Health Impact Review of SHB 1368
Requiring and funding the purchase of zero-emission school buses
(2023 Legislative Session)

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WASHINGTON STATE BOARD OF HEALTH

HEALTH EQUITY
Governor's Interagency Council on Health Disparities

Full review
The full Health Impact Review report is available at:
https://sboh.wa.gov/sites/default/files/2023-02/HIR-2023-06-HB%201368.pdf

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We would like to thank the key informants who provided consultation and technical support during this Health Impact Review.

Contents

Executive Summary
SHB 1368, Requiring and funding the purchase of zero-emission school buses
(2023 Legislative Session)

Evidence indicates that SHB 1368 would likely result in some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033, which would likely decrease environmental exposure to diesel exhaust, improve health outcomes, and decrease inequities for students, school staff, bus drivers, and communities.

BILL INFORMATION

Sponsors: Senn, Fey, Berry, Doglio, Peterson, Chapman, Fosse, Slatter, Gregerson, Callan, Lekanoff, Ramel, Stonier, Street, Santos, Fitzgibbon, Berg, Reed, Simmons, Bergquist, Goodman, Pollet, Cortes, Macri, Leavitt

Summary of Bill:

- Requires that 70% of school buses purchased annually by public school districts, charter schools, state-tribal education compact schools, or used for pupil transportation services contracts be zero-emission school buses beginning September 1, 2030, and 100% of school buses purchased be zero-emission by September 1, 2033.
  - Establishes a one-time extension process for schools unable to meet the 2030 and 2033 purchasing requirements.
  - Defines "zero-emission school bus" as one that produces zero exhaust emission of any air pollutant and any greenhouse gas.
- Directs the Washington State Department of Ecology (Ecology) to establish and administer a zero-emission school bus grant program for K-12 public schools[a] and pupil transportation services contractors.
- Directs the Washington State Office of Superintendent of Public Instruction (OSPI) to amend school bus purchasing protocols of public school districts to account for the 2030 and 2033 zero-emission school bus purchasing requirements.

HEALTH IMPACT REVIEW

Summary of Findings:
This Health Impact Review found the following evidence for provisions in SHB 1368:

- **Informed assumption** that requiring Ecology to establish and administer the zero-emission school bus grant program would likely lead to some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1,

[a] Throughout this HIR, "public school" includes K-12 public schools and districts, charter schools, and state-tribal education compact schools.

2033. This assumption is based on current zero-emission school bus grant program structures in Washington State and information from key informants.

- **Informed assumption** that requiring OSPI to adopt rules to require K-12 public schools to make 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 would likely lead to some K-12 public schools and pupil transportation services contractors meeting these requirements. This assumption is based on current school bus replacement program structures in Washington State and information from key informants.
- **Strong evidence** that some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 will lead to decreased environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities.
- **Very strong evidence** that decreased environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities will improve health outcomes.
- **Strong evidence** that improved health outcomes for students, school staff, bus drivers, and communities will decrease inequities.

Introduction and Methods

A Health Impact Review is an analysis of how a proposed legislative or budgetary change will likely impact health and health disparities in Washington State (RCW 43.20.285). For the purpose of this review 'health disparities' have been defined as differences in disease, death, and other adverse health conditions that exist between populations (RCW 43.20.270). Differences in health conditions are not intrinsic to a population; rather, inequities are related to social determinants (access to healthcare, economic stability, racism, etc.). This document provides summaries of the evidence analyzed by State Board of Health staff during the Health Impact Review of Substitute House Bill 1368 (SHB 1368).

Staff analyzed the content of SHB 1368 and created a logic model depicting possible pathways leading from the provisions of the bill to health outcomes. We consulted with experts and contacted key informants about the provisions and potential impacts of the bill. We conducted an objective review of published literature for each pathway using databases including PubMed, Google Scholar, and University of Washington Libraries. We evaluated evidence using set criteria and determined a strength-of-evidence for each step in the pathway. More information about key informants and detailed methods are available upon request.

The following pages provide a detailed analysis of the bill, including the logic model, summaries of evidence, and annotated references. The logic model is presented both in text and through a flowchart (Figures 1). The logic model includes information on the strength-of-evidence for each pathway. The strength-of-evidence has been established using set criteria and summarized as:

- **Very strong evidence:** There is a very large body of robust, published evidence and some qualitative primary research with all or almost all evidence supporting the association. There is consensus between all data sources and types, indicating that the premise is well accepted by the scientific community.
- **Strong evidence:** There is a large body of published evidence and some qualitative primary research with the majority of evidence supporting the association, though some sources may have less robust study design or execution. There is consensus between data sources and types.
- **A fair amount of evidence:** There is some published evidence and some qualitative primary research with the majority of evidence supporting the association. The body of evidence may include sources with less robust design and execution and there may be some level of disagreement between data sources and types.
- **Expert opinion:** There is limited or no published evidence; however, rigorous qualitative primary research is available supporting the association, with an attempt to include viewpoints from multiple types of informants. There is consensus among the majority of informants.
- **Informed assumption:** There is limited or no published evidence; however, some qualitative primary research is available. Rigorous qualitative primary research was not possible due to time or other constraints. There is consensus among the majority of informants.

- **No association:** There is some published evidence and some qualitative primary research with the majority of evidence supporting no association or no relationship. The body of evidence may include sources with less robust design and execution and there may be some level of disagreement between data sources and types.
- **Not well researched:** There is limited or no published evidence and limited or no qualitative primary research and the body of evidence was primarily descriptive in nature and unable to assess association or has inconsistent or mixed findings, with some supporting the association, some disagreeing, and some finding no connection. There is a lack of consensus between data sources and types.
- **Unclear:** There is a lack of consensus between data sources and types, and the directionality of the association is ambiguous due to potential unintended consequences or other variables.

This review was completed during the Legislative Session and was subject to the 10-day turnaround required in law. This review was subject to time constraints, which influenced the scope of work for this review. The annotated references are only a representation of the evidence and provide examples of current research. In some cases, only a few review articles or meta-analyses are referenced. One article may cite or provide analysis of dozens of other articles. Therefore, the number of references included in the bibliography does not necessarily reflect the strength-of-evidence. In addition, some articles provide evidence for more than one research question, so are referenced multiple times.

Analysis of SHB 1368 and the Scientific Evidence

Summary of relevant background information

- Pollution from diesel exhaust includes: "Soot or particulate matter (PM); Oxides of nitrogen (NO_x) which contributes to the production of ground-level ozone (smog) and acid rain; Hydrocarbons (HC); Carbon monoxide (CO); and Other hazardous air pollutants (HAPs) and air toxics."[1]
  - PM are "inhalable and respirable particles composed of [sulfate], nitrates, ammonia, sodium chloride, black carbon, mineral dust and water."[2]
  - NO_x comprise a group of highly reactive gases.[3] The United States Environmental Protection Agency (EPA) uses Nitrogen dioxide (NO_2), which forms from emissions of cars, trucks, and buses; power plants; and off-road equipment, as the indicator for NO_x.[3]
- Research has found that air quality generally returns to background levels at about 500 feet up to nearly 2,000 feet downwind of major roadways or areas with high traffic, trucking, or rail activity.[4]
- The first federal emission standard for heavy-duty highway engines became effective in 1973 (personal communication, Washington State Department of Ecology (Ecology), February 2023).In 2000, EPA signed new emission standards for model year 2007 and later heavy-duty highway engines.[5] This rule significantly reduced emissions and imposed cleaner burning low sulfur diesel fuel requirements (personal communication, Ecology, February 2023).
  - The EPA's 2000 diesel emission standard for heavy-duty highway engines and vehicles include "very stringent limits for PM (0.01 [grams per brake horsepower hour] g/bhp·hr) and NO_x (0.20 g/bhp·hr)."[5] The PM emission standard took full effect in 2007. The NO_x standard was phased-in for diesel engines: 50% of sales from 2007 to 2009 and 100% in 2010.[5] However, "very few engines meeting the 0.20 g/bhp·hr NO_x limit actually appeared before 2010."[5] Therefore, engine model years 2007 and later are required to meet the 2007 PM standards. Engines produced in 2010 and later are required to meet both the 2007 PM standards and the 2010 NO_x standards.
  - In 2011, EPA and the National Highway Traffic Safety Administration, on behalf of the U.S. Department of Transportation, established a program to develop the first fuel efficiency standards to reduce greenhouse gas (GHG) emissions and fuel consumption for new onroad heavy-duty vehicles (personal communication, Ecology, February 2023). New fuel efficiency standards were finalized in 2016 and were expected to lower CO_2 emissions (personal communication, Ecology, February 2023).
  - The most recent federal diesel emission standard was adopted by the EPA in March 2022 and includes lowering NO_x emission limits to 0.035 g/bhp·hr.
    - In August 2020, the California Air Resources Board (CARB) adopted a standard of 0.02 g/bhp·hr (personal communication, Ecology, February 2023).

        - In December 2022, Washington State adopted the CARB standard (personal communication, Ecology, February 2023).
- In 2015, "EPA issued a Notice of Violation of the Clean Air Act to Volkswagen AG, Audi AG, and Volkswagen Group of America, Inc (collectively, 'Volkswagen'). The notice alleges that Volkswagen installed software in its model year 2009-2015 2.0 liter diesel cars that circumvents EPA emissions standards. These vehicles emit up to 40 times more pollution than emissions standards allow."[6]
    - The EPA has negotiated several cases against Volkswagen for the sales of approximately 590,000 model year 2009 to 2016 diesel motor vehicles that were equipped with "defeat devices" which contained computer software designed to cheat on federal emissions tests.[6]
    - In 2017, Volkswagen pled guilty to three criminal felony counts, and agreed to pay $2.8 billion in criminal penalties, and $1.5 billion in civil resolutions of environmental, customs, and financial claims.[6]
        - Some of these funds have been allocated to provide low- and zero-emission school buses in Washington State.[7] Several other states have received similar funding.
- The 2021 Federal Bipartisan Infrastructure Law includes $5 billion for federal fiscal year (FFY) 2022-2026 to replace existing school buses with zero-emission and low-emission models.[8] One component of this law is the Clean School Bus Rebate Program administered by EPA.[8]
    - In October 2022, four Washington State school districts received over $2.7 million from this program to purchase 7 zero- and low-emission school buses.[9]
- Some states have taken additional action to purchase zero-emission school buses:
    - In 2022, Maryland passed the Climate Solutions Now Act, which requires that all new school bus purchases be zero-emission by 2025.[10]
        - The Maryland Department of the Environment received funds from the U.S. Department of Energy to administer a Zero-emission School Bus Transition Grant Program to purchase zero-emission school buses, install charging infrastructure, and transition to zero-emission school bus fleets.[11]
    - New York State has mandated that all new school bus purchases to be zero-emission by 2027, and the state school bus fleet be entirely zero-emission by 2035.[12]
    - Connecticut has mandated that all school buses in environmental justice communities to be zero-emission by 2030 and the rest of the state's school bus fleet to be zero-emission by 2040 (personal communication, Ecology, February 2023).
    - Maine has mandated that 75% of new school bus purchases and contracts to be zero-emission by 2035 (personal communication, Ecology, February 2023).
    - California passed laws mandating GHG reduction by 40% by 2030 and by 80% by 2050 (personal communication, Ecology, February 2023). Part of this goal includes a fully zero-emission school bus fleet by 2045.[13]

- RCW 82.12.816 currently defines “zero-emission bus” as a bus that emits no exhaust gas from a vehicle’s onboard source of power, other than water vapor.[14]
    - Zero-emission buses include battery electric buses and fuel cell electric buses (i.e., that run on hydrogen).[15] Most zero-emission school buses are battery electric buses as fuel cell electric buses are not commonly available and hydrogen fueling stations are not common in the U.S.[16] While “[i]t will likely be a few years before fuel cell school buses are common […] several models [are] aiming for a 2023 release […]”[16] In Washington State, battery electric school buses are currently available and in use (personal communication, Ecology, February 2023).
- Chapter 173-423 WAC outlines Washington State’s zero-emission and low-emission vehicle standards, and includes:
    - Washington State’s adoption of California’s vehicle emission standards.[17]
    - A sales mandate that requires 35% of new passenger vehicles sales to be zero-emission vehicles beginning in model year 2026, with an increase of 6% to 9% per year until zero-emission vehicles make up 100% of new sales starting in model year 2035.[17]
- The Washington State Office of Superintendent of Public Instruction (OSPI) "[works] with the state's 295 public school districts and 6 state-tribal education compact schools [...to] allocate funding and [provide] tools, resources, and technical assistance so every student in Washington [State] is provided a high-quality public education."[18] As part of their authority, OSPI’s Office of Student Transportation “oversees the allocation of operations funding and the school bus depreciation and replacement systems, and manages the state bidding process for school buses.”[19]
    - RCW 28A.160.130 (Transportation vehicle fund—Deposits in—Use—Rules for establishment and use) outlines the Washington State transportation vehicle fund, where funds are deposited with each county treasurer for each school district of the county for the purchase of approved transportation equipment or repairs.[20] OSPI is responsible for adopting rules regarding the transportation vehicle fund.[20]
    - RCW 28A.160.140 (Contract for pupil transportation services with private nongovernmental entity—Competitive bid procedures) establishes requirements for an open competitive bid process for pupil transportation services with private nongovernmental entities.[21]
    - RCW 28A.160.195 (Vehicle acquisition—School bus categories—Competitive specifications—Purchase—Reimbursement—Rules) outlines specifications OSPI must follow when establishing specifications for school bus categories.[22]
    - RCW 28A.160.200 (Vehicle acquisition—Reimbursement schedule—Maintenance and operation—Depreciation schedule) outlines OSPI’s current school bus replacement and depreciation process.[23]
    - RCW 28A.710.040 (Charter Schools – Requirements) states that Washington State charter schools are subject to the supervision of OSPI and the State Board of Education, including accountability measures, to the same extent as other public schools, except as otherwise provided in this chapter.[24]

    - RCW 28A.715.010 (Authority to enter into compacts—Process—Rules—Retirement systems) gives OSPI authority to enter into state-tribal education compacts.[25]
- In 2019, Franklin Pierce High School in Tacoma received the first electric school bus in Washington State.[26]
- In 2020, the Washington State Legislature updated its GHG emission limits to require a reduction of 95% below 1990 levels by 2050 (personal communication, Ecology, February 2023). Ecology is tasked with inventorying the state's GHG emissions and tracking progress toward these limits.[27] Ecology carries out several regulatory and incentive programs designed to help the state achieve its GHG limits, including the following:
    - In 2021, Washington State passed the Climate Commitment Act, which directs Ecology to develop and implement a statewide program to reduce GHG emissions by 95% by 2050 (personal communication, Ecology, February 2023).
    - Ecology also administers grant programs that have a goal of reducing diesel pollution emissions, including grants that have been used to purchase zero-emission school buses (personal communication, Ecology, February 2023).
        - Ecology operates Washington State's Clean Diesel Program and manages $112.7 million from the Federal Volkswagen Settlement and $28.4 million from the Washington State Volkswagen Settlement (personal communication, Ecology, February 2023). Ecology's Clean Diesel Program includes Zero-emission Grant Projects which have goals of replacing diesel school buses with all electric buses including charging infrastructure, as well as vocational training programming to prepare students for jobs created through zero-emission vehicle adoption (personal communication, Ecology, February 2023).
        - Ecology operates Washington State's Clean Cars Program, which includes a range of rules restricting emissions from fossil fuel-powered vehicles and requiring that increasing percentages of new vehicles sold in the state over time be zero-emission (personal communication, Ecology, February 2023).

Summary of SHB 1368

- Requires that 70% of school buses purchased annually by public[b] school districts, charter schools, state-tribal education compact schools, or used for pupil transportation services contracts be zero-emission school buses beginning September 1, 2030, and 100% of school buses purchased be zero-emission by September 1, 2033.
    - Establishes a one-time extension process for schools unable to meet the 2030 and 2033 purchasing requirements.

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[b] Throughout this HIR, "public school" includes K-12 public schools and districts, charter schools, and state-tribal education compact schools.

    - Defines “zero-emission school bus” as one that produces zero exhaust emission of any air pollutant and any GHG.
- Directs Ecology to establish and administer a zero-emission school bus grant program for K-12 public schools and pupil transportation services contractors.
- Directs OSPI to amend school bus purchasing protocols of public school districts to account for the 2030 and 2033 zero-emission school bus purchasing requirements.

Health impact of SHB 1368

Evidence indicates that SHB 1368 would likely result in some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033, which would likely decrease environmental exposure to diesel exhaust, improve health outcomes, and decrease inequities for students, school staff, bus drivers, and communities.

Pathway to health impacts

The potential pathway leading from the provisions of SHB 1368 to health and equity are depicted in Figure 1. Based on provisions of the bill, we made the informed assumptions that requiring Ecology to establish and administer the zero-emission school bus grant program and requiring OSPI to adopt rules that K-12 public schools make 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 would lead to some K-12 public schools and pupil transportation services contractors meeting these requirements. These assumptions are based on current zero-emission school bus grant program and school bus replacement program structures in Washington State and information from key informants.

There is strong evidence that some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 would decrease environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities.[15,28-32]

There is very strong evidence that decreased environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities will improve health outcomes.[4,33-44] Finally, there is strong evidence that improved health outcomes for students, school staff, bus drivers, and communities will reduce inequities.[35,36,37,45-51]

Scope

Due to time limitations, we only researched the most linear connections between provisions of the bill and health and equity and did not explore the evidence for all possible pathways. For example, we did not evaluate potential impacts related to:

- Non-public schools. Provisions of SHB 1368 would not apply to K-12 private schools, homeschools, cyber schools, etc. in Washington State. This HIR did not explore potential health and equity impacts for these schools.

- Cost savings. This HIR did not evaluate potential impacts on cost of fuel, maintenance costs, monetized health damages, or the cost-benefit of transitioning to zero-emission school buses.
    - In general, zero-emission buses are more fuel efficient than diesel buses and have lower operational and maintenance costs compared to diesel buses.[15,28,30]
    - The Clean Air Task Force uses emissions and other data from the EPA to calculate projected health impacts of diesel.[44] The tool projects that the monetized health damages due to diesel in Washington State in 2023 will be over $1.3 million.[44]
    - Cost benefit analyses have been conducted on the use of electric school buses compared to diesel school buses, and findings are conflicting. In one study, researchers analyzed cost of fuel, electricity and battery costs, health externalities, and frequency regulation market price and found that: 1) electric buses lead to school savings of $6,070 per seat, and 2) the electric school buses become a net benefit after 5 years of operation.[52] In a separate study that included the economic implications of cold temperature extremes on electric vehicle battery operations, the researchers found that electric buses increased net costs by $7,200/seat relative to a diesel bus.[53] However, these studies were conducted in 2014 and 2015, and technology has changed since their publication.
    - Ecology has conducted a zero-emission school bus transition cost model, using provisions of SHB 1368 to project a rough estimate of the cost to the state of increasing zero-emission bus purchases between 2023 and 2033 (personal communication, Ecology, February 2023). The model used the following data to build the model: current cost of an electric school bus, current cost of an internal combustion school bus, the number of both types of actives buses in Washington State, the number of buses purchased annually, the range of time between ordering and receiving electric school buses, the World Resource Institute's projected year for electric school bus price parity, already allocated Washington Clean Diesel program funds, and Washington State population estimates (personal communication, Ecology, February 2023). The model assumes that zero-emission school buses will be at price parity with internal combustion engine buses from 2033 onward, and therefore there is no "zero-emission bus premium" to account for in the transition after 2033 (personal communication, Ecology, February 2023). Based on the purchase requirements in SHB 1368, Ecology predicts that the number of Washington State zero-emission school bus purchases will increase over time, while the cost of the buses will decrease over time (unpublished data, Ecology, February 2023). The model predicts that by 2030, 428 zero-emission buses will be purchased annually, and by 2033, 556 zero-emission school buses will be purchased annually (unpublished data, Ecology, February 2023). The model also predicts that the Washington State school bus fleet would be completely zero-emission by late 2047 or 2048 (unpublished data, Ecology, February 2023). Further, the model predicts that the total expenditure on zero-emission school buses from 2023 to 2033 would be $397,832,036, and that, when

compared to the total expenditure on internal combustion engine school buses (without the zero-emission purchasing requirements) the additional cost from choosing zero-emission buses is $245,756,236 (unpublished data, Ecology, February 2023). Electric charging infrastructure or hydrogen fueling infrastructure may represent additional costs (personal communication, Ecology, February 2023).

- Noise pollution. Zero-emission buses are quieter than conventional buses, which has the potential to reduce noise pollution in areas they serve.[28,30] Key informants stated that a benefit of zero-emission school buses is decreased noise, which may affect mental health (e.g., anxiety), particularly in urban areas (personal communication, Ecology, February 2023). This HIR did not evaluate the effect of zero-emission school buses on levels of noise pollution.
- Larger, long-term impacts on climate change. Changes in demand for zero-emission school buses could result in infrastructure changes (e.g., increased production of other low- or zero-emission vehicles) that could help mitigate the impacts of climate change. This HIR did not evaluate the potential impacts SHB 1368 may have on larger, longer-term climate change issues.
- Longer-term health outcomes related to climate change and consequences of diesel emissions (e.g., sea level change, temperature changes).[54] As the consequences of diesel emissions are global, adoption of zero-emission school buses in one jurisdiction (state or country) alone will not significantly affect the trajectory of climate change or risks associated with adverse health outcomes. Therefore, this analysis focused on the pollutants associated with diesel emissions that can be affected locally and in the short-term and are independently associated with adverse health outcomes.

Magnitude of impact

SHB 1368 would impact Washington State K-12 public school students, staff, school bus drivers, and communities.

Washington State has 295 public school districts and 6 state-tribal education compact schools.[55] There were 1,096,304 students enrolled in the 2022-2023 school year, and 68,625 classroom teachers, 3,500 principals, and 6,847 other school leaders employed during the 2020-2021 school year.[56] Based on data from the Washington State Charter Schools Association, there are 17 Charter Schools in Washington State and, as of January 2023, the monthly enrollment for the 2022-2023 school year was 4,819 students.[57] The number of school-aged children increased an average of 11,300 per year between 2012 and 2022.[55] Beginning in 2020, public school enrollment has decreased due to remote learning policies to mitigate the spread of COVID-19.[55]

There are approximately 8,350 school bus drivers and 180 school bus monitors in Washington State.[58] Most school bus drivers are employed directly by school districts while some are employed by private companies contracting transportation services to school districts.[59]

Washington State school buses provide over 700,000 student trips per day and travel over 100 million miles per year.[59] As of February 2023, OSPI reports that of the 10,623 school buses in

Washington State's fleet, 35 are electric buses, while the remaining (99.7%) operate on fossil fuels (gas, diesel, propane, or compressed natural gas [CNG]) (unpublished data, OSPI, February 2023). Approximately 8,040 (75.7%) of Washington State school buses are diesel (unpublished data, OSPI, February 2023). The bus purchase dates range from 1988 to 2023, and approximately 12.9% of active school buses in Washington State were purchased before 2007 (unpublished data, OSPI, February 2023).

School buses in Washington State may be owned by the Educational Service District (ESD), school district, or pupil transportation services contractors.[60] As of 2023, there are 6 contractors providing 1,331 school buses in Washington State: 1) First Student, Inc. provides 747 school buses; Durham School Services provides 375 buses; Zum provides 142 buses; Harlow's Bus Service provides 45 buses; Lind-Ritzville Cooperative provides 12 buses; and Garfield-Palouse Cooperative provides 10 buses.[60]

According to 2019 roadway traffic data from Washington State Department of Transportation (WSDOT), 8% of the state's population lives close to heavily trafficked roadways.[49] According to 2014 Washington Tracking Network data (the most current data available), Washington State's diesel emission levels of NO_x was 9.18 annual tons/Km^2 and estimates of $PM_{2.5}$ emissions were 10.78 annual tons.[49] Ecology notes that, "[g]enerally, nitrogen dioxide levels are far lower [in Washington State] than the national standard, even at the sites located next to high traffic areas of Interstate-5 in Seattle and Tacoma."[61]

Overall, SHB 1368 would impact Washington State K-12 public school students, staff, school bus drivers, and communities.

Logic Model

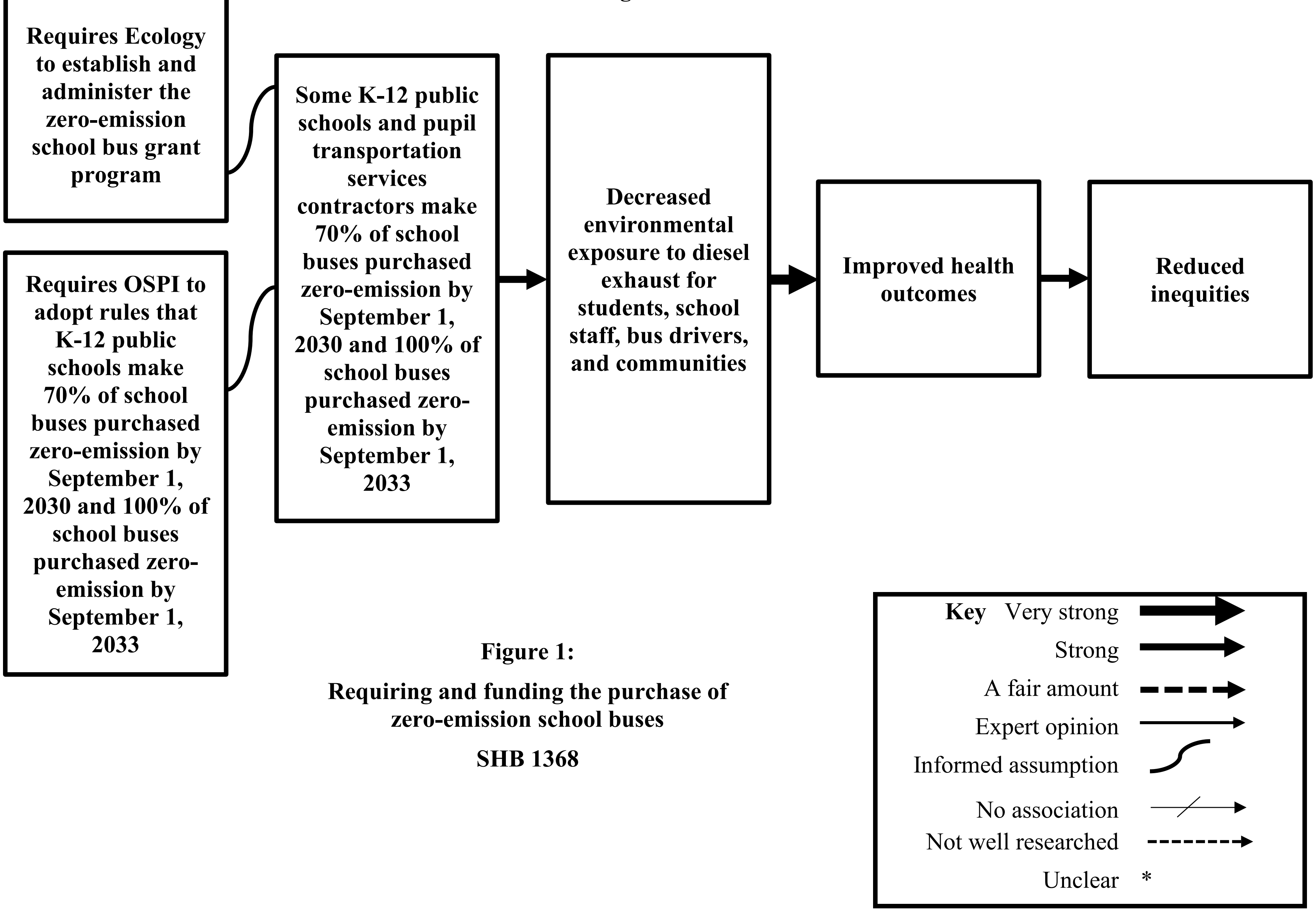

Figure 1:

Requiring and funding the purchase of zero-emission school buses

SHB 1368

Summaries of Findings

Would Washington State Department of Ecology establishing and administering the zero-emission school bus grant program result in some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033?

We have made the informed assumption that Washington State Department of Ecology (Ecology) establishing and administering the zero-emission school bus grant program would result in some K-12 public schools[c] and pupil transportation services contractors making 70% of school buses purchased zero-emission by 2030 and 100% of school buses purchased zero-emission by 2033. This informed assumption is based on current zero-emission school bus grant program structures in Washington State and information from key informants.

SHB 1368 would amend Chapter 70A.15 RCW to direct Ecology to establish and administer a zero-emission school bus grant program that provides funds to K-12 public school districts, charter schools, state-tribal education compact schools, and pupil transportation services contractors under RCW 28A.160.140 to replace fossil fuel school buses with zero-emission school buses.

Ecology currently operates Washington State's Clean Vehicles Program and Clean Diesel Program and manages $112.7 million from the Washington State Volkswagen Settlement (personal communication, Ecology, February 2023). Ecology's Clean Diesel Program includes Zero-emission Grant Projects which has goals of replacing diesel school buses with all electric buses including charging infrastructure, as well as vocational training programming to prepare students for jobs created through zero-emission vehicle adoption (personal communication, Ecology, February 2023). Ecology's 2021-2023 grant awards included 39 new electric buses, and 3 school districts receiving vocational training programming (personal communication, Ecology, February 2023). Under Ecology's management of the Volkswagen Settlement funds, allocations have been made for 40 electric school buses, 39 workplace electric vehicle charging stations, and 41 corridor electric vehicle charging stations (personal communication, Ecology, February 2023). Therefore, in total, Ecology's current programs have supported the purchase of 79 zero-emission school buses in Washington State (personal communication, Ecology, February 2023).

The National Academies has summarized challenges with implementing zero-emission buses. Generally, first-time implementation of zero-emission buses "require[s] new fueling infrastructure, increasing up-front capital costs. [Fuel cell electric buses] require a hydrogen fueling station and [battery electric buses] require charging stations, both of which will likely necessitate additional land-use considerations and electric infrastructure upgrades."[15] Previous studies have identified challenges with each type of zero-emission bus. For battery electric buses, documented challenges include range limitations, charging time, high electricity rates for some locations, complicated utility rate structures, and higher capital costs.[15] For example, the range for long/extended-range battery electric buses is "likely less than 150 miles in transit service on a

[c] Throughout this HIR, "public school" includes K-12 public schools and districts, charter schools, and state-tribal education compact schools.

single charge."[15] Moreover, charging at bus depots may require hours to fully charge.[15] Fast charge buses may help alleviate some of these challenges, though initial capital costs may be higher and buses may require different charging infrastructure.[15]

Key informants in Washington State also shared concerns regarding various zero-emission school bus infrastructure needs (charging stations, heated garages, sustained battery life, electrical grid capacity, specialty bus maintenance, rate of bus manufacturing, etc.) (personal communications, February 2023). School districts in mountainous, colder regions and rural school districts may have more infrastructure needs due to impact of temperature on electric vehicle battery charging and overall distances traveled by school buses, including travel for sports events and field trips (personal communications, February 2023). Some Washington State school districts with these characteristics may also have less overall district funding or transportation funding available (personal communications, February 2023). Key informants stated that these concerns may prevent some school districts from participating in SHB 1368's proposed grant program (personal communications, February 2023). Key informants also stated that some Washington State schools that have participated in electric school bus grants have returned funding for zero-emission buses because of the cost of or lack of infrastructure available (personal communication, February 2023). SHB 1368 does allow for the purchase, installation, and repair of zero-emission vehicle charging and fueling stations and additional costs associated with station installation.

Further, key informants from Ecology stated that they are working on initiatives to alleviate zero-emission vehicle infrastructure needs (personal communication, Ecology, February 2023). For example, Ecology is in the process of developing a statewide Clean Fuel Standard, where higher carbon fuels generate deficits and lower carbon fuels generate credits (personal communication, Ecology, February 2023). Within this credit and deficit system, credit generators can sell credits, while deficit generators buy credits. Electric utilities are required to invest their credit revenue in transportation electrification (personal communication, Ecology, February 2023). While there is no requirement that they invest in school transportation, they may choose to do so, which would most likely be an eligible use of credit revenue. Ecology anticipates that this system, in collaboration with already-funded expansion of statewide charging infrastructure will support school district needs (personal communication, Ecology, February 2023). Some key informants also discussed the potential benefits of hydrogen-powered school buses, for which statewide infrastructure does not yet exist (personal communications, February 2023).

Generally, key informants stated that schools with more financial resources and transportation budgets and those with larger school bus fleets may be more likely to apply to the grant program (personal communications, February 2023). SHB 1368 directs Ecology to prioritize grants that reduce diesel pollution and greenhouse gases (GHG) from the oldest school buses, for disproportionately impacted communities, for economically-disadvantaged children, and that accelerate the transition of the state school bus fleet to zero-emissions. It is not possible to predict which school districts would apply to the grant program or the impact of the grant prioritization provisions. Key informants shared that the full implementation outcomes of a zero-emission school bus grant program would depend on allocated funding, staff resources, and communication with school districts (personal communications, February 2023).

In addition, SHB 1368 includes a one-time extension from the 2030 and 2033 zero-emission school bus purchasing requirements. If a school bus purchaser finds that purchasing a zero-emission bus is not feasible due to route and zero-emission bus technology constraints, they are able to request an extension. Extensions may be jointly granted by OSPI and Ecology. It is not possible to predict which school bus purchasers may request and be granted an extension for purchasing zero-emission school buses.

Lastly, SHB 1368 would make pupil transportation services contractors eligible to apply for the zero-emission school bus grant program. The three contractors providing the greatest number of buses in Washington State (First Student, Inc., Durham School Services, and Zum)[60] all have goals to transition to zero-emission buses. First Student, Inc., the contractor with the greatest number of school buses in Washington State, serves two of the largest public school districts in the state (i.e., Seattle Public Schools and Tacoma Public Schools) as well as other districts.[60,62] First Student, Inc. states that they assist school districts to transition to electric buses, and have a goal of offering 30,000 electric schools buses nationally by 2040.[63] In a January 2023 press release, the parent company of Durham School Services, National Express LLC, stated that Durham School Services plans to transition their fleet to all zero-emissions vehicles by 2035.[64] In 2022, the Seattle School Board voted to award their three-year contract for school buses to 2 contractors. In addition to First Student, Inc., Zum began providing 142 school buses to Seattle Public Schools on January 3, 2023.[60,65] Zum stated that all of its on-road fleet will be electric vehicles by 2025.[66] However, "[f]or now, [the] company will provide a couple of electric buses in Seattle […] Bus fleets will transition to all-electric in three to four years […]"[67]

Both First Student, Inc. and Zum state that they provide "solutions for school districts interested in adding electric buses to their fleet."[63]Among other services available to school districts, First Student, Inc. states that they help districts identify funding options and manage grant applications.[63] Zum states that they help with planning and provide expertise to make the transition to electric vehicles successful.[66] This suggests that at least some of the current pupil transportation services contractors in Washington State have made commitments to provide zero-emission school buses and may have interest in and/or apply for a zero-emission school bus grant if SHB 1638 were to pass.

Given information from key informants about Ecology's current zero-emission school bus grant program implementation, the bill's one-time extension option, and potential future challenges for school districts, we have made the informed assumption that SHB 1368's requirement that Ecology establish and administer a zero-emission school bus grant program would likely lead to some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033.

Would Washington State Office of Superintendent of Public Instruction adopting rules that K-12 public schools make 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 result in some K-12 public schools meeting this requirement?

We have made the informed assumption that Washington State Office of Superintendent of Public Instruction (OSPI) adopting rules to require K-12 public schools make 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 would likely lead to some K-12 public schools meeting these requirements. This informed assumption is based on current school bus replacement program structures in Washington State and information from key informants.

SHB 1368 would amend RCW 28A.160.130 (Transportation vehicle fund—Deposits in—Use—Rules for establishment and use) and RCW 28A.160.195 (Vehicle acquisition—School bus categories—Competitive specifications—Purchase—Reimbursement—Rules), and add new sections to chapter 28A.160 RCW (Student Transportation), chapter 28A.710 RCW (Charter Schools), and chapter 28A.715 RCW (State-Tribal Education Compacts Authority).

Under current statute, RCW 28A.710.040 (Charter Schools – Requirements), charter schools are subject to the supervision of OSPI and the State Board of Education, including accountability measures, to the same extent as other public schools.[24] Also under current statute, RCW 28A.160.130 outlines the Washington State transportation vehicle fund, where funds are deposited with each county treasurer for each school district of the county for the purchase of approved transportation equipment or repairs.[20] School bus purchases by public schools are currently made out of respective transportation vehicle funds. OSPI is responsible for adopting rules regarding the transportation vehicle fund. RCW 28A.160.140 establishes requirements for an open competitive bid process for pupil transportation services with private nongovernmental entities.[21]

Further, RCW 28A.160.195 outlines the transportation alternate funding grant program.[22] Currently, OSPI "is responsible for developing categories and competitive specifications for school bus acquisitions as well as a corresponding list of school bus dealers with the lowest purchase price quotes. School districts and [ESDs] that purchase buses through this competitive quote process or through a separate lowest price competitive bid process are eligible for certain state funds that are based on the category of vehicle, the anticipated lifetime of vehicles of this category, and a state reimbursement rate. The accumulated value of the state payments received by the district and the potential investment return is designed to be equal to the replacement cost of the vehicle, less its salvage value, at the end of its anticipated lifetime".[68]

SHB 1368 would also adopt OSPI's current school bus replacement and depreciation process (RCW 28A.160.200)[23] and expand the eligibility for replacement to zero-emission school buses. SHB 1368 would amend RCW 28A.160.195 to establish that once nonzero-emission school bus pricing is deemed no longer necessary by OSPI for calculating reimbursement or depreciation, school buses must be zero-emission school buses. Finally, SHB 1368 would establish that OSPI require school bus vendors to ensure that emission-related features meet the definition of zero emission in SHB 1368 by September 1, 2033.

Key informants from OSPI stated that each school district makes decisions regarding when it is time to replace a school bus (personal communication, OSPI, February 2023). Currently, some districts will sell their buses to other districts, which allows for some cost savings (personal communication, OSPI, February 2023). OSPI pointed out that there are likely not enough zero-emission school buses currently in Washington State to allow for district-to-district purchases, meaning all districts may be purchasing new buses, which would likely incur large initial costs, particularly for smaller districts (personal communication, OSPI, February 2023). A key informant from the Washington State School Directors' Association (WSSDA) shared concerns that SHB 1368's zero-emission school bus requirements could lead to some schools needing to reallocate funds from their core education programming budget to cover the costs of zero-emission buses (personal communication, WSSDA, February 2023). Information from Ecology and the World Resource Institute's Electric School Bus Initiative indicate that "relying primarily on depreciation payments to cover the cost of new school bus purchases will likely be insufficient for the transition to electric school buses […] Historically underserved districts face greater barriers to purchasing electric school buses without additional incentives, presenting an equity concern" (personal communication, Ecology, February 2023).

As of February 2023, OSPI reports that of the 10,623 school buses in Washington State's fleet, approximately 8,040 (75.7%) are diesel (unpublished data, OSPI, February 2023). Ecology has conducted a zero-emission school bus transition cost model, using provisions of SHB 1368 to project a rough estimate of the cost to the state of increasing zero-emission bus purchases between 2023 and 2033 (personal communication, Ecology, February 2023). The model predicts that by 2030, 428 zero-emission school buses will be purchased annually and, by 2033, 556 zero-emission school buses will be purchased annually (unpublished data, Ecology, February 2023). The model further predicts that the Washington State school bus fleet would be completely zero-emissions by late 2047 or 2048 (unpublished data, Ecology, February 2023).

Given information from key informants about current school bus depreciation and replacement programming and potential future challenges, we have made the informed assumption that SHB 1368's requirement that OSPI adopt rules to require K-12 public schools make 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 would likely lead to some K-12 public schools meeting these requirements.

Will some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 impact environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities?

There is strong evidence that some K-12 public schools and pupil transportation services contractors making 70% of school buses purchased zero-emission by September 1, 2030 and 100% of school buses purchased zero-emission by September 1, 2033 would decrease environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities.

Combustible diesel engines, including school buses, emit Carbon monoxide, Carbon dioxide, Nitrogen oxides, Sulfur oxides, and volatile organic compounds, such as benzene and formaldehyde.[41] The majority of literature on environmental exposure to diesel exhaust is focused on levels of particulate matter (PM) and oxides of nitrogen (NO_x).[2,3] In 2000, the U.S. Environmental Protection Agency (EPA) signed emission standards for model year 2007 and later heavy-duty highway engines ("Clean Diesel Emissions Standards").[5] Even though newer diesel school buses likely meet the EPA's emission standards, school buses still release pollutants, including PM and NO_x, in their vehicle exhaust.[28] Studies have shown that heavy-duty diesel vehicles contribute 3% to 6% of the U.S. fleet in terms of distance traveled, but contribute disproportionate amounts of NO_x emissions (7 times more than gasoline).[48] Further, research shows that diesel filtration methods do not mitigate negative health effects that are associated with whole diesel exhaust,[41] and that filtration systems on diesel engines emit ultrafine PM, which may easily pass the blood-brain barrier.[43] Students, school bus drivers, school staff, and communities are exposed to diesel exhaust inside and near diesel school buses.[28]

Key informants from Ecology stated that any movement along the spectrum from diesel engines to clean diesel engines to zero-emission vehicles results in positive impacts for pollution and health (personal communication, Ecology, February 2023). The U.S. Centers for Disease Control and Prevention (CDC) noted that "replacing [diesel] buses with those that use cleaner or alternative fuels reduces air pollution, including soot [PM]. Retrofitting diesel buses can reduce diesel emissions of [PM] up to 90[%] […]"[32] For example, a natural experiment before, during, and after the adoption of clean diesel technologies between 2005 and 2009 found 10% to 50% reductions in fine and ultrafine PM on school buses that adapted clean diesel technologies compared to buses without these technologies.[29] Study authors concluded that "when children ride buses with clean air technologies and/or fuels they experience lower exposures to air pollution."[29]

Zero-emission buses have even greater positive impacts on pollution and health. Zero-emission buses emit no harmful tailpipe emissions, which can significantly decrease exposure to air pollutants like PM and NO_x and lead to improved local air quality.[15,28,30-32] According to a fact sheet from the U.S. Department of Transportation, a zero-emission bus may eliminate 1,690 tons of CO_2, 350 pounds of diesel PM, and 10 tons of NO_x, over its 12-year lifespan.[30]

Zero-emission buses may also reduce GHG emissions.[28] However, zero-emission buses can still generate upstream GHG emissions due to their need to recharge, and levels of emissions may vary depending on the source of electricity generation.[31] Since the majority of U.S. electricity is generated from coal and natural gas, most research and modeling have estimated total reductions in GHG emissions using these sources of electricity generation.[31] In communities that have tracked or estimated GHG emission savings, transit agencies have predicted a reduction in CO_2 of 154 to 162 tons per year when diesel buses were replaced by battery electric buses.[31]

About 21% of GHG emissions in Washington State are from electricity generation.[27] However, renewable energy sources "account for about 90% of [Washington State's] total energy production."[69] In 2020, the majority (66%) of electricity generation in Washington State came from hydroelectric power.[69] After hydroelectric power, 12% of electricity generation was from natural gas, 9% from other renewable resources (i.e., wind and biomass), 8% from nuclear power, and less than 5% from coal.[69] Renewable energy sources are associated with much lower emissions of GHGs than coal or natural gas (e.g., 26 to 85 grams of carbon dioxide per kilowatt hour [grams CO_2-eq/kWh] for renewable emergency sources compared to 1,002 grams CO_2-eq/kWh for coal).[31] Since the majority of Washington State's electricity generation is from renewable sources, there is the potential that upstream GHG emissions for zero-emission buses in the state may be even lower than available evidence suggests.

While zero-emission school buses have the potential to reduce local air pollution, emissions from school buses are only one source of diesel emissions. The largest sources of diesel exhaust in Washington State are from heavy duty trucks, ships, construction equipment, locomotives, farm equipment, and buses.[70] Students, school staff, bus drivers, and communities may still be exposed to diesel exhaust from these other sources. However, researchers have noted that children are exposed to elevated pollution levels while riding on diesel school buses and "commuting is a major contributor to children's exposures to traffic-related air pollutants."[29] Another study found that, "children's exposure to diesel exhaust from school buses constitutes an additional exposure beyond background levels of particulates […]."[47] Despite potential exposure from other sources, reducing diesel emissions from school buses will likely reduce exposure to diesel emissions for students, school staff, bus drivers, and communities.

Lastly, some school districts currently sell their buses to other districts, which allows for some cost savings (personal communication, OSPI, February 2023). However, under current statute related to the school bus replacement incentive program (RCW 28A.160.205), school districts are required to demonstrate to OSPI that buses being replaced are scrapped and not purchased for road use.[71] SHB 1368 retains this statute, and the statute's continued implementation would likely further reduce diesel emissions across the state as diesel school buses are scrapped or removed from road use.

Overall, since zero-emission school buses eliminate harmful tailpipe emissions, there is strong evidence that zero-emission school buses will reduce environmental exposure to diesel exhaust for students, staff, bus drivers, and communities.

Will decreased environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities impact health outcomes?

There is very strong evidence that decreasing environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities will improve health outcomes.[2,3,33,34,36-40,44,72,73] Fossil fuel-powered engines produce emissions (e.g., PM, NO_x, Carbon monoxide, hydrocarbons) associated with negative health effects,[39,40] and diesel vehicles emit more PM and NO_x than gasoline or hybrid counterparts.[39] Evidence shows that diesel exhaust emissions generally, and PM and NO_x independently, impact health.

An analysis of National Air Toxics Assessment 2014 data[72] indicates that diesel exhaust is the most harmful air pollutant affecting people's health in Washington State.[73,74] Diesel exhaust is linked to several adverse health outcomes, such as airway inflammation, vascular dysfunction, developmental toxicity, neuroinflammation, and respiratory mortality.[41] The Clean Air Task Force uses emissions and other data from the EPA to calculate projected health impacts of diesel.[44] The tool projects that in Washington State there will be 122 deaths; 1,487 cases of asthma exacerbation; 1,444 cases of upper respiratory symptoms; and 49 heart attacks due to diesel in 2023.[44] These data also indicate the 2023 predicted rate of lifetime cancer due to diesel is 142 cases per million Washingtonians.[44]

In 2013, the International Agency for Research on Cancer classified diesel exhaust as a carcinogen in humans based on evidence from occupational epidemiological studies.[40] Washington State is currently ranked 33 of 49 for risk of cancer from diesel soot, compared to other U.S. states.[44] Ecology has stated that diesel exhaust “contributes more than 70[%] of the total cancer risk from toxic air pollution.”[70]

In a systematic review that explored the impacts of whole diesel and filtered diesel on health, statistically significant health effects were associated with exposure to both types of exhaust across all cardiovascular, nervous system, and endocrine health outcomes studied.[41] The results of this review indicate that diesel filtration methods do not mitigate negative health effects that are associated with whole diesel exhaust.[41]

Researchers have also evaluated health impacts for students riding diesel school buses. Researchers found that “children riding a diesel-fueled school bus can have a cancer risk that is 23-46 times higher than the federal standard” and that up to 0.3% of the air in school buses is from the bus exhaust.[42] By conducting a modeling study to examine the concentration levels of school bus exhaust inside the bus cabin that is attributed to the bus itself, researchers found that exhaust can enter the bus cabin from the back of the bus, that the cabin pollution is highest when buses drive at medium speed, and that the location of the bus tailpipe can influence the level of pollution that enters the bus.[42]

Specific to bus drivers, a systematic review and meta-analysis on the association between professional drivers’ potential exposure to diesel exhaust and lung cancer, the results show “professional drivers who were potentially exposed to diesel exhaust have a 18% excess risk of lung cancer compared with non-drivers, after adjustment for smoking”.[75] The risk of lung cancer increased with longer duration of professional driver employment.[75]

Particulate matter (PM)
A 2012 systematic review of the association between PM and human health found the preponderance of data show that “PM exposure causes a small but significant increase in human morbidity and mortality.”[33] While PM with a diameter greater than 10 microns (µm) (PM_{10}) are largely filtered out by the nose and upper airway, smaller particles are capable of penetrating peoples’ lungs and entering their bloodstream.[2] The World Health Organization (WHO) notes that particles with a diameter of less than 10 µm pose the greatest risks to health.[2] PM with a diameter between 2.5 and 10 µm ($PM_{2.5–10}$) are defined as “coarse,” less than 2.5 µm as “fine,” and less than 0.1 µm as “ultrafine” particles.[33] The associations between $PM_{2.5}$ and cardiovascular and respiratory mortality and morbidity are well-documented.[36,37] For example, $PM_{2.5}$ or less “contributes to approximately 2 million premature deaths per year, ranking it as the 13th leading cause of worldwide mortality.”[37] It is well-established that “elevated exposures to $PM_{2.5}$ and PM_{10} lead to declines in lung function and worsening of heart and lung diseases (like triggering asthma attacks) that may result in hospitalizations or death”.[4] Further, exposure to $PM_{2.5}$ and PM_{10} lead to stroke, type 2 diabetes, neurological and cognitive impairment, and pre-term and low-birth weight babies, and other negative health impacts.[4] Diesel vehicles disproportionately contribute to $PM_{2.5}$ present in the atmosphere.[38]

Evidence shows “populations subjected to long-term exposure to PM have a significantly higher cardiovascular incidence and mortality rate.”[33] Evidence also indicates PM exposure exacerbates respiratory diseases (e.g., worsening respiratory symptoms, more frequent medication use, decreased lung function, recurrent healthcare use, and increased mortality).[33] Data demonstrate "a dose-dependent relationship between PM and human disease."[33] Further evidence suggests that decreased PM exposure results in decreases in overall mortality.[33]

Nitrogen oxides (NO_x)
Globally, diesel vehicles contribute about 20% of NO_x,[39] of which NO_2 is the most prevalent form. Evidence shows breathing air with a high concentration of NO_2 over short or longer exposures can irritate airways in the human respiratory system and contribute to respiratory health concerns (e.g., asthma).[3]

Recent research has also shown that levels of PM and NO_x can impact mental health and brain function.[43] For example, an increase in ambient PM ($PM_{2.5}$ and PM_{10}) concentration has been strongly associated with increased risk of depression and suicide.[43] Increases in PM and NO_x are associated with higher rates of anxiety and depression, as well as neurostructural and neurofunctional effects (e.g., increased inflammation and oxidative stress, changes to neurotransmitters and neuromodulators and their metabolites).[43]

Overall, there is very strong evidence that decreasing environmental exposure to diesel exhaust for students, school staff, bus drivers, and communities improves health outcomes.

Will improving health outcomes for students, school staff, bus drivers, and communities impact inequities?
There is strong evidence that improving health outcomes for students, school staff, bus drivers, and communities would decrease inequities.[35-38,45-51,76] It is well-documented that children, people with heart or lung diseases, older adults (65 years and older), people with low socioeconomic status, people living in certain areas, and communities of color and are most likely to be affected by air particle pollution exposure.

Inequities by age
Children are generally more susceptible to air pollutants, including PM and NO_x, as their respiratory systems are still developing and they have a faster breathing rate.[38,46,76] For example, a prospective cohort study of 1,759 children (average age, 10 years) found associations between air pollution and three measures of lung function—forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), and maximum midexpiratory flow rate.[38] Results of the study showed the effects of ambient air "pollutants on FEV_1 were similar [regardless of gender], and remained significant among children with no history of asthma and among those with no history of smoking, suggesting that most children are susceptible to the chronic respiratory effects of breathing polluted air."[38] Specifically, "cumulative deficits in the growth of lung function during the eight-year study period resulted in a strong association between exposure to air pollution and a clinically low FEV_1 at the age of 18 years."[38] Authors noted such lung function deficits may increase the risk of respiratory conditions in young adulthood.[38] Furthermore, "reduced lung function is a strong risk factor for complications and death during adulthood."[38]

Older adults are also more susceptible to air pollutants than the general population.[45] In a study that examined the effects of chronic exposure to traffic from a heavy-duty diesel fueled vehicle area, respiratory symptoms associated with asthma and airway inflammation were significantly higher in the elderly population, compared to a nonsmoking adult population.[77]

Inequities by existing health conditions
People with existing health conditions (i.e., respiratory infections, respiratory diseases, heart or circulatory disease, diabetes, history of stroke) are especially sensitive to air pollution.[45-47] For example, "diesel exhaust can adversely affect children with underlying respiratory illnesses such as asthma, bronchitis, and infections".[46,47] People with heart or lung diseases are also at increased risk, because PM can aggravate these health conditions.[46]

Inequities for children may be compounded by intersecting inequities due to health conditions. According to the 2021 Washington Healthy Youth Survey, 16.0% of Washington 10th graders reported that a doctor or nurse told them they had ever had asthma.[78] A natural experiment before, during, and after the adoption of clean diesel technologies between 2005 and 2009 concluded that "when children ride buses with clean air technologies and/or fuels they experience lower exposures to air pollution, less pulmonary inflammation, more rapid lung growth over time, and reduced absenteeism than when they are on buses without these technologies and fuels. These improvements were often strongest among children with asthma, suggesting that cleaner buses may be especially important to protecting the health of [these] students."[29]

Inequities due to geography, socioeconomic status, and racism
It is well-documented that geography and socioeconomic status impact air quality-related equity outcomes.[48,50,51] The largest sources of diesel exhaust in Washington State are from heavy duty trucks, ships, construction equipment, locomotives, farm equipment, and buses,[70] and the areas of Washington State with the highest diesel exhaust emissions are urban areas, areas with ports, and areas along the Interstate-5 corridor (e.g., Seattle, Tacoma, Spokane, Vancouver, Port Angeles, Anacortes, Everett, Lynnwood).[49]

Inequities for children may be compounded by intersecting inequities due to socioeconomic status. According to the Bureau of Transportation Statistics' analysis of 2017 National Household Travel Survey data, 20% of low-income families do not own any vehicles, and the majority (70%) of children from these families take a school bus to school.[79] In contrast, 99% of non-low-income families own at least one vehicle, and over 50% of children from these families take a private vehicle to school.[79]

Inequities in air quality for low socioeconomic families may also be compounded by inequities due to racism. Low-income Black families are more likely to be below the federal poverty level than other families (53% of Black families, compared to 39% of non-Hispanic white, 44% of Hispanic, and 42% of other-race families).[80] Air pollution is also higher in areas of the U.S. that house more people of color and more people with low socioeconomic status.[48] Research shows that communities of color and people with lower household incomes experience higher concentrations of and exposures to NO_x and diesel emissions, which contribute to measurable differences in health and life expectancy.[48] A large cohort study found that men; Black, Asian, and Hispanic people; and people eligible for Medicaid (interpreted as an indication of low socioeconomic status) were found to have greater risk of death with exposure to $PM_{2.5}$ than the general population.[4] A separate study used data collected by satellite that measured NO_2 emissions and additional atmospheric gases from space (TROPospheric Ozone Monitoring

Instrument [TROPOMI]) and examined differences among neighborhood-level data on race, ethnicity, and income levels.[48] The study explored emissions in 52 major cities representing 130 million people from June 2018 to February 2020, and found a "62% reduction in diesel emissions would decrease race-ethnicity and income inequities by 37%".[48]

Inequities due to environmental racism

Environmental racism can be defined as "any policy, practice or directive that differentially affects or disadvantages (where intended or unintended) individuals, groups or communities based on race".[81] In contrast, environmental justice can be defined as "the right to a clean environment and workplace."[50] The impacts of environmental racism on exposure to outdoor air pollution have been examined. One study found that areas of the U.S. with higher-than-average Black, Asian and Hispanic or Latino populations have been consistently exposed to higher $PM_{2.5}$ levels, as compared to areas with higher-than-average white and Native American populations.[51] In a separate multilevel analysis of over 65,000 U.S. census tracts, the researcher used a state racism index to gauge Black-white inequities to measure differences in exposure to outdoor pollution.[50] Results of the study show that states with higher levels of Black–white gaps had higher levels of exposure to air pollution and more environmental health risk.[50] The author stated that, "the disproportional exposure across communities is tied to systematic inequalities in environmental regulation and other structural elements such as housing and incarceration."[50] The National Academies has noted that implementing zero-emission buses "on blocks that serve environmental justice communities [which may experience pollutants from multiple sources] provides direct health benefits to the people living there."[15]

Overall, there is strong evidence that improving health outcomes for students, school staff, bus drivers, and communities would decrease inequities, particularly for children, people with heart or lung diseases, older adults (65 years and older), people with low socioeconomic status, people living in certain areas, and communities of color.

Annotated References

1. **About Diesel Fuels. 2022; Available at: https://www.epa.gov/diesel-fuel-standards/about-diesel-fuels#:~:text=Pollution%20from%20diesel%20exhaust%20includes%3A%201%20Soot%20or,Other%20hazardous%20air%20pollutants%20%28HAPs%29%20and%20air%20toxics. Accessed 2/21/2023.**
This U.S. EPA webpage includes information about diesel fuel. As of April 2022, 33% of the entire transportation fleet in the U.S. was fueled by diesel. Pollution from diesel exhaust includes: "Soot or particulate matter (PM); Oxides of nitrogen (NOx) which contributes to the production of ground-level ozone (smog) and acid rain; Hydrocarbons (HC); Carbon monoxide (CO); and Other hazardous air pollutants (HAPs) and air toxics."

2. **World Health Organization. Ambient air pollution: Pollutants. Air Pollution Available at: https://www.who.int/airpollution/ambient/pollutants/en/. Accessed 31 December 2019, 2019.**
This World Health Organization (WHO) webpage provides an overview of ambient air pollution and discussion of various pollutants and the sources from which they are emitted. Authors note, "Adverse health consequences to air pollution can occur as a result of short- or long-term exposure. The pollutants with the strongest evidence of health effects are particulate matter (PM), ozone (O3), nitrogen dioxide (NO2) and sulphur dioxide (SO2)." Fine particulate matter (PM_{10} and $PM_{2.5}$) are particularly harmful to human health because they are small enough to penetrate human lungs and enter the bloodstream. Furthermore, evidence indicates that NO_2 can "increase symptoms of bronchitis and asthma, as well as lead to respiratory infections and reduced lung function and growth." Additionally, "NO_2 may be responsible for a large disease burden, with exposure linked to premature mortality and morbidity from cardiovascular and respiratory diseases."

3. **U.S. Environmental Protection Agency. Nitrogen Dioxide (NO_2) Pollution | Basic Information about NO_2. Available at: https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2. Accessed 31 December 2019, 2019.**
This U.S. Environmental Protection Agency (EPA) webpage provides an overview of Nitrogen Dioxide (NO2) and its role as an indicator for the larger group of nitrogen oxides (NOx). The agency identifies breathing air with a "high concentration of NO2 can irritate airways in the human respiratory system." Specifically, "exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections." Those at greater risk for the health effects of NO2 include people with asthma, as well as children and the elderly.

4. **Cowlitz County Washington State Department of Health. Millennium Bulk Terminals - Longview Health Impact Assessment, September 2018. September 2018 2018**
Cowlitz County and the Washington State Department of Health conducted a health impact assessment ("a process that helps support the required review and analysis of potential health

effects of a plan, project, or policy before it is built or implemented") for the Millennium Built Terminals. The assessment focused on neighborhoods near the proposed terminal, as well as community facilities along the BNSF rail line in Cowlitz County. The full assessment includes an introduction, health evaluation, impacts of coal export, population characteristics, recommendations, and references. Research included in the assessment has found that air quality generally returns to background levels at about 500 feet up to nearly 2,000 feet downwind of major roadways or areas with high traffic, trucking, or rail activity. Further, it is well established that "elevated exposures to PM2.5 and PM10 lead to declines in lung function and worsening of heart and lung diseases (like triggering asthma attacks) that may result in hospitalizations or death". Finally, exposure to PM2.5 and PM10 lead to stroke, type 2 diabetes, neurological and cognitive impairment, and pre-term and low-birth weight babies, and other negative health impacts. A large cohort study found that men; black, Asian, and Hispanic persons; and people eligible for Medicaid (interpreted as an indication of low economic status) were found to have greater risk of death with exposure to PM2.5 than the general population. The full report is available online.

5. **United States: Heavy-Duty Onroad Engines. Emissions Standards Available at: https://www.dieselnet.com/standards/us/hd.php#stds. Accessed December, 2019.**
This DieselNet page provides an overview of the EPA's emission standards for heavy-duty onroad diesel engines from Model Year 1974 through present.

6. **Learn About Volkswagen Violations. 2022; Available at: https://www.epa.gov/vw/learn-about-volkswagen-violations. Accessed February 2023.**
The EPA has negotiated several cases against Volkswagen for the sales of approximately 590,000 model year 2009 to 2016 diesel motor vehicles that were equipped with "defeat devices" which contained computer software designed to cheat on federal emissions tests. In 2017, Volkswagen plead guilty to three criminal felony counts, and agreed to pay $2.8 billion in criminal penalties, and $1.5 billion in civil resolutions of environmental, customs, and financial claims.

7. **$22 million from VW settlement goes toward electric transit buses and low-emission school buses [press release]. 2018.**
Washington State Department of Ecology reports on state allocations from the Volkswagen diesel emissions settlement.

8. **Clean School Bus Program. 2023; Available at: https://www.epa.gov/cleanschoolbus. Accessed.**
The Federal Bipartisan Infrastructure Law includes $5 billion for FY 2022-2026 to replace existing school buses with zero emission and low emission models. One component of this Law is the Clean School Bus Rebate Program. These programs are managed by the United States Environmental Protection Agency.

9. **Washington Schools Receive $2 Million from EPA's Clean School Bus Program [press release]. 2022.**
The United States Environmental Protection Agency reports on the Clean School Bus Program rebate competition. Four Washington school districts received over $2.7 million from President

Biden’s Bipartisan Infrastructure Law that will go toward purchasing seven clean school buses. This funding is part of the first $1 billion of a five-year, $5 billion program created by President Biden’s Bipartisan Infrastructure Law.

10. **State of Maryland Climate Solutions Now Act of 2022. 2022.**
In 2022, Maryland passed the Climate Solutions Now Act, which requires that all new school bus purchases be electric after 2024.

11. **Department of the Environment funds electric and alternative fuel school buses under Volkswagen settlement [press release]. 2019.**
The Maryland Department of the Environment received nearly $2.5 million in funding for electric and alternative fuel school buses. The funding source was part of the settlement of the Volkswagen “defeat devices” case. Funding was allocated to a pilot program to begin use of electric school buses.

12. **N.Y. Educ. Law § 3638.**
Under N.Y. Educ. Law § 3638, New York State’s has mandated that all new school bus purchases to be zero emission by 2027, and the state school bus fleet be entirely zero-emission by 2035.

13. **California Air Resources Board Appendix E: 2022 SB 1403 School Bus Incentive Program Report.2022.**
California Air Resources Board provides an update on their School Bus Incentive Program. California is mandated to reduce greenhouse gases by 40% by 2030 and by 80% by 2050; part of this goal includes a fully zero emission school bus fleet by 2045

14. **Exemptions—Electric vehicle batteries and fuel cells—Labor and services—Infrastructure. (Expires July 1, 2025.), RCW 82.12.816 RCW 82.12.816(2022).**
RCW 82.12.816 defines "Zero emissions bus" as a bus that emits no exhaust gas from the onboard source of power, other than water vapor.

15. **National Academies of Sciences Engineering, and Medicine. Guidebook for Deploying Zero-Emission Transit Buses.Washington, D.C.: The National Academies Press;2021.**
The National Academies published a guidebook in 2021 to provide “public transit agencies with best practices, case studies, and lessons learned from previous [implementations] of battery electric buses, fuel cell electric buses, and related fueling infrastructure […] to improve their decision-making and business practices for planning, implementing, and operating zero-emission buses.” The guidebook provides information about: 1) assessing needs and requirements; 2) selecting technology; 3) determining capital costs and funding opportunities; 4) fueling infrastructure strategy and costs; 5) developing and implementing fueling infrastructure; 6) accepting and validating buses to ensure they meet specifications; 7) personnel training and development; 8) establishing operations and maintenance practices; and 9) and data monitoring and evaluation. The National Academies provided background information about zero-emission buses, which include battery electric buses and fuel cell electric buses (i.e., that run on hydrogen). All zero-emission buses “have zero harmful tailpipe emissions, improving local air

quality." They stated, first-time implementation of zero-emission buses "require new fueling infrastructure, increasing up-front capital costs. [Fuel cell electric buses] require a hydrogen fueling station and [battery electric buses] require charging stations, both of which will likely necessitate additional land-use considerations and electric infrastructure upgrades." Previous studies have identified the primary challenges with each type of electric bus. Challenges associated with implementing fuel cell electric buses include cost, fuel cell system issues, parts supply, range issues, and access to and cost of hydrogen fuel. For battery electric buses, challenges include range limitations, charging time, high electricity rates for some locations, complicated utility rate structures, and higher capital costs. National Academies lists technology specifications for electric buses. There are two types of battery electric buses: long/extended range and fast charge. The range for long/extended range battery electric buses is "likely less than 150 miles in transit service on a single charge." Moreover, charging at bus depots may require hours to fully charge. Electric buses "are more expensive than diesel buses in 2020 [and] [c]harging infrastructure costs vary and may not scale easily; incremental costs or space requirements increase with fleet size." The fast charge buses, "can often be a 1:1 replacement for conventionally fueled buses" as they can charge on-route several times a day. Fuel cell electric buses and infrastructure costs are higher than both diesel and battery electric buses; however, "scaling up hydrogen fueling infrastructure may be less costly and less land-intensive than scaling up battery charging infrastructure." Overall, zero-emission buses "eliminate harmful tailpipe emissions and localized pollution, resulting in cleaner air and healthier communities. The National Academies notes that implementing zero-emission buses "on blocks that serve environmental justice communities provides direct health benefits to the people living there." However, zero-emission buses may still have "upstream greenhouse gas emissions from electricity generation for charging [battery electric buses] or hydrogen production and delivery for fueling [fuel cell electric buses]."

16. **Hydrogen Fuel Cell School Bus Entering the Market this Year [press release]. 2023.**
On January 4, 2023, FuelCellWorks stated that "Pegasus Specialty Vehicles announced a joint venture to bring hydrogen school buses to market in 2023." Most electric school buses are battery electric buses. One challenge to fuel cell electric buses is "the need for widespread hydrogen fueling infrastructure As of mid-2020, there were only 43 retail hydrogen fueling stations in the U.S., most of which are in California." The company states, "[i]t will likely be a few years before fuel cell school buses are common. However, with several models aiming for a 2023 release, that future may be nearer than some might have initially expected." Fuel cell electric buses have a larger range and less recharging needs than battery electric buses.

17. **Clean Vehicles Program, Chapter 173-423 WAC Chapter 173-423 WAC(2022).**
Chapter 173-423 WAC outlines Washington's new zero-emission and low-emission vehicle standards, and includes Washington's adoption of California's vehicle emission standards, and a sales mandate that requires 35% of new passenger vehicles sales to be zero-emission vehicles beginning in model year 2026, with an increase of 6-9% per year until zero-emission vehicles make up 100% of new sales starting in model year 2035.

18. **About OSPI. Available at: https://www.k12.wa.us/about-ospi. Accessed.**
The Washington State Office of the Superintendent of Public Instruction (OSPI) reports on their goals and duties. OSPI "[works] with the state's 295 public school districts and 6 state-tribal

education compact schools [...to] allocate funding and [provide] tools, resources, and technical assistance so every student in Washington [State] is provided a high-quality public education."

19. **Student Transportation. Available at: https://www.k12.wa.us/policy-funding/student-transportation. Accessed.**
As part of their authority, OSPI's Office of Student transportation "oversees the allocation of operations funding and the school bus depreciation and replacement systems, and manages the state bidding process for school buses."

20. **Transportation vehicle fund—Deposits in—Use—Rules for establishment and use., RCW 28A.160.130 (2022).**
RCW 28A.160.130 (Transportation vehicle fund—Deposits in—Use—Rules for establishment and use) outlines the Washington State transportation vehicle fund, where funds are deposited with each county treasurer for each school district of the county for the purchase of approved transportation equipment or repairs. OSPI is responsible for adopting rules regarding the transportation vehicle fund.

21. **Contract for pupil transportation services with private nongovernmental entity—Competitive bid procedures., RCW 28A.160.140 (1990).**
RCW 28A.160.140 establishes requirements for an open competitive bid process for pupil transportation services with private nongovernmental entities.

22. **Vehicle acquisition—School bus categories—Competitive specifications—Purchase—Reimbursement—Rules., RCW 28A.160.195 (2005).**
RCW 28A.160.195 (Vehicle acquisition—School bus categories—Competitive specifications—Purchase—Reimbursement—Rules) outlines specifications OSPI must follow when establishing specifications for school bus categories.

23. **Vehicle acquisition—Reimbursement schedule—Maintenance and operation—Depreciation schedule., RCW 28A.160.200 (1995).**
RCW 28A.160.200 outlines OSPI's current school bus replacement and depreciation process.

24. **Charter schools—Requirements., RCW 28A.710.040 (2018).**
RCW 28A.710.040 (Charter Schools – Requirements) states that Washington State Charter schools are subject to the supervision of OSPI and the state board of education, including accountability measures, to the same extent as other public schools, except as otherwise provided in this chapter.

25. **Authority to enter into compacts—Process—Rules—Retirement systems., RCW 28A.715.010 (2018).**
RCW 28A.715.010 (Authority to enter into compacts—Process—Rules—Retirement systems) gives authority for OSPI to enter into state-tribal education compacts.

26. **Washington's first electric school bus rolls through Tacoma [press release]. 2019.**
In 2019, Franklin Pierce High School in Tacoma received the first electric school bus in Washington State.

27. **Washington's Greenhouse Gas Inventory. 2023; Available at. Accessed 2/21/2023.**
The Washington State Department of Ecology publishes the Greenhouse Gas Inventory every two years. The inventory "[measures] the state's progress in reducing greenhouse gases compared to a 1990 baseline." The most recent report available details greenhouse gas emissions through 2019. Among other information, the report states that 39% of Washington State greenhouse gas emissions are from transportation; 25% are from residential, commercial, and industrial heating; 21% are from electricity generation; and 14% are from other sources.

28. **Agency U.S. Environmental Protection. EPA Clean School Bus Program Second Report to Congress 2023.**
The EPA has a Clean School Bus (CSB) Program, which funds the replacement of school buses emitting higher levels of pollutants with buses that emit zero or much lower levels of pollutants. This report is the EPA's second report on this program to Congress.

29. **Adar S.D., D'Souza J., Sheppard L., et al. Adopting Clean Fuels and Technologies on School Buses: Pollution and Health Impacts in Children. *American Journal of Respiratory and Critical Care Medicine.* 2015;191(12):1413-1421.**
Adar et al. stated that children "experience elevated pollution levels on diesel-powered school buses." They conducted a natural experiment before, during, and after the adoption of clean diesel technologies between 2005 and 2009. Among other findings, they found 10% to 50% reductions in fine and ultrafine PM on school buses that adapted clean diesel technologies between 2005 and 2009. The authors concluded that "when children ride buses with clean air technologies and/or fuels they experience lower exposures to air pollution, less pulmonary inflammation, more rapid lung growth over time, and reduced absenteeism than when they are on buses without these technologies and fuels. These improvements were often strongest among children with asthma, suggesting that cleaner buses may be especially important to protecting the health of our most vulnerable students."

30. **Transportation U.S. Department of. Benefits of Zero Emission Buses fact sheet.2017.**
This fact sheet from the U.S. Department of Transportation provides an overview of the benefits of zero-emission buses. The U.S.-China Race to Zero Emissions challenge aims to increase the number of zero-emission buses in both countries. This fact sheet highlights the benefits of zero-emission buses, including pollutant remission reduction, better fuel efficiency, market acceleration and job creation, and operational/maintenance cost savings. Specific to pollutants, a zero-emission bus may eliminate 1,690 tons of CO_2 over its 12-year lifespan, which is the equivalent of taking 27 cars off the road. Moreover, zero-emission buses "eliminate 10 tons of nitrogen oxides and 350 pounds of diesel particulate matter, improving air quality in the communities that they serve." The flyer also stated that, "[f]leets that have deployed zero-emission buses have seen a substantial reduction in operational and maintenance costs compared to conventional buses." They are also quieter than conventional buses, which has the potential to reduce noise pollution in areas they serve. Lastly, "[z]ero-emission buses are more fuel efficient than diesel buses."

31. **Deliali A., Chhan D., Oliver J., et al. Transitioning to zero-emission bus fleets: State of practice implementations in the United States. *Transport Reviews.* 2021;41(2):164-191.**
Deliali et al. state that there are three types of zero-emission buses: battery electric buses, fuel cell electric buses, and fuel cell plug-in hybrid buses. They state that battery electric buses “present the highest fuel efficiency and lowest procurement, operation, and maintenance costs, and have been chosen by most transit agencies.” All three types of zero-emission buses “have the potential to reduce the impact of transportation operations on air quality.” The authors present emissions data from battery electric buses. Since zero-emissions buses have no tailpipe emissions, most studies use “Well-to-Wheel” assessments that “account for emissions related to electricity generation and transportation.” Depending on the dominate sources for electricity generation in a community, battery electric buses will still result in varying greenhouse gas emissions due to the need to recharge. The majority of electricity generation in the U.S. is from natural gas and coal. Estimates of greenhouse house gas emissions vary “depending on the model and assumptions used for the lifecycle analysis, mainly the energy source for electricity generation.” In communities that have tracked or estimated greenhouse gas emission savings, transit agencies have predicted a reduction in carbon dioxide of 154 to 162 tons per year when diesel buses were replaced by battery electric buses.

32. **Cleaner and Alternative Fuel Bus Fleets: Interventions addressing the social determinants of health. 2023; Available at: https://www.cdc.gov/policy/opaph/hi5/cleandiesel/index.html#:~:text=Diesel%20emissions%20can%20adversely%20affect%20health%20by%20contributing,clean%20diesel%20technology%2C%20can%20reduce%20these%20emissions.%20. Accessed 2/21/2023.**
On this webpage, the U.S. Centers for Disease Control and Prevention (CDC) provides information about alternative fuel bus fleets, including clean diesel bus fleets. CDC noted that “[a]lternatives to diesel engines include battery-electric and compressed natural gas fleets. Retrofitting existing buses or replacing buses with those that use cleaner or alternative fuels reduces air pollution, including soot. Retrofitting diesel buses can reduce diesel emissions of particulate matter up to 90[%] whereas battery-electric buses have zero tailpipe emissions.” They state that zero-emission buses decrease exposure to air pollutants and “emit no harmful-to-health tailpipe emissions, which can lead to improved air quality.”

33. **Anderson J. O., Thundiyil J. G., Stolbach A. Clearing the air: a review of the effects of particulate matter air pollution on human health. *J Med Toxicol.* 2012;8(2):166-175.**
Anderson et al. conducted a scientific review of all available published literature to determine the association or lack of association between particulate matter (PM) and human health. Authors also summarized the proposed mechanisms for associations based on existing human, animal, and in vitro studies. PM is made up of "extremely small particles and liquid droplets containing acids, organic chemicals, metals, and soil or dust particles. PM is categorized by size and continues to be the fraction of air pollution that is most reliably associated with human disease." It is thought to contribute to cardiovascular and cerebrovascular disease "by the mechanisms of systemic inflammation, direct and indirect coagulation activation, and direct translocation into systemic circulation." The data demonstrating PM's effect on the cardiovascular system show "[p]opulations subjected to long-term exposure to PM have a significantly higher cardiovascular incident and mortality rate." Moreover, "[s]hort-term acute exposures subtly increase the rate of cardiovascular events within days of a pollution spike." The data for PM's effects on

cerebrovascular disease is less strong, "though some data and similar mechanisms suggest a lesser result with smaller amplitude." Evidence also indicates that respiratory diseases are similarly exacerbated by exposure to PM. "PM causes respiratory morbidity and mortality by creating oxidative stress and inflammation that leads to pulmonary anatomic and physiologic remodeling. The literature shows PM causes worsening respiratory symptoms, more frequent medication use, decreased lung function, recurrent health care utilization, and increased mortality." Overall, authors found PM exposure "to have a small but significant adverse effect on cardiovascular, respiratory, and to a lesser extent, cerebrovascular disease. These consistent results are shown by multiple studies with varying populations, protocols, and regions." Furthermore, "[t]he data demonstrate a dose-dependent relationship between PM and human disease, and that removal from a PM-rich environment decreases the prevalence of these diseases." Authors conclude "the preponderance of data shows that PM exposure causes a small but significant increase in human morbidity and mortality" and recommend "further study [...] to elucidate the effects of composition, chemistry, and the PM effect on susceptible populations" Authors provide examples of "common sense" recommendations to reduce exposure. For example, "[s]usceptible populations, such as the elderly or asthmatics, may benefit from limiting their outdoor activity like limiting outdoor activity during peak traffic periods or poor air quality days." Such changes "may benefit individual patients in both short-term symptomatic control and long-term cardiovascular and respiratory complications."

34. **Krall J. R., Anderson G. B., Dominici F., et al. Short-term exposure to particulate matter constituents and mortality in a national study of U.S. urban communities. *Environ Health Perspect.* 2013;121(10):1148-1153.**
This study by Krall et al. provides "the first national, season-specific, and region-specific associations between mortality and PM2.5 constituents." Using data from the National Center for Health Statistics, authors "estimated short-term associations between nonaccidental mortality and PM2.5 constituents across 72 urban U.S. communities from 2000 to 2005." They used U.S. Environmental Protection Agency (EPA) Chemical Speciation Network data to "analyze seven constituents that together compose 79-85% of PM2.5 mass: organic carbon matter (OCM), elemental carbon (EC), silicon, sodium ion, nitrate, ammonium, and sulfate." Authors then "applied Poisson time-series regression models, controlling for time and weather, to estimate mortality effects." The analysis found that interquartile range increases in OCM, EC, silicon, and sodium ion were associated with estimated increases in mortality of 0.39% [95% posterior interval (PI): 0.08, 0.70%], 0.22% (95% PI: 0.00, 0.44), 0.17% (95% PI: 0.03, 0.30), and 0.16% (95% PI: 0.00, 0.32), respectively, based on single-pollutant models." EC and OCM are often generated by motor vehicles. Authors did not find evidence that associations between mortality and PM2.5 or PM2.5 constituents differed by season or region. Limitations include: the study focused on chemical composition and did not evaluate potential effects of PM2.5 mass; analyses did not account for exposure misclassification; authors estimated community-level ambient average pollutant concentrations using the arithmetic mean of monitoring concentrations, however spatial models may be less biased. Overall, "findings indicate that some constituents of PM2.5 may be more toxic than others and, therefore, regulating PM total mass alone may not be sufficient to protect human health."

35. **Zheng Xue-yan , Ding Hong , Jiang Li-na , et al. Association between Air Pollutants and Asthma Emergency Room Visits and Hospital Admissions in Time Series Studies: A Systematic Review and Meta-Analysis. *PLOS One.* 2015(18 September 2015).**
Zheng et al. conducted a systematic review of literature "to quantify the associations between short-term exposure to air pollutants [ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter 10μm (PM_{10}) and $PM_{2.5}$] and the asthma-related emergency room visits (ERV) and hospitalizations." They conducted their initial search without language limitation, and screened 246 studies of which 87 were included in the final analyses (86 in English and 1 in Spanish; 62 time-series and 25 case cross-over studies). Of those included, 50 studies focused on children, 21 on adults, 13 on elderly population, and 44 on general population. Pooled relative risks (RRs) and 95% confidence intervals (95%CIs) were estimated using the random effect models, and sensitivity analyses and subgroup analyses were also performed. Results showed that air pollutants were associated with "significantly increased risks of asthma ERVs and hospitalizations." Fifty one studies included PM_{10} and 37 included $PM_{2.5}$. Sensitivity analyses resulted in compatible findings as compared with the overall analyses without publication bias. Overall, "stronger associations were found in hospitalized males, children and elderly patients in warm seasons with lag of 2 days or greater." Authors concluded that "short-term exposures to air pollutants account for increased risks of asthma-related ERVs and hospitalizations that constitute a considerable healthcare utilization and socioeconomic burden."

36. **Achilleos S., Kioumourtzoglou M. A., Wu C. D., et al. Acute effects of fine particulate matter constituents on mortality: A systematic review and meta-regression analysis. *Environ Int.* 2017;109:89-100.**
Achilleos et al. note that "the link between $PM_{2.5}$ exposure and adverse health outcomes is well documented from studies across the world." Authors conducted a meta-analysis on associations between short-term exposure to $PM_{2.5}$ constituents and mortality using city-specific estimates. Authors systematically reviewed epidemiological studies on particle constituents and mortality up to July 2015. Forty-one studies (142 cities) met all inclusion criteria and were included in the meta-analysis (37 all-ages analysis; 9 subgroup analysis of those aged 65 or older). Ten studies were conducted in the U.S., and the number of U.S. cities included in the analysis surpassed those of any other region. Studies examined the association between short-term exposure to PM2.5 constituents and all-cause, cardiovascular, and respiratory mortality, in the general adult population. "Each study was summarized based on pre-specified study key parameters (e.g., location, time period, population, diagnostic classification standard), and [reviewers] evaluated the risk of bias using the Office of Health Assessment and Translation (OHAT) Method for each included study." Authors used city-specific mortality risk estimates for each constituent and cause of mortality. Studies that included multiple cities required reviewers to request city-specific risk estimates from the authors if not included in the article. Researchers performed "random effects meta-analyses using city-specific estimates, and examined whether the effects vary across regions and city characteristics ($PM_{2.5}$ concentration levels, air temperature, elevation, vegetation, size of elderly population, population density, and baseline mortality)." Results revealed a "0.89% (95% CI: 0.68, 1.10%) increase in all-cause, a 0.80% (95% CI: 0.41, 1.20%) increase in cardiovascular, and a 1.10% (95% CI: 0.59, 1.62%) increase in respiratory mortality per 10mug/m(3) increase in $PM_{2.5}$." Once authors accounted for "the downward bias induced by studies of single days, the all-cause mortality estimate increased to 1.01% (95% CI:

0.81, 1.20%)." The meta-analysis for elemental carbon (EC), black smoke, and SO_4^{2-} mortality effect estimates among the elderly population (65 years of age and older) revealed EC and BS were statistically significantly associated with all-cause mortality. Meanwhile, "The observed pooled associations between PM constituents and cardiovascular mortality were not as consistent as all-cause mortality." Overall, authors identified significant associations between mortality and several $PM_{2.5}$ constituents. "The most consistent and stronger associations were observed for [EC] and potassium (K)." For most of the constituents, there was high variability of effect estimates across cities. Authors conclude the meta-analysis suggests that "(a) combustion elements such as EC and K have a stronger association with mortality, (b) single lag studies underestimate effects, and (c) estimates of $PM_{2.5}$ and constituents differ across regions." They recommend future studies account for PM mass in constituent's health models to determine if they lead to more stable and comparable effect estimates across different studies.

37. **Requia W. J., Adams M. D., Arain A., et al. Global Association of Air Pollution and Cardiorespiratory Diseases: A Systematic Review, Meta-Analysis, and Investigation of Modifier Variables. *Am J Public Health.* 2018;108(S2):S123-S130.**
Requia et al. "systematically reviewed the evidence on the association between air pollution and cardiorespiratory diseases (hospital admissions and mortality), including variability by energy, transportation, socioeconomic status, and air quality." Authors conducted a literature search (PubMed and Web of Science) for studies published between 2006 and May 11, 2016, that met the following criteria: "(1) considered at least 1 of these air pollutants: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, or particulate matter (PM2.5 or PM10); (2) reported risk for hospital admissions, mortality, or both; (3) presented individual results for respiratory diseases, cardiovascular diseases, or both; (4) considered the age groups younger than 5 years, older than 65 years, or all ages; and (5) did not segregate the analysis by gender." They then extracted data from included studies and performed a meta-analysis to "estimate the overall effect and to account for both within- and between-study heterogeneity." Authors initially assessed 2,183 studies, of which 529 were selected for in-depth review, and 70 articles fulfilled the study inclusion criteria. "Most of the studies reported results for more than category of pollutant, health outcome, disease, or age." Eleven of 28 studies reporting results for PM2.5 were conducted in the US, as were 2 of the 36 studies reporting results for PM10. "The 70 studies selected for meta-analysis encompass more than 30 million events across 28 countries. [Authors] found positive associations between cardiorespiratory diseases and different air pollutants." For example, the association between PM2.5 and respiratory diseases showed a risk equal to 2.7% (95% confidence interval = 0.9%, 7.7%). "With regard to hospital admissions, the youngest age group (aged <5 years) demonstrated the highest risk across all pollutants, except NO2 and CO." Specifically, "[r]espiratory diseases showed the strongest association, especially for O3 and PM10, for which [authors] found a risk equal to 2.4% (95% CI = 1.6%, 3.7%) and 2.3% (95% CI = 1.6%, 3.2%), respectively." Overall, "results showed statistical significance in the test of moderators for all pollutants, suggesting that the modifier variables influence the average cardiorespiratory disease risk and may explain the varying effects of air pollution." For example, clean electricity, consumption of motor gasoline, consumption of cooking fuel, population density, and education accounted for 64% of the heterogeneity in mortality attributable to PM2.5 exposure among regional populations studied.

38. **Gauderman W. James , Avol Edward , Gilliland Frank , et al. The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age. *The New England Journal of Medicine.* 2004;351(11):1057-1067.**
Gauderman et al. conducted a prospective cohort study to assess whether exposure to air pollution adversely affects the growth of lung function during the period of rapid lung development that occurs between the ages of 10 and 18 years. The Children's Health Study recruited 1,759 children "(average age, 10 years) from schools in 12 southern California communities and measured lung function annually for eight years [1993 to 2001]. The rate of attrition was approximately 10 percent per year." The study included communities representing "a wide range of ambient exposures to ozone, acid vapor, nitrogen dioxide, and particulate matter." The relationship of air pollution to the forced expiratory volume in one second (FEV 1) and other spirometric measures was assessed using linear regression. Results showed that "over the eight-year period, deficits in the growth of FEV1 were associated with exposure to nitrogen dioxide (P=0.005), acid vapor (P=0.004), particulate matter with an aerodynamic diameter of less than 2.5 µm (PM2.5) (P=0.04), and elemental carbon (P=0.007), even after adjustment for several potential confounders and effect modifiers." Moreover, associations were also observed for other spirometric measures. "Exposure to pollutants was associated with clinically and statistically significant deficits in the FEV1 attained at the age of 18 years. For example, the estimated proportion of 18-year-old subjects with a low FEV1 (defined as a ratio of observed to expected FEV1 of less than 80 percent [a criterion often used in clinical settings to identify those who are at increased risk for adverse respiratory conditions]) was 4.9 times as great at the highest level of exposure to PM2.5 as at the lowest level of exposure (7.9 percent vs. 1.6 percent, P=0.002)." Furthermore, results showed similar associations between these pollutants and a low FEV1 in the subgroup of children with no history of asthma and the subgroup with no history of smoking. Authors concluded "[t]he results of this study indicate that current levels of air pollution have chronic, adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in attained FEV1 as children reach adulthood."

39. **Liu Norrice M , Grigg Jonathan Diesel, children and respiratory disease. *BMJ Paediatrics Open.* 2018;2018(2).**
Liu and Grigg conducted a review of evidence of adverse health effects of diesel emissions on UK children and policies to reduce exposure of children to fossil-fuel-derived air pollution in the UK. Transport (i.e., exhaust, tyre, brake wear), combustion, industrial processes, and construction comprise the main sources of PM10 and PM2.5, and transport and combustion are the main sources of nitrogen dioxide (NO2). Authors note "For emissions from diesel, there is a strong correlation between locally emitted PM10 and NOx and it is reasonable to assume that, where diesel vehicles predominate, either metric is a good marker of exposure to the locally generated pollutant mix in urban areas." Globally, diesel vehicles contribute about 20% of NOx, and diesel engines emit more PM and NOx than petrol [gasoline] or hybrid counterparts. The review discusses antenatal exposure and childhood exposures. Authors note, "it is reasonable to extrapolate from studies that have assessed exposure to either PM or NOX since (1) diesel PM is not less toxic than other types of PM, and (2) the adverse effects of gases such as NOX are independent of source." Specific to childhood exposure, evidence indicates "air pollutants, particularly NOX (reflecting exposure to both NOx and PM), are associated with reduced lung function in children—for both FVC and FEV." Results of a meta-analysis reviewed showed "exposure to NO2 is linked to new-onset asthma, while exposure to PM is linked to new-onset

wheeze." Authors provide national level and individual level approaches to limit exposure to diesel emissions to protect children's health.

40. **IARC. Humans IMotEotCRt.Diesel and gasoline engine exhausts and some nitroarenes.Lyon, France: International Agency for Research in Cancer;2013.**
This 2012 report, the International Agency for Research on Cancer (IARC) classified diesel exhaust as a carcinogen in humans. The determination was largely based on results from two epidemiological studies of occupational diesel exhaust exposures among nonmetal miners (Diesel Exhaust in Miners Study) and truck drivers in confined spaces. Because the key epidemiologic studies are based on occupational exposure and were conducted with adults, staff rated this article as moderately generalizable as opposed to highly.

41. **Weitekamp C. A., Kerr L. B., Dishaw L., et al. A systematic review of the health effects associated with the inhalation of particle-filtered and whole diesel exhaust. *Inhal Toxicol.* 2020;32(1):1-13.**
Weitekamp et al conducted a systematic review to explore the impact of whole versus fractions of diesel exhaust on various health outcomes. The researchers examined animal inhalation and controlled human exposure research studies. The authors cite prior research to explain that diesel exhaust contains carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, and volatile organic compounds, such as benzene and formaldehyde. Further, diesel exhaust is linked to several adverse health outcomes, such as airway inflammation, vascular dysfunction, developmental toxicity, neuroinflammation, and respiratory mortality. The International Agency for Research on Cancer has categorized diesel exhaust as 'carcinogenic to humans'. The authors outline U.S. Environmental Protection Agency (U.S. EPA) diesel exhaust standards. In 2001, the EPA adopted standards for heavy-duty diesel engines, which led to the production of new technology engines and a 90% reduction in total mass emissions of particulate matter, but increased nitrogen dioxide and sulfate emissions, as compared to engines under the prior standards. In 2010, new diesel engines included selective catalytic reduction devices, which then led to a 94% reduction in nitrogen dioxide emissions, as compared to 2007-compliant diesel engines. The authors point out that despite these federal policy changes, many vehicles in operation do not utilize the latest emission control technologies. The researchers of this review utilized a Population, Exposure, Comparator, Outcome (PECO) methodology to define the research question, literature search, and screening. Research was assessed for reporting quality; allocation; observational bias/blinding; confounding/variable control; selective reporting and attrition; chemical administration and characterization; exposure timing, frequency, and duration; outcome assessment; and results presentation. Limitations and bias were considered, and two reviewers independently assessed the research. There were 26 studies ranging from 2005-2012 publication dates that were included in the study quality evaluation and data extraction processes, where 6 of these were rated as high confidence, 20 as medium confidence, and no studies as low confidence. None of the studied included "reflect 2010-compliant diesel engines with manufacturer built-in catalyzed filters, which greatly reduce emissions of oxides of nitrogen". Statistically significant health effects were associated with exposure to both types of exhaust, indicating that unfiltered diesel exhaust likely contributes more heavily to adverse health outcomes than unfiltered exhaust. Significant effects were associated with filtered-diesel exhaust exposure across all respiratory and immune system health endpoints studied, as well as gestational exposure. The researchers found that co-exposure to an allergen resulted in

significantly increased airway responsiveness after both filtered and whole diesel exhaust. Significant effects were associated with both particle-filtered and whole diesel exhaust across all cardiovascular, nervous system, and endocrine health outcomes studied. The results of this review show that diesel filtration methods do not mitigate negative health effects that are associated with whole diesel exhaust.

42. **Li Fei, Lee Eon S., Liu Junjie, et al. Predicting self-pollution inside school buses using a CFD and multi-zone coupled model. *Atmospheric Environment.* 2015;107:16-23.** Li et al. conducted a modeling study to examining the concentration levels of school bus exhaust inside the bus cabin that is attributed to the bus itself. Citing prior research, the authors point out that "children riding a diesel-fueled school bus can have a cancer risk that is 23-46 times higher than the federal standard." A separate study found that up to .3% of the air in school buses was from the bus exhaust, and that this increased when all bus windows were closed. In this study, the researchers used a coupled computational fluent dynamic model to stimulate outside concentration and a multi-zone model for inside the school bus. The researchers examined nine scenarios to simulate driving speed and tailpipe location on bus self-pollutant rates, including three driving speeds and three tailpipe locations. Study results indicate that exhaust can enter the bus cabin from the back of the bus, that the pollution is highest when buses drive at medium speed, and that the location of the bus tailpipe can influence the level of pollution that enters the bus.

43. **Zundel C. G., Ryan P., Brokamp C., et al. Air pollution, depressive and anxiety disorders, and brain effects: A systematic review. *Neurotoxicology.* 2022;93:272-300.** Zundel et al. conducted a systematic review of the effects of air pollution on 1) internalizing symptoms and behaviors (anxiety or depression) and 2) frontolimbic brain regions (i.e., hippocampus, amygdala, prefrontal cortex). The authors point to other research to point out that "[e]xposure to air pollution impacts the central nervous system" with specific "adverse effects on cognitive and behavioral functioning, poor attention, decreased intelligence quotient (IQ), memory, and academic performance." One meta-analysis found that an increase in ambient PM (PM2.5 and PM10) concentration was strongly associated with increased risk of depression, as well as suicide. For this systematic review, the researchers followed PRISMA review guidelines, and conducted their search through MEDLINE. Both human and animal studies were included in the review. Regarding mental health outcomes, 111 articles were included (76% human, 24% animals), and regarding brain structure and function, 92 articles were included (11% human, 86% animals). Regarding the search on mental health outcomes, "the most common pollutants examined were PM2.5 (64.9%), NO2 (37.8%), and PM10 (33.3%)". Regarding the search on brain structure and function, "the most common pollutants examined were PM2.5 (32.6%), O3 (26.1%) and Diesel Exhaust Particles (DEP) (26.1%)." The publication dates of the articles included ranged from 1969 – 2022. The researchers found that , "air pollution exposure is consistently associated with increased anxiety and depression across different exposure windows and in both human and animal models". Most (73%) of studies "reported higher internalizing symptoms and behaviors with higher air pollution exposure". The overwhelming majority (95%) of studies found that "air pollution was consistently associated … with neurostructural and neurofunctional effects (e.g., increased inflammation and oxidative stress, changes to neurotransmitters and neuromodulators and their metabolites) within multiple brain regions (24% of articles), or within the hippocampus (66%), PFC (7%), and amygdala (1%)". The research

suggests “that air pollution is associated with increased depressive and anxiety symptoms and behaviors, and alterations in brain regions implicated in risk of psychopathology”. There is limited information on the biological mechanisms at play and the neural consequences of air pollution. The authors point out that it is possible that ultrafine particles pass the blood-brain barrier, which contributes to these poor health outcomes. The authors conclude with a call for additional research to be conducted, particularly among sex differences since internalizing disorders are more prevalent in females than males, and among length of exposure to pollution, since pollution may have different effects on adults and children, and may have different effects over time.

44. **Force Clean Air Task. Deaths by Dirty Diesel 2023.**
The Clean Air Task Force uses emissions and other data from the EPA to calculate projected health impacts of diesel. The tool projects that in Washington State there will be 122 deaths, 1,444 cases of upper respiratory symptoms, 1,487 cases of asthma exacerbation, and 49 heart attacks due to diesel in 2023. This data also indicates the 2023 predicted rate of lifetime cancer due to diesel is 142 cases per million Washingtonians. The tool projects that the monetized health damages due to diesel in Washington State in 2023 will be $1,355,031,759.

45. **U.S. Environmental Protection Agency. Health and Environmental Effects of Particulate Matter (PM) Available at: https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm. Accessed January 2020, 2020.**
This U.S. Environmental Protection Agency webpage provides an overview of the health and environmental effects of particulate matter. It states, "Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: premature death in people with heart or lung disease nonfatal heart attacks irregular heartbeat aggravated asthma decreased lung function increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing." Particularly sensitive populations to particle air pollution include people with heart or lung diseases, children, and older adults.

46. **Radiation U.S. EPA Office of Air and. Particle Pollution and Your Health. In: Agency USEP, ed. Vol EPA-452/F-03-001. Washington, DC: U.S. Environmental Protection Agency; 2003.**
This pamphlet from the U.S. Environmental Protection Agency discusses particle pollution, associated risks, and ways to protect health. Risk appears to vary throughout an individual's lifetime: higher in early childhood, lower in healthy adolescents and younger adults, and increasing in middle age through old age (as the incidence of heart and lung disease and diabetes increases). Authors note, children's "lungs are still developing; they spend more time at high activity levels; and they are more likely to have asthma or acute respiratory diseases, which can be aggravated when particle levels are high."

47. **Wargo John, Brown David, University of Connecticut Environmental Research Institute. Environment and Human Health I.Children’s Exposure to Diesel Exhaust on School Buses.North Haven, Connecticut: Environment & Human Health Inc.; February 2002 2002.**
This study was designed and results were analyzed by J. Wargo, D. Brown, and the University of Connecticut's Environmental Research Institute. The study consisted of: experimental

monitoring, experimental controls, and school day personal monitoring. Experimental monitoring measured black carbon and PM2.5 on buses while idling and en route to test the effects of a) windows being opened and b) the location of monitoring equipment on the bus. Experimental control tests were run to determine how experimental buses (i.e., diesel engine next to driver; diesel engine at rear of bus; and natural gas powered) contributed to carbon and particle levels. Finally, school day personal monitoring of children's (n=15) indoor and outdoor exposure to PM10 and PM2.5 averaged 7 hours. Each child was "accompanied by a research assistant and monitored [i.e., logging behavior, movement, and environmental conditions] from the time each left their home in the morning to the time they each returned home in the afternoon." Each study participant carried a particulate meter, personal sampling pump, and VOC canister throughout the day. Researchers noted that "children's exposure to diesel exhaust from school buses constitutes an additional exposure beyond background levels of particulates reported from current monitoring efforts." Authors found, "Fine particulate concentrations (PM2.5) measured on buses in this study were often 5-10 times higher than average levels measured at the 13 fixed-site PM2.5 monitoring stations in Connecticut." Results showed, "Levels of fine particles were often higher under certain circumstances: when buses were idling with windows opened, when buses ran through their routes with windows closed, when buses moved through intense traffic, and especially when buses were queued to load or unload students while idling." Researchers found queued idling buses had the highest levels of particles and black carbon measured. Moreover, "idling buses tend to accumulate diesel exhaust which may be retained during the ride, depending upon bus ventilation rates," and "particulate and carbon concentrations rise rapidly once idling begins." Such increased exposure is of concern due to associated health outcomes (e.g., exacerbated of respiratory symptoms, decreased lung function, delayed lung development, increased mortality among those with cardiopulmonary diseases) and correlated healthcare needs (i.e., hospital admissions and emergency department visits for respiratory illnesses). Children are more susceptible due to their developing lungs and higher rates of respiration. Based on results, authors made multiple suggestions of how to reduce children's exposure to diesel emissions including, prohibiting bus idling, especially while loading and unloading students. While, the Connecticut Department of Environmental Protection (DEP) did have a regulation (DEP 22a-174-18 [a][5]) to limit idling time to 3 minutes, authors noted "it is neither monitored nor enforced." This finding indicates that compliance monitoring and enforcement is an important component of successful implementation to reduce exposure. Finally, authors report that "bus drivers' exposure to motor vehicle and diesel exhaust is significantly higher than children's, due to longer periods of time spent on buses."

48. **Demetillo Mary Angelique G., Harkins Colin, McDonald Brian C., et al. Space-Based Observational Constraints on NO2 Air Pollution Inequality From Diesel Traffic in Major US Cities. *Geophysical Research Letters.* 2021;48(17).**

It is well documented that air pollution is higher in areas of the U.S. that house more people of color and more people with low socioeconomic status. Research shows that communities of color and people with lower household incomes experience higher concentrations of and exposures to NOx and diesel emissions, which contribute to measurable differences in health and life expectancy. Heavy-duty diesel vehicles (HDDVs) contribute 3-6% of the US fleet in terms of distance traveled, but contribute disproportionate amounts of NOx emissions (7x more than gasoline). The authors describe that "stationary sources [of diesel emissions] may be more important across more suburban metropolitan areas." This study utilizes data collected by the

TROPospheric Ozone Monitoring Instrument (TROPOMI) which uses a satellite to measure NO2 emissions and additional atmospheric gases from space. This research explores NO2 in 52 major cities representing 130 million people between June 2018 to February 2020. Neighborhood-level data on race, ethnicity, and income levels are examined, and reported both alone, and as combined measures of race/ethnicity and income categories (lowest median income quintile [LIN] tracts and highest median income quintile [HIN] tracts). The researchers computed three metrics to quantify and report on racial segregation within the cities included in the analysis, and point out that "without segregation, air pollution disparities would not be possible". Weekday versus weekend differences in emissions are included to determine an estimated impact of diesel emissions, as prior research has found that diesel emissions are substantially higher on weekdays. The researchers also account for differences in NO2 lifetime by season, and found that "LIN HIW disparities decrease by 37 ± 3% on weekends in the summer and 32 ± 2% in the winter". The researchers found that a 62% reduction in on-road diesel traffic leads to a 37% decrease in LIN-HIW inequalities. Population-weighted NO2 tropospheric vertical column densities (TVCDs) were found to be 17 ± 2% higher for Black and African Americans, 19 ± 2% higher for Hispanics/Latinos, 12 ± 2% higher for Asians, and 15 ± 2% higher for Native Americans compared to whites. Further, rates were higher for people living in poverty (17 ± 2% higher for people living below, and 10 ± 2% higher for people living near the poverty line, compared to people above). Once the researchers accounted for weekday and weekend emissions, they found that HDDVs contribute significantly to emissions inequalities for Black and African Americans (63 ± 13%), Hispanics/Latinos (52 ± 10%), Asians (36 ± 7%), and Native Americans (62 ± 12%) and for people living below and near the poverty line (56 ± 11%). The researchers found that controlling for HDDV's would not eliminate these disparities. Higher inequalities are found when race-ethnicity and income measures were combined, with 28 ± 2% greater population-weighted NO2 for LINs than HIWs. In conclusion, the researchers found that a "62% reduction in diesel emissions would decrease race-ethnicity and income inequalities by 37%".

49. **Washington State Department of Health Washington Tracking Network (WTN). In: Washington DoE, ed2018.**
The Washington Tracking Network (WTN), a Washington State Department of Health program, publishes public health data, and tracks diesel emissions and roadway traffic data. According to 2014 WTN data, Washington's diesel emission levels of NOx was 9.18 annual tons/Km2 and estimates of PM2.5 emissions were 10.78 annual tons. According to 2019 roadway traffic data from Washington State Department of Transportation (WSDOT), 8% of the Washington population lives close to heavily trafficked roadways.

50. **Alvarez C. H. Structural Racism as an Environmental Justice Issue: A Multilevel Analysis of the State Racism Index and Environmental Health Risk from Air Toxics. *J Racial Ethn Health Disparities.* 2023;10(1):244-258.**
Alvarez conducted a cross-sectional multilevel analysis of over 65,000 U.S. census tracts to evaluate the following research question: "Do neighborhoods located in states with higher state racism index report greater environmental health risk from outdoor air toxics?" The researcher used a state racism index (an aggregate of Black-white gaps, from the social determinants of health literature) to gauge Black-white inequities to measure differences in exposure to outdoor pollution. The index is the average of five scales: residential segregation and Black-white ratios

in incarceration, educational attainment, economic status, and employment. Higher scores in the index indicate greater systemic Black-white gaps. The dependent variable examined was estimated cancer risk and noncancer respiratory system risk from outdoor air toxics. This data was pulled from the National Air Toxics Assessment (NATA). The researcher controlled for race, levels of female-headed households, renter status, geographical factors, and EPA regions. The researcher conducted multilevel modeling to calculate differences across groups. Results of the study show that states with higher levels of Black–white gaps had higher levels of exposure to air pollution and more environmental health risk. "The findings demonstrate the importance of identifying neighborhood-level environmental conditions (i.e., outdoor air pollution exposure) for understanding systematic racism. We found that the greater systematic racism of a state is linked to greater levels of outdoor air pollution in all neighborhoods." The author states that, "the disproportional exposure across communities is tied to systematic inequalities in environmental regulation and other structural elements such as housing and incarceration."

51. **Jbaily A., Zhou X., Liu J., et al. Air pollution exposure disparities across US population and income groups. *Nature.* 2022;601(7892):228-233.**
Jbailey et al. connect demographic data from the US Census Bureau and American Community Survey and PM2.5 data across the USA. The researchers use 2000-2016 data across approximately 32,000 zip codes. The researchers created a dataset with median household income, race/ethnicity, and population density, then used publicly available data to track PM2.5 levels. Then, the researchers developed methods to quantify disparities by "defin[ing] a state of equality (or lack of relative disparities) among various populations as a state in which equal proportions of the various populations are exposed to pollution levels higher than a threshold of interest, chosen in relation to the EPA standard and WHO guidelines for PM2.5." The data are mapped and viualized to demonstrate connection between race/ethnicity and income with PM2.5 levels across the U.S.. The data and code used in this study are publicly available. Sensitivity analyses were conducted to test the methods used. The study finds that areas of the U.S. with higher-than-average Black, Asian and Hispanic or Latino populations have been consistently exposed to higher PM2.5 levels, as compared to areas with higher-than-average white and Native American populations, and that areas with low-income populations have been consistently exposed to higher PM2.5 levels, as compared to areas with high-income groups. The authors also examine disparities relative to policy standards. The research also shows that exposure relative to safety standards set by the EPA and WHO have had increasing disparities over time. The authors state that the research is descriptive and cannot be used to investigate causal relationships. The researchers point out the "importance of strong, targeted air-pollution-reduction strategies, not only to reduce overall air-pollution levels but also to move closer towards the EPA's aim to provide all people with the same degree of protection from environmental hazards."

52. **Noel Lance, McCormack Regina. A cost benefit analysis of a V2G-capable electric school bus compared to a traditional diesel school bus. *Applied Energy.* 2014;126:246-255.**
Noel and McCormack conducted a cost benefit analysis on the use of electric vehicles and of using a Vehicle-to-grid (V2G)-capable electric school bus compared to a diesel school bus. The researchers analyzed cost of fuel, electricity and battery costs, health externalities, and frequency regulation market price. The results of the analysis indicate that the electric buses lead to school savings of $6,070 per seat, and that electric school buses become a net benefit after 5 years of operation.

53. **Shirazi Yosef, Carr Edward, Knapp Lauren. A cost-benefit analysis of alternatively fueled buses with special considerations for V2G technology.** ***Energy Policy.*** **2015;87:591-603.**
Shirazi, Carr, and Knapp conducted a cost benefit analysis of owning and operating a V2G capable electric school bus and included economic implications of cold temperature extremes on electric vehicle battery operations. This study found that a small V2G-enabled electric bus increases net present costs by $7,200/seat relative to a diesel bus.

54. **How is sea level rise related to climate change? 2021; Available at: https://oceanservice.noaa.gov/facts/sealevelclimate.html#:~:text=First%2C%20as%20the%20oceans%20warm,adds%20water%20to%20the%20ocean. Accessed February 2023.**
The National Oceanic and Atmospheric Administration reports on ways that temperature and sea level rise are related to climate change. A warming climate can cause seawater to expand and ice over land to melt, both of which can cause a rise in sea level.

55. **Kindergarten through grade 12 (K-12) enrollment 2022; Available at: https://ofm.wa.gov/washington-data-research/statewide-data/washington-trends/budget-drivers/kindergarten-through-grade-12-k-12-enrollment. Accessed February, 2023.**
Washington Office of Financial Management tracks data on K-12 enrollment, school-aged youth, and the population forecast.

56. **Washington Office of Superintendent of Public Instruction. State Report Card: State Total. 2022.**
The Washington Office of Superintendent of Public Instruction collects and publicly presents data on Washington schools. Data is available at the statewide, District, and School level. There were 1,096,304 students enrolled in the 2022-2023 school year, and 68,625 classroom teachers in the 2020-2021 school year.

57. **Washington Charter Public School Enrollment, Demographic, and Academic Data. 2023; Available at: https://wacharters.org/washington-charter-public-school-data/. Accessed.**
The Washington State Charter Schools Association reports on enrollment and demographic data. There are 16 Charter Schools in Washington State and the monthly enrollment for the 2022-2023 school year was 4,819 students.

58. **United States Bureau of Labor Statistics. May 2021 State Occupational Employment and Wage Estimates. 2021.**
The U.S. Bureau of Labor Statistics reports data on occupational employment and wage estimates. Results are calculated with data collected from employers in all industry sectors in metropolitan and nonmetropolitan areas in Washington.

59. **Washington Office of Superintendent of Public Instruction. School Bus Driver Handbook.2019.**

The WA Office of Superintendent of Public Instruction compiled a school bus driver handbook. The handbook includes driver requirements, student management, and additional resources.

60. **Washington State Office of the Superintendent of Public Instruction (OSPI). School Bus Inventory Report. 2023.**
OSPI's School Bus Inventory Report includes information about all active school buses operated by a particular Educational Services District (ESD), school district, or contractor. According to OSPI's online School Bus Inventory Report, as of 2023, there are 6 contractors providing 1,331 school buses in Washington State: 1) First Student Inc. provides 747 school buses (Battleground School District, Colville School District, Seattle School District, Tacoma School District, etc.); Durham School Services provides 375 buses (Everett School District, Spokane School District, Steilacoom Historical School District); Zum provides 142 buses to the Seattle School District; Harlow's Bus Service provides 45 buses (primarily to charter schools); Lind-Ritzville Cooperative provides 12 buses to the Lind School District; and Garfield-Palouse Cooperative provides 10 buses to the Garfield School District.

61. **Nitrogen dioxide in Washington's air. 2023; Available at: https://ecology.wa.gov/Air-Climate/Air-quality/Air-quality-targets/Air-quality-standards/Nitrogen-dioxide. Accessed 2/21/2023.**
Washington State Department of Ecology states that "[g]enerally, nitrogen dioxide levels are far lower [in Washington State] than the national standard, even at the sites located next to high traffic areas of Interstate-5 in Seattle and Tacoma."

62. **Transportation. 2023; Available at: https://www.tacomaschools.org/departments/transportation. Accessed 2/21/2023.**
Tacoma Public Schools contracts with First Student to provide daily bus transportation for approximately 10,000 students.

63. **Electric School Buses. 2023; Available at: https://firststudentinc.com/innovation/electric-school-buses/. Accessed 2/21/2023.**
On this webpage, First Student provides information about electric school buses, stating that they provide "a turnkey solution for the electrification process" and "create turnkey solutions for school districts interested in adding electric buses to their fleet." They stated that, "[a]s the largest school bus transportation provider, we leverage our size and scale to drive down the price of electrification." Among other services available to school districts, First Student states that they perform geographic analyses; identify funding options and manage grant applications; optimize fleet and routing; build, certify, and manage necessary infrastructure requirements; and establish and monitor charging schedules. They state that their transition to electric buses has reduced their CO2 emissions by 63%, nitrogen oxide emissions by 73%, and PM2.5 emissions by 82% in the past three years. First Student plans to offer a fleet of 30,000 electric schools buses nationally by 2040.

64. **Durham School Services donates bus to Farmingville Fire Department in New York for Emergency Evacuation Training [press release]. 2023.**
National Express LLC is the parent company of Durham School Services. There is little information available about National Express LLC or Durham School Services efforts to

transition to zero-emission vehicles. In a January 2023 press release, National Express LLC stated that Durham School Services plans to transition their fleet to all zero-emissions vehicles by 2035.

65. **Transportation. 2023; Available at: https://www.seattleschools.org/departments/transportation/. Accessed 2/21/2023.**
On January 3, 2023, Seattle Public Schools changed transportation service providers from First Student to Zum on multiple school bus routes in the district.

66. **Zum. 2023; Available at: https://www.ridezum.com/. Accessed 2/21/2023.**
Zum states that 100% of their on-road fleet will be electric vehicles by 2025. The company states that they "make planning, deployment and ongoing management simple and easy offering expertise and turnkey solutions to make your transition to [electric vehicles] a success."

67. **Velez M. Seattle Schools will have two bus contractors in the fall. *Seattle Times.* 7/7/2022, 2022.**
This Seattle Times news article announced that the Seattle School Board voted to "award a three-year…contract to both relative newcomer Zum and 30-year transportation provider First Student, one of the largest bus providers in the country." The Seattle Times also reported that First Student has a goal for all First Student buses in Seattle to be electric in the next 10 years. They reported that, "Zum says it is committed to having all of its buses be electric by 2025. For now, the company will provide a couple of electric buses in Seattle […] Bus fleets will transition to all-electric in three to four years […]"

68. **Lipson Jacob. Bill Analysis: HB 1368. In: Committee EE, ed2023.**
Staff of the House Environment & Energy Committee completed a bill analysis of HB 1368.

69. **Administration U.S. Energy Information. Washington State Profile and Energy Estimates.2022.**
The U.S. Energy Information Administration provides state energy profiles. In Washington State, renewable energy sources "account for about 90% of the [state's] total energy production." In 2020, the majority (66%) of electricity generation in Washington State came from hydroelectric power. Washington State produces more hydroelectric power than any other state and accounts for 27% of all hydroelectric power generation in the U.S. After hydroelectric power, 12% of electricity generation is from natural gas, 9% is from other renewable resources (i.e., wind and biomass), 8% is from nuclear power, and less than 5% is from coal. Washington State is "part of the West Coast Electric Highway, a network of public charging stations for electric vehicles located along Interstate 5 and other major roads in the Pacific Northwest. It is part of the larger West Coast Green Highway that extends from Canada to Mexico." As of December 2020, Washington State had more than 50,000 registered electric vehicles, the fourth most of all U.S. states. As of February 2022, the state had 1,600 electric vehicle charging stations and 3,900 charging ports.

70. **Reducing diesel emissions. 20223; Available at: https://ecology.wa.gov/Air-Climate/Reducing-Emissions/Diesel-emissions#:~:text=Washington%27s%20largest%20sources%20of%20diesel%20exhaust**

%20are%3A%201,equipment%204%20Locomotives%205%20Farm%20equipment%206%20Buses. **Accessed 2/21/2022.**
This Washington State Department of Ecology webpage provides information about diesel emissions in the state. Ecology stated that, "[d]iesel exhaust is the most harmful air pollutant in Washington [State]. It contributes more than 70[%] of the total cancer risk from toxic air pollution." The largest sources of diesel exhaust in Washington State are: heavy duty trucks, ships, construction equipment, locomotives, farm equipment, and buses.

71. **School bus replacement incentive program—Rules., RCW 28A.160.205 (2007).**
Under current statute related to the school bus replacement incentive program, school districts are required to demonstrate to OSPI that buses being replaced are scrapped and not purchased for road use

72. **U.S. Environmental Protection Agency NATA Overview. National Air Toxics Assessment Available at: https://www.epa.gov/national-air-toxics-assessment/nata-overview#what-nata-is-not. Accessed 2020, January.**
This U.S. Environmental Protection Agency webpage provides an overview of the National Air Toxics Assessment (NATA), an ongoing review of air toxics in the U.S. Results help state, local, and tribal air agencies identify which pollutants, emission sources, and places might be considered for further study and/or intervention. It uses a snapshot of outdoor air quality to "suggest long-term risks to human health if air toxics emissions are steady over time." Specifically, it estimates the cancer risks from breathing air toxics over many years and noncancer health effects for some pollutants, including diesel particulate matter. Based on necessary assumptions, "NATA can't give precise exposures and risks for a specific person. Instead, NATA results are best applied to larger areas – counties, states and the nation." NATA uses a single year's emission data to calculate concentration and risk estimates. Note, "The risk estimates assume a person breathes these emissions each year over a lifetime (or approximately 70 years)."

73. **Palcisko Gary. Overview of National Air Toxics Assessment (NATA) 2014. In: Ecology WSDo, ed. Olympia, Washington: Washington State Department of Ecology; 2018.**
This Washington State Department of Ecology presentation provides an overview of 2014 National Air Toxics Assessment (NATA) data specific to Washington State. It presents results of cancer risk. Diesel particulate matter comprises 72% of the cancer risk associated with breathing toxics present in the air. NATA risk per million varies by location and has reduced over time statewide.

74. **Washington State Department of Ecology. Clean diesel grants. Available at: https://ecology.wa.gov/About-us/How-we-operate/Grants-loans/Find-a-grant-or-loan/Clean-diesel-grants. Accessed January 2020, 2020.**
This Washington State Department of Ecology website provides an overview of its clean diesel grants program. Funding is available for eligible projects (e.g., idle reduction) for cities, counties, school districts, public utility districts/co-ops, ports, state government, transit, tribes, non-profit organizations, local clean air agencies, privately-owned diesel fleets operating mainly in Washington.

75. **Tsoi C. T., Tse L. A. Professional drivers and lung cancer: a systematic review and meta-analysis. *Occup Environ Med.* 2012;69(11):831-836.**
Tsoi et al. conducted a systematic review and meta-analysis on the association between professional drivers potentially exposed to diesel exhaust and lung cancer. Twenty articles were included in the review, and 19 of these were included in the meta-analysis. Literature was pulled from Medline and Embase, and case-control and cohort studies were examined. Many types of drivers were included in the studies analyzed, including bus drivers, truck drivers, and taxi drivers. "If a study included measures for several different kinds of drivers, the measure for the type most likely exposed to diesel was selected." However, the review does not include a direct measurement of diesel exhaust. The publication dates of studies included were 1997 – 2011. The quality of studies was assessed using the checklist developed by Downs and Black, and a sensitivity analysis was conducted to explore heterogeneity between the included studies. The results show that "professional drivers who were potentially exposed to diesel exhaust have a 18% excess risk of lung cancer compared with non-drivers, after adjustment for smoking". The risk of lung cancer increased with longer duration of employment.

76. **Kinsey JS, Williams DC, Dong Y, et al. Characterization of Fine Particle and Gaseous Emissions during School Bus Idling. *Environmental Science Technology.* 2007;2007(41):4972-4979.**
Kinsey et al. examine whether restarting school buses will result in higher emissions of diesel pollutants than those attributable to periods of continuous idle. In 2005 (before the implementation of the EPA's 2010 Clean Diesel Standards) researchers measured the idle emissions from 6 diesel school buses (model years ranging from 1997 to 2004) under wintertime conditions to test the hypothesis that "the benefit of anti-idling, including restart, results in less net emissions than continuous idling." Specifically, particulate matter (PM) and gaseous emissions were determined over a simulated waiting period typical of schools in the northeastern U.S. "Testing was conducted for both continuous idle and hot restart conditions using a suite of on-line particle and gas analyzers installed in the [EPA's] Diesel Emissions Aerosol Laboratory." Researchers measured $PM_{2.5}$ as well as carbon monoxide (CO), carbon dioxide, nitrogen oxides (NOx), total hydrocarbons (THC), oxygen, formaldehyde, and the tracer gas in the raw exhaust. Overall, results showed "little difference in the measured emissions between a 10 min post-restart idle and a 10 min continuous idle with the exception of THC and formaldehyde." Meanwhile, engine restart resulted in an emissions pulse. Researchers developed a predictive equation from the experimental data, allowing a comparison between "continuous idle and hot restart for NOx, CO, $PM_{2.5}$, and PAHs and which considers factors such as the restart emissions pulse and periods when the engine is not running." This equation indicates that restart is the preferred operating scenario as long as there is no extended idling after the engine is restarted. Authors note that the emissions data provided are limited and only applicable to the specific engines, emission controls, diesel fuel, ambient conditions and operating procedures evaluated in the study.

77. **Carvalho-Oliveira R., Amato-Lourenco L. F., Almeida P. S., et al. Effects of long-standing exposure to heavy-duty diesel vehicle traffic on respiratory symptoms and airway inflammation in older adults. *Environ Pollut.* 2021;268(Pt B):115893.**
Carvalho-Oliveira et al. conducted a longitudinal panel study in Brazil to evaluate the effects of chronic exposure to traffic from a heavy-duty diesel fueled vehicle area. The researchers

examined the effects on respiratory symptoms and airway inflammation in a nonsmoking adult and elderly population. The study area was at the intersection between two main federal highways, where there is also a truck cargo terminal. Study volunteers aged 55 or older were included in the study. Participants had to have lived in the study area for more than a year. Participants' respiratory symptoms were evaluated using the International Study of Asthma and Allergies (ISAAC) questionnaire, while airway inflammation was assessed by fractional exhaled nitric oxide (FeNO). A subset (n=40) of participants who completed the ISAAC questionnaire (n=112) were also examined for FeNO over 6 months. Some (24%) participants reported wheezing in the last 12 months, only 2.7% of whom had asthma. "When comparing FeNO values by age group, the older elderly group (volunteers [75 years or older]) had significantly higher values than the adult and early old age groups ($p = 0.025$ and $p = 0.006$, respectively). However, no significant differences were found in FeNO values among the six periods studied ($p > 0.05$)." Further, the researchers found that "[a] high frequency of respiratory symptoms and high levels of FeNO were described in an underdiagnosed adult population living very close to a heavy-duty diesel-traffic area." The results indicate that respiratory symptoms associated with asthma and airway inflammation were significantly higher in the elderly population, compared to a nonsmoking adult population included in the study.

78. **Washington Healthy Youth Survey Report of Results 2021.**
The Washington State Healthy Youth Survey measures health risk behaviors that contribute to morbidity, mortality, and social problems among youth in Washington State. Over 200,000 students participated in the 2021 survey administration.

79. **U.S. Department of Transportation Federal Highway Administration. 2017 National Household Travel Survey. https://www.bts.gov/topics/passenger-travel/back-school-2019: Bureau of Transportation Statistics 2017.**
The National Household Travel Survey is conducted by the Federal Highway Administration. It is the only source of national data that allows one to analyze trends in personal and household travel. It includes daily non-commercial travel by all modes, including characteristics of the people traveling, their household, and their vehicles. According to the Bureau of Transportation Statistics analysis of 2017 survey data, 20% of low-income families (defined as at or below the poverty line) do not own any vehicles, and the majority (70%) of children from these families take a school bus to school. The data also show that 99% of non-low-income families own at least one vehicle, and the majority (over 50%) of children from these families take a private vehicle to school.

80. **Institute The Urban. Racial and Ethnic Disparities Among Low-Income Families.2009.**
The Urban Institute compiled information on race/ethnicity disparities among low income families, and found that low-income Black families are more likely to be below the federal poverty level than other families (53% of Black families, compared to 39% of non-Hispanic white, 44% of Hispanic, and 42 percent of other-race families).

81. **The complicated history of environmental racism. 2020; Available at: http://news.unm.edu/news/the-complicated-history-of-environmental-racism. Accessed February 2023.**

The University of New Mexico newsroom publishes a news article about environmental racism. The article focuses discussion with Honors College Assistant Professor Myrriah Gómez, who studies environmental racism. Gomez quotes a defintition of environmental racism from Robert Bullard's book Dumping in Dixie. Bullard defines environmental racism as "any policy, practice or directive that differentially affects or disadvantages (where intended or unintended) individuals, groups or communities based on race."