Sustainable Aviation Fuel Use at a Washington State International Airport: Regional Air Quality Benefits

Submitted: December 1, 2025

Period covered: Year 2024

Prepared by the Department of Environmental & Occupational Health Sciences at the University of Washington

ENVIRONMENTAL & OCCUPATIONAL HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH
UNIVERSITY of WASHINGTON

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Preamble

This is the second in a series of annual reports mandated by the Washington State Legislature under **SB 5447** to quantify the benefits of alternative jet fuels (AJFs) compared to fossil jet fuel. This initial report focuses on **sustainable aviation fuels (SAFs)**, a subset of AJFs, to assess their emissions benefits and potential to improve regional air quality. While the legislative directive under SB 5447 encompasses all alternative jet fuels, this report focuses on SAFs as the most immediately viable subset of AJFs, aligning with the Port of Seattle's reporting framework and regional sustainability goals.

The Port of Seattle has set ambitious targets for SAF adoption at Seattle-Tacoma International Airport (Sea-Tac), aiming for 10% of the fuel available produced locally from sustainable sources by 2028 and 25% by 2035. SAFs, which include fuel types such as Hydroprocessed Esters and Fatty Acids (HEFA) and Alcohol-to-Jet (ATJ), are derived from renewable resources and offer significant environmental benefits. These fuels are compatible with existing aviation infrastructure and engines, making them a practical and impactful choice for immediate emissions reductions.

This work evaluates approaches that can be used to estimate the benefits of SAF use to regional health. It also identifies specific metrics that can be used to estimate emission benefits of SAF for different landing and takeoff (LTO) conditions.

The University of Washington's Department of Environmental & Occupational Sciences developed this series of reports based on method development, peer reviewed publication of findings, while Washington State University contributed by reporting on the current usage of conventional jet fuel and SAFs at Sea-Tac.

This report series serves as a groundwork for future evaluations, identifying current knowledge, methodologies and data gaps. Through an extensive literature review and synthesis, the University of Washington team provides insights into the state of SAF research and outlines potential directions for future studies and reporting.

Sustainable Aviation Fuels Usage

For the calendar year 2024, the Port of Seattle reported to partners at the University of Washington, for the purpose of generating this report, that 687,648,571 gallons of conventional petroleum Jet A fuel were uplifted at Sea-Tac International Airport. **No sustainable aviation fuels were used in 2024.** These use figures were reported in accordance with the requirements of SB5447 in July 2025 by the Port of Seattle to the University of Washington team, through coordination with the WA State Alternative Jet Fuels Work Group.

Executive Summary

This is the second annual University of Washington report mandated under SB 5447. The work presented here advances this mandate by reporting on current fuel usage at Seattle Tacoma International Airport and by providing new methods and describing new regional air monitoring systems that directly support future evaluations of regional air quality and community health benefits associated with sustainable aviation fuel use.

For the calendar year 2024, the Port of Seattle reported that 687,648,571 gallons of conventional petroleum Jet A were uplifted at Seattle-Tacoma International Airport. No sustainable aviation fuels were used during this period. Although SAF was not deployed due to production challenges, this report provides the technical basis needed to assess the regional co-benefits of future SAF adoption. The work introduces methods for estimating the regional impact of reductions in aviation-related ultrafine particles and a reproducible health impact assessment that integrates demographic data, dispersion modeling, ground measurements, and open-source tools to quantify mortality reductions associated with reduced aviation emissions.

Regional air monitoring capacity has now expanded to support this work. Two new air quality monitoring stations operate north and south of the airport through regional and federal collaboration. These stations measure size resolved particle number concentrations and are positioned to characterize LTO emissions as well as potential changes associated with fuel use and other emission control strategies. Together, they form the first coordinated regional system specifically designed to observe real world variation in ultrafine particle exposures that may result from sustainable aviation fuel adoption.

The report also includes a review of current scientific literature describing how sustainable aviation fuels influence emissions that affect community exposures. These scientific efforts were paired with stakeholder engagement activities, including advisory group discussions and an on-site monitoring visit, which connected technical work with community priorities related to emissions, monitoring needs, and health implications. These contributions establish a foundation for regional impact evaluation and position Washington state as a national leader in assessing community level air quality and health implications of sustainable aviation fuels.

Legislative Directive

A new section is added to chapter 28B.20.545 RCW to read as follows:

(1) To assess the potential co-benefits of alternative jet fuel for Washington's communities, by December 1, 2024, and December 1 of each year until such time as the joint legislative audit and review committee has completed its final report on the tax preferences contained in sections 9 through 12 of this act, the University of Washington's Department of Environmental and Occupational Health Sciences, in collaboration with Washington State University, ***shall calculate emissions of ultrafine and fine particulate matter and sulfur oxides from the use of alternative jet fuel as compared to conventional fossil jet fuel, including the potential regional air quality benefits of any reductions***. This emissions calculation shall be conducted for alternative jet fuel used from an international airport owned by a port district in a county with a population greater than 1,500,000. The University of Washington may access and use any data necessary to complete the reporting requirements of this section.

(2) To facilitate the calculation required in subsection (1) of this section, an international airport owned by a port district in a county with a population greater than 1,500,000 must report to the University of Washington the total annual volume of conventional and alternative jet fuel used for flights departing the airport by July 1, 2024, and July 1st of each year until such time as the joint legislative audit and review committee has completed its final report on the tax preferences contained in sections 9 through 12 of this act.

Abbreviation Key

ACR	Attributable case reduction
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AJF	Alternative jet fuel
AMRR	Attributable mortality rate reduction
BenMAP	Environmental Benefits Mapping and Analysis Program
CI	Confidence interval
CO	Carbon monoxide
CO_2	Carbon dioxide
EI	Emission index
EPA	U.S. Environmental Protection Agency
HR	Hazard ratio
LTO	Landing-Takeoff
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
nvPM	Non-volatile particulate matter
$PM_{2.5}$	Fine particulate matter
PNC	Particle number concentration
PSCAA	Puget Sound Clean Air Agency
SAF	Sustainable aviation fuel
SD	Standard deviation
Sea-Tac	Sea-Tac International Airport (unless stated otherwise)
SES	Socioeconomic status
SMPS	Scanning Mobility Particle Sizer
SVI	Social Vulnerability Index
UFP	Ultrafine particle

Introduction

The legislative directive under SB 5447 calls for an evaluation of **alternative jet fuels (AJFs)** to mitigate aviation emissions and improve regional air quality. AJFs encompass a broad category of non-conventional aviation fuels, including biofuels, synthetic fuels, and other innovative pathways. Among these, **sustainable aviation fuels (SAFs)** represent the most immediately viable option for real-world application, given their compatibility with existing aviation infrastructure and engines, and their established environmental benefits.

At the state level, the Port of Seattle has demonstrated leadership by setting a goal of 10% fuel usage at Sea-Tac International Airport be produced from locally sustainable sources by 2028, making it the first U.S. airport to set a target and timeline for SAF adoption. In 2024, the Washington State Legislature introduced, but did not pass, a bill (SB6114) that would have mandated a 10% SAF blend for certain aircraft, depending on local production capacity. The 2022 report from the Alternative Jet Fuels Work Group underscores the importance of SAF adoption for reducing greenhouse gas emissions and aligning with Washington State's broader decarbonization and clean energy goals, emphasizing the need for continued investment in SAF production and infrastructure to achieve these targets (WSU 2022).

This second report presents current evidence and approaches for calculating and reporting changes in emissions of ultrafine and fine particulate matter and sulfur oxides from the use of SAFs, as compared to conventional fossil jet fuel, as well as the potential regional air quality benefits of reductions in Jet A fuel usage. New for this year, we have proposed and developed a method to directly estimate co-benefits of regional air quality improvements on health. We also report on the current usage of SAFs at Sea-Tac International Airport, which is the only airport in Washington state owned by a port district in a county with a population greater than 1.5 million. The reporting from the Port of Seattle to the University of Washington was provided in the context of SAF use. This focus aligns with the Port's reporting and supports the broader goals of the Washington State Alternative Jet Fuels Work Group to promote the adoption of SAFs and reduce aviation-related emissions in the region.

Report goals

This second report sets the stage for subsequent evaluations mandated under SB 5447 by the Washington State Legislature. Given the absence of SAF usage at Sea-Tac International Airport in 2024, this report focuses on foundational analysis and lays the groundwork for future reports by focusing on four key sections:

Section 1 Regional air quality monitoring updates: Report on efforts to expand regional air monitoring in the year 2024 to better monitor direct benefits of SAF implementation as usage expands.

Section 2 Human health: Development of a peer-reviewed framework to conduct a health impact assessment of SAF use, based on modeled changes to regional air pollution. This framework can be used prospectively to describe specific co-benefits to regional communities of different SAF implementation scenarios.

Section 3 Updates to the review of SAF literature emissions: Updates from the literature to better capture regional air quality level implications of SAF adoption.

Section 4 Engagement activities: Description of regional engagement activities over the past year.

Section 5 Implications and next steps: Outlines the University of Washington's perspective on implications and next steps, offering a framework for future reports and ongoing discussions with state-level stakeholders.

This December 1, 2025, report will be shared with the Washington State Legislature. The materials therein are suggested as technical guidance in developing and reporting benefits of different SAFs production and SAF use scenarios.

Report highlights

- New north and south monitoring stations now capture size-resolved UFPs and fine particles near Sea-Tac landing and takeoff operations.
- UW developed a replicable SAF health-risk model, allowing for future health benefits to be estimated when considering SAF adoption scenarios.
- A systematic literature review found limited research connecting engine-level SAF emission changes to community exposure.
- Stakeholder engagement ensured analyses reflected community priorities related to emissions, monitoring, and health.

Section 1. Regional Air Quality Monitoring

Highlights

- Two new air quality monitoring stations north and south of Sea-Tac International Airport.
- Dual-site configuration with size-resolved UFP measurement capabilities offers an essential foundation for SAF impact assessment.

Background

The 2023 University of Washington report on SAFs, *Sustainable Aviation Fuel Use at a Washington State International Airport: Regional Air Quality Benefits*, highlighted essential needs to improve monitoring and data collection to allow for quantification of the regional air quality benefits of SAF adoption. In the year 2024, through U.S. Environmental Protection Agency (EPA) and State support, a new air quality monitoring station was installed in the city of SeaTac, and State support in 2025 provides resources to install another in the city of Des Moines. These monitoring sites are strategically placed to best capture regional benefits of emission changes at Sea-Tac. These two new sites directly address the specific gaps and recommendations outlined in Section 5 of the previous report, particularly the need for enhanced monitoring to quantify LTO emissions, improved characterization of airport-related UFP concentrations under different operational conditions, and better integration of monitoring data with modeling and exposure assessment.

Regional monitoring efforts

Sunset Park air quality monitoring station

The Sunset Park air quality monitoring station is operated by the Puget Sound Clean Air Agency (PSCAA) and represents the northern anchor of the monitoring system. The site is located north of the airport and began collecting data in April 2025. The Sunset Park site is able to capture the aircraft emission characteristics primarily associated with the landing phase (~70% of the year). PSCAA instrumentation at Sunset Park includes size-resolved

particle monitoring capable of characterizing particle number concentrations (PNC) across the ultrafine size spectrum. This provides detailed temporal and size distribution information that is essential for source apportionment and for identifying landing related plume behavior, likely improving the ability to characterize co-benefits of SAF implementation in future years. The site's location is close to a community center, residential areas, a park and a school and offers an important foundation for future work that seeks to characterize the impact of SAFs on regional air pollution. The list of instrumentation at this site is provided in Table 1.

Table 1. List of instruments deployed at the Sunset Park Air Quality Monitoring Site

Instrument	Target species	Unit
Nephelometer Aurora 1000	$PM_{2.5}$	$\mu g/m^3$ (by correlation from light scattering coefficient)
Aethalometer AE-33	Black carbon concentration	ng/m^3
Scanning Mobility Particle Sizer TSI 3938	UFP count (total & by size bin)	pt/cm^3

Des Moines air quality monitoring site

The Des Moines air quality monitoring station will be installed and operated by the University of Washington and serves as the southern complement to the Sunset Park site. This station is south of the airport and primarily captures emissions associated with takeoff (~70% of the time), and landing emissions characterization during mostly the summer season when flight patterns are opposite. Based on the literature review conducted in 2023, takeoff-related benefits of SAF are expected to be significant, however co-benefits to regional air quality are expected to be less significant than for landing due to rapid climbing of the aircraft to the upper troposphere, above the ground level where impacts on people and communities are not as significant. Once data collection begins at this site, it will provide essential information about the magnitude and characteristics of takeoff driven emissions plumes further refine estimates of expected regional SAFs benefits to air quality. The University of Washington instrument suite will mirror the size-resolved measurement capabilities at Sunset Park to allow direct comparison across the two locations. The Des Moines site is also situated in a community that has expressed longstanding concerns about airport-related emissions, which creates opportunities for research, engagement, and transparent communication of results. The list of instruments proposed for this site is provided in Table 2.

Table 2. List of instruments deployed at the Sunset Park air quality monitoring site

Instrument	Target species	Unit
Nephelometer Aurora 1000	$PM_{2.5}$	$\mu g/m^3$ (by correlation from light scattering coefficient)
microAethalometer MA200	Black carbon concentration	ng/m^3
Scanning Mobility Particle Sizer TSI 3938	UFP count (total & by size bin)	pt/cm^3
LI-850 analyzer	Carbon dioxide (CO_2)	ppm
CAPS NO_2 monitor	Nitrogen dioxide (NO_2)	ppb
Serinus 30 analyzer	Carbon monoxide (CO)	ppm

Summary

Together, the Sunset Park and Des Moines air quality monitoring stations establish the first coordinated regional system designed to capture aircraft related UFP emissions across both primary operational phases that influence community exposure. This system is highly novel and unique to our region, a real highlight of the forward thinking and engaged approach to regional air pollution. This dual-site configuration directly supports the next steps identified in the 2023 report by expanding monitoring coverage, providing size-resolved measurements needed for source apportionment, and generating the real-world emissions data required to refine air quality modeling and exposure assessment. These efforts will strengthen the state's ability to evaluate the regional air quality benefits of SAF adoption and address longstanding community concerns related to airport emissions. As data collection progresses, the monitoring network will provide an essential foundation for future SAF assessments, improved quantification of co-benefits, and more robust reporting to the Legislature under SB 5447.

Section 2. Human Health: Quantifying Community Health Benefits of Sustainable Aviation Fuels

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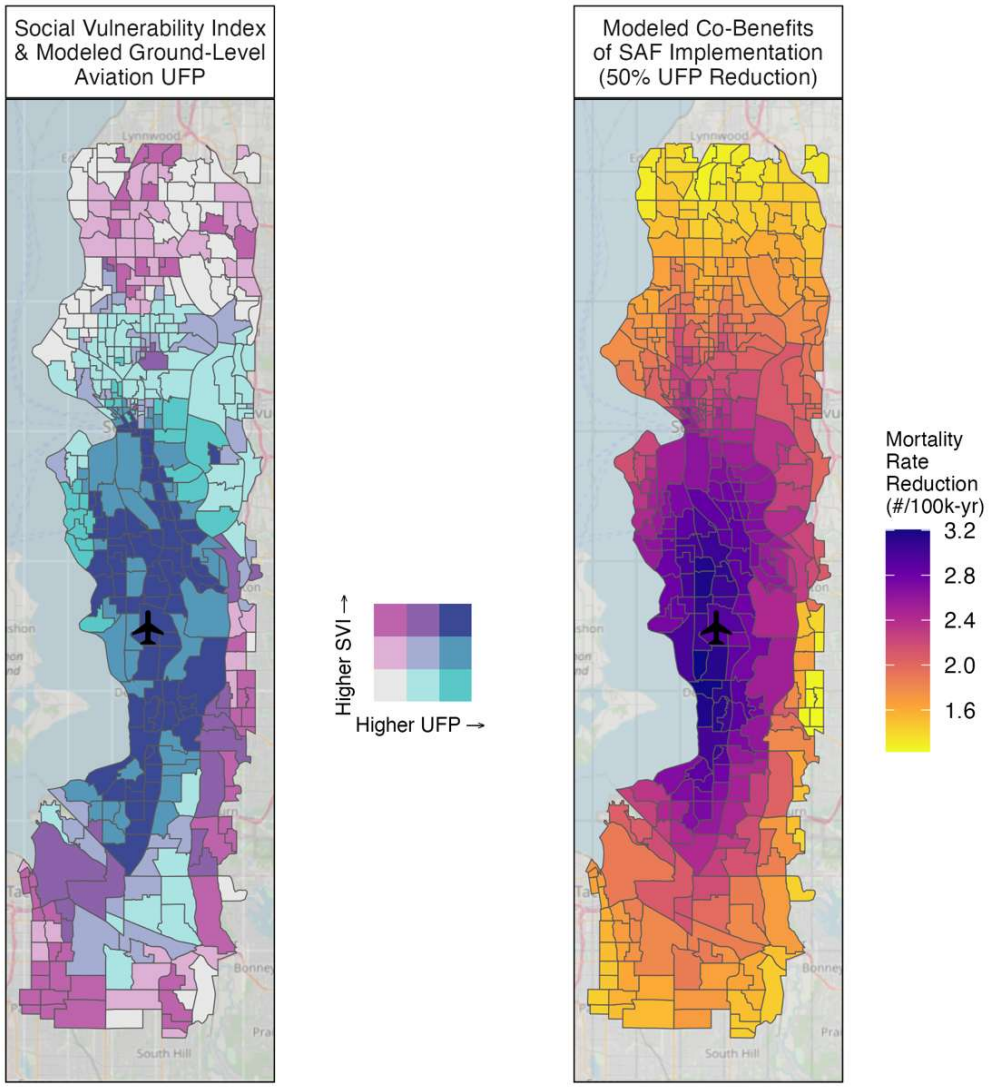
Attribution: This work has been published in the journal Atmospheric Environment and is reproduced here under creative license CC BY 4.0. (Blanco et al., 2025)

Highlights

- UFPs are linked to adverse outcomes, including mortality.
- SAF has the potential to reduce aviation-related UFP.
- We developed a reproducible health impact assessment approach for aviation UFPs.
- Lower UFP from SAF adoption was associated with mortality reductions near Sea-Tac.
- The method is adaptable for evaluating aviation-related health impacts elsewhere.

Graphical abstract



Introduction

Exposure to ultrafine particles (UFPs, ≤100 nm in diameter) is an emerging health concern (Brugge & Fuller, 2020; HEI, 2013; Wu et al., 2021), with emerging evidence linking this to premature mortality (Bouma et al., 2023; Weichenthal et al., 2024). Jet fuel combustion from aviation is a significant source of local UFP pollution, often resulting in elevated UFP levels tens of kilometers downwind from airports (Austin et al., 2021; Hudda et al., 2014; Stacey et al., 2023).

A growing number of federal and local policies support the adoption of sustainable aviation fuel (SAF) and low-emission fuels, including biofuels and synthetic fuels, to reduce aviation impacts on climate and improve air quality (FAA, 2024; Senate Bill 6114, 2024). The primary goal of these adoptions is to reduce carbon emissions and achieve carbon neutral aviation. However, these fuels also offer other various co-benefits including the potential to improve ground level air quality. The degree of these reductions depends on the specific SAF blend and jet engine design, with larger reductions anticipated to occur as SAF technologies advance and blending ratios increase (Harlass et al., 2024). Currently, a 50% SAF blend, such as those using Hydroprocessed Esters and Fatty Acids (HEFA) or Fischer-Tropsch (FT) fuels, can reduce particulate matter, including UFP, emissions by roughly 50%, depending on the aromatic content and fuel properties (Beyersdorf et al., 2014; Corporan et al., 2010; Durdina et al., 2021; Harlass et al., 2024; Schripp et al., 2022).

Nonetheless, capturing these potential co-benefits of SAF fuels on exposure reduction and associated health outcomes remains challenging. While emission reductions from SAF have been characterized through experiment-based observations and modeling (e.g., Airport Cooperative Research Program (Corporan et al., 2010)), further research is needed to quantify associated reductions in UFP exposures and health benefits. This is particularly relevant for disproportionally impacted near airport areas, which tend to have higher proportions of people of color and lower-income residents (Fajersztajn et al., 2019; Rissman et al., 2013; Serry, 2020; Transport & Environment, 2024). These communities face heightened risks of adverse health effects from airport-related emissions and are also well-positioned to benefit from emission reductions.

The EPA's Environmental Benefits Mapping and Analysis Program (BenMAP) has been widely used to evaluate the potential health benefits air pollution reducing policies (Sacks et al., 2018). BenMAP estimates health impacts by applying concentration-response functions derived from epidemiological studies to relevant population datasets. The program is primarily designed to assess reductions in regulated criteria pollutants, such as fine particulate matter ($PM_{2.5}$) and ozone (O_3), which have well-documented health risks

and extensive monitoring data available through the EPA's Air Quality System (AQS) monitoring network. BenMAP is particularly effective when used for large-scale analyses aimed at understanding health outcomes across standard population demographics, such as age and sex (Sacks et al., 2018). While the program uses a user-friendly click-based interface, its dependence on rigid input data formats can make it difficult to adapt for non-standardized applications involving smaller spatial-scales, less well-characterized pollutants, and unique demographic groups of interest. Since UFPs are not routinely monitored and have fewer studies to support long-established concentration-response functions, for example, they are not included as an input option in BenMAP. UFPs are generally measured by individual studies, and epidemiologic evidence linking these to adverse effects in humans has only recently begun to emerge (Brugge & Fuller, 2020; Garcia-Marlès et al., 2024; Kalkavouras et al., 2024; Stacey, 2019; Trechera et al., 2023; US EPA, 2019). While other programs that assess air pollution health risks are used in the U.S. (e.g., COBRA, AirQ+), these also focus on regulated or commonly measured pollutants and are generally less detailed and flexible than BenMAP (Hassan Bhat et al., 2021). Alternative methods are thus needed to evaluate the potential health benefits of UFP reductions, in a spatially resolved fashion, from SAF adoption in disadvantaged, near-airport communities.

We develop a method to characterize aviation-related UFP emissions around the Sea-Tac airport and apply it in a risk assessment to evaluate potential mortality reductions from SAF adoption, focusing on disadvantaged near-airport communities. Our approach encompasses the characterization of aviation-related UFPs, the use of publicly available population data, the incorporation of emerging risk estimates from the literature, and the application of open-source software (R) to conduct analyses. This work can be adapted to advance research and inform public health policies and regulations, identify and characterize uncertainty around different SAF implementation scenarios and provide an approach to prioritize equity-based air quality interventions in airport communities.

Methods

Overview

We used the following approach to assess the health impacts of reducing aviation-related UFP exposures through SAF adaptation:

1. **Define the Study Area**: We established a geographic study area centered around Sea-Tac, corresponding to the region where atmospheric dispersion modeling (AERMOD) estimated non-zero ground-level concentrations on land from aircraft LTO activities.

2. **Collect Population Data**: We collected population counts and relevant demographic information for census tracts in the study area as well as baseline mortality information to allow for spatially granular assessments.
3. **Generate Baseline and Control Scenario Exposure Surfaces**: We created an aviation-related UFP exposure surface using a combination of AERMOD, flight count information, and ground-level UFP measurements. We developed several UFP control scenarios that could result from SAF adaptation.
4. **Estimate Risk**: We applied a concentration-response function from the literature to estimate mortality reductions resulting from control scenarios for the overall population as well as disadvantaged groups.

We used R (v4.3.1) and RStudio (2023) for these analyses whenever possible, as described below.

Study area

The study area encompassed a 1,700 km^2 region around Sea-Tac within King County. This area was selected based on the estimated aviation-related UFP impacted zone, as described below.

Population data

We used the *tigris* (Walker, 2024) and *tidycensus* (Walker & Herman, 2024) R packages to gather 2020 U.S. Census tract information within the study area (defined below) including total adult population (18+) counts, self-identified sex, and self-identified race and ethnicity. We also collected information on the percentage of households below the poverty line.

We used the Centers for Disease Control and Prevention (CDC) Agency's Toxic Substances and Disease Registry (ATSDR) Social Vulnerability Index (SVI) to evaluate socioeconomic vulnerability within each tract (CDC/ATSDR, 2020). This index ranges from 0 to 1, with higher levels indicating greater susceptibility in domains related to socioeconomic status (SES), household characteristics, racial and ethnic composition, and housing type and transportation. SES is summarized by indicators of poverty, unemployment, educational attainment, and health insurance status for SES. Household characteristics are summarized by age distribution, disability status, single-parent households, and English language proficiency. Racial and ethnic composition is captured by racial and ethnic minority status. Finally, housing type and transportation is characterized by housing density, mobile home residency, vehicle access, and living in group quarters.

Modeling aviation UFP

We utilized the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD 23112), accessed through AERMOD View (Lakes Software v10.2.1) (Lakes Software, 2024), along with aviation LTO count data, and UFP measurements to generate baseline aviation-related UFP exposure surfaces from Sea-Tac. AERMOD is a Gaussian dispersion model that integrates source, meteorological, and terrain information, including surface roughness, boundary layer dynamics, and wind patterns, to simulate air pollution dispersion from sources. We modeled aircraft traffic at Sea-Tac using 2019 Federal Aviation Administration (FAA) records, defining four independent scenarios representing north and south flows for both landings and takeoffs. Emissions were modeled in AERMOD using parameters for carbon monoxide (CO), a relatively long-lived gas, to approximate the dispersion characteristics of UFPs in the absence of available UFP parameters. A 1 g/s emission rate was applied as a scalable factor with which to estimate ground-level concentrations. The receptor grid consisted of 1,743 receptors spaced 1 km apart, covering an 86 km by 40 km area centered on Sea-Tac's runway. Flight paths were represented by volume sources configured as 50-meter cubes to simulate wake turbulence and air mixing before pollutant release. Meteorological data for the lower and upper atmospheric layers were obtained from the National Oceanic and Atmospheric Administration (NOAA), and terrain data were sourced from the National Elevation Dataset. Simulations were conducted for unidirectional traffic flow days to simplify traffic patterns.

The final study area was defined as the subset region within King County, Washington where AERMOD estimated non-zero ground-level concentrations on land from LTO activities, covering approximately 1,700 km^2. We transformed AERMOD estimates, which represent relative ground-level concentrations ranging from 0% to 100%, into percentiles. These percentiles were calibrated using ground-based, aviation-related UFP values to improve accuracy and convert the estimates into typical UFP units (PNC). These aviation-related UFP estimates were derived from a 2019-2020 mobile monitoring campaign in the greater Seattle area (Blanco et al., 2022) and Positive Matrix Factorization (PMF), which was used to identify annual average source contributions to air pollution in the region (Liu et al., 2025). In summary, PMF used repeated measures of size-resolved UFP, fine particulate matter ($PM_{2.5}$), black carbon (BC), nitrogen dioxide (NO_2), and carbon dioxide (CO_2) to derive six emission source profiles from particle size distributions, spatial mapping, land use regression, and pollutant ratios. Derived sources included emissions from aircraft, diesel trucks, gasoline and hybrid vehicles, aged vehicle emissions, oil combustion, and wood combustion. Across all sites, aircraft emissions contributed to approximately 12% of the total PNC in the 10-420 nm size range, as measured by the TSI NanoScan 3910, and were

the dominant source within the 10-13 nm (83%) and 13-18 nm (52%) size ranges. Aircraft contributions were highest around Sea-Tac and downwind during the prevailing southerly wind conditions. This approach afforded the unique opportunity to calibrate a modeled, unitless dispersion results with extensive field based ambient measurement.

We linked each ground-based location with an airport-related UFP estimate to the nearest grid location containing AERMOD-derived emission estimates from aircraft LTO activities (N=220 paired locations within 500 m of each other). We then modeled the log-transformed airport-related UFP at location l (log PNC_l) as a function of the estimated contributions from LTO activities based on AERMOD ($AERMOD_{landing,l}, AERMOD_{takeoff,l}$). We did not include emissions from other aviation activities, such as idling and taxiing, which likely contribute to a lesser extent and primarily within constrained areas near the airport, rather than across the broader study area and population of interest. We used the resulting model fit to estimate total ground-level UFP concentrations across the study area by calibrating AERMOD-derived LTO activity impacts:

$$\log \widehat{UFP_l} = \hat{\alpha} + \hat{\beta}_1 \times AERMOD_{landing,l} + \hat{\beta}_2 \times AERMOD_{takeoff,l} \quad (1)$$

Exposure assessment

We estimated the tract-level UFP by averaging the UFP grid point predictions that fell within each census tract in the study area. For tracts with no grid points within their boundaries, we assigned the UFP from the nearest grid point. These resulting tract-level UFP estimates served as the baseline scenario for our analysis.

We evaluated potential UFP control scenarios using a tool developed by the National Academies and Transportation Research Board (TRB) to estimate air pollutant reductions at specific airports based on their operational characteristics and SAF blend scenarios (The National Academies of Sciences, 2019). The tool incorporates emissions data from 51 SAF blend measurement reports, covering scenarios from business-as-usual jet fuel consumption (100% Jet A-1) to SAF blends of 5%, 25%, 35%, and 50%. For Sea-Tac, emissions reductions were estimated using the airport's operational data, including the annual number of flight operations and the proportion of piston and non-piston engine types in the total flight volume. This resulted in approximately 7%, 31%, and 51% reduction of non-volatile particulate matter (nvPM) from 5%, 25%, and 50% SAF blends, respectively. Since UFP reductions were not directly available, we assumed that reductions in total particulate matter were comparable and used similar pollution reductions of 5%, 30%, and 50%, respectively. Prior work has shown that burning a 50% SAF blend can reduce both

particle number and mass emissions by approximately 50–70% under certain conditions (Moore et al., 2017). Although these reductions are theoretical and not based on ground-truthed pollution reduction measures, this allowed us to provide a reasonable range of possible exposure reduction values.

To assess population exposures, we calculated population-weighted UFP exposures for each population group of interest p (e.g., race and ethnicity) by weighting the UFP predictions for each tract t by the population counts for group p in that respective tract t:

$$\text{Population-Weighted UFP}_p = \frac{\sum_t (\text{UFP}_t \times \text{Populatio}_{t,p})}{\sum_t \text{Population}_{t,p}} \quad (2)$$

This approach reflects overall exposure differences based on where population groups reside. It assumes that an individual's residential location is representative of their overall exposure and is widely used in air pollution epidemiology and health burden assessments (e.g., BenMAP) (Bramble et al., 2023; Sacks et al., 2018).

Mortality risk estimate

Although no studies have directly linked aviation UFPs to mortality, two large population studies have investigated associations between total ambient UFPs and mortality, reporting similar findings. For this study, we relied on findings from the more generalizable of the two: a national-level study by Bouma et al. involving 10.8 million adults aged 30 and older in the Netherlands (Bouma et al., 2023). Bouma et al. estimated annual average UFP exposures using a land-use regression model developed from data gathered during a nationwide mobile monitoring campaign, linking these exposures to natural mortality outcomes from 2013 to 2019 while adjusting for individual and area-level socioeconomic factors. They reported a 1.2% increase in the hazard of natural mortality per 2,723 particles per cubic centimeter (pt/cm³) increment of UFP (hazard ratio [HR]: 1.012; 95% CI: 1.010, 1.015). This was consistent and slightly more conservative than the findings by Weichenthal et al., who reported a similar HR of 1.073 (95% CI: 1.061, 1.085) per 10,000 pt/cm³ increment (equivalent to an HR of 1.019 per 2,723 pt/cm³) in their study of 1.5 million Canadian adults 25 and older observed between 1991 and 2016 (Weichenthal et al., 2024). The flexible approach presented here can allow for other health impact functions to be applied to the exposure reduction scenarios, as emerging research is reported in future.

We gathered natural mortality counts, defined by ICD-10 codes A00-R99 and consistent with Bouma et al. (2023), for adults aged 30 and older in King County for the year 2020 from the CDC's WONDER database (CDC, 2024). We selected 2020 to align with available

census tract-level population data and the ground-level UFP measurements used to calibrate AERMOD-derived estimates, as described earlier.

Risk assessment

To evaluated burden reductions, we first calculated the attributable fraction (AF) for mortality under control scenario *c* by tract *t* as (EEA, 2024; WHO, 2024):

$$AF_{c,t} = \frac{HR_{c,t}-1}{HR_{c,t}} \quad (3)$$

where $HR_{c,t}$ is the hazard ratio for mortality under control scenario c, which represents a percentage reduction from baseline concentrations. The magnitude of change (ΔUFP) thus varies by tract t based on initial baseline concentrations.
The total attributable case reductions (ACR) for population group p and control scenario c, summed over all tracts (t), were calculated as:

$$ACR_{p,c} = \sum_t (AF_{c,t} \times Incidence \times Population_{t,p}) + \varepsilon \quad (4)$$

where $Incidence$ was the natural mortality rate, $Population_{t,p}$ represented the total population for group p in tract t, and ε denotes some uncertainty due to model assumptions and data limitations. This approach is equivalent to the approach most commonly used with BenMAP, which assumes a log-linear relationship between an exposure and outcome (Sacks et al., 2018).
For comparability and to better assess the impact across groups with varying population sizes, we also calculated the attributable mortality rate reduction (AMRR), which is independent of population size:

$$AMRR_{p,c} = \sum_t (AF_{c,t} \times Incidence) + \varepsilon \quad (5)$$

This standardization facilitates direct comparisons of attributable burden across subgroups, independent of their total population size (e.g., Hispanic or Latino residents comprise a smaller fraction of the total population, and so ACR will naturally be lower for this group).

We present point estimates for ACR and AMRR along with their 95% range estimates based on the point estimate and 95% confidence interval (CI) of the HR presented by Bouma et al. (2023).

Results

Study population

We included 412 census tracts representing 1,484,029 adults in this analysis. On average, 60% of the population self-reported being White, 17% Asian, 7% Black or African American, 1% Native Hawaiian and Other Pacific Islander, <1% American Indian and Alaska Native, and 14% other or more than one race. Ten percent of the population identified as Hispanic or Latino. The median household income was approximately $93,834, with a per capita income of $52,484. Income inequality, as measured by the Gini Index (ranging from 0 [indicating perfect equality] to 1 [indicating perfect inequality]), averaged 0.4, indicating a moderate level of income disparity. Housing costs were relatively high, with the median value of owner-occupied housing units at $584,556. Additionally, 9% of households were below the poverty level, and 9% were considered rent burdened. The overall SVI averaged 0.5 (standard deviation (SD) 0.3), reflecting moderate overall vulnerability. The mean SES and Housing SVI components were 0.4 (SD 0.3), indicating moderate vulnerability in these areas. The Race and Ethnicity component was higher, with a mean of 0.6 (SD 0.2). The highest vulnerability was observed for the Housing and Transportation component, with a mean score of 0.7 (SD 0.3).

Based on proximity to Sea-Tac, census tracts closer to the airport (<10 km) had a higher proportion of Hispanic or Latino residents, a higher proportion of residents that did not identify as White, a lower proportion of residents above the poverty line, and overall more disadvantaged individuals (*Figure 1*).

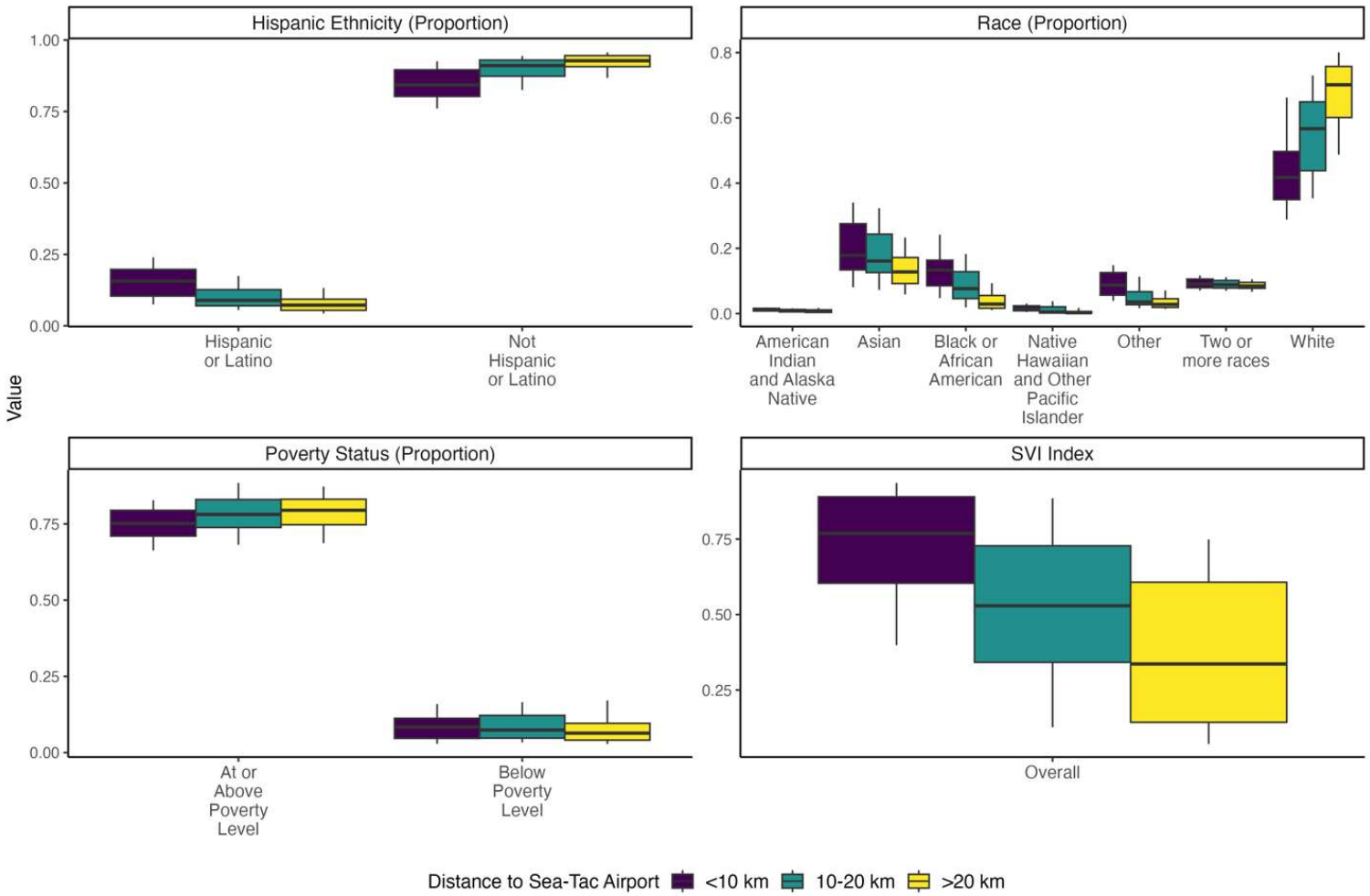


Figure 1. Demographics based on distance to Sea-Tac (N=412 Census Tracts). Overall SVI ranges from 0 to 1, with higher levels indicating greater overall vulnerability.

Aviation UFP exposures

AERMOD LTO impacts were concentrated around Sea-Tac, with landings producing the highest concentrations north and south of the airport. Similarly, aviation-related UFP estimates used to calibrate AERMOD showed the highest concentrations within approximately 4 miles of Sea-Tac. Each percentile increases in aviation takeoff activity impact, as estimated by AERMOD, was associated with a 0.82 increase in log PNC (95% CI: 0.54, 1.09; $p < 0.001$) based on PMF, while each percentile increase in landing activity was associated with a 0.23 increase (95% CI: -0.02, 0.48; $p = 0.066$). The overall in-sample adjusted model R^2 was 0.25. While the resulting model fit was relatively low, the primary objective of this work was to convert AERMOD output to UFP PNC units that were consistent with risk estimates reported in the literature. Moreover, studies generally report burden based on *changes* in air pollution exposures rather than absolute concentrations.

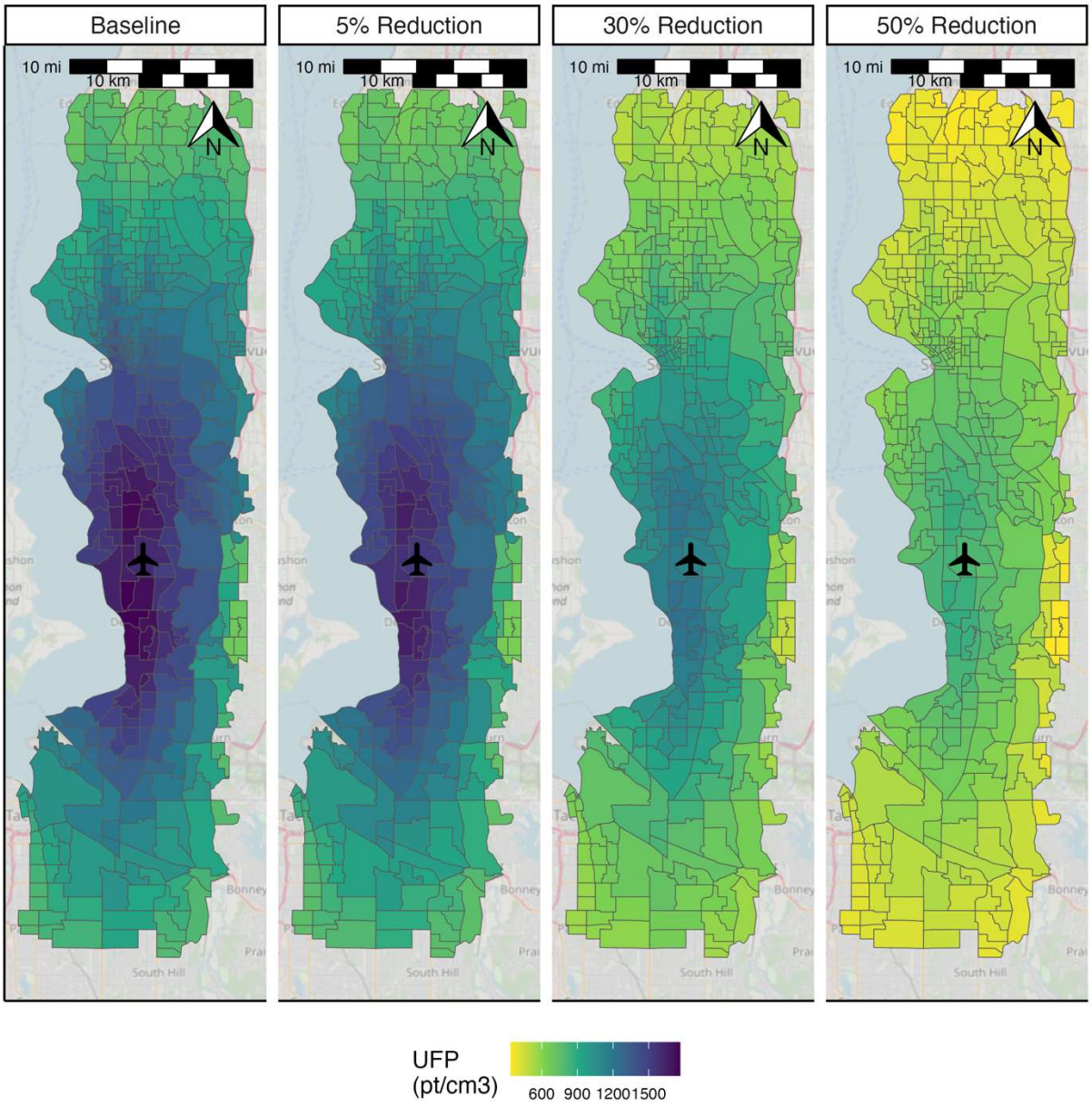


Figure 2 - Predicted aviation-related UFP at baseline and under SAF control scenarios.

Calibrated AERMOD results showed the highest aviation-related UFP directly north and south of Sea-Tac along the LTO paths (Figure 2).

The average aviation-related UFP at baseline was approximately 1,145 (SD: 277) pt/cm^3. Control scenarios reduced average aviation-related UFP to about 1,088 (SD: 264) pt/cm^3

under a 5% reduction control scenario, and down to 573 (SD: 139) pt/cm^3 under a 50% reduction control scenario. Tracts surrounding the airport observed the highest UFP reductions, especially during more stringent control scenarios.

The overall population-weighted baseline aviation-related UFP exposure was 1,149 pt/cm^3 (*Figure 3*). On average, disadvantaged populations had greater exposures, with racial-ethnic minorities, populations below the poverty level, socially vulnerable groups, and households with lower median and per capita incomes experienced exposures that were approximately 2-10% higher.

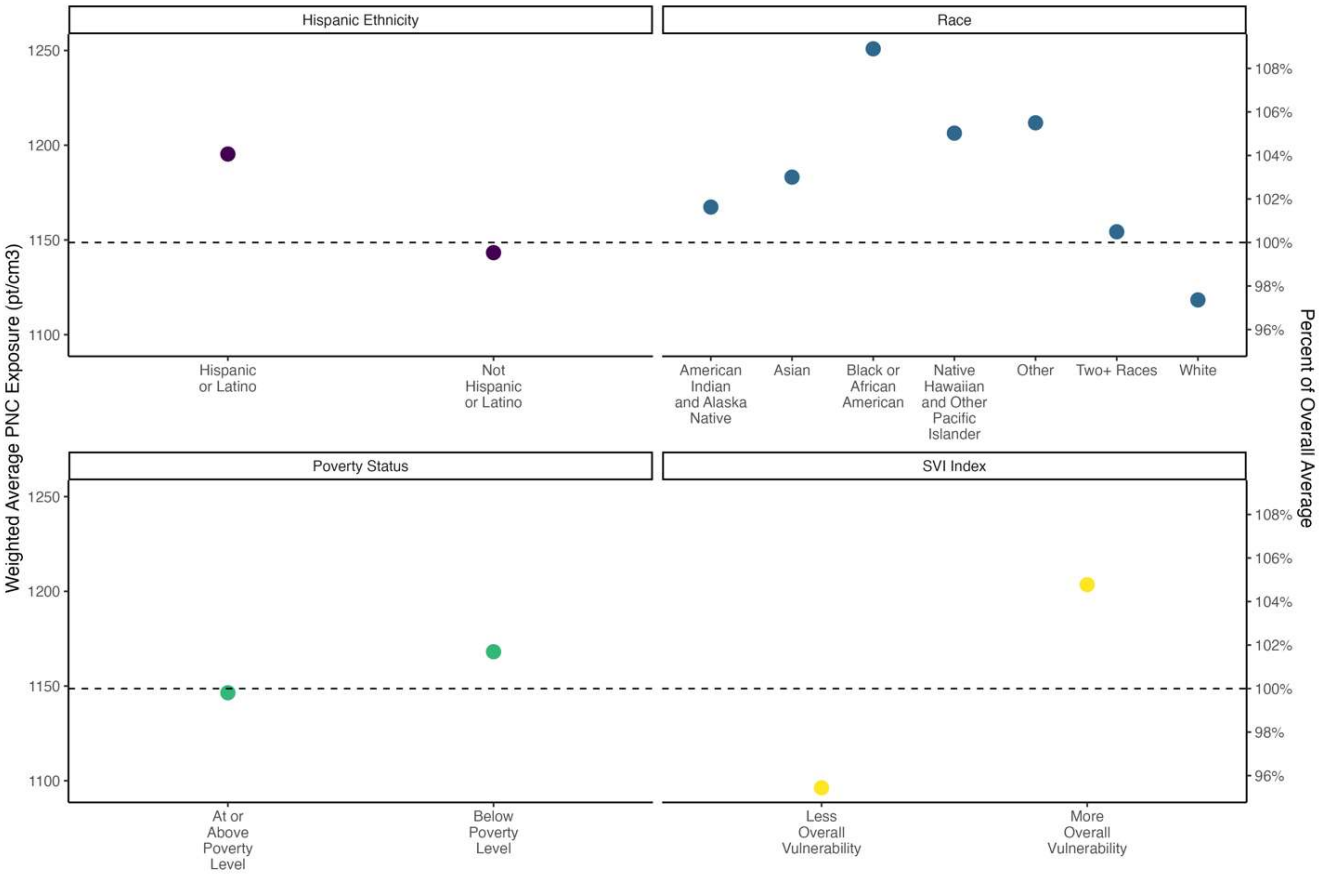


Figure 3. Population-weighted UFP exposures at baseline. "High" and "low" income categories are based on the overall median across the study tracts. SVI vulnerability was defined as values above 0.5. The dashed horizontal line indicates the overall population-weighted average (1,149 pt/cm^3).

Risk assessment

There were 11,924 natural deaths among the 30+ adult population of 1,435,726 in King County during 2020, corresponding to a baseline adult mortality rate of 8.31 per 1,000 population (CDC, 2024). In combination with Census population information, estimated aviation-related UFP exposures, and UFP burden, we estimated a baseline ACR of 61.9 (95% range: 49.1, 74.6) cases and AMRR of 4.2 (3.3-5.0) cases per 100,000 people per year for the study area. Under SAF adaptation scenarios, ACR ranged from 3.1 (2.5-3.7) for a 5% reduction in aviation-related UFP to 31.0 (24.6-37.4) for a 50% reduction. AMRR ranged from 0.2 (0.2-0.3) cases per 100,000 people per year for a 5% reduction to 2.1 (1.7-2.5) cases per 100,000 people for a 50% reduction. While ACR (mortality counts) was larger among residents who were not Hispanic or Latino, above the poverty level, and White, the AMRR (mortality rate), which is independent of population size, showed the opposite pattern, with somewhat AMRR among residents who were Hispanic or Latino, below the poverty level, and did not identify as White (*Figure 4*). Moreover, under control scenarios, tracts with higher overall vulnerabilities experienced a greater reduced in both ACR and AMRR (*Figure 5*).

These differences can be attributed to the fact that disadvantaged populations are more likely to reside closer to the airport where higher baseline pollution (Figure 2AERMOD LTO impacts were concentrated around Sea-Tac, with landings producing the highest concentrations north and south of the airport. Similarly, aviation-related UFP estimates used to calibrate AERMOD showed the highest concentrations within approximately 4 miles of Sea-Tac. Each percentile increases in aviation takeoff activity impact, as estimated by AERMOD, was associated with a 0.82 increase in log PNC (95% CI: 0.54, 1.09; $p < 0.001$) based on PMF, while each percentile increase in landing activity was associated with a 0.23 increase (95% CI: -0.02, 0.48; $p = 0.066$). The overall in-sample adjusted model R2 was 0.25. While the resulting model fit was relatively low, the primary objective of this work was to convert AERMOD output to UFP PNC units that were consistent with risk estimates reported in the literature. Moreover, studies generally report burden based on *changes* in air pollution exposures rather than absolute concentrations. Calibrated AERMOD results showed the highest aviation-related UFP directly north and south of Sea-Tac along the LTO paths (Figure 2).
) and mortality (*Figure 6*) reductions were observed.

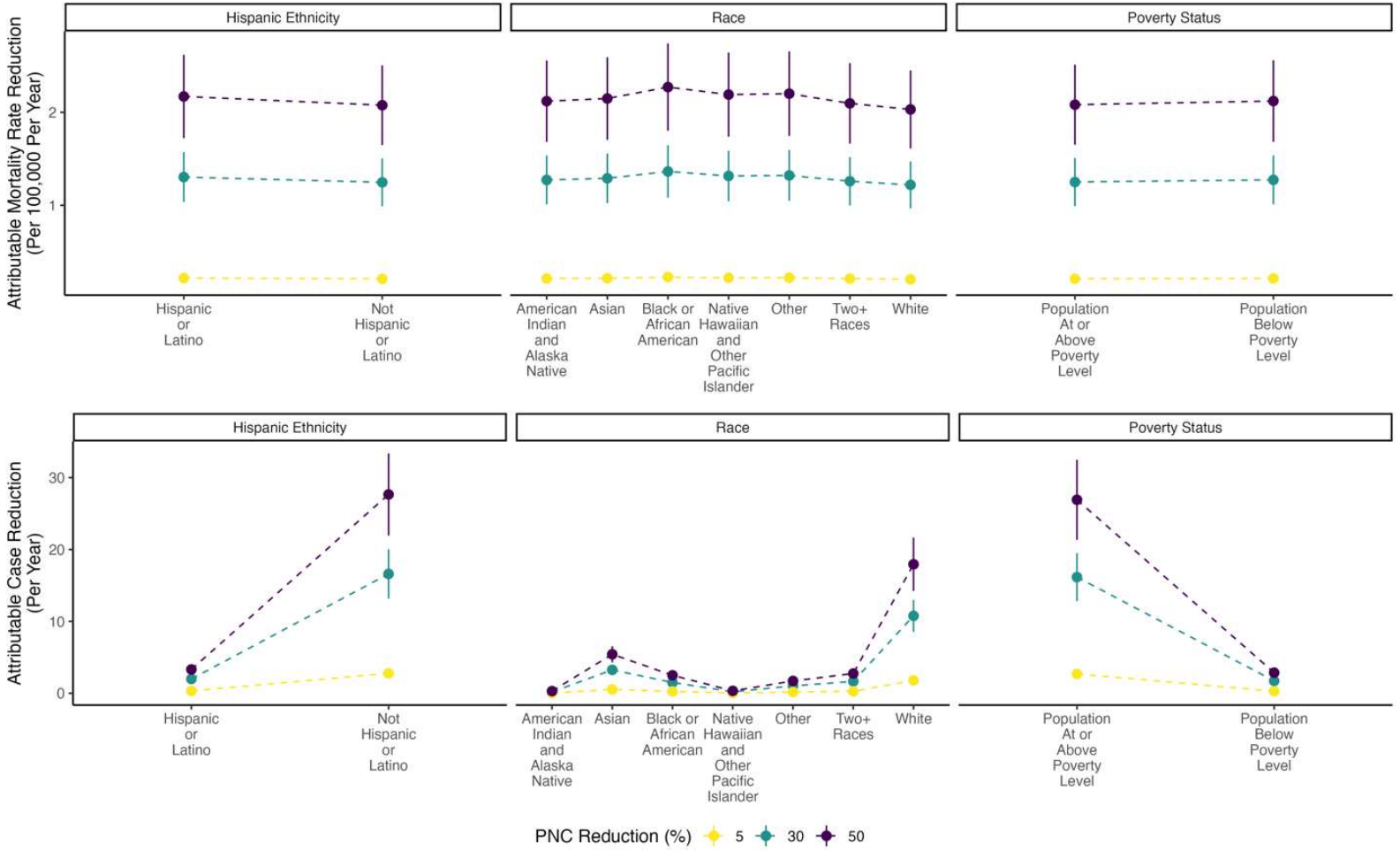


Figure 4. Estimated AMRR and ACR (mean and 95% range) under SAF (aviation-related UFP) control scenarios. Case counts are impacted by each group's population size (see Equation 4; e.g., Hispanic or Latino residents make up a small fraction of the total population, and so case counts are naturally lower).

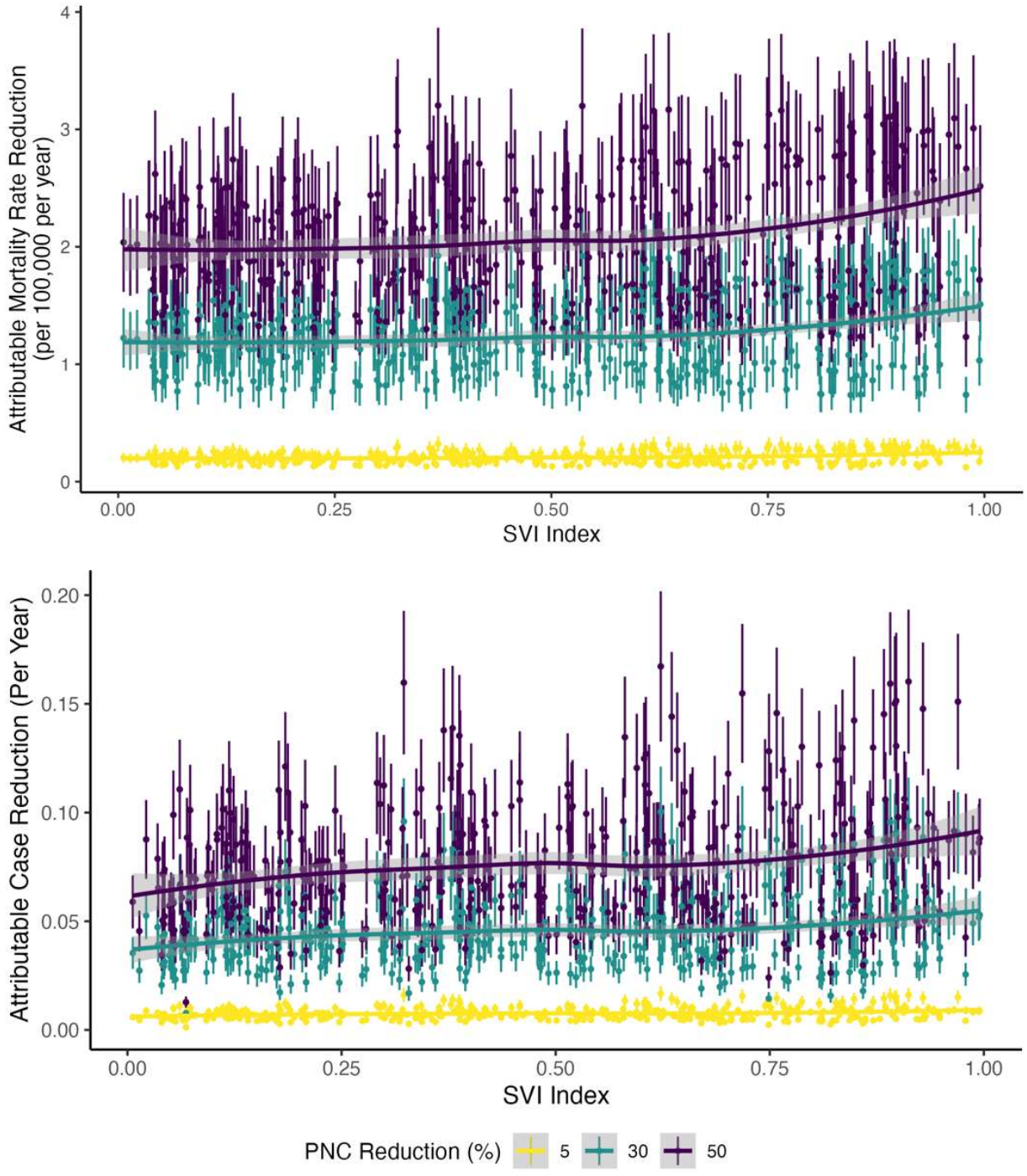


Figure 5. Estimated tract-level AMRR and ACR (mean and 95% range) by overall SVI Index under SAF (aviation-related UFP) control scenarios. Index values closer to one indicate greater vulnerability.

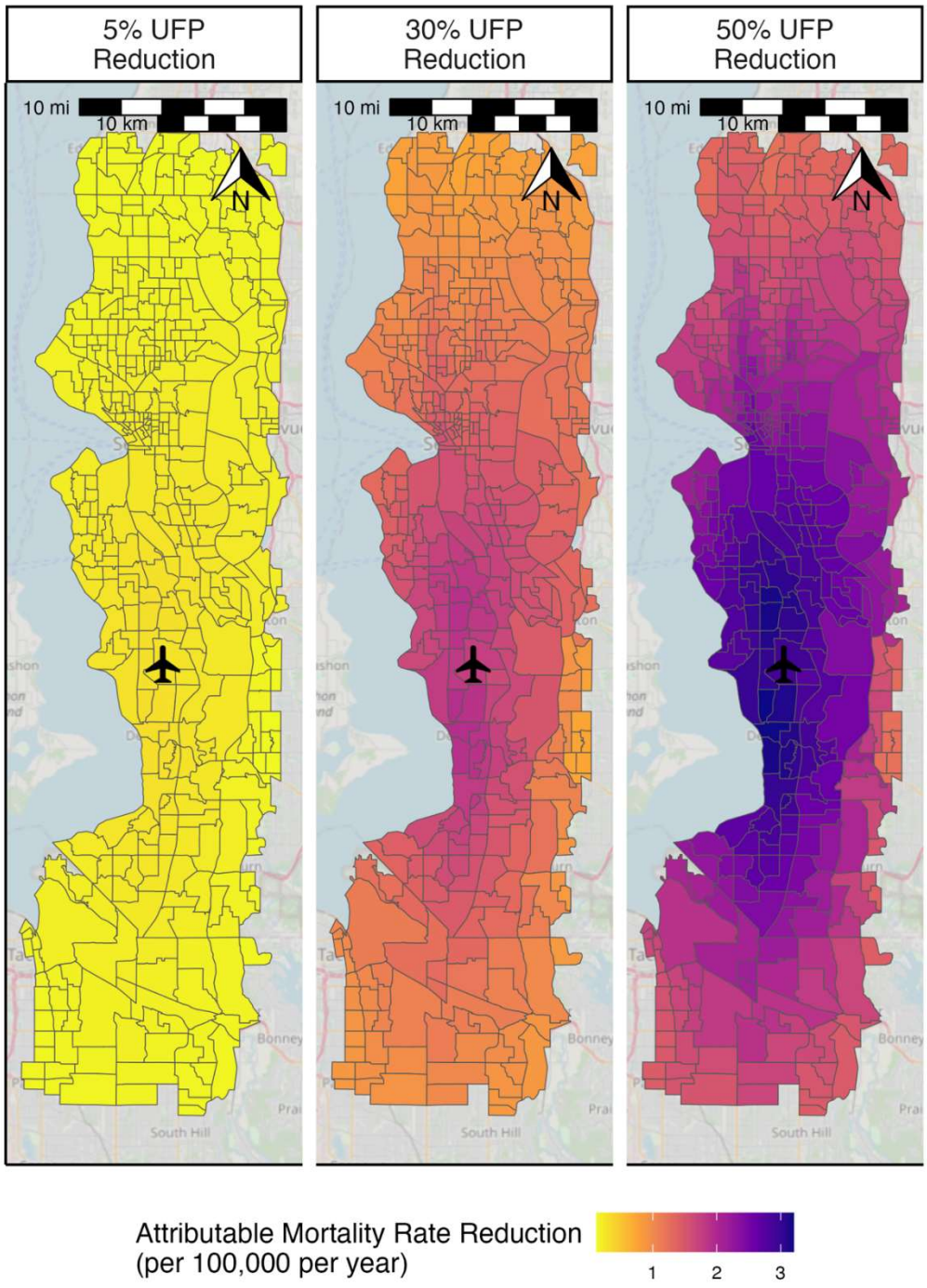


Figure 6. Reduction in AMRR under various SAF (aviation-related UFP) control scenarios.

Discussion

In this study, we estimated attributable mortality reductions around Sea-Tac that could be expected from reductions in aviation-related UFP as a result of SAF adoption. Greater UFP reductions from more stringent control scenarios were associated with larger mortality reductions. While absolute reductions (i.e., ACR) were greater for residents who were non-Hispanic or Latino, above the poverty line, and identified as White due to their greater counts, the standardized rate (AMRR) showed larger reductions among residents who were Hispanic or Latino, below the poverty line, and those that did not identify as White since these populations were more likely to reside in areas where exposure reductions were the greatest. Moreover, areas with higher overall vulnerability experienced the greatest reductions in both mortality case counts and rates.

While characterization of population exposures to aviation emissions, including UFPs, and associated health effects is still emerging, our findings generally align with prior evidence in the field (Lammers et al., 2020; Rissman et al., 2013; Schlenker & Walker, 2016; Stacey et al., 2023; Transport & Environment, 2024). A recent report found that approximately 52 million people living within 20 kilometers of Europe's busiest airports are exposed to elevated levels of UFPs, with lower-income and socioeconomically disadvantaged groups experiencing higher exposures due to their closer proximity to these airports (Transport & Environment, 2024). Moreover, these exposures were associated with higher levels of adverse health outcomes, including high blood pressure, diabetes, and dementia. In a study at Hartsfield-Jackson Atlanta International Airport, investigators reported that aircraft $PM_{2.5}$ concentrations were significantly higher in census tracts with lower income, lower educational attainment, and higher proportions of nonwhite residents (Rissman et al., 2013). Additionally, they estimated that aircraft-related $PM_{2.5}$ contributes to approximately 1.4 premature adult deaths per year in the Atlanta metropolitan area. In another study evaluating elevated CO levels from runway congestion at the twelve largest airports in California, investigators reported increased respiratory and heart-related hospital admissions among approximately 6 million individuals residing within a 10 km-radius (Schlenker & Walker, 2016).

The study has several limitations. In terms of exposure characterization, capturing aviation-related UFP emissions is inherently challenging since UFPs are not regulated, and data are limited. We estimated these emissions using AERMOD with CO as a proxy, assuming that, due to the velocity of the aircraft emissions and downthrust of the engine turbines, UFP emissions exhibit minimal agglomeration and transformation as they disperse to the ground. To improve accuracy, we calibrated these estimates against previously derived aircraft-related emissions (Liu et al., 2025). However, this calibration approach offered moderate agreement, which may be partially influenced by additional activities that impact UFP levels to a smaller degree, including aviation idling and taxiing as well as airport

ground support operations and vehicular traffic. Future work should refine these estimates as more aviation-specific UFP data become available. Furthermore, since direct UFP reduction estimates from SAF adoption were unavailable, we assumed total particle reductions were similar to those observed for nvPM (Moore et al., 2017). More specific SAF blend compositions and their associated UFP reductions should be evaluated in future analyses as empirical data become available. Finally, UFP reduction control scenarios assumed uniform UFP reduction across the study area (e.g., 25%), which likely misses some of the spatial variability expected from emissions reductions.

Moreover, in line with standard risk assessment frameworks, we made several additional assumptions. While we report specific mortality reductions in this work, the actual population benefits will depend on various factors, including true group-specific baseline mortality rates, baseline population exposures, the extent of UFP reductions achieved through SAF, and the true underlying exposure-response relationship. For example, in this work, we applied county-level mortality rates uniformly across the study area, which may underestimate baseline mortality rates and, consequently, health impacts for certain communities, including those that are disadvantaged. For population data, we relied on Census tract counts, which comes with inherent uncertainties. We also used data for the entire adult population (18+ years), as it is more readily accessible for all the subpopulation groups of interest in this study, though it included a slightly younger age range than Bouma et al. (30+ years) (Bouma et al., 2023). Moreover, this widely applied approach (including in tools like BenMAP and other regulatory frameworks) assumes a causal relationship between aviation-related UFPs and mortality, the absence of confounding, a log-linear exposure-response relationship, and no effect modification across subpopulations. Consequently, we assumed that the health risk associated with total ambient UFPs reported by Bouma et al. would apply to aviation-related UFPs around Sea-Tac Airport, in the absence of specific local estimates. This evaluation could be strengthened as more flexible, context-specific exposure-response functions become available.

This study has several strengths. First, by leveraging AERMOD alongside ground-level UFP measurements–which are rarely available and challenging to obtain–we were able to evaluate the impact of aviation-related UFPs reductions on health, a topic largely absent from the literature (Riley et al., 2021). In addition, our findings provide insights into how disadvantaged communities might benefit from SAF adaptation, a challenge for many existing tools. Finally, the large sample size in this study, representing over 1.4 million residents, enhances the generalizability of these findings.

It's notable that, while we focus on mortality in this work, additional health benefits are likely from aviation UFP mitigation, given evidence linking air pollution, including aviation-

related sources, to respiratory and cardiovascular diseases, as well as other adverse health outcomes (Dominski et al., 2021; Riley et al., 2021). Consequently, more progressive policies promoting SAF adoption are likely to lead more broadly to equitable health improvements.

Overall, our findings suggest that reductions in aviation-related UFPs around the Sea-Tac Airport could decrease mortality, particularly among near-airport communities with higher social and economic vulnerabilities. We present a reproducible approach to assess how these communities may experience health benefits from SAF adoption and UFP reductions. This flexible framework can be applied to other regions with airport emissions and adapted to investigate other relevant health outcomes. Finally, this approach can support environmental justice studies and policy initiatives aimed at understanding and mitigating the health risks of aviation-related UFP emissions among near-airport communities.

Acknowledgements

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Section 3. SAF Literature Update

Highlights

- Conducted a systematic literature review on community-level implications of SAF adoption.
- Recent engine studies consistently report beneficial effects of SAFs on particulate emissions across multiple engine types.
- Research on the potential health co-benefits of SAF adoption remains limited.

Literature update

To document the current and future directions regarding SAF research, we conducted a systematic literature review on the community-level implications of air quality and health impacts of SAF adoption. Current work is in preparation for peer reviewed publication (Cheong et al., in preparation).

Methods

A literature search was conducted using two scientific databases (Web of Science and PubMed) to collect relevant information on SAF. Considering the development and real-world application of SAFs, the search was limited to articles published from January 1, 2010, to September 10, 2025. Search was retrieved on September 10, 2025.

Search queries were developed to collect literature that addresses the public health perspective of SAF usage. First, we collected articles related to SAF emissions. Then, this baseline search was combined with other search terms related to air quality and public health, respectively. The flow chart of the literature search is shown below (Figure 8).

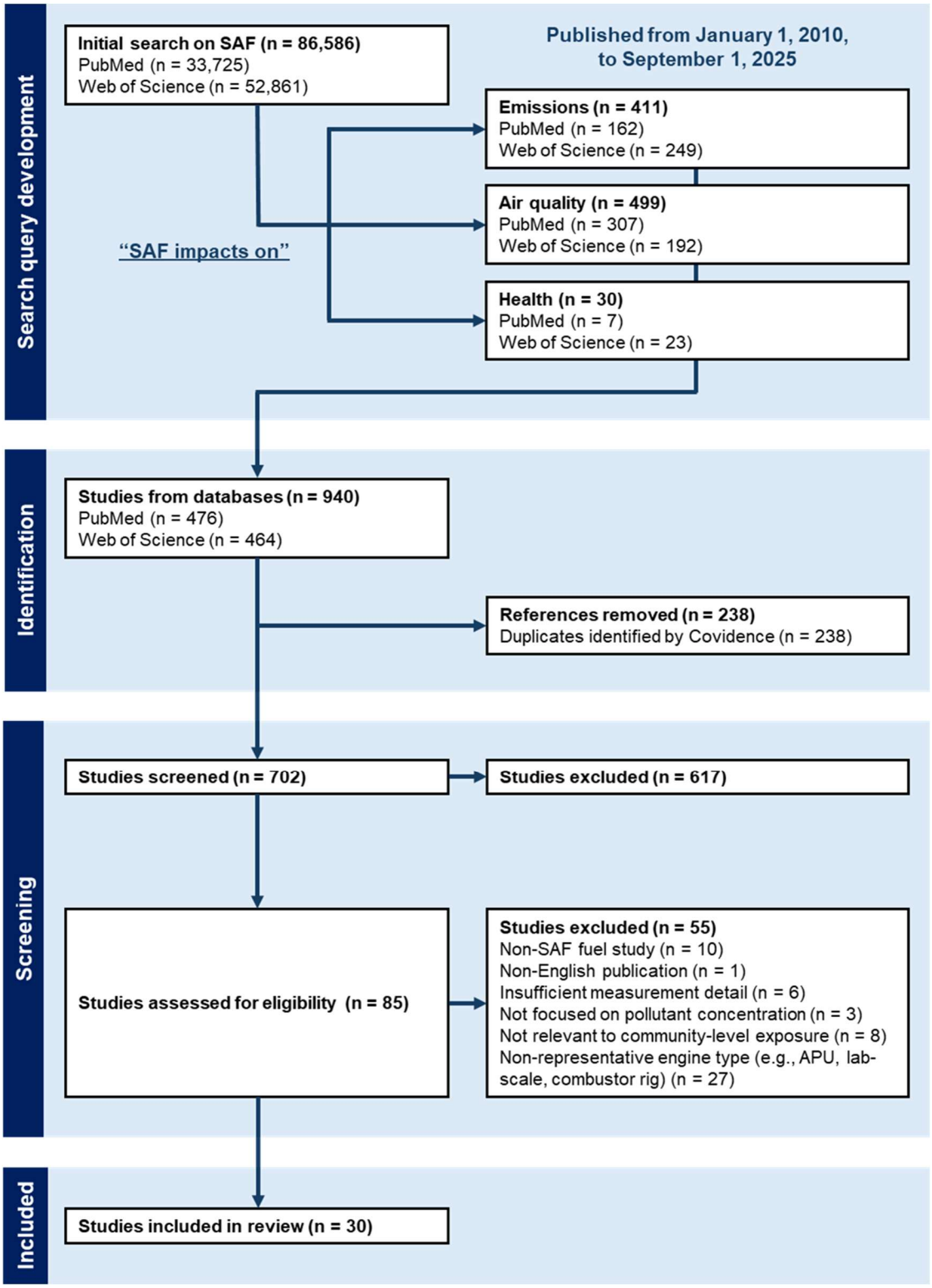

Figure 7. Flow chart of systematic literature review.

The initial search query for SAF retrieved 52,861 records from Web of Science and 33,725 from PubMed. SAF-specific filters (impacts on air quality and public health, respectively) were applied afterwards; searches on SAF emissions retrieved 249 articles were retained from Web of Science and 162 from PubMed. Searches on SAF emissions and air quality yielded 192 and 307 records, respectively, while SAF emissions and health returned 23 from Web of Science and 7 from PubMed. In total, 940 records were identified across both databases for the period of January 1, 2010, to September 1, 2025. After excluding 238 duplicates, 702 records remained for title and abstract screening. Of these, 617 records were excluded as irrelevant to SAF emissions.

The remaining 85 full-text articles were assessed for eligibility. Fifty-five articles were further excluded as they were not representative of full-scale commercial aircraft engines, did not use SAFs, lacked detailed emissions data, not related to community-level exposure, or was not English. The final number of articles was 30.

Results

Most studies (N=24; 80%) focused on the effects of SAFs on emissions. nvPM number and mass were predominantly measured, followed by typical gaseous species such as NO_x, CO, and unburned hydrocarbons. LTO-specific emission indices (EIs) for nvPM revealed effective reduction with increasing SAF blends, especially for low-thrust operating modes (i.e., idle, taxi). Across these studies, SAF use consistently reduced nvPM emissions (Figure 9).

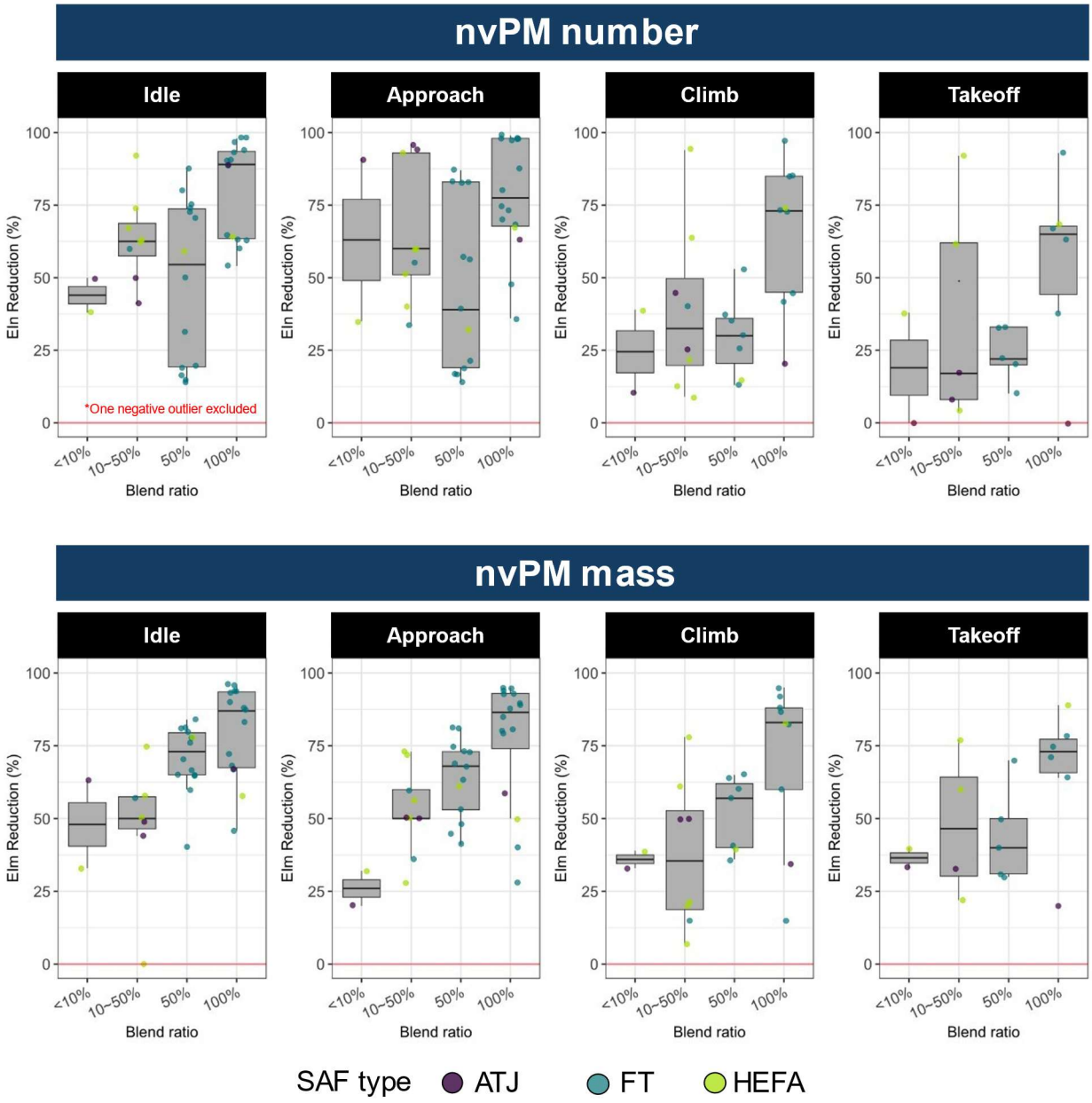

Figure 8. LTO-specific nvPM EIs by blend ratios by SAF type.

Research explicitly addressing air quality or human health impacts remains limited (N=6; 20%). Three studies estimated the air quality impacts of SAF use at local, regional, nationwide level (Arter et al., 2022; Benosa et al., 2018; Blanco et al., 2025). A 50% SAF blend relative to a Jet A baseline was the most common scenario, although Blanco et al. also assessed lower blend ratios (e.g., 5% and 25%). All modeling studies reported reductions in particulate emissions associated with SAF use. Notably, Blanco et al. were the

only authors to estimate UFP concentrations; other studies focused on $PM_{2.5}$. For gaseous pollutants, 50% SAF blends effectively reduced sulfur dioxide emissions by 68% but negligible effect for NO_x (Arter et al., 2022; Benosa et al., 2018; Blanco et al., 2025).

Recent toxicological and health-risk assessment efforts (Blanco et al., 2025; Gualtieri et al., 2022; Melzi et al., 2024) have expanded on early work by Jonsdottir et al. (2019), but these assessments rely primarily on laboratory assays or model-based scenarios. Population-level analyses remain limited because real-world SAF usage is still minimal.

Discussion

Due to differences in fuel composition, SAF combustion generally produces less particulate and sulfur emissions. Relatively large reductions in nvPM are observed in low-thrust modes (e.g., idle, taxi, landing). As such, LTO-specific EIs are important for identifying where SAF use can deliver the greatest emission reductions. However, only a limited number of studies report LTO-specific EIs (Durdina et al., 2021; Lobo et al., 2011; Schripp et al., 2018, 2021). Although these studies link LTO-specific improvements to potential health benefits near airports, community and regional level health implications of SAF adoption remain poorly characterized, as most research points only broadly to public-health relevance without more local-scale exposure impacts.

Existing modeling work would benefit from incorporating UFP metrics and finer spatial resolution, especially in areas near major airports where exposure gradients are steep (Austin et al., 2021; Chung et al., 2023; Wing et al., 2020). Real-world SAF usage remains limited, constraining efforts to assess regional air quality and population-level health impacts. At Sea-Tac, for example, SAF adoption is currently restricted to a 10% blend for departing flights by 2028. Available LTO-specific EIs suggest that strategies such as increasing blend ratios for departures or prioritizing SAF use during specific LTO phases (e.g., idle) could further mitigate community exposure.

Summary

We find that SAFs reduce aircraft emissions, with the largest benefits occurring during low-thrust ground operations. By lowering PM and sulfur emissions, SAF use offers meaningful co-benefits for regional air quality and reducing health risks for populations living near airports. However, while emissions from SAF use are increasingly well characterized, far less is known about how these reductions translate to human exposure and health

benefits. Real-world impacts ultimately depend on dispersion dynamics, airport activity patterns, and implementation strategies, which currently vary by airport and often exclude arriving flights.

Advancing knowledge of SAF implications on air quality and community health in near-airport communities is critical to reducing exposure burdens, supporting adoption, and guiding the transition toward more equitable and sustainable aviation policies. The broader community-level implications of SAF-induced emissions changes require evaluating socioeconomic and health co-benefits, yet the limited real-world SAF use remains a major barrier to measurement-based studies. Our review underscores the need for expanded real-world SAF usage and dedicated air-quality monitoring campaigns to translate emissions reductions into measurable community exposure outcomes.

Section 4. Community Engagement

Highlights

- Site visit and tour of the Sunset Park air quality monitoring site in September 2025.
- UFP Advisory group gathered for a meeting in October 2025.

Monitoring site visit

On September 15, 2025, PSCAA hosted local stakeholders interested in regional air quality activities at the Sunset Park monitoring site. Attendees included city, county, and state officials, University of Washington researchers, and members of PSCAA's Air Quality Program (Figure 10). The Technical Analysis Manager of the PSCAA Air Quality Program shared information about the newly running site and results from preliminary data collection efforts.

Figure 9. Group photo of attendees at the Sunset Park monitoring site visit on September 15, 2025.

UFP Advisory group meeting

A UFP Advisory group meeting was hosted by the UW Department of Environmental & Occupational Health on October 3, 2025. The meeting brought together WA state legislators, a congressional office representative, city council members, state and county regulatory agency members, local school district representatives, community organizers and UW researchers.

Meeting attendees were updated on current air quality initiatives at the UW, discussed emerging needs and jointly prioritized research directions on UFP exposures, health effects and mitigation strategies. Emphasis was placed on balancing scientific content with input and questions, and on building partnerships that connect research, policy and agency priorities to promote healthy living in aviation-impacted communities.

Using an interactive process, advisory members were asked to rank and discuss research priorities and goals. Some important priorities that emerged through conversation with the advisory group include:

1. Participants ranked research intended to distinguish Jet A from SAF emissions at the community level as a priority research area for the coming years.
2. SAFs were explicitly raised as a mitigation/emission reduction strategy of interest.
3. Local government representatives identified adoption of SAF as a current action item of the King County Strategic Climate Plan (SCAP) and discussed the importance of co-benefits analysis in advancing that conversation.
4. Several participants highlighted that current UFP monitoring and modeling efforts need to be able to resolve SAF-related changes:
    a. Members highlighted interest in capturing UFP temporal trends linked to changes in flight operations, which would include SAF uptake.
    b. Regional monitoring with time-resolved UFP instruments could help quantify operational changes such as those associated with fuel switching at Sea-Tac.
5. Community questions related to SAF and health
    a. Whether UFP compositions differ between Jet A and SAF, and whether the group's exposure measurements will be able to characterize those differences.
    b. How temporal changes in UFP levels (e.g., as SAF usage increases) can be measured and communicated through dashboards or public-facing tools.
    c. How to evaluate SAF's impact in the context of cumulative exposures (UFP + noise + housing conditions), particularly for vulnerable populations.

Although the conversation was much broader than SAF use and co-benefits, this advisory meeting reflected a shared view among participants that implementation and evaluation of SAF use and tracking of co-benefits is a regional priority and interest area.

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