Health Impact Review of HB 1513
Improving environmental health by reducing carbon emissions through increasing climate resilience and mitigating the effects of climate change by levying a carbon pollution tax, authorizing a climate finance bond program, and investing in clean economic growth
(2021 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/Portals/7/Doc/HealthImpactReviews/HIR-2021-11-HB1513.pdf

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

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BILL INFORMATION

Sponsors: Lekanoff, Shewmake, Wicks, Valdez, Thai, Ramel, Peterson, Dolan, Goodman, Taylor, Kloba, Slatter, Frame, Hackney, Wylie, Pollet, Harris-Talley

Summary of Bill:
Full details about the provisions of this bill can be found in the bill text linked above. Given the length of the bill and the large number of provisions, the summary highlights provisions most relevant to this review.

- Imposes a carbon pollution tax beginning January 1, 2023, equal to $25 per metric ton of greenhouse gas (GHG) emissions on the sale or use of all fossil fuels and natural gas within the State of Washington, except for the sale or use of electricity in Washington generated using fossil fuels.
- Deposits 100% of tax revenue into the climate finance account and stipulates funds from the account must be used to reduce GHG emissions, support natural climate solutions, and invest in overburdened communities, as defined in the bill.

HEALTH IMPACT REVIEW

Summary of Findings:
This Health Impact Review found the following evidence for the specified provision in HB 1513:

- **A fair amount of evidence** that creating a carbon pollution sales and use tax on GHG emissions will decrease consumption of fossil fuels and natural gas in Washington State.
- **A fair amount of evidence** that decreasing consumption of fossil fuels and natural gas in Washington State will decrease emissions of GHGs and other co-pollutants.
- **Very strong** evidence that decreasing emissions of GHGs and other co-pollutants will improve health outcomes.
- **Unclear evidence** of the bill’s impact on health inequities, as the effect on highly impacted communities is dependent on the amount and allocation of available funding as well as the exact magnitude and distribution of decreased emissions (GHGs and co-pollutants) and resulting health outcomes in Washington State generally is unknown.

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 (e.g., access to healthcare, economic stability, racism). This document provides summaries of the evidence analyzed by State Board of Health staff during the Health Impact Review of House Bill 1513 (HB 1513).

Staff analyzed the content of HB 1513 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. 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 (Figure 1). The logic model includes information on the strength-of-evidence for each pathway. The strength-of-evidence has been defined using the following criteria:

- **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 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 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 HB 1513 and the Scientific Evidence

Summary of relevant background information

- The U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) identify carbon dioxide (CO_2), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride as greenhouse gases (GHGs) because of their capacity to trap heat in the earth's atmosphere.
- Carbon pollution taxes (or carbon taxes) are charges on the carbon content of fossil fuels which contribute to the accumulation of CO_2 and other GHGs in the atmosphere through emissions.[1] The additional tax increases the prices of these energy sources, with the goal of promoting a shift to lower-carbon fuels and/or renewable energy sources.[1] Revenue generated by the tax can then be used for various purposes (e.g., mitigating climate change).
- Worldwide, the largest source of GHG emissions is electricity generation.[2] However, in Washington State, the largest contributor of GHG emissions is the transportation sector (44.9%), followed by residential, commercial, and industrial heating (23.4%); electricity (16.3%); and other sources (e.g., agriculture, industrial processes, waste management, natural gas distribution) (15.4%).[2]
- Ecology noted that, "the effects of the COVID-19 pandemic are expected to significantly reduce emissions in 2020. However, these reductions are not expected to last as our state and nation recover from the pandemic."[2]
- Traffic-related air pollution (TRAP) refers to air pollution from motor vehicle emissions that result from fossil fuel combustion.[3] Sources of TRAP include passenger cars, diesel trucks and buses, and nonroad equipment (e.g., recreational vehicles, lawn and garden equipment).[3] These sources emit large amounts of CO_2, carbon monoxide (CO), nitrogen and sulfur oxides (NO_x and SO_x, respectively), volatile organic compounds (VOCs), and particulate matter (PM).[3] The EPA regulates many of these pollutants and uses them as surrogates for criteria air pollutants, which can harm human health and the environment.[4]
- Washington state legislators have established GHG emission reductions targets in statute (RCW 70A.47.020). By 2020, the state was to reduce overall emissions of GHG to 1990 levels (90,500,000 metric tons).[5] Overall emissions of GHG are to be further reduced by 2030 (50 million metric tons; 45% below 1990 levels), 2040 (27 million metric tons; 70% below 1990 levels), and 2050 (5 million metric tons; 95% below 1990 levels).[5]
- Washington State's Clean Energy Transformation Act (CETA) (Chapter 288, Laws of 2019) applies to all electric utilities serving retail customers in the state. The law requires utilities supply Washington customers with electricity that is 100% renewable or non-emitting by 2045, with no provisions for offsets.[6] It sets specific milestones beginning in 2022 to reach the required clean electricity supply.[6]
- As of December 2020, Washington has more than 1,100 public electric charging stations with more than 3,300 charging outlets across the state and "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, and is part of the West Coast Green Highway that extends from Canada to Mexico."[7]

Summary of HB 1513

Full details about the provisions of this bill can be found in the bill text linked above. Given the length of the bill and the large number of provisions, the summary highlights provisions most relevant to this review.

- Imposes a carbon pollution tax beginning January 1, 2023, equal to $25 per metric ton of GHG emissions on the sale or use of all fossil fuels and natural gas within the State of Washington, except for the sale or use of electricity in Washington generated using fossil fuels.
    - The carbon pollution tax is applicable to: motor vehicle fuel (Chapter 82.38 RCW); special fuel (Chapter 82.38 RCW); every other petroleum product (Chapter 82.23A RCW); fossil fuels not listed (Chapters 82.08 and 82.12 RCW), unless expressly provided otherwise in the bill; and fossil fuels consumed in refineries.
    - Specific to natural gas, the carbon tax is imposed on the gas distribution business upon the sale of natural gas to the retail customer and the direct access gas customer upon the consumption of the natural gas by the customer.
    - The tax rate increases annually by 5% and adjusts for inflation as measured by the consumer price index starting on January 1, 2024.
    - As of January 1, 2030, if Ecology determines the sources of emissions covered by the tax are not predicted to achieve their combined share of the emission reductions necessary for the State to achieve the emissions limits established in RCW 70A.45.020, the tax rate increases by $10 effect January 1, 2031. Each year thereafter, the tax rate increases by 5% per year plus inflation, with an additional increase of $2 per year until Ecology determines relevant sources of emissions are expected to meet established limits, at which point the $2 increase is retired.
- Deposits 100% of tax revenue into the climate finance account and stipulates funds from the account must be used to reduce GHG emissions, support natural climate solutions, and invest in overburdened communities, as defined in the bill.
    - 75% of the moneys go to the GHG emissions reduction account and must be used by the Departments of Transportation and Commerce for projects and incentive programs that yield reductions in GHG emissions. Seventy-five percent must be directed to transportation investments.
    - 25% of the moneys go to the natural climate solutions account and must be used to increase the resilience of the State's waters, forests, and other vital ecosystems to the impacts of climate change and carbon pollution reduction capacity.
    - Additionally, at least 35% of total investments must provide direct and meaningful benefits to vulnerable populations within the boundaries of highly impacted communities, as designated by the Washington State Department of Health (DOH) (RCW 19.405.140). At least 10% of total investments must be used in projects formally supported by a resolution with an Indian tribe.

Health impact of HB 1513

Evidence indicates that relevant provisions of HB 1513 would likely decrease consumption of fossil fuels and natural gas, decrease emissions of greenhouse gases and other co-pollutants, and improve health outcomes. The impacts on equity are unclear.

Pathway to health impacts
The potential pathway leading from the provisions of HB 1513 to health inequities are depicted in Figure 1. There is a fair amount of evidence that creating a carbon pollution sales and use tax on GHG emissions will decrease consumption of fossil fuels and natural gas in Washington State[8-11] and decreasing consumption of fossil fuels and natural gas in Washington State will decrease emissions of GHG and other co-pollutants.[8,12,13] There is very strong evidence that decreasing emissions of GHG and other co-pollutants will improve health outcomes.[11,14-25] This review found unclear evidence of the bill's impact on health inequities, as the effect on highly impacted communities is dependent on the amount and allocation of available funding as well as the exact magnitude and distribution of decreased emissions (GHGs and co-pollutants) and resulting health outcomes in Washington State generally is unknown.[26]

Scope
Due to the complexity of HB 1513 and time limitations, this Health Impact Review represents a broad, general discussion about potential impacts of imposing a carbon emissions tax in Washington State. Staff recognize the diversity of potential pathways and impacts resulting from the broad range of fossil fuel and natural gas sources, payers, and consumers as well as investment projects and programs that may be affected by this bill. Staff acknowledge that evaluating each specific factor and related pathway could result in different strength-of-evidence ratings or unintended consequences. Since the transportation sector is the largest contributor of GHG emissions in Washington State (approximately 44.9%),[2] this review focuses primarily on the impacts of a carbon tax on the transportation sector.

For this review, we were only able to research the most direct connections between the provisions of the bill and decreased health inequities and did not explore the evidence for all possible pathways. For example, we did not evaluate potential impacts related to:

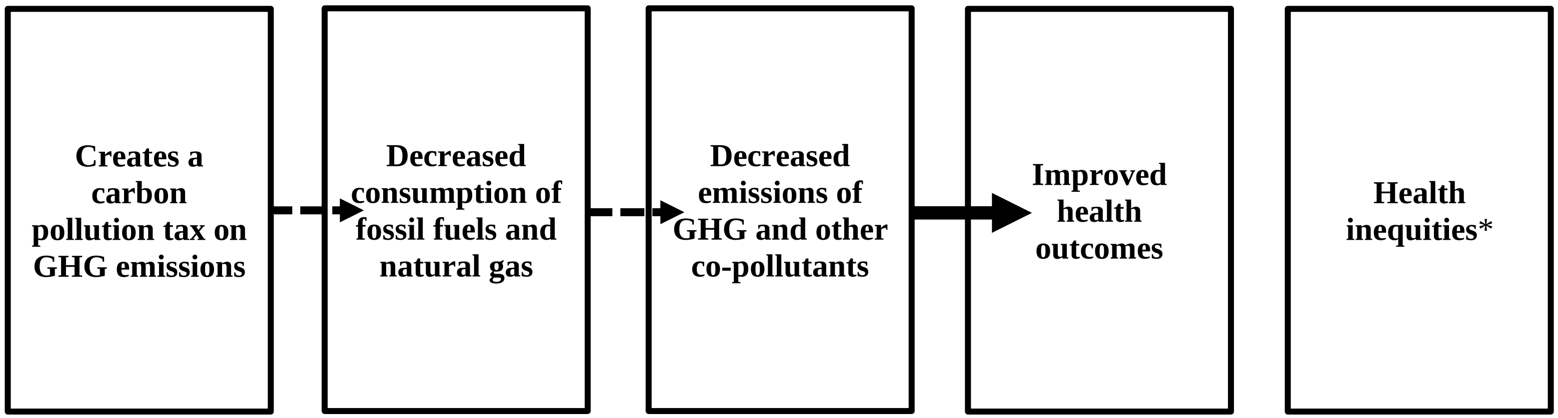
- Larger, long-term impacts of the bill on climate change. For example, key informants noted that changes in carbon demand could result in infrastructure changes (e.g., increased production of electric vehicles) that could help mitigate the impacts of climate change (personal communication, March 2021).
- Longer-term health outcomes related to climate change and consequences of GHG emissions (e.g., sea level change, temperature changes). As the consequences of GHG emissions are global, a carbon tax in one jurisdiction (state or country) alone will not significantly affect the trajectory of climate change[27] or risks associated with adverse health outcomes. Therefore, this analysis focuses on the co-pollutants associated with GHG emissions that can be affected locally and in the short-term[10] and are independently associated with adverse health outcomes.

Magnitude of impact
Washington State Department of Revenue (Revenue) reported a carbon pollution sales and use tax of $25 per metric ton of GHG emissions would apply to an estimated 1,500 taxpayers, as the tax is imposed on the first seller or user of the fuels in the state.[28] Evidence suggests that some portion of the tax to be passed through to consumers via price increases (e.g., increased fuel prices).[8,9] Revenue estimates the carbon pollution tax would generate approximately $655

million in Fiscal Year (FY) 2023, $1.64 billion in FY 2024, $1.76 billion in FY 2025, $1.83 billion in FY 2026, and $1.94 in FY 2027.[28]

Revenue also modeled provisions of HB 1513 (e.g., a carbon pollution tax rate of $25.00 per metric ton beginning January 1, 2023) and standard consumption elasticities. In 2030, the model predicts a 12.4% decrease in CO_2 emissions in the industrial sector, 5.2% decrease in the residential sector, 4.9% decrease in in the commercial sector, and 1.5% decrease in the transportation sector compared to if no carbon pollution tax was implemented (unpublished data, Revenue, March 2021). Whether reductions result in meaningful changes in health outcomes depends on a long causal chain wherein each step there is a question about the exact magnitude and distribution of impacts.

Logic Model



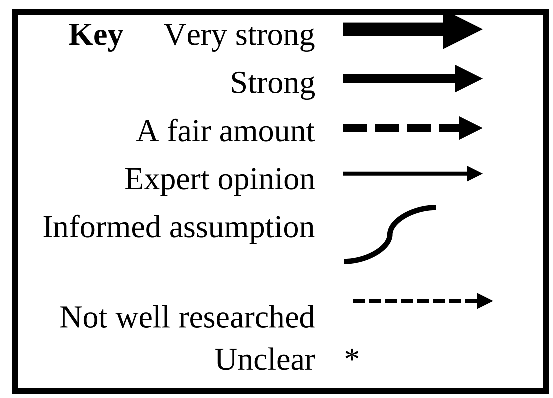


Figure 1:

Improving environmental health by reducing carbon emissions through increasing climate resilience and mitigating the effects of climate change by levying a carbon pollution tax, authorizing a climate finance bond program, and investing in clean economic growth

HB 1513

Summaries of Findings

Will creating a carbon pollution sales and use tax on GHG emissions decrease consumption of fossil fuels and natural gas in Washington State?

There is a fair amount of evidence that creating a carbon pollution sales and use tax on GHG emissions will decrease consumption of fossil fuels and natural gas in Washington State. For example, "modeling results clearly show that implementing a carbon [pollution] tax lowers the demand for emissions-intensive energy sources such as coal and oil, while it increases the demand for relatively less emissions-intensive energy sources such as natural gas and renewables [energy generated by hydroelectric, wind, solar, etc.]."[29]

In 2018, the largest contributors to GHG emissions nationally were the transportation sector (28%) and electricity sector (27%).[30] The U.S. Environmental Protection Agency (EPA) reports "the largest sources of transportation-related [GHG] emissions include passenger cars and light-duty trucks, including sport utility vehicles, pickup trucks, and minivans. These sources account for over half of the emissions from the transportation sector."[30] Between 1990 and 2018, the number of vehicle miles traveled by passenger cars and light-duty vehicles increased by 46.1%.[30] Contributing factors include population growth, economic growth, urban sprawl, and periods of low fuel prices.[30] In Washington State, the transportation sector is also the largest contributor to GHG emissions (44.9% of emissions), with half of transportation-related emissions from personal cars and trucks.[2] Unlike other regions of the U.S. that rely heavily on coal to produce electricity, Washington's electricity production is generally cleaner due to the state's access to renewable energy sources, like hydroelectric power which generally accounts for more than two-thirds of the state's electricity generation.[7]

A modeling study by the Stanford Energy Modeling Forum (EMF) examined potential implications of a U.S. economy-wide carbon pricing policy. Authors used "11 models to assess emissions, energy, and economic outcomes from a range of economy-wide carbon price policies to reduce carbon dioxide (CO_2) emissions in the [U.S.]."[10] Authors evaluated four policy alternatives including a $25 tax per ton of carbon emissions increasing by either 1% or 5% per year as well as a $50 tax per ton of carbon emissions increasing by either 1% or 5% annually.[10] Projections show that "all of the price trajectories cause significant shifts in fossil fuel demand [in the U.S.], with coal shifting the most significantly."[10] Models indicated the demand for natural gas and oil are highly dependent on technology cost assumptions.[10] Additionally, models indicate that nationally the electricity sector is the most responsive to carbon price (across all four policy alternatives) with 72-91% of the emission reductions projected in this sector.[10] Meanwhile, EMF results show that nationally the residential and transportation sectors were projected to be least responsive.[10] Authors noted that "residential housing and transportation […] both feature a very large stock of houses/cars that can be slow to turn over."[10] Although a carbon pollution tax may prompt innovation through research incentives, "models generally do not represent induced research and development spending and the associated spillovers."[10] Therefore, results "may underestimate the environmental effectiveness of the policies" but it is unclear by how much.[10]

Similarly, a study modeling the impact of a national carbon pollution tax on carbon emissions in the U.S. found that, while emissions decreased across all energy sectors, the transportation sector was the least responsive to the carbon tax and "reductions are small and develop slowly relative…to the power sector."[8] The study found that, in the transportation sector, "a carbon tax increases the retail price of gasoline, diesel, and jet fuel, as well as natural gas and propane, in proportion to their carbon intensity. As the carbon tax is passed through to consumers, the overall cost of mobility increases."[8] The authors presented two explanations for why the transportation sector is less responsive to a carbon tax. First, driving is typically considered to be inelastic and the "short-term responsiveness of transportation emissions to a carbon tax is driven primarily through reductions in driving, rather than fuel substitution."[8] The authors estimated that a carbon tax ranging from $14 per ton of CO_2 emissions to $73 per ton of CO_2 emissions would increase the average price of a gallon of gasoline by $0.12 to $0.64, which is "still well within the price range [of gasoline] over the past five years. With these cost increases within historical variability, it's unsurprising to see modest reductions in emissions in response to a carbon tax."[8] Second, the authors explained that "[energy] sectors with high capital costs relative to operating costs [like automobiles] are less likely to be responsive to a carbon tax because the tax primarily affects operating costs…For that reason, a carbon tax does more to shift generation from coal to gas in the power sector, for example, than from internal combustion engine vehicles to electric vehicles in the transportation sector."[8] The authors noted that significantly faster timelines for the electrification of vehicles could produce greater reductions in emissions in the transportation sector.[8]

Modeling in Washington State has shown similar results. In 2015, Washington State Office of Financial Management (OFM), Forecasting and Research Division modeled the economic impacts of a carbon tax in Washington. The model assumed that a carbon tax would be passed on to consumers, resulting in higher fuel and energy prices for consumers.[9] However, the modeling showed that "the estimated gas price changes [($0.12 to $0.41 increase per gallon)] are smaller than historic price volatility, and the potential increases in fuel costs do not affect the overall net positive effect of the program on the statewide economy."[9]

Overall, there is a fair amount of evidence that creating a carbon pollution sales and use tax on GHG emissions in Washington will likely decrease consumption in all energy sectors, though the transportation sector (which is the largest contributor to GHG emissions in Washington) is likely to experience more modest changes compared to other sectors.

Will decreasing consumption of fossil fuels and natural gas in Washington State decrease emissions of GHGs and other co-pollutants?

There is a fair amount of evidence that decreasing consumption of fossil fuels and natural gas in Washington State will decrease emissions of GHGs and other co-pollutants.

A recent study compared the effectiveness of various policies at reducing GHG emissions in the electricity sector.[12] Compared to other policy mechanisms, the authors found that, "if the goal is reducing [CO_2] in the atmosphere, what we found [in our case study] is that putting a price on carbon and then letting suppliers and consumers make their production and consumption choices accordingly is much more effective than other policies [at reducing CO_2 emissions]."[31] Overall, they found "that market-based policies (e.g., carbon taxes) achieve decarbonization targets most efficiently."[12]

A study modeling the impact of a national carbon tax on carbon emissions in the U.S. concluded that, "the impact of a carbon tax on U.S. GHG emissions is dependent on both the level of the tax and the sector in which the emissions occur."[8] The authors found that, "a carbon tax can drive substantial reductions in U.S. GHG emissions in the near and medium term" and "an economy-wide carbon tax set at $50/ton in 2020 and rising at a real rate of 2 percent achieves emission reductions of 39 to 47 percent below 2005 levels by 2030."[8] While declines occurred in all energy sectors, the authors found that the electricity sector was the most responsive to a carbon tax and had the largest decrease in emissions.[8] Additionally, "the transportation sector appears not to be very responsive to different tax rates" and reductions in emissions appeared to be a 1-3% reduction from current policies by 2030.[8] They found that a $50/ton tax decreased carbon emissions in the transportation sector by approximately 200 million metric tons from 2015 levels.[8]

The Washington State Department of Commerce created the Carbon Tax Assessment Model (CTAM) to predict how different carbon tax scenarios would impact CO_2 emissions (not including toxics or other co-pollutants) in the five primary energy sectors (i.e., residential, commercial, industrial, transportation, electricity) in Washington State.[13] The model predicts similar reductions as national models. The Washington State Department of Revenue (Revenue) ran the CTAM using provisions of HB 1513 (e.g., a carbon pollution tax rate of $25.00 per metric ton beginning January 1, 2023) and standard consumption elasticities. The model predicted a decrease in emissions as a result of implementing a carbon pollution tax across the residential, commercial, industrial, and transportation energy sectors through 2050. For example, in 2030, the model predicts a 12.4% decrease in CO_2 emissions in the industrial sector, 5.2% decrease in the residential sector, 4.9% decrease in in the commercial sector, and 1.5% decrease in the transportation sector compared to if no carbon pollution tax was implemented (unpublished data, Revenue, March 2021).

While the model only evaluates CO_2 emissions, decreasing consumption of fossil fuels and natural gas will also decrease emissions of other GHGs and other co-pollutants.[8,10] For example, results of the Stanford EMF study found that "consistent with earlier studies, the models suggest that a carbon price can lead to significant reductions in GHG emissions" and reductions in fossil fuel use, especially from coal and transportation fuels, also reduce other conventional air pollutants.[10] Additionally, "the potential co-benefits of reductions in particulate matter (i.e., $PM_{2.5}$), nitrogen oxides (NO_x), and sulfur dioxide (SO_2) have been especially well documented."[10] The authors stated, "these emissions reductions are especially notable because they are often significant in terms of magnitude (they can be twice the percentage reduction of CO_2), the resulting health benefits can be significant on a macroeconomic scale, and the reductions occur rapidly in the first decade of the policy — accruing benefits to current generations."[10]

Overall, there is a fair amount of evidence that decreasing consumption of fossil fuels and natural gas will decrease emissions of GHGs and other co-pollutants.

Will decreasing emissions of GHGs and other co-pollutants improve health outcomes?
There is very strong evidence that decreasing emissions of GHG and other co-pollutants will improve health outcomes.[11,14-25]

An economic analysis estimated U.S. economy-wide impacts of a carbon emissions tax on co-pollutants (PM, SO_2, and NO_x) and associated co-benefits (i.e., lower rates of illness from air pollutants that are reduced as a result of the policy).[11] Like other national analyses, the largest percentage changes in fuel use occur in the electricity sector with smaller changes in the transportation sector.[11] Overall, results suggest a nationwide tax of $25/ton of CO_2 increasing at 5% per year would avert an estimated "8,600-19,300 cases of premature mortality worth $72-162 billion in total monetized health effects based on the present value of emissions reductions of the policy period 2020-2040 ($2016)."[10,11] Additionally, the model estimates $1.5-2 billion ($2016) in morbidity co-benefits (e.g., reduced medical expenditures related to asthma or chronic obstruct pulmonary disease [COPD]).[11] The author estimated that average monetized co-benefit varies widely by U.S. region and is approximately $150-1,250 per household.[11]

Exposure to air pollution (i.e., GHGs and co-pollutants) is linked to many serious health outcomes, including respiratory infections, lung cancer, stroke, and cardiopulmonary disease.[14] For example, the components of transportation-related air pollution (TRAP) are recognized nationally and internationally as risk factors for cardiovascular disease in the general population.[3] Additionally, a systematic review by the U.S. Department of Health and Human Services' National Toxicology Program concluded that TRAP exposure (traffic-related $PM_{2.5}$ and NO_2) during pregnancy increases the likelihood of developing hypertensive disorders of pregnancy.[3] Moreover, "because of the recognized relationship between maternal blood pressure status and the effect of hypertension during pregnancy on fetal and infant health outcomes, hypertensive disorders of pregnancy associated with TRAP exposure may have significant adverse health effects in the developing offspring."[3]

Exposure to TRAP has also been found to affect health outcomes among children and adults. A systematic review and meta-analyses including 41 studies examined the association between children's exposure to TRAP metrics and their risk of asthma incidence or lifetime prevalence (birth to age 18 years).[15] Results of the meta-analyses found statistically significant associations between exposures to black carbon, NO_2, $PM_{2.5}$, and PM_{10} and risk of asthma development.[15] Overall, "findings support the hypothesis that childhood exposure to TRAP contributes to their development of asthma."[15] Another systematic review found that "exercising in an environment with high TRAP exposure increases markers of respiratory and systemic inflammation, as well as impairs the vascular function and increases artery pressure, when compared with an environment with low-TRAP exposure."[17] Those with asthma and Chronic Obstructive Pulmonary Disease (COPD) were particularly sensitive to air pollution while participating in moderate physical exercise (i.e. walking).[17] The same trend held true for children.[17]

Recent research has shown that long-term exposure to poor air quality increases risk of death from COVID-19. Pre-existing conditions like cardiovascular disease and lung disease that increase the risk of death in those with COVID-19 are the same diseases that are affected by long-term exposure to air pollution."[32] In a study evaluating the association between average $PM_{2.5}$ levels and COVID-19 death rates in 3,000 U.S. counties (representing 98% of the U.S. population), researchers found that an increase of 1 μg/m3 in $PM_{2.5}$ is significantly associated with an 8% increase in the COVID-19 death rate.[32]

Lastly, evidence indicates "a small fraction of emissions, concentrated in or near densely populated areas, plays an outsized role in damaging human health with the most damaging 10% of total emissions accounting for 40% of total damages."[14] Because primary $PM_{2.5}$ is often released at ground level in fine particle form, a greater share of its impacts occurs near the emissions source.[14] Therefore, there can be significant "within-county variation in marginal damages in terms of the ratio of the marginal damages in the most- to least-damaging ground-level emission locations within each county."[14] For example, in the most densely populated U.S. counties (10% of counties with 58% of the U.S. population) primary $PM_{2.5}$ is on average approximately 8 times more harmful per unit in one location than in another location within the same county.[14] In 2011, King County, WA, data showed the monetary marginal damages for primary $PM_{2.5}$ spanned a 127-fold range from $7,000 to $890,000 depending on the location in the county.[14]

Overall, there is very strong evidence suggests that decreasing emissions of GHGs and other co-pollutants will improve health outcomes, particularly cardiovascular and respiratory conditions and symptoms.

Will improved health outcomes decrease health inequities?

There is unclear evidence of how a carbon pollution sales and use tax on GHG emissions would likely impact health inequities. Generally, "there is broad agreement [in the published literature] that distributional impacts [of carbon taxes] are ultimately largely driven by what is done with the collected revenue."[26] Research also shows carbon emission pricing "can have differing effects on household welfare, depending on income level and region. Households will be affected through changes in the price of carbon-intensive goods, as well as changes in consumption behavior, productive technology, and incomes."[26] Therefore, it is unclear how HB 1513 would impact health inequities as the effect on highly impacted communities is dependent on the amount and allocation of available funding as well as the exact magnitude and distribution of decreased emissions (GHGs and co-pollutants) and resulting health outcomes in Washington State generally is unknown.

HB 1513 would require use of an environmental justice lens to allocate a portion of tax revenues. Environmental justice refers to "the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income with respect to development, implementation, and enforcement of environmental laws, regulations, and policies."[33,34] This includes addressing disproportionate environmental and health impacts by prioritizing vulnerable populations and overburdened communities, equitably distributing resources and benefits, and eliminating harm.[34] The bill stipulates that at least 35% of total investments must provide direct and meaningful benefits to vulnerable populations in highly impacted communities and at least 10% of total investments must be used in projects formally supported by a resolution with an Indian tribe. The bill defines "highly impacted communities" as those communities highly impacted by fossil fuel pollution and climate change in Washington, as designated by the Department of Health (DOH) under RCW 19.405.140, or a community located in a census tract that is fully or partially located on "Indian country," as defined in 18 U.S.C. Sec. 1151. The bill defines "vulnerable populations" as communities that experience a disproportionate cumulative risk from environmental burdens due to adverse socioeconomic factors and sensitivity factors." However, since the impact on highly impacted communities is largely dependent on the amount and allocation of tax revenue, it is unclear how HB 1513 would impact inequities (see Other Considerations for further discussion).

Both national and Washington-specific data show that people of color and people with low-incomes are disproportionately exposed to environmental hazards in their communities.[33] The Washington State Environmental Justice Task Force stated, "racially and economically segregated neighborhoods across the [U.S.] are the resulting legacy of redlining and other racist and discriminatory policies."[33] Continued divestment in Black, Indigenous, and People of Color neighborhoods has contributed to the racial wealth gap and has negatively affected access to safe and healthy homes, schools, jobs, and community spaces.[33] For example, DOH's Washington Tracking Network's Environmental Health Disparities (EHD) map compares census tracts across Washington for environmental health disparities.[35] DOH uses the EHD map as the cumulative impact analysis to designate communities highly impacted by climate change and fossil fuel pollution as required by the Clean Energy Transformation Act (CETA).

The EHD map is comprised of four themes with a total of 19 measures, five of which are related to environmental exposures (i.e., NO_x-diesel emissions, $PM_{2.5}$ concentration, ozone concentration, populations near heavy traffic roadways, and toxic release from facilities). Overall, data show that census tracts with greater environmental exposures also have greater percentages of Black, Indigenous, and People of Color communities than census tracts with fewer environmental exposures when analyzing the environmental exposure rank for communities (unpublished data, DOH, March 2021).[35] Specifically, census tracts with the lowest environmental exposures rank are 80.5% white, 1.0% Black, and 9.5% Hispanic or Latino, while census tracts with the highest environmental exposures rank are 48.9% white, 10.4% Black, and 17.4% Hispanic or Latino (unpublished data, DOH, March 2021).[33] Financial poverty is also associated with exposure to environmental health disparities.[33] The poverty rate (i.e., percent of total population under 185% of the Federal Poverty Level) in the highest environmental exposures ranked census tract (rank 10) is nearly 1.3 times that of the lowest environmental exposures ranked census tract (rank 1) (unpublished data, DOH, March 2021). Finally, living in areas with greater exposure to environmental hazards and pollution is associated with a shorter lifespan. Data show that populations living in census tracts with the lowest environmental exposures (rank 1) have a life expectancy that is 1.7 years longer than those in census tracts with the highest environmental exposures (rank 10) (unpublished data, DOH, March 2021). When looking more broadly at environmental health disparities (including measures of environmental effects, socioeconomic factors, and sensitive populations), data show that the disparity in life expectancy is 5.7 years longer for those living in rank 1 census tracts compared to rank 10 tracts.[33]

National modeling results indicate that co-benefits of reducing carbon emissions can be "strongly heterogenous, meaning national [or state] averages could mask significant variation in the benefits enjoyed by households across geography, income and health."[26] Specifically, variation depends on differences in local atmosphere, demographics, and health. For example, "[w]ithin a given geographic area, lower-income households may face higher exposures if they are more likely to work outdoors or less likely to be able to afford leaving the city for better air quality, meaning higher benefits to pollution abatement for these populations."[26] Additionally, not all people are at the same risk of experiencing pollution-induced morbidity, and "air pollution is likely to be particularly problematic for individuals already suffering from respiratory illness and less so for those in good health."[11]

Overall, there is general consensus in the literature that the distributional impacts of a tax on carbon pollution is dependent on how the revenue is used.[26] Therefore, since the effect on highly impacted communities is dependent on the amount of funding available and on how funds are allocated, it is unclear how HB 1513 would impact health inequities. However, if revenues are invested in highly impacted communities to implement programs and activities that effectively reduce GHG emissions and other co-pollutants, then there is the potential to decrease health inequities.

Other considerations

This Health Impact Review focused on the most direct pathway between provisions in the bill and health outcomes and health equity. We also examined potential pathways related to impacts on consumers, on labor and employment, and related to the reinvestment of tax revenue.

Impacts on consumers

Prior research has shown that "carbon pricing affects low-income households proportionately more than high-income households (i.e., is regressive), given the relatively more emissions-intense consumption bundles of lower-income groups."[26]According to the U.S. Department of Treasury, state sales taxes impact individuals differently depending on their income "because the people with smaller incomes pay a larger percentage of their money into the sales tax system than people with higher incomes."[36] For example, a 2018 report from the Institute of Taxation and Economic Policy found that Washingtonians with incomes in the lowest 20% (less than $24,000 annually) pay 13.3% of their family income in sales and excise taxes compared to those with incomes in the top 20% (more than $116,300 annually) that pay less than 4.7% of their family income.[37] The Institute also calculates a Tax Inequality Index "which measures the impact of each state's tax system on income inequality."[37] According to their measures, "Washington has the most unfair state and local tax system in the country. Incomes are more unequal in Washington after state and local taxes are collected than before."[37] One reason for this inequity is due to Washington's comparatively high combined state and local sales tax rate.[37]

In a 2015 modeling report, OFM noted that national data suggested that "low-income households spending is relative 'inelastic' relative to gasoline prices, meaning these households continue to spend their income on fuel despite increases in gas prices. Looking at electricity, the consumption patterns suggest that the lowest-income households spend about 4.3 percent of their total expenditures on electricity compared to just 3.3 percent for middle-income households."[9] Carbon-based fuels make up approximately 11% of household expenditures in households with low-incomes and changing the price of carbon-based energy sources would likely increase the cost of expenditures.[9] For example, under the policy scenario modeled by OFM (which is different than the proposed provisions of HB 1513), household expenditures on carbon-based fuels in households with the lowest-incomes increased by $144 per year.[9]

Since there is limited research examining the extent to which the specific carbon tax proposed by HB 1513 would impact household expenditures or income, this pathway was not included in the logic model.

Impacts on labor and employment
We also explored the potential impact of a sales and use tax on carbon emissions on businesses and employment. There is limited research evaluating this relationship.

In 2015, OFM modeled the economic impacts of a carbon tax in Washington. While the model inputs differed from the proposed provisions of HB 1513, the model showed "negligible impacts on income, employment, and output, with most measures showing slight improvement over time. This is mostly due to reinvestment of the [revenue] and the relatively small size of the program compared to the overall state economy."[9] The model showed that the increased price of carbon, higher energy costs, and use of revenue resulted in more jobs gained than lost over time and that "the [model] results imply that implementing a carbon price policy with revenue recycling will increase employment slightly above the natural job creation that would otherwise be expected."[9] The report noted that jobs are especially likely to increase in sectors where revenues are invested.[9] However job growth is expected across the economy and, of "94 occupations…95 percent realize job gains (however small) above baseline and only about 5 percent lose jobs relative to baseline during the 20-year scenario period."[9] The model also suggested that the majority of job sectors would also experience increases in wages and salaries "due to the stimulative effect of the carbon charge as funds move across sectors."[9]

Additionally, revenue investments have the potential to support labor-intensive business in the state and green jobs. A modeling analysis by the Low Carbon Prosperity Institute (LCPI) and Climate Xchange (CXC) found that for every dollar Washington were to invest in clean transportation, forest conservation and ecosystem restoration, clean energy, water and energy efficiency, low carbon agriculture, and sustainable industry, $0.64 would support employee compensation compared to $0.40 in the state's largest industries.[38] The model also showed investments result in "$51,400 in average wages across all jobs supported, which is slightly [more than] the statewide average of $50,200, although lower than the top ten industry average of $67,900 (as of 2018)."[38]

Since there is limited evidence examining the impact of a carbon emission sales and use tax on labor and employment we did not include this pathway in the logic model. However, since existing evidence from Washington State suggests that carbon pricing policies may increase jobs, and since it is well-documented that access to jobs, higher wages, and economic stability improve health outcomes, there is the potential that HB 1513 could have a greater impact on improving health outcomes and decreasing health inequities.

Impacts of tax revenue
HB 1513 stipulates that 100% of the revenue from the carbon emissions tax must be deposited into the Climate Finance Account created by the bill. The first and primary obligation of these funds is the timely repayment of all special tax obligation bonds (payment of principal and interest) issued under the Climate Finance Program authorized by the bill (Section 10). Beginning July 1, 2023, and annually thereafter, any funds remaining after bond obligations are met, shall be distributed as follows: 75% to the Greenhouse Gas Emissions Reduction Account (Section 17) and 25% to the Natural Climate Solutions Account (Section 18).

Moneys in the Greenhouse Gas Emissions Reduction Account must fund projects or programs physically located in Washington State. Programs and projects eligible for funding include, but are not limited to: supplementing the growth management planning and environmental review fund (RCW 36.70A.490); deploying renewable energy resources; promoting electrification and decarbonization of new and existing buildings; increasing energy efficiency or reducing GHG emissions of industrial facilities, the agricultural sector, new and existing buildings, and the transportation sector. Moneys in the Natural Climate Solutions Account are to be used to increase the resilience of the state's waters, forests, and other vital ecosystems to the impacts of Climate Change and increase their carbon pollution reduction capacity (i.e., sequestration, storage, and overall ecosystem integrity). Moneys must be used in ways consistent with the assessments of climate risks and resilience from the scientific community and expressed concerns of and impacts to highly impacted communities. The bill defines highly impacted communities as those communities highly impacted by fossil fuel pollution and climate change in Washington, as designated by the Department of Health (DOH) under RCW 19.405.140, or a community located in a census tract that is fully or partially located on "Indian country," as defined in 18 U.S.C. Sec. 1151.

Section 9 of the bill states that at least 35% of the total investments authorized through the Greenhouse Gas Emissions Reduction Account and the Natural Climate Solutions Account, as well as the Climate Bond Proceeds Account (Section 14), "must provide direct and meaningful benefits to vulnerable populations within the boundaries of highly impacted communities, as designated by [DOH]." Additionally, at least 10% of the total investments "must be used for programs, activities, or projects formally supported by a resolution of an Indian tribe, with priority given to otherwise qualifying projects directly administered or proposed by an Indian tribe."

Generally, evidence suggests that, "while the literature has not seemingly reached a consensus regarding the progressivity or regressively of carbon taxation itself, there is broad agreement that distributional impacts are ultimately largely driven by what is done with the collected revenue."[26]

A 2020 report by the LCPI and CXC analyzed the potential jobs and community health benefits created by a sample portfolio of investments (i.e., Resilient Recovery Portfolio) in Washington.[38] Authors used an economic input-output model (IMPLAN) to map 18 proposed projects' flow of economic activity between 546 sectors and institutions in Washington to measure resulting employment, output, labor income, and fiscal impacts.[38] They then used a cost-benefit model to compare the health and climate benefits of each investment to upfront costs.[38] Modeling results showed "investing in clean transportation, forest conservation and ecosystem restoration, clean energy, water and energy efficiency, low carbon agriculture, and sustainable industry" would support 10.1 full-time-equivalent (FTE) jobs per million dollars invested, compared to 4.3 FTE jobs per million dollars invested in Washington's 10 largest industries.[38] Authors used the U.S. Interagency Working Group's social cost of carbon estimate, in which avoided emissions have a societal benefit of $52 per metric ton of carbon dioxide equivalent (adjusted to 2020 dollars), to estimate community health benefits.[38] They found every million dollars invested in the identified programs would prompt an estimated "$2.4 million in health and climate benefits, including $1.6 million in clean air benefits."[38] Authors noted that "other studies project the social cost of carbon to be as high as $417 per metric ton of carbon dioxide equivalent," which would result in climate benefits 8 times higher than authors estimated.[38] Moreover, the model does not account for additional co-benefits beyond cleaner air (e.g., reduced traffic fatalities, increased active transportation), and authors expect total co-benefit returns (in dollar value) to be higher than the analysis indicates.[38] Estimated benefits are specific to the projects analyzed, and authors recommended further consideration and analysis of how investments may impact social justice, the distributional economic and health outcomes of selected recovery measures, job quality, etc.[38]

Revenue estimates the total revenue impact as approximately $655 million in Fiscal Year (FY) 2023, $1.64 billion in FY2024, $1.76 billion in FY2025, $1.83 billion in FY 2026, and $1.93 billion in FY 2027.[28] Since the impact on highly impacted communities is dependent on the amount of funding available and on how funds are allocated, we did not include this pathway in the logic model. However, available evidence suggests that, if the tax revenue is invested to address the impacts of climate change,[38] particularly among highly impacted communities,[14] there is the potential that HB 1513 would have a greater impact on improving health outcomes and decreasing health inequities.

Annotated References

1. **Parry, I. Putting a Price on Pollution: Carbon-pricing strategies could hold the key to meeting the world's climate stabilization goals. *International Monetary Fund Finance & Development.* 2019(December 2019):16-19.**

This article by a principal environmental fiscal policy expert at the International Monetary Fund's Fiscal Affairs Department discusses carbon taxation from a global perspective.

2. **Ecology Washington State Department of. 2018 Greenhouse gas data.2021.**

Washington State Department of Ecology compiles an annual greenhouse gas (GHG) emissions inventory that estimates the combined emissions from all sources in the state. Worldwide, the largest source of carbon emissions is electricity generation. However, in Washington State, the largest contributor of GHG emissions is the transportation sector (44.9%), followed by residential, commercial, and industrial heating (23.4%), electricity (16.3%), and other sources (e.g. agriculture, industrial processes, waste management, natural gas distribution) (15.4%). Transportation emissions include on-road gasoline and diesel vehicles, marine vessels, jet fuel and aviation gasoline, railroads, and natural gas used in transportation. Emissions from personal cars and trucks contribute to 50% of transportation emissions. Data from 2018 suggest that GHG emissions increased by 1.3% between 2017 and 2018. Emissions from electricity generation decreased 2.5% from 2017 to 2018 due to the 2019 Clean Energy Transformation Act, which requires Washington utilities to stop using coal power by 2025. These reductions in the electricity sector were offset by an increase in emissions of 3.3% in the transportation sector. Ecology also noted that, "the effects of the COVID-19 pandemic are expected to significantly reduce emissions in 2020. However, these reductions are not expected to last as our state and nation recover from the pandemic."

3. **Program National Toxicology. NTP Monograph on the Systematic Review of Traffic-related Air Pollution and Hypertensive Disorders of Pregnancy. In: Services USDoHaH, ed. Vol MGRAPH-07. December 2019 ed. Research Triangle Park, North Carolina2019.**

This systematic review by the U.S. Department of Health and Human Services' National Toxicology Program (NTP) Office of Health Assessment and Translation (OHAT) evaluated whether exposure to traffic-related air pollution (TRAP) during pregnancy is associated with hypertensive disorders of pregnancy. TRAP is known to contribute significantly to ambient air pollution which has been "established as a risk factor for hypertension and cardiovascular disease in adults." The review "considered a range of traffic-related air pollutant measurements (e.g., fine particulate matter [PM2.5]) and traffic measures (e.g., proximity to major roads) in the literature search." Measures of hypertension included "changes in blood pressure during pregnancy, gestational hypertension, preeclampsia, eclampsia, or hemolysis, elevated liver enzyme levels, and low platelet count (HELLP) syndrome." Eighteen relevant epidemiological studies and one relevent animal study met the objective and inclusion criteria. Among relevant human studies, "evidence for traffic-related $PM_{2.5}$ and NO_2 present a consistent pattern of findings that exposure to these pollutants is associated with the development of hypertensive disorders of pregnancy." Authors found "a similar pattern of findings, but a smaller effect size, for bodies of evidence that residing in high-traffic density regions or in close proximity to major roads are associated with developing hypertensive disorders during pregnancy." Furthermore, "in addition to consistency

across bodies of evidence, mechanistic data evaluating single pollutants indicate that the individual $PM_{2.5}$ and NO_2 exposures can act independently to affect different pathways (e.g., vascular inflammation and oxidative stress) that lead to increased blood pressure." Overall, studies "demonstrate a moderate level of evidence that exposure to TRAP is associated iwth the development of hypertensive disorders of pregnancy and support a conclusion of presumed to be a hazard to pregnant women." Moreover, as maternal blood pressure status and hypertension during pregnancy can affect fetal and infant health outcomes, "hypertensive disorders of pregnancy associated with TRAP exposure may have significant adverse health effects in the developing offspring."

4. **U.S. Environmental Protection Agency. Criteria Air Pollutants. 2021; Available at: https://www.epa.gov/criteria-air-pollutants. Accessed 17 March 2021, 2021.**
This U.S. EPA webpage provides an overview of six common air pollutants known as "criteria air pollutants." The Clean Air Act requires EPA set National Ambient Air Quality Standards for these pollutants that harm health and the environment. Criteria pollutants include ground-level ozone, particulate matter, carbon monoxide, lead, sulfur dioxide, and nitrogen dioxide.

5. **Greenhouse gas emissions reductions—Reporting requirements., RCW 70A.45.020 (2020).**
This Washington state statute sets limits on anthropogenic emissions of GHG to achieve emission reductions for the state.

6. **Commerce Washington State Department of. CETA: A Brief Overview.**
This Department of Commerce document provides a high-level overview of the Clean Energy Transformation Act (CETA) (E2SSB 5116) passed in 2019. The law commits Washington to an electricity supply free of greenhouse gas emissions by 2045.

7. **Administration U.S. Energy Information. Washington State Energy Profile. 2021.**
According to the U.S. Energy Information Administration, "Washington benefits from access to abundant low-cost energy, and its significant renewable energy resources, especially hydroelectric power, are major contributors to the state's economy." The transportation sector accounts for about 33% of end-use energy consumption in the state; the industrial sector accounts for more than 25%; the commercial sector account for nearly 20%; and the residential sector accounts for nearly 25%. Washington consumes twice as much energy as it produces. Hydroelectric power generally accounts for more than two-thirds of the state's electricity generation. In 2019, other sources of electricity generated in Washington included natural gas (15%), nuclear power (8%), renewable resources other than hydroelectric power (8%), and coal (<7%). "In 2019, Washington produced about 10% of the total renewable-sourced utility-scale electricity nationwide [90% hydroelectric]." Annually, wind power accounts for 6% or more of the state's net generation. While the state does not have crude oil production, it is a major crude oil refining center (5 refineries capable of processing 650,000 barrels of crude oil per calendar day). The transportation sector accounts for roughly 80% of the petroleum consumed in the state. The industrial sector is the 2nd largest petroleum consumer in the state (16%). Washington has no natural gas reserves or production, and relies on production in Canada (30% directly and nearly 70% from Canada by way of Idaho). Roughly two-thirds of the natural gas that enters the state is transported to Oregon and California. More than one-third of households rely on natural

gas for heating. The last coal-fired unit in the state will be retired in 2025. Several tribal lands in Washington are located in areas with substantial renewable energy resources (e.g., biomass, wind, hydroelectric, solar).

8. **Larsen J., Mohan S., Marsters P., et al. Energy and Environmental Implications of a Carbon Tax in the United States. Rhodium Group for Columbia University, School of International and Public Affairs, Center on Global Energy Policy;2018.**

This report, prepared by the Rhodium Group for Columbia University's School of International and Public Affairs, Center on Global Energy Policy, evaluated the impact of a national carbon tax on carbon emissions in the U.S. The report, "provides projections of the U.S. energy system and emissions implications of carbon taxes and associated policy choices" through national modeling. They evaluated how responsive different energy sectors are to a carbon tax and how different tax rates impact energy prices, production, and consumption. They explained that, "putting a price on carbon internalizes the societal costs caused by consumption of fossil fuels and other activities that emit GHGs. The concept sits firmly in the tradition of Pigouvian taxation, which as been applied to address other 'externalities.'" They modeled three different tax scenarios: 1) $14/ton of carbon dioxide emissions with 3% annual increase; 2) $50/ton with 2% annual increase; and 3) $73/ton with 1.5% annual increase. Overall, "the impact of a carbon tax on U.S. GHG emissions is dependent on both the level of the tax and the sector in which the emissions occur." They found that, "a carbon tax can drive substantial reductions in U.S. GHG emissions in the near and medium term. In our analysis, an economy-wide carbon tax set at $50/ton in 2020 and rising at a real rate of 2 percent achieves emission reductions of 39 to 47 percent below 2005 levels by 2030." While declines occurred in all sectors, the authors found that the electrical sector is the most responsive to a carbon tax and had the largest decrease in emissions. In the transportation sector, "a carbon tax increases the retail price of gasoline, diesel, and jet fuel, as well as natural gas and propane, in proportion to their carbon intensity. As the carbon tax is passed through to consumers, the overall cost of mobility increases." They found that a $50/ton tax decreased carbon emissions by approximately 200 million metric tons from 2015 levels. Additionally, "the transportation sector appears not to be very responsive to different tax rates" and reductions appeared to be a 1-3% reduction from current policies by 2030. The "short-term responsiveness of transportation emissions to a carbon tax is driven primarily through reductions in driving, rather than fuel substitution. In addition, history suggests driving demand is relatively price inelastic." The authors also explain that, "sectors with high capital costs relative to operating costs are less likely to be responsive to a carbon tax because the tax primarily affects operating costs…For that reason, a carbon tax does more to shift generation from coal to gas in the power sector, for example, than from internal combustion engine vehicles to electric vehicles in the transportation sector." The three tax scenarios would increase the average price of a gallon of gasoline by $0.12 to $0.64, which is "still well within the price range over the past five years. With these cost increases within historical variability, it's unsurprising to see modest reductions in emissions in response to a carbon tax." The authors note that a much higher tax rate (i.e. above the $73/ton scenario) would be necessary to see larger changes in transportation emissions. The authors also found that carbon taxes results in large declines in coal production and large increases in renewable energy production. However, the authors cautioned that, "beyond 2030, a carbon tax at the levels considered in this analysis may not be sufficient for achieving emissions targets. In the long-term, the range of tax rates considered in this analysis will likely be insufficient to reduce U.S. GHG emissions 80 percent below 2005 levels by 2050, absent complementary GHG policies, significant improvements in technologies that can act as direct substitutes for fossil fuels, and/or significantly faster electrification of the transportation, buildings, and industrial sectors than we considered in this analysis." Lastly, the authors found that a carbon tax also results in a small reduction in GHG emissions from other sources (e.g. agriculture, waste). The report also outlines potential changes to energy sources/markets and anticipated tax revenues.

9. **Management Washington State Office of Financial. Washington State Economic Modeling of Greenhouse Gas Emission Reductions.2015.**
In 2015, Washington State Office of Financial Management, Forecasting and Research Division modeled the economic impacts of a carbon tax in Washington. The model was based on recommendations from the Carbon Emissions Reduction Task Force (created by Executive Order 14-04 in April 2014) and proposed legislation during the 2015 Legislative Session to implement a carbon pollution market program from emissions. Their model showed "negligible impacts on income, employment, and output, with most measures showing slight improvement over time. This is mostly due to reinvestment of the [revenue] and the relatively small size of the program compared to the overall state economy." Their report assumed that a carbon tax would be passed on to consumers, resulting in higher fuel and energy prices for consumers. However, "the estimated gas price changes [($0.12 to $0.41 increase per gallon)] are smaller than historic price volatility, and the potential increases in fuel costs do not affect the overall net positive effect of the program on the statewide economy." Additionally, the model shows that the increased price of carbon, higher energy costs, and use of revenue results in more jobs gained than lost over time. While the revenue investment scenario used in the model is different than the proposed provisions of HB 1513, OFM found that "the simulation results imply that implementing a carbon price policy with revenue recycling will increase employment slightly above the natural job creation that would otherwise be expected." They noted that jobs are especially likely to increase in sectors where revenues are invested. However, of "94 occupations…95 percent realize job gains (however small) above baseline and only about 5 percent lose jobs relative to baseline during the 20-year scenario period." The model also suggests that the majority of job sectors would also experience increases in wages and salaries "due to the simulative effect of the carbon charge as funds move across sectors." OFM noted that national data suggest that "low-income households spending is relative 'inelastic' relative to gasoline prices, meaning these households continue to spend their income on fuel despite increases in gas prices. Looking at electricity, the consumption patterns suggest that the lowest-income households spend about 4.3 percent of their total expenditures on electricity compared to just 3.3 percent for middle-income households." Carbon-based fuels make up approximately 11% of household expenditures in households with low-incomes and changing the price of carbon-based energy sources would likely increase the cost of expenditures. For example, under the policy scenario modeled by OFM (which is different than the proposed provisions of HB 1513), household expenditures on carbon-based fuels in households with the lowest-incomes increased by $144 per year.

10. **Barron A. R., Fawcett A. A., Hafstead M. A. C., et al. Policy Insights from the Emf 32 Study on U.S. Carbon Tax Scenarios. *Clim Chang Econ (Singap)*. 2018;9(1).**
This study by the Stanford Energy Modeling Forum exercise 32 (EMF 32) examines potential implications of an economy-wide carbon pricing policy in the U.S. by two key parameters: the trajectory of the carbon price and the use of the revenue. It used "11 models to assess emissions,

energy, and economic outcomes from a range of economy-wide carbon price policies to reduce carbon dioxide (CO_2) emissions in the [U.S.]." Authors note that by using various models with different areas of relative strength, multi-model analyses can provide useful information around complex economic impacts. Results across all models showed "carbon prices lead to significant reductions in CO_2 emissions and conventional pollutants." Specifically, a carbon tax of $25/ton in 2020 "that rises at 1% per year reduces CO_2 emissions roughly 16–28% below 2005 CO_2 emissions levels by 2020 and 17–38% below 2005 levels by 2030. A carbon [tax] of $50[/ton] in 2020 rising at 5% per year reduces emissions 21–35% below 2005 levels by 2020 and 26–47% below 2005 levels by 2030." While, "a $25/ton tax rising at 5% only reduces emissions 19% more by 2030 than a $25/ton tax rising at 1% [...] The escalation rate matters more over longer time scales." As the analysis focused on the U.S. as a whole, the vast majority of projected reductions occurred in the electricity sector, which relies more heavily on fossil fuels like coal in other parts of the country (e.g., Northeast). Authors also noted, the electricity sector is more responsive in the short term as transitioning these facilities to achieve emissions reductions is easier than transitioning other sectors like residential housing an transportation, "which both feature a very large stock of houses/cares that can be slow to turn over." Specific to fuels and energy consumption, "all of the price trajectories cause significant shifts in fossil fuel demand, with coal shifting the most significantly." Models show, "a carbon tax has a mixed impact on natural gas demand in 2020 in all of the models, with natural gas use ranging from a decline of 31% to an increase of 24% above baseline levels." Finally, "oil use in [...] sees the smallest changes of the three major fossil fuels," which authors largely contributed to the historical calibration of responsiveness of the U.S. economy to changes in oil price. Results also show that overall "emissions reductions do not significantly depend on the rebate or tax cut used to return revenues to the economy. Expected economic costs, as modeled by either GDP or welfare, are modest, but vary across models." While authors discuss how costs are "offset by benefits from avoided climate damages and health benefits from reductions in conventional air pollution at a high level," the models "do not fully account for their ripple effects through the economy, compounding over time, the way they do other outcomes (i.e., costs)" as these economic modeling approaches are still developing. Carbon prices at $25/ton or even lower levels cause significant shifts away from coal as an energy source with responses of other energy sources highly dependent upon technology cost assumptions. "Beyond 2030, [authors] conclude that model uncertainties are too large to make quantitative results useful for near-term policy design."

11. **Woollacott J. The Economic Costs and Co-Benefits of Carbon Taxation: A General Equilibrium Assessment*. *Climate Change Economics.* 2018;9(1):1840006.**
In this article Woollacott examines the "general equilibrium costs of climate policies that levy taxes on carbon dioxide (CO_2) emissions in the [U.S.] and return the revenue in the form of lump-sum rebates and tax relief over the years 2020 to 2040". Like other analyses, the largest percent changes occur in the electricity sector (coal: -60.2%; oil: -32.9%; gas: -16.4%) with smaller changes in the transportation sector (highway vehicles: -3.3%; lightduty highway vehicles: -3.0%). The author approximates the value of co-benefits to these policies that arise from [accompanying] reductions in GHG emissions using the CO-Benefits Risk Assessment Model (COBRA). The COBRA model specifically quantifies "the health benefits of reduced PM abated either directly or via its precursors, NOx and SOx." The author notes that "co-benefits can be strongly heterogeneous," meaning averages (national or state-level) could mask significant variation in the benefits enjoyed by households across geography, income, and health." This

heterogeniety depends on variations in local atmosphere, demographics, and health. Overall, "there is significant heterogeneity in costs and co-benefits from climate policies across space and income." Results indicate policy costs are generally less than 0.5% (range from a few tens of dollars to several hundred per household, dependent on income quintile). Meanwhile, policy co-benefit values vary across regions (roughly $150-1,250 per household). Within the revenue neutral frame (sums returned via lump-sums or tax credits), Woollacott identified "a marginal welfare cost of $58/ton CO_2 and a marginal co-benefit of $31/ton CO_2 at a national level across all households. They conclude, "Further research into how exposure, vulnerability, medical care efficacy, and willingness to pay for improved mortality and morbidity vary by income could reveal heterogeneity in co-benefits that alters our understanding of optimal climate policy design."

12. **Liu Y., Hunter-Rinderle R., Luo C., et al. How Climate-Related Policy Affects the Economics of Electricity Generation. *Current Sustainable/Renewable Energy Reports.* 2021;8:17-30.**
Liu et. al. conducted a review of literature to determine how effective various policies are at reducing greenhouse gas (GHG) emissions in the electricity sector. They also present a case study modeling the evaluating the ability of three different policy mechanisms (i.e. carbon taxes, renewable portfolio standard, and production tax credit for renewable energy) to reduce carbon emissions in the electricity sector. Overall, they found "that market-based policies (e.g., carbon taxes) achieve decarbonization targets most efficiently." Based on their model, they found that a carbon tax of $12 per megawatt hour (MWh) for coal and $6/MWh for natural gas would reduce carbon emissions by 80% relative to 2010 levels by 2040. The authors summarized that, "a carbon tax is most efficient, which follows from basic economic principles that internalizing the cost of an externality can align private and societal incentives efficiently." For example, they found that using a production tax credit is 8 times as costly as using a carbon tax to reduce emissions.

13. **Carbon Tax Assessment Model. 2021; Available at: https://www.commerce.wa.gov/growing-the-economy/energy/washington-state-energy-office/carbon-tax/. Accessed 3/15/2021.**
The Washington State Department of Commerce provides information abotu the Carbon Tax Assessment Model, including links to the current open source model.

14. **Goodkind A. L., Tessum C. W., Coggins J. S., et al. Fine-scale damage estimates of particulate matter air pollution reveal opportunities for location-specific mitigation of emissions. *Proc Natl Acad Sci U S A.* 2019;116(18):8775-8780.**
Goodkind et al. provide a detailed examination of the health and economic impacts of fine particulate matter ($PM_{2.5}$) pollution in the U.S. by linking emission sources with resulting pollution concentrations. Authors "estimate that anthropogenic $PM_{2.5}$ was responsible for 107,000 premature deaths in 2011, at a cost to society of $886 billion. Of these deaths, 57% were associated with pollution caused by energy consumption [e.g., transportation (28%) and electricity generation (14%)]; another 15% with pollution caused by agricultural activities." Evidence indicates "a small fraction of emissions, concentrated in or near densely populated areas, plays an outsized role in damaging human health with the most damaging 10% of total emissions accounting for 40% of total damages." Depending on the pollutant authors found that

"33% of damages occur within 8 km of emission sources, but 25% occur more than 256 km away, emphasizing the importance of tracking both local and long-range impacts."

15. **Khreis H., Kelly C., Tate J., et al. Exposure to traffic-related air pollution and risk of development of childhood asthma: A systematic review and meta-analysis. *Environ Int.* 2017;100:1-31.**
Khreis et al. conducted a systematic review and meta-analyses to analyze the association between TRAP and asthma development in childhood. Authors systematically reviewed epidemiological studies published through September 8, 2016 which examined the association between children's exposure to TRAP metrics and their risk of 'asthma' incidence or lifetime prevalence, from birth to age 18 years. Authors identified 41 studies that met eligibility criteria (7 in the USA; 20 in Europe; 4 in Canada; 10 in Asia). "There was notable variability in asthma definitions, TRAP exposure assessment methods and confounder adjustment." Results of the meta-analyses showed "the overall random-effects risk estimates (95% CI) were 1.08 (1.03, 1.14) per 0.5x10(-5)m(-1) black carbon (BC), 1.05 (1.02, 1.07) per 4mug/m(3) nitrogen dioxide (NO2), 1.48 (0.89, 2.45) per 30mug/m(3) nitrogen oxides (NOx), 1.03 (1.01, 1.05) per 1mug/m(3) Particulate Matter <2.5mum in diameter ($PM_{2.5}$), and 1.05 (1.02, 1.08) per 2mug/m(3) Particulate Matter <10mum in diameter (PM_{10}). Sensitivity analyses supported these findings." Authors concluded "the overall risk estimates from the meta-analyses showed statistically significant associations for BC, NO_2, $PM_{2.5}$, PM_{10} exposures and risk of asthma development." These findings support the hypothesis that childhood exposure to TRAP contributes to their development of asthma.

16. **Perera F., Ashrafi A., Kinney P., et al. Towards a fuller assessment of benefits to children's health of reducing air pollution and mitigating climate change due to fossil fuel combustion. *Environ Res.* 2019;172:55-72.**
Perera et al. conducted a systematic review of peer-reviewed literature to identify concentration-response (C-R) functions for six outcomes related to fossil fuel combustion by-products, including particulate matter ($PM_{2.5}$ and PM_{10}), polycyclic aromatic hydrocarbons (PAH), and nitrogen dioxide (NO_2). Sixty-three articles published between January 1, 2000 and April 30, 2018 met inclusion criteria. Available evidence shows causal or likely relationships between pollutants and preterm birth (PTB), low birthweight (LBW), autism, and the development of childhood asthma. For example, multiple studies and meta-analyses have documented an association between exposure to $PM_{2.5}$ and PTB, LBW, Autism Spectrum Disorder (ASD), and asthma incidence. A meta-analysis by Bowatte et al. including "four birth cohort studies found that increased longitudinal childhood exposure to PM2.5 was significantly related to the incidence of asthma (OR 1.14, 95% CI: 1.00, 1.30) per 2 µg/ m3."

17. **Madureira M., Brancher E.A., Costa C., et al. Cardio-respiratory health effects of exposure to traffic-related air pollutants while exercising outdoors: A systematic review. *Environmental Research.* 2019;178(108647).**
Madureira et al. conducted a systematic review to "investigate the effects of TRAP exposure, specifically particulate matter and nitrogen dioxide (NO_2), during outdoor exercise on cardio-respiratory health effects." Thirteen peer-reviewed studies published from 2000 to 2018 were included (10 European studies and 3 USA studies). Study results suggested that "exercising in an environment with high TRAP exposure increases markers of respiratory and systemic

inflammation, as well as, impairs the vascular function and increases artery pressure, when compared with an environment with low-TRAP exposure." Evidence shows that those with asthma and COPD are particularly sensitive to air pollution with moderate physical exercise (walking) in ambient exposure adversely affecting forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC). The same trend held true for children. Additionally, evidence indicates "smaller particles appear to have the most severe health consequences compared with the larger coarse particles and NO_2." There is a need for more studies focused on the relationship between air pollution, physical exercise and health, as large societal benefits can be obtained from healthy environments that can promote outdoor physical exercise.

18. **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."

19. **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."

20. **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.

21. **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 [O_3: RR(95% CI), 1.009 (1.006, 1.011); I^2 = 87.8%, population-attributable fraction (PAF) (95%CI): 0.8 (0.6, 1.1); CO: RR(95%CI), 1.045 (1.029, 1.061); I^2 = 85.7%, PAF (95%CI): 4.3 (2.8, 5.7); NO_2: RR(95%CI), 1.018 (1.014, 1.022); I2 = 87.6%, PAF (95%CI): 1.8 (1.4, 2.2); SO_2: RR (95%CI), 1.011 (1.007, 1.015); I^2 = 77.1%, PAF (95%CI): 1.1 (0.7, 1.5); PM_{10}: RR(95%CI), 1.010 (1.008, 1.013); I^2 = 69.1%, PAF (95%CI): 1.1 (0.8, 1.3); $PM_{2.5}$: RR(95%CI), 1.023 (1.015, 1.031); I^2 = 82.8%, PAF (95%CI): 2.3 (1.5, 3.1)]." 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."

22. **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.

23. **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.

24. **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."

25. **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.

26. **Caron J., Cole J., Goettle R., et al. Distributional Implications of a National Co2 Tax in the U.S. Across Income Classes and Regions: A Multi-Model Overview. *Clim Chang Econ (Singap).* 2018;9(1).**
Caron et al. conducted modeling assessments to determine the potential impacts of various carbon pricing policies on household income and household welfare in the U.S. The authors

noted that, "climate change mitigation policies that aim at putting a price on carbon emissions can have differing effects on household welfare, depending on income level and region. Households will be affected through changes in the price of carbon-intensive goods, as well as changes in consumption behavior, productive technology, and incomes." Overall, prior research has shown that "carbon pricing affects low-income households proportionately more than high-income households (i.e., is regressive), given the relatively more emissions-intense consumption bundles of lower-income groups." However, "while the literature has not seemingly reached a consensus regarding the progressivity or regressively of carbon taxation itself, there is broad agreement that distributional impacts are ultimately largely driven by what is done with the collected revenue." The authors model carbon taxes at $25 or $50 on fossil fuel combustion and increasing at 1% or 5% annually. They present findings for three revenue investment scenarios: 1) rebates to households; 2) capital income tax reduction; and 3) labor income tax reduction.

27. **Poelhekke S. How expensive should CO2 be? Fuel for the political debate on optimal climate policy. *Heliyon.* 2019;5(11):e02936.**
Poelhekke discusses available evidence on the social cost of carbon, policy tradeoffs, and considers global and unilateral policy options. Poelhekke advocates an international approach in which carbon taxes are negotiated as part of trade agreements to limit leakage (movement of fossil fuel emitting activities across borders) to other countries without a carbon tax. For example, "it would be globally inefficient to raise a CO2 tax in the United States only, although it may have local benefits by lowering related air pollution." The author concludes a carbon tax of "$77 per metric ton of carbon is defensible if we give 95% weight to damage occurring two generations (or 50 years) from now but higher if we want to further reduce the risk of catastrophic damage."

28. **Management Washington State Office of Financial. Multiple Agency Fiscal Note Summary, HB 1513 (Carbon emissions).2021.**
The Fiscal Note for HB 1513 includes estimated costs and revenues from the Washington State Department of Revenue.

29. **Macaluso N. , Tuladhar S. , Woollacott J. , et al. The Impact of Carbon Taxation and Revenue Recycling on U.S. Industries*. *Clim Chang Econ (Singap).* 2018;9(1).**
Macaluso et al. conducted a detailed, cross-model analysis and discuss the implications of carbon tax scenarios on changes in sectoral output, energy production and consumption and the competitiveness of the U.S. economy. Authors noted that economists and scholars generally agree that "a properly implemented carbon tax is the most economically efficient way to reduce a country's carbon emissions." Specifically, a properly implemented carbon tax would "help consumers and firms make more economically efficient decisions regarding their use of fossil fuels and leads consumers and firms to shift toward using cleaner fuels including renewable energy sources."

30. **U.S. Environmental Protection Agency Sources of Greenhouse Gas Emissions. 2020; Available at: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#:~:text=In%202018%2C%20greenhouse%20gas%20emissions,of%20U.S.%20greenhouse%20gas%20emissions. Accessed 16 March 2021, 2021.**

This U.S. EPA webpage provides an overview of greenhouse gas emissions in the U.S. and the sectors that represent the largest sources. The largest contributor to GHG emissions is the transportation sector (28%). Over 90% of the fuel used for transportation in the U.S. is petroleum based (gasoline and diesel). The second largest share of GHG are from generating electricity (27%). Nationally, approximately 63% of electricity in the U.S. comes from burning fossil fuels, mostly coal and natural gas. Additionally, industry (22%), commercial and residential (12%), and agriculture (10%) contributed to GHG emissions.

31. **Arenschield L. Want to cut emissions that cause climate change? Tax carbon. *Ohio State News*2021.**
This news article from Ohio State University summarized findings from Liu et. al. 2021 and provided an interview with Ramteen Sioshansi, one of the study authors. Sioshansi stated that, "if the goal is reducing carbon dioxide in the atmosphere, what we found [in our case study] is that putting a price on carbon and then letting suppliers and consumers make their production and consumption choices accordingly is much more effective than other policies [at reducing carbon dioxide emissions]." Overall, the study found that "other policies, including mandates that a certain amount of energy in a region's energy portfolio come from renewable sources…were either mor expensive or not as effective as carbon taxes at reducing the amount of carbon dioxide in the air. Subsides for renewable energy sources were…also not as effective at reducing carbon dioxide, the study found."

32. **Wu X., Nethery R.C., Sabath M.B., et al. Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. 2021.**
Wu et al. conducted a nationwide, cross-sectional study to determine whether long-term exposure to poor air quality increased risk of death from COVID-19 in the U.S. They stated, "many of the pre-existing conditions [e.g. cardiovascular and lung disease] that increase the risk of death in those with COVID-19 are the same diseases that are affected by long-term exposure to air pollution." They collected COVID-19 mortality data from 3,000 counties in the U.S. (representing 98% of the U.S. population) through April 20, 2020. They compared this data to county-level long term average levels of fine particulate matter (PM2.5) and controlled for a number of factors (population size, time since the beginning of the outbreak, socioeconomic status, etc.). Results showed that an increase of 1 ug/m3 in PM2.5 is statistically significantly associated with an 8% increase in the COVID-19 death rate.

33. **Report to the Washington State Governor and Legislature Environmental Justice Task Force Recommendations for Prioritizing EJ in Washington State Government.Tumwater, WA: Environmental Justice Task Force;2020.**
The Environmental Justice Task Force (EJTF) was created through a proviso in the state's 2019-2021 operating budget (Engrossed Substitute House Bill 1109, section 221, subsection 48). EJTF's final report to the Governor and State Legislature includes recommendations for measurable goals, model policies, use of the Washington Environmental Health Disparities map, and community engagement. The EJTF developed a statewide definition of Environmental Justice for use by state agencies. It also includes a discussion of the Department of Health's (DOH) Washington Tracking Network (WTN) Environmental Health Disparities map and presents data illustrating the disproportionate burdens faced by Black, Indigenous, and People of Color communities and people living in poverty. Limitations of the analysis presented are

outlined here. “One of the measures is People of Color (POC), a measure of the percent of a census tract’s population that is non-white.” It accounts for 3.6% of the weight of the ranking. A preferred method would be to remove the POC measure and recalculate EHD rankings before running the analysis. However, due to staff activations to the COVID-19 response this information is not currently available. “However, given the clear trends seen in the data and the relatively small weight of the POC measure in the overall ranking, [WTN staff] do not expect meaningful changes in the outcome of the analysis.” The same limitation applies to the association between poverty and environmental health disparities.

34. **Relating to reducing environmental and health disparities and improving the health of all Washington state residents by implementing the recommendations of the environmental justice task force. Senate Ways & Means (originally sponsored by Senators Saldaña L, Carlyle, Das, Frockt, Hasegawa, Hunt, Keiser, Kuderer, Liias, Nobles, Pedersen, Rolfes, Stanford, and Wilson, C.), trans. 67th Legislature Regular Session ed2021.**
E2SSB 5141 intends to implement recommendations of the Environmental Justic Task Force established in section 221(48), Chapter 415, Laws of 2019 entitled "Report to the Washington state governor and legislature, Environmental Justice Task Force: Recommendations for Prioritizing EJ in Washington State Government (October 2020). This legislative proposal presents a definition of environmental justice for use by state agencies.

35. **Washington Tracking Network. Environmental Health Disparities Map. Available at: https://fortress.wa.gov/doh/wtn/WTNIBL/. Accessed March, 2021.**
The Washington State Department of Health (DOH) chose to use the Environmental Health Disparities (EHD) map to designate highly impacted communities under the Clean Energy Transformation Act's cumulative impact analysis. "The EHD map ranks the risks communities face from environmental burdens including fossil fuel pollution and vulnerability to climate change impacts that contribute to health inequities. It is a well-known vulnerability index for environmental health disparities, and is being used by other state processes to guide funding to reduce environmental health disparities." The EHD map rankings are based on a conceptual formula of Risk = Threat x Vulnerability. Therefore, "threat is comprised of both environmental effects and exposures, and vulnerability is comprised of socioeconomic factors and sensitive populations."

36. **State and Local Taxes. 2020; Available at: https://www.treasury.gov/resource-center/faqs/Taxes/Pages/state-local.aspx. Accessed February 2020.**
The U.S. Department of Treasury outlines and defines state and local taxes.

37. **Policy Institute of Taxation and Economic. Who Pays? A distributional anlysis of the tax systems in all 50 states.2018.**
This 2018 report from the Institute of Taxation and Economic Policy analyzes each states tax system and its impact on equity. They found that Washingtonians with incomes in the lowest 20% (less than $24,000 annually) pay 13.3% of their family income in sales and excise taxes compared to those with incomes in the top 20% (more than $116,300 annually) that pay less than 4.7% of their family income. The Institute also calculates a Tax Inequality Index “which measures the impact of each state’s tax system on income inequality.” According to their

measures, "Washington has the most unfair state and local tax system in the country. Incomes are more unequal in Washington after state and local taxes are collected than before." One reason for this inequity is due to Washington's comparatively high combined state and local sales tax rate.

38. **Kurman-Faber J., Tempest K. , Wincele R. . Building Back Better Investing in a Resilient Recovery for Washington State. Low Carbon Prosperity Institute and Climate Xchange 2020.**
This report is a collaboration by the Low Carbon Prosperity Institute (LCPI) and Climate Xchange (CXC). LCPI is a project of the Washington Business Alliance's PLAN Washington to guide the state to achieve greenhouse gas reduction and build a thriving shared economy. CXC is a nonpartisan, nonprofit organization with a mission to advance the transition towards a low-carbon economy. This report analyzes the potential jobs and community health benefits created by a sample portfolio of investments in Washington. Authors use an economic input-output model (IMPLAN) to map 18 proposed projects' (i.e., Resilient Recovery Portfolio) flow of economic activity between 546 sectors and institutions in Washington to measure resulting employment, output, labor income, and fiscal impacts. They then used a cost-benefit model to compare the health and climate benefits of each investment to upfront costs. Of the 18 projects, "14 [had] sufficient data to derive metric tons of CO2 equivalent (mtCO2e) reduced per million dollars invested, and 10 [had] sufficient data to derive statewide health benefits, in dollar terms, per million dollars invested." Modeling results show "investing in clean transportation, forest conservation and ecosystem restoration, clean energy, water and energy efficiency, low carbon agriculture, and sustainable industry" supports 10.1 full-time-equivalent (FTE) jobs per million dollars invested, compared to 4.3 FTE jobs per million dollars invested in the state's 10 largest industries. Investments also "support labor-intensive productive business in the state with $0.64 of each dollar invested supporting employee compensation compared to $0.40 in the state's ten largest industries" and "provide robust broader economic value, both in terms of gross state product ($0.94 for every dollar spent versus $0.50 for the state's largest industries), as well as overall productive output ($1.75 for every dollar invested versus $1.59 for the state's largest industries [or $1.73 if invested in the broad economy])." Evidence indicates that investment in the Resilient Recovery Portfolio "results in $51,400 in average wages across all jobs supported, which is slightly above the statewide average of $50,200, although lower than the top ten industry average of $67,900 (as of 2018)." Additionally, results indicate that for every million dollars invested in these programs an estimated "$2.4 million in health and climate benefits, including $1.6 million in clean air benefits." Authors used the U.S. Interagency Working Group's social cost of carbon estimate (adjusted to 2020 dollars) in which avoided emissions have a societal benefit of $52 per metric ton of carbon dioxide. While authors chose to use this conservative estimate, they noted that "other studies project the social cost of carbon to be as high as $417 per metric ton of carbon dioxide equivalent." Use of this would result in climate benefits 8 times higher than reported. As the model does not include additional co-benefits beyond cleaner air (e.g., reduced traffic fatalities, increased active transportation), authors also expect total co-benefit returns (in dollar value) to be higher than this analysis indicates. Authors recommend further consideration and analysis of how investments may impact social justice, the distributional economic and health outcomes of selected recovery measures, job quality, etc.