT BA at 42.
[61] *Id.*
[62] *See also*, NEXT Renewable Fuels, Inc., *50,000 BPD Renewable Diesel Project, Project Design Basis, May 2021 Rev B.* at 25 (May 2021).
[63] ORS 468.070 grants DEQ the authority to refuse to issue a permit issued pursuant to ORS 468.065, if it finds the facility to have violated ORS Chapters 468, 468A and 468B, or has violated any applicable rule, standard, or order of the Environmental Quality Commission.

be NEXT's first operation in Oregon, it is not without concern that NEXT's backers have a troubled history of environmental compliance in the region. Given this fraught history, DEQ can and should use its authority under ORS 468.070 to deny this request for Certification, based on NEXT's historic disregard for environmental regulations.

V. NEXT's Refinery Operations Will Negatively Impact Water Quality.

The construction and operation of NEXT's refinery will negatively impact the water quality of the Columbia River, McLean Slough, and Clatskanie River. Additionally, the project will affect waterways inside and outside of the levee system, which NEXT's materials do not contemplate.[64]

A. Water Quality Standards for Individual Criteria

Per DEQ's latest Integrated Report,[65] this segment of the Columbia River is designated as Category 5 (water quality limited and in need of a total maximum daily load) impaired for DDE 4,4, and PCBs, both human health toxics, *and* Category 4 limited (meaning that at least one designated use is not being supported) for Dioxin, a human health toxic, temperature, and dissolved gas. These impairments hinder attainment of beneficial uses for the drinking water, aquatic life, and fish and shellfish consumption. Concentrations of these listed criteria could be impacted by Applicant's proposed project through stormwater exposure, infrastructure leaks, insufficient treatment of wastewater streams, spills, and pollutant-bearing sediment mobilization from the site. Applicant has neither analyzed potential conflicts, nor refuted assumptions of non-compliance, to allow DEQ to be assured that discharges from this site will not lead to further impairment of these criteria. A complete application from NEXT must address these parameters and how discharges—stemming both from the construction *and* the operation of the facility—will impact the requisite impairment criteria and beneficial uses. NEXT's application materials contain no information or even *acknowledgement* of these impairment pollutants (or any pollutants for that matter), by which DEQ could possibly assess compliance with water quality standards.

In light of the fact that NEXT has provided no information about how the proposed project will impact concentrations of DDE, PCBs, dioxin, temperature, or dissolved gas, DEQ cannot be reasonably assured that the Applicant's activity will not cause further impairment. Additionally, for the reasons articulated below, Commenters believe that the construction and activity—because of both the nature of the proposed operations *and* the loss of the wetland

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[64] See discussion *infra*, Section VI.A.1.
[65] Available here: https://geo.maps.arcgis.com/apps/instant/sidebar/index.html?appid=7d13b19e01a44f1dbfd12903576e6d29.

benefits of 105 acres—will ultimately result in further degradation of impairment pollutants. In short, DEQ accepts NEXT's premises and conclusions as true, simply because NEXT says they are. However, evidence prepared by EPA and other scholars on refining suggests otherwise. DEQ has an obligation not only to respond to these concerns, but to substantiate that the facility can and will comply with all applicable standards, beyond merely accepting NEXT's promises as true. Absent such, DEQ cannot be reasonably assured that the facility's construction and operation, for the duration of its lifetime, will comply with all water quality standards.

Toxics

OAR 340-041-0033(1) provides that toxic substances may not be introduced above natural background levels in waters of the state in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life to levels that affect public health, safety, aquatic life or other designated beneficial uses.[66] The Applicant and DEQ have not presented information sufficient to assess if the proposed activity will result in discharges which add pollutants beyond the requisite threshold of acceptability set forth in OAR 340-041-0033.

Table 30 sets forth the applicable water quality criteria for toxic pollutants, as it pertains to protecting aquatic life.[67] These criteria apply to water bodies, like this segment of the Columbia and its tributaries, where the protection of fish and aquatic life are a designated use. Commenters acknowledge that establishing a site-specific criteria for these pollutants involves a complex analysis of the receiving waterways background, the hydrology and potential for dilution of the area and pollutant, as well as a rather complex determination that the pollutant will indeed raise pollutant concentrations by more than 3 percent.[68] However, there are toxics of concern that warrant DEQ's attention. For example, Table 30 sets forth limitations on ammonia, noting that both the acute and chronic criterion are pH and temperature dependent.[69] Noting that the relevant segment of the Columbia is impaired for temperature and high pH readings are typically associated with biofuels refining wastewater streams,[70] DEQ must assess the potential for addition of ammonia beyond the 3 percent background threshold. Similarly, NEXT's own BA, discussed *infra* Section V.B.1., acknowledges that copper—which is "highly toxic to aquatic biota"[71]—will enter salmonid-bearing waterways, exposing salmon and steelhead to heavy metals, including copper.[72] Given that copper is an identified toxic substance and will be

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[66] OAR 340-041-0033(1).
[67] Table 30, OAR 340-041-0833.
[68] *See* OAR 340-041-0033(5).
[69] *See* Table 30 OAR 340-041-0033, No. 3.
[70] *See* I.M. Atadashi, et. al., *The effects of water on biodiesel production and refining technologies: A review,* Renewable and Sustainable Energy Reviews, 3466 (Mar. 2012).
[71] NEXT BA at 51
[72] *Id.*

discharged into waterways from the facility's operations, DEQ must provide substantive analysis that NEXT's activities will comply with the standards set forth in OAR 340-041-0033. Moreover, DEQ cannot punt this analysis to the less-protective 1200-Z permit or coverage under Port Westward's NPDES permit, because NEXT's own documents illustrate that there will be pollutant loading of toxic substances that will further degrade aquatic life uses.

Aerial Deposition of Refinery Pollution

The facility's ACDP, granted in 2022, allows for significant Plant Site Emissions Limits ("PSEL") of various air pollutants.[73] Similarly, the Biofuels Triennial Report also reiterates that significant amounts of nitrogen oxides, sulfur dioxides, carbon monoxide, ammonia and particulate matter are emitted during each stage of biofuel production and distribution, as well as usage.[74] Indeed, atmospheric deposition is noted as the "primary process" through which atmospheric gases and PM enter aquatic ecosystems, posing a "major threat" to these ecosystems and aquatic life.[75] Researchers even note that air emissions, regulated separately from water quality and monitoring of aquatic ecosystems, causes a "gap[] in our understanding" of air pollutants impacts on water quality and aquatic life.[76]

Given the facility's significant air pollution load and proximity to the Columbia River and other waters of the United States, atmospheric deposition of the facility's air pollution is reasonably certain to occur as part of the facility's activities. NEXT's air pollutants are likely to reach Oregon's waterways by direct air deposition into the water and via air deposition onto land near the refinery where precipitation runoff, irrigation, or seasonal flooding in the Port Westward area will convey them into nearby waterways. Potential water quality standards violations resulting from this kind of non-point source pollution caused by a facility's operations are clearly within DEQ's authority, and duty, to consider in the 401 certification process. Accordingly, this source of pollution and its impacts on water quality must be—but are not—addressed and analyzed in the Application and draft Certification.

Given the substantial emissions profile afforded to the facility in their ACDP, DEQ must consider the Facility's propensity to emit, and how these air contaminants will enter waterways that are inhabited by sensitive aquatic species. For example, the facility has a PSEL allotment of nine tons per year of hydrogen sulfide, as well as 27 tons per year *each* for PM, PM10, and PM2.5. The Application does not explain how the facility's operations—given the ACDP's massive emissions allowances—will both ensure that these emissions (1) do not result in

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[73] *See* Permit No.: 05-0030-ST-01, Condition 14 at Page 10.
[74] Biofuels Triennial Report at IS-3.
[75] Vignesh Thiagarajan et. al., *Impacts of atmospheric particulate matter on phytoplankton: a review,* Science of the Total Environment, Volume 950 (Nov. 10, 2024).
[76] *Id.*

atmospheric deposition into a water of the United States, or (2) how these odors will not cause objectionable odors, will not be deleterious to fish or other aquatic life, or will not hinder other reasonable uses of such water. As such, the 401 cannot assure compliance with OAR 340-041-0031(1) or the aquatic life or toxics criteria.

pH

NEXT also provides that it will treat its wastewater, as well as its stormwater, to fall within the requisite pH criteria. However, NEXT does not contemplate the processes which cause high pH waste streams, nor does it contemplate *how* it will treat its wastewater and stormwater in a manner that will be sufficient to comply with pH criteria. As articulated *supra* Section III, refining facilities have wastewater streams that are notoriously acidic, and pH is a contributing factor to the Columbia's aquatic use impairment. As such, it is unclear how DEQ is reasonably assured that the facility will not cause or contribute to further impairment as it pertains to pH criteria.

The aforementioned pollutants of concern are relevant, especially in light of NEXT's offered, conclusory analysis that the activity will not result in any addition of pollutants to requisite waterways. For example, NEXT's own technical memo recognizes that Renewable Diesel facilities "provide[] unique waste treatment challenges"[77] but simply assures that the "flow scheme has been designed to 'segregate and optimize'" treating stream contaminants.[78] However, the only discussion provided to this point is a series of seven bullet points that name the "WWT system" pieces, *e.g.* anaerobic digestors and post equalization tanks.[79] However, this section does not provide any sort of analysis on the quantity or quality of wastewater that is to be treated, and *how* these processes will be sufficient to treat the wastewater in a manner that assures compliance with water quality standards. This is par for the NEXT course and cannot be accepted as sufficient to demonstrate that this massive industrial operation will not result in additional pollution that violates water quality standards.

B. Oregon's Antidegradation Standard

Oregon's Antidegradation standard is set forth in OAR 340-041-0004. The stated purpose of this standard is to "guide decisions that affect water quality such that unnecessary further degradation from new or increased point and nonpoint sources of pollution is prevented, and to protect, maintain, and enhance existing surface water quality to ensure the full protection of all

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[77] NEXT Renewable Fuels, Inc., *50,000 BPD Renewable Diesel Project, Project Design Basis, May 2021 Rev B.* at 25 (May 2021).
[78] *Id.*
[79] *Id.*

existing beneficial uses."[80] Federal regulations require a State to ensure that instream water uses protect a level of water quality necessary to protect existing uses.[81] To effectuate this policy, regulations require that:

> Where the quality of water exceeds levels necessary to support the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality *shall* be maintained and protected unless the state finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that *allowing lower water quality* is necessary to accommodate important economic or social development in the area… In allowing such degradation or lower water quality, the State *shall* assure water quality adequate to protect existing uses fully. Further, the State *shall* assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost effective and reasonable best management practices for nonpoint source control.[82]

For water quality limited waters, such as the Columbia River and the Bradbury and McLean slough, the standard actually prohibits *any* further degradation, unless explicitly authorized in certain limited circumstances and after detailed findings have been made. [83]This means, for those pollutants for which the receiving body of water is listed as water quality limited, and for the designated uses that are impaired based on the presence of relevant impairment pollutants, DEQ must assure that any additional pollution does not cause further degradation of those waters.[84] A critical question to be answered in the Antidegradation review process is whether "the proposed activity would likely result in any measurable change in water quality away from conditions unimpacted by anthropogenic sources."[85] If it would, "then the proposed activity will be considered to likely result in a lowering of water quality."[86] Thus, to obtain a 401 Certification for its proposed project, Applicant must demonstrate to DEQ that there will be no "measurable change" in the requisite affected water bodies as a result of this project. To do so, DEQ and the Applicant must address, head on, *how* the facility will not cause further degradation, through addition of thermal loads, toxic pollutants per Table 30 and OAR 340-041-0033, and the

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[80] OAR 340-041-0004(1).
[81] 40 C.F.R. § 131.12(a).
[82] *Id.* § 131.12(a)(2) (emphasis added).
[83] *See* OAR 340-041-0004(7), (9).
[84] *See* 40 C.F.R. § 131.12; *See also, PUD No. 1,* 511 U.S. at 705; *N. Plains Res. Council v. Fid. Expl. & Dev. Co.,* 325 F.3d 1155, 1162 (9th Cir. 2003) (Recognizing that discharging "salty, industrial waste water" from coal bed methane activities "alters" the water quality of the receiving river, creating a conflict with the antidegradation policy and ultimately "undermin[ing] the integrity of the CWA's prohibitions").
[85] DEQ, *Antidegradation Policy Implementation: Internal Management Directive for NPDES Permits and Section 401 Water Quality Certifications,* at 17 (Mar. 2001).
[86] *Id.*

potential addition of particulate matter and ammonia to waterways—all parameters for which the Columbia is water quality limited–in order to comply with the State's antidegradation policy.

Ultimately, it is NEXT's burden to demonstrate that its entire operation will not cause further degradation of water quality that harms beneficial uses. DEQ has the authority to consider a wide array of impacts that stem from the construction and operation of this proposed refinery. Indeed, EPA emphasizes that the definition of "water quality requirements" is also broad, including "any limitation, standard, or other requirement" of State law.[87] A certifying authority can ensure compliance with "*any and all* components of applicable water quality standards," including designated uses, consistent with *PUD No. 1*.[88] To avoid considering NEXT's impacts on designated uses and antidegradation requirements would be leaving a vital piece of DEQ's authority to protect water quality on the table.

Here, NEXT has not met that burden of demonstrating compliance with water quality standards for two reasons. First, as articulated above, NEXT does not even provide the requisite information or discussion, much less analysis, as to how the Antidegradation standard will be met. Again, NEXT simply provides conclusory statements that the project will not pose any threat to water quality, without offering any substantive analysis. For example, NEXT's supplemental materials provide two paragraphs in regards to the Antidegradation Policy, which concludes, without any analysis, that the facility will not violate the state's antidegradation policy:

> The Facility and its Access Stormwater are not considered a point-source discharge and no activities associated with the Facility or Access Stormwater will further degrade existing surface water quality or beneficial uses of waters of the state. The Facility will operate in compliance with the 1200-C permit during construction and the 1200-Z permit during operation. Its process water will be pre-treated to ensure its effluent meets and/or is less than the Port Westward NPDES effluent limitations.[89] Access stormwater will be

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[87] *Id.* at 66602.
[88] *Id.* at 66606 (citing PUD No. 1, 511 U.S. at 714-15 (emphasis in original) ("We think the language of [section] 303 is most naturally read to require that a project be consistent with *both* components, namely the designated use *and* the water quality criteria. Accordingly, under the literal terms of the statute, a project that does not comply with the designated use of the water does not comply with the applicable water quality standards.").
[89] Commenters also note that the further "analysis" that NEXT provides in the way of "demonstrating compliance" with the Port's NPDES permit merely includes a chart that identifies the Port's effluent limitations and conveniently includes a column stating that NEXT's wastewater will have pollutant loads that are "<" than the requisite pollutant. For example, the Port's NPDES permit allows for 0.15 mg/L of Total Residual Chlorine, so NEXT states–without any sort of justification– that its wastewater design basis will result in a wastewater stream with "<0.15 mg/L of Total Residual Chlorine". *See* May 2024 Response at 11.

collected and treated in detention ponds constructed per DEQ's Section 401 Water Quality Certification Post-Construction Stormwater Management Plan Guidelines and designed to meet the SLOPES V standards.[90]

This is the extent of NEXT's offerings to demonstrate compliance with the State's Antidegradation Policy. DEQ cannot accept these unsupported conclusions as true. It is highly unlikely that the proposed development will protect, enhance, or even maintain water quality in the requisite water bodies: Applicant proposes to destroy over 100 acres of wetland, add over 70 acres of impervious surfaces, build multiple roads and pipelines, and operate a refinery.[91] While Applicant does suggest that the additional wetlands that will be created will enhance water quality, it is important to note that the mitigation ratios used—which are required by law, not due to NEXT's commitment to environmental stewardship—are mitigation ratios determined to achieve "no net loss." The no net loss standard is a reflection of the fact that there are palpable harms that occur when natural wetlands are filled.

Second, the ecological changes discussed above, as well as the future operation of the facility, have the high potential to impair several beneficial uses and impact aquatic life, yet NEXT'S JPA neither acknowledges nor addresses the Antidegradation standard, let alone provide any sort of persuasive documentation that the project will result in "no measurable change" to the water quality of the Columbia River or the applicable sloughs. Without such information that both supports NEXT's presumed assertions of water quality compliance, and certainly absent information that can refute the wealth of literature suggesting degradation will occur, DEQ cannot issue a § 401 Certification for the project.

1. The NEXT Biological Assessment

Pursuant to the Endangered Species Act, Ecological Land Services, Inc. ("ELS") completed a Biological Assessment ("BA") on behalf of NEXT and its proposed project. The BA noted that there is designated critical habitat for all 13 ESUs/DPSs in the Columbia River and that this project will result in exposure of contaminants to the McLean Slough and ultimately, the Columbia River. Ultimately, the BA concluded that, due the contaminant exposure, that the project is likely to adversely affect 13 ESUs/DPs of salmon and steelhead.[92] However, despite this analysis, the Application does not contemplate the impacts of the pollutant exposure, which is relevant both in terms of increased loading of specific pollutants, and to further impairment of beneficial uses.

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[90] May 2024 Response at 13.
[91] *See infra* Section V.B.2.
[92] NEXT BA at 76.

The BA notes that contaminants of concern are present at all phases of the refining process. Contaminants from feedstocks include metals like calcium, sodium, magnesium, potassium iron, and aluminum, as well as high levels of phosphorus, solids, free fatty acids, color bodies, and phospholipids that are of similar nature to surfactants and soaps that consist of saturated and unsaturated carbon atom chains with a hydrophilic head.[93] The refining process creates contaminant loading of sodium hydroxide, soaps, metals, phosphorus, solids, gums, and phospholipids.[94] The mitigation associated with the project will also include heavy loads of glyphosate, as the herbicide will be used to control invasive plants at the mitigation site.[95] Indeed, these contaminants present exposure to pollutant loading to waterways both due to the inevitable reality of infrastructure leaks and failures, as well as through exposure to stormwater.

The BA determined that the following pollutants will be present in aquatic habitats *as a result of this project*: Copper, Zinc, PAHs, renewable fuels, sustainable aviation fuel, microplastics, and glyphosate. These contaminants are not contemplated in the Application materials and will have detrimental impacts to aquatic habitat, water quality, and will impact listed species. For example, the BA notes that copper from automobiles on site will be present in stormwater, and that zinc, which is highly mobile in aquatic environments and can be transported even miles downstream, will also be present in stormwater runoff.[96] These contaminants, as well as their impacts to beneficial uses, aquatic life, and overall water quality are not contemplated in the Application materials.

Similarly, the BA notes that polycyclic aromatic hydrocarbons (PAHs) will be present in stormwater runoff.[97] PAHs are harmful to water quality and pose significant threats to aquatic life. PAHs are hydrophobic and bind to sediments and organic matter, allowing them to persist for long periods of time, creating long-term accumulation and contamination to aquatic ecosystems. Moreover, PAHs bioaccumulate in the tissues of aquatic species. These toxic compounds are then passed up through the food chain, creating impacts not only for smaller aquatic organisms, but also larger species, including fish and bird species. Moreover, PAHs disrupt oxygen exchange and nutrient cycling processes, ultimately contributing to lower dissolved oxygen levels, posing further stress to aquatic systems. Overall, PAHs pose serious threats to aquatic species as well as water quality as a whole.

Finally, the BA recognizes that the use of the herbicide glyphosate will result in further pollutant loading.[98] Ironically enough, the project's mitigation plan cannot comply with water quality standards because it will result in further pollutant loading of the pesticide glyphosate. In

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[93] *Id.* at 35.
[94] *Id.*
[95] *Id.*
[96] *Id.*
[97] *Id.*
[98] *Id.*

order to mitigate the loss of 105 acres of wetland habitat, the Applicant proposes to build 476 acres of wetland habitat.[99] The Applicant also plans to treat the mitigation site with glyphosate in order to control invasive plants at the mitigation site. Glyphosate, however, has known risks to water quality and aquatic ecosystems, none of which are contemplated in the Certification or the Application itself. For example, glyphosate, which can persist in aquatic ecosystems, often breaks down to phosphate, further exacerbating issues of eutrophication in a water body. Moreover, glyphosate in surface and groundwater poses threats to drinking water and is notoriously difficult to remove through standard, accessible filtration methods. Glyphosate is also known to impair reproduction cycles in fish and amphibians, and disrupts microbial communities that are necessary to aquatic nutrient cycling and organic matter decomposition. These disruptions impair functions that are necessary to maintain water quality, thereby creating further threats to overall aquatic ecosystem health. The use of glyphosate is a key component of the overall project and the Application does not contemplate the myriad of effects to water quality and aquatic life that the herbicide will pose to the McLean slough or Columbia River. It is not enough to institute buffer zones for glyphosate, when used to this extent, in an area with such a high water table.

The "primary concern" for ESA-listed receptors is exposure of contaminants through stormwater.[100] However, the BA also notes that pollutant exposure will occur through contaminated soils, including soils near pipelines and rail yards, as well as groundwater and direct exposure from waterways.[101] There are numerous ways that the BA is emphasizing additional pollutant loading that will harm ESA listed fish. This BA even contemplates the use–and indeed, the limitations—of Best Management Practices included in other applicable permitting schemes—and still concludes that measures will not be sufficient to protect ESA-listed species from contaminant exposure. Not only is this ESA harm a concern in and of itself, but it speaks to the fact that this project has reasonably certain, documented analysis that the project's operation will cause further harm to aquatic ecosystems and aquatic habitat beneficial uses.

Given that the receiving water bodies are impaired specifically for pesticides and toxic inorganic chemicals, parameters which hinder attainment of beneficial uses for drinking water, aquatic life, and fish and shellfish consumption uses, DEQ can neither accept this application as complete as it fails to consider the further impacts to relevant pollutants and beneficial uses, nor can DEQ allow for the Applicant to engage in activity that causes further degradation to water

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[99] Draft Certification at 1.
[100] NEXT BA at 39.
[101] *Id.* at 38.

quality.[102] As such the Application must be denied for its failure to comply with the State's Antidegradation Policy, which prohibits further degradation of the Columbia River.[103]

2. Loss of Wetlands and Riparian Buffer Services will Exacerbate Existing, Future Water Quality Impacts

The authorization to fill 105 acres of wetlands and add 76 acres of impervious surfaces raises significant concerns about the short-term and long-term impacts to water quality and ecosystem health in the Columbia estuary and associated tributaries and wetlands. Given the critical role that wetlands play in protecting and maintaining the already compromised water quality of this segment of the Columbia, it is imperative that DEQ ensures that functioning riparian systems remain intact in order to continue to provide the necessary ecosystem services—known in Clean Water Act parlance as beneficial uses—in this industrialized area. Even the Corps acknowledges that this is a major potential impact, writing in a December 2021 memo, "The loss of waters of the United States proposed for the NEXT Renewable Fuels Oregon, LLC project is 3 times greater than the largest loss authorized in Oregon in the last ten years and is 81 times greater than the median loss for development projects authorized in Oregon . . . . The degree of effects on wetlands from the proposed project far exceeds that of typical development projects in Oregon."[104] Indeed, the loss of wetland function will only exacerbate the aforementioned water quality concerns, demonstrating that this project cannot comply with water quality standards due to the nature of the environmentally-intensive operations itself *as well as* the need to degrade 105 acres of wetlands in order to facilitate the building of the operation.

Wetlands play a critical role in filtering pollutants, managing stormwater, and supporting biodiversity. Allowing the destruction, through the filling and addition of impervious surfaces, of such a large expanse of wetlands will not only reduce the watershed's capacity to mitigate pollutant loading and bolster floodplain resilience, but will also exacerbate existing and future water quality concerns. The refinery itself will continue to contribute to increased runoff and, as

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[102] Commenters also note that the BA recognizes the relatively new, yet conclusive, data suggesting that 6PPD-quinone ("6PPD-q") is the "chemical culprit causing acute coho salmon death in small streams after rain events." BA at 37. While there is no applicable water quality standard to regulate 6PPD-q at this time, the BA concludes that, due to the impacts of 6PPD-q's impacts on water quality, the project is "likely to adversely affect designated critical habitat for salmon and steelhead." BA at 59. This conclusion further suggests that inherent to the project, is degradation of water quality to a degree that it harms ESA-listed salmonid species, and in turn, is expressly in conflict with the aquatic life beneficial use of the Columbia and its tributaries.
[103] OAR 340-041-0004(1).
[104] U.S. Army Corps of Engineers, Memorandum for the Record, Environmental Impact Statement Determination for the Above-Referenced Standard Individual Permit Application (Dec. 2021) at 10.

illustrated by the facility's BA, levels of hazardous pollutant loading sufficient to harm salmon and steelhead, a designated beneficial use of the Columbia River.[105] With these wetlands gone, the Columbia and nearby tributaries will bear the brunt of increased pollutant loading, harming both human and non-human communities that depend on this waterway for drinking water, aquatic resources, fishing access, and recreation.

Indeed, effective floodplain and wetland management protects the myriad ecosystem services that wetlands provide to communities and the environment. Under natural conditions, these aquatic ecosystems serve as biodiversity hotspots, as these waterways, banks and floodplains create highly complex, functional habitat systems.[106] As floodplains are filled, they become disconnected from rivers, thereby reducing the complexity of the ecosystems as a whole, and reducing the critical roles they play in flood and drought mitigation, habitat function, and water quality protection.[107] This area plays a critical role for a variety of wildlife and this industrial development results in both the outright loss of the physical habitat and the consequential loss of ecosystem function. Moreover, and most relevant to this decision, is the development's detrimental impact on water quality. Removal of wetland habitat prompts soil erosion, removal of vegetation, and most importantly, discharges of pollutants and increases the quantity of impervious surfaces, which thereby exacerbates the impacts of increased industrial pollutant loading.

These shifts in land use increase sedimentation and pollutant loads in waterways, reducing water quality and viability of habitat. In addition, the increase in impervious surfaces, coupled with the loss of wetland function, drastically alters the natural hydrology of the ecosystem, thereby increasing the risk and severity of flooding. Loss of ecosystem resiliency associated with filling of the wetlands subjects communities and ecosystems to more harm and loss, and intensifies the degree of losses associated with flood events, as the environment is no longer equipped to handle such rapid inundation of floodwaters. Given the precarious nature of the levees, discussed *infra* Section VI.A.1., DEQ must come to terms with the reality that this project has very high flood exposure. When this facility floods, the pollutants from NEXT's industrial activities will flood directly into the Columbia River, causing immense threats to the potability of the water and viability of the aquatic ecosystem as a whole.

Moreover, DEQ cannot simply rely on mitigation efforts as a catch all to offset the impacts of wetland function loss. While mitigation efforts such as the creation or restoration of wetlands at high mitigation ratios are often proposed as a way to compensate for

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[105] *See supra* Section V.B.1.
[106] JV Ward et. al., *Biodiversity of Floodplain River Ecosystems: ecotones and connectivity* (1999), available at https://onlinelibrary.wiley.com/doi/abs/10.1002/%28SICI%291099-1646%28199901/06%2915%3A1/3%3C125%3A%3AAID-RRR523%3E3.0.CO%3B2-E
[107] *Id.*

development-induced wetland loss, they frequently fall short of replicating the full range of ecological functions that natural wetlands provide. Even when mitigation ratios are high, this approach cannot fully account for the complex and irreplaceable ecosystem services provided by naturally occurring wetlands.

Constructed wetlands are often unable to replicate the biological, hydrological, and chemical processes that develop over decades in natural wetlands. Indeed, the loss of the spatial proximity to the main stem of the river undercuts the mitigation project's ability to sufficiently account for the additional pollutant loading and impervious surface concentration that will occur directly on the Columbia's tributaries. Natural wetlands are highly dynamic systems that provide a wide range of support to plant and animal species, help regulate local water cycles, and provide critical ecosystem services like flood control, riparian buffer benefits, and carbon sequestration. Constructed wetlands, no matter how well-designed, often fail to establish the same level of biodiversity, soil structure, and long-term hydrological function. And here, NEXT proposes the addition of 400+ acres of Glyphosate-treated soils, thereby adding additional pollutant load and undermining the overall efficacy of the mitigation strategy. Ultimately, mitigation strategies such as this one are insufficient to account for the loss of habitat quality and require long-term management to maintain even basic function goals.

Moreover, the timing and success rate of mitigation projects is often problematic. Constructed wetlands take years, or even decades, to return to an ecologically meaningful function, if they succeed at all.[108] In contrast, the impacts of wetland destruction are borne immediately, leaving a substantial gap in ecosystem services for the watershed. It is well documented that mitigation projects often fail to meet their performance goals, with some even experiencing abject failure due to improper site selection, inadequate hydrology or inability to maintain invasive species.[109] Consequently, the loss of wetland function—namely as it pertains to flood control, providing a riparian buffer, and providing and enhancing aquatic habitat—is not truly mitigated by offset projects elsewhere, even when conducted at high ratios. Given the irreplaceable need for wetland function in this watershed to even maintain current water quality, coupled with the additional water quality threats this facility poses, it is unlikely that this mitigation strategy will be sufficient to account for aforementioned water quality impacts.

C. Statewide Narrative Criteria

OAR 340-041-0007 sets forth Oregon's statewide narrative water quality criteria. This standard mandates use of the "highest and best practicable treatment and/or control of wastes,

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[108] Todd Bendor, *A dynamic analysis of wetland mitigation process and its effects on no net loss policy,* Landscape and Urban Planning, Volume 89 Issues 1-2 (January 30, 2009).
[109] Marla Setlk, et. al., *Wetland Restoration: Contemporary Issues & Lessons Learned,* Association of State Wetland Managers, Windham, Maine (2017).

activities and flows… to maintain dissolved oxygen and other water quality criteria to the highest levels," and that temperature, toxics, and other "deleterious factors" are kept at the "lowest possible levels."[110] Further, the rule specifically provides that "for any new waste sources, alternatives that utilize resume or disposal with *no discharge* to public waters must be given *highest priority* for use whenever practicable."[111]

NEXT's compliance with multiple statewide narrative criteria standards is premised on a completely unrealistic and unsupported conclusory idea that oil spills or leaks from the various tanks, pipelines and other conduits will not happen. Indeed, the Applicant and DEQ continue to find assurance that if (or when) something spills or leaks, NEXT will simply implement some sort of spill response. However, Oregon's statewide narrative criteria, in multiple instances, articulates that creation of toxic conditions, or creation of sludge deposits that are deleterious to aquatic life, for example, may not be allowed.[112] It is beyond well established that refinery operations—including transit, refining, or loading—create conditions that result in both the deposition of sludge, and the creation of odors or toxic conditions which are deleterious to aquatic life. NEXT does not confront how it will ensure that its operations will avoid this outcome. However, statewide narrative criteria condemns the result that is beyond likely. DEQ cannot certify that the Application complies with these standards, nor can it rest assured that any sort of reactive spill response will be sufficient to negate the fact that this operation is squarely at odds with the calls of the statewide narrative criterium set forth in OAR 340-041-0007(10)-(12).

VI. NEXT's Materials and Conclusions of Compliance are Premised on Faulty Assumptions, Undermining DEQ's Assurances of Compliance with Water Quality Standards

A. NEXT's Application Materials are Inadequate for DEQ to Make an Informed Certification Decision

NEXT's materials provide insufficient information for DEQ to evaluate project compliance with state water quality standards, or to support a decision to grant 401 Certification for the proposed project. Indeed, the materials contain nothing of substance—beyond conclusory statements that water will be "sufficiently" treated—that could be interpreted as information "necessary to demonstrate that the activity will comply with applicable provisions of…the Clean Water Act, including water quality standards set forth in OAR Chapter 340, Division 041, and other applicable requirements of state law."[113] Below, this comment highlights several specific

[110] OAR 340-041-0007(1).
[111] OAR 340-041-0007(3) (emphasis added).
[112] *See* OAR 340-041-0007(10)-(11).
[113] OAR 340-048-0020(2). Commenters also point out that NEXT's Technical Memo conveniently states, with no technical justification, that wastewater will be pre-treated to comply

standards and other issues that NEXT and DEQ must address for the project before Certification may be granted.

NEXT's materials provide no information about how discharges from the project will comply with relevant water quality standards in the Columbia River, the Bradbury Slough,[114] or the McLean slough. Nor does the JPA contemplate the water quality implications of the simultaneous loss of 105 acres of wetlands, and the converse addition of 72.6 acres of impervious surfaces. The proposed development will clearly fill several wetlands with a discernable nexus to already impaired waters. Moreover, the stormwater from this construction and operation will have an impairing effect that is *exacerbated* due to the loss of wetland function at the site. These water bodies, which are already listed as water quality limited for several parameters, and which are used by listed salmonids during much of the year, are not suitable for such increased levels of pollutant loading. Moreover, the JPA contains no information pertaining to water quality, relevant impairments, or potential pollutant loads reasonably likely to occur from the construction and operation of a refinery that will occur on the banks of the Columbia River and its tributaries. As such, there is no information on how this activity will, or even can, comply with those standards. Rather, NEXT submits a conclusory application that promises not to pollute, which DEQ purports to accept. However, this does not comply with federal law, nor does it comply with the obligations set forth in OAR Chapter 340, Division 041. NEXT's proffered analysis in insufficient for two reasons: first, it is incomplete in that it neither sufficiently identifies the requisite water quality standards and/or water bodies at issue relevant to assessing Certification; second, literature pertaining to the construction and operation of a fuel refining facility indicates that there will be pollutant loading to waters of the United States. As such, DEQ cannot simply accept NEXT's conclusory statements, which fail to provide any analysis of potential water quality impacts, in order to grant a 401 Certification.

1. NEXT Incorrectly Concludes that the Drainage District Confines Water Movement

NEXT's analysis of water quality impacts rests on the incorrect assumption that "water within the drainage district is confined by a network of levees, which prevents the free exchange of water into or out of the district."[115] This implies that pollution from project operations will not

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with effluent limitations of the Port's NPDES Permit and/or the standards of the forthcoming and anticipated 1200-Z Permit. *See generally,* May 2024 Response.

[114] Commenters point out that the application does not even contemplate the Bradbury Slough as an affected waterway, which should render the application incomplete. *See* OAR 340-048-0020(2)(f) ("An application filed with the department must contain, at minimum, the following information… the names of affected waterways, lakes, or other water bodies.").

[115] May 2024 Response at 1 ("The proposed NEXT Renewable Fuels facility is strategically located within the Beaver Drainage District (BDD), which is comprehensively protected by a levee system. This system isolates the BDD from neighboring waterways, including the

reach the Columbia or other waters outside the levee, and therefore that DEQ does not need to analyze the effect of refinery operation pollution (spills, sedimentation, failed stormwater treatment) on surrounding waterways. This assumption ignores three vital aspects of the area: (1) the status of the levee infrastructure purportedly preventing water exchange; (2) the propensity for regular and extreme flooding; and (3) the drainage district practice of pumping water out of Port Westward and into the Beaver Slough and Lower Clatskanie River in the winter when seepage and rainwater flood Port Westward. These aspects mean that pollution will move more freely away from the site, resulting in water quality violations. NEXT's reliance on drainage district infrastructure for containment is inappropriate, and undermines the legality of DEQ's review and conclusion that no water quality standards will be violated.

First, DEQ should consider the degraded status of the levee infrastructure in the area before accepting NEXT's assumption that water and pollutants are contained. The levee system protecting the area has not been sufficient to support accreditation under the National Flood Insurance Program ("NFIP") for well over a decade.[116] In 2012, inspections determined that the BDIC levee system is height deficient and required so much work to protect from a 100-year flood that further analysis for certification and accreditation[117] was not possible: "USACE cannot complete levee system evaluations for NFIP accreditation on levee systems that have less than 2 feet of freeboard."[118] And, "the Phase 1 evaluation identified additional items of significant concern requiring correction by BDD prior to moving to Phase 2, including unwanted vegetation, encroachments, slope stability, depressions, and animal control."[119] Since then, the levee infrastructure has further degraded. Subsequent construction of a wetland mitigation site near the Port Westward docks in 2016 introduced "over 800 ft of clear, active seepage" and has been noted as active several times in recent Corps inspections.[120]

Columbia River to the northwest, the Clatskanie River to the west and southwest, the Beaver Dredge cut to the south and Bradbury Slough to the east. Notably, there are no direct or open connections from the facility or the BDD to these water bodies, which plays a crucial role in preventing any potential contamination from reaching them.").

[116] Beaver Drainage Improvement Company, Comment in NEXT County Land Use Proceeding (Jan. 2024) at 4, https://www.columbiacountyor.gov/media/Board/BOC/BOC%20Hearings/DR%20MOD%20and%20CUP%20Sept%2019%202023/Beaver%20Drainage%201.10.24.pdf.

[117] Federal Emergency Management Agency (FEMA), Levee Certification vs. Accreditation, https://www.mvk.usace.army.mil/Portals/58/docs/LSAC/LeveeCertification.pdf.

[118] FEMA, BDIC Phase I Levee System Evaluation for National Flood Insurance Program Accreditation, Beaver Drainage District (Mar. 2014) at 1. Enclosed.

[119] *Id.* at 10.

[120] Beaver Drainage Improvement Company, Comment in NEXT County Land Use Proceeding (Jan. 2024) at 4, https://www.columbiacountyor.gov/media/Board/BOC/BOC%20Hearings/DR%20MOD%20and%20CUP%20Sept%2019%202023/Beaver%20Drainage%201.10.24.pdf. We urge DEQ to

As explained by local farmers, the proposed site for the NEXT Refinery is in the middle of active farm land. Wendy Schmidt within the Beaver Drainage District spoke to DEQ and highlighted that the "area is between 3-15 feet above sea level and the groundwater becomes surface water seasonally. The crop irrigation and livestock depend on the waters within the sloughs and drainage systems. The levees are fragile and any tampering is felt throughout the system. Building a facility of this magnitude alone would be catastrophic to farms. The nature of this project, in its entirety, would destroy the area." Commenters urge DEQ to carefully consider comments from farmers in the area with deep familiarity with the local hydrology.

Recent LIDAR data demonstrates the levee's elevation, showing areas susceptible to overtopping.[121] And, there is significant concern that construction and traffic will cause subsidence on the levees.[122] Kallunki Road sits atop the levee, and will be used by heavy construction vehicles and experience increased traffic as a result of refinery operation. The status of the levee infrastructure is crucial to understanding impacts to drainage, stormwater flow, and the fate of pollution inside and outside of the drainage district. NEXT's conclusory assumption that pollution will be contained within the levee system is incorrect, given known information about the levee infrastructure.

Second, this site and surrounding area are extremely flood prone—a factor that NEXT's materials and justifications do not properly consider. NEXT's entire site, including the proposed driveway, pipe rack, and rail yard is at risk of a major flood event because the levees are not certified. FEMA's 2014 report concluded that the levee could not proceed into Phase 2 and is only provisionally certified, there is no analysis or conclusion that the levee crest elevation provides assurance of protection from overtopping by 1% annual chance exceedance flood event.[123] Not only is the area at risk of a major, 100-year flood event, it also experiences regular flooding and has an extremely high water table due to significant annual precipitation. Locals describe the area as a "bathtub" and the entire watershed is interconnected upon any significant rain event.[124] NEXT's reliance on the levee system for pollution containment underestimates the movement of pollution during regular and extreme flooding. DEQ does not have sufficient

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review BDIC's comments to the Army Corps, County, and Department of State Lands closely. They raise issues important to the safety of area residents.

[121] BDIC LIDAR Data, collected Aug. 2023 (showing low elevation of levee infrastructure).

[122] There is ongoing litigation over the Army Corps' determination that a Section 408 permit is not required to protect levee infrastructure from construction activities. *Columbia Riverkeeper and 1000 Friends of Oregon v. U.S. Army Corps of Engineers* (D. Or.) No. 3:24-cv-00868-AN.

[123] FEMA, Phase I Levee System Evaluation for National Flood Insurance Program Accreditation, Beaver Drainage District (Mar. 2014) at 10. A 1% annual chance exceedance flood event is also known as a 100-year flood, meaning there is 1% probability of the flood occurring in any given year.

[124] Jim Hoffman, Comment in NEXT County Land Use Proceeding (Jan. 5, 2024).

information to determine that flooding at the site will not cause violations of water quality standards, and therefore must deny the Certification.

Third, BDIC regularly pumps water out of Port Westward and into the Beaver Slough and Lower Clatskanie River in the winter when seepage and rainwater flood Port Westward. All of Port Westward, including the area around the refinery, is uphill of the pump station and could be contributing pollutants to the pumped water. BDIC often has to pump that water out in the winter to avoid flooding inside the levee. BDIC, not NEXT, is in charge of if and when pumping happens, meaning contamination from the site could be pumped off-site and contribute to water quality violations. NEXT's assumptions about water movement in and around the site ignore yet another important aspect of the hydrology, undermining DEQ's conclusion that refinery operations will not violate water quality standards of the Columbia River and its tributaries, as well as the requisite drainage ditches, including the McLean Slough, the Bradbury Slough, and the Beaver Slough, all of which will receive pollutants from NEXT's refinery activities.

2. NEXT Does Not Address Impacts from Refining Processes

Literature on the water quality impacts from biofuel production emphasizes that biofuel storage—similar to crude oil storage—often results in the release of products into groundwater and surface water, due to leaking from infrastructure.[125] These releases can threaten human health and the environment, as they contaminate soil and groundwater. From 1988 to 2019, the underground storage tank system ("UST") has confirmed that there have been 555,384 UST releases, 64,670 of which have not reached cleanup completed status.[126] While Commenters recognize that NEXT will not use USTs, the sentiment remains true: fuel infrastructure leaks and that poses threats to environmental quality. EPA recognizes that leaks from storage tanks and pipelines, "continue to occur regularly" and are "likely to continue."[127] Moreover, corrosion of USTs from biofuel blends "have become common" and should, accordingly, be contemplated as a significant part of this facility's operation.[128] As EPA notes, there are significant uncertainties regarding future effects on water quality, especially as it pertains to water quality impacts from refining, but it is fairly certain that this facility will experience leaks from various forms of infrastructure, and DEQ must contemplate those impacts in this Certification, as they will affect various beneficial uses, conflict with statewide narrative criteria, and cause further degradation of the already-impaired waterway. This, coupled with the site's location in an area with a shallow water table means that leaks are reasonably certain to reach the surface water and migrate away from the site.

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[125] *See e.g.*, United States Environmental Protection Agency, *Biofuels and the Environment Third Triennial Report to Congress,* ("Biofuels Triennial Report") at 10-24.
[126] *Id.*
[127] *Id.* at 10-41.
[128] *Id.*

3. NEXT Cannot Rely on the Forthcoming 1200-Z Permit as Sufficient to Assure Compliance with Water Quality Standards

NEXT's posits that it will comply with water quality standards because it will comply with the 1200-Z permit, which covers industrial stormwater discharges.[129] This is insufficient for two reasons. First, the 1200-Z permit is a general permit that does not impose numeric effluent limitations that are sufficiently responsive to both the on-site activity and the impairments and uses of the receiving waterway. Rather, the permit relies on an adaptive management approach that uses benchmarks and monitoring protocols to "assist the permit registrant in determining whether site controls are effectively reducing pollutant concentrations."[130] This is not sufficiently protective for a facility of this magnitude and proximity to salmon-bearing waterways.

Second, and of most concern, is the fact that DEQ's Draft Certification Condition, which is supposed to respond to the likely situation of groundwater contamination, expressly contradicts NEXT's own stormwater management plan. In the likely situation that groundwater is encountered during construction, the draft 401 requires NEXT to install a liner "to prevent the facilities from intercepting sub-surface flow."[131] This is inconsistent with NEXT's own stormwater management plan: "Proposed ponds were designed with a shallow depth to avoid the need for a liner. . . . Liners can negatively impact the pond vegetation, make maintenance more difficult and expensive and are subject to buoyancy; therefore, a liner is not recommended at this time."[132] The plan goes on to note that there will be further studies of groundwater elevations, and that pond designs may need adjustment to minimize groundwater intrusion. This contradiction undermines DEQ's assumption that the 1200-Z permit will be sufficient to protect water quality *because* DEQ's condition of installing a liner expressly contradicts NEXT's stormwater management plan.

VII. Other Considerations

- **DEQ should not proceed without a draft EIS from the Corps.**

For a project this complex, in a sensitive area, with such varied and significant environmental impacts, it is appropriate for DEQ to require a draft EIS (and review public comments on the draft EIS) before proceeding with Certification. While the Corps' timeline is out of DEQ's control, DEQ still has authority to require additional information to inform its analysis of the overall project's water quality impacts—including from construction and future operations. In

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[129] *See* Joint Permit Application No. 2020-393 at 5.
[130] DEQ, *Permit Evaluation Report 1200-Z - March 2021,* at 9.
[131] Draft Certification at 12.
[132] Post Construction Stormwater Management Plan at 7 (Aug. 2023).

other projects of this magnitude, DEQ has required a draft EIS before completing Certification, and DEQ should follow its own practice here.

- **If the Land Use Board of Appeals overturns NEXT's land use permit(s), DEQ must deny the certification.**

The underlying land use permits for this facility are currently being appealed at Oregon's Land Use Board of Appeals ("LUBA"), for a second time.[133] A decision is expected on November 12, 2024. A complete application for certification must include a valid Land Use Compatibility Statement.[134] Without valid land use permits for the entire facility, DEQ may not issue the 401. Additionally, DEQ cannot make a determination regarding water quality impacts without a final site design, which underlies the project's stormwater management plan—the document that purports to mitigate water quality impacts from the facility.

- **DEQ must consider impacts to water quality from increased vessel traffic as part of the facility's direct operational impacts.**

NEXT's application materials do not address impacts to water quality as a result of increased vessel traffic, despite this being a direct operational impact of the facility. The fact that NEXT's vessel traffic will be managed by a different entity does not absolve DEQ from its responsibility to evaluate those impacts. Commenters encourage DEQ to read EPA's preamble to the 2023 Rule, which explains in detail the extent of DEQ's authority to consider any water quality impacts from the permitted activity's construction and operation.[135]

Vessel impacts to water quality will be significant. A 2024 study on large river vessel traffic found that a pause of large vessel traffic on a busy river shipping corridor resulted in decreased water turbidity, and increased the presence of sound-sensitive, rheophilic, and abundant forage fish: "The implications of turbidity reduction are wide-ranging, as sediment concentrations in the water column can have cascading effects on river ecology locally and downstream."[136]

Vessel wakes from ships calling at NEXT's proposed facility would kill and injure juvenile salmon and steelhead as they migrate through in the Columbia River, a designated beneficial use of this waterway. Wake stranding occurs when a wave caused by a vessel wake lifts an aquatic organism onto the shoreline. NMFS' SLOPES BiOPs identify ship wake stranding as a limiting

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[133] Columbia Riverkeeper et al v. NEXT, LUBA Nos. 2024-045/046.
[134] OAR 340-048-0020(2)(i).
[135] 88 Fed Reg. 66,588 (Sept. 27, 2023). Particularly, section IV.E.2.b of EPA's preamble goes into great detail about this authority.
[136] Spear et al., Reduction of Large Vessel Traffic Improves Water Quality and Alters Fish Habitat-Use Throughout a Large River, 946 Science of the Total Environment 172705 (2024) at 10, available at https://www.sciencedirect.com/science/article/pii/S0048969724028523.

factor for recovery of Lower Columbia River ("LCR") Chinook salmon, Columbia River chum, LCR coho salmon, and LCR steelhead, with juvenile ocean–type Chinook originating from LCR tributaries and CR chum being particularly vulnerable. NEXT's BA also acknowledges that wake stranding will occur, but provides no concrete details about the extent of the problem other than comparing the vessel traffic proposed by NEXT to previous proposals at the Beaver Dock.[137] However, a verified model[138] exists that could help DEQ estimate—even roughly—the impacts of wake stranding from NEXT's proposal. DEQ should use that model to determine whether vessel wake stranding from NEXT's proposal will cause or contribute to violations of the beneficial use of salmon migration in the Columbia River.

- **Irrigation is a beneficial use of waterways within the levee system.**

When considering water quality impacts, DEQ should recognize irrigation as a beneficial use of waterways within the levee system. This beneficial use could be impaired by the likely contamination of groundwater from on-site spills, failed stormwater infiltration, or by disruptions to the physical irrigation and drainage system from refinery and rail yard construction.

- **DEQ should consider water quality impacts resulting from the seismically hazardous site location.**

In addition to refinery infrastructure's propensity to leak via normal operations, DEQ should consider impacts to water quality in the event of a major earthquake, given NEXT's choice to site the refinery in a liquefaction zone. Scientists predict a 37% chance of a megathrust earthquake of 7.1 magnitude in western Oregon within the next 50 years.[139] That NEXT's facility will be built according to general seismic standards is not sufficient. Assuming NEXT's tanks will not survive the earthquake intact, and will therefore spill at least into the groundwater which is hydrologically connected to the surface water and drainage systems, this will cause a violation of the toxics standard and the ability to use water for irrigation. The likelihood of a major seismic event, coupled with the foreseeable consequences to water quality conflict with DEQ's duty to provide reasonable assurances that approving this project in a seismically hazardous area will not violate water quality standards.

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[137] NEXT BA at 46.

[138] *See, e.g.*, Pearson and Skalski, *Factors affecting stranding of juvenile salmonids by wakes from ship passage in the Lower Columbia River*, 27 River Research and Applications 926–936 (2011); *see also* Exhibit J, Kock *et al.*, *Review of a model to assess stranding of juvenile salmon by ship wakes along the Lower Columbia River, Oregon and Washington* (2013).

[139] Oregon Department of Emergency Management, *Cascadia Subduction Zone*, https://www.oregon.gov/oem/hazardsprep/pages/cascadia-subduction-zone.aspx#:~:text=Currently%2C%20scientists%20are%20predicting%20that,in%20the%20next%2050%20years.

VIII. Conclusion

As articulated above, there are a wealth of unknowns regarding the water quality, as well as the broader environmental quality, implications to the false climate solution that is "renewable fuels." NEXT has been able to capitalize on taking a piecemeal approach to the permitting of the facility, where they provide conclusory statements of compliance, with little critical review. Moreover, NEXT promises to subvert obligations by, for example, transferring wastewater to the Port of Columbia County and deferring critical analysis to a stormwater permit that is focused on BPMs rather than compliance with water quality standards. In doing so, NEXT is able to subvert critical and holistic analysis of the true environmental impacts of the construction and operation of this facility, all while making unrealistic promises of compliance that are premised on future permits and the aspiration that this facility—unlike any other in the country—will not leak, will not spill, and against all odds, will somehow not degrade the environmental quality of the sensitive, yet already compromised, surrounding environment. NEXT has subverted permitting obligations by splicing review to deliberately avoid any substantive critical, cumulative analysis of the threats this operation poses to environmental and public health. However, in doing so, they have failed to offer the bare minimum information necessary to allow DEQ to ensure compliance with federal and state law. As such, DEQ must deny this permit.

Respectfully submitted,

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Staff Attorney
Northwest Environmental Defense Center

Audrey Leonard
Staff Attorney
Columbia Riverkeeper

Enclosures

FEMA, BDIC Phase I Levee System Evaluation for National Flood Insurance Program Accreditation, Beaver Drainage District (Mar. 2014)

BDIC LIDAR Data, collected Aug. 2023 (large file, sent separately)

Fueling Sickness:
The Hidden Health Costs of Fossil Fuel Pollution

Endorsed By:

Alliance of Nurses for Healthy Environments
APHA American Public Health Association
Children's Environmental Health Network
climate psychiatry alliance
Climate Psychology Alliance North America
ISEE North America Chapter
The Medical Society Consortium on Climate & Health
Medical Students for a Sustainable Future
NMA Since 1895
OUCH International Oncology Advocates United for Climate and Health
PSR Physicians for Social Responsibility
Public Health Institute

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Introduction

Fossil fuels - including coal, oil and gas - have shaped the modern world, powering advances in industry, mobility and daily life, including in medicine and public health. Yet the human health costs of fossil fuel use are enormous. From extraction to end use, pollution from fossil fuels contaminates the air we breathe, the water we drink and the food we eat, driving illness and premature death across every stage of life and every system of the body.

Air pollution from fossil fuels kills hundreds of thousands of people in the U.S. and millions worldwide every year. Fossil fuel combustion also causes climate change, another profound threat to human health. They also pollute our water and food through their use in making plastics and other petrochemicals.

This brief is not a comprehensive technical report. Instead, it offers a summary of how fossil fuels directly damage health: across the human life span and body systems and across the fossil fuel life cycle, from extraction to end use. It also highlights populations at heightened risk and points to key steps for protecting health. The extensive health impacts of climate change, driven by fossil fuel usage, are addressed after the direct health impacts.

Health and medical professionals see these harms in patients and communities every day. Our aim is to elevate the often-overlooked health costs of fossil fuels in conversations about our energy future. Too often, debates about the energy transition focus on economics, security or consumer choice. But we cannot ignore the devastating health burden of fossil fuels, especially when cleaner, more affordable alternatives are available. As health and medical professionals and organizations, we believe a transition to non-polluting energy is not only possible, but essential - for a healthier future.

Key Health Impacts

Fossil fuels are non-renewable resources. They formed millions of years ago when prehistoric plants and animals died and were gradually buried by layers of rock, then transformed by changing temperatures and pressure into coal, oil and gas. These fossil fuels are now extracted, processed, transported, burned and disposed of in ways that pollute air, water and land. At every stage of their life cycle, they harm human health and the environment.

Everyone in the U.S. is exposed to many toxic pollutants from fossil fuels. These exposures accumulate in our bodies over time and cause long-term health harms.[1] They affect every stage of human life, from before birth through old age. There is no safe threshold for fossil fuel pollution exposure – even very low levels of exposure may be harmful.[2]

While national and state air quality standards have led to significant improvements in air quality over several decades, air pollution remains a leading environmental health risk in the U.S. Globally, studies estimate that fossil fuel pollution is responsible for between 5 and 8 million deaths each year - including an estimated 350,000 premature deaths in the U.S. alone.[3,4]

Beyond deaths, fossil fuel pollution is making people sick, including through heart and lung disease, cancer, adverse reproductive outcomes, neurological disorders and other chronic conditions. The healthcare, economic and societal costs of illness and deaths attributable to fossil fuel pollution are immense. These illnesses and deaths are preventable, which is why strong, evidence-based policy action is essential. This report includes recommendations that policymakers can take to protect health and accelerate the transition to a cleaner, healthier future.

Health Harms Across the Fossil Fuel Life Cycle

Each stage of the fossil fuel life cycle – extraction, processing, transportation, combustion and waste - creates significant health harms. Emissions from oil and gas use in the U.S. alone are estimated to cause more than 216,000 cases of childhood asthma and 10,000 preterm births each year. Communities of color and low-income populations bear a greater share of the health burden at nearly every stage of the fossil fuel supply chain.[5] The cumulative health harms of fossil fuels extend far beyond climate change, imposing an enormous and preventable toll on public health.

Extraction:

Coal mining, oil drilling and hydraulic fracturing (fracking) for gas release harmful air pollutants that endanger workers and nearby communities. Coal extraction also scars the land, pollutes waterways and leaves behind toxic waste that threatens both ecosystems and human health. Fracking for methane gas (called "natural gas") is linked to water contamination and health problems including childhood cancer, birth defects, kidney and respiratory disease. Gas leaks and flaring (the burning of excess gas) release hazardous pollutants such as volatile organic compounds (VOCs) and nitrogen oxides (NOx), which increase cancer risk and trigger asthma, respectively.

Processing, Refining and Petrochemical Manufacturing:

After extraction, fossil fuels are processed and refined in industrial facilities called petrochemical plants, often located near residential neighborhoods. Workers and nearby residents are exposed to a complex mixture of hazardous air pollutants, including benzene, formaldehyde and other carcinogens, which heighten risks of cancer, respiratory illness and adverse birth outcomes. These facilities also emit particulate matter, nitrogen oxides and sulfur dioxide, worsening asthma and other chronic lung diseases in surrounding communities.

Transportation and Distribution:

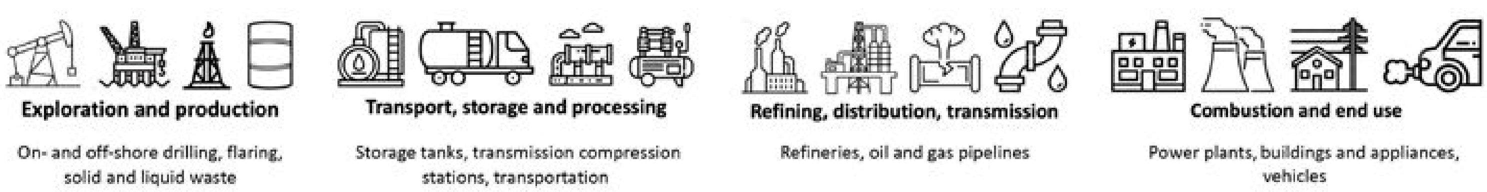
Pipelines, trains, ships and trucks each pose hazards throughout the transport of fossil fuels. Pipeline leaks and ruptures happen regularly and contaminate soil and water and can cause explosions. Transport by rail and truck increases risks of accidents, spills and community exposure to harmful pollutants. Port communities near shipping hubs also face high concentrations of diesel exhaust, which is classified as a known carcinogen and linked to asthma, heart disease and premature death.

Combustion:

The greatest health damage arises from burning coal, oil and gas for electricity, transportation, heating and industrial use. Alongside greenhouse gases, combustion generates harmful air pollutants, including fine particulate matter (PM2.5), NOx, sulfur dioxide, ozone and toxic metals – pollutants strongly linked to cardiovascular disease, respiratory illness, adverse birth outcomes and premature death. Transportation is a major source of this pollution, as cars, trucks, trains, ships and other equipment powered by fossil fuels emit large volumes of exhaust that directly harm health, particularly in urban areas and those nearest traffic-related pollution sources.[6,7]

Waste Products:

Even after combustion, fossil fuel waste continues to harm health. Coal-fired power plants generate coal ash, one of the nation's largest industrial waste streams, containing arsenic, cadmium, lead, mercury and radioactive elements. When stored in unlined ponds or landfills, these contaminants can leach into groundwater, pollute surface waters and contaminate drinking water supplies.[8] Oil and gas refining produces chemicals that are used to manufacture plastics, pesticides and fertilizers, extending fossil fuel harms into consumer products. Many of these byproducts, such as plastics and agricultural chemicals, are associated with additional health harms from endocrine disruption to cancer (see Plastics section).



How Do Fossil Fuels Impact Our Health?

Fossil Fuels and Respiratory Health

The extraction, processing and burning of fossil fuels releases air pollutants that can penetrate deep into the lungs to cause inflammation, cell and tissue damage, immune system disorders, changes in the structure of the airways and chronic respiratory damage. Long-term exposure causes asthma and asthma attacks, chronic obstructive pulmonary disease (COPD), reduced lung function and lung development in children, increased respiratory infections, premature deaths from COPD and lung cancer.[9,10]

Children are particularly vulnerable: they have greater exposure than adults as they spend more time outdoors, are more physically active and have faster respiratory rates. As children's lungs are still developing, they are more susceptible to damage from pollutants.[11,12]

People living and working near the extraction or processing of fossil fuels also face significant risk. Coal miners can develop black lung disease, COPD and lung cancer from breathing in coal dust.[13,14] Those living near coal-burning plants or coal ash storage facilities are at increased risk of respiratory symptoms (such as cough) and respiratory infections. Air pollution from oil and gas production (e.g. drilling and fracking) in one year alone resulted in 410,000 asthma flare-ups, 2,200 new cases of childhood asthma and 7,500 excess deaths.[15] Residents living near mountaintop removal mining are exposed to pollutants such as particulate matter, polycyclic aromatic hydrocarbons (PAHs), heavy metals and hydrogen sulfide, linked to higher rates of birth defects, cardiovascular disease and respiratory illness.[16]

Reducing air pollution from fossil fuel facilities can deliver immediate and measurable health benefits. For instance, when a coal coking plant in Pittsburgh, Pennsylvania shut down, nearby communities saw a rapid decline in emergency department visits - over 20% fewer for respiratory symptoms and more than 40% fewer for pediatric asthma.[17]

Methane ("natural") gas is used to generate electricity and to power home appliances such as dryers, furnaces, ovens, stoves and water heaters.[18] It is linked to an array of health problems including childhood cancer, birth defects and respiratory issues. Methane gas appliances (like gas stoves and furnaces) in our homes can emit carcinogenic benzene, carbon monoxide, nitrogen dioxide and fine particulate matter, increasing the risk of asthma and other respiratory symptoms, particularly in children and vulnerable populations.[19]

Burning fossil fuels releases air pollutants that lead to respiratory harm, such as particulate matter (PM2.5 and P10), ozone, nitrogen oxides (NO2) and sulfur dioxide (SO2).

$PM_{2.5}$

Everyone in the U.S. is exposed to $PM_{2.5}$ and at risk of its harmful effects, which accumulate over time. There is no safe threshold of exposure, meaning even low levels of exposure are associated with health risks. People with higher exposures – most often found in urban and low-income communities and communities of color – are most impacted.[20,21] Short-term $PM_{2.5}$ exposure can cause coughing, wheezing, phlegm production, increased respiratory infections, asthma attacks, increased emergency department visits and hospitalizations for respiratory conditions and deaths from respiratory illness. Long-term exposure is associated with significantly escalated risks of asthma, chronic respiratory diseases like COPD and pneumonia, lung cancer and premature death, even at low exposure levels routinely experienced in the US.[22]

Ozone

Short-term ozone exposure (up to 8 hours) causes injury and inflammation of the respiratory tract leading to airway constriction and coughing. This results in decreased lung function, increased respiratory symptoms (such as coughing, throat irritation, chest discomfort, increased sensitivity to asthma triggers), emergency department visits and hospital admissions from asthma exacerbations and respiratory infections. Even healthy individuals have experienced decreased lung function and respiratory symptoms after short-term ozone exposure.[23] Long-term ozone exposure causes new-onset asthma as well as worsening symptoms in individuals with asthma. It is also associated with altered lung development, COPD and respiratory mortality.[24]

NO_2

Short-term exposure to nitrogen dioxide causes development of asthma in children, increases airway responsiveness (or sensitivity) in adults with asthma, decreases lung function and increases respiratory-related hospital admissions and emergency department visits.[25] Long-term exposure can also decrease lung development in children and increase asthma or chronic bronchitis in adults. [26]

SO_2

Exposure to sulfur dioxide worsens asthma. SO_2 may increase the risk of lung disease and death, especially in the elderly and people with chronic lung disease or cardiovascular disease.[27]

Fossil Fuels and Cardiovascular Disease

Fossil fuels significantly increase the risk for cardiovascular diseases – heart attacks, strokes and heart failure - which are leading causes of death both in the U.S. and globally. Of the millions of deaths attributable to fossil fuel pollution, the greatest proportion are due to cardiovascular diseases.[28]

Hundreds of studies have shown that short-term (hours to days) elevations in outdoor $PM_{2.5}$ levels increase the risks for heart attacks, strokes and deaths from cardiovascular disease. Short-term exposure to particulate matter has also been linked to higher risks of atrial fibrillation, other arrythmias and heart failure.[29] While brief exposures can be harmful, living in locations with poor air quality over the long term is related to much larger increases in cardiovascular risk. Fine particulate matter and NOx are consistently associated with hypertension, myocardial infarction, stroke and ischemic heart disease, while long-term exposures to $PM_{2.5}$ increase the risk of atherosclerosis, incident stroke and stroke mortality.[30]

Fossil Fuel Use and Impacts on Brain Function

Air pollution from burning fossil fuels can harm the brain. Research shows that exposure to air pollutants - especially $PM_{2.5}$, NO_2 and ozone - can cause inflammation, stress and changes in brain chemistry. These changes can damage brain cells, interfere with how the brain communicates and increase the risk of neurological diseases such as Alzheimer's or Parkinson's.[31,32]

Both short-term and long-term exposures to $PM_{2.5}$ raise the risk of stroke.[33] Studies have found that people living in areas with higher levels of $PM_{2.5}$, NO_2 or ozone are more likely to experience strokes, hospitalization or premature death. A nationwide study of millions of Medicare enrollees found that reducing NO_2 levels by just 12.4 parts per billion - the difference between living in a large city like Los Angeles and a smaller one like Portland- was associated with a 6% reduction in stroke rates.[34]

Long-term exposure to polluted air has also been linked to dementia and cognitive decline.[35] Another large study of Medicare beneficiaries found that every small increase in annual $PM_{2.5}$ levels was associated with a higher risk of hospitalization for Alzheimer's, Parkinson's and other dementias, even at pollution levels below current air quality standards.[36]

Children's developing brains are especially sensitive to fossil fuel pollution. Studies show that when pregnant women are exposed to high levels of air pollution, their children are more likely to have behavioral and learning problems. In one study, children exposed to more NO_2 before birth and $PM_{2.5}$ in early childhood had more behavioral challenges and performed worse on cognitive tests at ages 4 to 6.[37] Other research has found that children exposed to polycyclic aromatic hydrocarbons (PAHs), compounds produced during incomplete fossil fuel combustion, have more difficulty with impulse control later in childhood.[38]

Exposure to higher levels of air pollution has also been linked to poor cognitive function in adults. Although specific findings vary, a recent review of research found general agreement across studies that NO_2 and $PM_{2.5}$ exposure is associated with lower cognitive performance in adults.[39]

The neurocognitive harms of fossil fuel pollution disproportionately impact children, older adults and communities already facing environmental and health inequities. People living near busy roadways, diesel truck routes or polluting industries are exposed to higher levels of $PM_{2.5}$ and other air pollutants. These communities are more likely to be low-income or communities of color, compounding the risks.

In children, exposure before and soon after birth can alter brain development, leading to smaller head circumference, reduced brain volumes and long-lasting neurologic effects.[40] Such exposures are associated with increased risks of autism spectrum disorder, attention deficit hyperactivity disorder (ADHD), behavioral problems, lower IQ and reduced academic performance.[41] Alarmingly, studies have even found early signs of brain changes linked to Alzheimer's and Parkinson's disease in children exposed to high levels of air pollution.[42]

Fossil Fuels and Mental Health

A substantial and growing body of research demonstrates that fossil fuel pollution has adverse impacts on mental health. Exposure to pollutants such as $PM_{2.5}$ and NO_2, can cause inflammation, stress and neurotoxicity on the brain and nervous system, which are linked to higher risks of depression, anxiety and other mental health challenges.

Both short-term and long-term exposure to air pollution have been connected to depression.[44] Risks of depression grow even larger with long-term exposure to elevated levels of $PM_{2.5}$ and NO_2. Research has also found that long-term exposure to higher levels of PM_{10} and NO_2 is associated with higher risk of anxiety.[45]

Air pollution has also been linked to suicide risk. In one study, short-term exposure to significant increases in particulate matter was found to be associated with a 1-2% increased risk of completing suicide[46], while a second found that increases in NO_2 were associated with a 3% increased risk.[47] Separate research has also found a connection between PM_{10} exposure and increased suicide risk over the subsequent 24-48 hours.[48]

Children are especially vulnerable to the mental health effects of fossil fuel pollution.[49] Research has found that children who grow up breathing higher levels of air pollution are more likely to develop depression and behavioral disorders as teenagers. One study found that children experiencing the highest levels of air pollution at age 12 were up to 4 times more likely to be diagnosed with depression and up to 5 times more likely to be diagnosed with conduct disorder by age 18 - effects comparable to those seen from childhood abuse or trauma.[50]

Pollution exposure may also play a role in more severe mental health conditions. While schizophrenia is largely influenced by genetics, environmental factors also contribute. Research found that people exposed to higher levels of NO_2 from birth through age 10 were 62% more likely to develop schizophrenia by age 37 compared to those growing up with cleaner air.[51]

Fossil Fuels and Reproductive Health

Exposure to fossil fuel pollution is linked to poor pregnancy health, pregnancy loss, fetal neurodevelopmental disruption and adverse birth outcomes such as preterm birth, low birth weight and birth defects.[52] Inequitable distribution of fossil fuel pollution in the US is driving and worsening social and racial inequities in reproductive health.[53,54,55]

Pregnant women and the developing fetus are especially vulnerable to the impacts of pollution because they experience many crucial and precisely timed physical and psychologic changes. When these processes are disrupted by pollutants, the impacts on pregnancy and the fetus can be profound and sometimes lifelong.[56] Due to pregnancy stress on the body, pregnant women are at additional risk of many serious diseases that can also be worsened by fossil fuel pollution, such as hypertension[57] and diabetes.[58] Pregnant women also breathe in more air than non-pregnant people, exposing them to more air pollution.[59]

Numerous studies find convincing evidence that exposure to $PM_{2.5}$ during pregnancy raises the risks of unfavorable birth outcomes and pregnancy complications, including low birth weight, preterm birth, stillbirth, small for gestational age and birth defects.

Pregnant women exposed to $PM_{2.5}$ had a significantly higher risk of developing hypertensive disorder of pregnancy, gestational diabetes, gestational hypertension and preeclampsia.

Exposure to oil and gas well sites during pregnancy is associated with increased risk of spontaneous preterm birth.[60] Babies born in Pennsylvania within 1 km of a fracking site were more likely to have low birthweight[61], and fracking has been associated with pre-term birth.[62] Pregnant women living close to an oil or gas extraction site during pregnancy have an increased risk of hypertensive conditions, such as preeclampsia.[63]

One of the strongest associations between air pollution and negative birth outcomes like low birth weight and preterm birth are with power plants and petrochemical industries.[64] Oil refineries produce a wide range of toxics, including benzene, which can harm fetal development and the male reproductive system; carbon monoxide, which during pregnancy can affect fetal brain development and cause pregnancy loss; and lead, a heavy metal that can adversely impact fetal brain developments, cause learning and behavioral problems in children and harm the reproductive systems of both men and women.[65]

A study of exposure to traffic-related pollutants near the end of pregnancy showed that greater exposure was associated with an increase in NICU admissions.[66] Air pollution can disrupt fetal brain development.[67] People who live closer to fossil fuel power plants are more likely to have preterm delivery, even if they live up to 20 km (12.4 miles) away.[68]

Other Reproductive Health Harms

Many petrochemicals are endocrine-disrupting chemicals (EDCs), which means they interfere with normal hormonal activity and increase risk for adverse health risks, including infertility.[69] A growing body of evidence also suggests that EDCs, including from fossil fuel-derived products are associated in studies with female reproductive health diseases such as painful and underdiagnosed conditions like fibroids, breast cancer and girls getting their periods increasingly earlier in life.[70]

Exposure to endocrine disrupting chemicals is associated with reproductive harms (including reduced fertility in both women and men and adverse pregnancy outcomes).[71] Consistent with these observations, women living near fracking sites have increased risks of preterm birth.[72] Another report documented that women living near coal and oil power plants had a lower rate of preterm births after the plants were closed.[73]

Fossil Fuels and Kidney Health

Fossil fuel pollution increases the risk of chronic kidney disease (CKD).[74] It has been estimated that the global burden of CKD attributable to $PM_{2.5}$ is 6.95 million new cases of CKD each year.[75] The burden is greatest in low- and middle-income countries, where air pollution levels are higher and health risk factors like diabetes and high blood pressure are also more common. Both of these conditions, which can be made worse by fossil fuel pollution, increase the risk of developing CKD.[76,77]

Both short- and longer-term exposure to $PM_{2.5}$ are associated with significantly increased risks for development of acute kidney injury, progression of CKD and increased mortality in those with end state kidney disease (ESKD).[78] Several studies have demonstrated an association between short-term elevations in $PM_{2.5}$ and higher risk of death from kidney disease as well as emergency department visits.[79,80] Short-term exposure to $PM_{2.5}$ is also associated with an increased risk of hospital admissions and deaths in patients receiving dialysis for ESKD.[81] A meta-analysis showed a higher risk for CKD and lower kidney function among people living near petrochemical plants than those without such exposure.[82]

Fossil Fuels and Endocrine (Hormonal) Disease

Fossil-fuel driven air pollution poses substantial risks to the endocrine system, which controls growth and development, metabolism and reproduction. Studies have consistently demonstrated significant associations between levels of $PM_{2.5}$ in the air and risks of obesity[83], Type 2 diabetes (and diabetes-associated mortality)[84] and high blood pressure.[85] Higher exposure to $PM_{2.5}$ is also associated with higher risk for preterm birth, low birthweight, stillbirth[86] and preeclampsia.[87] While most of the evidence linking air pollution to endocrine system dysfunction is observational, a randomized trial in healthy adults showed significantly lower blood pressure, and lower levels of markers of stress and inflammation in healthy adults given air purifiers to reduce $PM_{2.5}$ exposure.[88]

Fossil fuel extraction releases many chemicals that interfere with normal function of the endocrine system. For example, hormone-disrupting chemicals are used in fracking for gas and often contaminate surface water, groundwater and even drinking water. A study of water samples from a region in Colorado with a high density of gas drilling and reports of spills and discharges found significantly elevated endocrine-disrupting activity compared with water from areas without gas drilling.[89] In addition, coal mining releases toxic metals (including lead, arsenic and mercury) that also act as endocrine disrupters.

Endocrine disrupting chemicals are also produced from fossil fuel products, such as microplastics/nanoplastics and PFAS, which have been detected in a variety of human tissues, including placenta.[90] Additionally, other fossil-fuel derived chemicals including pesticides act as endocrine disrupters.

Fossil Fuels and Cancer

Fossil fuel pollution is a contributor to the large burden of cancer in the U.S., affecting both the occurrence of cancer and its outcomes. About 2 million Americans will be diagnosed with cancer and more than 600,000 will die from cancer in 2025.[91]

Lung cancer is one of the most common cancers worldwide. It is estimated that approximately 15% of lung cancer worldwide is due to air pollution.[92] The International Agency on Research on Cancer (IARC) has found $PM_{2.5}$ and diesel exhaust are proven to cause cancer, damaging and mutating lung cells.

There is extensive evidence that people exposed to outdoor air pollution from car, truck and diesel exhaust have an increased risk for lung cancer and death.[93] Studies show that for each 10 mg/m3 increase in $PM_{2.5}$ in the air, there is about a 13% increase in the risk for death from lung cancer.[94] Individuals who have never smoked can also face as much as a 27% increase in lung cancer deaths due to $PM_{2.5}$.[95] People of color who are diagnosed with lung cancer face worse outcomes compared to white Americans, including: less likely to be diagnosed early, less likely to receive surgical treatment, more likely to receive no treatment and less likely to survive five years.[96]

A growing body of evidence also shows an association between air pollution and increased risk for breast, colorectal, brain, bladder and liver cancers, including many studies linking traffic pollution with increased adult cancer risk.[97] Similarly, many studies have found an increased risk of brain, kidney, bone cancers and leukemia in children living near heavy-traffic roads or near industrial sites.[98,99]

Workers and communities can be exposed to cancer-causing substances across the life cycle of fossil fuels. Fracking for oil and gas uses many chemicals - including benzene, 1,3-butadiene and formaldehyde - that are known human carcinogens. Children living near unconventional oil and gas development have shown an increased risk of leukemias and lymphomas and some studies suggest that it may be related to fracking. [100]

Refinery and other petroleum workers may have repeated exposures to cancer-causing substances - including asbestos - and have been found to have increased risks of mesothelioma, lung cancer, malignant skin melanoma, acute lymphoid leukemia, multiple myeloma and bladder cancer.[101] Residents in fence-line communities near petroleum industry sites and facilities also have elevated risks for leukemia.

Plastics and Health

Plastics are manufactured chemical products, more than 98% of which are made from coal, oil and gas. They persist in the environment for years to decades, contributing to a rapidly growing global pollution burden that now totals an estimated 8 billion tons. Despite efforts to promote plastics as recyclable, fewer than 10% of plastic (and only 1-2% of single use plastics) is recycled globally, leaving the vast majority to accumulate in landfills, waterways and ecosystems.[102]

All plastics contain chemical additives, of which more than 10,000 are in use, and the vast majority have not been tested for toxicity. Of the chemicals that have been closely studied for health impacts, four major categories of chemicals are of particular concern: phthalates (used to soften plastic), bisphenols (BPA - used to produce linings), per- and polyfluoroalkyl substances (PFAS); and brominated flame-retardants.[103] These additives include known carcinogens (vinyl chloride, 1-3 butadiene and PFAS), neurotoxicants (lead and brominated and organophosphate flame retardants) and endocrine disruptors (phthalates and BPA). As these substances leach from plastics into the environment, they drive many of the health and ecological harms now associated with plastic pollution.

Plastics threaten human health across their entire life cycle – from fossil fuel extraction to production, use and disposal. Workers in fossil fuel extraction, plastic production, plastic textile workers and plastic recycling workers are all exposed to air pollutants and to multiple toxic chemicals. They suffer increased rates of cardiovascular, pulmonary, metabolic and neurologic diseases and cancer.[104]

Microplastics and nanoplastics, very tiny plastic particles, have been detected in human hearts, brains and blood vessels, where they are associated with cardiovascular disease. Everyday exposures from food packaging, bottled water, indoor air and dust contribute to infertility, obesity, kidney disease, cancers and other chronic conditions. These chemicals disrupt endocrine function and increase risk for premature births, neurodevelopmental disorders, male reproductive birth defects, obesity, cardiovascular disease, renal disease and cancer. These particles are pervasive in indoor air, household dust, bottled water, tap water, meat, salt, fruits, vegetables, seafood, baby formula and breast milk.[105] When plastic is heated or damaged, bisphenol A (BPA) and phthalates can leach into food and beverages.[106]

Infants and young children are especially vulnerable to plastics. Fetuses in the womb are exposed to plastics chemicals absorbed by their mothers. Prenatal exposures are linked to miscarriages, premature births, stillbirth, low birth weight, birth defects of the reproductive organs, neurodevelopmental impairment, impaired lung growth and childhood cancer. Early-life exposures to plastic chemicals increases risk of heart disease, Type-2 diabetes and obesity in childhood and across the life span.

The harms caused by plastics are not fairly distributed. People of color, Indigenous populations, low-income communities and workers in production and waste facilities face disproportionate exposures and health burdens including have increased risks of premature birth, low birth weight, asthma, leukemia, cardiovascular disease, chronic obstructive pulmonary disease and lung cancer.

People Disproportionately Impacted by the Health Harms of Fossil Fuels

While fossil fuel pollution harms everyone, its health impacts are not evenly distributed. Certain populations, including low-income communities, communities of color, children, older adults and people with preexisting health conditions, face disproportionate exposure and heightened vulnerability. These inequities reflect a combination of environmental, social and physiological factors that place greater health burdens on already at-risk groups.

Vulnerability due to exposure:

Low-income and Communities of Color:

A complex array of interconnected factors (including but not limited to historical redlining, lending discrimination, exclusionary land use policies, disinvestment and urban renewal projects) have resulted in low income and communities of color disproportionally living in areas with a greater concentration of polluting sources, like highways and factories, and thus have greater exposure to multiple pollutants from multiple sources.[107,108] As a result, a higher percentage of racial minorities are exposed to particulate matter and ozone, contributing to a greater incidence of childhood asthma and other respiratory conditions. More than 1 in 5 African Americans live within a half-mile of an oil or gas production, processing or storage facility.[109] Low-income neighborhoods also tend to have older and less maintained housing that allow for greater penetration of outdoor air pollution into homes, making it difficult to escape the poor air quality.

Individuals Who are Unhoused

People experiencing homelessness are significantly more vulnerable to the adverse health impacts of fossil fuels due to increased exposure to air pollution. As many unhoused individuals seek shelter near highways[110], they face long-term exposure to harmful pollutants such as particle pollution coming from car tailpipes.[111] Additionally, individuals who are unhoused are disproportionately impacted by other chronic and pre-existing conditions and may be less able to access care, which further increases their vulnerability to adverse health risks.[112]

Individuals Who Work Outdoors

People who work outdoors can face higher health risks due to their increased amount of time spent outside breathing in air pollution. Additionally, outdoor workers are often engaged in strenuous activity that increases their breathing rate and the amount of polluted air they inhale. Outdoor workers may also have limited options for reducing their exposure without jeopardizing their employment.

Workers in the Fossil Fuel Industry

Individuals who work in the fossil fuel industry face severe occupational health risks and disparities in health outcomes. Miners other than coal workers face disparities in other health outcomes, such as increased mortality from cardiovascular disease and several types of cancer, including mesothelioma.[113] Workers in these industries also face substantial safety hazards, including but not limited to explosions and fires due to the ignition of flammable vapors or gases, falls from platforms or equipment and transportation issues. Highway vehicle crashes are the leading cause of death among oil and gas extraction worker fatalities.[114]

Vulnerability due to physiology:

Children

Children are uniquely vulnerable to the health harms of fossil fuels because their bodies, organs and immune systems are still developing. The impacts of pollution can exert multiple and cumulative adverse effects starting in utero and through childhood. Compared with adults, they spend more time outdoors, are more physically active and breathe more air in relation to their body size - factors that increase their uptake of pollutants that can penetrate deep into the lungs and bloodstream. Research has linked these exposures to a wide range of health effects in children, including low birth weight, asthma, reduced lung function, respiratory infections and allergies, as well as elevated risks for chronic disease later in life. Children living near fracking sites in Pennsylvania around their birth were two to three times more likely to be diagnosed with leukemia between the ages of 2-7 than children not living near these sites.[115] Studies show that children's disproportionate burden stems from both biological and social vulnerabilities. Their developing lungs, brains and immune systems, along with immature detoxification pathways, make them less able to process and recover from toxic exposures.[116] Disadvantaged and minority children are more likely to live in areas with higher concentrations of pollution, leaving them with elevated asthma rates and greater lifelong health challenges.[117,118]

Older Adults

Older adults are more likely to have other pre-existing conditions, such as high blood pressure, that increase their risk of adverse impacts from air pollution. Air pollution can exacerbate COPD and increase the risk of heart attacks and strokes in older adults, especially those who are also obese and/or have diabetes. In terms of fossil fuel extraction, elderly people living near or downwind from gas extraction sites have a higher risk of premature death than seniors who do not.[119]

Individuals with Chronic Illness

People with asthma, COPD, cardiovascular disease, lung cancer, diabetes or obesity are at particularly high risk from particle pollution from fossil fuel combustion. Fossil fuel pollution causes cellular injury and inflammation that puts more stress on the lungs and heart and other systems already harmed by disease. People with chronic illness who are exposed to pollution may experience worse symptoms than those without, and have more emergency department visits, more hospitalizations and higher risk of premature death.[120]

Pregnant Women and Fetuses

Pregnant women are especially vulnerable to air pollution because they breathe more often. Pregnant women who live in counties with higher levels of fracking in Texas have been found to be at much higher risk of giving birth to children with specific birth defects.[121] Additionally, another study found people living close to fracking sites in Pennsylvania had an increased risk of giving birth prematurely and of having high-risk pregnancies.[122] Fetal development and health after birth may also be harmed by environmental contaminants that have been shown to cross the placenta.

Fossil Fuels, Climate Change and Health

Human activities are the cause of increased greenhouse gas emissions causing climate change, and burning fossil fuels is the single largest driver of climate change. Health professionals and scientists around the world agree that climate change is the biggest health threat of this century. Reducing fossil fuel pollution is the most effective way to protect current and future generations from the health harms of climate change.[123]

Climate change causes warmer temperatures, more frequent extreme weather events, changes in drought and rainfall patterns and sea level rise. These changes affect the air, food, water and land on which human life depends, with health impacts already evident in communities across the U.S. Every small rise in global temperatures increases the likelihood of catastrophic health consequences, raising concern that our capacity to adapt or build resilience will be overwhelmed.

Climate Health Impacts

Heat-related deaths are increasing rapidly in the U.S. as extreme heat events become more frequent and severe. Extreme heat increases the risk of heart attack, worsens asthma and COPD, stresses the kidneys, increases the risk of complications from diabetes and worsens mental health. Scientists predict as many as tens of thousands of additional heat deaths in coming decades.[124]

Hotter temperatures also worsen air quality due to the formation of ground-level ozone (smog). Wildfires, driven by hotter, drier conditions, expose millions to $PM_{2.5}$ and toxic pollution that damages lungs, trigger cardiovascular disease, harm brain development and increase cancer risk. Warmer temperatures are even making allergy seasons longer.

Extreme weather events such as hurricanes, floods and severe storms cause injury and death, contaminate drinking water and overwhelm health systems. Power outages and facility closures disrupt medical care, including dialysis, insulin refrigeration and cancer treatment. Many patients - particularly older adults, people with disabilities and those without financial resources or transportation - face added risks because they may be unable to evacuate safely during floods, fires or smoke events.

Climate change also impacts food. Rising temperatures cause increased risk of food poisoning, while droughts and floods can destroy crops, increase prices and worsen food insecurity. Climate change alters the distribution of mosquitoes and ticks, expanding risks for diseases like West Nile virus, dengue and Lyme disease.

Mental health is also deeply impacted. Nearly a third of people who experience a natural disaster may subsequently experience stress, PTSD and depression related to property damage, home loss or loss of loved ones.[125]

Climate Change and Chronic Disease

Climate change compounds existing chronic health burdens, with extreme heat, wildfires, storms and other disasters worsening health outcomes. Heat stress, for example, raises the likelihood of heart attack, stroke, heart failure and dangerous arrhythmias. Heat also can lead to hospitalization for endocrine and metabolic conditions as well as adverse pregnancy outcomes including preterm birth, low birthweight and stillbirth.[126] Wildfire smoke, extreme cold and hurricanes have also been linked to higher rates of heart disease, stroke and cardiovascular deaths. Cancer risks also rise with increased wildfire smoke exposure.[127] The increase in vector-borne diseases aggravates kidney disease and may cause endocrine disturbances such as hypoglycemia and hyponatremia. Kidney disease is also worsened by extreme heat and dehydration.

Extreme weather and disasters also disrupt access to critical healthcare, particularly for those who rely on steady, reliable treatments for their chronic condition. For example, after Hurricane Katrina, women with breast cancer and patients with lung cancer experienced worse long-term survival due to disruptions in care.[128] Similarly, both Hurricane Katrina and Superstorm Sandy were followed by increases in heart attack incidence and mortality.[129] Heat waves have also been shown to disrupt cancer care delivery, further highlighting how climate-related events can endanger patients who rely on timely medical treatment.[130]

Climate Vulnerability

While climate change threatens everyone's health, some populations bear greater burdens, which exacerbates existing health inequities. Children, pregnant women, the elderly and people with chronic illness and disabilities are more vulnerable to climate health threats. Low-income communities and communities of color face higher exposures and fewer resources to adapt, compounded by historic disinvestment, less green space and higher baseline pollution. Outdoor workers, residents of hotter regions and fence line communities near industrial or transportation facilities are also disproportionately affected.

Reducing Climate Health Impacts

The most powerful health protection strategy is to reduce climate pollution by transitioning away from fossil fuels. The recommendations listed below to reduce pollution from fossil fuels will also deliver long-term benefits of mitigating climate change. At the same time, communities can build climate resilience through cooling centers, greening neighborhoods and weatherizing homes as well as implementing early warning systems and stronger healthcare infrastructure. These measures reduce risk from current climate impacts while we work to prevent even greater harm.

Conclusions and Recommendations

Fossil fuels harm nearly every system of the body across the human life cycle both in the U.S. and worldwide. Fossil fuels are also the leading driver of climate change, which the healthcare community recognizes as the greatest health challenge of this century.

Extensive medical and scientific evidence makes clear: to safeguard health today and for future generations, we must transition away from fossil fuels toward clean, non-polluting energy sources as quickly as possible. This transition is not only possible but increasingly practical thanks to affordable clean energy technologies. The health benefits of rapid action are immediate and profound. Each step away from fossil fuels reduces air pollution, prevents disease and saves lives, while also delivering cost savings through reduced healthcare burdens.

As health and medical professionals and organizations, it is our duty not only to treat those already harmed by fossil fuel pollution, but also to speak out about its dangers. We must inform the public and policymakers about the health risks, and advocate for policies that reduce exposure to fossil fuel pollution for our patients and communities.

Individuals can also play a vital role by engaging with local organizations that are advocating for clean air and a clean energy transition, talking to community members and policymakers about the health harms of fossil fuel pollution and reducing personal reliance on fossil fuels where possible.

But individuals and health professionals alone are not enough. Protecting communities from the health harms of fossil fuel pollution requires bold policy and systemic change.

Recommendations for Policymakers

- Transition rapidly from fossil fuels to clean, non-polluting energy and transportation.
- Protect communities from exposure to fossil fuel pollution by protecting, enforcing and strengthening clean air and water standards.
- Implement a public health campaign to educate the public about the health harms of fossil fuel pollution, even at low, everyday levels of exposure.
- Hold the fossil fuel industry accountable for its health harms.
- Invest in public health systems, healthcare infrastructure, research and innovation to protect and promote health and accelerate clean technology progress.

The costs of inaction are measured in illness, lives lost and mounting healthcare burdens. The benefits of a clean energy transition are measured in healthier communities and a safer future for our children and grandchildren. Protecting health demands nothing less than urgent action.

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RE: 401 Water Quality Certification for the NEXT Renewable Fuels LLC

Dear Ms. Feldon:

The Columbia River Inter-Tribal Fish Commission (CRITFC) is concerned about the impacts of the NEXT Renewable Fuels, LLC project (project) on area resources. Oregon DEQ has an obligation to safeguard the water quality of Oregon's waters as well as protect the aquatic resources within these waters. On the broad scale, the project will create significant greenhouse gas emission impacts and is in direct conflict with regional climate change goals. On a local scale, the project will contribute to the degradation of waters, negatively impacting juvenile salmon and other aquatic species, resources vital to the tribal people of the region. This project is a massive step backwards from the years of effort to improve aquatic habitat. Therefore, CRITFC recommends that ODEQ deny this 401 water quality certification.

CRITFC was established in 1977 by the Yakama Nation, the Confederated Tribes of Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe. CRITFC's mission is "to ensure a unified voice in the overall management of the fishery resources, and as managers, to protect reserved treaty rights through the exercise of the inherent sovereign powers of the tribes." In line with these goals and our commitment to safeguarding aquatic ecosystems, tribal cultural resources, and the rights and welfare of tribal fishers, CRITFC has worked tirelessly over the last decade to reduce the impacts from fossil fuel transport and other energy projects along the Columbia River. Our efforts have included opposition to numerous proposed terminal expansion projects, including from the previous owner of the project site, Global Partners.

In 2022, CRITFC published the *Tribal Energy Vision for the Columbia River Basin*[1], which outlines the tribes' vision for sustainable energy development. The Energy Vision emphasizes the creation of

[1] https://critfc.org/energy-vision

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a regional energy portfolio that safeguards environmental quality and treaty-protected resources, while preventing new and ongoing damage to Columbia Basin fish, wildlife, water quality, and tribal cultural resources. Goal 4 of the Energy Vision aims to "Mitigate climate change impacts to protect Northwest ecosystems by replacing fossil-fuel electric generation and reducing the reliance on fossil fuels for power, transportation, and other uses." The construction of a bio-refinery does not achieve this goal when it emits more than a million tons of greenhouse gasses per year to convert feedstock to fuel. This significant emissions footprint does not even account for the emissions from producing the proposed soybean feedstock, or the secondary emission of rail and vessel transport.[2]

CRITFC is also concerned by the arbitrarily narrow scope of this permit review. ODEQ's proposed decision currently fails to contemplate the full range of project activities as set out by the Environmental Protection Agency's ("EPA") 2023 Clean Water Act Section 401 Final Rule for certifying agencies.[3] The rule requires ODEQ to review requests for certification by not only looking at the project's potential discharges, but its activity as a whole, "including the activity's construction and operation."[4]

The direct impacts to water quality and salmon rearing habitat from this project are substantial. The Columbia River is listed under §303(d) as limited and impaired by several water quality parameters, including temperature and toxics. Near this project, the river is listed as impaired from PCBs and DDE, and limited for temperature, dioxin, and dissolved gasses. The project's proposed refining process will include contaminants that would be present in all stages of production. The project's Biological Assessment does not define the name or concentrations of the "various contaminants in the waste stream" nor the efficacy of the proposed tertiary filter treatment at removing them. Without this information it is impossible for CRITFC or DEQ to judge how this will affect the quality of water discharged under the Port of Columbia County's NPDES permit.

The sloughs and wetlands that will be impacted by the construction and operations of this facility are critical habitat for ESA-listed salmon and steelhead stocks, many of which are essential tribal treaty resources. Despite the significant risk of increased pollutant exposure identified in the applicant's draft biological assessment (BA),[5] the present application does not contemplate these impacts or the likelihood of further impairment of the river's beneficial uses.[6] For these reasons alone this certification should be denied.

CRITFC understands that the NEXT facility's operation will significantly increase vessel traffic to and from the adjoining Columbia Pacific Bio-Refinery (CPBR). Like the construction of the facility,

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[2] Oregon Department of Environmental Quality, Air Contaminant Discharge Permit for NEXT Renewable Fuels LLC (2022) at 26, https://www.oregon.gov/deq/Programs/Documents/NEXT-ACDP-permit.pdf.
[3] 88 Fed. Reg. 66,558 (Sept. 27, 2023).
[4] 40 C.F.R. 121.3.
[5] *NEXT Renewable Fuels Oregon, LLC: Biological Assessment for Renewable Green Fuel Facility*, at 76 (Mar. 30, 2023)
[6] The applicant responds with "unknown" to the question of critical habitat.

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these transfers are an integral part of the applicant's proposed operations at the site. ODEQ must assess the water quality impacts of these activities. Because this application does not present adequate information to properly analyze these issues, the certification should be denied.

1. **The direct impacts of the project threaten the water quality of critical juvenile salmon habitat.**

Salmon are the lifeblood of the Columbia River and the tribal people who have lived in the region since time immemorial. Clean water for fish survival is a beneficial use protected by Oregon's water quality standards. NEXT's proposed project directly impacts the critical habitat of thirteen endangered salmon and steelhead stocks, including critically endangered spring/summer Snake River chinook.[7] Juvenile salmon migrate to the lower river to feed near the shoreline before heading out to sea, including in the vicinity of the project area and the Bradbury and McClean sloughs. The company's commissioned BA accurately identifies the action area as essential fish habitat (EFH) under the Magnus-Stevens' Fisheries Conservation and Management Act, concluding: "Because of potentially lethal effects from stormwater contaminants, the project will adversely affect Pacific Salmon EFH and Pacific Coast groundfish EFH."[8] Further, the stretch of Columbia River in the vicinity of this project is already 303(d) impaired for several water quality parameters known to threaten salmon survival. ODEQ has a duty to prevent further degradation of these conditions and cannot adequately do so given the limited information provided by the applicant and the known risks of this project.[9]

The project poses acute risks of water quality degradation through its construction and operation. Heavy metal and 6PPD-quinone contamination—a common byproduct of tire erosion from construction and continuous road use—are lethal to salmon in small concentrations. By constructing roads and filling drainages in a low-lying floodplain, NEXT's proposed activities will likely result in contaminants accumulating throughout the site over the life of project and especially in adjacent sloughs critical for juvenile salmon rearing. From these impacts alone, the BA authors concluded that the project is likely to adversely affect steelhead and salmon habitat.[10]

Moreover, the refining process poses its own unique risks of discharge and contamination that are not properly described in the application. Of particular concern are the potential for discharge of heavy metals, ammonia (impacting pH criteria) and other chemical releases impacting dissolved gas and temperature criteria.[11] These discharge risks are compounded by the proposed degradation of the site's existing ecological functions from the infill of adjacent wetlands. Wetlands provide valuable on-site ecosystem services that cannot be replaced by offsite

[7] NEXT BA, at 76.
[8] NEXT BA at D-1.
[9] OAR 340-048-0042(2).
[10] NEXT BA at 55.
[11] *See, e.g.,* I.M. Atadashi, et. al., *The effects of water on biodiesel production and refining technologies: A review,* Renewable and Sustainable Energy Reviews, 3466 (March 2012).

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mitigation. The hydrological dynamics of riparian areas are complex and interconnected, especially in porous soils that are prone to flooding as this floodplain is. Refining processes create continuous risks for leaks and spills that lead to groundwater penetration and subsequent surface water contamination in floodplains. ODEQ needs to carefully evaluate how filling wetlands will affect pollutant levels (e.g., nutrients and sediments), temperature regulation, and flood management.[12] These impacts pose foreseeable and systematic risks to water quality and salmon survival.

2. **Certification should not occur without review of the project's secondary impacts.**

NEXT proposes a refinery operation that would produce 50,000 barrels per day of fuel – a production scale that would require an annual average of 115 medium-sized tankers for imported feedstock and 56 medium-sized or Panamax vessels for export. The lower Columbia River and its estuary system cannot support salmon survival while sustaining vessel traffic of this magnitude.

These impacts are an essential component of the project, yet they are wholly absent from discussion in this application. In publishing its 2023 Rule governing 401 water quality certification, EPA made clear that the purpose of 401 certification is to consider the scope of a project's "activity as a whole."[13] Indeed, the EPA clarifies this scope of review with an example that is directly on point: describing a dock proposal, EPA writes that a certifying authority would appropriately review for both construction impacts "as well as water quality impacts related to the subsequent operation of the marina (*e.g.,* increased vessel pollution in the water associated with increased vessel traffic due to the construction of the dock)."[14] Just as vessels are owned by other operators and construction teams led by outside contractors, there is no reason here why ODEQ should limit its review to refinery operations simply because the attendant vessel traffic *lands* at a legally separate but functionally integrated dock facility. The impacts result from the same source: the proposed project activity.

Increased vessel traffic causes numerous impacts to water quality and salmon survival. Impacts can include riparian erosion, turbidity reduction, sediment accumulation,[15] and periodic wake-

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[12] OAR 340-048-0042(d), (e).
[13] 88 Fed Reg. 66,592-94 (Sept. 27, 2023). The 2023 rule reinstates the "activity as a whole "standard of review, encompassing all activas originally affirmed by the Supreme Court in *PUD No. 1 of Jefferson County* v. *Washington Department of Ecology,* 511 U.S. 700 (1994).
[14] *Id.* at 66598.
[15] Spear et al., *Reduction of Large Vessel Traffic Improves Water Quality and Alters Fish Habitat-Use Throughout a Large River*, 946 Science of the Total Environment 172705 (2024) at 10, available at https://www.sciencedirect.com/science/article/pii/S0048969724028523.

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stranding of juvenile salmonids.[16] A study of salmon stranding events in the lower Columbia River found the frequency significantly related to shore height, salmon density in the shallows, and vessel traffic speed, among other factors.[17] These dynamics are complex and result from cumulative factors, while the impacts are far-reaching and substantial. Because these impacts are foreseeable, could dramatically harm protected fish species, and no holistic assessment of risks and mitigation strategies has yet occurred, ODEQ must deny certification of this project.

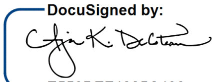
Conclusion

ODEQ should reject this water quality certification due to the project's profound, long-term impacts on tribal resources and the region's ecosystem. This "renewable" diesel refinery will impact critical wetland habitats, threaten already impaired waterways essential to ESA-listed fish, and endanger resources that are integral to treaty tribes' cultural and economic well-being. By certifying this project, ODEQ will not only compromise local water quality but also contradict state and national climate goals through its immense greenhouse gas emissions. ODEQ must prioritize the river and its resources by protecting them for future generations, rather than permitting industrial development that jeopardizes their sustainability and health.

For the foregoing reasons, CRITFC strongly urges ODEQ to reject this certification. If you have any further questions, please contact me or my staff, Julie Carter or Elijah Cetas, at (503) 238-0667.

Sincerely,

DocuSigned by:



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Aja K. DeCoteau
Executive Director

Cc: Haley Teach, haley.teach@deq.oregon.gov

[16] W.H. Pearson and J.R Skalski, *Factors affecting stranding of juvenile salmonids by wakes from ship passage in the Lower Columbia River*, River Res. Applic., 27: 926-936 (2011). https://doi.org/10.1002/rra.1397

[17] *Id.*

Sustainable Aviation Fuel (SAF):

A Critical Analysis, with a Focus on Agriculture, Land, and Food

A Report by the National Farmers Union
Written by Darrin Qualman
November 2024

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Canada's NFU is a direct-membership national organization. Founded in 1969, and with roots going back more than a century, the NFU represents thousands of Canadian farm families, farm units, and farm workers from coast to coast, and also enjoys the support of many non-farmer Associate Members. The NFU embodies the principle that all farmers share common problems and that all farmers must come together, and work with non-farmer allies, in order to address those problems. Our organization believes that agriculture should be economically, socially, and environmentally sustainable. Food production should lead to enriched soils, clean water, a more beautiful countryside, adequate and stable farm incomes, jobs for non-farmers, thriving rural communities, healthy natural ecosystems, diverse habitats for all species, and Canadian tables arrayed with diverse, delicious, nutritious foods.

The NFU's governance structures are democratic, participatory, and progressive. A farm unit membership gives equal participation rights to all family members over the age of 14. The NFU has leadership positions for youth, women, men, and BIPOC (black, Indigenous, and people of colour) farmer representatives. It was the first major farm organization in Canada to elect a woman as President. To learn more, go to our website: www.nfu.ca .

Please join the NFU, as a farm family or farm unit, as a farm youth member, as a farm worker member, or as a non-farmer associate member. There is a place in the NFU for every person concerned about farms and food systems.

Table of Contents

Executive Summary

> "There's an underappreciation of how big the energy problem is for aviation. ... We are working at this problem and realizing it's a lot harder than we thought. We are late to the game. We are in the dark ages in terms of sustainability, compared to other sectors."
> —Phil Ansell, Director, Center for Sustainable Aviation, University of Illinois, 2024.[1]

Sustainable Aviation Fuels (SAFs) are lower-emission, non-fossil-fuel energy sources for the world's aircraft fleet—"drop-in" fuels that require no modifications to aircraft or engines. The proposal is to make SAFs largely from biological sources: corn, soybeans, and canola now and over the next decade or so, and then increasingly from straw and other "agricultural residues" and from purpose-grown energy crops such as grasses or fast-growing trees (with a minor portion from forestry residues). There is a third phase proposed: to use clean renewable energy to extract hydrogen from water and carbon from the air and combine these into a liquid fuel. But such "Electro-fuels" remain speculative and the very high costs and energy requirements suggest they may remain unfeasible.

Why should citizens and policymakers be concerned about SAFs? Because the immense scale of the global SAF project creates significant potentials to move us *away* from many of our food system, climate, decarbonization, sustainability, and social justice goals. At the same time, the huge, global SAF project may fail in its stated intent: to slash greenhouse gas (GHG) emissions and warming effects from a rapidly expanding aviation sector.

Citizens want affordable food and sustainable food systems. Farmers want to maximize soil carbon sequestration and begin to reduce emissions from fertilizer use. We all want to be able to develop renewable energy supplies that are adequate to the tasks of decarbonizing home heating, motor vehicle travel, and industry. The global SAF project risks moving us away from all these goals: it will likely raise food prices; reduce the sustainability of food systems; slow or reverse agricultural soil carbon sequestration; drive up fertilizer use and attendant agricultural GHG emissions; and put impossible-to-meet demands onto limited supplies of clean, renewable energy thereby slowing emissions reduction in other sectors.

If governments continue to encourage and subsidize the SAF megaproject, those governments risk "policy incoherence"—pursuing policies that work directly *against* the attainment of other policies and social and environmental goals. SAFs attempt to solve one problem but create many larger problems.

More important, there are reasons to question whether the SAF megaproject is even possible. Is it real? Or is it a distraction which will delay more effective emission-reduction measures and direct trillions of dollars toward the wrong investments and away from superior alternatives? Worse than a huge global project that increases food prices and on-farm emissions while solving an aviation emissions problem is a project that creates those food and farming problems while *simultaneously failing* to slash aviation emissions. That latter scenario is a significant probability. Considered within the context of planetary boundaries, limited resources and trade-offs, and the need to simultaneously solve *multiple* climate and sustainability problems—to tackle the polycrisis—the global SAF project (which includes *doubling* air travel) may simply be impossible. *At the very least*, the project raises so many questions and affects so many other parts of the economy and biosphere that every policymaker and citizen should want to learn more. The "twenty points" that follow outline why this is such a crucial issue.

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1 Oliver Milman, "'Magical Thinking': Hopes for Sustainable Jet Fuel Not Realistic, Report Finds," *The Guardian*, May 14, 2024, sec. Environment, https://www.theguardian.com/environment/article/2024/may/14/sustainable-jet-fuel-report.

Twenty points to help you understand why it is important that you read this report:

1. Air travel is projected to more than double by 2050—to 22 trillion passenger-kilometres per year.[2] Boeing and Airbus plan to deliver 40,000 new aircraft by 2043. (See Chapter 2, below)

2. Globally, passenger and air freight aircraft currently consume 379 billion litres (100 billion US gallons) of fuel per year.[3] By 2050, fuel use will increase to two-thirds of a trillion litres per year (military aircraft fuels not counted, though substantial). (Ch. 2)

3. The world's airlines have pledged to reduce GHG emissions to net zero by 2050. The largest part of airlines' net-zero plan is to switch from fossil fuels to SAFs. (Battery-electric planes and hydrogen fuels are not viable large-scale options before 2050—perhaps not ever.) (Ch. 1)

4. The raw-material feedstocks for most of the SAFs will be sourced from farmland. The near-term focus is on feedstock crops such as soybeans, canola, and corn; the medium-term on agricultural residues such as straw and corn stover and on purpose-grown energy crops such as switchgrass, miscanthus, poplar, willows, etc. SAFs will shift the energy source for aviation from oil fields to farm fields. (Ch. 3, 4, and 5)

5. A thought experiment, merely to give a sense of the scale of the proposed SAF project: If all global SAFs were sourced from seeds and oilseeds (soybeans, canola, corn, etc.) and, hence, from farmland, and if all 2050 aviation fuel were SAFs, the two-thirds of a trillion litres of demand would require roughly 2 billion acres—20 times the total cropland area of Canada (5 times the cropland area of the United States). This is a thought experiment, not the plan, but it gives a sense of scale. (Ch. 3)

6. Producing even a small fraction of the huge SAFs demand from grains and oilseeds (and another larger fraction from energy crops grown on farmland) will exert upward pressure on food prices (especially as we simultaneously add two billion people to our global population). These food-price impacts will hit the poorest and hungriest hardest, but will also have negative impacts on nearly every family on Earth. SAF may come to stand for "Sacrificing Affordable Food." The SAF project will put the food-purchasing dollars of Earth's poorest billion people into competition with the vacation dollars of the richest billion. (Ch. 3 and 12)

7. In parallel, "land use change"—often a euphemism for cutting down rainforests, wilderness, and wild-animal habitat—may be extensive. GHG emissions from that deforestation and land use change are large, and though considered in SAF "life cycle analysis" (LCA) emissions estimates, we should interrogate those estimates, especially in light of the huge portion of the Earth that humans have already annexed and the immense portion of the global biomass production we are already appropriating. (Ch. 3, 7, 8, and 10)

8. The actual SAF project will be different than outlined in the corn-soy-canola thought experiment above; but will it be better? Instead of relying wholly on grains and oilseeds, airlines and fuel makers also plan to use crop residues (incl. straw and corn stover) as feedstocks. This could require hundreds-of-millions of tonnes of biomass from croplands—potentially slowing or reversing carbon sequestration and risking soil health. Another proposed feedstock is purpose-grown energy crops, which can lead to land competition and food-price impacts. (Ch. 4, 5, and 7)

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2 A passenger-kilometre is equal to moving one passenger one kilometre. Thus, a flight that moves 200 passengers 1,000 kilometres is equal to 200,000 passenger kilometres. 22 trillion passenger kilometres is equivalent to 110 million such flights.

3 This and the other figures in this Executive Summary are detailed and footnoted in the chapters that follow.

9. Partly because of the huge demands for biomass feedstocks, the airline industry is exploring production in Africa and other food-insecure parts of the world. It appears that the lands of the poor may be used to fuel the jets of the rich. (Ch. 12 and 13)

10. Many of the land-sourced SAF feedstocks targeted by the aviation industry are the same as those required for bioenergy with carbon capture and storage (BECCS). BECCS proponents say that they can produce negative-emission electricity by using carbon capture in thermal powerplants and fuelling those generating stations using forest wastes, crop residues, and energy crops—*exactly the same biomass feedstocks cited by SAF proponents*. Crop residue biomass and energy crop removals for SAFs will come atop billions of tonnes of removals for BECCS. (Ch. 4 and 8)

11. Can the planet's land surface and biosphere sustain humanity's ever-increasing demands? Here is the plan for the middle decades of this century: feed two billion additional people; produce more (land-costly) meat and dairy products for increasingly affluent households in the Global South; provide biomaterials to replace plastics; provide more cotton and other fibres for an expanding population and to replace plastic fibres; provide roughly 8 billion tonnes of biomass feedstocks annually for bioenergy with carbon capture and storage (BECCS); provide perhaps 7 billion tonnes of feedstocks annually for SAFs; generate these additional farmland-sourced food and feedstock gigatonnes even as climate impacts intensify and hit farmers harder; provide space for carbon-capturing tree-planting; do all the preceding even as we reduce fertilizer use in an attempt to reduce emissions from agriculture and return global nitrogen flows to within planetary boundaries; and do all this without expanding our agricultural or forestry land bases, in an attempt to slow the fastest extinction event in 65 million years. Policymakers and citizens must not consider SAFs in isolation, but rather within the context of the *many* other demands we plan to impose onto our biosphere and farmland. (Ch. 8)

12. SAF production will compete for scarce supplies of clean, renewable electricity, which risks slowing decarbonization in other sectors. In some airline-industry scenarios, by 2050, producing SAFs could require a quantity of electricity equivalent to half of all electricity produced globally today. Thus, SAFs may not create emissions reduction, but rather emissions *shifting*: with reductions in aviation emissions leading to slower reductions elsewhere because there is not enough clean electricity to go around. As we struggle to electrify and decarbonize automobiles, home heating, industry, etc. is it responsible public policy to add another huge demand for clean energy? (Ch. 6, 14 and 18)

13. Similarly, SAFs will create large demands for green hydrogen—with those coming atop demands for low-carbon hydrogen for fertilizer production, building heating, heavy industry, railways, ocean shipping, etc. Airline industry trade association IATA is projecting 2045 demand for green hydrogen at nearly 100 million tonnes annually. Current production of low-emission ("blue") and zero-emission ("green") hydrogen is just 1–2 million tonnes per year—implying the need for a fifty-fold scale-up, *just for aviation*. Adding aviation as a major demand for green hydrogen will slow emissions reductions in other sectors. Again, emissions shifting. (Ch. 14)

14. Net zero is <u>not</u> zero. The airlines may succeed in reducing emissions per flight and per passenger-kilometre, but they plan to double or triple the number of flights and passenger-kilometres by the 2050s, resulting in a situation wherein total emissions from the sector, in absolute terms, may be not much lower than today. To deal with this, the industry plans to use offsets and other means to reach net-zero, despite hundreds-of-millions of tonnes of actual emissions projected for 2050. Moreover, aviation is just one sector planning to fall short of actual zero emissions and make up the shortfall with offsets. The supply of credible offsets in 2050 is unlikely to meet the many large demands from multiple industries. (Ch. 16)

15. For jet aircraft, zero CO_2 emissions does not equal zero warming. Only a portion of the warming effects from aviation are caused by CO_2 emissions from burning fuel; the largest part is caused by the high-altitude cumulus clouds often visible after jets pass overhead and by nitrogen oxide effects. Even if aircraft fuels can be engineered so that they no longer add CO_2 to the atmosphere from combustion, the millions of flights annually will still drive warming as a result of non-combustion effects. Even if airlines reach their narrow net-zero CO_2 goal, as a result of doubling flight volumes, non-CO_2 effects may still drive *more* warming in 2050 than today. (Ch. 16)

16. In addition to potential food-price impacts of SAFs, there is also the issue of public subsidies. Both raise justice issues. Globally, subsidies, tax credits, and other taxpayer supports may add up to many tens of billions of dollars per year—a trillion dollars or more over the next two-and-a-half decades. But with many people struggling to afford shelter, childcare, food, or medicines, should limited government dollars be used to reduce vacation or business-travel costs? (Ch. 17)

17. SAFs present one of the largest-ever scale-up challenges. Analysts note the need for a thousand-fold increase in production and the need to complete, on average, one SAF production facility every two days between now and 2050. This will require trillions of dollars in investments. Thus, there is a good chance that airlines will fall short of their commitments. Indeed, the industry has set dozens of decarbonization goals and failed to meet almost every one. (Ch. 18 and 19)

18. The massive scale of the SAF project raises many other concerns including impacts on water availability (some SAF feedstocks will be irrigated), biodiversity losses, land access and affordability, Indigenous control of lands, land grabbing, etc.

19. For many reasons, SAFs are a farm and agricultural issue. In addition to the above, SAF production and massive demands for farm-sourced feedstocks will drive up nitrogen fertilizer use and, hence, on-farm emissions. The aviation industry's climate solution creates an agricultural emissions problem. Again, emissions shifting. (Ch. 15)

20. Superior alternatives exist (Ch. 20), including:
    a. For travel within continents and over medium distances: trains powered directly by clean, renewable electricity (which can be true zero emission and zero warming, unlike SAF-powered aviation, and which are now a mature and fully deployable technology);
    b. Demand-management measures to decrease flying (rather than doubling it by 2050) in order to moderate scale-up challenges, mitigate problems caused by competing demand for biomass and clean energy, and make over-ambitious SAF scenarios actually achievable; and
    c. Leapfrogging land-based Bio-SAFs and going directly to Electro-SAFs that do not compete for land, raise food prices, slow or reverse soil carbon sequestration, increase on-farm emissions, etc.

We are in a climate emergency which requires near-wartime-levels of action on the part of all governments and citizens. It requires rigorous, holistic, long-term thinking; hard choices; the acknowledgement of trade-offs and limits; wisdom; and bold, courageous action. No matter what the fuel source, doubling or tripling air travel by mid-century is incompatible with any responsible, science-based assessment of the challenges and trade-offs we face or the painful and damaging impacts already occurring and set to multiply in coming decades. And any plan to fuel that doubling of air travel largely from the planet's oversubscribed land base reveals an ignorance of the magnitude by which we have already transgressed planetary boundaries—how far we have already moved outside the "safe operating space for humanity" when it comes to nitrogen and phosphorus flows, land use change, species extinction, and biomass removal. (Ch. 10)

1. Introduction and SAF Primer

> "The most obvious problem is the manner in which technology is introduced to us. The first waves of description are invariably optimistic.... The information we are given describes the technologies solely in terms of their best-case use. ... Corporate and government marketers present only idealized, glamorized versions of technology, since they have no stake in the public being even dimly aware of negative potentials—the worst-case scenarios—though negative results are at least as likely to occur as positive results."
> —Gerry Mander, *In the Absence of the Sacred*, 1991.[4]
>
> "In the process of developing a new technology, could we proceduralize thinking through the total set of effects, not just the intended set of effects and the market benefits of those, but thinking through [the implications] if this technology really takes off, and goes to its full scale."
> —Daniel Schmachtenberger, 2024.[5]

The net zero plan for air travel

At the UN COP21 Climate Conference in Paris in 2015, the world's governments agreed to reach net zero emissions by 2050. Partly in response, in October 2021, airline industry association IATA (International Air Transport Association) approved a resolution for the global air transport industry to achieve net-zero carbon emissions by 2050. The following year, the United Nations agency ICAO (International Civil Aviation Organization) adopted a similar net-zero resolution.[6] (Note that airline industry commitments regarding emissions predate, by many years, their 2021 and 2022 net-zero commitments. E.g., Canada and its airlines' 2005 agreement regarding fuel efficiency.)

The world's passenger airline and air freight corporations have limited options for decarbonization. Electric planes would require batteries too heavy for anything other than small aircraft taking short flights. This will be the case for many decades, perhaps permanently. The use of pure hydrogen (compressed or super-cooled liquid) is a possibility, but that, too, is a far-in-the-future option—requiring the complete redesign of aircraft, their engines, and global fuel-supply chains. "Both hydrogen and electric propulsion are ill-suited to long-haul flights.... Near- and long-term decarbonization hinges on SAF," writes the Canadian Council for Sustainable Aviation Fuel (C-SAF).[7]

The only option to decarbonize aviation is to find a low-emission "drop-in fuel" that is compatible with the current aircraft fleet and their engines and can be scaled up to replace fossil fuels, litre-for-litre. The answer that airlines and policymakers have fixed upon is Sustainable Aviation Fuels (SAFs).

4 Jerry Mander, *In the Absence of the Sacred: The Failure of Technology and the Survival of the Indian Nations* (San Francisco: Sierra Club Books, 1991).

5 Nate Hagens, "The Great Simplification. Guest: Daniel Schmachtenberger: Moving from Naive to Authentic Progress: A Vision for Betterment, June 5, 2024," n.d., https://www.thegreatsimplification.com/episode/126-daniel-schmachtenberger-7; "Transcript from Nate Hagens, The Great Simplification Podcast. Guest: Daniel Schmachtenberger: Moving from Naive to Authentic Progress: A Vision for Betterment," accessed June 25, 2024, https://static1.squarespace.com/static/61d5bc2bb737636144dc55d0/t/665f7fbf34207744ae9868de/1717534656165/TGS+126+Daniel+Schmachtenberger+Transcript.pdf.

6 International Air Transport Association, "Net Zero 2050: Sustainable Aviation Fuels" (IATA, December 2023), www.iata.org/flynetzero.

7 Bentley Allan, Jonas Goldman, and Geoff Tauvette, "The C-SAF Roadmap: Building a Feedstocks-to-Fuels SAF Supply Chain in Canada" (Canadian Council for Sustainable Aviation Fuels, 2023), 59.

What are SAFs?

Sustainable Aviation Fuels (SAFs) are almost chemically identical to petroleum/fossil-fuel derived jet fuel: "Jet A." Most SAFs can be used safely now when blended up to 50 percent with conventional/petroleum jet fuel and, in the future, when used unblended.

Current aviation fuel is produced from one feedstock (crude oil) via one process (oil refining), but SAFs can be created from a wide range of feedstocks (grains, oilseeds, used cooking oils, animal tallow, agricultural or forestry residues, municipal solid waste aka "garbage" and sewage, algae, carbon and hydrogen from air and water, etc.) and by diverse chemical-industry pathways. Some SAF production feedstocks and pathways are similar to those now used to make biofuels such as renewable diesel, but others are wholly different, such as SAFs made from green hydrogen[8] that is reacted with carbon captured directly from the air. Importantly, not all SAFs are biofuels. Some are (such as those made from canola or forestry residues) but other SAFs are not (such as those made directly from hydrogen from water and carbon from the air)—these latter fuels have no biological or land-sourced inputs.

Considered over their full life cycle, many SAFs are said to produce lower GHG emissions. While conventional/petroleum Jet A fuel produces 89 grams of carbon dioxide equivalent (CO_2e) per megajoule of energy,[9] many SAFs are, according to models, projected to produce roughly half that amount, and a number are claimed to be extremely low emission, near-zero, or even negative emission.[10] According to industry models, some SAFs may be zero emission or near zero but many are *not*. *At best*, SAFs made from corn, canola, and soy *might* reduce emissions by 50 percent, compared to fossil-fuel-derived Jet A.[11] (How land-use change and soil carbon changes are handled in the Life Cycle Analysis, LCA, for such fuels is often the determining factor regarding modelled total emissions.)

Finally, some SAFs are real: in production, mature technologies, and relatively cost-competitive. Examples include corn-feedstock SAF via the Alcohol to Jet (AtJ) process/pathway. In contrast, fuels made from air and water via renewable energy remain in the R&D phase, have yet to be scaled up, and may prove so costly that they are never deployed at scale. A big part of the task of understanding SAFs is understanding what is real and what is not and what is actually feasible to be deployed in coming decades if we do, indeed, go down the SAF path. Many SAFs may prove to be no more than wishful thinking—distractions to buy time for a rapidly expanding, high-emission airline industry. For this reason, this report capitalizes "Sustainable Aviation Fuel," to indicate that it denotes, not just a set of energy sources and fuel options, but also a set of speculative plans and, potentially, a policy advocacy or public relations tool. SAF is both a descriptor and a brand.

The many varieties of SAFs

Some of us are familiar with one process for making SAFs—the method now used to make renewable diesel. Feedstocks such as canola and soy oil can be fed into the hydro-processed fatty esters and fatty

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8 Grey hydrogen, the most common now, is made from fossil fuels, usually natural gas, and the resulting carbon dioxide is released into the atmosphere; Blue hydrogen is produced similarly, but the CO_2 is captured and not released; Green hydrogen is produced without GHG emissions, for example by using clean renewable electricity to split water via electrolysis into oxygen and hydrogen.

9 Air Transport Action Group, "Beginner's Guide to Sustainable Aviation Fuel," 4th Edition (Geneva: ATAG, April 2023), 2, https://aviationbenefits.org/media/168027/atag-beginners-guide-to-saf-edition-2023.pdf.

10 For the most part, this report will not delve into the tortuously complex task of unpacking and critiquing the life-cycle analysis (LCA) models and their estimates of emissions from various fuels. This report takes the position that even if one uncritically accepts the best-case versions of those SAF emission values, the SAF megaproject remains profoundly unwise—in collision with planetary boundaries. Nonetheless, the NFU remains profoundly sceptical of modelled emissions estimates, especially in light of land-use change effects. The NFU urges academics, civil servants, energy analysts, and others to dig deeply into the assumptions and processes behind LCA emissions estimates and provide a much broader range of possible LCA outcomes—beyond what may be best-case scenarios propounded by those connected to the airline and fuel industries. Most important, the NFU urges analysts to look, not at the emissions of the next litre of SAF, perhaps produced in 2025, but the last litre produced in 2050 (produced in a world struggling to feed billions more people, fuel BECCS powerplants, etc.) and consider likely land-use choices and conversions under those scenarios in those decades.

11 Kentucky Corn Growers Assoc., "A Farmers Guide to the GREET Model," KY Corn, May 9, 2024, https://kycorn.org/farmers-guide-to-greet-model/.

acids (HEFA) pathway. Post-use "waste" oils (e.g., used cooking oils) and other feedstock such as tallow can also be used in HEFA processes.

There are also existing SAF pathways and feedstocks that resemble current ethanol production. Corn (or wheat or any grain) can be transformed to alcohol and on into SAF via a process called Alcohol to Jet (AtJ).

Solid biomass such as agricultural residues (grain straw, corn stover, husks, etc.), forestry residues (twigs, branches, bark, chips, sawdust), even municipal solid waste (MSW, aka "garbage") can be converted into "syngas" and then converted to SAF via the Fischer-Tropsch (FT) process.[12]

Similarly, dedicated "energy crops" such as poplar, willow, switchgrass, and miscanthus can likewise be turned into SAF via the FT process.

Algae can provide oils as a feedstock for the HEFA process, though it is important to know that algae fuels have been discussed for decades but have yet to be scaled up or commercialized.

Finally, in this inexhaustive listing, there is a non-biomass/non-biofuel route: using renewable energy to capture carbon from the air and hydrogen from water and combining these in a process with several names: power-to-liquids (PtL); Solar-to-Jet; electro-fuels, e-fuels, or, as we name it below, Electro-SAF.

Figure 1 provides a colourful representation of how various feedstocks can be linked to various SAF production technologies. Only a subset of feedstocks and pathways are shown.

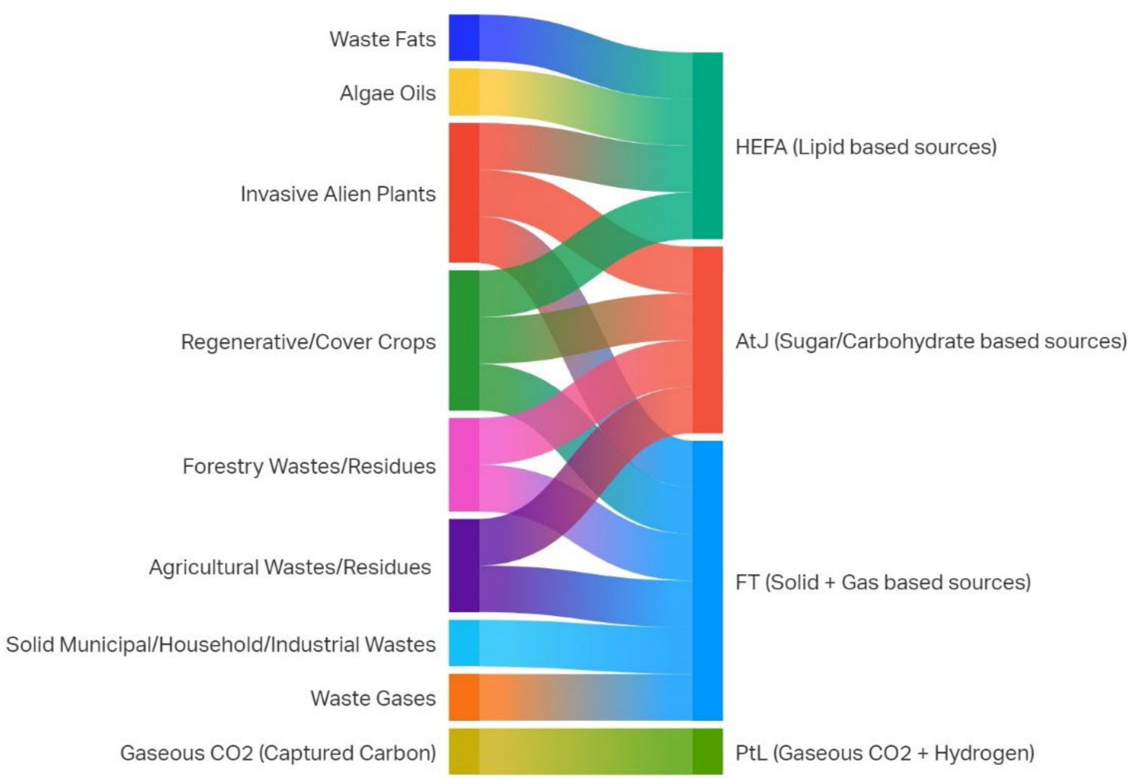

Figure 1. Some selected SAF feedstocks and associated production processes.
Note: HEFA=hydro-processed fatty esters and fatty acids (similar to the renewable diesel pathway); AtJ=Alcohol-to-Jet; FT=Fischer-Tropsch; and PtL=Power-to-Liquids, aka electro-fuels or Electro-SAF.
Source: Reproduced from International Air Transport Association, "SAF Handbook" (IATA, May 2024).

12 Those curious about the enormous challenges of turning garbage into jet fuel should study the failures of Fulcrum BioEnergy and Air Products and Chemicals: https://cen.acs.org/energy/Fulcrum-BioEnergy-abandons-trashfuel-plant/102/web/2024/06

With seven or eight approved production pathways and (depending on how you subdivide them) many dozens of feedstocks, there are a lot of combinations for SAF production. This is complicated chemistry. To simplify, in this report we divide SAFs into four main classes and focus on these:

1. Bio-SAF {seeds}: SAF from corn, soy, canola, and other grains and oilseeds produced using processes similar to current biofuels.

2. Bio-SAF {residues}: "more advanced" biofuels from agricultural straw, forest residues, and other biomass—the long-awaited "cellulosic" fuels.

3. Bio-SAF {energy crops}: purpose-grown energy crops—trees, grasses, and other plants—that maximize biomass production (these, too, are cellulosic fuels).

4. Electro-SAF (aka Power-to-Liquids, PtL): non-biofuels that utilize processes that turn clean renewable electricity, water (a source of hydrogen), and air (a source of carbon) into liquid hydrocarbon jet fuel.

In this report, we will use these four categories: Bio-SAF {seeds}; Bio-SAF {residues}; Bio-SAF {energy crops}; and Electro-SAF. Other SAF feedstock/process combinations exist, but these four encompass the majority of probable SAF tonnage, and are the ones of most interest to farmers. (The final one, Electro-SAF, does not entail the use of biomass or farmland, but it is of interest to farmers because an assessment of its viability is crucial to determining just how much SAF will be made from bio-/land-sourced feedstocks. Unless Electro-SAF can be rapidly scaled up and reduced in cost, bio-/land-sourced feedstocks will have to supply almost all the two-thirds-of-a-trillion litres of fuel needed each year by mid-century.)

It is likely that SAF processes and feedstocks will be developed in a certain order—in stages. Bio-SAF {seeds} may play a significant part in the early stage. Indeed, processes and feedstocks now used to produce automotive ethanol, biodiesel, and renewable diesel may be expanded and/or redeployed toward SAFs. There are limits, however, as these first-stage fuels trigger impacts and concerns, including:

- land-use change and associated emissions (e.g., diverting canola or soy tonnage to biofuels in one country can spur farmland expansion and subsequent forest clearance in another, releasing carbon from soils and reducing biodiversity);

- reducing food supplies or increasing demand for crops and, thus, driving food-price increases;

- driving up fertilizer use and attendant agricultural GHG emissions; and

- limits on feedstock availability.

(Some types of stage-one SAFs, however, may not trigger these problems, such as SAFs made from used cooking oil. This feedstock, however, is very limited and may be little more than a distraction.[13])

Industry associations IATA (International Air Transport Association), ATAG (Air Transport Action Group), and ICAO (United Nations International Civil Aviation Organization) and virtually all airlines acknowledge these limits and impacts and are clear that only a minor portion of total SAF supplies can come from Bio-

13 Ryanair CEO Michael O'Leary stated bluntly: "You want everybody running around collecting fucking cooking oil? *There isn't enough cooking oil in the world to power more than one day's aviation*," [italics added]. Gwyn Topham, "Ryanair's Michael O'Leary: 'There Isn't Enough Cooking Oil in the World to Power One Day of Green Aviation,'" *The Guardian*, December 26, 2023, sec. Business, https://www.theguardian.com/business/2023/dec/26/ryanairs-michael-oleary-there-isnt-enough-cooking-oil-in-the-world-to-power-one-day-of-green-aviation .

SAF {seeds}. Also note that stage-one Bio-SAF {seeds} are far from zero-emission. Canola, corn, soy, and other grain and oilseed feedstocks produce significant emission from on-farm fuel and fertilizer use, land use change, etc.

Because most stage-one Bio-SAF {seeds} fuels have these many limitations and defects, airlines and other proponents point to stage-two fuels made from agricultural or forest residues or purpose-grown energy crops: Bio-SAF {residues} and Bio-SAF {energy crops}.

Stage-three fuels, Electro-SAFs, are not biofuels, have no biomass inputs, are not land-sourced, and, theoretically, have no feedstock limits. The message from airlines and their industry associations is that after an initial reliance on stage one fuels and then stage two, as we move closer to 2050, airlines will diversify SAF supplies and rely more on zero-emission stage-three Electro-SAFs. But there are many reasons to critically evaluate such predictions, and to instead adopt the more conservative view that SAFs will be primarily land-source fuels, with the impacts and limitations that entails. Chapter 3 through 6 provide more detail on SAF stages, feedstocks, processes, and probable costs.

2. SAF Demand

> "2010 global production of biofuels was 20 million tonnes per year [25 billion litres]. That's expected to *explode* with the advent of new fuel mandates. If those mandates are met, we have something like 100 million tonnes [125 billion litres] of biofuels that we're looking at supplying" [italics added].
> —Aaron Hanson, Global Data, 2024.[14]

> "In 2052, global passenger traffic is expected to reach close to 25 billion, approximately 2.5 times the 2024 projection."
> —Airports Council International, Advisory Bulletin, 2024.[15]

> "Airbus and Boeing expect that manufacturers will deliver more than 40,000 new commercial aircraft over the next 20 years."
> —Cathy Buyck, *Aviation International News*, 2023.[16]

> "Demand for jet fuel [is] expected to more than double by 2050 and triple by 2070...."
> —US Department of Energy, National Renewable Energy Laboratory, 2024.[17]

Above, this report gave an introduction to SAF *supplies*: feedstocks and production pathways. Here, we look at *demand*: assessing the quantities of SAFs that may be required in coming decades.

Key to understanding the likely future trajectory of SAF production and feedstock demand is to understand the expansion plans of airlines. A revenue passenger-kilometer (RPK) is a unit used to measure air travel. As we might expect, it means moving one paying passenger one kilometer. In 2019, the global airline industry delivered travel equal to 8.7 trillion passenger-kilometres.[18] COVID-19 slashed travel, for a time, but numbers have now rebounded such that IATA projects 2024 air-travel volume at 9.1 trillion revenue passenger-kilometers.[19]

Most important for our analysis is where the airline industry sees itself going. Most projections are for a two-and-a-half-fold increase by 2050—increasing to about 22 trillion passenger-kilometres per year.[20] Figure 2 shows the past, present, and projected future of global air travel.

14 Don Norman, "Feed Markets and the 'Big Oil Deficit,'" *Manitoba Co-operator*, May 30, 2024.

15 Airports Council International, "Advisory Bulletin," February 13, 2024, https://aci.aero/2024/02/13/the-trusted-source-for-air-travel-demand-updates/.

16 Cathy Buyck, "Airbus and Boeing Tout Demand for More Than 40,000 New Aircraft," *Aviation International News*, June 18, 2023, https://www.ainonline.com/aviation-news/air-transport/2023-06-18/airbus-boeing-raise-20-year-forecasts-aircraft-deliveries.

17 R. Gary Grim et al., "The Challenge Ahead: A Critical Perspective on Meeting U.S. Growth Targets for Sustainable Aviation Fuel," March 26, 2024, 1, https://doi.org/10.2172/2331423.

18 International Air Transport Association, "Global Outlook for Air Transport: A Local Sweet Spot" (IATA, December 2023), 17, https://www.iata.org/en/iata-repository/publications/economic-reports/global-outlook-for-air-transport---december-2023---report/.

19 International Air Transport Association, "Global Outlook for Air Transport: Deep Change" (Montreal: IATA, June 2024), 16, https://www.iata.org/en/iata-repository/publications/economic-reports/global-outlook-for-air-transport-june-2024-report/.

20 International Air Transport Association et al., "Aviation Net-Zero CO2 Transition Pathways: Comparative Review" (IATA, April 2024), tbl. 3, https://www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/nz-roadmaps.pdf.

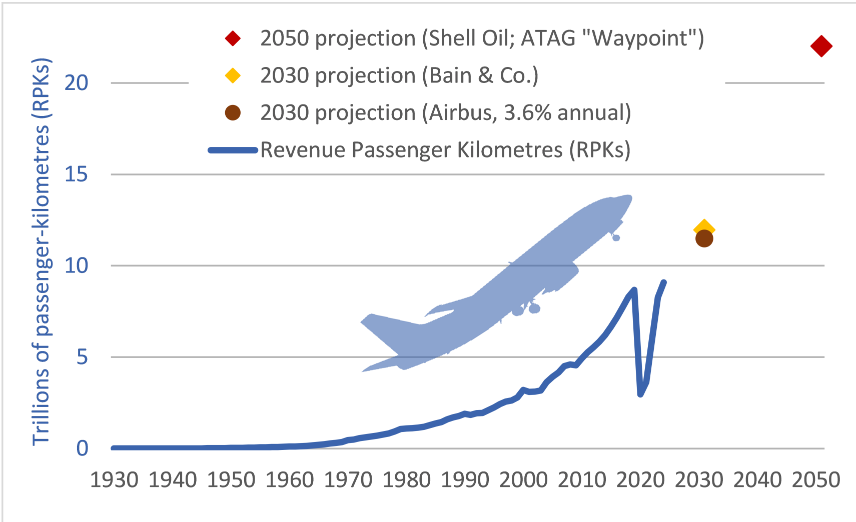

Figure 2. Air travel, passenger-kilometers, global, 1930–2023, with 2024, 2030, and 2050 projections.
Sources: Airlines for America; International Air Transport Association (IATA); Bain & Company; Air Transport Action Group (ATAG); Airbus; Shell Oil.[21]

Note that it took many decades for air travel to reach 5 trillion passenger-kms per year—it took until 2010; we are on track to add to that total another 5 trillion passenger-kms per year by 2026 (just 16 years later); and the next 5 trillion passenger-kms per year added by 2038 (12 years later); and another 5 trillion per year by 2047 (9 years later).

As demand for flying grows, so, too, will demand for fuels. The projection is for a rise from 375 billion litres (99 billion US gallons) of fossil fuel in 2024[22] to 640 billion litres (512 million tonnes or about 169 billion US gallons) of predominantly SAFs in 2050.[23] By 2050 or soon after, SAF demand may be two-thirds of a trillion litres per year.[24]

21 Airlines for America, "World Airlines Traffic and Capacity," Traffic and Operations: 1929-Present, accessed January 22, 2023, https://www.airlines.org/dataset/world-airlines-traffic-and-capacity/; Bain & Company, "Air Travel Forecast to 2030: The Recovery and the Carbon Challenge," Bain, March 27, 2024, https://www.bain.com/insights/air-travel-forecast-interactive/; Air Transport Action Group (ATAG), "Waypoint 2050: Summary Report," Second Edition, September 2021, https://aviationbenefits.org/media/167418/w2050_v2021_27sept_summary.pdf; International Air Transport Association, "Global Outlook for Air Transport" (Montreal: IATA, 2023), https://www.iata.org/en/iata-repository/publications/economic-reports/global-outlook-for-air-transport---december-2023---report/; Shell Oil and Deloitte, "Decarbonising Aviation: Cleared for Take-Off" (Shell, 2021), https://www.shell.com/sustainability/our-climate-target/reducing-emissions-from-transport-and-industry/_jcr_content/root/main/section_1553918000/slider/promo_copy_42179059_.multi.stream/1667916442677/e4f516f8d0b02333f1459e60dc4ff7fd1650f51c/decarbonising-aviation-industry-report-cleared-for-take-off.pdf; Airbus, "Global Market Forecast 2023" (Toulouse, June 13, 2023), https://www.airbus.com/sites/g/files/jlcbta136/files/2023-06/GMF%202023-2042%20Presentation_0.pdf.

22 International Air Transport Association, "Industry Statistics: Fact Sheet" (IATA, December 2023), https://www.iata.org/en/iata-repository/pressroom/fact-sheets/industry-statistics/.

23 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap" (Montreal: IATA, September 2024), 11, https://www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/finance-net-zero-roadmap.pdf; See also: International Air Transport Association, "Net Zero 2050: Sustainable Aviation Fuels," 4; Air Transport Action Group (ATAG), "Waypoint 2050: Summary Report"; International Air Transport Association, "Energy and New Fuels Infrastructure: Net Zero Roadmap," 4; Johnathan Holladay, Zia Abdullah, and Joshua Heyne, "Sustainable Aviation Fuel: Review of Technical Pathways" (Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2020), https://www.energy.gov/sites/prod/files/2020/09/f78/beto-sust-aviation-fuel-sep-2020.pdf.

24 This estimate for passenger aviation and air freight does not include military aircraft, which burn tens-of-billions of litres per year.

3. Bio-SAF {seeds}: Canola, Soybeans, Corn, and Farmland

> "Mark my words: [for] the next 20 years, farmers are going to be providing 95 percent of all the sustainable airline fuel."
> —US President Joe Biden, July 28, 2023.[25]

> "In feedstocks, Canada has opportunities across all SAF pathways. In the short-run, commercial volumes will be dominated by HEFA-based SAF from oilseeds. ... Canola will produce the balance of early volumes."
> —The Canadian Council for Sustainable Aviation Fuel (C-SAF), 2023.[26]

> "Today in Manitoba, the Honourable Jonathan Wilkinson, Minister of Energy and Natural Resources, joined the Honourable Wab Kinew, Premier of Manitoba, to announce a new combined federal investment of $6.2 million in [Azure Sustainable Fuels Corp.] to support the future of sustainable aviation fuels in Manitoba.... Azure's planned processing facility will ... [produce] around one billion litres of sustainable aviation fuel annually, primarily from Canadian feedstock such as canola and soybean oils."
> —Government of Canada news release, 2024.[27]

> "Expanded use of commodity vegetable oils including soybean and canola could play a role in growing SAF volumes."
> —USDA, US EPA, US DOT, US DOE, 2022.[28]

> "If just one-quarter of the world's aviation fuel likely needed in 2050 were to come from vegetable oil, its production would need to double globally."
> —World Resources Institute, 2024.[29]

> "Today, nearly 40 percent of America's corn crop is turned into ethanol, up from 10 percent in the mid-2000s."
> —*New York Times,* 2023.[30]

SAF is a farming issue. It is a land issue. It is an agricultural policy issue. Because SAF will increase demand for grains and oilseeds, it is a food-price issue. Because it will drive up fertilizer use, it is an agricultural emissions issue. Despite speculation about entropy-reversing fuels made from air and water and powered by renewable electricity, for the next couple decades, at least, most feedstocks will be taken from the biosphere, and most of that from farmland. Figure 3 shows a projection of Canada's most promising biogenic and waste feedstocks. Note three categories: "oilseeds," "ag residue," and "ethanol": feedstocks in the first two of those categories will come wholly from farmland and the third mostly from that land.

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25 The White House, "Remarks by President Biden on Helping Workers and Innovators Invent and Make More in America | Auburn, ME," The White House, July 29, 2023, https://www.whitehouse.gov/briefing-room/speeches-remarks/2023/07/28/remarks-by-president-biden-on-helping-workers-and-innovators-invent-and-make-more-in-america-auburn-me/.

26 Allan, Goldman, and Tauvette, "The C-SAF Roadmap: Building a Feedstocks-to-Fuels SAF Supply Chain in Canada," 9 & 27.

27 Natural Resources Canada, "Minister Wilkinson Announces Over $6 Million to Unlock Sustainable Aviation Fuel Production in Manitoba," news releases, January 17, 2024, https://www.canada.ca/en/natural-resources-canada/news/2024/01/minister-wilkinson-announces-over-6-million-to-unlock-sustainable-aviation-fuel-production-in-manitoba.html.

28 U.S. Department of Energy et al., "SAF Grand Challenge Roadmap: Flight Plan for Sustainable Aviation Fuel" (Washington, D.C.: DOE, DOT, USDA, EPA, September 2022), 17, https://www.energy.gov/sites/default/files/2022-09/beto-saf-gc-roadmap-report-sept-2022.pdf.

29 Dan Lashof and Audrey Denvir, "Under New Guidance, 'Sustainable' Aviation Fuel in the US Could Be Anything But," September 5, 2024, https://www.wri.org/insights/us-sustainable-aviation-fuel-emissions-impacts.

30 Max Bearak, Dionne Searcey, and Mira Rojanasakul, "Airlines Race Toward a Future of Powering Their Jets with Corn," *The New York Times*, November 30, 2023, https://www.nytimes.com/interactive/2023/11/30/climate/airlines-jet-fuel-ethanol-corn.html.

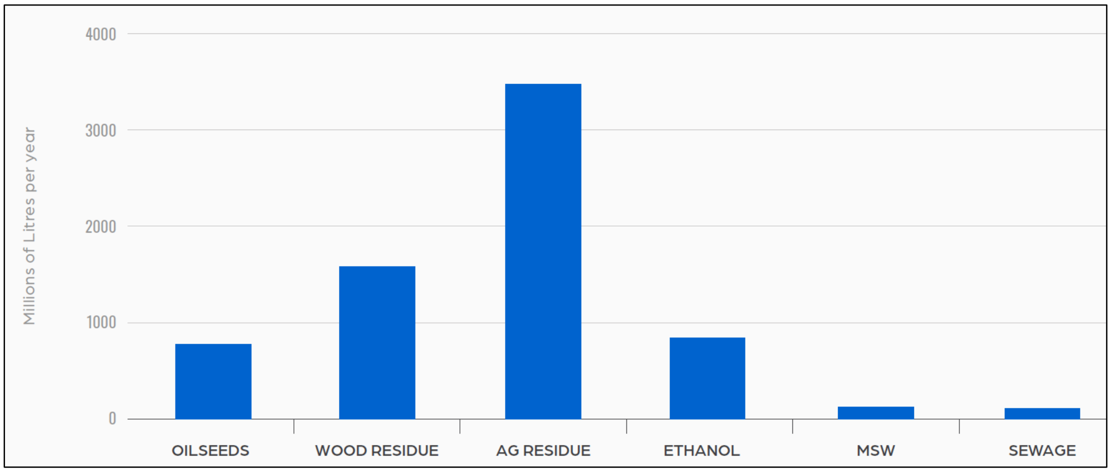

Figure 3. Most promsing Canadian SAF feedstock from biogenic and waste sources.
Source: Reprinted from Canadian Council on Sustainable Aviation Fuel (C-SAF), "The C-SAF Roadmap...," 2023.[31]

A thought experiment (merely to give an idea of the massive scale of the global SAF proposal): How much land would be required worldwide if the aviation sector was fuelled 100 percent by SAFs in 2050 and all those SAFs were produced from oilseeds such as canola and soybeans? As a rough rule of thumb, each tonne of canola or soybean feedstock can produce about 300 litres of SAF (more for canola, less for soybeans). (See Appendix 3 for multiple estimates, sources, and assumptions.) In Canada, each acre yields roughly a tonne of canola or soybeans (more for soybeans and less for canola). Using these two approximations, we can compute that producing the 640 billion litres per year of SAFs projected for 2050 would require about 2.1 billion acres of cropland (and more if SAF output from distillate was not maximized).[32] Canada has just under 100 million acres of cropland. Hypothetically, *to produce all 2050 SAFs from oilseeds might take an area equal to 21 times Canada's total cropland area* (more than 5 times the US cropland area).

Granted, some of the world's agricultural areas produce higher yields than Canada, so the hypothetical global area needed might be only 15 times the Canadian cropland area, or just 12 times—maybe just 4 times the cropland area of the US rather than 5. On the other hand, the preceding calculations grant a high SAF-yield-from-distillate[33] so the hypothetical global cropland area needed could be higher if a lower SAF fraction is assumed.

This report acknowledges that no one is proposing that the entire 2050 aviation fuel supply—two-thirds of a trillion litres—be produced solely from canola and soybeans. Clearly, that is impossible. Airlines and their industry associations acknowledge this and are forthright that only a portion of SAFs can be produced from such crops. Nonetheless, this thought experiment reveals the magnitude of the proposed SAF project and the challenges and impacts it will create—*impacts that will remain large even if only a fraction of SAFs come from field crops*.

Clearly impossible from soybeans and canola, we should ask: is it any more feasible if we add in agricultural residues and energy crops grown on farmland? We will explore that question below, in Chapters 4 and 5.

31 Allan, Goldman, and Tauvette, "The C-SAF Roadmap: Building a Feedstocks-to-Fuels SAF Supply Chain in Canada," 45.

32 One tonne of canola or soybeans per acre times 300 litres of SAF per tonne equals 300 litres per acre. 640 billion litres of projected 2050 demand divided by 300 litres per acre equals 2.1 billion acres.

33 When a bio-refinery produces SAF, it also produces other fuels (with longer or shorter carbon chains). A given tonnage of feedstock (e.g., corn, canola, straw, or switchgrass) produces a certain tonnage of "distillate"—the industry term to encompass the various fuel outputs, including SAF, renewable diesel, and gasoline-like fuels. Only a portion of the distillate is SAF, and the size of that portion is under the control of the plant operator. There is a trade-off: maximize the SAF percentage and the bio-refinery sacrifices output of total liquid fuels. Maximize overall output and the SAF fraction falls. SAF fractions run from 20 percent to 70 percent of distillate, depending on operator choices. See International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 19 & 16; International Air Transport Association, "SAF Handbook" (IATA, May 2024), 16, https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-handbook.pdf.

4. Bio-SAF {residues}: Spinning Straw into Gold

> "To meet longer-term (2050) targets, the aforementioned feedstocks will be joined by ... agricultural residuals (e.g., corn stover, cover crops, and livestock manure).... 2050 SAF goals cannot be reached without the use of agricultural residues such as corn stover...."
> —USDA, US EPA, US DOT, US DOE, "SAF Grand Challenge Roadmap," 2022.[34]

The initial phase of SAF production will be fed largely from grains and oilseeds; the second phase will rely on non-food feedstocks such as agricultural residues. Figure 3, above, shows the medium-term projection for Canadian feedstocks: ag residues make up more than half. The plan is to source many millions of tonnes of straw, corn stover, and other biomass residues from Canadian farm fields, and many times that amount globally.[35]

Several concerns arise from the plan to remove straw, stover, and other plant material. First, soil carbon is built up and maintained partly by crop residue inputs. Canada's National Inventory Report (NIR)—our official calculations and reporting of GHG emissions and soil carbon changes—notes that soil carbon gains are a function of "the change in crop productivity/*crop residue C input* to soils based on yield estimates" [italics added].[36] Soil carbon levels are, to a significant extent, a direct function of the crop residue carbon inputs going into the soil—a direct function of the amount of residue left on the land. Simply stated, soil carbon sequestration is largely determined by the *balance* between two factors: carbon input, largely from crop biomass, and carbon release, largely from bacterial decomposition/oxidation of soil carbon. When C inputs exceed C releases, soils gain carbon, and when releases (or removals) exceed inputs, soils lose.

Crop residue removals may have *large* impacts on soil carbon levels. For example, sequestration on Canadian cropland averaged 20 million tonnes per year in the decade preceding 2021, but a 2021 drought changed that situation; reduced production of crop biomass caused the balance to shift. In 2022, as a result of the 2021 drought, soil carbon flows switched from 20 million tonnes of sequestration to a *release* of nearly 20 million tonnes. Soils released or desequestered carbon as CO_2 emissions as a result of below-normal levels of crop residues being returned to the soils. Figure 4 shows that large 2021-'22 swing.

34 U.S. Department of Energy et al., "SAF Grand Challenge Roadmap: Flight Plan for Sustainable Aviation Fuel," 12 & 30.

35 Are not crop residues now often burnt? In Canada, no. Residue burning is mostly confined to flax acres. AAFC notes that "burning is no longer a common practice in Canada..." and that "the practice of burning straw has declined dramatically due to environmental concerns and improvements in the ability of field machinery to till and plant in heavy residue." See Clearwater and Hoppe, Environmental sustainability of Canadian agriculture: Agri-environmental indicator report series – Report #4, AAFC, 2016, https://publications.gc.ca/collections/collection_2016/aac-aafc/A22-201-2016-eng.pdf . The Canadian situation is largely reproduced in the US. Globally, about 6% of residue is burnt. See Smerald, Rahimi, and Scheer, "A global dataset for the production and usage of cereal residues in the period 1997–2021," Scientific Data 10:685 (2023), https://pmc.ncbi.nlm.nih.gov/articles/PMC10562449/pdf/41597_2023_Article_2587.pdf

36 "National Inventory Report 1990–2020: Greenhouse Gas Sources and Sinks in Canada," Part 1, Canada's Submission to the United Nations Framework Convention on Climate Change (UNFCC) (Ottawa: ECCC, April 2022), 187.

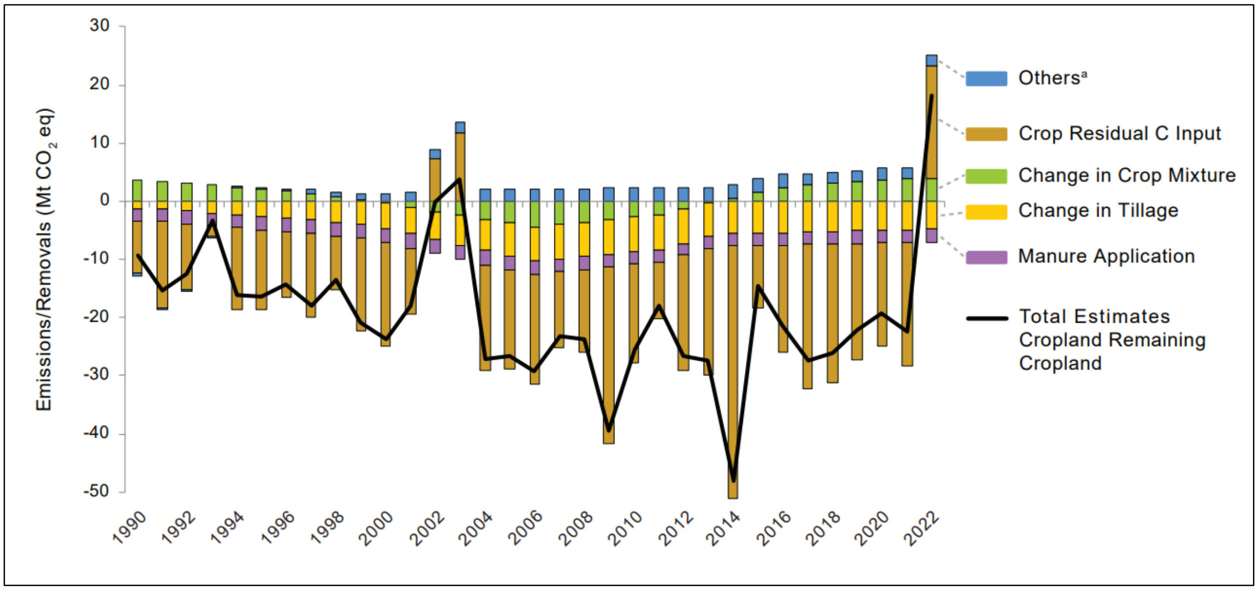

Figure 4. Canadian cropland soil carbon flows: sequestration and emissions, 1990–2022.
Source: Reprinted from ECCC, NIR, 2024.[37]

Note from the graph that the switch from soils gaining carbon to soils releasing carbon was driven wholly by a change in one factor: Crop Residual C Input (see the long, tan bar in the graph above). Less crop biomass residue on the land tipped the balance from soil carbon gain to soil carbon loss. This is an important point: a perhaps 30 to 50 percent reduction in biomass input as a result of low rainfall did not reduce sequestration rates by 30 to 50 percent—rather, it reduced sequestration rates by *more than 100 percent*—driving sequestration rates below zero and up into release/desequestration territory. A reduction of biomass left on fields did not slow sequestration, it reversed it. And even if biomass removal will not, in every case, cause soil carbon losses, it will almost certainly reduce rates of gain. Soil carbon gains are crucial means of improving soil health and the water-holding capacities of soils, thereby increasing climate change resilience.

The airline industry acknowledges these potential negative effects noting that "There are worries about soil health impacts if too much residue is removed from fields."[38]

Before we invest trillions of dollars globally in fuel systems that will remove billions of tonnes of straw, corn stover, and other biomass annually, we should precisely quantify effects on farmland soil carbon and soil health.

In addition to the negative effects of biomass removal on soil carbon levels, those levels will also be adversely affected by warming. Earth is on track to warm 2.6–3.1 degrees Celsius this century.[39] The Canadian Prairies are warming at twice the global average rate and are projected to continue doing so.[40] Thus, 80+ percent of Canadian farmland is on track for 5 or 6 degrees C of warming this century. We know from scientific studies that warmer temperatures can cause carbon losses because, as soils warm, micro-organisms can become more numerous and more active and break down and release soil carbon faster. One study reports that "nearly all models of global climate change predict a loss of carbon from

37 Environment and Climate Change Canada, "National Inventory Report 1990-2022: Greenhouse Gas Sources and Sinks in Canada, Part 1" (Ottawa: ECCC, 2024), 200, https://publications.gc.ca/collections/collection_2024/eccc/En81-4-2022-1-eng.pdf.

38 SimpliFlying and Sustainable Aviation Futures, "Pathways to Sustainable Aviation Fuel: North American Edition" (SimpliFlying, 2024), 30.

39 United Nations Environment Programme, "Emissions Gap Report 2024" (Nairobi: UNEP, 2024), https://www.unep.org/resources/emissions-gap-report-2024.

40 F. Warren and D. Lemmen, Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation (Ottawa: Government of Canada, 2014), 6, http://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2014/internet/w14-26-U-E.html/collections/collection_2014/rncan-nrcan/M174-2-2014-eng.pdf . This high rate of warming is not unexpected: continental interiors and higher latitudes warm much faster than the global average rate.

soils as a result of global warming...."[41] Thus, even without residue removal, warming will make it difficult to maintain soil carbon levels and sequestration rates. Residue removal will compound that difficulty.

Beyond soil carbon impacts are effects on fertility and nutrients. Every tonne of straw or stover removed will take from the field, in addition to carbon, smaller quantities of nitrogen, phosphorus, potassium, and micronutrients.[42] A portion of these quantities will have to be replaced, requiring additional chemical fertilizer tonnage.

Removing straw and other residues increases the risk of wind and water erosion. And less straw on the surface can increase evaporation and moisture loss, hurting yields and reducing climate resilience.

Given the many negative impacts of residue removal, the quantities needed will be of interest. One indicator is the US Department of Energy's *Billion-Ton Report* published in 2024. That report projects agricultural residue availability in the United States at 183 million US tons (166 million tonnes) per year, mainly corn stover with a contribution from wheat straw.[43]

The US DOE's *Billion-Ton Report* implies an annual residue removal rate of about 1.6 tonnes per acre of corn stover (144 million tonnes ÷ 90 million acres of corn) and 0.4 tonnes per acre for wheat straw (16.3 million tonnes ÷ 40 million acres of wheat).

Important to understand, however, is that these per-acre numbers are idealized averages. In the real world, market forces and transportation logistics will not lead to uniform removals across all acres, but rather very uneven draws of crop residues, with land close to SAF bio-refineries pushed to provide high levels and land far away tapped for less or none. Transporting biomass is costly; thus, the net price received by the farmer will vary inversely with distance creating the very clear market signal to draw heaviest from the land that is closest.

Millions of acres to bale and millions of tonnes to truck

Any ag-residue-based SAF production stream will require huge amounts of labour, materials, fuel, machinery, transportation, logistics coordination, etc. Farmers, already working flat-out during the grain harvest, would somehow have to collect and compact ("bale") residues over much of their land—over tens-of-millions of acres in Canada, perhaps a hundred-million acres in the US, and across billions of acres globally. That process would require energy (and farm machinery that is energy-intensive to produce). The relatively bulky baled residues would have to be loaded and trucked to numerous plants spread across the landscape (or to hub-and-spoke collection sites where they may be further compacted or pyrolyzed to prepare them for further transport to SAF production facilities). The exact details of the collection and transport processes are not important because all scenarios reveal the need for huge quantities of time, labour, material, and energy and the creation of enormous logistics challenges.

Important to understand, though this report focuses on fuels for aviation, many of the points made here will apply to any sector that intends to draw massively on biomass for fuels or materials. The concerns raised here apply equally to any potential biofuels megaprojects for ocean shipping, railways, or heavy trucking. They apply, very specifically, to bio-energy with carbon capture and storage (BECCS) which also plans to draw heavily on biomass from farmland (see Ch. 5 & 8). And this report's concerns apply *especially* to the *concurrent* demands from *several* such sectors and megaprojects. Though we focus on SAFs, citizens and policymakers are urged to think more broadly about all bio-based "solutions."

41 William Schlesinger and Jeffrey Andrews, "Soil Respiration and the Global Carbon Cycle," *Biogeochemistry* 48, no. 1 (January 2000): 11.

42 Kevin Gould, "Corn Stover Harvesting" (Michgan State University, 2007), https://www.canr.msu.edu/uploads/236/58572/CornStoverHarvesting.pdf.

43 U.S. Department of Energy and M. H. Langholtz, "2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources" (Oak Ridge, TN: U.S. DOE, Oak Ridge National Laboratory, March 2024), 99.

5. Bio-SAF {energy crops}: Wood-Burning Jet Planes?

> "By growing biomass crops for SAF production, American farmers can earn more money during the off seasons by providing feedstocks to this new market...."
> —*Ontario Grain Farmer* magazine, 2022.[44]
>
> "Agricultural lands are the greatest single source of biomass production potential explored in this report. By ... integrating about 9% of [US] agricultural land into purpose-grown energy crop production, agricultural lands can provide about ... *398* ... million [US] tons of cellulosic biomass per year...."
> —US Department of Energy, *Billion-Ton Report*, 2024.[45]

Purpose-grown energy crops include woody or grassy/herbaceous crops that are fast growing and high-yielding. Examples of grassy/herbaceous energy crops include switchgrass and miscanthus. Examples of woody energy crops include willow and poplar, often coppiced: grown to a medium height and then cut low in order to spur rapid and bushy regrowth. These "cellulosic" feedstocks are then turned into jet fuel via the Fischer-Tropsch (FT) or Alcohol to Jet (AtJ) SAF pathways.

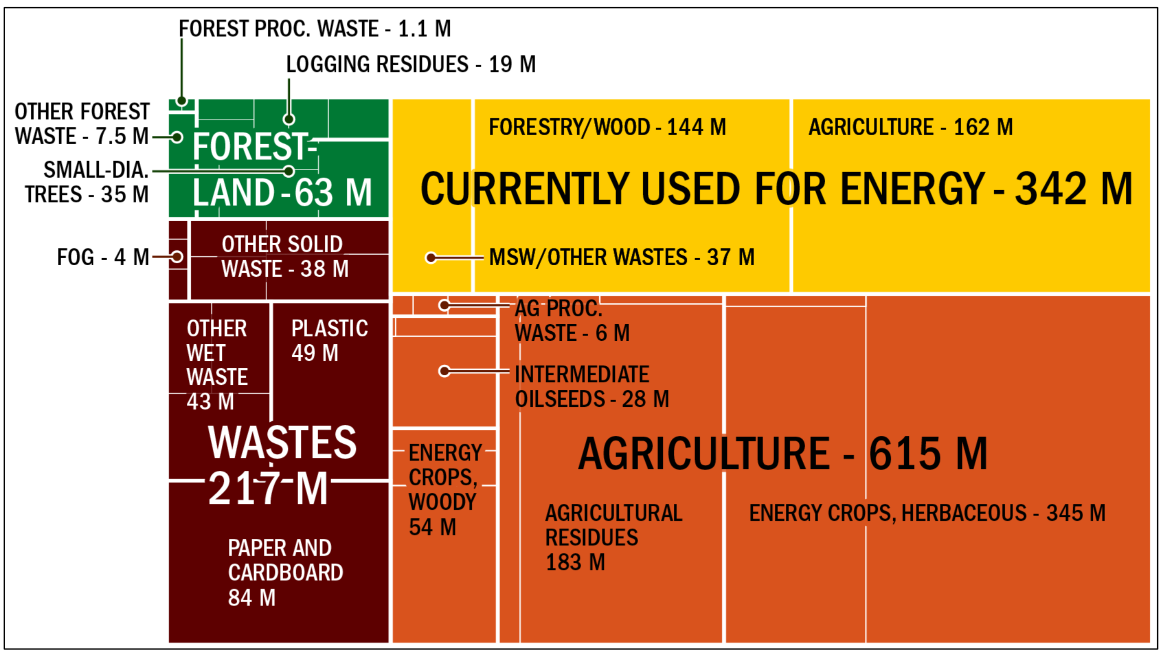

Figure 5. US biomass resources (in the mature-market medium scenario), millions of dry US tons per year.
Source: US DOE, *Billion-Ton Report*, 2024.[46]

Figure 5 shows that biomass-based SAFs will probably come mainly from farmland—in the US, North America, and likely globally. Note the small green rectangle in the upper left: US forest residues are projected to provide perhaps 63 million US tons (57 million tonnes) of feedstocks per year, but US agriculture is projected to provide nearly ten times as much: 615 million US tons (558 million tonnes). Agricultural residues (straw, corn stover, etc.) contribute 183 million tons per year—three times more than forest residues. But the largest biomass feedstock source is projected to be energy crops grown on

44 Owen Roberts, "Turning the Friendly Skies Green," *Ontario Grain Farmer*, May 2022, 6, https://www.google.com/search?q=turning+the+friendly+skies+green&oq=turning+the+friendly+skies+green&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIHCAEQIRigATIHCAIQIRigATIHCAMQIRigAdIBCDY2NzFqMGo3qAIAsAIA&sourceid=chrome&ie=UTF-8.

45 U.S. Department of Energy and Langholtz, "2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources," 121.

46 U.S. Department of Energy and Langholtz, "2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources," xxiii.

farmland, contributing about 400 million US tons (363 million tonnes) per year. While this is a US analysis, the general outlines are probably applicable globally.

Unlike some analyst organizations, which try to make the case that energy crops will be grown on unused, marginal, abandoned, or degraded land,[47] the US Department of Energy is more realistic. The DOE says that "allocating purpose-grown energy crop production to tracts of low-yielding lands in isolation of economic interactions would fail to reflect realistic futures and inevitable economic interactions among crop markets."[48] The DOE goes on to project that energy crops in the US will be grown "on 8%–11% of agricultural land"[49] and quantifies this as the conversion of 26 million acres of US cropland and 50 million acres of pastureland from food production to energy crops.[50]

A question arises: would this conversion of 8–11% of US farmland be replicated around the world? If so, what could be the effects as we simultaneously expand other demands on farmlands? To put this another way, as we add billions more people to our planetary population, and as we do so amid intensifying climate impacts on food production, are we confident that 10 percent of our farmland is surplus to need?

Below, in Chapter 7, we return to this questionable idea that there exists large areas of unused or surplus land that are available for energy-crop cultivation.

Another issue for energy crops is scale-up challenges. Currently, in the US, energy crop production and utilization is essentially zero[51]—suggesting that the economics and on-farm returns of these crops may be disappointing. And not only will there be a scale-up challenge to get farmers to plant and harvest tens of millions of acres of these crops, there will be a parallel problem in scaling up collection and processing of these hundreds of millions of tonnes, in the US, and billions of tonnes globally. All of this will require massive adjustments and investments on-farm and in processing—on-farm investments and changes that are unlikely if farmers continue to make good returns on traditional crops.

Déjet vu

Readers who have been following the biofuels debate over the past couple decades will read the preceding about SAFs from agricultural residue and energy crops and recall the long-touted "cellulosic ethanol"—biofuels made from cellulose in wood and straw rather than from starches in corn or wheat.

Despite years of "coming soon," cellulosic ethanol has failed to debut. In a 2022 article in *Physics Today*, entitled "Whatever Happened to Cellulosic Ethanol?" author David Kramer notes that "Despite a decade and a half of big US federal investments in R&D and in pilot and demonstration plants, ethanol from noncrop biomass has yet to become a commercial reality in the US."[52]

From some perspectives, in the past, it seems that the promise of cellulosic ethanol was deployed to blunt objections to the land-use and food-price impacts of corn, soy, and canola biofuels—to defuse the "food vs fuel debate." There is good reason to question whether we should today pin our hopes for low-emission air travel on these long-promised and long-delayed fuels.

47 International Air Transport Association, "SAF Handbook," 15.
48 U.S. Department of Energy and Langholtz, "2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources," 101.
49 U.S. Department of Energy and Langholtz, "2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources," xxiii.
50 U.S. Department of Energy and Langholtz, "2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources," xxviii.
51 U.S. Department of Energy and Langholtz, "2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources," 34.
52 David Kramer, "Whatever Happened to Cellulosic Ethanol?," *Physics Today* 75, no. 7 (July 1, 2022): 22–24, https://doi.org/10.1063/PT.3.5036.

How much biomass feedstock globally?

Very briefly, just how much agricultural biomass—crop residues plus energy crops—might SAFs demand? Here is an approximation:

Table 1. Back-calculation from litres of SAF in 2050 to tonnes of biomass feedstock potentially needed.

Descriptor	Value	Unit	Source
SAF needed in 2050	640,000,000,000	Litres/year	See above
Conversion factor for litres of fuel to tonnes	1,250	Litres/tonne	https://aviationbenefits.org/media/167233/fact-sheet_13_saf-metrics-and-conversions_4.pdf
SAF needed in 2050	512,000,000	Tonnes/year	By calculation. See also IATA, "Finance: Net Zero CO_2 Emissions Roadmap," 2024, p. 11.
SAF fraction from distillate	0.5	SAF/distillate	IATA, Finance: Net Zero CO_2 Emissions Roadmap, Sept. 2024, Table 2.
Distillate needed to yield SAF needed	1,024,000,000	Tonnes/year	By calc'n. Note that distillate is split 50%/50% into SAF & other products (incl. renewable diesel)
Tonnes of distillate per tonne of feedstock	0.14	Distillate/feedstock	IATA, Finance: Net Zero CO_2 Emissions Roadmap, Sept. 2024, Table 2.
Tonnes of biomass needed	**7,314,000,000**	Tonnes/year	By calculation

Table 1 shows that the biomass needed in 2050 could be approximately 7.3 billion tonnes per year.[53] Feedstocks such as corn, soy, and canola are limited. Used cooking oil, even more so.[54] On the other hand, there is no clear indication whether Electro-SAFs will ever be a viable reality; IATA projects them to remain about three-times more expensive than fossil fuel Jet A, even past 2050.[55] Thus, it may remain the case that most of the feedstocks will need to come from biomass, and most of that from farm fields.

But there's more....

Bio-SAF *plus* BECCS

The 7 billion tonnes annually of biomass calculated above would come atop other demands for biomass, with the largest probably coming from bioenergy with carbon capture and storage (BECCS) when that technology is deployed at massive scale, as is planned.

BECCS and other "negative emissions technologies" (NETs) are built into most of the United Nation's Intergovernmental Panel on Climate Change (UN IPCC) scenarios that project future temperatures below 2.0 degrees of warming.[56] To explain: Given current and probable future levels of GHG emissions, most IPCC scenarios assume we will overshoot safe GHG concentrations in the medium-term (2040s, '50s, '60s, etc.) and then later have to draw back those GHGs from the atmosphere and sequester them in the ground or oceans. Thus, though seldom voiced, BECCS and other NETs are a big part of most governments' plans to keep our biosphere stable and habitable—they are *assumed* in future projections that keep warming within tolerable limits. Most important, *BECCS systems would draw on exactly the same biomass supplies as SAFs: crop and forest residues, purpose-grown energy crops, etc*.

53 This will yield 640 billion litres of SAF and an equal volume of non-SAF biofuels based on an assumed 50 percent SAF-from-distillate fraction. The 7.3 billion tonnes of biomass per year will create about 640 billion litres of SAF per year <u>and</u> an equal quantity of non-SAF fuels such as renewable diesel.

54 See footnote 13

55 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 23.

56 Pete Smith et al., "Biophysical and Economic Limits to Negative CO2 Emissions," *Nature Climate Change* 6, no. 1 (January 2016): 42, https://doi.org/10.1038/nclimate2870.

Scientists estimate that the quantity of BECCS (or other NETs) needed to be deployed in the second half of this century is equivalent to the removal of 3.3 billion tonnes of carbon per year.[57] Agricultural straw is roughly 40 percent carbon and energy crops would have a comparable carbon content, if slightly higher. So, assuming 100 percent carbon capture at BECCS plants (real-world performance will be much lower), to sequester 3.3 billion tonnes of carbon, if all was provided from agricultural feedstocks, the requirement would be 8.3 billion tonnes of biomass annually. This tonnage for BECCS added to the 7.3 billion tonnes annually for SAFs equals 15.6 billion tonnes per year.[58]

Total global farmland area, cropland and grazing land, is just under 12 billion acres. Of course, most of that will be fully subscribed feeding our soon-to-be-10-billion-person global population. Even if we could find a spare couple billion acres (which is more than twenty times the cropland area of Canada), we'd have to extract more than seven tonnes of biomass per acre, every year, year after year. (For context, this represents about double the harvestable per-acre tonnage of corn stover[59] and a large multiple of the harvestable per-acre tonnage of wheat straw.)

Also to consider, many of the Earth's acres are already contributing straw and other biomass: for livestock bedding, garden mulching, heating and cooking fuels, construction materials such as thatch or mud-brick making, paper and packaging materials, etc.

Finally, when thinking about our limited supplies of crop residues, energy crops, and other biomass, we should consider that not all uses are equal in their benefits. As with SAFs, there are many problems with BECCS, but leaving aside those problems for the moment, it is useful to compare the benefits of channeling our limited biomass to BECCS rather than SAFs. BECCS is GHG net-negative, whereas SAFs, considered in aggregate, are not even GHG neutral, but rather a net source of emissions and, as we will see below, a major source of non-emission-related warming effects. Again, BECCS has its own problems, but putting those aside, we should consider this question: for the largest climate benefits, if there exist sustainably harvestable agricultural biomass supplies, should we direct those limited residue streams to BECCS or SAFs? The answer seems clear: BECCS provides negative emissions, whereas SAFs do not. Further, the electricity from BECCS provides a broad benefit to most citizens, while SAF-powered flying is only for the few. (See Ch. 12 re the small percentage who fly.)

Moreover, aviation can use Electro-SAFs to wholly eliminate its need for biomass, whereas BECCS cannot. This is one reason why the SAF project should leapfrog its biomass "transition" phase and go straight to Electro-SAFs. The best course is to refrain from building a costly, unsustainable, feedstock-limited, and soon-to-be-obsolesced biomass-based SAF production system and instead invest those trillions of dollars into Electro-SAF facilities.

Academics conclude:

> "The scaling up of SAF to not only maintain but grow global aviation is problematic as it competes for land needed for nature-based carbon removal, clean energy that could more effectively decarbonise other sectors, and captured CO_2 to be stored permanently. As such, SAF production undermines global goals of limiting warming to 1.5°C; a conflict that is neither recognised in the roadmaps nor in the public debate."[60]

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57 Smith et al., "Biophysical and Economic Limits to Negative CO2 Emissions," 43.

58 This report struggles with the fact that not all sources list whether their calculations and coefficients are based on dry straw or stover or straw or stover with moisture levels normal at the time of collection and baling—often 10 to 25 percent. Thus, all figures here should be taken as ±20 percent. Future versions of this report can tackle this dry vs not-dry issue. That said, the final refinement of these values will have no effect on the overall conclusions and analysis of this report.

59 Gould, "Corn Stover Harvesting."

60 Susanne Becken, Brendan Mackey, and David S. Lee, "Implications of Preferential Access to Land and Clean Energy for Sustainable Aviation Fuels," *Science of The Total Environment* 886 (August 15, 2023): 2, https://doi.org/10.1016/j.scitotenv.2023.163883.

6. Electro-SAFs: Liquifying Electricity

> "E-fuels made from hydrogen and captured carbon dioxide (CO_2) via the power-to-liquids (PtL) process can boast extremely low emissions compared to the fossil fuels they replace, depending on the source of carbon. Moreover, e-fuels don't face the same challenges as biofuels regarding the availability and sustainability of biomass feedstock. As a result, hard-to-abate transport sectors like shipping and aviation are looking to e-fuels to help them decarbonize. The PtL pathway is set to expand rapidly throughout the 2020s, from a handful of pilot plants in 2024 to a potential global capacity of over one billion gallons per year in 2030."
> —Bloomberg New Energy Finance, "Power-to-Liquids Primer: Fuel from Thin Air," 2024.[61]

> "Third-generation SAF or synthetic fuels represent the cutting edge of SAF technology. This category includes fuels synthesised using renewable electricity, also known as Power-to-Liquid (PtL) or e-fuels. ... While theoretically promising, the practical challenges of integrating green hydrogen and captured CO_2 into jet fuel production at scale are formidable. The aviation industry's tight margins further complicate adoption of potentially costlier fuels."
> —Simpliflying, "Pathways to Sustainable Aviation Fuel...," 2024.[62]

This report uses the term "Electro-SAF" to refer to drop-in jet fuels made from air (a source of carbon, C) and water (a source of hydrogen, H) all powered by renewable electricity. That same process is variously called power to liquids (PtL), solar-to-jet, air-to-fuel, sun-to-liquids, electrofuels, and e-fuels. Figure 6 shows a simplified diagram of the process. Figure 7 shows a similar process in more detail. The CO_2 for such processes can be taken from the air (direct air capture, or DAC) or from the exhaust of an industrial or energy-producing source, such as an ethanol refinery.

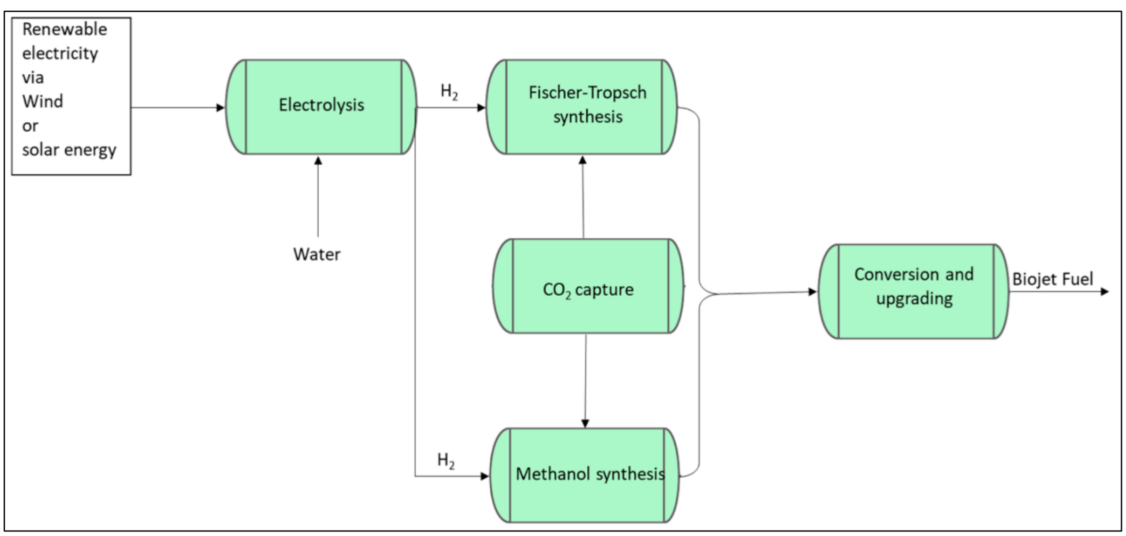

Figure 6. Simplified schematic of Electro-SAF production from renewable electricity, electrolyzed hydrogen, and captured CO_2.
Source: Reproduced from Peters et al., 2023.[63]

61 Rose Oates, "Power-to-Liquids Primer: Fuel From Thin Air," *BloombergNEF* (blog), May 7, 2024, https://about.bnef.com/blog/power-to-liquids-primer-fuel-from-thin-air/.

62 SimpliFlying, "Pathways to Sustainable Aviation Fuel: APAC Edition" (Sustainable Aviation Futures, 2024), 17–18.

63 Morenike Ajike Peters, Carine Tondo Alves, and Jude Azubuike Onwudili, "A Review of Current and Emerging Production Technologies for Biomass-Derived Sustainable Aviation Fuels," *Energies* 16, no. 16 (January 2023): fig. 10, https://doi.org/10.3390/en16166100.

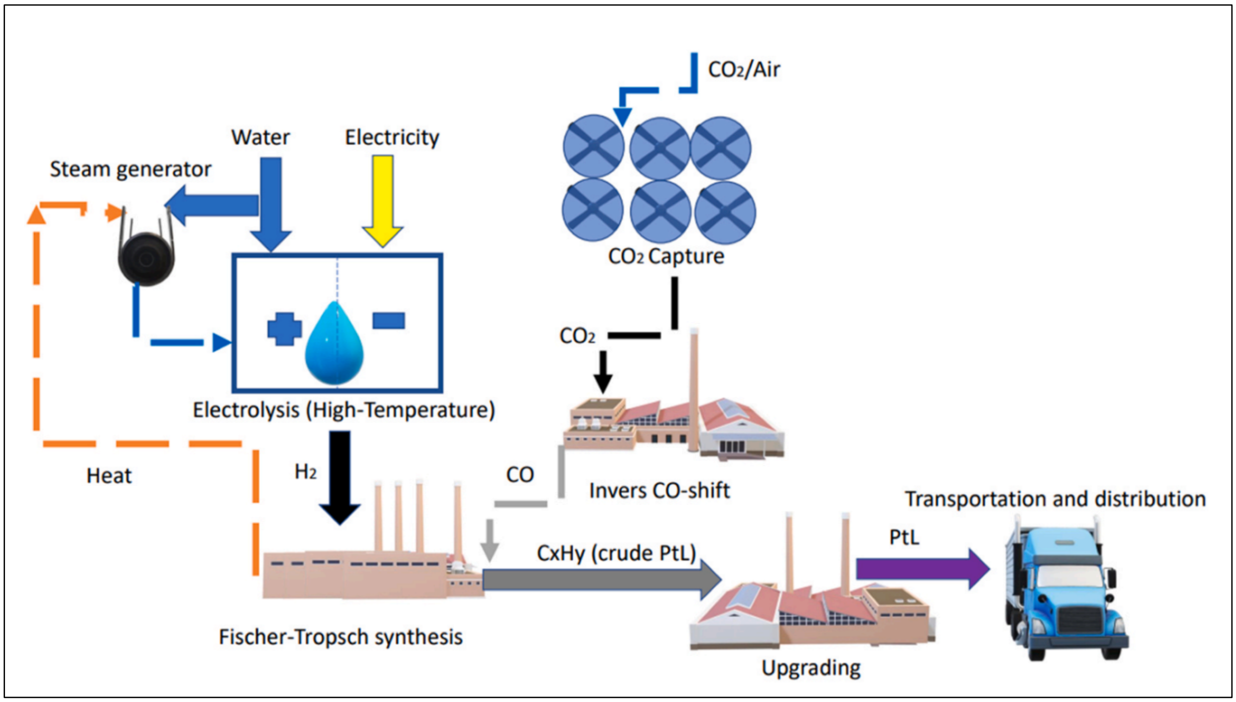

Figure 7. Electro-SAF fed by CO_2 capture and processed via the Fischer-Tropsch method.
Source: Reproduced from Amhamed et al., 2024.[64]

A survey of analyses and reports show a wide range of estimates regarding the 2050 share for Electro-SAFs among SAFs overall, but the average is about 50 percent.[65] A more recent IATA report, however, put the PtL/Electro-SAF percentage at just 14 percent in 2045 and 35 percent in 2050.[66] As we will see below, any estimation of future utilization is highly speculative and almost certainly inadequately mindful of limits to renewable electricity supplies and green hydrogen production capacity (Ch. 14). Though projected to scale up to hundreds-of-billions of litres in just 25 years, Electro-SAF production is rare today, wholly reliant on government subsidies, and projected to remain far more expensive than alternatives.[67]

The case for Electro-SAFs

One could assert that Electro-SAF is SAF done right. The process requires no biological inputs so there are no food-price or land-use impacts. There are no negative effects on soils, sequestration rates, or agricultural GHG emissions. Also, without the need for inputs beyond electricity, water, and air, Electro-SAF is, in theory, not feedstock limited.

Perhaps most important, Electro-SAFs can be truly zero-emission (assuming all processes, fuel transport, etc. are energized by clean, renewable electricity). This is unlike Bio-SAF {seeds}, which will always have large emissions footprints from fertilizer use, etc.

In effect, Electro-SAFs enable jets to be powered by solar panels and windmills, via liquid Electro-SAF energy-carrier intermediaries.

64 Abdulkarem I. Amhamed et al., "Alternative Sustainable Aviation Fuel and Energy (SAFE)- A Review with Selected Simulation Cases of Study," *Energy Reports* 11 (June 1, 2024): fig. 9, https://doi.org/10.1016/j.egyr.2024.03.002.
65 International Air Transport Association et al., "Aviation Net-Zero CO2 Transition Pathways: Comparative Review," tbl. 4.
66 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 2.
67 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 23.

The case <u>against</u> electro-SAFs

> "CO_2 could not be more different than conventional petroleum feedstock; CO_2 has no intrinsic energy content, is nearly 73% oxygen by mass, and is completely devoid of hydrogen. Therefore, whereas petroleum starts from a place of molecules with high molecular weight and high energy that are cracked down to size, CO_2 must be reconstructed molecule by molecule via energy-intensive processes to establish new carbon-carbon and carbon-hydrogen bonds to create fuels and products. While the precise energy demand depends on the conversion process utilized, estimates suggest an energy intensity on the order of 100 kWh required per gallon of CO_2-derived SAF. This implies that [the U.S. 2050 target of] 35 billion gallons of SAF would require 3,500 TWh, *about 85% of the current total U.S. electricity generation* of 4,100 TWh" [italics added].
> —U.S. Department of Energy, National Renewable Energy Lab (NREL), 2024.[68]
>
> "Energy required to produce the 12 Mt of power-to-liquid e-jet fuel required in the UK: 468–660 TWh. 2020 UK electricity generation: 306 TWh."
> —The Royal Society, 2023.[69]
>
> "Lufthansa boss Carsten Spohr has claimed that to power his airline's fleet with e-fuels would use the equivalent of half of Germany's total electricity capacity."
> —Simpliflying, 2024.[70]

Not surprising, Electro-SAF is too good to be true. Indeed, as we make hard decisions on the road to a net-zero 2050, our first question must be: is it real? Can it ever be cost-competitive and scale up to provide hundreds-of-billions of litres of fuel per year? Most important, can it do so by 2050, given that it is largely a set of small pilot projects today, with per-litre costs that are a multiple of conventional Jet A and even other SAFs.[71]

There are many reasons to question the feasibility and reality of Electro-SAF; the first is its energy requirement. Another thought experiment: if Electro-SAF provided the entire 2050 supply, how much clean, renewable energy would be needed? Scaling up from the US numbers—100 kWh per US gallon—we can calculate a global 2050 energy requirement of 16.9 trillion kilowatt hours (16.9 petawatt hours) to produce the 169 billion US gallons projected for that year. That number of petawatt hours is equal to just over half the current global electricity production (which is 29 petawatt hours per year). The IATA confirms this calculation, noting that to make even a significant portion of the SAF needed in 2050 could require "roughly the equivalent of half of all electricity produced globally in 2021...."[72]

Electro-SAFs are energy-inefficient in the extreme. This is a result of a core aspect of these fuels: Electro-SAFs seek to run entropy backwards—to unburn hydrocarbons. While combustion turns hydrocarbon fuels such as Jet A into CO_2 and water and in-so-doing releases energy, the processes that create Electro-SAF do the reverse: inject energy into the system to turn CO_2 and water into fuels. Figure 8 shows the simplified chemical reaction for combustion of jet fuel and its reverse: a simplified equation for injecting energy and making new fuels from CO_2 and water. (Note that jet fuel is a mixture of hydrocarbons, primarily 9–16 carbons each, and this equation uses a representative 10-carbon molecule: dodecane.)

68 Grim et al., "The Challenge Ahead," 4.

69 The Royal Society, "Net Zero Aviation Fuels: Resource Requirements and Environmental Impacts" (London: The Royal Society, February 2023), tbl. 5, https://royalsociety.org/-/media/policy/projects/net-zero-aviation/net-zero-aviation-fuels-policy-briefing.pdf.

70 SimpliFlying and Sustainable Aviation Futures, "Pathways to Sustainable Aviation Fuel: North American Edition," 49.

71 International Civil Aviation Organization, "SAF Rules of Thumb," accessed March 4, 2024, https://www.icao.int/environmental-protection/Pages/SAF_RULESOFTHUMB.aspx.

72 International Air Transport Association, "Energy and New Fuels Infrastructure: Net Zero Roadmap," 2.

Combustion

$$2\ C_{10}H_{22} + 31\ O_2 \rightarrow 20\ CO_2 + 22\ H_20 + \textit{energy out}$$

(2 dodecane + 31 oxygen → 20 carbon dioxide + 22 water + energy out)

Reverse combustion, i.e., creation of Electro-SAFs

$$\textit{Energy in} + 20\ CO_2 + 22\ H_20 \rightarrow 2\ C_{10}H_{22} + 31\ O_2$$

(Energy in + 20 carbon dioxide + 22 water → 2 dodecane + 31 oxygen)

Figure 8. Chemical reactions of combustion and reverse-combustion to produce Electro-SAF.

The energy input in the bottom equation in Figure 8 will have to be very large. Running entropy backwards to produce Electro-SAFs requires an energy input almost three times as large as the fuel's eventual energy output: roughly 100 kWhs per gallon energy input versus 37 kWhs energy output when the fuel is burnt. Producing Electro-SAF squanders nearly two-thirds of the renewable energy input.

Another way of thinking about the energy inefficiency of Electro-SAF is to perceive it as a liquid battery. It is an energy-carrier—packaging renewable electricity into a liquid form compatible with existing jet engines. Just as in a normal battery, electrical energy is added in to change the states of the battery's chemical components. The same is partly true here. But instead of discharging the chemical-energy bonds back to electricity (as could occur in a fuel cell), they are combusted for heat.

The industry notes that "The overall energy efficiency of the e-fuel production process can be as low as 20%, meaning that a large amount of renewable electricity is required to produce a relatively small amount of fuel."[73] This inefficiency is a crucial consideration. Electro-SAF-powered planes would be among the least energy-efficient transportation systems on Earth. In Chapter 20, we compare the efficiency (energy per person-kilometre) of Electro-SAF-powered planes to renewable-electricity-powered trains and ask: In a climate emergency; as we struggle to electrify vehicles, industry, home heating, etc.; as we face inadequate supplies of clean, renewable energy for decades to come; is it responsible public (or private) policy to spend trillions to create one of the least-energy-efficient transportation systems possible? Is it prudent to build out an Electro-SAF aviation system that uses more than three times[74] as much scarce clean energy per passenger kilometre as alternatives such as high-speed trains?

Finally, the efficiency and cost situation may be even worse than outlined above. Plucking carbon directly from the air (direct air capture, DAC) remains highly uncertain, as do energy requirements and costs. And there is the scale-up problem. This assessment from airline industry group IATA:

> "The largest carbon capture plant in the world in 2023 had a 4,000 tonne per year (t/y) nominal capacity but Climeworks, the company behind the project, has plans for a plant ten times that size to start operating in 2025. Carbon Engineering ... has future projects with a planned capacity of 1 million t/y by 2026. The PtL route alone will need more than 500 million t/y in terms of captured carbon inputs by 2050, showing the size of the scale-up required."[75]

To summarize: though no large DAC plants now exist, IATA projects that the fuel industry will need to complete 500 by 2050—completing one every three weeks. Relevant to this scale-up challenge: one of the largest DAC projects announced so far—the Bison Project in Wyoming—was put on hold as a result of insufficient clean energy supplies because of competition from data centres and artificial intelligence (AI).[76]

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73 SimpliFlying and Sustainable Aviation Futures, "Pathways to Sustainable Aviation Fuel: North American Edition," 49.

74 More likely, trains are six times as energy efficient (rather than three times), but, below, we credit SAF-powered aviation with a speculative/hypothetical 2x efficiency gain in order to satisfy those who would have us believe that innovation will significantly boost efficiency. See Ch. 20.

75 International Air Transport Association, "Energy and New Fuels Infrastructure: Net Zero Roadmap," 5.

76 Vasil Velev, "CarbonCapture Inc. Pauses Development Of Project Bison In Wyoming," *Carbon Herald* (blog), September 1, 2024, https://carbonherald.com/carboncapture-inc-pauses-development-of-project-bison-in-wyoming/.

7. Land Use Change and Emissions from SAFs

Burning conventional jet fuel (Jet A) releases carbon dioxide (CO_2) and other GHGs totalling 89 grams of carbon dioxide equivalent (CO_2e) per megajoule of energy.[77] 89 grams CO_2e/MJ is Jet A's emissions intensity. Each SAF produced from the various feedstock/production-process combinations has its own emissions intensity and that intensity will differ for fuels produced from feedstocks from different regions.

Most simply, the emissions intensity of a SAF is made up of two main components:

1. **Core life-cycle** emissions—the GHGs released from producing, collecting, and processing the feedstock into the SAF and transporting the SAF; and

2. **Induced land use change** (ILUC) emissions—often soil carbon released when production of a feedstock is modelled as causing a shift in production/demand to another place and, as a result, the creation of new farmland from forests or grasslands.

Examples of #1, core life-cycle emissions, could include those from fertilizer use or tractor fuel if the feedstock is canola or corn or a purpose-grown energy crop.

This report is agnostic regarding whether the emissions calculated by ICAO/CORSIA for each SAF feedstock/production-process pairing are correct. Those wanting to delve deeper into such questions are directed toward two reports: *CORSIA Methodology for Calculating Actual Life Cycle Emissions Values* (40 pages)[78] and *CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels* (7 pages).[79] For a deeper dive, consider the 203-page *CORSIA Eligible Fuels – Life Cycle Assessment Methodology*.[80]

To begin to better understand how ICAO models its emissions values, it is important to know:

A. It is assumed that there are no *combustion* emissions, as the CO_2 coming out of the jet engine is equal to CO_2 that was photosynthesized into the biomass feedstock (or was captured from the air in Electro-SAF).

B. Emissions values may be lower than many expect, because a portion of emissions (from on-farm diesel fuel or fertilizer use, for instance) are assigned to co-products. E.g., when SAF is made from soybeans, a portion of the emissions from on-farm production is assigned to the soybean oil that goes into making SAF, but another portion of the emissions is assigned to the meal destined for cattle feeding. Emissions can be split between SAFs and co-products in various ways: by the dollar value of each, by mass, or by energy content. ICAO/CORSIA uses the latter.[81]

C. Wastes and residues, such as grain straw or corn stover or forest trimmings, are assumed by ICAO/CORSIA to have zero emissions from Induced Land Use Change (ILUC).[82]

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77 Air Transport Action Group, "Beginner's Guide to Sustainable Aviation Fuel," 2.

78 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Methodology for Calculating Actual Life Cycle Emissions Values" (CORSIA and ICAO, June 2022), https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2007%20-%20Methodology%20for%20Actual%20Life%20Cycle%20Emissions%20-%20June%202022.pdf.

79 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels" (CORSIA and ICAO, June 2022), https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2006%20-%20Default%20Life%20Cycle%20Emissions%20-%20June%202022.pdf.

80 ICAO, "CORSIA Eligible Fuels – Life Cycle Assessment Methodology" (ICAO, June 2022), https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/CORSIA_Supporting_Document_CORSIA%20Eligible%20Fuels_LCA_Methodology_V5.pdf.

81 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Methodology for Calculating Actual Life Cycle Emissions Values," 5, point 6.

82 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Methodology for Calculating Actual Life Cycle Emissions Values," Page 5, point 7.

D. Wastes and residues, such as grain straw or corn stover or forest trimmings, are assumed to have zero emissions from production, though emissions from collection and processing are counted.[83]

E. ICAO/CORSIA offers options to reduce ILUC including the "yield increase approach" and the "unused land approach."[84] The former invites SAF makers to show that the feedstock is created as a result of somehow increasing output and the latter invites them to show that the feedstock comes from land that has not recently (i.e., the past five years) been in agricultural production.

F. For some energy crops, the ILUC value is *negative*—based on the notion that although there are land use changes (i.e., growing energy crops in some places may cause forest or grassland to be converted to farmland in other places) the soil carbon sequestration effects of growing these woody and grassy energy crops are so large as to wholly offset and reverse those LUC effects. Much more assessment is needed of this questionable assumption. For example, soils eventually "fill up" with carbon—they reach maximal "saturation" levels and cease sequestering new carbon. It is not clear how ICAO/CORSIA values incorporate this reality.

Region	Fuel Feedstock	Pathway Specifications	Core LCA Value	ILUC LCA Value	LS_f (gCO_2e/MJ)
Global	Agricultural residues	Residue removal does not necessitate additional nutrient replacement on the primary crop	7.7		7.7
Global	Forestry residues		8.3	0.0	8.3
Global	Municipal solid waste (MSW), 0% non-biogenic carbon (NBC)		5.2		5.2
Global	Municipal solid waste (MSW) (NBC given as a percentage of the non-biogenic carbon content)		NBC*170.5 + 5.2		NBC*170.5 + 5.2
USA	Poplar (short-rotation woody crops)		12.2	-5.2	7.0
Global	Poplar (short-rotation woody crops)		12.2	8.6	20.8
USA	Miscanthus (herbaceous energy crops)		10.4	-32.9	-22.5
EU	Miscanthus (herbaceous energy crops)		10.4	-22.0	-11.6
Global	Miscanthus (herbaceous energy crops)		10.4	-12.6	-2.2

Figure 9. Selected examples of CORSIA life cycle emissions values for SAFs produced via Fischer-Tropsch.
Source: Reproduced from ICAO, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels."[85]

Note in Figure 9 that ICAO/CORSIA assigns to agricultural residues a core LCA of 7.7 grams CO_2e emissions per MJ of energy and assigns zero for land-use change, for a total of 7.7 grams CO_2e per MJ. This is well below the 89 grams CO_2e per MJ produced when conventional, fossil-fuel Jet A is combusted. Note also the proviso: "residue removal does not necessitate additional nutrient replacement on the primary crop." This raises questions, as every tonne of residue removed takes with it a quantity of nitrogen, phosphorus, potassium, and micro-nutrients.[86]

83 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Methodology for Calculating Actual Life Cycle Emissions Values," Page 5, point 8.

84 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Methodology for Calculating Actual Life Cycle Emissions Values," 12.

85 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels," tbl. 1.

86 Gould, "Corn Stover Harvesting."

Note also in Figure 9 that the energy crop miscanthus is assigned a negative value for land-use change (because of assumed high rates of sequestration) and a negative value overall. The contention is that burning SAF made from miscanthus feedstock would be net-negative—that it would sequester more soil carbon from the atmosphere than its production and processing would emit.

Region	Fuel Feedstock	Pathway Specifications	Core LCA Value	ILUC LCA Value	LS_f (gCO_2e/MJ)
Global	Tallow		22.5	0.0	22.5
Global	Used cooking oil		13.9		13.9
Global	Palm fatty acid distillate		20.7		20.7
Global	Corn oil	Oil from dry mill ethanol plant	17.2		17.2
USA	Soybean oil		40.4	24.5	64.9
Brazil	Soybean oil		40.4	27.0	67.4
Global	Soybean oil		40.4	25.8	66.2
EU	Rapeseed oil		47.4	24.1	71.5
Global	Rapeseed oil		47.4	26.0	73.4

Figure 10. Selected examples of CORSIA life cycle emissions values for SAFs produced via HEFA.
Source: Reproduced from ICAO, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels."[87]

Notice in Figure 10 that emissions from both soybean and canola ("rapeseed") feedstocks are in the mid-60s and mid-70s, far above the 44.5 grams CO_2e per MJ (half of the 89 grams from Jet A) needed to qualify for subsidies under US *Inflation Reduction Act* rules. This is why US farmers and governments are pushing for a recalculation using the made-in-the-USA GREET modelling system.[88] Below, in Figure 11, the same problem is visible for corn-based SAF. And, again, the solution is to recalculate using GREET.

Region	Fuel Feedstock	Pathway Specifications	Core LCA Value	ILUC LCA Value	LS_f (gCO_2e/MJ)
Global	Agricultural residues	Residue removal does not necessitate additional nutrient replacement on the primary crop.	29.3	0.0	29.3
Global	Forestry residues		23.8		23.8
Brazil	Sugarcane	Standalone or integrated conversion design	24.0	7.3	31.3
Global	Sugarcane	Standalone or integrated conversion design	24.0	9.1	33.1
USA	Corn grain	Standalone or integrated conversion design	55.8	22.1	77.9
Global	Corn grain	Standalone or integrated conversion design	55.8	29.7	85.5
USA	Miscanthus (herbaceous energy crops)		43.4	-54.1	-10.7
EU	Miscanthus (herbaceous energy crops)		43.4	-31.0	12.4
Global	Miscanthus (herbaceous energy crops)		43.4	-23.6	19.8
USA	Switchgrass (herbaceous energy crops)		43.4	-14.5	28.9

Figure 11. Selected examples of CORSIA life cycle emissions for SAFs produced via alcohol to jet (AtJ).
Sources: Reproduced from ICAO, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels."[89]

87 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels," tbl. 2.
88 Kentucky Corn Growers Assoc., "A Farmers Guide to the GREET Model."
89 Carbon Offsetting and Reduction Scheme for International Aviation and International Civil Aviation Organization, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels," tbl. 3.

"Marginal land"

Above, this report quoted the US government as stating that it is not realistic to expect that purpose-grown energy crops will be constrained to marginal or currently unused land. Nonetheless, some SAF proponents including ICAO/CORSIA wish to minimize land-use change emissions from purpose-grown energy crops by asserting that such crops will be largely planted and harvested on marginal, degraded, abandoned, or unused land.[90] This raises many questions. Where in the world are farmers choosing not to utilize viable land? Alternatively, if land appears "unused," might it be providing ecosystem benefits and habitat? How does the community adjacent to that unused or abandoned land understand its value and function? Is it used by anyone or for any purpose? Is it used by grazers or gleaners or hunters or gatherers? Is it a commons, perhaps held temporarily out of production to mitigate risks of droughts or food shortfalls? Are these marginal or unused acres currently delivering ecosystem services—as watersheds, carbon sinks, biodiversity reserves, or refugia for birds and other animals?

Thus, we have two issues related to land-use change: 1. Purpose-grown energy crops will take prime farmland and will not be confined solely to surplus acres: unused, abandoned, degraded, or marginal areas; and 2. Even where energy crops are confined to such areas, they may displace other traditional land uses (grazing, commoning, gleaning, hunting, shifting cultivation, etc.) and ecosystem services (wildlife habitat, water purification, pollinator habitat, etc.).

[90] International Air Transport Association, "SAF Handbook," 15.

8. Land Use Change and Demands Upon Our Earth, *The Big Picture*

> "The demand for harvestable biomass (food, fuel, and fibre) by a growing, wealthier, and increasingly urbanized global human population is placing relentless pressure on the Earth's ecosystems. To a large extent, this demand has been met by converting [natural] ecosystems into production ecosystems—ecosystems modified for the production of one or a few harvestable species.... Although these alterations occur at local scales, their cumulative effect is causing global transformation of the Earth's biosphere.... Humans have already altered more than 75% of the world's terrestrial habitats—nearly 40% of all productive land has been converted into agricultural areas and two thirds of all boreal forests are under some form of management, mainly for wood production...."
> —Nyström et al., *Nature*, 2019.[91]

The preceding chapter looks narrowly and technically at land-use change, but a big-picture, long-term view is even more revealing.

Take 1

Consider SAFs within the larger context of what humans are going to attempt this century:

- Feed two billion more people as our population rises past 10 billion and
- Feed those hundreds-of-millions who do not today have enough to eat and
- Expand a high-land-requirement meat- and dairy-heavy diet to billions more people as populations grow and purchasing power increases (many analysts estimate that global grain production must rise by roughly 50 percent by mid-century, as a result of rising populations, incomes, and meat consumption[92]) and
- Produce biomaterials to replace petroleum plastics and
- Produce more land-sourced biofibres (cotton, hemp, linen, wool) to replace petro-fibres and to clothe a larger population with enlarged purchasing capacities and
- Produce and remove from the land billions of tonnes of energy-system biomass annually for BECCS and
- Produce and remove billions of tonnes of energy-system biomass annually for SAFs and
- Produce the preceding billions of tonnes of food, fibre, and feedstocks even as the global climate deteriorates and impacts on farmers intensify and
- Maximize soil health, soil building, and soil carbon sequestration and
- Find land areas to plant trees in order to draw down CO_2—two billion trees in Canada and perhaps a trillion globally[93]—and
- Do the preceding while simultaneously working to reduce nitrogen fertilizer use—global use of which has now far exceeded planetary boundaries and
- Do all the preceding while trying to use less farmland, in an effort to reverse habitat destruction which is now driving the fastest extinction event in 65 million years.

Placing SAFs in the context of these many proposed 21st century megaprojects leads us to ask: Is there enough land?

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91 Magnus Nyström et al., "Anatomy and Resilience of the Global Production Ecosystem," *Nature* 575, no. 7781 (November 7, 2019): 98.
92 "World must sustainably produce 70 per cent more food by mid-century – UN report," United Nations, UN News, Dec. 3, 2013, https://news.un.org/en/story/2013/12/456912
93 Maxine Joselow, "Republicans Want to Plant a Trillion Trees. Scientists Are Skeptical.," *Washington Post*, August 2, 2023, https://www.washingtonpost.com/climate-environment/2023/08/02/trillion-trees-republicans-climate/ .

Take 2

Let's push SAF out of the centre of our attention and start with a clean sheet of paper. Let's ask: if we really have hundreds-of-millions of acres of farmland not needed for the project of feeding people, what is the best use of that land? Perhaps it would be best to give it back to nature—to slow extinction, create refuges for fast-disappearing birds and other wild animals, protect watersheds and aquifers, maximize soil health and sequestration, and serve as a strategic reserve of potential foodland acres should it turn out that feeding the ten billion amid a deranged climate is harder than we imagine. Alternatively, perhaps it would be best to use that land to plant trees—biological, zero-energy-demand carbon-removal devices that simultaneously provide habitat, beauty, recreation, and spiritual renewal. Using land for tree-planting is negative-emission, whereas using that land for SAF feedstocks produces emissions. As we slide into the jaws of an intensifying polycrisis, we should ask: What is humanity's best use of these hundreds-of-millions of acres? It is unlikely that the answer is: to fuel vacation jets.

Take 3

Those who promote land-based energy systems—SAFs, automobile biofuels, BECCS, etc.—suffer from historical amnesia: they forget the step-by-step process over the past several centuries that led us to this point. Here is a quick reminder of our history and our path to the present.

For many thousands of years, until about three centuries ago, virtually all energies for human systems were sourced from the land. Food energy was land-sourced, of course. But so, too, was heating energy—taken mostly from forest land as firewood, with small additions from dung, straw, peat, etc. Traction and transport energy, too—the energy for horses, oxen, and draft animals—was similarly sourced from the land, as grass, grain, and fodder. The land provided all energies: for heat, food, and movement.[94]

This universal dependence on land-sourced energies imposed limits on human societies and economies. Everything was a trade-off. Cut down forests to create more land to produce food energy and you have less heating energy. Use your farmland acres to grow more fodder and create more pasture for transport and traction energy (horses and oxen) and you have less food energy. For thousands of years, these limits and trade-offs throttled back the growth of human economies and populations, with famine and die-off often being the result of hitting these limits.

Moving forward from that period centuries ago, we see that, one after another, energy demands were *removed* from the land. The first energy demand removed from the land was heating—we began to get more of our heat from coal and less from wood. Next, we began to remove from the land the requirement to provide energy for transport. Trains energized by coal replaced horses and carriages energized by land-sourced grasses, grains, and fodders. Somewhat later, with the proliferation of oil and the creation of the internal combustion engine, we fully removed from the land, in many places, the requirement to provide energy for transport and traction. In places such as North America and Europe, the land was relieved of all demands save for the provision of food energy for people.

But now, seemingly forgetting the steps that led us to our soon-to-be-ten-billion-person mega-civilization, we are about to embark on multiple projects that reimpose onto our landbase requirements to provide heat energy (BECCS electricity to heat homes, etc.) and transport energy (SAFs). That *may* be possible, but a default assumption should probably be that it is not. Moreover, resuming reliance on land-sourced heating and transport fuels should not be seen as some dazzling new high-tech move into the future, but rather a move backward into our past. With SAFs from willow and poplar, we are literally

94 A couple minor exceptions exist: wind-powered sailing ships and water- and wind-powered mills.

considering wood-fired passenger jets (though, admittedly, with exotic-chemistry intermediaries to transmogrify that firewood into kerosene-like liquid fuels).

Figure 12 shows how, over the course of building our mega-civilization, biomass was supplanted by fossil fuels. SAF proponents would have us believe we can now reverse this process: replacing fossil fuels with biomass.

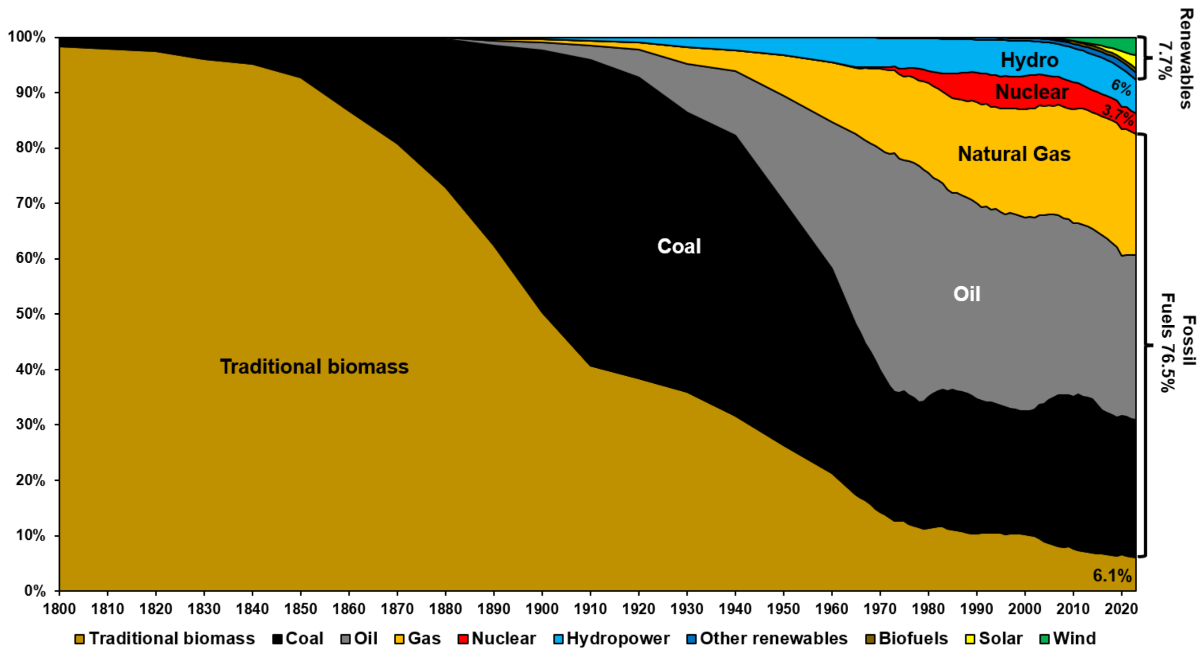

Figure 12. World Primary Energy Consumption, 1800–2023.
Sources: David Hughes, Global Sustainability Research Inc., with data from Energy Institute and Vaclav Smil.[95]

Take 4

Staying with the big picture, as we contemplate removing billions of tonnes of biomass annually, we can acquaint ourselves with the concept of HANPP: Human Appropriation of Net Primary Productivity.

Green plants and other photosynthesizing organisms (incl. algae and bacteria) create solar-energized carbon-rich biomass, the food-energy basis of virtually all life on Earth. "Net primary productivity" (NPP) is the term scientists use when quantifying the tonnage of carbon photosynthesized into organic matter. When plants turn sunlight, water, CO_2, and nutrients into new biomass—roots, stems, trunks, branches, leaves, flowers, fruits, and seeds/grains—those plants create NPP.

"Human appropriation of net primary productivity" (HANPP) is the term scientists use to quantify the portion of annual plant biomass production taken and used by humans: for food, fibre, livestock feed, building materials, paper products, heating fuels, etc. HANPP is a measure of humanity's draw upon the biosphere, and that measure is high: Humans are appropriating nearly 30 percent of terrestrial aboveground NPP—nearly 30 percent of the plant biomass tonnage that grows on land worldwide.[96] This is a remarkable draw for just one species. Until recent centuries, no single species appropriated more than 1 or 2 percent of NPP.

95 Energy Institute, "Statistical Review of World Energy," 73rd ed. (London: EI, 2024); Vaclav Smil, *Energy Transitions: Global and National Perspectives*, 2nd ed. (Santa Barbara, California: Praeger, 2016).

96 Helmut Haberl et al., "Quantifying and Mapping the Human Appropriation of Net Primary Production in Earth's Terrestrial Ecosystems," *Proceedings of the National Academy of Sciences* 104, no. 31 (July 31, 2007): 12943. See also Peter Vitousek et al., "Human Appropriations of the Products of Photosynthesis," *Bioscience* 36, no. 6 (June 1986): 368 & 372. Vitousek estimates HANPP at nearly 40 percent.

Our high rate of HANPP matters for at least two reasons: First, all animals feed on NPP (either directly by eating plants or indirectly by eating animals that eat plants) so, when humans take more we leave other species less. Second, HANPP is a proxy for how much productive land area we have taken for our own—how much physical and biological space we are occupying on the planet.

And though this overall HANPP percentage is high, regional figures in much of Europe and Asia are even higher: above 70 percent.[97] Scientists such as Katherine Richardson, Will Steffen, and Johan Rockström, looking at safe operating limits for planet Earth, conclude that "HANPP is well beyond a precautionary planetary boundary aiming to safeguard the functional integrity of the biosphere and likely already into the high-risk zone."[98]

Take 5

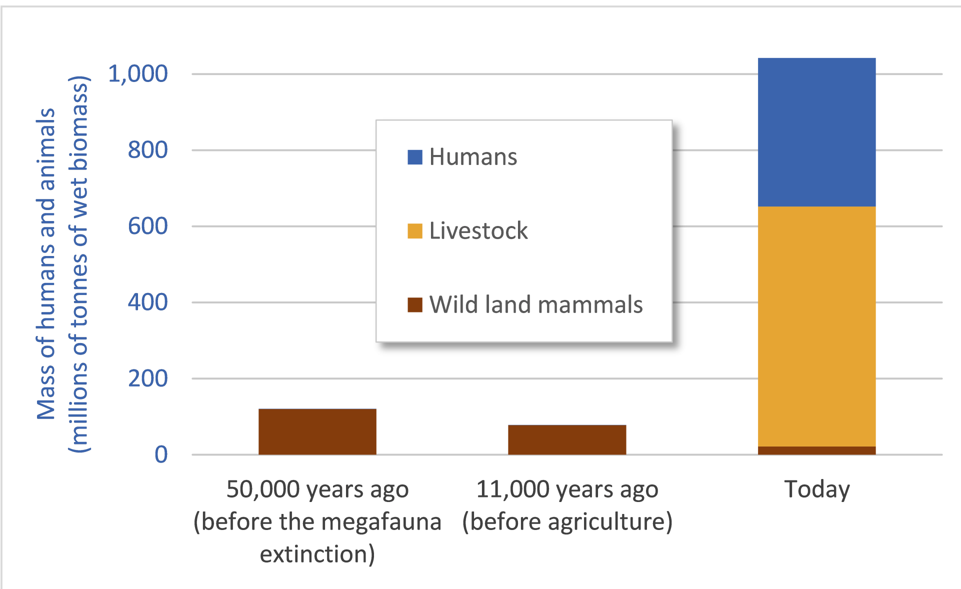

Figure 13. Mass of humans, livestock, and terrestrial wild animals, selected periods.
Sources: Bar-On, Phillips, and Milo; Barnosky; and Smil.[99]

Figure 13 provides another view of humanity's annexation of Earth's NPP and land area. It shows the mass of humans (blue), our livestock (tan), and terrestrial wild mammals (brown). Three periods are shown. On the left is the period 50,000 years ago: before humans were significant factors in most of Earth's ecosystems. In the middle is the period around 11,000 years ago: after humans had spread over most of the Earth but before we began practicing agriculture. (On both the left and in the centre, the mass of humans is very small and not visible on the graph.) On the right is the situation today: We and our livestock dominate the Earth.

97 Helmut Haberl et al., "Quantifying and Mapping the Human Appropriation of Net Primary Production in Earth's Terrestrial Ecosystems," *Proceedings of the National Academy of Sciences* 104, no. 31 (July 31, 2007): 12943. See also Peter Vitousek et al., "Human Appropriations of the Products of Photosynthesis," *Bioscience* 36, no. 6 (June 1986): 368 & 372. Haberl, Table 3, lists rates of NPP appropriation for Europe and Asia as 35 percent to 63 percent (excl. Central Asia and Russian Federation). These NPP percentages include above- and below-ground biomass. Thus, above-ground-only values would be about 15 percent higher than figures in Table 3. Also, see Marc Imhoff et al., "Global Patterns in Human Consumption of Net Primary Production," *Nature* 429 (June 24, 2004): 872. Imhoff et al. list human appropriations of NPP in Western Europe as 72.22 percent and in south-central Asia as 80.39 percent.

98 Katherine Richardson et al., "Earth beyond Six of Nine Planetary Boundaries," *Science Advances* 9, no. 37 (2023).

99 Yinon Bar-On, Rob Phillips, and Ron Milo, "The Biomass Distribution on Earth," *Proceedings of the National Academy of Sciences* 115 (2018); Anthony Barnosky, "Megafauna Biomass Tradeoff as a Driver of Quaternary and Future Extinctions," *Proceedings of the National Academy of Sciences* 105 (2008); Vaclav Smil, *Harvesting the Biosphere* (Cambridge, MA: MIT Press, 2013).

The biomass of humans and our livestock outweigh remaining wild animals 32-to-1, with wild species making up *just 3 percent of terrestrial animal biomass*. This unprecedented mass of humans and livestock upon the Earth has been enabled by humanity's seizure of land for grazing, feedgrain production, and food-crop production—our multiplication of HANPP. And this massive human land-taking is the main reason why the Earth is now undergoing the most rapid extinction event in 65 million years.[100]

The most comprehensive study of life on Earth ever undertaken, the 1,100-page *Global Assessment Report on Biodiversity and Ecosystem Services*, compiled by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), tells us that:

> "The global rate of species extinction is already at least tens to hundreds of times higher than the average rate over the past 10 million years and is accelerating.... Habitat loss and deterioration, largely caused by human actions, have reduced global terrestrial habitat integrity.... Around 9 per cent of the world's estimated 5.9 million terrestrial species—*more than 500,000 species—have insufficient habitat for long-term survival, and are committed to extinction, many within decades, unless their habitats are restored...*" [italics added].[101]

Another study found that "Most of the 177 mammal species we sampled have lost more than 40% of their geographic ranges in historic times, and *almost half have lost more than 80% of their ranges in the period* ~1900–2015" and that "as much as 50% of the number of animal individuals that once shared Earth with us are already gone, as are billions of populations."[102]

In light of the preceding, any planetary megaproject to utilize hundreds of millions of acres of land and extract billions of tonnes of biomass to produce energy, biomaterials, etc. should be looked at with *extreme* thoroughness, caution, and *scepticism*. Scientists estimate that we are already exceeding, by 60 percent, sustainable levels of human appropriation of net primary productivity (HANPP).[103] Yet SAFs are a massive planetary appropriation of yet more NPP. Research by Milo, Bar-On, and others (see Figure 13, above) shows that we have slashed the mass of wild animals, largely as a result of our extraction of biomass, annexation of land, destruction and fragmentation of habitat, and destruction and degradation of remote and wild places. It is in this context that we now contemplate extracting billions of tonnes more biomass to fuel vacation jets. If there is land that is not needed to feed hungry people, and if we have already exceeded the sustainable removal of biomass by perhaps 60 percent, then the wisest move would be to reduce our farmland area and reduce our draws upon the biosphere's plant mass so as to leave space for other species and return HANPP back to within planetary boundaries. And if this reduced farmland area can host grass and trees and thereby draw down carbon/CO_2 and slow warming, we gain yet another benefit.

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100 Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Synthesis, 2005, (Island Press, Washington), 5, 36, & 38.

101 IBPES et al., "The Global Assessment Report on Biodiversity and Ecosystem Services" (Bonn: IBPES, 2019), XXVII.

102 Gerardo Ceballos, *The Annihilation of Nature: Human Extinction of Birds and Mammals* (Baltimore: Johns Hopkins University, 2015).

103 Justin D. K. Bishop, Gehan A. J. Amaratunga, and Cuauhtemoc Rodriguez, "Quantifying the Limits of HANPP and Carbon Emissions Which Prolong Total Species Well-Being," *Environment, Development and Sustainability* 12, no. 2 (April 1, 2010): 213, https://doi.org/10.1007/s10668-009-9190-7.

9. SAFs and Water

> "The world is facing an imminent water crisis, with demand expected to outstrip the supply of fresh water by 40% by the end of this decade.... Governments must urgently stop subsidising the extraction and overuse of water through misdirected agricultural subsidies, and industries from mining to manufacturing must be made to overhaul their wasteful practices, according to a landmark report on the economics of water."
> —*The Guardian*, 2023.[104]

> "With more than 733 million people currently living in areas of high or critical water stress ... and a projected 30% increase in global water demand by 2050 compared to 2010 ..., the role of water access, allocation, and management is key for sustainable economic development. To feed a projected global population of 10 billion in 2050, agricultural production will need to increase by almost 50% compared to 2012 ..., with much of this growth expected to be achieved through irrigation and water capture and storage...."
> —United Nations, *World Water Development Report*, 2024.[105]

> "Without irrigation you just wouldn't have corn on this farm," said [Minnesota farmer Jake] Wildman, who is president of the state's irrigators association. "And the market tells us to raise corn. So you could say that the market is also telling us to irrigate." ... In western Minnesota, applications for new irrigation wells spiked amid the first ethanol boom.
> —*New York Times*, 2023.[106]

> "The water footprint of drop-in fuels produced via HEFA from soybean oil has been estimated at between 2 and 309 gallons of water per gallon of fuel, depending on the irrigation method used and location."
> —U.S. Department of Energy, National Renewable Energy Laboratory (NREL), 2024.[107]

This chapter is a one-page stub: a short mention to highlight the importance of the water issue and to ensure that it is considered in future analyses.

Significant portions of both energy production *and* food production are water intensive. Thus, it is wholly foreseeable that the production and processing of SAFs and their feedstocks will be water intensive. Irrigation, likely for many feedstock acres, will multiply that water intensity. It is beyond the scope of this report to detail water use and limitations for SAFs as we move into a world of 10+ billion people. Nonetheless, *existing* water constraints and shortages and projected future increases in water demand all indicate that extreme caution is warranted before investing trillions of dollars in SAF production systems that will consume many trillions of litres of water annually.

Finally, it is important to look beyond *direct* irrigation-water requirements for SAF feedstock acres to the expanding irrigation demands for agriculture overall. The diversion of farmland to SAF production (tens of millions of acres in the US alone) will require intensified food production elsewhere, *indirectly* driving up irrigation and water demands on farmland overall. Even if 100 percent of SAF feedstocks were unirrigated, the land requirements for those feedstocks will trigger intensified food production on farmland elsewhere, and, hence, irrigation. So, just as there is "induced land use change" (ILUC), there is "induced water use change" (IWUC). The latter is almost universally ignored by SAF analysts.

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104 Fiona Harvey, "Global Fresh Water Demand Will Outstrip Supply by 40% by 2030, Say Experts," *The Guardian*, March 17, 2023, sec. Environment, https://www.theguardian.com/environment/2023/mar/17/global-fresh-water-demand-outstrip-supply-by-2030.

105 UN Water and UNESCO, "The United Nations World Water Development Report 2024: Water for Prosperity and Peace" (Paris: UNESCO, 2024), 34.

106 Bearak, Searcey, and Rojanasakul, "Airlines Race Toward a Future of Powering Their Jets with Corn."

107 Oscar Rosales Calderon et al., "Sustainable Aviation Fuel State-of-Industry Report: Hydroprocessed Esters and Fatty Acids Pathway" (NREL, July 30, 2024), 28, https://doi.org/10.2172/2426563.

10. SAFs and Planetary Boundaries

> "Earth is now well outside of the safe operating space for humanity. ... As primary production [of biomass] drives Earth system biosphere functions, human appropriation of net primary production [HANPP] is proposed as a control variable for functional biosphere integrity. This boundary is also transgressed."
> —Richardson, Steffen, Rockström, et al., "Earth Beyond Six of Nine Planetary Boundaries," 2023.[108]

In Canada, over the past 31 years, agricultural diesel fuel use has doubled;[109] over the past 18 years, nitrogen fertilizer use has doubled;[110] and over the past 14 years, pesticide use has doubled.[111] Farmers doubled the use of these inputs and others in order to increase output—to add millions of tonnes to the annual amounts of grains, oilseeds, legumes, forage and livestock feed, and other biomass we take from our farm fields. Farmers did so partly because agribusiness corporations have farmers on a treadmill where they are relentlessly spurred to produce more and more. More output requires more inputs, as evidenced by the doubling of fuel, fertilizer, and pesticide use.

Like all human systems—like transport, manufacturing, housing, mining, forestry, fisheries, etc.—agricultural production is creating environmental problems. For agriculture, these problems include GHG emissions, ocean dead zones created by fertilizer run-off, pesticide-induced reductions of insects and birds, tree removal and deforestation, destruction of wetlands, etc.

Again, like all human systems, agriculture is crashing past planetary boundaries. Virtually all human systems are now unsustainable. Agriculture is not an exception—not uniquely sustainable or benign. Nothing in this report is an indictment of agriculture, farmers, or farming, but rather a clear-eyed assessment that in a global petro-industrial system that has moved far outside the safe operating limits of planet Earth, agriculture has done so, too. It is within this context—human systems far outside of sustainable limits and moving farther outside—that we should evaluate SAF proposals.

Over the past decade-and-a-half, scientists Will Steffen, Johan Rockström, Katherine Richardson, and dozens of others have developed and refined the concepts of "planetary boundaries" and "the safe operating space for humanity."[112] Their peer-reviewed academic articles have been published in top journals such as *Nature* and *Science*. In these reports, the authors detail several domains in which humans have pushed farthest past Earth's safe operating limits, including:

1. biodiversity loss (humans are driving the fastest extinction rates in millions of years);
2. nitrogen and phosphorus fertilizer tonnage; and
3. Land-use change (see Figure 14).

108 Katherine Richardson, Will Steffen, Johan Rockström, et al., "Earth beyond Six of Nine Planetary Boundaries," *Science Advances* 9, no. 37 (September 15, 2023).

109 Data provided by Environment and Climate Change Canada (ECCC) upon request; see also National Inventory Report (NIR).

110 Statistics Canada Tables 32-10-0274-01 and 2-10-0039-01.

111 Health Canada, Pest Management Regulatory Agency (PMRA), "Pest Control Products Sales Report," various years (Ottawa: PMRA); United Nations Food and Agriculture Organization (UN FAO), FAOStat: Pesticides Use, https://www.fao.org/faostat/en/#data/RP

112 Johan Rockström et al., "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society* 14, no. 2 (2009); Johan Rockström et al., "A Safe Operating Space for Humanity," *Nature* 461, no. 7263 (2009); Wim de Vries et al., "Assessing Planetary and Regional Nitrogen Boundaries Related to Food Security and Adverse Environmental Impacts," *Current Opinion in Environmental Sustainability* 5, no. 3 (2013); Will Steffen et al., "Planetary Boundaries: Guiding Human Development on a Changing Planet," *Science* 347, no. 6223 (2015); Katherine Richardson et al., "Earth beyond Six of Nine Planetary Boundaries," *Science Advances* 9, no. 37 (September 15, 2023).

All these boundary breaches will be exacerbated by the SAF project to produce, remove, process, and combust billions of tonnes of grains, oilseeds, agricultural residues, and energy crops—trees and grasses.

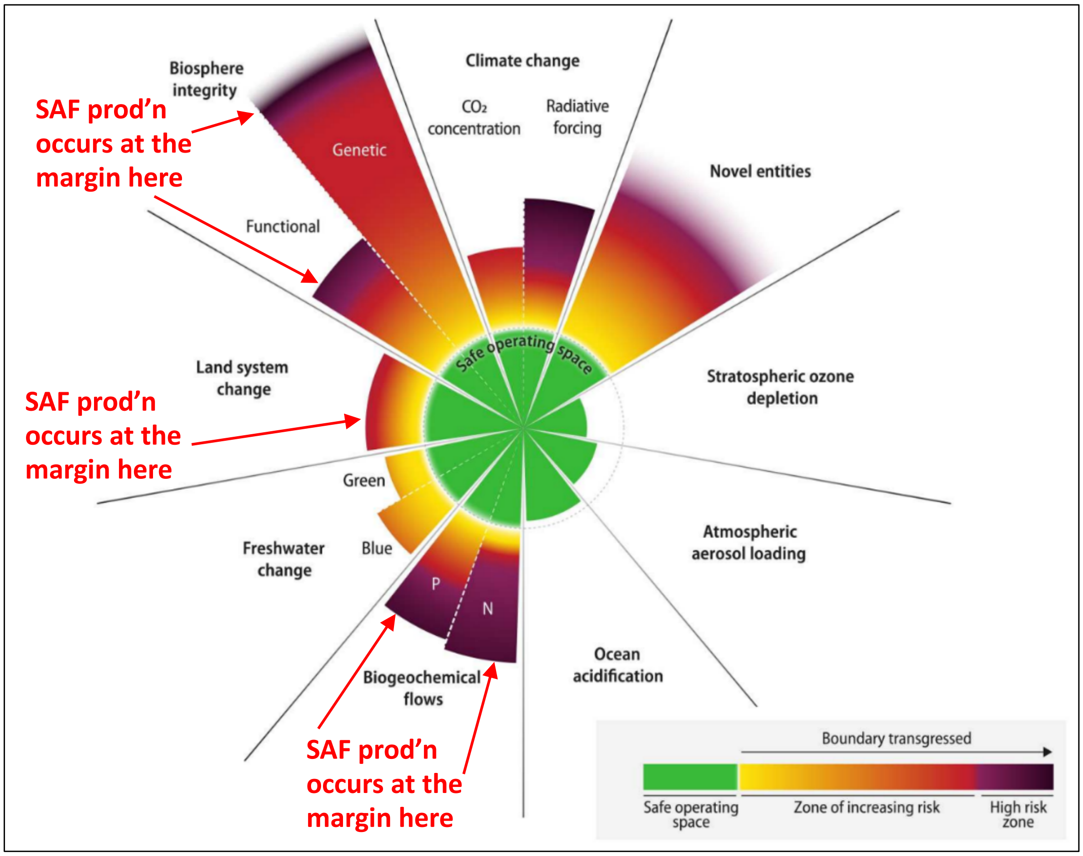

Figure 14. A diagram of human transgressions of planetary boundaries.
Source: Richardson, Steffen, Rockström, et al., "Earth beyond Six of Nine Planetary Boundaries," 2023.[113]
Notes: In the above diagram, under "Biogeochemical flows," N and P are short for nitrogen and phosphorus, i.e., mainly fertilizer use. And "Biosphere integrity" and "Functional" can be thought of as correlating to habitat and species losses.

Crucial to understand is this: even if SAF production is wholly neutral in its impacts on the environment—with no new or additional adverse effects—even if, by some unexpected miracle, it in no way makes things worse, it will still be unsustainable, because most metrics are already well into unsustainability territory. SAF production will take place at the margins—on the outer edge of those red/purple wedges above—far outside the sustainability space. If nitrogen flows are already unsustainable (see N wedge at bottom), flowing in more nitrogen to produce SAF feedstocks cannot be sustainable. Similarly, if biomass removal (HANPP) is already unsustainable, the additional biomass required by SAFs cannot be produced sustainably. If land system change is already unsustainable, allocating millions of acres to fuel production cannot be sustainable. *Sustainable* Aviation Fuel is a misnomer.[114]

113 Katherine Richardson, Will Steffen, Johan Rockström, et al., "Earth beyond Six of Nine Planetary Boundaries," *Science Advances* 9, no. 37 (September 15, 2023): Fig. 1.

114 One of the expert reviewers who read a draft of this report pointed out that the UN agency International Civil Aviation Organization (ICAO)—the agency that oversees CORSIA—has engaged with civil society and non-governmental organizations (NGO) regarding sustainability, biodiversity, food security, etc. This NFU report has not accessed information on that process but will endeavour to do so and to understand ICAO's consultation process and how that may have shaped the global SAF initiative.

11. SAFs and Food Prices

> "Following an intense lobbying campaign by the [U.S.] ethanol industry, the Treasury's recent guidance allows for the use of an alternative model, a version of GREET [Greenhouse gases, Regulated Emissions, and Energy use in Transportation], which opens the door for corn ethanol and other crop-based biofuels to qualify for the credit. Major U.S. airlines supported the ethanol industry's push despite previously agreeing that SAF production should not compete with food production."
> —World Resources Institute, 2024.[115]

> "I do worry over the longer term, though, on sustainable aviation fuels … what's that going to do to food prices going forward? ... I think we're going to reach a point in the next 10 or 20 years where there will be challenges posed not just for the airline industry, but for industry in general, around sustainable aviation fuels where it may have an upward impact on food prices."
> — Michael O'Leary, CEO of Ryanair, 2021.[116]

> "The Renewable Fuel Standard (RFS) specifies the use of biofuels in the United States and thereby guides nearly half of all global biofuel production.... We find that the RFS increased corn prices by 30% and the prices of other crops by 20%...."
> —Lark et al., "Environmental Outcomes of the US Renewable Fuel Standard," 2022.[117]

> "As a response to higher crop prices encouraged by biofuel production, households and firms will *reduce their crop consumption* or increase the consumption of their substitute" [italics added].
> —Zhou et al., "Estimated Induced Land Use Change Emissions....," 2021.[118]

SAF may come to stand for "Sacrificing Affordable Food." It is likely that entire reports will be needed on this important topic. Here, we simply raise the issue and begin to sketch the magnitude of the problem.

Perhaps anecdotally, Global olive oil prices have doubled over the past three years (though, admittedly, climate-related production problems have played a role).[119] In Canada, margarine, made from canola oil, is up 40 percent since 2022.[120] But perhaps this is not anecdotal: analysts are now talking about the coming "big oil deficit" driven by biofuel/vegetable-oil demand set to "explode."[121]

It is hard to predict the magnitude of food-price impacts because there are many unknowns:

- How sincere and committed are airlines and fuel providers to actually undertaking the herculean scale-up needed to reach future SAF supply targets?
- How much SAF feedstock will come from conventional crops such as corn, soy, and canola?
- To what extent will any expansion of those crops displace other crops and reduce supplies?

115 Lashof and Denvir, "Under New Guidance, 'Sustainable' Aviation Fuel in the US Could Be Anything But."
116 Anmar Frangoul, "Sustainable Jet Fuel Targets Could Push Food Prices Higher, Ryanair CEO O'Leary Warns," CNBC, October 21, 2021, https://www.cnbc.com/2021/10/21/ryanair-ceo-worried-about-sustainable-aviation-fuel-and-food-prices-.html.
117 Tyler Lark et al., "Environmental Outcomes of the US Renewable Fuel Standard," *Proceedings of the National Academy of Sciences* 119, no. 9 (March 2022).
118 Xin Zhao et al., "Estimating Induced Land Use Change Emissions for Sustainable Aviation Biofuel Pathways," *Science of The Total Environment* 779 (July 20, 2021): 4.
119 Natalie Stechyson, "Olive Oil Is How Much Now? Prices Jump — Again — amid Worldwide Shortage," *CBC News*, May 16, 2024, https://www.cbc.ca/news/business/olive-oil-price-1.7203884.
120 Statistics Canada, Table 18-10-0004-01.
121 Norman, "Feed Markets and the 'Big Oil Deficit.'"

- How much will purpose-grown energy crops such as grasses and trees compete for farmland, potentially displacing food crops and reducing supplies?

Despite these unknowns, in light of the potentially devastating impacts on the world's poorest families, it is prudent to assume a significant negative impact on food prices. Airlines now spend about $280 billion USD per year on fuel, globally.[122] Those airlines plan to double or triple air travel by mid-century. SAFs will be significantly higher in prices than conventional fossil-fuel Jet A. Thus, driven primarily by a plan to multiply air travel, airline expenditures on fuel may quadruple, or more, by mid-century—exceeding $1 trillion USD per year (in 2024 dollars). Granted, not all of that money will flow into food markets, but a significant amount will, either to purchase grain and oilseed feedstocks in the near term, or to purchase purpose-grown energy crops in the medium-term. Even a portion of that perhaps $1 trillion per year will exert upward pressure on food prices. Worse, as noted above, this food and land demand from SAFs will come atop other demands: to feed one or two billion more people; to expand dairy- and meat-heavy (and land-costly) diets to a growing global middle class; to produce additional land-sourced fibres and materials to replace petro-fibres and plastics, etc. Demands for food, fuel, fibre, and biomaterials from our farmland will increase dramatically in coming decades. Supplies will be constrained by efforts to hold land area, fertilizer use, and irrigation water use constant (or reduce the use of each). Rising demands intersecting with constrained supplies will mean increasing prices. SAFs are just one part of this equation, but unlike feeding people, SAFs are wholly *optional* uses of our farmland, especially because superior transportation alternatives exist (for those alternatives, see Ch. 20).

122 International Air Transport Association, "Industry Statistics: Fact Sheet."

12. SAFs and Justice

> "Globally, 1% of the world's population produces 50% of aviation emissions, while approximately 80% have never set foot on a plane."
> —Chapman, Mang, and Magdalena, "A Frequent Flying Levy in Europe...," 2024.[123]

> "Only a small minority of the global population will ever set foot on a plane, and even within the richest nations, most flights are taken by just a few people. When it comes to climate change, air travel is a uniquely damaging behaviour, resulting in more emissions per hour than any other activity [except] starting forest fires. ... It is also uniquely iniquitous. Everybody eats. But only the privileged few fly."
> —Hopkinson and Cairns, "Elite Status: Global Inequalities in Flying," 2021.[124]

About 4 percent of the global population take international air flights and *just 1 percent account for most of the miles in the air*.[125] The one or so percent of the global population that does most of the flying has a problem—large and rapidly growing GHG emissions from their preferred mode of travel. And this, in a world that must soon reach net-zero emissions. The solution to the problem faced by this one percent is SAFs. But those SAFs have impacts on 100 percent of people, including ecosystem damage and higher food prices. This last issue is one of justice. Everyone eats, but only a few fly. And if SAFs drive any significant land use competition (either for grains and oilseed production or the production of purpose-grown energy crops) then this can be seen as transferring land/wealth from poor food buyers to rich air travellers. Indeed, this is largely what is proposed, as airline trade groups speculate about growing SAF feedstocks for the traveling rich on the land in some of the world's poorest nations (see next chapter).

SAFs repurpose farmlands from food production, something that serves 100 percent of people, to aviation fuel production, something that serves a few percent. SAFs are yet another way that the world's richest people take for themselves an inordinate and unjust portion of the planet's resources.

Moreover, moving the sources for jet fuel from oil fields to farm fields will have the wholly predictable effect of accelerating land grabbing—undermining local ownership and control, local food production, and Food Sovereignty. The SAF project is one of global land colonization—imposing upon lands the new requirement to fuel business and vacation travel.

Further, in previous biofuel initiatives, one country could choose to produce such fuels and do so mostly using its own land, e.g., the US could produce ethanol from its corn acres but other nations could choose not to use their lands in these ways. But, because global air travel is a wholly integrated system, SAFs require a *global* project: production in most nations—production that may become increasingly mandatory as time goes on. The decision to pursue SAFs as an aviation decarbonization strategy is a de facto decision to require most nations to allocate some of their acres to fuel biomass production (see next chapter).

The brevity of this chapter should in no way indicate that this is a small issue: just the opposite. In a world soon to host 10 billion souls, and with hundreds of millions going to bed hungry today, and with millions dying for lack of food, the injustice of using foodland to fuel vacation jets may, indeed, be the largest and most grave issue touched on in this report. Many future reports and analyses must be written about these injustices, and the need for governments to ensure they are not complicit.

123 Alex Chapman, Sebastian Mang, and Magdalena Heuwieser, "A Frequent Flying Levy in Europe: The Moral, Economic, and Legal Case" (London: New Economics Foundation and Stay Grounded Network, October 2024).

124 Lisa Hopkinson and Sally Cairns, "Elite Status: Global Inequalities in Flying" (Possible, March 2021).

125 Stefan Gössling and Andreas Humpe, "The Global Scale, Distribution and Growth of Aviation: Implications for Climate Change," *Global Environmental Change* 65 (November 1, 2020): 102194, https://doi.org/10.1016/j.gloenvcha.2020.102194.

13. SAFs and the Non-Rich World

> "SAF can generate economic benefits to all regions of the world, but especially developing nations, that have non-productive land for food crops which can be suitable for producing SAF feedstock."
> —Air Transport Action Group (ATAG), 2023.[126]

> "For many developing countries, SAF represents a significant economic and employment opportunity.... SAF can also provide economic benefits to parts of the world that have large amounts of land that qualifies as marginal, abandoned, or unviable for growing food, but is suitable for growing energy crops.... Many of these countries are developing nations that could benefit greatly from a new industry such as SAF production with the added benefit that it does not negatively impact their local food production and in some cases could actually strengthen the agricultural sector and improve food security for the region."
> —ATAG, 2023.[127]

An entire report could be written on the potential for SAFs to compete for land, undermine food availability, and raise prices in the poorest and most food-insecure nations. Here, we merely touch on these negative prospects. To get some sense of what might be happening or planned, we look briefly at Kenya.

Kenya Airways' Senior Manager of Innovation and Sustainability, Grace Vihenda, stated on a recent podcast regarding SAFs:

> "When it comes to bio-feedstocks, we have quite a bit, the weather is perfect and we have a lot of land for energy agriculture, which means if people want to plant, say, for example, castor or jatropha for bio-feedstocks.... To be truly sustainable in this journey of SAF, in my opinion, we have to set up locally, because there is everything we need to set up locally, and if the major manufacturers are not willing to do it, it doesn't mean we don't have capability in Kenya."[128]

Energy transnationals have also focused on Africa and countries such as Kenya as potential feedstock suppliers for biofuels, including SAFs. Italian oil company Eni supplied the biofuel for Kenya Airways first SAF-powered flight. According to one report:

> "Italian oil giant Eni ... has promised to create an entirely new supply chain of 'sustainable oils' from agricultural crops and has set up partnerships with six African countries in order to develop 'agri-hubs' that will supply vegetable oil for its refineries. The main crop that Eni is betting on, castor, is advertised as being drought-resistant and suitable for planting on poor quality land. In Kenya alone, Eni aims to enrol 400,000 farmers producing up to 200,000 tonnes a year by 2027."[129]

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126 Air Transport Action Group, "Beginner's Guide to Sustainable Aviation Fuel," 13.

127 Air Transport Action Group, "Beginner's Guide to Sustainable Aviation Fuel," 10.

128 Sustainability in the Air, "How Kenya Airways Plans to Unleash the Country's Untapped SAF Potential," accessed June 20, 2024, https://green.simplifying.com/p/grace-vihenda-kenya-airways?publication_id=1539074&utm_campaign=email-post-title&r=2nfxf0&utm_medium=email.

129 "Uncovered: Italian Oil Giant's African Biofuels Gamble Falls Short," Transport & Environment, July 1, 2024, https://www.transportenvironment.org/articles/uncovered-italian-oil-giants-african-biofuels-gamble-falls-short-of-green-promises.

Eni and similar companies state that they plan to grow energy crops on "degraded, semi-arid or abandoned land that are not in competition with the food supply chain."[130] Many would wonder, though, why such acres could not instead be regenerated to grow food rather than energy crops?

Contrast the energy- and airline-industry plans for energy crop production, above, with these assessments of Kenyan food insecurity and hunger:

> "As parts of Somalia, Kenya and Ethiopia enter an expected sixth failed rainy season—the longest on record—and South Sudan, suffers a fifth consecutive year of severe flooding, 29 million people across the region are already experiencing severe hunger. In Kenya, data shows an unprecedented deterioration in the country's food security situation with the number of people facing severe hunger expected to rise by one million (from 4.4 million to 5.4 million) between March and June this year."
> —Oxfam, March 2023.[131]
>
> "Communities across Africa including in Kenya, Nigeria, Ethiopia, and Somalia are facing the worst food crisis seen in 40 years. ... Parents are being forced to skip meals so that their children can eat—sometimes not eating for days themselves. Children are being taken out of school to work to earn money, or to be sent to beg in nearby towns. According to the UN, 46 million people in Africa experienced hunger in the aftermath of the Covid-19 pandemic...."
> —British Red Cross, December 2023.[132]

In light of these assessments of human suffering—of hungry children begging so they can eat—who would not ask: if this "degraded" African land can grow castor or energy-crop grasses or trees, can it not grow fruit trees or berry bushes, pasture livestock, or in some way contribute to feeding people?

The bulk of SAF feedstocks from Kenya and elsewhere are shipped back to the EU and a significant part of the subsequent fuel is going to EU-based airlines.[133] African land is powering EU travel, not African.

The human population of the African continent is expected to be almost twice as large in 2050 as in 2020—2.5 billion people versus 1.4. In light of this, it seems unwise to assume that African lands can shoulder the added burden of producing fuel for vacation and business jets. Note also that Africa's most iconic species are firmly on the path to extinction: rhinos, tigers; lions; elephants; giraffes; leopards; cheetahs; and gorillas.[134] Thus, if there exists African land that is surplus to the need of feeding people, is jet-fuel production its best use? Will we prioritize flying over saving elephants and lions from oblivion?

This section is too brief to establish whether SAFs will undermine food security and increase starvation in the world's lowest-income regions, but the risks are large. These risks must be evaluated within the context outlined above: the massive quantities of biomass feedstocks (grains and oilseeds, energy crops, and/or crop residues) seemingly needed from the planet's croplands. Many SAF producers point to used cooking oil, agricultural "wastes," and other seemingly benign feedstocks; they point to using only non-agricultural or "abandoned" land, so as not to compete with food production; but sophisticated observers of global energy and food markets will feel immediate concerns as to how multi-billion-dollar aviation and energy industries, desperate for billions of tonnes of SAF feedstocks, may govern themselves amid poor farmers and other citizens in places such as Africa, Asia, and South America.

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130 Eni SpA, "Our Activities in Kenya," accessed July 1, 2024, https://www.eni.com/en-IT/actions/global-activities/kenya.html.

131 "Hunger Soars in East Africa as Sweeping Aid Cuts and Another Failed Rainy Season Looms," Oxfam GB, March 27, 2023, https://www.oxfam.org.uk/media/press-releases/hunger-soars-in-east-africa-as-sweeping-aid-cuts-and-another-failed-rainy-season-looms/.

132 "Africa Food Crisis: More Than 150 Million People Are Going Hungry," British Red Cross, accessed June 20, 2024, https://www.redcross.org.uk/stories/disasters-and-emergencies/world/africa-hunger-crisis-100-million-struggling-to-eat.

133 "From Farm to Fuel: Inside Eni's African Biofuels Gamble," Transport & Environment, July 1, 2024, https://www.transportenvironment.org/articles/from-farm-to-fuel-inside-enis-african-biofuels-gamble.

134 Franck Courchamp et al., "The Paradoxical Extinction of the Most Charismatic Animals," *PLOS Biology* 16, no. 4 (April 12, 2018): e2003997, https://doi.org/10.1371/journal.pbio.2003997.

14. SAFs and Competition for Clean Energy and Green Hydrogen

> "low-carbon electricity generation ... is an absolute requirement for aviation to reach net zero CO_2 emissions by 2050. ... Making alternative aviation fuels could increase the industry's electricity demand by up to 10,000 TWh (36EJ) by 2050, *adding roughly the equivalent of half of all electricity produced globally in 2021*..." [italics added].
> —International Air Transport Association (IATA), 2023.[135]

> "Aviation could require in excess of 100 million tonnes of hydrogen by 2050 (about as much as the whole global hydrogen production today).... Furthermore, about 99% of all hydrogen used today is not green.... The scaling-up of green hydrogen production from this very low base is absolutely necessary for aviation to reach its net zero goals...."
> —International Air Transport Association (IATA), 2023.[136]

> "The central problem is that a number of these feedstocks have other potential markets. ... Hydrogen, a key input into advanced biofuels conversions processes and most importantly power-to-liquids, has many potential downstream markets in the power sector, transportation sector, and heavy industry. There will be competition for the lowest carbon hydrogen, which SAF producers will need...."
> —Canadian Council on Sustainable Aviation Fuel (C-SAF), 2023.[137]

> "There is, however, an opportunity cost in devoting clean energy resources to decarbonizing aviation when these limited resources could be deployed to decarbonize other, more essential sectors through less energy-intensive means...."
> —Institute for Policy Studies and Inequality.org, 2024.[138]

The net-zero-by-2050 aviation project requires huge amounts of clean solar and wind electricity and huge amounts of zero-emission green hydrogen—quantities of clean electricity and green hydrogen that are *multiples* of current global production. Thus, decarbonizing aviation via SAFs will require a large build-out of these electricity and hydrogen supplies. But so, too, will the decarbonization of everything else. The large demands from aviation for clean energy and green hydrogen will come atop, and *be in competition with*, large demands for electricity and hydrogen to decarbonize home heating, industry, other forms of transport, and even just the existing electricity grid. For *many decades* to come, supplies of clean electricity and green hydrogen will continue to fall short of potential needs. Thus, it is prudent to ask: On top of the home-heating decarbonization megaproject, the electrify-all-the-cars-with-clean-electricity megaproject, the decarbonize heavy industry megaproject, etc. should we add the SAFs megaproject? To put it another way, is it not likely that by adding yet another huge demand source for energy and hydrogen we will delay decarbonization elsewhere? Will SAFs lead to emissions reduction? ...or emissions *shifting*? ...as ambitious decarbonization of the aviation sector slows decarbonization elsewhere as a result of constrained resources to produce the needed clean energies and green fuels?

SAFs and clean electricity

Net-zero global GHG emissions by 2050 is an *ambitious* goal. Properly understood, it requires near-wartime levels of activity. For the global electricity system, we are, in effect, planning to:

135 International Air Transport Association, "Energy and New Fuels Infrastructure: Net Zero Roadmap," 2.
136 International Air Transport Association, "Energy and New Fuels Infrastructure: Net Zero Roadmap," 2.
137 Allan, Goldman, and Tauvette, "The C-SAF Roadmap: Building a Feedstocks-to-Fuels SAF Supply Chain in Canada," 46.
138 Kalena Thomhave, Omar Ocampo, and Chuck Collins, "Greenwashing the Skies: How the Private Jet Lobby Uses 'Sustainable Aviation Fuels' as a Marketing Ploy" (Washington, DC: Institute for Policy Studies and Inequality.org, May 2024), 12.

1. Decarbonize current electricity generation by replacing remaining fossil-fuelled power-stations (coal and natural gas) with clean, renewable options such as solar and wind;

2. Transfer the home-heating energy load from fossil fuels such as natural gas to electricity via the installation of heat pumps and similar technologies;

3. Transfer the light-vehicle energy load from gasoline and diesel fuel to electricity via EVs;

4. Probably transfer the energy load for heavy trucks to electricity, too;

5. Transfer much of the energy load for industry from natural gas and coal to clean electricity;

6. Add large amounts of capacity to power artificial intelligence (AI) data centres;

7. Install still more clean generating capacity to make green hydrogen (see next section); and

8. Add another large increment of clean-energy-generating capacity to supply a larger global population (billions more people) and a growing economy. (In the 20th century, the global economy grew sixteenfold! It will grow less in the 21st, but still by a multiple.)

To accomplish all the preceding, we must multiply our overall electricity generating capacity; increase our clean energy generating capacity by an even larger multiple; and increase the capacity of our distribution grids, perhaps by a multiple. In the face of these daunting tasks, is it wise to blithely add to our "to do" list yet another green-energy megaproject? Is it reasonable to assume we can accomplish all the above and also create enough additional surplus capacity to produce a large portion of the SAFs needed for a doubled or tripled air-travel sector? Recall: "Making alternative aviation fuels could [require] ... adding roughly the equivalent of half of all electricity produced globally in 2021."

Here is a bracing assessment from the United States Department of Energy (US DOE):

> "E-fuels by their nature will be reliant on the accessibility of abundant, very low-cost, and low-carbon electricity and/or hydrogen produced from sources such as wind, solar, hydropower, and nuclear. With an energy intensity on the order of about 100 kWh/gal e-SAF, moving forward, one of the greatest enablers to producing SAF will be the rapid and sustained build-out of renewable electricity infrastructure.... If the 35-billion-gal/yr [U.S. 2050] target were met entirely with e-fuels, estimates show that nearly 3,500 TWh of electricity would be required, *representing a more than 5-times increase from current wind and solar generation levels*.... Hitting 35 billion gallons of SAF per year would draw significantly from domestic low-carbon resources and likely *face competition from a variety of other use cases*" [italics added].[139]

Just to produce Electro-SAFs, the US may have to increase its solar and wind generating capacity *five-fold*. Again, this comes atop demands for clean energy to decarbonize heating, industry, and transport.

SAFs and green hydrogen

Even more than clean energy, supplies of green hydrogen will be in short supply. IATA projects 2045 demand for green hydrogen at nearly 100 million tonnes annually.[140] Current production of low-emission ("blue") and zero-emission ("green") hydrogen is just 1–2 million tonnes annually[141]—implying

139 Grim et al., "The Challenge Ahead," 8.
140 International Air Transport Association, "Energy and New Fuels Infrastructure: Net Zero Roadmap," 3.
141 International Energy Agency, "Global Hydrogen Review 2023" (IEA, 2023), 13.

the need for a fifty-fold scale-up, *just for aviation*. And this massive increase in demand for hydrogen for aviation will come alongside similar multiplications in demand from many industries and economic sectors which are counting on green hydrogen supplies to solve their emission problems.

Given this massive projected reliance on hydrogen, a couple things to consider:

1. Green hydrogen is energy inefficient. If we use clean electricity directly, in an EV or train or factory motor, the usable work from that device is probably about 90 percent efficient—90 percent of the energy in the electricity comes out as usable work and only 10 percent is lost as heat and noise. But if we turn that green electricity into hydrogen and then convert that hydrogen back into electricity in a fuel cell (perhaps in a bus or train) overall system efficiency is much lower. And it is much lower still if we turn it into liquid or gaseous fuel and then combust it, as there are very large heat losses; and

2. It will take a massive scale-up of green hydrogen just to decarbonize *current* hydrogen uses. One of the largest uses is nitrogen fertilizer production. Nearly all that production uses grey hydrogen—from fossil fuels with attendant GHG emissions. Merely decarbonizing *existing* hydrogen uses will probably demand all foreseeable green hydrogen scale-up for many years to come—perhaps decades. If we are severely challenged to decarbonize *existing* hydrogen uses, there simply will not be any new green hydrogen available for novel uses, such as SAFs.

That last point means that until we decarbonize existing hydrogen uses, it is premature to imagine adding new demands. To do so, amid very constrained supplies of green hydrogen, will simply delay decarbonization elsewhere. If using more green hydrogen for SAFs production means less green hydrogen for fertilizer production we have emissions shifting, not emissions reduction. Figure 15, right-hand side, shows the many sectors that may want to rely on green hydrogen for decarbonization.

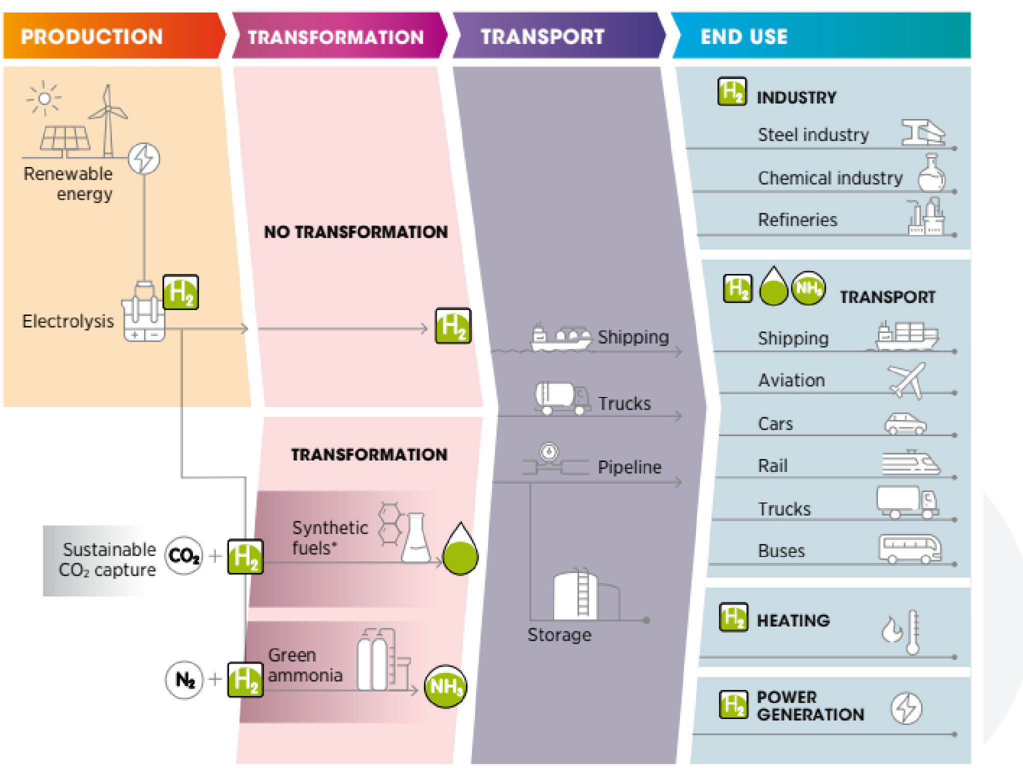

Figure 15. Projected end-uses for green hydrogen.
Source: Reproduced from International Renewable Energy Agency (IRENA).[142]

142 International Renewable Energy Agency, "Green Hydrogen: A Guide to Policy Making" (Abu Dhabi: IRENA, 2020).

Note that both the aviation sector *and* the ocean-shipping sector may vie for green hydrogen.

> "Strategic developments in the [ocean] shipping and aviation sector should be in line with the objectives of reducing carbon emissions.... But huge efforts are needed to achieve a zero-carbon emission of both transport sectors because, given the estimations of the International Energy Agency, aviation sector requires about 220 Mton/year of biofuel oil equivalents to fully decarbonized, while ... the case of shipping sector is a little bit higher, amounting to 240 Mton/year of oil equivalents...."[143]

Thus, to the quantities of hydrogen and other feedstocks needed to decarbonize aviation, there may be an added demand, just as large, to decarbonize ocean shipping. And if heavy trucking cannot be decarbonized with battery-electric vehicles, that sector may also require comparable amounts of hydrogen. And it remains unclear whether we will electrify freight trains or whether those, too, will attempt to rely on hydrogen.

With low-emission (blue and green) hydrogen production effectively at zero today, is it reasonable to assert that multiple economic sectors can simultaneously and successfully scale up hydrogen production to decarbonize fertilizer production, aviation, ocean shipping, trucking, heavy industry, building heating, and a range of other uses? Are those who point to hydrogen as a decarbonization solution deceiving themselves? ...or us?

The colours of hydrogen

Grey hydrogen (H), most common now, is made from natural gas (CH_4), and the excess carbon (C) is released into the atmosphere as carbon dioxide (CO_2); Blue hydrogen is produced similarly, but much of the CO_2 is captured and not released; Green hydrogen is produced without GHG emissions, often by using renewable electricity from solar panels or wind turbines to split water (H_2O) via electrolysis into hydrogen (H) and oxygen (O_2).

Competition for clean energy and green hydrogen: conclusion

Ambitious efforts to reduce emissions from business-travel and vacation jets may slow emissions reduction in other sectors. There is only so much green hydrogen, clean electricity, farmland area, and harvestable biomass to go around; well past 2050, there will be too little. Commenting on SAFs, one analyst notes that "To bring these fuels to the scale needed would ... take resources away from more urgent decarbonization priorities."[144]

This is an especially crucial issue as the SAF megaproject is an *energy hog*—requiring *huge* quantities of energy and energy-derived hydrogen. SAFs require so much energy, partly because of their inherent inefficiencies. As this report details below, within the bounds of continents, trains provide a more feasible and much more energy-efficient option. Moving the same number of passengers the same distance on trains requires a fraction of the energy. As we move into a future of rapidly rising clean-energy demands and constrained supplies, choosing options that minimize overall energy requirements is key to success. SAFs fail this test.

Here is an assessment from the U.S. Department of Energy:

143 Ana Arias et al., "Assessing the Future Prospects of Emerging Technologies for Shipping and Aviation Biofuels: A Critical Review," *Renewable and Sustainable Energy Reviews* 197 (June 1, 2024): 3.

144 Milman, "'Magical Thinking.'"

> “Demand for jet fuel [is] expected to more than double by 2050 and triple by 2070.... However, with the demand for sustainable carbon resources anticipated to rise sharply in the coming decades across multiple other use cases (green chemicals, biohydrogen, bioenergy plus carbon capture, biomethanol, and other strategic fuels including marine and renewable diesel), there is some concern that as competition for this limited resource grows, it could impact the ability to wholly satisfy the projected sharp rise in demand for SAF.”[145]

To conclude this section, a systems-thinking assessment from a 2023 science journal article:

> “This paper examines aviation decarbonisation roadmaps from a system perspective. Clearly, the societal goal is not to achieve ‘net zero’ of one single sector, but to maximise our chances of averting catastrophic climate impacts.... If decarbonising one sector undermines the opportunity of transitioning other parts of the global socio-economic system, then questions need to be asked as to how allocation of scarce resources (here, land and clean energy) should be prioritised. Understanding the consequences of one sector's climate action on the ability to achieve collective mitigation goals is crucial. ... The real-world availability of clean primary energy at present and for the foreseeable future is limited. In terms of achieving global decarbonization, clean energy, just like land, represents a scarce resource. SAF is only one amongst many potential uses.”[146]

Especially relevant to the BECCS vs SAFs trade-off, that journal article goes on to note the “opportunity costs” of SAFs, i.e., the things we won’t be able to accomplish if we prioritize SAFs. It states: “Every unit of biomass or electricity dedicated to SAF is lost to other uses. Consuming electricity to produce e-kerosene represents a major opportunity cost of decarbonising other sectors, including the electricity sector itself.”

145 Grim et al., “The Challenge Ahead,” 1–2.
146 Becken, Mackey, and Lee, “Implications of Preferential Access to Land and Clean Energy for Sustainable Aviation Fuels,” 2–3.

15. Agricultural Emissions and SAFs

The aviation sector wants to make very significant progress toward net zero by 2050. But so does the agricultural sector. And even as farmers and governments struggle to reduce agricultural emissions, the SAF megaproject will almost certainly drive them up!

SAFs may require increased crop output (for the portion derived from grains and oilseeds); increased removals and deliveries of crop residue biomass (straw, corn stover, husks, chaff, etc.); and additional land planted to purpose-grown energy crops. The impacts on agricultural emissions include:

1. **More fertilizer use and attendant emissions.** Increased production of crops—either energy crops or grain and oilseed crops—will require more fertilizer. In addition, the removal of crop residue biomass will also remove nitrogen, phosphorus, and potassium nutrients, again requiring additional synthetic fertilizers to replace a portion of the tonnage removed. Increased fertilizer use will increase agricultural emissions, both in the production of those fertilizers and, in the case of nitrogen, from in-field GHG emissions.

2. **Lower rates of soil carbon sequestration.** As currently modeled in Canada's National Inventory Report (NIR), soil carbon changes are a function of "the change in crop productivity/crop residue C input to soils...." Soil carbon sequestration is, to a significant extent, a function of the crop residue carbon inputs going into the soil, i.e., sequestration is a direct function of the amount of residue left on the land. Removing residues will slow or reverse sequestration. For additional details and citations, see Chapter 4, above, on Bio-SAF {residues}.

Thus, reductions in aviation emissions may be partly offset by increases in agricultural emissions, driving up the latter and moving farmers further away from net zero. Again, we see *emissions shifting*.

Canadian agricultural emissions are up by 39 percent over the past 32 years. There is a concerted push to bend that trendline down. Canadian taxpayers are providing hundreds-of-millions of dollars per year to farmers via incentives and cost-shared programs to spur emission reductions. But as one Saskatchewan farmer noted, a biofuels megaproject and the amounts of added fertilizer any such project implies will veto agricultural emissions reduction.[147]

It is impossible that the Earth can supply the added quantities of grains, oilseeds, residue biomass, and purpose-grown energy crops without significantly increased quantities of fertilizers. And it is probably impossible that removing billions of tonnes of carbon-rich biomass each year—for BECCS and SAFs—can be accomplished without slowing or reversing soil carbon sequestration. The overall effect will be to drive agricultural emissions up. As this occurs, farmers risk finding themselves alone, mid-century, as one of the few sectors with very high and rising GHG emissions. Such a situation would place the agricultural sector under increasing scrutiny and criticism—raising the spectre of intrusive regulation to force rising agricultural emissions to fall.

Farmers should think carefully before supporting a project that will lower emissions from aviation while raising emissions from agriculture.

Again, though this report focuses on aviation fuels, many of the points made here will apply to any sector or industry that intends to draw massively on biomass for fuels or materials. The adverse effects on farmers' sequestration efforts or GHG emissions can be triggered, not only by SAFs, but also by similar potential biofuel megaprojects for ocean shipping, railways, or heavy trucking; by BECCS; and even, though to a lesser extent, by biomaterials projects to replace plastics and petro-textiles.

147 Personal conversation with Bladworth-area farmer Ian McCreary, 2022.

16. SAFs and Zero Emissions

Above, this report details the challenges and negative impacts of the ambitious proposal to shift the energy supply for the world's jets to the planet's land base and renewable electricity supply. Those challenges and impacts might be acceptable costs if SAFs decarbonized aviation, but SAFs will not. Even in most best-case scenarios, emissions continue and warming effects could *increase*.

Many SAFs won't deliver zero emissions

Near-term SAFs from corn, soy, and canola certainly are not zero-emission fuels. Even the later fuels from purpose-grown energy crops will not be zero-emission in many cases, as these will require fertilizers, tractor fuels, transport fuels, etc.[148]

Moreover, most studies project that SAFs will continue to be blended with fossil-fuels. A selection of studies from IATA, ICAO, and others project that about 30 percent of aviation fuel in 2050 will still come from fossil fuels.[149] Transport Canada projects that, for this country, "roughly 70 percent of fuel used by 2050 would be SAF" and the remainder fossil fuels.[150]

The International Air Transport Association (IATA) 2023 *Roadmap* summarized results from a dozen reports that estimated emissions in 2050, with more than half the reports projecting CO_2 emissions above 116 million tonnes per year and ranging as high as 465 million tonnes (the latter being approximately 60 percent of current global aviation emissions tonnage).[151]

Net zero is not zero

For the next several decades, jets will continue to create emissions from fossil fuels and from SAFs. And although emissions per flight or per passenger-kilometre may fall, the planned doubling of flights and passenger kilometres means that even with near-best-case SAF rollout, emissions a decade or two from now may be little changed from those today. Figure 16 shows a scenario for Canada.

148 CORSIA models some energy crops as having negative emissions due to the assertion of very rapid soil carbon increases. In a Canadian context such scenarios seem unlikely. The NFU does not, at this time, accept the modelled values for negative emissions. More scrutiny is needed on these extreme claims. Moreover, all soils trend toward maximum soil carbon levels—equilibrium or saturation levels. Thus, even if some very degraded and low-carbon soils could register very rapid carbon gains, over time those gains would slow to zero. Again, very significant critical analysis is needed before policymakers and farmers accept claims of carbon-negative SAF feedstocks.

149 International Air Transport Association et al., "Aviation Net-Zero CO2 Transition Pathways: Comparative Review," tbl. 4.

150 Transport Canada, "Canada's Aviation Climate Action Plan: 2022-2030" (Ottawa: Government of Canada, 2022), 11, https://www.icao.int/environmental-protection/Documents/ActionPlan/CANADAs-AVIATION-CLIMATE-ACTION-PLAN-2022-2030.pdf.

151 International Air Transport Association et al., "Aviation Net-Zero CO2 Transition Pathways: Comparative Review," tbl. 4.

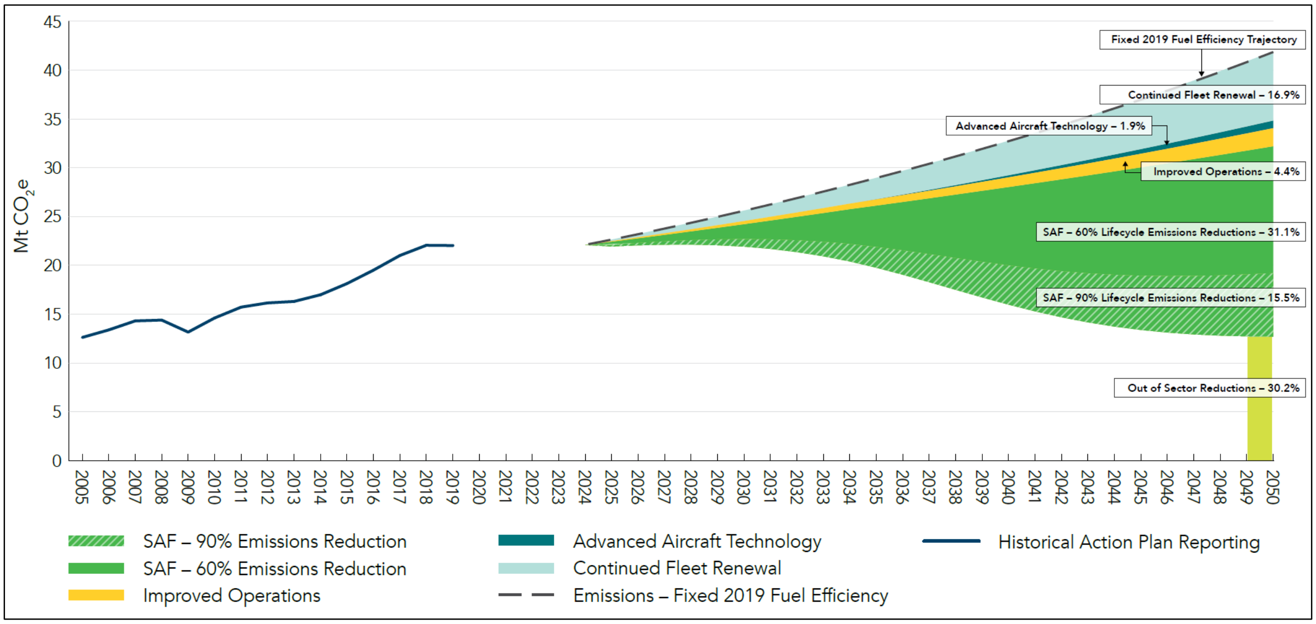

Figure 16. Canadian aviation emissions—a scenario to 2050.
Source: Reprinted from Transport Canada, "Canada's Aviation Climate Action Plan: 2022–2030."[152]

In this scenario, actual GHG emissions for Canadian aviation in 2050 are 12–13 million tonnes per year—about the same as in 2005, and roughly 60 percent of current emissions. Because SAFs themselves create emissions and because a projected 30 percent of aviation fuel will still come from fossil fuels in 2050 and because flight volumes are on track to double, not surprising, SAFs do not deliver on the goal of zero emissions. Rather, when combined with rapidly rising utilization, SAFs are projected to deliver about a 40 percent reduction by 2050. In reality, the aviation industry does not have a plan for net-zero.

Offsets

Note the bottom category on the right-hand side of Figure 16: "Out of Sector Reductions." This means emission offset schemes, emissions trading, and carbon markets. Transport Canada explains:

> "The Action Plan forecast suggests at minimum 12Mt of emissions would need to be offset in 2050. ... Fortunately, a key element of the net-zero emissions concept is that emissions do not need to reach zero for each discrete human activity and sector. For a sector to be net-zero, the GHG being released into the atmosphere must be balanced by reductions or removals from actions taken elsewhere. ... Out-of-sector emissions reductions must be achieved as a result of actions (e.g., investments or projects) that generate high quality offset credits, from GHG emission reduction or removal projects, such as biological sequestration and technology-based projects such as direct air capture and sequestration. Given that the Action Plan forecast that 12Mt of ... offsets will be required by 2050, this impl[ies] that substantial investments in GHG emission reduction and removal projects will be required."[153]

Similarly, airline trade group IATA tells us that: "To achieve net zero in 2050, almost all the global roadmaps suggest that the aviation sector will need help from market-based measures and carbon removals to bridge the gap (ranging from 95 $MtCO_2$ to 370 $MtCO_2$) between their residual emissions and net zero emissions in 2050."[154]

152 Transport Canada, "Canada's Aviation Climate Action Plan: 2022-2030," 10.
153 Transport Canada, "Canada's Aviation Climate Action Plan: 2022-2030," 24.
154 International Air Transport Association et al., "Aviation Net-Zero CO2 Transition Pathways: Comparative Review," 1.

Entire reports could be written about voluntary offsets, emissions trading, and carbon markets. Here, suffice to note the very sketchy past performance of voluntary offset schemes[155] and to flag the fact that, in the future, the number of sectors looking to buy their way out of emissions problems via offsets will almost certainly create more demand than can be met by any supply of credible offsets.

Zero GHGs ≠ zero warming

The operations of jet aircraft warm the planet in multiple ways. GHG emissions such as CO_2 from fuel combustion is one way, but non-CO_2 effects appear to be *even large*r. Fossil fuel CO_2 may be contributing less than half the warming effects from jet aviation, and other effects such as condensation trails (and resulting cirrus clouds) and nitrogen-oxides (NO_x) are calculated to produce half to two-thirds of the total warming effect.[156]

A 2024 peer-reviewed article in the journal *Atmospheric Chemistry and Physics* tells us that:

> "Aviation's cumulative CO_2 emissions account for one-third of its overall effective radiative forcing (ERF), while the remaining two-thirds are estimated to arise from non-CO_2 components such as contrail cirrus, nitrogen oxides (NO_x), particulate matter, and stratospheric water vapour emissions."[157]

The condensation-trail warming effects of aircraft can be reduced by changing flightpaths and times. Some airlines are examining steps to reduce warming effects in these ways. Also, some initial research indicates that some SAFs may reduce condensation trail clouds and related warming.[158] But even if all such positive measures are taken, and the contributions of condensation trail cloud formation and nitrogen oxide effects are reduced, SAF-powered flights will still have very significant warming effects. And, given industry plans to double or triple flight numbers by mid-century, even very significant reductions in per-flight condensation-cloud-related warming will likely leave overall warming effects higher, not lower, by mid-century.

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155 Patrick Greenfield, "Revealed: More than 90% of Rainforest Carbon Offsets by Biggest Certifier Are Worthless, Analysis Shows," *The Guardian*, January 18, 2023, sec. Environment, https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe; Patrick Greenfield, "'Reform or Go out of Business,' Carbon Offsetting Industry Told," *The Guardian*, June 26, 2024, sec. Environment, https://www.theguardian.com/environment/article/2024/jun/26/voluntary-carbon-market-offsetting-industry-reforms-cccg-climate-crisis-advisory-group-aoe; Patrick Greenfield, "Carbon Credit Speculators Could Lose Billions as Offsets Deemed Worthless," *The Guardian*, August 24, 2023, sec. Environment, https://www.theguardian.com/environment/2023/aug/24/carbon-credit-speculators-could-lose-billions-as-offsets-deemed-worthless-aoe; Patrick Greenfield, "Market Value of Carbon Offsets Drops 61%, Report Finds," *The Guardian*, May 31, 2024, sec. Environment, https://www.theguardian.com/environment/article/2024/may/31/market-value-of-carbon-offsets-drops-61-aoe; Nina Lakhani, "Revealed: Top Carbon Offset Projects May Not Cut Planet-Heating Emissions," *The Guardian*, September 19, 2023, sec. Environment, https://www.theguardian.com/environment/2023/sep/19/do-carbon-credit-reduce-emissions-greenhouse-gases; Nina Lakhani, "Corporations Invested in Carbon Offsets That Were 'Likely Junk', Analysis Says," *The Guardian*, May 30, 2024, sec. Environment, https://www.theguardian.com/environment/article/2024/may/30/corporate-carbon-offsets-credits.

156 David Simon Lee et al., "The Contribution of Global Aviation to Anthropogenic Climate Forcing for 2000 to 2018," *Atmospheric Environment* 244 (January 1, 2021); Roger Teoh et al., "Global Aviation Contrail Climate Effects from 2019 to 2021," *Atmospheric Chemistry and Physics* 24, no. 10 (May 27, 2024).

157 Teoh et al., "Global Aviation Contrail Climate Effects from 2019 to 2021," 6071.

158 Raphael Satoru Märkl et al., "Powering Aircraft with 100% Sustainable Aviation Fuel Reduces Ice Crystals in Contrails," *Atmospheric Chemistry and Physics* 24, no. 6 (March 27, 2024): 3813–37, https://doi.org/10.5194/acp-24-3813-2024.

17. Taxpayer Subsidies (to Reduce the Cost of Flying)

> "Role of governments: To develop policies that efficiently accelerate the commercial production and deployment of SAF. Positive, supply-side incentives are the most effective policy tool and involve the allocation of public funds...."
> —International Air Transport Association (IATA), 2023.[159]

> "Today in Manitoba, we announced a significant investment to seize global economic opportunities and help position Manitoba and Canada as leaders in the future of Sustainable Aviation Fuel production."
> —Honourable Jonathan Wilkinson, Minister of Energy and Natural Resources, 2024.[160]

> "Launched in June 2021, [Canada's] Clean Fuels Fund aims to invest $1.5 billion to grow the production of clean fuels in Canada, such as hydrogen, biofuels and synthetic fuels."
> —Government of Canada news release, 2024.[161]

> "We calculate the transition cost of SAF use ... [as] an annual average transition cost of USD 174 billion, though it rises from USD 1 billion in 2025 to a rather eye-watering USD 744 billion in 2050. Our forecast for the net profits of the airline industry in 2024 is USD 30 billion.... Putting the transition cost in perspective in this way should *make it blatantly clear that policy support is urgently required* to bring the cost of the transition solutions down and to minimize their premium over fossil fuels. ... The challenge of meeting the financial needs of the net zero transition by the air transport industry itself becomes *impossible without policy support*" [italics added].
> —International Air Transport Association (IATA), 2024.[162]

> "The landmark [US] IRA [*Inflation Reduction Act*] ... raises SAF support under the blender's tax credit (BTC) to provide $1.25–$1.75 per gallon of SAF...."
> —World Economic Forum, 2024.[163]

> "Currently, unsubsidized (e,g, without any government or state incentives) SAF trades at a substantial premium compared to conventional jet fuel, typically costing 2–5 times more."
> —Simpliflying, 2024.[164]

> "Air transport's net zero CO_2 emissions goal is ... critically dependent upon policy makers' concerted efforts to make it happen."
> —International Air Transport Association (IATA), 2024.[165]

All SAFs are more expensive than fossil fuel Jet A; Electro-SAFs are especially expensive. IATA projects that even after dramatic cost decreases over the next two decades, in 2050, all major SAF types will be two to three times more expensive than the projected long-term average price of fossil fuel Jet A.[166]

As we explore below (see chapter 18 on Scaling Up) the airline industry's SAF transition will cost trillions. The industry's solution to this cost problem is to use taxpayer money to keep flying affordable. But these

159 International Air Transport Association, "Net Zero 2050: Sustainable Aviation Fuels," 2.
160 Canada, "Minister Wilkinson Announces Over $6 Million to Unlock Sustainable Aviation Fuel Production in Manitoba."
161 Canada, "Minister Wilkinson Announces Over $6 Million to Unlock Sustainable Aviation Fuel Production in Manitoba."
162 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 1 & 28.
163 World Economic Forum and Kearney, "Scaling Up Sustainable Aviation Fuel Supply: Overcoming Barriers in Europe, the US and the Middle East" (World Economic Forum, March 2024), 18, https://www3.weforum.org/docs/WEF_Scaling_Sustainable_Aviation_Fuel_Supply_2024.pdf.
164 SimpliFlying and Sustainable Aviation Futures, "Pathways to Sustainable Aviation Fuel: North American Edition," 43.
165 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 1.
166 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 23.

subsidies, in effect, transfer money from the large percentage of citizens who pay taxes to the small percentage who do most of the flying, to the corporations who utilize business travel, to airlines and fuel makers, and to the shareholders of those corporations.

Airlines and their trade associations assert that once we get past an initial roll-out phase, the cost of SAFs will fall and become competitive and that subsidies will no longer be needed. It is worth asking whether this is likely. Given that SAFs will be in short supply for decades (again, the Scale-Up Problem, next chapter), demands exceeding supplies would seem to imply continued elevated prices. And given airlines' ongoing strategies to continue to double and redouble the amount of flying they do, they seem intent on driving demand higher and higher and higher. It is very likely that supply and demand imbalances will mean that SAFs will be high-cost well through the second half of this century.

Before governments and their taxpayer dollars get drawn into a multi-decade, multi-trillion dollar scheme, those governments should ponder the justice implications of subsidizing flying, the opportunity costs of pouring hundreds-of-billions of taxpayer dollars into aviation rather than alternative transport systems, the negative effects of SAFs listed in this report and elsewhere, and the significant chance that the SAF megaproject will fail—not only missing its own decarbonization timelines and targets but also causing (via competition for resources) other sectors to miss theirs.

Let us conclude with one final variation on the quotes that began this chapter—the airline industry's self-assessment of its financial challenges and risks:

> "Relating the projected transition costs [an average of 232.8 billion per year] to the profitability of the airline industry, we obtain a measure of the size of the challenge. In 2024, the net profit of the air transport industry is estimated to reach USD 30.5 billion.... Awareness of these numbers ought to make it unambiguously clear to all that *policy measures are urgently needed to bring the SAF MSPs [minimum selling prices] down to levels that airlines can conceivably pay and still remain in business*" [italics added].[167]

The annual average cost of the SAF transition is roughly 8 times the total annual profits of the airline industry: $232.8 billion vs $30.5. SAF costs create the risk that airlines may not be able to "remain in business." The major airlines and aircraft makers are admitting that, in the face of the planetary net-zero imperative, they are insolvent. Before democratic governments get sucked into this multi-trillion-dollar vortex and begin flowing thousands of dollars per taxpaying-family to airline shareholders, it is absolutely crucial that governments initiate a broad democratic consultation and that all involved completely understand the full implications of the SAF megaproject and the opportunity costs of putting our limited financial, energy, and other resources into this speculative plan.

Unless taxpayers cover many of the costs, the SAF transition cannot happen. A thorough democratic discussion is needed before we commit to this path. It is arrogant and undemocratic for airlines to simply assume that citizens want to pay the costs of the SAF transition.

167 International Air Transport Association, "Finance: Net Zero CO2 Emissions Roadmap," 29.

18. The Scale-Up Problem

> "SAF production needs to be expanded exponentially."
> —USDA, US EPA, US DOT, US DOE, 2022.[168]
>
> "Aviation's decarbonization depends critically upon the significant scale-up of SAF production—by a factor of 1,000 between 2023 and 2050."
> —International Air Transport Association (IATA), 2024.[169]
>
> "[Net zero aviation] will require close to 7,000 SAF bio-refineries by 2050. More than 700 million tonnes of CO_2 will need to be extracted from the atmosphere in 2050 with carbon capture technologies, either to produce SAF, or for permanent carbon removals. The largest projects in the pipeline today are planning on delivering a carbon dioxide removal capacity of 0.5–1 million tonnes per year, showing the scale of the challenge ahead. Over 100 million tonnes of low-carbon hydrogen will also be needed, mostly for the production of SAF...."
> —International Air Transport Association (IATA), 2023.[170]
>
> "The vast majority of technologies related to the aviation net zero transition are currently in the R&D stage."
> —International Air Transport Association (IATA), 2023.[171]
>
> "As things stand there is not going to be enough SAF to meet our goal of Net Zero 2050. *Production will need to be scaled up 80 or 100 times even to reach 10 [percent] SAF by 2030*, and that requires urgent government action" [italics added].
> —Holly Boyd-Boland, Virgin Atlantic airline's VP for corporate development, 2024.[172]
>
> "From now 'til 2050, you need an almost 1,000-times increase in the production of SAF.... And if you break that in terms of plant size of average of 50-70,000 tonnes per annum, you need almost 300 plants per year."
> — Preeti Jain, IATA, Head of Net Zero Transition Program, 2024.[173]

Worldwide, in 2023, SAFs production tripled to 600 million liters, representing 0.2 percent of global jet fuel use[174] and approximately 0.1 percent of projected 2050 demand for SAFs. Thus, SAF production must be scaled up 500- to 1,000-fold in just 26 years.

Looking at the US situation, the USDA, EPA, DOT, and DOE offer this bracing assessment of US supply challenges: "Going from 5 million to 3 billion gal/yr by 2030 is a 600-fold increase that requires a 122% year-over-year growth in production to 2030. ... More than 400 biorefineries and 1 billion tons of biomass and/or gaseous carbon oxide feedstock will be needed to produce 35 billion gal/yr by 2050."[175]

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168 U.S. Department of Energy et al., "SAF Grand Challenge Roadmap: Flight Plan for Sustainable Aviation Fuel," 18.
169 International Air Transport Association, "SAF Handbook," 30.
170 International Air Transport Association, "Energy and New Fuels Infrastructure: Net Zero Roadmap," 8.
171 International Air Transport Association, "Finance: Net Zero Roadmap" (Montreal: IATA, June 4, 2023), 6, https://www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/finance-net-zero-roadmap.pdf.
172 Christopher Jasper, "Why Aviation Chiefs Fear Net Zero Could Cripple Air Travel," *The Telegraph*, June 2, 2024, https://www.telegraph.co.uk/business/2024/06/02/why-aviation-chiefs-fear-net-zero-could-cripple-air-travel/.
173 "IATA's Blueprint for Accelerating SAF Production and Adoption," Sustainability in the Air, June 6, 2024, accessed July 5, 2024, https://open.spotify.com/episode/1k06nE6EljXBhHgOfTOdnh.
174 International Air Transport Association, "Net Zero 2050: Sustainable Aviation Fuels," 2.
175 U.S. Department of Energy et al., "SAF Grand Challenge Roadmap: Flight Plan for Sustainable Aviation Fuel," 3.

Such a dramatic and rapid scale-up will be costly. According to IATA: “Several reports have analyzed the investment required to achieve the air transport industry’s goal of reaching net zero CO_2 emissions.... The investments required to be undertaken in the 27-year period (2023-2050) amount up to USD 5.3 trillion.”[176] In a more recent assessment, the top end of the estimate is even higher: “The total capital investments [CAPEX] required to build new renewable fuel plants over the whole transition period [2025–2050] are estimated at USD 4.2 trillion in the high SAF yield case, and at USD 8.1 trillion in the low SAF yield case.”[177] IATA points to “eye-watering” investment requirements, rising to three-quarters of a trillion (US) dollars *per year*, globally, in 2050[178] (and not stopping in that year, but continuing to increase). The previous numbers are for capital expenditures, so-called CAPEX. In addition, there may be additional operating expenses (OPEX) such as the purchase of offsets, etc. Total costs of about $10 trillion USD globally (nearly $14 trillion CDN) fall within the range of possibility. (IATA notes that the estimated transition costs it calculates are “most likely to be at the lower end of any future possible range”[179] and that “our baseline case assumes rather optimistically that SAF product yields regarding all four major pathways are at the high end of their theoretical maximum levels.”[180])

Most of those trillions of dollars will need to be turned into concrete and steel. IATA estimates the need for an additional 3,400 to 6,700 new SAF production plants between now and 2050.[181] There are less than 10,000 days between now and the end of 2050, implying the need to complete, on average, one major SAF production plant every two or three days and keep up this pace for 25 years.[182]

The SAF megaproject—the massive 500- to 1,000-fold scaleup—would be excruciatingly challenging if it was happening alone. But, as detailed previously, airlines and SAF makers will attempt this forbidding scale-up alongside numerous other industries that are planning similar scale-ups. Competition from other sectors and high costs for components and finished products, driven by ongoing shortages and exponentially increasing demands, will add to the challenge. The multiple and competing scale-up challenges should make us question the feasibility of the SAF megaproject. A consistent pattern of past failures (see next chapter) should add to our scepticism.

176 International Air Transport Association, “Finance: Net Zero Roadmap.”
177 International Air Transport Association, “Finance: Net Zero CO2 Emissions Roadmap,” 1.
178 International Air Transport Association, “Finance: Net Zero CO2 Emissions Roadmap,” 1.
179 International Air Transport Association, “Finance: Net Zero CO2 Emissions Roadmap,” 8.
180 International Air Transport Association, “Finance: Net Zero CO2 Emissions Roadmap,” 19.
181 International Air Transport Association, “Finance: Net Zero CO2 Emissions Roadmap,” 1.
182 A more “realistic” scenario—the one IATA uses—is an exponential ramp-up of plant completion, rising from a handful of plants per year in 2025 to 500 per year in 2050: 1.4 production plants completed per day or one every 17 hours.

19. Past Failures to Scale Up

> "A new report ... which assessed every public climate target which the international aviation industry set itself since 2000, has shown that all but one of over 50 separate climate targets has either been missed, abandoned, or simply forgotten about. ... The industry's targets for increasing use of alternative fuels were missed every single time...."
> —Possible, 2022.[183]

> "Targets for Sustainable Aviation Fuel (SAF) began to appear in 2007 and at first were extremely bullish about the potential for biofuels to be deployed at scale in the run up to 2020. Over time these targets have been replaced with progressively less ambitious ones, while the original targets were quietly abandoned, as alternative fuel supplies remained multiple orders of magnitude lower than required by these original targets."
> —Green Gumption and Possible, "Missed Targets...," 2022.[184]

> "Target setting appears to function principally as a tactic for giving an impression of progress and action to address aviation's environmental impacts to the public and policymakers, in order to prevent any policy barriers to ongoing growth in the industry."
> — Green Gumption and Possible, "Missed Targets...," 2022.[185]

The aviation industry has recently set ambitious targets for 2030 and 2050. But these are not their first. Airlines and their industry associations have a two-decade history of setting and *missing* targets. In 2007, IATA announced a goal of 10 percent SAF use by 2017.[186] That 10 percent target has yet to be met; indeed, current blend rates are just 0.2 percent[187]—one-fiftieth of its target for 2017.

Not cowed by its failure to meet the target set in 2007, IATA tried again in 2011, though it set a less-ambitious target: 6 percent SAF (rather than 10 percent) by 2020. It failed to come close. Additional targets followed in 2012, 2014, and 2018, each less ambitious than the one before, but each time actual performance fell far short.[188] Again, SAF utilization today remains just 0.2 percent.

Given its record of missing even modest targets and given the *massive* challenge of scaling up SAF production 1,000x, we should assume that the world's airlines will fall short of their 2050 commitments. But even if airlines only miss their targets by, say, half, the negative impacts outlined above will still be large. As we get close to 2050, we may find ourselves in the worst of all possible worlds:

- even more over-dependant upon air travel as the industry achieves its doubling or tripling of travel volumes and we fail to invest in alternatives such as trains;
- contending with high emissions from air travel as SAF production is perhaps half of what is needed (and fossil fuels make up the bulk of aviation energy supplies); and
- yet still contending with significant land use, agricultural emission, food price, and sustainability impacts as a result of the production of hundreds-of-billions of litres of SAFs from feedstocks drawn from the global land-base.

In many scenarios, the 2050 SAF megaproject can cause the negative impacts outlined in previous chapters <u>and</u> fail to make air travel compatible with the need to reach net-zero globally by 2050.

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183 "Aviation Industry Has Missed All but One of 50 Climate Targets in the 21st Century," Possible, May 10, 2022, https://www.wearepossible.org/press-releases/aviation-industry-has-missed-all-but-one-of-50-climate-targets-in-the-21st-century.
184 Jamie Beevor and Keith Alexander, "Missed Targets: A Brief History of Aviation Climate Targets of the Early 21st Century" (Green Gumption and Possible, May 2022), 46.
185 Beevor and Alexander, "Missed Targets: A Brief History of Aviation Climate Targets of the Early 21st Century," 5.
186 Thomhave, Ocampo, and Collins, "Greenwashing the Skies," 5.
187 International Air Transport Association, "Net Zero 2050: Sustainable Aviation Fuels," 2.
188 Thomhave, Ocampo, and Collins, "Greenwashing the Skies," 15.

20. Superior Alternatives and More-Appropriate Responses

If not the SAF megaproject, what are the alternatives? Briefly, they include:

1. Reduce demand. If we fly less, many SAF options (see next point) become more feasible.
2. Skip Bio-SAFs and go directly to Electro-SAFs. Further, require all private jets to use Electro-SAFs.
3. For travel within continents, invest in fast, energy-efficient passenger rail systems.

1. Reduce demand

Part of what makes the SAF project so damaging and unlikely to succeed is its colossal scale. Key to making the SAF project possible and positive is to make its scale workable. One way is to reduce demand—get people to fly less. Perhaps introduce a frequent-flyer levy on tickets for those who fly more than twice per year.[189] If we can reduce demand by half over the next couple of decades (to go from about 9 trillion passenger-kilometres per year today to about 4.5 trillion), many SAF options become much less damaging and less likely to fail. For those worried that such reduced air-travel volumes represent a step back to the dark ages—to a few DC-3-like creaky prop-planes plying the airways—it is revealing to learn that the last year in which flying volumes were 4.5 trillion passenger-kilometres per year was *2009*. Reverting to 2009-levels of global air travel makes many SAF options possible and potentially beneficial (see point 2). And holding air travel volumes relatively steady at those rates could mean 2050 volumes at 4.5 trillion passenger-kilometres per year rather than the currently projected 22 trillion. SAF-powered air travel could be prioritized for trans-oceanic and very-long-distance flights and trains could be used for medium-length journeys inside of continents (see point 3).

Taking steps to reduce air travel also buys time—helping defuse the near-impossible scale-up challenges outlined above. And reducing demand—reducing the number of planes in the air—also reduces non-combustion warming effects such as condensation-trail cirrus clouds. Finally, reducing demand can happen *now*, with actual emissions reductions next year, whereas SAFs slow start combined with aviation's planned rapid expansion means that emissions will remain high for years to come.

2. Go directly to Electro-SAF

Most of the negative impacts outlined in previous chapters are a result of choosing land-based fuels: Bio-SAF {seeds}, Bio-SAF {residues}, and Bio-SAF {energy crops}. The solution is to leapfrog land-sourced biofuels and move directly and rapidly to real zero-emission, zero-land-use Electro-SAFs. While this option may be impossible if air travel volumes are allowed to double, it becomes more feasible as volumes gradually trend down to half.

As an important short-term tool in creating demand and early markets for Electro-SAFs, governments should require all private jets to use such fuels within the next three or four years. The high-income individuals who use such planes are cost insensitive. Thus, private jets and their owners can serve as lucrative early markets for such fuels, enabling makers to ramp up production confident in the existence of buyers. (Globally, private jets consume about 2.5 percent of aviation fuel—about 9.5 billion litres per year[190]—making this a multi-billion-dollar market for nascent Electro-SAF makers.)

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189 As (unsubsidized) SAFs make flying more expensive, this may exacerbate exclusivity and inequality—increasingly only the rich will be able to afford to fly. Thus, governments may want to consider making a frequent-flyer levy (partly) revenue-neutral by, perhaps, providing a modest subsidy to those who travel only once per year of who have to travel for health reasons. Key is to reduce the air-miles of those who fly often while not barring infrequent flyers from accessing sometimes-crucial air travel options.

190 Thomhave, Ocampo, and Collins, "Greenwashing the Skies," 7.

3. Use trains instead

If people need to cross the ocean or go very long distances (e.g., Canada to Brazil) then Electro-SAF-powered planes are a reasonable choice. But within continents, passenger and goods transport must be moved onto trains. To accomplish this, governments must utilize their taxpayer-supplied dollars to incentivize rail rather than air travel, and governments must encourage industries to spend part of the trillions earmarked for SAFs to build railways instead—toward building extensive medium-, higher-, and high-speed rail systems throughout the Americas, Africa, Asia, and elsewhere.

This is not a report about trains, but a few points will be illuminating:

- Since 2008, China has built 37,900 kilometers (about 23,500 miles) of high-speed rail lines. The network is expected to double in length, to 70,000 kilometers, by 2035.[191]
- Between 1880 and 1918, Canada built nearly 70,000 kms of railway track—enough to cross Canada twelve times! We did so using crude tools and machines; as a young and relatively poor nation; and at a time when population densities were a fraction of those today.[192]
- One km of large-diameter oil pipeline contains enough steel to build two kms of railway track.[193]
- A passenger-rail-construction megaproject can provide jobs at family-supporting wage levels for soon-to-be displaced petroleum-sector and pipeline workers.
- Trains powered by clean renewable electricity can be true zero emission and zero warming; aircraft powered by most SAFs (esp. if blended with fossil fuels) cannot.
- Trains powered directly by electricity and driven by electric motors are much more energy-efficient than planes that require renewable electricity to be turned into liquid fuels that are combusted in jet engines. This final point is worth exploring further.

The energy efficiency of trains vs planes

Consider these two energy pathways:

Trains powered by renewable electricity
I.e., renewable electricity to trains via overhead catenary wires and on into electric motors.
Overall efficiency roughly 90 percent.

Jets powered by Electro-SAFs
I.e., Renewable electricity to direct air capture (carbon) and hydrolysis of water (hydrogen) to Fischer-Tropsch processing (to make liquid SAF) to combustion in jet engines.
Overall efficiency about 15 percent, which is the product of the next two factors:

- Electro-SAF production is about 37 percent efficient (100 kWh renewable electricity per gallon to produce, see above, while each gallon contains 37 kWh energy equivalent).[194]
- The overall (thermodynamic and propulsive) efficiency of a jet engine is about 40 percent.[195] (As in all combustion engines, much energy is lost as heat, noise, etc.)

191 Ben Jones, "The Evolution of China's Incredible High-Speed Rail Network," CNN, May 20, 2021, https://www.cnn.com/travel/article/china-high-speed-rail-cmd/index.html.

192 Darrin Qualman, "Rail Lines, Not Pipelines: The Past, Present, and Future of Canadian Passenger Rail," *Darrin Qualman* (blog), March 6, 2018, https://www.darrinqualman.com/canadian-passenger-rail/.

193 Qualman, "Rail Lines, Not Pipelines."

194 For other estimates, see Patrick Schmidt et al., "Power-to-Liquids as Renewable Fuel Option for Aviation: A Review," *Chemie Ingenieur Technik* 90, no. 1–2 (2018): tbl. 2; Stefan Bube et al., "Kerosene Production from Power-Based Syngas – A Technical Comparison of the Fischer-Tropsch and Methanol Pathway," *Fuel* 366 (June 15, 2024): 13; Maria Fernanda Rojas-Michaga et al., "Sustainable Aviation Fuel (SAF) Production through Power-to-Liquid (PtL): A Combined Techno-Economic and Life Cycle Assessment," *Energy Conversion and Management* 292 (September 15, 2023): 1; Carlotta Panzone et al., "Power-to-Liquid Catalytic CO2 Valorization into Fuels and Chemicals: Focus on the Fischer-Tropsch Route," *Journal of CO2 Utilization* 38 (May 1, 2020): tbl. 2.

195 National Academies of Sciences, Engineering, and Medicine et al., "Aircraft Gas Turbine Engines," in *Commercial Aircraft Propulsion and Energy Systems Research Reducing Global Carbon Emissions* (Washington, D.C.: National Academy Press, 2016),

To allow for future technological advances, let us generously *double* the assumed efficiency of Electro-SAF-powered planes—grant an assumed 30 percent efficiency instead of 15. Even with this assumption, trains remain three times more efficient: 90 percent vs 30. Renewable electricity to power trains directly will provide *three times* the passenger-kilometres compared to turning that same quantity of renewable electricity into a liquid fuel and combusting it in a jet. (A 3x efficiency advantage for trains is documented in journal articles, even without the efficiency sacrifices inherent in e-fuels.[196])

At this moment in our climate crisis, is it reasonable to invest trillions of dollars into perhaps the least efficient transportation mode so-far conceived? If we can move a passenger 1,000 kms on 1 unit of electricity in a train, is it responsible public policy to instead invest in systems that require three times the energy to move the passenger the same distance? And if we do make the less-efficient choice and squander that scarce clean electricity; and potentially deny it to other, competing, decarbonization initiatives; is it honest to call Electro-SAF-powered planes a "climate solution"? As we move past 8 billion people toward 10, and as those people become more affluent and demand more travel, should we attempt to supply that travel via one of the least-efficient modes? If we do, can this be called "sustainable"?

We conclude this section with a graphic from the BBC (based on data from the UK's Department of Business, Energy, and Industrial Strategy and Department for Environment, Food, and Rural Affairs). The graphic shows climate impacts per passenger-kilometre. It reminds us that aircraft warming effects come both from fuel combustion (dark-blue bands) and other sources (light-blue). Thus, while trains may be just three times more energy efficient, they are many times more efficient when it comes to total warming effects per passenger-km because they do not create high-altitude condensation-trail clouds. Total warming effects of flights are equivalent to about 200 grams CO_2e per passenger-kilometre but the Eurostar train produces just 6—one-thirtieth as much. Even an 80 percent decarbonization of air travel (a daunting, unlikely prospect for 2050) will leave overall warming effects of planes in that distant year a large multiple of the warming effects of trains operating now. And if we clean up the electricity supply and stop burning coal and natural gas, the emissions from train shown below fall even further.

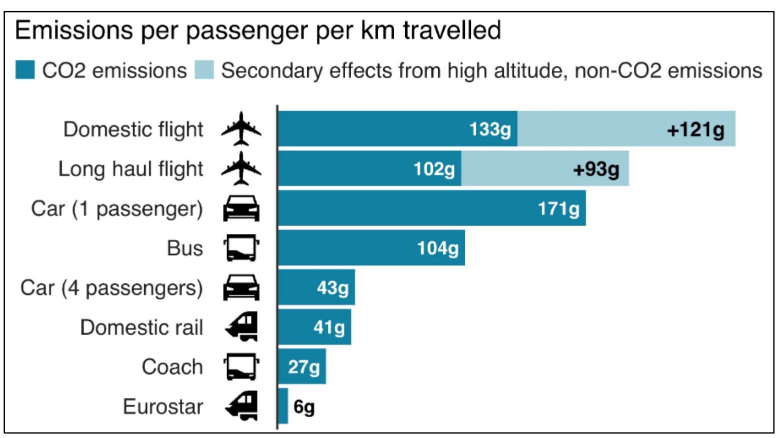

Figure 17. Emissions from various modes of travel.
Source: Reprinted from BBC.[197] BBC original cites UK BEIS/DEFRA Greenhouse Gas Conversion Factors 2019. For updated data see https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023

https://doi.org/10.17226/23490; Intergovernmental Panel on Climate Change, "Aviation and the Global Atmosphere: 7.4.1.2. Propulsive and Overall Efficiency," accessed June 22, 2024, https://archive.ipcc.ch/ipccreports/sres/aviation/index.php?idp=97.

196 Jing-Hua Zheng et al., "A Universal Mass-Based Index Defining Energy Efficiency of Different Modes of Passenger Transport," *International Journal of Lightweight Materials and Manufacture* 4, no. 4 (December 1, 2021): 426.

197 BBC, "Climate Change: Should You Fly, Drive or Take the Train?," August 23, 2019, https://www.bbc.com/news/science-environment-49349566.

21. Conclusion

> "Large scale SAF production may actually contribute to ecological collapse rather than prevent it."
> — Thomhave, Ocampo, and Collins, "Greenwashing the Skies, 2024.[198]

Humanity is in overshoot. We are taking all the planet can sustainably give, and much, much more. That is what Steffen, Rockstrom, and others are trying to tell us when they say we have pushed past the safe operating limits for planet Earth. Already, today, we are spreading far too much fertilizer, taking too much land, and removing too much biomass. We are far past the point where any of this can be considered sustainable. Yet the SAF megaproject would require more fertilizer, land, and biomass.

The largest parts of proposed future SAF production are currently pilot projects with wholly unknown costs and chances of success. Worse, the SAF megaproject may be an energy-system and transportation dead-end that damages the biosphere. Even worse, it may be a cynical fiction designed to buy time, distract, and greenwash a high-emission sector that has plans to multiply its operations, revenues, and profits. Sustainable Aviation Fiction? Pie in the sky?

And worse still, citizens will be required to shoulder airlines' costs via tax-funded transfers to those corporations.

SAFs are not feasible decarbonization solutions, but they are very likely a food-price problem, a soil health problem, a clean energy and green hydrogen demand problem, and a cause of accelerating extinctions and warming.

Though many questions remain unanswered, we need not delay for lack of information. We know enough to act. We know enough to assess SAFs and determine whether private and taxpayer investments should be turned toward these ends, or toward alternatives.

The National Farmers Union (NFU) strongly recommends that our democratically elected leaders and our public servants:

1. **Do <u>not</u> transfer taxpayer dollars to airline and fuel companies in an attempt to facilitate a risky and damaging SAF megaproject; instead, require airlines, fuel companies, and frequent fliers to shoulder the multi-trillion-dollar costs, and in that way prevent market distortions that will have the negative effects of increasing flights and flying;**

2. **Take very seriously ecosystem limits, planetary boundaries, limits to growth, and concepts of justice when evaluating proposal such as SAFs and the plan to double or triple air travel and fuel that huge air travel load from farmland, biomass, and an already overtaxed biosphere;**

3. **Invest in *appropriate* technologies such as extensive passenger rail infrastructure; and**

4. **Act courageously, decisively, and *rapidly* to deal with climate change. Time is short to avert catastrophe. As the aviation sector might say: we're running out of runway.**

198 Thomhave, Ocampo, and Collins, "Greenwashing the Skies," 17.

Appendix 1: Acronyms

ATAG: Air Transport Action Group
AtJ: Alcohol-to-Jet
BECCS: Bioenergy with Carbon Capture and Storage
CAPEX: Capital expenditures
CI: Carbon intensity, i.e, grams of CO_2 per megajoule of energy
CO_2: Carbon dioxide
CO_2e: Carbon dioxide equivalent
CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation
C-SAF: The Canadian Council for Sustainable Aviation Fuel
DAC: Direct air capture
DOE: US Department of Energy
FAO: United Nations Food and Agriculture Organization
FT: Fischer-Tropsch
GHG: Greenhouse gas
GREET: Greenhouse gases, Regulated Emissions, and Energy use in Technologies, a life cycle analysis model
GWP: Global warming potential
H or H_2: Hydrogen
HEFA: Hydroprocessed esters and fatty acids
IATA: International Air Transport Association
ICAO: United Nations International Civil Aviation Organization
ILUC: Induced land use change
IPCC: Intergovernmental Panel on Climate Change
kWh: Kilowatt-hour
LCA: Life cycle assessment
LUC: Land use change
MSP: Minimum selling price
MSW: Municipal solid waste
Mt: Megatonnes or millions of tonnes
mWh: Megawatt-hour
PtL: Power to Liquids, aka Electro-SAF
RFS: Renewable Fuel Standard
RPK: Revenue passenger kilometre
SAFs: Sustainable Aviation Fuels
SOC: Soil organic carbon
tWh: Terrawatt-hour
UCO: Used cooking oil
UNDP: United National Development Programme

Appendix 2: Some Conversion factors

- Acres to hectares: multiply acres times 0.4047

- Kilometres to miles: multiply kilometres by 0.6214

- Tonnes (of jet fuel) to (US) gallons: multiply tonnes times 330
- Tonnes (of jet fuel) to (US) gallons: multiply tonnes times 1,250

Appendix 3: Calculations of land area to produce all SAF from oilseeds (canola & soybeans)

Ratios of tonnes of oilseed feedstock to litres of SAF (or renewable diesel)

Canola
688.2 litres (renewable diesel) **per tonne canola seed**. (757 million litres per 1.1 million tonnes)
"Two hundred million [US] gallons of canola renewable diesel would require about 1.1 million tonnes of canola seed, as shown in the following formula: 200 million gallons*6.5 lb/gal *0.8 lb RD/lb canola oil /0.43 lb oil/lb canola/2205 lb canola/tonne seed = 1,096,873 tonnes seed."[199]

688.5 litres (renewable diesel) **per tonne canola seed**. (568 million litres per 0.825 million tonnes)
"150 million gallons of canola renewable diesel would require about 825,000 tonnes of canola seed, as shown in the following formula: 150 million gallons*6.5 lb/gal *0.8 lb RD/lb canola oil /0.43 lb oil/lb canola/2205 lb canola/tonne seed=825,000 tonnes seed."[200]

475 litres (renewable diesel) **per tonne canola seed**.
"A canola solvent-based oil extraction plant at its optimal size of 190 million liters per year would require approximately 400,000 green tonnes of canola per year."

250-333 litres SAF per tonne of canola
"Assuming a maximised SAF yield, a small-scale plant, capable of producing 50 ML of SAF per year would require 3% of Australia's projected canola seed production in 2025 (0.2 Mt). A large-scale plant producing 300 ML per year would require 17% of canola seed production in 2025 (0.9 Mt)."[201]

262 litres SAF per tonne of canola
125,000,000 litres SAF per 477,000 tonnes of canola
100,000 tonnes SAF per 477,000 tonnes of canola
"Archer et al. [20] report it would take about 2.1 kg of rapeseed oil to produce 1 kg of SAF. Assuming 44% oil content in its feedstock, a small SAF refinery with a 100-million-kg-per-year capacity would require approximately 477 million kg of feedstock."[202]

Soybeans
186.3 litres SAF per tonne of soybeans.
18% oil by weight,[203] and oil converts to HEFA SAF at 83% by weight,[204] for a total conversion of 0.149. So, one tonne of soy makes 149 kgs of SAF.

159.7 litres of SAF per tonne of soybeans. Via 83% yield SAF from soybean oil[205]
192 litres of soybean oil per tonne of soybeans. Via division
3.35 billion litres soybean oil per 18.17 million tonnes of soybeans. Via 1079 litres soybean oil per tonne
3.24 million tonnes of soybean oil per 18.17 million tonnes of soybeans. Via 36.74 bushels per tonne

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199 U.S. Canola Association, "Letter to the Honorable Michael Regan, Administrator, U.S. Environmental Protection Agency, Re: Renewable Fuel Standard Program: Canola Oil Pathways to Renewable Diesel, Jet Fuel, Naphtha, Liquified Petroleum Gas and Heating Oil," May 18, 2022, https://www.uscanola.com/wp-content/uploads/2022/05/USCA-RD-NPRM-Comments.pdf.

200 U.S. Canola Association and Tom Hance, "Fuel Pathway Requested.," March 12, 2020, https://www.agri-pulse.com/ext/resources/pdfs/EPA-HQ-OAR-2021-0845-0040_content-(1).pdf.

201 CSIRO, "Sustainable Aviation Fuel Roadmap," 2023.

202 Conner J. McCollum et al., "Estimating the Supply of Oilseed Acreage for Sustainable Aviation Fuel Production: Taking Account of Farmers' Willingness to Adopt," *Energy, Sustainability and Society* 11, no. 1 (December 2021): 33, https://doi.org/10.1186/s13705-021-00308-2.

203 Canada's Biojet Supply Chain Initiative, "HEFA Production and Feedstock Selection," 2019, 20, https://cbsci.ca/wp-content/uploads/CBSCI-HEFA-Production-and-Freedstock-Selection-single-page.pdf.

204 International Civil Aviation Organization, "SAF Rules of Thumb."

205 International Civil Aviation Organization, "SAF Rules of Thumb."

"Biodiesel consumption in 2017/2018 required production use of 3.24 million metric tons of soybean oil, or the oil from 667.44 million soybean bushels."[206]

186.46 litres of SAF per tonne of soybeans
274.10 litres of SAF per 1.47 tonnes of soybeans
72.41 gallons of SAF per 54.14 bushels of soybeans.[207]

Yield

Table 2

		Seeded area (acres)	Production (metric tonnes)	Yield (tonnes per acre)
Canola	2020	20,782,600	19,484,700	0.94
	2021	22,270,249	14,248,281	0.64
	2022	21,395,700	18,694,768	0.87
	2023	22,081,700	18,328,233	0.83
Soybeans	2020	5,070,300	6,358,500	1.25
	2021	5,157,986	6,224,029	1.21
	2022	5,274,200	6,543,158	1.24
	2023	5,630,700	6,980,525	1.24

Source: Stats. Can. Table: 32-10-0359-01

206 "Biodiesel," United Soybean Board, accessed June 4, 2024, https://www.unitedsoybean.org/issue-briefs/biodiesel/.
207 Andrew Swanson and Aaron Smith, "Alternative Land-Use Impacts of the Sustainable Aviation Fuel Grand Challenge: Corn Ethanol vs. Soybean Oil Pathways" (American Enterprise Institute, April 2024), tbl. 1.

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