Preliminary Cost-Benefit Analysis & Significant Legislative Rule Analysis

Sections 296-820-805 WAC through 296-820-860 WAC and 296-307-09805 WAC through 296-307-09860, Wildfire Smoke

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Acronyms

APA	Washington State's Administrative Procedure Act
APF	Assigned Protection Factor
APP	Accident Prevention Program
AQI	Air Quality Index
COPD	Chronic Obstructive Pulmonary Disease
DOSH	Division of Occupational Safety and Health, Labor & Industries
EPA	U.S. Environmental Protection Agency
IHD	Ischemic Heart Disease
L&I	Washington State Department of Labor & Industries
NAAQS	National Ambient Air Quality Standards
OSHA	U.S. Occupational Safety and Health Administration
PM	Particulate Matter
$PM_{2.5}$	Particulate matter that is 2.5 micrometers or less in diameter
PPE	Personal Protective Equipment
POC	Parameter Occurrence Code
RCW	Revised Code of Washington
RPP	Respiratory Protection Program
RR	Relative Risk
WAC	Washington Administrative Code
WISHA	Washington Industrial Safety & Health Act
WFS	Wildfire Smoke
WSRP	Wildfire Smoke Response Plan
$\mu g/m^3$	Micrograms per cubic meter

Chapter 1: Background

1.1 Requirements of the Administatrative Procedures Act

The Administrative Procedure Act (APA; Chapter 34.05 RCW) requires that, before adopting a significant legislative rule, the Department of Labor & Industries (L&I) must analyze the probable costs and benefits of the rule, and determine that the "benefits are greater than its probable costs, taking into account both the qualitative and quantitative benefits and costs." [RCW 34.05.328(1)(d)] . Under certain circumstances, a rule or rule component is exempt from this requirement. These exemption criteria are listed in RCW 34.05.328(5)(b) including:

- Emergency rules adopted under RCW 34.05.350;
- Rules relating only to internal governmental operations that are not subject to violation by a nongovernment party;
- Rules adopting or incorporating by reference without material change federal statutes or regulations, Washington state statutes, rules of other Washington state agencies, shoreline master programs other than those programs governing shorelines of statewide significance, or, as referenced by Washington state law, national consensus codes that generally establish industry standards, if the material adopted or incorporated regulates the same subject matter and conduct as the adopting or incorporating rule;
- Rules that only correct typographical errors, make address or name changes, or clarify language of a rule without changing its effect;
- Rules the content of which is explicitly and specifically dictated by statute;
- Rules that set or adjust fees under the authority of RCW 19.02.075 or that set or adjust fees or rates pursuant to legislative standards, including fees set or adjusted under the authority of RCW 19.80.045.

This cost-benefit analysis has been prepared to comply with the APA for the proposed new rule under Sections 296-820-805 WAC through 296-820-860 WAC and 296-307-09805 WAC through 296-307-09860, Wildfire Smoke that do not fall under the exemptions described above.

1.2 Legal Authority

The Washington State Constitution mandates that "[t]he legislature shall pass laws for the protection of persons working in mines, factories, and other employments dangerous to life or deleterious to health." In enacting c. 49.17 RCW, Washington Industrial Safety and Health Act (WISHA), the Washington Legislature found "that personal injuries and illnesses arising out of conditions of employment impose a substantial burden upon employers and employees in terms of lost production, wage loss, medical expenses, and payment of benefits under the industrial insurance act. Therefore, in the public interest for welfare of the people of the state of Washington and in order to assure, insofar as may be reasonably possible, safe and healthful working conditions for every man and woman working in the state of Washington, the legislature…in keeping with the mandates of Article II, section 35 of the state Constitution, declares its purpose by the provisions of this chapter to create, maintain, continue, and enhance the industrial safety and health program of the state…"

WISHA mandates that the Director of L&I shall "[p]rovide for the promulgation of health and safety standards and the control of conditions in all workplaces concerning…harmful physical agents which shall set a standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity."

In Rios v. Dept. of L&I[1], the Washington Supreme Court concluded that L&I must consider rulemaking for recognized workplace hazards.

1.3 Wildfire Smoke: A Serious Occupational Health Hazard

1.3.1 Why is wildfire smoke a human health hazard?

Wildfire smoke is a complex mixture of gases, water vapor, and particles created from the burning of materials including vegetation. Air pollution from wildfire smoke can spread a long distance from its source.[2] When inhaled, wildfire smoke can cause health problems. Outdoor workers, along with pregnant women, older adults, individuals with existing cardiovascular and respiratory disease, and individuals living in areas of lower socioeconomic status, are especially at risk for wildfire smoke-related health effects.

Particle pollution, particularly fine particles sized 2.5 microns (μm) in diameter or smaller (referred to as $PM_{2.5}$) composes approximately 90% of the total particulate mass in wildfire smoke and is a significant primary health concern (Vicente 2013, Grob 2013). $PM_{2.5}$ is a major component in ambient air pollution as well and has been studied globally for its impact on health. The U.S. Environmental Protection Agency (EPA) has provided systematic literature reviews of $PM_{2.5}$ exposure and its relation to adverse health outcomes since at least 2009. A full summary of the EPA's hierarchy that describes the causality between $PM_{2.5}$ exposure and health outcome is provided in Section 3.1. In summary, the EPA has classified the relationship to both short- and long-term $PM_{2.5}$ exposure *as likely to be causal* for respiratory effects; *causal* for cardiovascular effects; and *causal* for all cause (non-accidental) mortality. The relationship for long-term $PM_{2.5}$ exposure is *likely to be causal* for nervous system and *likely to be causal* for cancer (EPA 2022).

Finally, although potential differences in toxicity between ambient $PM_{2.5}$ compared to that generated from wildfires has been incompletely characterized, available animal toxicological and human epidemiologic evidence suggest worse outcomes from wildfire-associated $PM_{2.5}$ exposure. The adverse human health outcomes investigated in this evidence included respiratory and cardiovascular outcomes (e.g., hospitalization, morbidity) as well as all-cause mortality (Aguilera 2021, DeFlorio-Barker 2019, Doubleday 2020, Gan 2017, Jones 2020,Liu 2015, Liu 2021, Reid 2016, Wettstein 2018, Youssouf 2014).

1.3.2 Why a Wildfire Smoke Standard is Necessary

Prior to the issuance of the L&I Emergency Wildfire Smoke Rule in summer 2021, there

[1] *Rios v. Dep't of Lab. & Indus*., 145 Wn.2d 483, 491-92, 39 P.3d 961 (2002)
[2] NOAA: https://twitter.com/noaasatellites/status/1032311533668319232?lang=en.

were no regulations to address the hazard of wildfire smoke inhalation among outdoor workers in Washington State. While the Federal Occupational Safety and Health Administration (OSHA) provides resources to workers and employers regarding the hazard of wildfire smoke, no federal regulations exist to mandate protections.

That said, several Washington State regulations exist that address wildfire smoke generally, if not specifically, and apply to workers exposed to this hazard.

RCW 49.17.060 requires that "each employer…furnish to each of his or her employees a place of employment free from recognized hazards that are causing or likely to cause serious injury or death." Known as the "Safe Place" standard, this provision, which is also codified in WAC 296-800-11005 and 296-307-018, is construed to apply broadly to any hazard which may cause serious harm to employees. Wildfire smoke, under certain circumstances, could invoke safe place protections for employees.

Chapter 296-802 WAC addresses employee medical and exposure records, and applies to non-agricultural employers that make, maintain, contract for, or have access to records of employee exposures to toxic substance, which is interpreted to include wildfire smoke. This standard requires that employers maintain these records, inform employees of these records, and provide access to these records when requested. Chapter 296-802 WAC has been interpreted to not apply to freely available regulatory air monitoring data generated by the EPA or Washington State Department of Ecology.

Chapter 296-841 WAC regulates airborne contaminants in the workplace. As wildfire smoke is a complex mixture of airborne contaminants, including gases and particulates, WAC 296-841 would apply to exposures in the workplace. While the primary pollutant in wildfire smoke is fine particulate matter ($PM_{2.5}$), the specific chemical components of the particulate vary depending on several factors, including the fuel (wood, buildings, equipment, etc.) that is burned, the temperature of the burn, and atmospheric aging. (Balmes 2018) While regulatory thresholds may exist for each component, the changeable nature of wildfires and the resultant smoke render it impossible to conduct an actionable chemical analysis of the particulate component of wildfire smoke. No Washington State occupational regulatory threshold currently exists for either wildfire smoke or $PM_{2.5}$.

While a Washington occupational health standard does not exist for fine particulate matter ($PM_{2.5}$), L&I does have a regulatory threshold for the respirable fraction (median diameter of approximately 4 µm) of "particulates not otherwise regulated" as an 8-hour time weighted average (TWA_8) permissible exposure limit (PEL) of 5 mg/m^3 (5,000 $\mu g/m^3$), and a 15-minute short term exposure limit (STEL) of 10 mg/m^3. (WAC 296-841-20025) However, this regulatory threshold is designed to cover particulates that are unregulated elsewhere, including nuisance dusts, that when inhaled, "have little adverse effect on the lungs and do not produce significant organic disease or toxic effect." (WAC 296-841-300) Given the diverse array of adverse health effects caused by $PM_{2.5}$ exposure from wildfire smoke, this regulatory threshold is not appropriate to address the hazard caused by particulate pollution from wildfire smoke.

This absence of protection is underscored by the United States EPA noting that exposures to

$PM_{2.5}$ at 250 µg/m^3 are hazardous; with the current 8-hour PEL for respirable particulates at 5,000 µg/m^3 there is clearly inadequate protection for workers. Without a PEL or STEL, there is no requirement to reduce exposures to wildfire smoke by engineering, administrative, or other controls. A companion to the Airborne Contaminants standard, Chapter 296-842 WAC, Respirators, addresses the use of respirators in the workplace, including both voluntary and required use. This standard mandates that respirators be provided when they are required to protect the health of an employee, which has been interpreted to mean that a PEL has been exceeded (with the exception of biological hazards, which do not have PELs). Without a PEL for wildfire smoke or $PM_{2.5}$, the Respirators standard, Chapter 296-842 WAC, is not adequate to protect employees from hazardous levels of wildfire smoke.

Chapter 296-307 WAC, which applies to agricultural operations, mirrors the regulatory limitations in 296-842, Respirators, and 296-841, Airborne Contaminants, with regard to wildfire smoke exposures. While Chapter 296-305 WAC, Safety Standards for Firefighters addresses smoke exposures for firefighters actively fighting fires, it does not address exposures for those in proximity to the fire, but not actively fighting, such as those working at wildland fire camp, where exposures to particulate may be elevated, but controls unavailable.

This rulemaking was originally initiated in response to a petition for L&I to create rules to protect agricultural workers during wildfire smoke events on September 28, 2020, in response to the historic 2020 wildfires. L&I responded by accepting the petition and initiating formal rulemaking by filing a pre-proposal statement of inquiry (CR-101) on October 20, 2020.

As noted above, Washington State is among the states most affected by the increase in frequency and severity of wildfires. The State of California continues to battle with wildfires within its borders, which led the California's Occupational Safety and Health Standard's Board to adopt an emergency regulation to protect workers from wildfire smoke, on July 18, 2019.[3] California's regulation was in effect during the 2019 and 2020 wildfire seasons, and permanently effective as of February 1, 2021. California's permanent rule is enforced by the State of California Department of Industrial Relations Division of Occupational Safety and Health (CAL/OSHA) and applies to outdoor workers where the current Air Quality Index (AQI) for PM2.5 is 151 or greater.

California's rule contains the following general provisions:

- Employers must implement a system for communicating wildfire smoke hazards to their employees;
- At AQI 151, employers must provide employee training on the hazards of wildfire smoke and on the employer's response plan;
- At AQI 151, employers must employ engineering and administrative controls to reduce smoke exposures to the extent feasible;
- At AQI 151, employers must provide respirators for voluntary use; and
- At AQI 500, respirator use is required.

[3] California Code of Regulations, Title 8, Section 5141.1. Protection from Wildfire Smoke.

Oregon OSHA's State Plan, Oregon OSHA, has also adopted workplace wildfire smoke protectionsOn August 3, 2021, Oregon OSHA adopted temporary rules to protect employees from wildfire smoke[4]; a permanent rule was adopted on May 10, 2022[5]. Oregon OSHA's rule applies to outdoor workers above AQI 101 and contains the following general provisions:

- Above AQI 101: Assess and monitor the air quality, provide training to employees, implement a communication system, implement engineering and administrative controls to the extent feasible, and provide respirators for voluntary use;
- Above AQI 251: Use of respirators is required; however, a full respiratory protection program is not mandatory; and
- Above AQI 500: Use of respirators is required, with the benefit of a full respiratory protection program.

After receiving the petition for rulemaking, L&I conducted a series of stakeholder meetings and released an emergency rule on July 16, 2021, that was active through November 13, 2022. As L&I was in midst of responding to the COVID-19 pandemic, permanent rulemaking could not be completed by the 2022 wildfire smoke season and thus a second emergency rule was in effect from June 15, 2022, which was active through September 29, 2022. For more details on the history of Washington State Wildfire Smoke Rule, see below, Section 1.4.

As mentioned above, L&I has several occupational health standards that could potentially apply to wildfire smoke, but none are sufficient to address the extent of the hazard of wildfire smoke.

Washington State L&I recognizes that employers and employees need regulations that are clear, actionable, and protective. These proposed rules provide the following benefits:

- The proposed rules address the current ambiguity regarding allowable exposures to wildfire smoke by specifying threshold-based interventions for $PM_{2.5}$ exposure.
- The proposed rules provide protections for outdoor workers, who have the highest exposures.
- The proposed rules are accompanied by user-friendly tools and templates including training slide decks and templates for the employer's wildfire smoke response plan.

1.4 Chronologic Summary of the Wildfire Smoke Rulemaking Project to Date

- **September 2020** Washington State experienced historic wildfire smoke exposures from a "super massive plume" of smoke.[6]

- **September 28, 2020** L&I received petition to engage in immediate rulemaking to

[4] Oregon Administrative Order 9-2021, OAR 437-002-1080, Temporary Rules Protection from Wildfire Smoke
[5] Oregon Administrative Order 4-2022, OAR 437-002-1081, Protection from Wildfire Smoke
[6] https://ecology.wa.gov/Blog/Posts/September-2020/A-smoky-siege.

address the hazard of wildfire smoke to agricultural workers.

- **October 20, 2020** L&I filed CR-101 (Preproposal) to address the hazard of wildfire smoke to outdoor workers.

- **January 21, 2021** L&I held a virtual stakeholder meeting regarding the hazards of wildfire smoke, discusses how wildfire smoke exposures are measured, and notes that the agency is considering the structure of CAL/OSHA's wildfire smoke rule. The components of the potential rule was reviewed with attendees. 100 stakeholders attended the meeting. Stakeholders had the option to listen and/or participate in both English and Spanish.

- **February 11, 2021** L&I held a virtual stakeholder meeting; the content is identical to the January 21, 2021 meeting. 146 stakeholders attended the meeting. Stakeholders had the option to listen and/or participate in both English and Spanish.

- **March 25, 2021** L&I held a virtual stakeholder meeting wherein CAL/OSHA's wildfire smoke rule is discussed and feedback is sought on the California language. Stakeholders had the option to listen and/or participate in both English and Spanish. 220 stakeholders attended the meeting.

- **April 20, 2021** L&I held a virtual stakeholder meeting where additional information is shared regarding the hazards of wildfire smoke and the $PM_{2.5}$ levels that are considered hazardous by various entities including EPA, Washington State Department of Ecology, and the World Health Organization (WHO). Information regarding historic $PM_{2.5}$ exposures in Washington was provided for reference. L&I solicited stakeholder input on $PM_{2.5}$ thresholds for interventions, including training, written program, two-way communication, exposure (engineering and administrative) controls, and respiratory protection. Stakeholders had the option to listen and/or participate in both English and Spanish. 209 stakeholders attended the meeting.

- **June 15, 2021** L&I shared a draft of the first emergency wildfire smoke rule for stakeholder comment. The invitation for comment was sent via DOSH's GovDelivery Rules electronic email distribution list, , a listserv which gives employers the ability to opt-in to L&I Communications.

- **June 18, 2021** A virtual stakeholder meeting was held to review a draft wildfire smoke emergency rule and solicited feedback via a question and answer session. Stakeholders had the option to listen and/or participate in both English and Spanish. 300 stakeholders attended the meeting.

- **July 16, 2021** L&I filed a CR-103E for a wildfire smoke emergency rule to ensure workers are protected from the hazard of wildfire smoke during the 2021 smoke season. The emergency rule remained in effect through November 13, 2021. The rule was available in English and Spanish. L&I provided tools including a training slide deck to ensure ease of implementation.

- **January 27, 2022** In response to stakeholder requests for more information on the hazards of wildfire smoke, L&I held a virtual stakeholder meeting featuring two experts on the hazard of wildfire smoke: Dr. Matt Kadlec, PhD, a Toxicologist employed the Washington State Department of Ecology, and Dr. Elena Austin, PhD, a Professor at the University of Washington's School of Public Health in the Department of Environmental and Occupational Health Sciences. Dr. Kadlec spoke on the trends and health effects of wildfire smoke in Washington State. Dr. Austin discussed the wildfire health threat and risk factors for outdoor workers. After the presentations, Drs. Kadlec and Austin answered questions from stakeholders. Stakeholders had the option to listen and/or participate in both English and Spanish. 284 stakeholders attended the meeting.

- **April 27, 2022** L&I held a virtual stakeholder meeting to discuss a stakeholder communication plan, the rulemaking timeline, review the draft 2022 wildfire smoke emergency rule, and answer stakeholder questions. Information was provided regarding the health effects of wildfire smoke and options are given for how wildfire smoke may be measured. The components of the draft emergency rules were reviewed, including the scope, exposure controls, the voluntary use of respirators, and mandatory use of respirators. Agency staff presented on the effectiveness of different types of respirators, as well as the importance of fit-testing to ensure that smoke does not create a hazard inside of the respirator. Stakeholders had the option to listen and/or participate in both English and Spanish. 265 stakeholders attended the meeting. Stakeholders were formally invited to provide feedback on the wildfire smoke emergency rule draft. The invitation was sent via DOSH's GovDelivery Rules electronic email distribution list..

- **June 1, 2022** L&I filed an emergency wildfire smoke rule. The emergency rule was in effect from June 15, 2022 through September 29, 2022.

- **August 10, 2022** L&I held two virtual stakeholder meetings to discuss options for respirator use provisions in the development of the permanent wildfire smoke rule. One stakeholder meeting was held in the afternoon and one was held in the evening to accommodate stakeholder work schedules. Stakeholders had the option to listen and/or participate in both English and Spanish.

    - During the afternoon meeting, information is provided regarding $PM_{2.5}$ and the hazards of wildfire smoke, historic $PM_{2.5}$ levels in various locations in Washington State, the purpose of respiratory protection, and elements of a required use respiratory protection program. L&I presented policy options for the required use of respirators. A question and answer session was held. Stakeholders were formally invited to provide written feedback. 168 stakeholders attended the afternoon stakeholder meeting.

    - One individual attended the evening stakeholder meeting and as that individual had been present at the afternoon meeting a formal presentation is not given. A question and answer session was held with the attendee.

- **September 13 and 29, 2022** Stakeholders were formally invited to provide feedback on

the wildfire smoke emergency rule draft by October 21, 2022. The invitation was sent via DOSH's GovDelivery Rules electronic email distribution list.

- **October 4, 2022** An in-person stakeholder meeting was held in Spokane. At this meeting, a draft of the permanent wildfire smoke rule wasreviewed with stakeholders with questions and input during the meeting. Stakeholders had the option to listen and/or participate in both English and Spanish. 13 stakeholders attended the meeting.

- **October 6, 2022** An in-person stakeholder meeting was held in Yakima. At this meeting, a draft of the permanent wildfire smoke rule was reviewed with stakeholders. There was an opportunity for stakeholder questions and input during the meeting. Stakeholders had the option to listen and/or participate in both English and Spanish. 29 stakeholders attended the meeting.

- **October 7, 2022** An in-person stakeholder meeting was held in Tukwila. At this meeting, a draft of the permanent wildfire smoke rule was reviewed with stakeholders. There was an opportunity for stakeholder questions and input during the meeting. Stakeholders had the option to listen and/or participate in both English and Spanish. 17 stakeholders attended the meeting.

- **October 13, 2022** A virtual stakeholder meeting was held. At this meeting, a draft of the permanent wildfire smoke rule was reviewed with stakeholders. There was an opportunity for stakeholder questions and input during the meeting. Stakeholders had the option to listen and/or participate in both English and Spanish. 230 stakeholders attended the meeting.

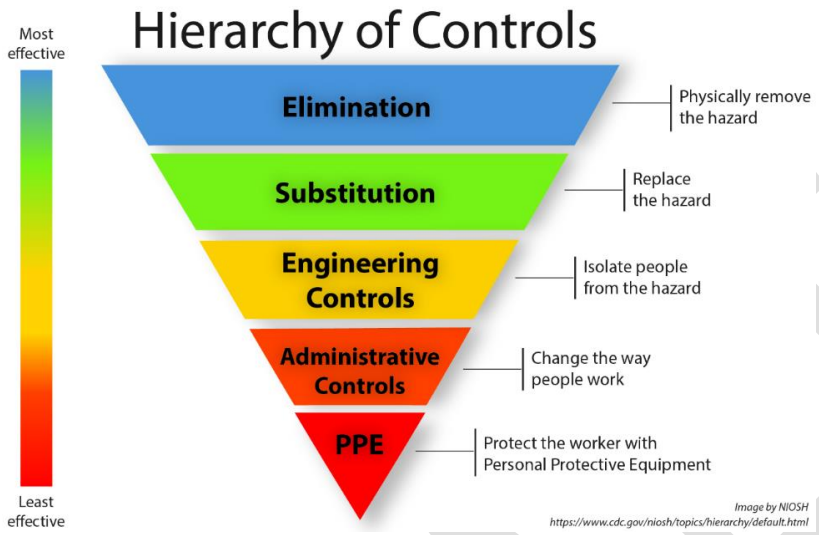
1.5 Description of the Proposed Rule

1.5.1 Overview of Prevention Goals

Labor and Industries' policy goals for this rulemaking included keeping actual worker exposures to less than 55.5 µg/m^3, and promoting the emergency preparedness needed for businesses to be ready for the diversity of wildfire smoke exposures Washington State has been experiencing.

These goals were approached with the understanding that some exposure interventions are more effective than others. The hierarchy of controls, as illustrated in Figure 1, is a fundamental concept in occupational safety and health as it describes different exposure interventions in order from most, to least effective.

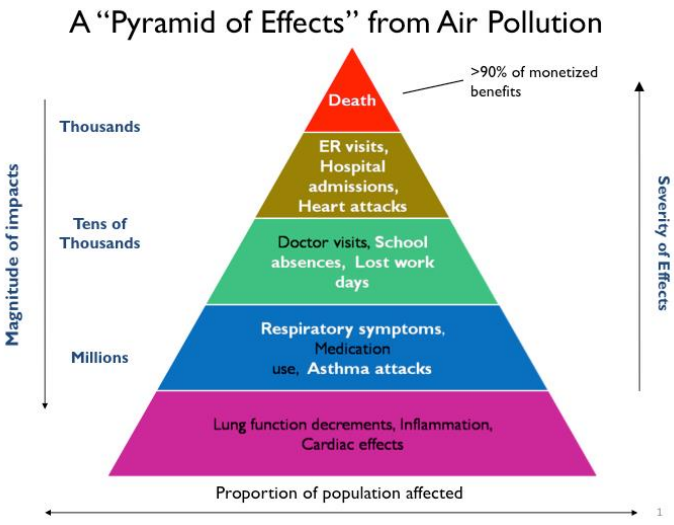
Figure 1: Hierarchy of Controls[7]



Wildfire smoke presents many unique challenges. Since the source of the exposure is not controlled by the employer, elimination and substitution are not a feasible option. This leaves engineering, and administrative controls as the most effective options, and PPE is used as a last line of protection to exposed workers. Working indoors with proper ventilation and air filtration is the best way to reduce worker exposure to wildfire smoke. However, this is not feasible for all work. The requirements in this rule describe the minimum protections that employers must implement to protect the health of their employees from the hazards of wildfire smoke when they choose to perform work under the scope of the rule. The details of how these concepts were incorporated into the requirements of the rule are explored further below .

[7] National Institute of Occupational Safety and Health (NIOSH), https://www.cdc.gov/niosh/topics/hierarchy/default.html

Figure 2: EPA Pyramid of Effects[8]



The health effects of wildfire smoke exist on a continuum from subclinical damage, to clinically-apparent damage requiring health care treatment (e.g. ED visits and hospitalizations), to death. The relationships between the proportion of the exposed population that experiences such effects with the severity and collective burden of those impacts can be represented graphically, as the EPA has done with their "Pyramid of effects from air pollution" infographic (See Figure 2). These health outcomes represent material impairment of health or functional capacity, and are often preventable using L&I's regulatory authority. As such, they represent targets for the individual and collective prevention goals of these rules.

1.5.2 Purpose and Scope - WAC 296-820-805 and 296-307-09805

This section of the rule sets purpose and scope of the rule to be applicable to all workplaces subject to the following exceptions:

- Enclosed structures in which openings are kept closed, except when needed to enter and exit
- Enclosed vehicles where the air is filtered and openings are kept closed, with the explicit exception of transit systems where doors are frequently opened and closed for boarding and deboarding
- Work within the scope of the Chapter 296-305 WAC, Safety Standards for Firefighters

1.5.3 Determining Harmful Exposures - WAC 296-820-815 and 296-307-09815

This section creates the requirement for employers to determine employee exposure to $PM_{2.5}$ in order for employers to be able to comply with the rule. There is no requirement of the frequency with which employers will need to check the air quality; rather, employers have the discretion to

[8] EPA ,"How BenMAP-CE Estimates the Health and Economic Effects of Air Pollution, "https://www.epa.gov/benmap/how-benmap-ce-estimates-health-and-economic-effects-air-pollution. Updated on August 10, 2022.

determine how often they will need to check the air quality in order to comply with the rule. That said, $PM_{2.5}$ data are refreshed every hour, and employers are encouraged to take advantage of the new information during changing wildfire smoke conditions. Employers have the choice to use publicly available data from the list in the rule, or to conduct their own monitoring using the instructions in the rule. Employers are only responsible for tracking exposures during working hours.

Employers have the option to check data from publicly available websites including (but not limited to) the EPA AirNow website and the Washington State Department of Ecology website, both of which publish $PM_{2.5}$ levels using the AQI.

What is the AQI?

The AQI currently in use was established by the EPA in 1999, revised from the Pollutant Standard Index developed in 1976 (88 FR 5637). The AQI is a unitless numbered index designed to provide the public with a uniform and easily understandable method of reporting air pollution hazards from criteria pollutants: ozone, carbon monoxide, nitrogen dioxide, particulate matter, and sulfur dioxide. But only the pollutant with the highest concentration relative to its national standard is used to calculate the AQI. Ambient $PM_{2.5}$, which is the primary pollutant of concern in wildfire smoke, may instead be reported as mass per volume in units of micrograms per cubic meter, i.e., mass concentration. These proposed permanent wildfire smoke rules are legally based on mass concentration of $PM_{2.5}$, not the AQI. Conversions to the AQI are provided to make it easier for regulated entities to comply with the rule.[9]

Though AQI health risk categories are sometimes linked to the NAAQS, the EPA has acknowledged that the AQI is not part of the NAAQS, nor was it designed to be a regulatory tool. (88 FR 5638). Important limitations of the AQI include that it may not account for potential adverse health effects of multiple pollutants, nor does it provide consistent, sufficiently protective population-level risk-based information (Cromar 2020, Perlmutt 2019). Hazard categories of the AQI meant to represent risk (e.g. “good”, “moderate”, “unhealthy for sensitive groups”, “very unhealthy”, “hazardous”) are demarcated by specific breakpoints, which in turn are defined by criteria pollutant concentrations. Furthermore, as a non-linear unitless index, the pollutant levels that are the basis for the index’s construction do not change consistently with incremental changes in the AQI, which complicates its utility to assess proportionate exposure and risk.[10][11]

[9] Air pollution from PM2.5 is most frequently reported to the public using some version of the EPA’s air quality index, whether it be the daily AQI, NowCast AQI, or the AQI forecast. The daily AQI is retrospectively calculated using air quality data from the previous 24 hours, whereas the NowCast AQI is intended to “…[tell] people whether it is a good time for outdoor activity” (88 FR 5638).

[10] "Perlmutt et al (2017) observed "...that the vast majority of excess cardiovascular hospital admissions attributable to PM2.5, regardless of whether PM2.5 is the driver pollutant, occur when the AQI is 'good" or 'moderate.'" and concluded that their study findings "...indicate that the current AQI might not be an effective risk communication tool with regards to cardiovascular mortality."

[11] EPA’s eptember 2018 publication, Technical Assistance Document for the Reporting of Daily Air Quality https://www.airnow.gov/sites/default/files/2020-05/aqi-technical-assistance-document-sept2018.pdf) Also, as a consequence of the way the AQI is constructed, it is not always the case that higher AQI values represent increases in health concern relative to lower values (Perlmutt 2019).

Finally, the AQI may incompletely characterize or insufficiently communicate specific acute health risks to workers vis-à-vis conditions unique to the occupational environment. Outdoor workers are uniquely exposed to higher levels of particulate air pollution, including wildfire smoke, compared to the general public and are regarded by Washington State to be a sensitive group with respect to particulate air pollution.[12]

While the general public may reduce exposure to air pollution through behavior modification, outdoor workers are subject to the authority of the employer and in many occupational settings may lack the autonomy to minimize exposure by changing location, lowering exertion, or otherwise altering occupational duties without adverse consequences.

Thus, workplace constraints prevent outdoor workers from sufficiently following the AQI's health messaging instructions to protect their health from the health hazards of wildfire smoke.

Rationale for Basing the Wildfire Smoke Rules on Mass Concentration Instead of the AQI
Because the AQI value and its associated health messages may underestimate or inaccurately represent actual health risks to specific individuals and population subgroups, including outdoor workers (Cromar 2020), the Washington State wildfire smoke rules are not legally based on the AQI. Although entities subject to L&I occupational safety and health wildfire smoke rules may demonstrate compliance with regulatory requirements using current AQI conversion, basing these rules on mass concentration of $PM_{2.5}$ instead of the AQI intends to avoid the confusion arising from the composite nature of the AQI.

1.5.4 Hazard Communication – WAC 296-820-820 and 296-307-820

WACs 296-820-820 and 296-307-820 require employers to establish a system for communicating wildfire smoke hazards to employees. As part of that system, employers must inform employees when the $PM_{2.5}$ concentration reaches applicable thresholds in the rule. Communication must be bi-directional; employees must be enabled to communicate to the employer when the air quality is worsening, if control measures such as respirators are unavailable, and any adverse symptoms being experienced. Additionally, employers must have a written wildfire smoke response plan in order to implement the provisions required by this rule. L&I DOSH Education & Outreach will be providing templates for employers to assist them with the implementation of the written response plan.

Rationale for notification to employees
Many protections in the wildfire smoke rule do not directly require specific actions to be implemented. Instead, the rule ensures that protective measures are available for employees to use voluntarily. As such, it is necessary that employees be aware of the $PM_{2.5}$ levels that they are being exposed to, and the protective measures available to them, so they can take action to protect themselves. Employees cannot rely on their senses alone to detect wildfire smoke as there is increased risk of adverse health outcomes at levels that cannot be seen or smelled.

[12] DOH, Washington Air Qulity Guide for Particulate Pollution, https://doh.wa.gov/sites/default/files/legacy/Documents/4300//waqa%20infographic_English.pdf; EPA's February 2023 publication, Air Quality Guide for Particle Pollution, https://www.airnow.gov/sites/default/files/2023-03/air-quality-guide-for-particle-pollution_0.pdf.

Employers are required to notify effected employees when each threshold in the rule is exceeded based on a one-hour average $PM_{2.5}$ reading. To avoid excess notifications at the lower thresholds, employers are not required to notify employees until two consecutive hourly readings above the 20.5 µg/m^3 threshold are exceeded.

Rationale for enabling employees to communicate with their employer
It is equally important that employees have a reliable means of communicating with their employer so the employer can respond to changing conditions and issues that arise appropriately. While the regulatory $PM_{2.5}$ monitoring network provides valuable information, many workplaces will be located some distance from the monitor, so the readings may not directly represent what is experienced at the worksite. Employees must be enabled, and encouraged, to report such changes in condition to the employer to allow appropriate response. Additionally, employees must be able to communicate any availability issues of exposure control measures, and any adverse symptoms of wildfire smoke exposure employees are experiencing.

1.5.5 Information And Training - WAC 296-820-825 and 296-307-09825

WACs 296-820-825 and 296-307-09825 require employers to provide information and training to employees regarding the hazard of wildfire smoke. Employees are to be trained before exposure to PM2.5 greater than 20.5 µg/m3 and annually thereafter, in a manner in which they can understand. Appendix A of the standard includes all of the required content of the training, and is available as a template for employers to use. Additionally, L&I DOSH Education & Outreach will be providing training templates for employers to assist the creation of their training program. Employees must receive training on all items listed below:

- Health effects and adverse symptoms of wildfire smoke exposures
- The importance of informing the employer when the employee is experiencing adverse symptoms of wildfire smoke exposure;
- The right to obtain medical treatment without fear of reprisal;
- The requirements of WAC 296-820-805 through WAC 296-820-860 Wildfire smoke;
- How employees can obtain the current $PM_{2.5}$, and the employers methods to communicate the current $PM_{2.5}$;
- The employer's response plan for wildfire smoke including methods to protect employees from wildfire smoke, and the exposure symptom response procedures;
- The importance, benefits, and limitations of using a properly fitted respirator when exposed to wildfire smoke;
- The risks and limitations of using an unfitted respirator, and the risks of wearing a respirator without a medical evaluation; and
- How to properly put on, use, and maintain the respirators provided by the employer.

Supervisors must receive the above training, and additional training listed below:

- The procedures the supervisor must follow to implement the applicable provisions of the wildfire smoke rule;
- The procedures the supervisor must follow if an employee exhibits adverse symptoms of wildfire smoke exposure; and

- Procedures for moving or transporting employees to an emergency medical service provider, if necessary.

1.5.6 Exposure Symptom Response - WAC 296-820-830 and 296-307-09830

WACs 296-820-830 and 296-307-09830 were created to provide a framework for employers to respond to employees who develop symptoms of wildfire smoke exposure, and to provide a pathway for employees to recover from those symptoms of exposure. These provisions require employers to monitor employees for adverse signs of exposure, to determine if medical attention is necessary, and to have a process for allowing employees to seek treatment.

Employees displaying symptoms may not be retaliated against for seeking medical treatment. Additionally, where the current PM2.5 is 250.5 µg/m3 (AQI 301) or greater, employers must ensure that employees displaying adverse symptoms have access to a location with clean air to allow a safe location to remove respirators, and recover, or wait for medical assistance.

1.5.7 Exposure Controls - WAC 296-820-835 and 296-307-09835

WACs 296-820-835 and 296-307-09835 were created to ensure that employers implement engineering and administrative controls (referred to collectively as "exposure controls" in this section) to prevent exposure to wildfire smoke, where feasible. While PPE such as respirators is commonly used as the primary method of protecting workers, it is the least effective means. PPE requires significant ongoing effort by workers and employers to be used properly, and is prone to misuse and failure. As illustrated in figure 1, engineering controls are the most effective means of controlling employee exposures to wildfire smoke followed closely by administrative controls. In many cases, employers may implement exposure controls in a way that their work is no longer covered by the scope of WAC 296-820 Wildfire smoke. For employers that cannot implement exposure controls to that extent, any reduction in $PM_{2.5}$ that could be achieved with exposure controls would be beneficial to worker health.

These provisions requires employers to implement exposure controls, whenever feasible, above a PM2.5 concentration of 35.5 µg/m3 (101 AQI), and employers are encouraged, though not required, to implement such controls above a PM2.5 concentration of 20.5 µg/m3 (69 AQI). A list of potential controls is provided to assist employers in identifying controls that will be feasible for their work. Exposure controls are not required during emergency response.

1.5.8 Respiratory Protection – WAC 296-820-840 and 296-307-09840

The Department organized policy alternatives for respiratory protection after analyzing the anticipated exposures to individual workers with and without the anticipated exposure reductions that would be assured using different types of respirators. WACs 296-820-840 and 296-307-09840 create the following requirements regarding respiratory protection for employees exposed to wildfire smoke:

- Where the $PM_{2.5}$ concentration is 35.5 µg/m^3 (101 AQI) or higher, employees must be provided N95 respirators for voluntary use. N95 respirators filtering facepiece respirators are inexpensive and readily available.
- Where the $PM_{2.5}$ concentration is 250.5 µg/m^3 (301 AQI) or higher,

employers must directly distribute N95 respirators to employees.

- Where the $PM_{2.5}$ concentration is 250.5 µg/m^3 (301 AQI) or higher, exposed employees must be enrolled in a respiratory protection program and be provided with one of the listed respirators for particulate matter.
- Where the $PM_{2.5}$ concentration is 555 µg/m^3 or higher, employees must be provided with more protective respirators (respirators with an assigned protection factor, or APF, higher than 10).

Figure 3: $PM_{2.5}$ Concentration inside respirator (µg/m^3)

$PM_{2.5}$ (µg/m^3)	EPA AQI	Unfitted N95 (see note)	Fit-tested N95 or half-face P100	Loose-fitting powered air purifying respirator	Full-facepiece air purifying respirator	Full-facepiece powered air purifying respirator
20.5	AQI 69-100	10	2	1	0	0
35.5	AQI 101-150	18	4	1	1	0
45		23	5	2	1	0
55.5	AQI 151-200	28	6	2	1	0
75		38	8	3	2	0
100		50	10	4	2	0
125		63	13	5	3	0
150.5	AQI 201-300	75	15	6	3	0
175		88	18	7	4	0
200		100	20	8	4	0
225		113	23	9	5	0
250.5	AQI 301-500	125	25	10	5	0
300		150	30	12	6	0
350		175	35	14	7	0
400		200	40	16	8	0
450		225	45	18	9	0
500.4		250	50	20	10	1
555	*Beyond the AQI*	278	56	22	11	1
Assigned Protection Factor (APF)		*None*	*10*	*25*	*50*	*1000*

Figure 3 provides an approximation of the actual concentration of $PM_{2.5}$ a worker would be exposed to inside the respirator at a given $PM_{2.5}$ level. Respirator use without fit-testing results in much less protection than a properly fitted respirator as shown in the "Unfitted N95" column (Coffey 1999, Coffey 2004). This figure assumes that unfitted N95s would allow 50% $PM_{2.5}$ penetration, however wearers cannot expect to reliably receive that level of protection with an unfitted respirator. The actual protection a worker would receive from an unfitted N95 is highly variable from person to person, and each donning by an individual. All other exposures in Figure 3 are calculated based on the respirator's assigned protection factor (APF).

Respirator Requirements in the Absence of Wildfire Smoke Rules

Current Division of Occupational Safety and Health (DOSH) respiratory protection requirements are found at Chapter 296-307 WAC Part Y-5, for agricultural employers, and at Chapter 296-842 WAC for all other employers.

Respirator Requirements For Employers Covered by Chapter 296-842 WAC

Chapter 296-842 WAC applies to all employers (except agricultural employers) whenever respirators are used at work. It requires respirators whenever respiratory hazards are present. Because it is applicable whenever respirators are used at work, it also applies when respirators are voluntarily used by employees, though some rule requirements may not apply in certain voluntary use scenarios. When employers require employees to wear respirators, such respirator use is not considered voluntary under WAC 296-842-11005 and the same rule requirements apply as when DOSH requires respirator use in a workplace to control a respiratory hazard.

This means that DOSH requires fit-testing whenever employers require employees wear respirators at work to protect them from wildfire smoke, and other respiratory hazards.

Requirements to Ensure Respiratory Protection Programs be Effective

Unless an exception applies, Chapter 296-842 WAC requires employers to:

- Designate a program administrator
- Develop and maintain a written program
- Keep respirator program records
- Select and provide appropriate respirators based on the requirements and results of the Hazard Evaluation the employer conducts
- Provide medical evaluations
- Conduct fit testing
- Provide effective training
- Maintain respirators in a clean and reliable condition13
- Store respirators properly
- Inspect and repair respirators
- Prevent sealing problems with tight-fitting respirators (i.e. ensure employees perform a user seal check)
- Make sure employees leave the use area before removing respirators
- Provide standby assistance in immediately dangerous to life or health conditions
- Ensure breathing air and oxygen are properly supplied and not hazardous to breathe
- Ensure correct labeling on respirator filters, cartridges, and canisters

According to OSHA, it is "…essential for the employer to provide for proper respirator selection, fit testing, medical evaluation, and care and maintenance to ensure that the respirator is providing sufficient protection against the [respiratory] hazard and that the use of the respirator is not imposing an additional health risk" (63 FR 1191)
Medical evaluations ensure the wearer of a negative pressure respirator "…can withstand…without suffering adverse health consequences" the "…significant physiologic burden…" the respirator adds to the wearer. (63 FR 1190)

[13] As OSHA explains, "…reusable tight-fitting negative pressure respirators can become contaminated if they are not cleaned, maintained, and stored properly. Thus if an employer allows use of this type of respirator, the employer must implement the program elements necessary to ensure that contamination does not harm the employee." (63 FR 1190).

According to OSHA, fit testing is "…necessary to ensure that discomfort is minimized and that the respirator selected is offering sufficient protection." (63 FR 1190) and to ensure that "…employees have an opportunity to reject respirator facepieces that they consider unacceptable." (63 FR 1201) OSHA also concluded "…that poorly fitting facepieces expose workers to contaminants" and was concerned about these preventable exposures to such a degree that the agency determined that the need to include fit testing in the 1998 changes to their respirator standard was one of the "major reasons" for that regulatory action. (63 FR 1221)

Voluntary Use Considerations And Requirements In The Absence Of Vertical Standards For Wildfire Smoke

Because under WAC 296-842-11005, the voluntary use of respirators is intended and permitted only for circumstances where no respiratory hazard is present, certain regulatory requirements that are otherwise essential to ensuring respiratory protection programs be effective usually do not need to be implemented in voluntary use situations. Circumstances where respirators are worn and a respiratory hazard is present is not voluntary use according to WAC 296-842-11005, and in such situations L&I requires a full respiratory protection program be implemented.

Under Chapter 296-820 WAC and WACs 296-307-624 through -628, L&I is making an exception to the requirement that a full respiratory protection program be implemented when respirators are worn and a respiratory hazard exists (in this case, wildfire smoke). Instead, L&I is permitting voluntary use of respirators instead of required use of respirators in response to that hazard for most of the $PM_{2.5}$ concentrations anticipated by these rules. Although wildfire smoke poses a respiratory hazard at all concentrations covered by these rules, L&I has determined that requiring a full respiratory protection program at $PM_{2.5}$ concentrations below 500.4 $\mu g/m^3$ is currently infeasible.

The voluntary use of respirators below 500.4 $\mu g/m^3$ is not expected to provide reliable respiratory protection in the way that a full respiratory protection program would. Unfitted respirators used on a voluntary basis under these rules at $PM_{2.5}$ concentrations below 500.4 $\mu g/m^3$ are not expected to reliably reduce $PM_{2.5}$ concentrations below the 55.5 $\mu g/m^3$ concentration that is L&I's policy goal as shown in figure 3. To address the risk that workers might unintentionally increase their hazardous exposure beyond the exposures they would bear without wearing respirators, Appendix A provides workers with information about the unreliable and more limited protection that non-fit-tested respirators provide.

L&I previously considered but has not included in the proposed permanent rules policy options that would require respirators be worn by workers without fit-testing, due to the risk of increasing the hazardous exposures to some workers beyond the exposures those workers would experience with voluntary use or no use of respirators at $PM_{2.5}$ concentrations anticipated by the wildfire smoke rules. The least burdensome alternative analysis further discusses these risks to workers and elaborates on the harm-avoidance rationale behind L&I's decision not to require workers wear un-fit-tested respirators.

By informing workers through Appendix A of the limits of the approach in these proposed permanent rules, and by avoiding policy options that would require respirators be worn without

fit-testing, L&I has concluded that workers will have better protections against the wildfire smoke hazard when voluntarily wearing respirators compared to wearing no respirators, while addressing the feasibility constraints that limit L&I's ability to require a comprehensive respiratory protection program be implemented at $PM_{2.5}$ concentrations below 500.4 $\mu g/m^3$.

1.5.9 Measuring PM2.5 Levels At The Worksite - WAC 296-820-845 And 296-307-09845

WACs 296-820-845 and 296-307-09845 create provisions for measuring $PM_{2.5}$ for those employers that choose to use direct-reading instruments to assess wildfire smoke at their worksites. While it is anticipated that most employers will use publicly available air monitoring data to determine the level of $PM_{2.5}$ at their worksites, some employers may choose to conduct their own monitoring. The provisions in this section ensure that employers choosing this option will obtain reasonably accurate, real-time data on the air quality at their worksites.

1.6 Description of the Affected Businesses and Workers

The proposed rule impacts all workplaces where workers may be exposed to a $PM_{2.5}$ concentration of 20.5 $\mu g/m^3$ (Air Quality Index of 69) or more for wildfire smoke. The rule exempts workplaces and operations which are (1) within enclosed buildings or structures where openings (windows, doors, bays, etc.) are closed and can be opened when necessary; (2) enclosed vehicles with cabin filters and with doors and windows which can be opened when necessary, and; (3) work within the scope of Chapter 296-305 WAC, Safety standards for firefighters.[14]

1.6.1 Affected Workers

In order to identify the occupations that are exposed to wildfire smoke and estimate the number of the workers in these occupations that are likely affected by the proposed rule, L&I relies on the outdoor exposure data from the U.S. Bureau of Labor Statistics' Occupational Requirements Survey (ORS) and the outdoor, exposed to weather data from the O*Net database.[15] L&I believes these are the best outdoor exposure data available for the purpose of identifying affected workers.

More specifically, L&I looked at the distribution of workers in each occupation by outdoor exposure level (no presence, seldom, occasionally, frequently, and constantly[16]) from the ORS data in the last few years (2018, 2021, and 2022) and a similar distribution of data from the O*Net database to distinguish the affected occupations from those not affected. The occupations that did not have outdoor work presence were first excluded from the affected population. For the affected occupations in which a specific exposure level was available, L&I estimates that

[14] WAC 296-62-08510(2)(a) through (c).
[15] More details about these data can be found on these websites: ORS Database: U.S. Bureau of Labor Statistics (bls.gov) and Work Context - Outdoors, Exposed to Weather (onetonline.org).
[16] Defined in the survey as no exposure, exposed to outdoors up to 2 percent of the workday, 2 percent and up to 1/3 of the workday, 1/3 up to 2/3 of the workday, and 2/3 or more of the workday respectively.

about 25% of the workers who indicated they were exposed to the outdoors occasionally[17] and all of the workers who were exposed to the outdoors frequently or constantly will be affected by the proposed rule. For the rest of the occupations, L&I used the reported percent of workers who said they were exposed to outdoors every day from O*Net as the share of affected workers in each of those occupations.

Based on the scope of this proposed rule, the share of likely affected workers in each occupation estimated from the previous step, and the most recent occupational employment data,[18] L&I estimates that overall, a total of 395,057 workers, or 11.7% of Washington's workforce, perform outdoor work activities at some point in time and therefore may be potentially affected by the rule. Table 1.1 below shows both the top 20 occupations with the largest share of workers potentially affected and the resultant number of potentially affected workers. It is also worth mentioning that the estimated number of affected workers for each requirement analyzed in Chapter 2 may only be a certain proportion of this population, which will be explained in each specific section.

Table 1.1. Top occupations with the largest share and number of affected workers

SOC	Job Title	% of workers affected	SOC	Job Title	Number of affected workers
435041	Meter Readers, Utilities	100.0%	452092	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	41,852
472151	Pipe layers	100.0%	537062	Laborers and Freight, Stock, and Material Movers, Hand	30,451
475013	Service Unit Operators, Oil and Gas	100.0%	472061	Construction Laborers	28,302
475071	Roustabouts, Oil and Gas	100.0%	373011	Landscaping and Grounds keeping Workers	21,102
373011	Landscaping and Grounds keeping Workers	99.6%	472031	Carpenters	15,607
499051	Electrical Power-Line Installers and Repairers	99.5%	471011	First-Line Supervisors of Construction Trades and Extraction Workers	12,538
475011	Derrick Operators, Oil and Gas	99.1%	499071	Maintenance and Repair Workers, General	12,277
333041	Parking Enforcement Workers	99.0%	339032	Security Guards	11,354
454023	Log Graders and Scalers	98.5%	472111	Electricians	10,180
472072	Pile Driver Operators	98.4%	533032	Heavy and Tractor-Trailer Truck Drivers	7,082

[17] Given the exemption of the workers who only have incidental outdoor exposure (workers who are not required to perform a work activity outdoors for more than 15 minutes in any 60-minute period).
[18] Occupations-Industry Matrices, 2022, ESD.

475012	Rotary Drill Operators, Oil and Gas	97.1%	472073	Operating Engineers and Other Construction Equipment Operators	5,994
537073	Wellhead Pumpers	97.0%	533033	Light Truck Drivers	5,086
472021	Brick masons and Block masons	96.8%	472181	Roofers	5,033
339091	Crossing Guards and Flaggers	96.0%	272022	Coaches and Scouts	4,399
474061	Rail-Track Laying and Maintenance Equipment Operators	95.5%	372011	Janitors and Cleaners, Except Maids and Housekeeping Cleaners	4,044
474071	Septic Tank Servicers and Sewer Pipe Cleaners	94.6%	452093	Farmworkers, Farm, Ranch, and Aquacultural Animals	3,805
454021	Fallers	94.4%	333051	Police and Sheriff's Patrol Officers	3,638
339011	Animal Control Workers	93.5%	111021	General and Operations Managers	3,503
373012	Pesticide Handlers, Sprayers, and Applicators, Vegetation	92.6%	472051	Cement Masons and Concrete Finishers	3,479
472181	Roofers	91.9%	537061	Cleaners of Vehicles and Equipment	3,367

1.6.2 Affected Industries and Businesses

The proposed rule applies to all employers with employees who are outdoors and are likely exposed to wildfire smoke. Using the number of affected workers in each occupation estimated in Section 1.6.1 and their employment by each industry, L&I was able to estimate the number of businesses in each industry that are likely affected by this proposed rule.[19] The share and number of affected businesses in each industry are presented in Table 1.2. It shows Agriculture, Forestry, Fishing and Hunting has the largest share of affected businesses (53.3%), but Construction is the top industry in terms of the number of employers affected by the rule (12,744). Altogether, more than 31,000 employers may be affected by this proposed rule.

Table 1.2 - Share and number of businesses that are likely affected in each industry

NAICS	Sector	Share of affected businesses	Number of affected businesses
11	Agriculture, Forestry, Fishing and Hunting	53.3%	3,592
21	Mining, Quarrying, and Oil and Gas Extract	22.2%	30
22	Utilities	16.7%	39
23	Construction	46.1%	13,443
31-33	Manufacturing	6.7%	534
42	Wholesale Trade	12.6%	1,599

[19] Assuming the share of affected workers in a certain industry is similar to that of affected businesses in that industry.

44-45	Retail Trade	6.0%	887
48-49	Transportation and Warehousing	22.2%	1,153
51	Information	3.4%	201
52	Finance and Insurance	3.1%	208
53	Real Estate and Rental and Leasing	16.8%	1,254
54	Professional, Scientific, and Technical Services	2.9%	972
55	Management of Companies and Enterprises	2.1%	14
56	Administrative, Support and Waste Management	25.5%	3,511
61	Educational Services	5.9%	231
62	Health Care and Social Assistance	2.9%	1,841
71	Arts, Entertainment, and Recreation	13.5%	426
72	Accommodation and Food Services	4.4%	679
81	Other services except public administration	9.4%	1,946
99	State and Local Governments	14.1%	292
	Total	**11.9%**	**32,850**

The share of affected businesses indicated here does not include workplaces that can easily move work indoors, or close windows and doors in a way that they are no longer covered by the scope of the rule. There are many workers who would otherwise be exposed if these simple steps were not taken. The cost to take these actions are negligible, but the benefits, while unquantified in this analysis, create significant reductions in exposure to wildfire smoke.

Chapter 2: Probable Cost of the Proposed Rule

The estimated costs in this analysis represent only the new costs of complying with the proposed rules for the affected parties, excluding realized potential costs associated with or originating from the current practices, or "baseline" standards under existing laws, rules or national consensus standards. Therefore, the costs that can be attributed to or are insignificantly different from these baseline standards are not analyzed or factored into our estimates.
This chapter assesses each of the proposed rule components that have been identified to have a probable cost implication. The chapter concludes by summarizing the total identified probable costs.

2.1 Exposure Data and Methodology

L&I utilized $PM_{2.5}$ concentration data from Washington's Department of Ecology. The original data contains more than 2.6 million of hourly observations for $PM_{2.5}$ between 2017 and 2021 from 68 air quality data monitors across the state. Some of the major treatments and adjustments made to the raw data before it was employed for the cost analysis include:

- Removing all the observations with no or negative $PM_{2.5}$ values.
- Removing all the hourly data observed in non-wildfire season (between November and May) as it is more likely that bad air quality is caused by activities (such as wood burning) other than wildfires during that period.
- Removing all the data observed in early mornings or late nights (between 10 pm and 4 am) as very few workers will be working and affected during those hours.
- Where there were duplicate records only differing by the type of data, regulatory data was used against non-regulatory data. In places where regulatory data was not available, non-regulatory data was used.
- Where there were duplicate records only differing by the parameter occurrence code (POC), a hierarchy of that factor was applied where POC 5 was used for regulatory data and POC 4 for non-regulatory data and then from the remaining POCs in order from lowest to highest.

The final data after all necessary adjustments contains approximately 721 thousand records in which 30% of observations are regulatory and the remaining 70% are non-regulatory type of data. It covers 31 counties across the state. Then, to calculate the average number of days when $PM_{2.5}$ concentration was at or above a certain threshold for cost analysis purpose, L&I employed the following method:

- First, L&I identified the days when there was at least one hour during that day that the observed $PM_{2.5}$ concentration was at or above that threshold (except for the threshold of 20.5 $\mu g/m^3$ which requires at least 2 hours in a day). Those days were counted and aggregated for each monitor and each observed month (June – October).
- Second, L&I averaged the total number of days obtained from Step 1 for each monitor in the same Workforce Development Area (WDA), weighted by the employment share of the county where each monitor is located, to obtain the number of days when the observed $PM_{2.5}$ concentration was at or above that threshold for each WDA and each observed month.

- Third, L&I averaged the total number of days obtained from Step 2 for each WDA, weighted by the employment share of that WDA, to obtain the total number of days when the observed $PM_{2.5}$ concentration was at or above that threshold for the whole state for each observed month.
- Last, L&I summed the number of days obtained from Step 3 in each month of the same year to obtain the annual total number of days for the whole state.

Table 2.1 shows the main results from the above analyses. 2019 $PM_{2.5}$ concentration data was lower than the other years examined as a result of relatively fewer wildfires, better air quality and lower average temperatures. This lower impact year has been reflected in several studies examining the impact of wildfire smoke in Washington State (Zuidema et al. 2022, L&I presentation for August 10, 2022 stakeholders' meeting, etc.).

Table 2.1. Summary of key $PM_{2.5}$ results

Total # of days over 5-month wildfire season when daily maximum $PM_{2.5}$ is								
Statewide	**≥20.5 (2 or more readings)**	**≥35.5**	**≥250.5**	**≥500.4**	**≥555**	**btw 35.5-250.4**	**btw 250.5-500.3**	**btw 500.4-554.9**
2017	23.12	15.00	0.22	0.00	0.00	14.77	0.22	0.00
2018	22.81	14.41	0.24	0.00	0.00	14.18	0.23	0.00
2019	3.92	1.32	0.00	0.00	0.00	1.32	0.00	0.00
2020	16.09	12.50	1.41	0.30	0.24	11.08	1.11	0.07
2021	10.24	7.02	0.16	0.00	0.00	6.85	0.16	0.00
Annual Average	15.23	10.05	0.41	0.06	0.05	9.64	0.35	0.01
Average excluding 2019	18.06	12.23	0.51	0.08	0.06	11.72	0.43	0.02
As % of time	10.0%	6.6%	0.3%	0.0%	0.0%	6.3%	0.2%	0.0%
As % of time excluding 2019	11.8%	8.0%	0.3%	0.1%	0.0%	7.7%	0.3%	0.0%

2.2 Compliance Cost Estimates by Provision

2.2.1 Cost of identification of harmful exposures

WAC 296-820-815 and 296-307-09815 require employers to determine employee $PM_{2.5}$ exposure levels at worksites periodically as needed. Employers have options in the methods used to collect this information including: (1) check $PM_{2.5}$ forecasts and current levels from one

of seven sources;[20] (2) obtain $PM_{2.5}$ forecasts and current levels directly from one of four sources by either telephone, email, text, or other effective methods;[21] or (3) measure current $PM_{2.5}$ levels at the worksite in accordance with WAC 296-820-845 and 296-307-09845.[22]

In order to estimate the cost of this requirement L&I looked at the amount of time it would take to determine the $PM_{2.5}$ levels as well the frequency of checks. Each option would require administrative time in order to obtain the necessary information. The number of checks would occur with greater frequency as the $PM_{2.5}$ levels rise and health risk increases due to exposure. This would predominantly occur during the wildfire season (July to September) [23] where the $PM_{2.5}$ levels would most likely be at the trigger levels outlined in the section and be related to wildfire smoke. Based on internal technical staff estimates employers would spend about one minute checking $PM_{2.5}$ levels and would do so at an increasing frequency as the $PM_{2.5}$ levels increase.[24]

Analysis of historical $PM_{2.5}$ data for the wildfire season show that for more than 96% of the time $PM_{2.5}$ concentrations were below 20.5 $\mu g/m^3$. Examination of levels above 20.5 $\mu g/m^3$ show about 64 hours when levels were 20.5 to 35.4 $\mu g/m^3$, 85 hours when it was between 35.5 to 250.4 $\mu g/m^3$,[25] 3.0 hours when it was between 250.5 to 500.3 $\mu g/m^3$, and 1.0 hours when the $PM_{2.5}$ levels were at or above 500.4 $\mu g/m^3$ (see Table 2.2).

Table 2.2. Average number of hours and frequency of $PM_{2.5}$ checks

$PM_{2.5}$ level at	Number of hours per wildfire season	Frequency of checks	Number of checks per season
20.5 - 35.4 $\mu g/m^3$	64	every 4 hours	16
35.5 - 250.4 $\mu g/m^3$	85	every 2 hours	43
250.5 - 500.4 $\mu g/m^3$	3.0	every 2 hours	2.0
$\geq$ 500.5 $\mu g/m^3$	1.0	every hour[26]	1.0

In estimating costs L&I uses an eight year forward period (2023-30) and discounts back to present day figures using the 5% social discount rate, going forward referred to as the model period. L&I relies upon two main assumptions to estimate these costs. First, in order to

[20] These include Washington Department of Ecology website, Air Quality WA mobile app, Washington Smoke Information website, U.S. EPA AirNow website, U.S. EPA AirNow mobile app, U.S. Forest Service AirFire website, or Local Clean Air Agency website.

[21] The four sources include the Department of Ecology, Local Clean Air Agency, U.S. EPA, or U.S. EPA EnviroFlash.info.

[22] These sections provide the guidance employers must follow when measuring $PM_{2.5}$ levels directly at worksites. This includes guidance on the design and manufacturing specifications of the monitor used to measure particulate levels, and the training requirement for the person(s) supervising, directing, or evaluating the monitoring, among others.

[23] According to the Emergency Management Division, the wildland fire season in Washington usually begins in early July and typically culminates in late September.

[24] This time would vary depending on various reasons, for instance the method the employer uses to obtain measures.

[25] The greater number of hours here is due to the wider spread in this $PM_{2.5}$ concentration range.

[26] For ease of assessing costs, L&I rounded the number of checks at this concentration to 1.

determine the concentration levels of the day, employers would have to check at least once every day for the total of 153 days in each wildfire season, most likely at the beginning of the work day. Second, L&I assumes that the number of checks needed during the day in addition to the initial check is dependent upon the daily maximum concentration level (see Table 2.3) from the historical data. Given the average monitoring time, and the hourly wage of a typical supervisor of $67.16, the estimated cost to impacted businesses to determine $PM_{2.5}$ levels would be $2.1 million each year.[27]

The method used by an employer to determine the $PM_{2.5}$ levels would most likely involve either the use of a mobile device, a computer with access to the internet, or special dedicated measuring equipment. The first two methods would impose none to minimal device cost since typical employers would most likely have such a device, even in most remote sites. For employers with remote worksites which are unconnected to the internet and without cellular service, employees would probably have to directly monitor $PM_{2.5}$ exposures with a dedicated device. The number of employees at those remote worksites who would need devices to do the direct measurement is estimated to be relatively small at 4,178 over the next eight years. However, given that the measurement choices that an employer can use are options and not requirements, we assume no device costs for this proposed requirement.

Table 2.3. Cost of identification of harmful exposure

	Cost factor	
	Minimum number of checks per wildfire season	153
Monitoring cost	Additional number of checks per wildfire season	
	20.5 - 35.4 µg/m^3	16
	35.5 - 250.4 µg/m^3	43
	250.5 - 500.4 µg/m^3	2.0
	≥ 500.5 µg/m^3	1.0
	Average time to monitor the $PM_{2.5}$ levels	1 minute
	Employee hourly wage plus benefit	$67.16
	Total monitoring cost over 8 years	$19,026,455
	Annualized cost	$2,128,351

2.2.2 Cost of hazard communication

WAC 296-820-820 and 296-307-09820 require employers to establish and implement a system for communicating the hazards of wildfire smoke in a form understandable by employees. Such a system must include procedures for (1) informing employees of the current $PM_{2.5}$ when at least two consecutive current $PM_{2.5}$ readings meet or exceed a certain threshold; (2) enabling and encouraging employees to inform employers of (a) worsening air quality, (b) availability issues of appropriate exposure control measures, and (c) adverse wildfire smoke exposure symptoms; and (3) a wildfire smoke response plan tailored to the workplace which must include at least nine

[27] L&I believes these estimates to be somewhat conservative as we do not assume an increasing frequency of concentration nor the negative impacts from extreme wildfires resulting from climate change.

listed minimum elements. This wildfire smoke response plan must also be included in the written Accident Prevention Program (APP).

Impacted businesses would incur new costs to create the necessary procedures for communicating with employees when trigger thresholds are met, and procedures for employees to communicate worsening air quality, issues with exposure control measures with employers, and any adverse wildfire smoke symptoms. The costs that employers are expected to incur include (1) the cost of creating the system for communication, broken down by (i) administrative time, and (ii) cost of any necessary assets; and (2) creation of a Wildfire Smoke Response Plan (WSRP).

System for communication

Creating any system for communication involves several stages including planning, design, implementation, testing, and deployment. The time and asset requirements of each depends on the complexity of the system. The proposed requirements of this section make this one a relatively simple communication system and is not expected to use any significant amount of time or assets.

L&I believes that a significant number of employers already have a communication system in place which satisfies the requirements of the proposed communication system here. The remaining number of businesses who would need to create this system is assumed to be relatively small. To determine the cost of this requirement to those impacted businesses, we first assess the administrative time needed to complete the system. Based on the variability of different business operations, L&I believes it would take approximately 2 to 3 hours to complete the various stages involved in the procedures.[28] Assuming that 80-90% of current employers have an existing communication system, and using the average hourly wage of $95.14 for a typical manager,[29] the cost to complete the procedures is estimated to be $148,072 to $386,104 annualized over the model period.

Next we analyzed possible asset requirements. In addition to communicating in-person, employers would most likely use existing communication devices like radios or cellular telephones to facilitate communication between themselves and employees. L&I believes there would be no or minimal cost for communication devices since most all employees would have at least a mobile phone equipped to receive and send voice and text messages. However, there may be a number of employees who are working remotely in locations with no cellular service and where a radio would be the most viable communication device. As mentioned in section 2.2.1 above, L&I estimates the number of these employees to be approximately 4,178 over the next eight years. On the high end of our estimates, if all of these workers require a device for communication then this results in a total of 8,356 devices being needed.[30] However, as we assume that 80-90% of businesses already have a system in place, we assume that on the low end approximately 10% of these workers would need a device, which results in 836 devices. Based

[28] Estimates based on internal technical staff advice.

[29] This hourly wage represents the average median starting wage plus benefits of 30.4% of employees most likely responsible for completing this task

[30] This assumes one device for the employee and one device for the employer to facilitate the two-way communication. This represents the upper end of probable devices needed.

on the average price of a long-range radio of $64.62, L&I estimates a cost of $6,628 to $66,278 on impacted businesses each year over the model period. Overall, the administrative time for communication procedures plus the equipment cost are expected to impose approximately $154,700 to $452,382 each year.

Wildfire smoke response plan

Employers would also incur costs of creating a WSRP and including this plan in their written accident prevention program (APP). L&I provides a template that employers could use to quickly complete their plan. Assuming the typical employer utilizes this template, internal staff estimates creating a typical WSRP would take on average 1 to 2 hours. Using the same average hourly wage of an employee most likely responsible for creating this plan of $95.14, L&I estimates the annualized cost to impacted businesses to be $381,836 to $763,671. Including this plan in the written APP would simply entail updating the APP with this information, and this is not expected to take any significant time.

Overall, the total cost of compliance with this requirement for impacted businesses is estimated to be $536,536 to $1.2 million each year over the model period (see Table 2.4).

Table 2.4 Cost of hazard communication

Cost factor		
Communication system	Number of employers requiring a new system	6,909 – 10,085
	Procedures	
	Average time to complete communication procedures	2 - 3 hours
	Hourly rate of an employee completing procedures	$95.14
	Total cost of creating and implementing procedures	$1,105,095 - $2,881,573
	Devices	
	Number of workers needing devices	418- 4,178
	Average device cost	$64.62
	Total cost in 8 years	$49,490 - $494,895
Wildfire smoke response plan	Total number of firms needing a WSRP	35,494
	Average time to complete a WSRP	1 - 2 hours
	Hourly wage of employee completing WSRP	$95.14
	Total cost of WSRP	$2,916,482 - $5,832,964
Overall	Total cost range in 8 years	$4,071,066 - $9,209,433
	Annualized cost	$536,536 - $1,216,053

2.2.3 Cost of information and training

WAC 296-820-825 and 296-307-09825 require employers to provide workers with information and training prior to work which exposes them to $PM_{2.5}$ concentration of at least 20.5 $\mu g/m^3$ (AQI 69) and at least annually thereafter. This training includes a minimum eight components

contained within the full Appendix A of the proposed rule. Employers are required to provide this training in a manner and language readily understandable by the employee. In addition, these sections also require supervisors to be provided information and training at similar concentration levels, on requirements in WAC 296-820-825(2) plus procedures they must follow (a) to implement the provisions of WAC 296-820-805 through 296-820-860 (and 296-307-09805 through 296-307-09860); (b) if an employee exhibits adverse wildfire smoke symptoms; and (c) to move or transport employees to an emergency medical service provider, if necessary.

The proposed sections would impose a new cost on businesses that need to train their employees and supervisors. Cost of compliance with this section was broken down into two parts: (1) cost of developing the training material, and (2) cost of providing the required training to employees and supervisors. Based on internal technical staff estimates, impacted businesses are expected to spend 2 to 4 hours developing the necessary training material. Using an average hourly wage of $95.14 of an employee most likely completing this task, L&I estimates one-time cost of $5.8 million to $11.7 million on impacted businesses, or $763,671 to $1,527,342 each year when annualized over the model period. Providing this training material in a language understood by employees imposes translation costs on impacted businesses. The distribution of workers with limited English proficiency across all impacted industries is not known. While the Agriculture, Forestry, Fishing and Hunting, and Construction industries would have workers who do not understand English and would need translation services, not all businesses in these sectors will need translation services. However, for the purposes of this analysis, we assume all businesses in these two sectors, 52% of total impacted businesses, would need translation services. This approach implies a probable over estimation of these costs. Using the average cost of $20 to $75 for translation services for each affected business, L&I estimates this to impose annualized cost of $43,477 to $163,037 over the model period to these affected businesses.

To estimate the cost of training employees and supervisors, L&I determined the number of those workers who would need training annually and the average amount of time this training would take. Using the average hourly wage of $55.70 for non-supervisory workers and $67.16 for supervisors, plus an average training time of 30 minutes for initial training and 15 minutes for subsequent trainings, L&I estimates this requirement would impose approximately $6 million upon impacted businesses each year. The total cost of the proposed information and training requirement is estimated to cost impacted businesses $6.8 million to $7.7 million each year over the model period (see Table 2.5).

Table 2.5. Cost of information and training

	Cost factor	
Training development	Total number of employers	35,494
	Average time to develop training materials	2 - 4 hours
	Hourly wage of manager	$95.14
	Total cost	$5,832,964 - $11,665,929
	Annualized	$763,671 - $1,527,342
Translation ser	Average number of employers	16,224

	Average cost of translation services	$20 - $75
	Total cost	$324,475 - $1,216,780
	Annualized	$43,447 - $163,037
Employee training	Number of employees over 8 years	435,361
	Average initial training time	30 minutes
	Average subsequent training time	15 minutes
	Hourly wage of employee	$55.70
	Total cost	$51,841,108
	Annualized	$5,906,118
Supervisor training	Average number of supervisors each year	4,709
	Supervisor hourly wage	$67.16
	Total cost	$674,180
	Annualized	$76,774
Overall	Total cost in 8 years	$57,994,952 - $63,941,726
	Annualized cost	$6,790,040 - $7,673,272

2.2.4 Cost of exposure symptom response

WAC 296-820-830 and 296-307-09830 require employers to (1) monitor employees who display symptoms of wildfire smoke exposure (WSE) to determine whether or not medical attention is necessary; (2) allow employees displaying symptoms of WSE to seek medical attention without retaliation; (3) have effective provisions in place in advance for prompt medical attention for employees displaying symptoms of WSE; and (4) where $PM_{2.5}$ is at least 250.5 $\mu g/m^3$, ensure employees who require medical attention are either moved to a location of cleaner air quality where the $PM_{2.5}$ is less than 20.5 $\mu g/m^3$, or to an enclosed structure with a space-appropriate high efficiency particulate air (HEPA) filter.

The requirements to allow employees to seek medical attention and for employers to have provisions in place for prompt medical attention to be given to injured employees or those displaying signs and symptoms of some illness, already exists, and should be outlined in an employers accident prevention program (APP). The APP requirements under DOSH rules, such as under WAC 296-800-14005, include how and when to report on the job injuries. DOSH rules also address first aid requirements, such as WAC 296-800-15005 which states "in the absence of an infirmary, clinic, or hospital in near proximity to the workplace, which is used for the treatment of all injured employees, employers must have a person or persons adequately trained to render first aid." WAC 296-128-630 requires employers to allow the use of paid sick leave to accommodate an employee's need for medical diagnosis, care or treatment of a mental or physical illness, injury or health condition; or an employees need for preventative medical care. As a result, L&I believes that the proposed requirements in this rule would not impose any new cost on impacted businesses as they are already subject to those requirements.

2.2.5 Cost of exposure controls

WAC 296-820-835 and 296-307-09835 encourages employers to implement exposure controls where the $PM_{2.5}$ is 20.5 µg/m^3 and require those exposure controls be implemented where the $PM_{2.5}$ level is 35.5 µg/m^3 or higher. Such controls would not be limited to providing enclosed buildings, structures or vehicles, changing work schedules, and providing additional rest periods, among others.

In assessing the possible costs of this requirement L&I considered the options a typical employer would most likely employ in order to address exposure. Examining the most likely options reveal that the majority of employers would elect those that impose no or only minimal cost, for instance, reducing work intensity or changing work schedules. L&I further assumes that in other situations impacted employers would resort to respiratory program requirements under WAC 296-820-840 instead of implementing exposure controls in order to minimize disruptions to work (outlined in section 2.2.6), and in situations of extremely high $PM_{2.5}$ levels, which is hazardous to health, employers could simply stop work to ensure worker safety. As a result, impacted employers are not expected to incur any cost from this subsection.

2.2.6 Cost of respiratory protection

WAC 296-820-840 and 296-307-09840 addresses employer requirements regarding respiratory protection. L&I only assessed the components of these sections which have a cost implication for impacted businesses. First, at $PM_{2.5}$ levels of 35.5 µg/m^3 (AQI 101) to 250.4 µg/m^3 (AQI 300) employers must provide, and encourage the use of, N95 filtering-facepiece respirators to all exposed employees either directly or by maintaining a sufficient supply at each worksite where exposure occurs. Second, at $PM_{2.5}$ levels of 250.5 µg/m^3 (AQI 301) to 500.3 µg/m^3 (AQI 499) employers must distribute N95 filtering-facepiece respirators directly to each exposed employee. Similar to the first requirement, employers must also encourage the use of the respirator by exposed employees. Third, $PM_{2.5}$ levels of 500.4 µg/m^3 (AQI 500) to 554.9 µg/m^3 (beyond the AQI) require employees to be enrolled in a complete Respiratory Protection Program (RPP). Employers must provide, and require the wearing of, either (a) N95 filtering-facepiece respirator, (b) half-facepiece air purifying respirator equipped with P100 filters, or (c) other respirators equipped with P100 filters with an Assigned Protection Factor (APF) of 10 or greater. At this threshold employees who are exposed for a total of 15 minutes or less during a 24-hour period are exempt. Fourth, where the current $PM_{2.5}$ level is at least 555 µg/m^3 employees must be enrolled in a complete RPP (in accordance with chapter 296-842 WAC). At these levels, employers must provide, and require to be worn, a respirator equipped with a P100 filter which is either a (a) loose-fitting powered air purifying, (b) full-facepiece air purifying, (c) full-facepiece powered air purifying, or (d) other respirators with an APF of 25 or more, such that the $PM_{2.5}$ levels inside the respirator are less than 55.5 µg/m^3. See Table 2.6 for a list of the respirator requirements at the stated thresholds.

Table 2.6. Respirator requirements at different $PM_{2.5}$ thresholds[31]

Respirator options	$PM_{2.5}$ ($\mu g/m^3$)			
	35.5 - 250.4	250.5 - 500.3	500.4 - 554.9	≥ 555
N95 filtering-facepiece	*	*	*	
Half-facepiece air purifying respirator equipped with P100 filter			*	
Other respirator equipped with P100 filter with an APF of at least 10			*	
Loose-fitting powered air purifying respirator w/ P100 filter				*
Full-facepiece air purifying respirator w/P100 filter				*
Full-facepiece powered air purifying respirator w/P100 filter				*
Other respirator with an APF of at least 25				*

Below we address each requirement within this subsection for cost implication.

i. $PM_{2.5}$ levels of 35.5 $\mu g/m^3$ (AQI 101) to 250.4 $\mu g/m^3$ (AQI 300)

Compliance with this proposed subsection would require employers to purchase and have available for use N95 respirators for all exposed employees. Here, employers are not required to distribute the respirators but simply to provide them and encourage employees to use them. The cost of compliance would be for the purchase of the respirators. The total number of respirators needed is a function of how many days those respirators would be needed and how many employees would need them. Historical data shows there were an average of 9.64 days during wildfire season that the daily maximum $PM_{2.5}$ was in this range,[32] and L&I assumes this will not change significantly over the next few years. The number of exposed employees at these levels is estimated at 316,339 annually over the next eight years. Each employee is assumed to require one mask per work day. Given the average cost of a typical N95 respirator of $0.40 to $1.40, the number of impacted employees, and the typical number of days when the $PM_{2.5}$ levels are at the trigger threshold, L&I estimates impacted businesses would incur approximately $857,959 to $3,002,856 each year over the model period.

ii. $PM_{2.5}$ levels of 250.5 $\mu g/m^3$ (AQI 301) to 500.3 $\mu g/m^3$ (AQI 499)

This subsection requires employers to distribute N95 respirators directly to each exposed employee. L&I anticipates that not all respirators purchased by employers as a result of requirement (i) above would have been used by employees as they are only encouraged, but not required, to use them at that specific $PM_{2.5}$ level, and there would be a sufficient quantity of N95 respirators available to be distributed to employees exposed at concentration listed in this subsection. Therefore, there is no cost for purchasing additional respirators, and any new cost associated with this requirement would be the time it takes the employer to actually distribute the

[31] At each PM level, the asterisk (*) indicates which respirator is an option the employee could use.
[32] This represents the calendar days. L&I used business days (calendar days minus weekends and holidays) in the calculation of the cost impact.

respirators. Distributing respirators directly to employees is not expected to take any significant time as employers would simply place the respirators in a common area and instruct employees to take one, or hand them out at the beginning of each shift. As a result, L&I estimates this would impose minimal to no cost on impacted businesses.

iii. $PM_{2.5}$ levels of 500.4 µg/m^3 (AQI 500) to 554.9 µg/m^3 (beyond the AQI)

At this $PM_{2.5}$ level, employers are required to enroll impacted employees in a complete respiratory protection program (RPP) in accordance with chapter 296-842 WAC. Employers must also provide and require to be worn either (a) N95 filtering-facepiece respirators, (b) half-facepiece air purifying respirators equipped with P100 filters, or (c) other P100 filter equipped respirator with assigned a protection factor of at least 10.

Consistent with prior sections, L&I assessed cost for this component in an 8-year model period. This requirement imposes two main cost components on impacted businesses – (1) cost of the respirators; and the cost of enrolling employees in a RPP, and its associated costs.

First, we determined how many employees would likely be exposed at these $PM_{2.5}$ concentrations. The increasing risk of negative health effects with each increase in $PM_{2.5}$ levels, means that the number of workers exposed at higher levels of $PM_{2.5}$ concentrations would be lower/reduced as employers act to address worker safety or because of operational constraints. As $PM_{2.5}$ levels rise to this extremely hazardous level L&I believes that there would be a specific set of occupations or employees deemed mission critical who would not necessarily be able to avoid work in these conditions. These are expected to constitute a very small number, on average 5% in certain industries, of total impacted workers. We estimate on average 875 employees would be exposed at these levels each year.

In addition to the N95 filtering-facepiece respirators, employers would need to provide the option of the two other types of respirators on exposure days. In estimating a reasonable cost of this requirement, L&I assumes an average of one day each year when the $PM_{2.5}$ concentration was in this range, which is much higher than the historical data indicates. L&I also assumes that two N95 respirators would be needed per employee. Using this average number of days, the number of exposed employees, and the average cost of the respirator options, L&I estimates this would impose new cost of about $689 to $30,761 each year on impacted businesses over 8 years (see Table 2.7).[33]

Next, we determined the RPP cost component. The RPP into which employees must be enrolled has several aspects which would probably impose a cost on impacted businesses. These include development of a written program, medical evaluations, conducting fit-tests, and training. The probable costs an employer would face depend on the actual number of employees who need to be enrolled in the RPP.

$PM_{2.5}$ levels of 250.5 µg/m^3 (AQI 301) and above are considered hazardous with caution for everyone to avoid outdoor exertion, so fewer workers would be exposed at $PM_{2.5}$ concentrations of 500.4 µg/m^3 to 554.9 µg/m^3. At those concentrations most employers would either stop work

[33] Due to the uncertainty of the degradation/replacement rate of the P100 filter which is based on the variability of its use, L&I did not factor the cost of replacement P100 filters into this analysis.

or implement some level of exposure control, like adjusting working schedules. We assume that approximately 25% of employers would be subject to work in these conditions. At such elevated $PM_{2.5}$ levels, most of those impacted employers would most likely already have an established respiratory protection program as per requirements of chapter 296-842 WAC. L&I believes that only a small number, 5-10% of these employers would need to fully create and enroll employees in an RPP.

To estimate the cost to impacted businesses, L&I assessed the RPP components starting with the development and maintenance of a written program (WAC 296-842-12005). Given the assumptions to the number of impacted businesses and the average time of 2 to 4 hours to complete a typical written program, L&I estimates this component of the RPP to impose approximately $9,044 to $36,178 annualized on impacted businesses.

Medical evaluations

WAC 296-842-14005 outline the scope of the medical evaluations. L&I assumes that employees will either use an online/virtual service for their medical evaluation or it can be an employer conducted one. Medical evaluations must be done before each fit-test. Since fit-testing must be done at least annually, then medical evaluations will also be an annual requirement. Given the nature of the evaluation, L&I believes that businesses within the health and safety industry would have the necessary competencies and qualifications to conduct their own evaluations. All other industries are assumed to use an online or virtual option. The number of employees who would be part of an employer conducted evaluation is estimated to be approximately 1,087 over the 8 years. Given the average time of 15 to 20 minutes to complete an evaluation, the hourly wage of $55.70 and $94.04 for an employee and evaluator respectively, L&I estimates this component to impose approximately $4,568 to $6,091 annually on impacted businesses. The number of employees likely to complete an online evaluation is estimated to be 5,916. Using an average online cost of $29.00 for medical evaluations, $55.70 for employee wages, and 15 to 20 minutes per evaluation, the estimated annualized cost is approximately $293,225 to $390,966.

Fit-testing

WAC 296-842-15005 outlines the scope of the fit-testing requirements. This subsection requires, among other things, that a quantitative fit-test be conducted at least twelve months after initial testing. In determining the cost of fit-testing to impacted businesses, L&I used an average cost of $30 to $80 for a quantitative fit test, an employee hourly wage of $55.70 and an average time to complete a fit-test of 15 to 20 minutes. Based on these, L&I estimates annualized cost of $34,740 to $74,388 to impacted businesses.

Provide effective Training

WAC 296-842-16005 outlines the provisions and requirements around the training employees must receive. This is an annual requirement with which employees must comply. From the WAC's description, L&I estimates this training will take about 15 to 30 minutes per impacted employee per year. The number of impacted employees over the 8-year model period is approximately 7,003. Using the same employee hourly wage as above, plus the average time per training, L&I estimates this requirement to impose about $10,950 to $21,901 annualized on impacted businesses.

Based on the number of required respirators, and the individual components of the RPP enrollment likely to impose a cost, L&I estimates this aspect to cost employers approximately $353,216 to $560,285 each year over the model period (see Table 2.7).

Table 2.7. Respirator & enrollment cost at $PM_{2.5}$ levels of 500.4 µg/m3 to 554.9 µg/m3

	Cost factors	
Respirators	Number of days when $PM_{2.5}$ was 500.4 to 554.9 µg/m^3	1
	Number of employees impacted	7,003
	Average cost of an N98 face-filtering respirator	$0.40 - $1.40
	Average cost of an alternative respirator	$19.33 - $35.70
	Total cost of respirators	$6,126 - $273,356
	Annualized	$689 - $30,761
RPP enrollment	Written program	$67,500 - $270,002
	Employee medical evaluations	$2,676,843 - $3,569,123
	Quantitative Fit-testing	$307,938 - $690,689
	Effective training	$97,860 - $195,719
	Total cost of RPP enrollment	$3,156,267 - $4,621,293
	Annualized	$352,527 - $529,524
Overall	Total cost in 8 years	$3,156,267 - $4,998,889
	Annualized Costs	$353,216 - $560,285

iv. PM2.5 level is at least 555 µg/m3 (beyond AQI)

For $PM_{2.5}$ levels of at least 555 µg/m^3, employers must also enroll employees in a complete RPP, and provide, and require to be worn, P100 filter-equipped respirators which are either (a) loose-fitting power air purifying, (b) full-facepiece air purifying, (c) full-facepiece powered air purifying, or (d) assigned a protection factor of 25 or more such that inside of the respirators would be less than 55.5 µg/m^3.

Requirements of this proposed subsection confer on employers the responsibility to ensure employees impacted at these thresholds are enrolled in an RPP. L&I believes there would be no cost for this aspect in this subsection since employees would have already been enrolled in an RPP for compliance in the previous subsection which has a lower threshold. As a result, the cost employers would incur from this requirement is that of providing the new respirators to address the risks of employee exposures at the higher $PM_{2.5}$ levels. However, historical data shows there were no days when the $PM_{2.5}$ concentrations were at this level over the last 5 years except just a few days from certain locations in 2020 and only 2 days from Okanogan County in 2021. Furthermore, at these levels, L&I believes that similar to employer response in (iii) above, only mission critical or emergency response employees would be exposed, and employers would most

likely stop work or implement some other exposure control. As a result, impacted employers are not expected to incur any cost from this proposed requirement.

Total cost of respiratory protection

Overall, L&I estimates this proposed requirement to impose $1.2 to $3.6 million each year on impacted businesses over the model period (see Table 2.8).

Table 2.8. Total annualized cost of respiratory protections

Cost factor	Annualized cost
Respirators	$858,648 - $3,033,617
RPP enrollment	352,527 - $529,524
Total	$1,211,176 - $3,563,142

2.3 Summary of Total Costs

Overall, the proposed rule is estimated to impose approximately $10.7 million - $14.6 million on all impacted businesses each year over the model period (see Table 2.9).

Table 2.9. Total annualized costs

Section	Annualized costs	
	low	high
Identification of harmful exposures	$2,128,351	
Hazard communication	$536,536	$1,216,053
Information and training	$6,790,040	$7,673,272
Respiratory protection	$1,211,176	$3,563,142
Total	**$10,666,102**	**$14,580,817**

Chapter 3: Probable Benefit of the Proposed Rule

3.1 Background of health impact of wildfire smoke

Causal relationship between $PM_{2.5}$ and health outcomes

The EPA has set National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) pollution. Across the disciplines of epidemiology, controlled human exposure studies, and animal toxicology, there is substantial scientific evidence that exposure to ambient particulate matter can result in a range of health effects. While certain individuals, like the elderly or those with preexisting respiratory and heart-related illness, are more susceptible to negative health reactions, even healthy individuals can get sick if there is enough exposure to smoke.

The EPA has developed a five-level hierarchy to describe the relationship between exposure to $PM_{2.5}$ and potential health impacts: 1) causal; 2) likely to be causal; 3) suggestive of but not sufficient to infer a causal relationship; 4) inadequate to infer the presence of a causal relationship; and 5) not likely to be causal. The designations incorporate the weight of evidence across disciplines as well as biologic pathway plausibility. Because health impacts are modified by duration of exposure, a distinction is made between short-term (hours up to approximately one month) and long-term (one month to years) exposure (EPA 2019).

The causal relationship between exposure to $PM_{2.5}$ and various health effects including respiratory, cardiovascular, and nervous systems as well as cancer and all-cause mortality are summarized below. The synopsis has a focus on short-term (such as would be expected during a wildfire event) exposure duration to $PM_{2.5}$ and studies that include all ages or adults (working age) rather than children.

Respiratory effects

The finding that there is a ***likely to be causal*** relationship between short-term $PM_{2.5}$ exposure and respiratory health effects was first established in the EPA's 2009 Integrated Science Assessment for Particulate Matter (ISA PM) and continued support for this relationship was found in the EPA's 2019 ISA PM and the EPA's 2022 Supplement (EPA 2009, EPA 2019, EPA 2022). The causality determinations were based on the consistency of findings within disciplines, as well as the coherence of evidence across epidemiologic and animal toxicological studies and the evidence supporting biologically plausible pathways for respiratory effects (U.S. EPA 2022). In terms of the epidemiological studies, multiple studies demonstrated generally consistent, positive associations for health outcomes of asthma, Chronic Obstructive Pulmonary Disease (COPD), and combined respiratory-related diseases as measured by Emergency Department (ED) visits and hospitalization following exposure to short-term $PM_{2.5}$. The U.S. EPA's overall summary of association between short-term $PM_{2.5}$ exposure and respiratory-related hospital admissions and emergency department visits includes 24 studies total. There are 18 relative risk estimates for an association between exposure and a respiratory health effect in populations of all ages (17 positive associations, 1 null association). Furthermore there are six risk estimates for population

ages 19 or under (5 positive, 1 null), and 15 risk estimates for elderly population (10 positive, 4 inconsistent, 1 null) (Figure 5-8, U.S. EPA 2019 and U.S. EPA 2018a).

More specifically, for asthma hospital admissions, there are four relative risk estimates that are positively associated for populations that are all ages, with an additional 12 risk estimates from studies with children or the elderly (11 positive, 1 inconclusive) (Figure 5-2, U.S. EPA 2019). For asthma emergency department visits, there are 14 estimates for all ages (13 positive, 1 inconclusive); with an additional 10 estimates in studies with children or elderly populations (8 positive, 1 inconsistent, 1 null) (Figure 5-3, U.S. EPA 2019). For COPD hospital admissions and ED visits, there are 10 estimates for all ages (6 positive; 2 inconsistent, and 2 null); seven estimates for the elderly (all positive); and three additional estimates for ages greater than 35 and ages greater than 15 (all positive) (Figure 5-6, U.S. EPA 2019).

Cardiovascular health effects

Scientific evidence indicates a ***causal relationship*** between short-term $PM_{2.5}$ exposure and cardiovascular effects (U.S. EPA 2022). Evidence from animal toxicological, controlled human exposure, and epidemiological studies points to two possible biologically plausible pathways by which short-term $PM_{2.5}$ exposure could lead to cardiovascular effects. The first proposed pathway begins with inflammation in the respiratory tract which leads to systemic inflammation. The second pathway starts with sensory nerve systems in the respiratory tract, which when activated, can lead to modulation of the autonomic nervous system. Once these pathways are initiated, a series of pathophysiological responses may occur that can lead to cardiovascular endpoints such as emergency department (ED) visits and hospital admissions for Ischemic Heart Disease (IHD) and heart failure, and ultimately mortality (U.S. EPA 2022, U.S. EPA 2019 Figure 6-1).

The causality determination is supported by generally positive associations from epidemiologic studies, as well as by experimental evidence from controlled human exposure and animal toxicological studies (U.S. EPA 2022). Among the epidemiological evidence are large nationwide Medicare studies, multicity U.S. studies conducted in the Northeast and across the U.S., and multicity Canadian studies all showing positive associations between short-term $PM_{2.5}$ concentrations and ED visits and hospital admissions for ischemic heart disease (IHD), heart failure, and/or combined cardiovascular-related endpoints. Single-city epidemiological studies contributed additional support for causality but were generally less consistent with findings that were positive as well as findings that were null (U.S. EPA 2022).

The epidemiological evidence for short-term $PM_{2.5}$ exposure and hospital admissions and ED visits for ischemic heart disease reviewed by the U.S. EPA include 23 studies with 53 risk estimates for association (32 positive, 12 null, 9 inconclusive) (Figure 3-1 in U.S. EPA 2022 and Table S6-1 in U.S. EPA 2018b). The epidemiological evidence for short-term $PM_{2.5}$ and hospital admissions and ED visits for heart failure include 15 studies with 27 risk estimates for association (20 positive, 3 null, and 4 inconclusive) (Figure 3-3 in U.S. EPA 2022 and Table S6-3 in U.S. EPA 2018b). The evidence for short-term $PM_{2.5}$ exposure and hospital admissions and emergency department visits for arrhythmia include 12 studies with 20 risk estimates for association (12 positive, 2 null and 6 inconclusive) (Figure 3-4 in U.S. EPA 2022 and Table S6-4 in U.S. EPA 2018b).

Mortality

Strong evidence supports that there is a ***causal relationship*** between short-term $PM_{2.5}$ exposure and total (non-accidental) mortality. Several multicity epidemiological studies across the U.S., Canada, Europe and Asia show consistent, positive associations between short-term $PM_{2.5}$ exposure and total (non-accidental) mortality as well as cause-specific respiratory and cardiovascular mortality (U.S. EPA 2022). The evidence includes studies conducted in urban settings reliant on PM monitors for exposure assessment as well as studies conducted in mixed urban/rural areas using monitoring, satellite and land use regression exposure assessments. For the association between short-term $PM_{2.5}$ exposure and total (non-accidental) mortality, the multicity studies reviewed by the U.S. EPA included 32 studies and 33 estimates (32 positive associations, 1 inconclusive) (Figure 3-13, U.S. EPA 2022). For the association between short-term $PM_{2.5}$ exposure and cardiovascular mortality 16 multicity studies including two meta-analyses were reviewed (15 positive, 1 inconclusive) and for respiratory mortality 17 studies including two meta-analyses were reviewed (14 positive, 3 inconclusive) (Figure 3-14, U.S. EPA 2022). The finding that cause-specific mortality is associated with $PM_{2.5}$ exposure is congruent with the evidence for an association between $PM_{2.5}$ exposure and total (non-accidental) mortality because total (non-accidental) mortality is comprised of approximately 33 percent cardiovascular mortality and approximately nine percent respiratory mortality (NHLBI 2017, U.S. EPA 2022). Thus, the cause-specific mortalities attributed to short-term $PM_{2.5}$ exposure further supports the associations found in the multicity studies between short-term $PM_{2.5}$ and total mortality. Evidence for biologically plausible mechanisms that could lead to mortality was coherent across the scientific disciplines of toxicological, controlled human, and epidemiological studies (U.S. EPA 2022). The biological plausibility for $PM_{2.5}$-related cardiovascular mortality was strong with morbidity related to ischemic events and heart failure leading to ED and hospital admissions. Meanwhile the biological plausibility for respiratory mortality was limited with less evidence for initial events and subsequent endpoints such as chronic obstructive pulmonary disease (COPD) and asthma (U.S. EPA 2022).

Nervous system

The U.S. EPA's characterization of health effects to the nervous system from exposure to short-term $PM_{2.5}$ is deemed ***suggestive of, but not sufficient to infer*** (U.S. EPA 2019). For short-term exposure to $PM_{2.5}$, the strongest evidence for an effect is seen through toxicological animal studies that show effects on the brain. Epidemiological studies showing a positive association are very limited. A single U.S. epidemiological study of Medicare enrollees found a positive association with Parkinson's disease (RR 1.03 [95% CI: 1.01, 1.05]), but not with Alzheimer's disease or dementia (Zanobetti et al. 2014, U.S. EPA 2019). Meanwhile a small study in Madrid, Spain showed no association between short-term $PM_{2.5}$ exposures and hospital admissions for dementia-related diagnoses (Linares et al 2017, U.S. EPA 2019).

The evidence for effects on the nervous system is somewhat stronger when the exposure to particulate matter is long-term. The relationship for nervous system health effects from exposure to long-term $PM_{2.5}$ is likely to be causal (U.S. EPA 2019). For long-term exposure to $PM_{2.5}$, there is evidence of a positive association from at least seven animal studies and six human adult epidemiological studies. The toxicological animal studies show a link between exposure-mediated activation of the sympathetic nervous system and subsequent cardiovascular effects. The evidence for neuroinflammation is supported and coherent across both animal studies and

epidemiologic studies. Toxicological studies in adult animals show neuroinflammation, neurodegeneration, impaired learning and memory, altered behavior, and indicators of Alzheimer's disease. Meanwhile epidemiological studies show associations for reduced cognitive function and neurodegeneration in adult populations (Table 8-20, U.S. EPA 2019).

Cancer

The scientific weight of evidence supports the notion that the relationship between long-term exposure to $PM_{2.5}$ and cancer is ***likely to be causal*** (U.S. EPA 2022). Experimental studies indicate genotoxicity, epigenetic effects, and increased carcinogenic potential are all associated with long-term $PM_{2.5}$ exposure. Additionally, epidemiological studies provide strong evidence for increased lung cancer incidence and mortality. The epidemiological studies on lung cancer include 18 risk estimates for cancer mortality (15 with a positive association, 3 inconsistent); eight for cancer incidence (6 positive, 2 inconsistent); and four meta-analyses each compiling 6 to 14 studies and all showing a positive association for either lung cancer mortality or lung cancer incidence (Figure 10-3, U.S. EPA 2019). These epidemiologic studies were diverse in terms of both geographic coverage as well as population characteristics such as men, women, and mixed. Other cancers, such as breast, brain, liver, leukemia, and multiple cancers have been studied; collectively the associations from these studies provide inconsistent evidence of an association with long-term $PM_{2.5}$ exposure and cancer in organs other than the lungs (U.S. EPA 2019).

Toxicity of particulate matter from wildfire smoke

While the toxicity of wildfire-specific PM compared to ambient sources of PM is not well understood, there is some evidence from animal toxicological studies that wildfire PM is more toxic than equal doses of ambient PM (Wegesser 2009, Kim 2018). Wildfire smoke includes a high proportion of carbonaceous compounds, which generate free radicals, in turn leading to inflammation and oxidative stress that is greater than what occurs with urban ambient particulate matter generated from the same region (Karthikeyan 2006, Williams 2013). At the population level, Aguilera et al. studied respiratory hospitalization data in Southern California and was able to compare hospitalizations attributed to wildfire-specific $PM_{2.5}$ versus non-wildfire $PM_{2.5}$, using spatial resolution at a relatively fine (zip-code) level for successive wildfire events spanning 14 years (Aguilera 2021). In their study, they concluded that hospitalizations from exposure to wildfire-specific $PM_{2.5}$ increased from 1.3% (95% CI 0.37-2.19) to 10% (95% CI 3.5-16.5) with a 10 $\mu g/m^3$ increase in wildfire–specific $PM_{2.5}$ compared to a smaller increase in hospitalizations of 0.67% (95% CI 0.48 – 0.86) to 1.3% (95% CI 0.97-1.7) associated with non-wildfire $PM_{2.5}$ (Aguilera 2021).

More generally, there is a body of epidemiological evidence showing consistency for a positive association between wildfire-smoke PM exposure and adverse health outcomes. Three systematic reviews on worldwide wildfire-specific exposure and health outcomes demonstrate consistent evidence for a positive association between wildfire smoke exposure and all-cause mortality as well as respiratory health (Youssouf et al. 2014, Liu et al. 2015, Reid et al. 2016). An additional four studies, all conducted in Washington State, found positive associations between wildfire-specific exposure and mortality (Doubleday 2020, Liu 2021) and respiratory morbidity (Gan et al. 2017, McDermot et al. 2022). In terms of cardiovascular outcomes, a systematic review by Liu et al. noted that while there was inconsistent association for

cardiovascular morbidities globally, five out of six studies in the U.S. did find a significant impact for wildfire-specific exposure and cardiovascular outcomes (Liu et al. 2015). Since Liu's systematic study in 2015, an additional three U.S. studies show a positive association between wildfire smoke and cardiovascular outcomes (Wettstein 2018, DeFlorio-Barker 2019, Jones 2020).

Consistent with the stated health effects of general exposure to wildfire smoke, several studies examining claims for different health effects following wildfire smoke exposure in Washington state show an increase in medical and emergency department visits following wildfire smoke exposure. McDermot and Kadlec studied asthma claims following wildfire smoke exposure in Washington and reported that a one-day increase of 10 $\mu g/m^3$ was associated with a 3% increase in medical claims for asthma for 10 days following exposure, and a 2% increase in emergency department visits on the same day of exposure (McDermot 2022). Arriagada, et al. also conducted a systematic review and meta-analysis, revealing that $PM_{2.5}$ levels from landscape fire smoke were positively linked to hospitalization and emergency department (ED) visits for asthma (Arriagada 2019). Scientific evidence indicates a causal relationship between short-term $PM_{2.5}$ exposure and cardiovascular effects (U.S. EPA 2022). Evidence from animal toxicological, controlled human exposure, and epidemiological studies points to two possible biologically plausible pathways by which short-term $PM_{2.5}$ exposure could lead to cardiovascular effects. The first proposed pathway begins with inflammation in the respiratory tract which leads to systemic inflammation. The second pathway starts with sensory nerve systems in the respiratory tract, which when activated, can lead to modulation of the autonomic nervous system. Once these pathways are initiated, a series of pathophysiological responses may occur that can lead to cardiovascular endpoints such as emergency department (ED) visits and hospital admissions for ischemic heart disease (IHD) and heart failure, and ultimately mortality (U.S. EPA 2022, U.S. EPA 2019 Figure 6-1).

In a health impact assessment of the 2020 Washington wildfire smoke episode estimating excess mortality attributable to increase $PM_{2.5}$ concentrations, Liu et al. reported that with odds ratio of wildfire smoke days 13-day exposures lead to 38.4 increased all-cause mortality cases and 15.1 increased respiratory mortality cases attributable to the wildfire smoke episode (Liu 2021). A variety of epidemiological studies across the U.S., Canada, Europe and Asia show consistent, positive associations between short-term $PM_{2.5}$ exposure and total (non-accidental) mortality as well as cause-specific respiratory and cardiovascular mortality (U.S. EPA 2022).

Risk assessment for impact of wildfire smoke on health outcomes

Relative risk (RR) is a ratio of the probability of an event occurring to the exposed group versus that probability to the non-exposed group. In the context of this rule, relative risk is the ratio of the probability of an individual becoming ill with a higher pollution level to the probability of that individual being ill with a lower pollution level. So it can measure the effect or probable effect of a treatment or variable to which a person is exposed. Several studies present different relative risk ratios for wildfire smoke exposure based on various study parameters. Separate studies by Gan et al. and Heaney et al. explored the RR of asthma hospitalization in individuals exposed to smoke (Gan 2017, Heaney 2022). In other literature the RR for diagnosing asthma while requiring an emergency department visit when individuals are exposed to smoke is investigated (ATSDR 2006; Peel 2005; Sarn 2015). However, the study conducted by Arriagada

et al. provides the most pertinent RR for our analysis, with an estimated value of 1.08 for risk of hospitalization and 1.07 for risk of emergency department visit related to asthma (Arriagada 2019). This suggests an elevated risk of asthma hospitalization in individuals exposed to wildfire smoke. Numerous studies have estimated RR for hospitalization due to Ischemic Heart Disease (IHD). These studies include those by Stieb (2009), Talbott (2014), Milojevic (2014), Sarnat (2015), Bell (2015), Weichenthal (2016), Krall (2018), and Leiser (2019). Additionally, Zanobetti et al. estimated the RR for emergency hospitalization associated with exposure to smoke and $PM_{2.5}$ to be 1.02 (U.S. EPA 2018b, Table S6-1). Among a vast majority of studies around the impacts of $PM_{2.5}$ concentrations exposure on Chronic Obstructive Pulmonary Disease (COPD), Slaughter et al. analyzed the RR for COPD hospitalizations due to exposure to smoke in Spokane WA (Slaughter 2005). However Gan et al. contains the RR for the entire state of Washington (Gan 2017). Furthermore, there have been numerous studies examining the likelihood of diagnosing someone with COPD visiting the emergency department after being exposed to smoke (Malig 2013, Peel 2005, Sarnat 2015, and Weichenthal 2016).

For our analysis, L&I relies upon those ratios which it believes apply to the set of scenarios being impacted by the proposed rule. These RR measures the change in risk for each 10 $\mu g/m^3$ change in $PM_{2.5}$ concentrations. Table 3.1 illustrates the list of RR and their most relevant source. When choosing a risk estimate, priority is placed on studies that are meta-analyses, multi-city, located in North America, and measure landscape or wildfire smoke. In reviewing the literature, studies summarized by the U.S. EPA for exposure to short-term ambient $PM_{2.5}$ were considered, along with contemporary studies that measured health effects associated with exposure to $PM_{2.5}$ from landscape fire (U.S. EPA 2019, U.S. EPA 2019(a), U.S. EPA 2019(b), U.S. EPA 2019(c), EPA 2022).

Table 3.1. Relative risk ratio literatures

Health Outcome	RR[34]	Reference	Study attributes
Asthma Hospitalization	1.08	Arriagada 2019	Meta-analysis of US landscape fire data
IHD Hospitalization	1.02	Zanobetti and Schwartz 2009	Multi-city US study
COPD Hospitalization	1.084	Gan 2017	WA state study on wildfire smoke
Asthma ED Visit	1.07	Arriagada 2019	Meta-analysis of US landscape fire data
IHD ED Visit	1.01	Kloog 2014	Multi-city US study
COPD ED Visit	1.02	Weichenthal 2016	North American study
Mortality (All Non-accidental)	1.0094	Atkinson 2014	Meta-analysis World Health Organization Region AMR A
Medication for Asthma and COPD	1.06	Elliott 2013	North American study specific to wildland fire smoke
Nonfatal Lung Cancer	1.43	Atkinson 2014	Meta-analysis World Health Organization Region AMR A

3.2 Quantitative benefits

[34] All risk estimates used in our analysis came from studies in which the estimates were found statistically significant using 95% confidence intervals.

3.2.1 Methods and Data for Benefit Estimate

Estimate of adverse health outcome associated with wildfire smoke

When analyzing the benefits of prevented or reduced numbers of injuries or illnesses from a proposed rule, L&I typically draws on workers compensation (WC) claims from its administrative data warehouse. For this rule, L&I did not use the claims data for the following reasons.[35] First, there may be a large proportion of relevant claims that are unidentified due to the inadequate or missing description of the claims or events. Second, there may be under-reporting of this type of claim.[36] Third, various studies have shown that there may be a significant lag between the time a worker is exposed to wildfire smoke and when they develop symptoms or need medical treatment. It could take months or years for them to submit their claims, which may complicate determining the cause of these illness claims. Last, it is difficult to distinguish wildfire smoke related claims from general smoke claims (like house fires) without detailed file reviews.

In light of these facts, L&I relied upon a wealth of epidemiologic studies that examined the health impact of wildfire smoke and the so-called Health Impact Function from Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE) model that EAP has developed for the estimate of health impacts from changes in air pollution concentrations. Specifically, the health impact function is expressed as:

$$\Delta Y = Yo * (1 - \exp(-\beta * \Delta PM)) * POP$$

Where:

- ΔY is the outcome of interest, which is the change in the health incidents due to the change in PM.
- Yo is the health baseline incidence rate measuring the average number of people who suffer from a specific adverse health effect in a given population over a given period of time
- exp is the exponential function with base e (Euler's number).
- β is the effect estimate measuring the percentage change in the risk of an adverse health effect due to a one unit change in ambient air pollution.
- ΔPM is the change in air quality based on a particulate matter (such as $PM_{2.5}$ and PM_{10}), and,
- POP is the exposed population.

To estimate the impact of wildfire smoke on each of the seven health outcomes discussed in Section 3.1, L&I needs to determine the values of each parameter in the health impact function:

- The baseline incidence rate for each health outcome is obtained from Washington Tracking Network (WTN) online database. Where the data is unavailable for a specific health outcome, an alternative data source is used (see Table 3.2).

[35] L&I did query the claim data using keywords parameters like wildfire or smoke, and 83 claims showed up within the last five and a half year. Due to the reasons described in the text, this result was not used in this analysis.

[36] See Pransky (1999), Fan, et al., (2006), and the preliminary CBA for Outdoor Heat Exposure Rule (2023).

- β for each health outcome is derived from the relative risk (RR) ratio listed in Table 3.1. Assuming the underlying relationship between the change in concentration of $PM_{2.5}$ and the change in population health response is in a log-linear form, β=LN(RR)/ ΔPM.[37]

- The exposed population is the number of workers that are likely affected by the rule. The method and the result for this variable is discussed in Section 1.6.

Table 3.2. Baseline incidence rate for various health effects

Health Outcome	Baseline Incidence Rate (per 100 persons per year	Data Source
Asthma Hospitalization	0.0433	WTN: for age group 15-64 and years of 2010-2014.[38]
IHD Hospitalization	0.1576	WTN: for age group 35-64 and years of 2016-2020.
COPD Hospitalization	0.0453	WTN: for age group 15-64 and years of 2016-2020.
Asthma ED Visit	0.4110	CDC: for adults and years of 2016-2018.
IHD ED Visit	0.3929	Healthcare Cost and Utilization Project (HCUP) for age group 18-64, years of 2011-2014.[39]
COPD ED Visit	0.4139	American Lung Association: for all age, years of 2016-2019.
Mortality (All Non-accidental)	0.3998	CDC: for all working age, years of 2016-2020
Nonfatal Lung Cancer	0.0140	American Lung Association: Washington State, 2020

The ΔPM was calculated using estimates of exposure reductions from a combination of respiratory protection usage rates, respirator effectiveness, administrative controls, engineering controls, and behavioral changes from training.

Two sets of ΔPM values were calculated to represent the range of interventions employers may implement at the worksites.

- Low estimate: Scenario with employers following the minimum requirements of the rule. Low uptake of voluntary use respirators at lower $PM_{2.5}$ levels, and moderate uptake at

[37] See Appendix C: Deriving Health Impact Functions of BenMAP User's Manual (January 2022 version).
[38] The 2016-2020 data for asthma hospitalization is suspicious, and 2015 data is not available. Therefore, 2010-2014 average is used as the proxy for this variable.
[39] The data is only available for cardiovascular as a whole so we assume IHD ED visits accounts for 1/3 of the total ED visits for cardiovascular on average. See Table D-6 in BenMAP manual for more details (January 2022 version).

higher $PM_{2.5}$ levels. Assumes the moderate range of effectiveness of unfitted N95 respirators with 50% penetration of particles across the population.

- High estimate: Scenario where employers and workers are taking the risks of wildfire smoke seriously, with good uptake of available engineering, administrative, and respiratory controls by the employer and employees. Moderate uptake of voluntary use respirators at lower $PM_{2.5}$ levels, and 100% of employees using respirators above 125.5 $\mu g/m^3$. Assumes the high estimate of unfitted N95 respirator effectiveness with 33% penetration of particulates across the population to represent efforts to ensure a proper respirator seal.

The low estimate indicates that the requirements in the rule, when implemented properly, generally keep worker exposures below 55 $\mu g/m^3$. This however does not hold for exposures between 125.5 $\mu g/m^3$ and 500.3 $\mu g/m^3$ as at those high levels, the controls available cannot reliably keep exposures below 55 $\mu g/m^3$ with significantly elevated exposures toward the higher end of that range. At 500.4 $\mu g/m^3$ and above, employers are required to implement a required use respiratory protection program, including fit-testing, which again reduces exposures below 55.5 $\mu g/m^3$.

The high estimate indicates that the requirements in the rule, when implemented properly and with high uptake of available administrative, engineering, and respiratory controls, can keep worker exposures generally below 25 $\mu g/m^3$. This again does not hold for exposures between 125.5 $\mu g/m^3$ and 500.3 $\mu g/m^3$ with significant exposures toward the higher end of that range. At 500.4 $\mu g/m^3$ and above, the required use respiratory protection program again reduces exposures below 25 $\mu g/m^3$.

In addition, L&I relies on the distribution of days by each $PM_{2.5}$ level to calculate the cumulative health effect for the entire period. The examination of the same air quality data described in Section 2.1 reveals that on average, the daily average $PM_{2.5}$ concentration was at or below 20.5 $\mu g/m^3$ (AQI $\leq$69) for about 96.7% of time, and only 1.5% of time at or above 35.5 $\mu g/m^3$ (AQI $\geq$101, considered as unhealthy for sensitive groups or higher) during the whole year. Table 3.3 below presents the breakdown statistics in each specific $PM_{2.5}$ range.[40]

Table 3.3. Distribution of time by daily average $PM_{2.5}$ in Washington State, 2017-2021

Daily average $PM_{2.5}$ ($\mu g/m^3$)	% of time each year[41]
$\leq$20.5	96.67%
20.5 - 35.4	1.84%
35.5 - 45.4	0.38%
45.5 - 55.4	0.27%
55.5 - 65.4	0.16%
65.5 - 75.4	0.11%

[40] The daily average was calculated based on the 17-hour period per day from 5 am to 9 pm, and these statewide numbers were the employment-weighted averages from each county where the air quality monitors are located.

[41] Statewide average weighted by employment share in each county.

75.5 - 85.4	0.07%
85.5 - 95.4	0.07%
95.5 - 105.4	0.06%
100.5 - 115.4	0.04%
115.5 - 125.4	0.03%
125.5 - 150.4	0.09%
150.5 - 200.4	0.15%
200.5 - 250.4	0.03%
250.5 - 350.4	0.02%
350.5 - 450.4	0.01%
450.5 - 500.4	0.005%
500.5 - 554.9	0.002%
≥555	0.0004%
Total	100.0%

Based on these estimates and the health impact function discussed above, L&I estimates the number of incidents that can be potentially avoided for each adverse health outcome if the intervention measures proposed in this new rule (exposure control, respiratory protection, information and training, etc.,) can successfully result in affected workers' exposure to $PM_{2.5}$ from an unhealthy or hazardous level to a much safer level (between 20.5 $\mu g/m^3$ to 55.5 $\mu g/m^3$ depending on the actual $PM_{2.5}$). Table 3.4 below presents the number of WFS related incidents that could be potentially prevented as a result of the implementation of the proposed rule for each relevant health outcome.

Table 3.4. Estimates of the Preventable Incidents by Each Health Outcome

Health Outcome	Number of incidents preventable by the rule each year (between 2023 – 2030)
Asthma Hospitalization	0.78 - 1.28
IHD Hospitalization	0.87 - 1.49
COPD Hospitalization	0.85 - 1.39
Asthma ED Visit	6.70 - 11.01
IHD ED Visit	1.13 - 1.95
COPD ED Visit	2.28 - 3.91
Mortality (All non-accidental)	1.08 - 1.87
Nonfatal Lung Cancer	0.76 - 1.12

Using the same method, L&I also estimates that the rule could reduce the annual cost of medication for asthma by $8.39 - $12.67, and medication cost for COPD by $8.29 - $12.52 for every affected worker who has asthma or COPD and takes medications regularly to control these health issues.[42]

3.2.2 Estimate of unit cost per health event

The other component that L&I needs to calculate the total benefit of the rule is the unit cost per event (hospitalization, ED visit, or death) that can be avoided for each of the health outcomes analyzed in Section 3.2.1. Lacking state-specific data, L&I adopted the estimates available to us from the following data sources that are considered reliable and relevant.

- For the medical costs of hospitalizations and ED visits for asthma and COPD, L&I mainly relies on a CDC report that examined the medical expenditures attributed to these two diseases among U.S. workers between 2011 and 2015 (Syamlal et al. 2020)[43]. The average medical costs from that report were then adjusted for inflation.
- For the unit cost of each hospitalization for IHD, L&I mainly relies on a report that systematically reviewed the medical costs with heart failure in the USA between 2014 and 2020 (Urbich et al. 2020). The average medical cost from that report was then adjusted for inflation.
- For the unit cost of each ED visit for IHD, L&I relies on the data from the Healthcare Cost and Utilization Project (HCUP),[44] adjusting the cost for inflation.
- For the unit cost of treating each lung cancer, L&I relies on a 2021 EPA report referencing a study from Kaye et al. (2018). It is the 5-year medical cost per lung cancer.
- For Value of Statistical Life (VSL), L&I relies on the result from Viscusi (2004) and adjusts the VSL value for inflation.
- For each hospitalization and ED visit, L&I adopted the indirect cost to direct medical cost ratio of 4.1 and 1.6 respectively from the Cost-Benefit Analysis for Outdoor Heat Rule given the similarity of heat related incidents and the incidents analyzed in this report.[45]

The table below summarizes the unit cost information for each health outcome.

[42] Data source for the annual medication costs for asthma and COPD: Nurmagambetov (2017) and Maleki-Yazdi (2012).

[43] The average cost per asthma ED visits is from Wang et al. (2014).

[44] See more details in BenMAP Manual (January 2022 version) about this data: "The 2016 Nationwide Emergency Department Sample (NEDS) provides recent, nationally representative information on medical treatment in emergency departments. In the case of emergency department visits, valuation estimates include only the medical costs.

[45] The indirect non-medical cost may include, but not limited to, any wages paid to injured or ill workers for absences, the overtime costs necessitated by the incidents, the administrative cost from supervisors, safety and health personnel, or other staff, the training costs for replacement workers, lost productivity related to work rescheduling, new employee learning curves, presenteeism, and accommodation of injured or ill workers.

Table 3.5. Estimate of total per-incident cost for each health outcome in 2023

Health Outcome	Medical cost per incident (2023$)	Indirect non-medical cost (2023$)	Total cost per incident (2023$)
Asthma Hospitalization	$10,531	$43,176	$53,706
IHD Hospitalization	$31,169	$127,792	$158,961
COPD Hospitalization	$35,252	$144,535	$179,787
Asthma ED Visit	$1,920	$3,072	$4,992
IHD ED Visit	$1,484	$2,375	$3,859
COPD ED Visit	$1,506	$2,409	$3,915
Mortality	$15,002,401		
Nonfatal Lung Cancer (nonfatal)	$42,184	$172,954	$215,138

3.2.3 Estimate of total quantified benefits

Based on the estimated health impact factors from Section 3.2.1.1 and 3.2.1.2, along with the projected growth of exposed population and the Washington workforce growth rate, L&I determines the estimated quantifiable benefits of the proposed rule to be $17.6 million to $27.8 million each year (see Table 3.6) on impacted businesses.

Table 3.6. Summary of quantifiable benefits from avoided health outcomes

Health Outcome	Annual Benefit (2023 $)
Asthma Hospitalization	$43,555 - 64,876
IHD Hospitalization	$142,823 - 223,228
COPD Hospitalization	$157,989 - 234,974
Asthma ED Visit	$34,584 - 51,855
IHD ED Visit	$4,488 - 7,105
COPD ED Visit	$9,228 - 14,447
Mortality (All Non-accidental)	$16,748,653 - 26,534,531
Medication for Asthma	$182,817 - 276,078
Medication for COPD	$100,777 - 152,199
Nonfatal Lung Cancer	$170,240 - 226,925
All Above	$17,595,155 - $27,786,218

3.3 Qualitative benefits

3.3.1 Limitations of health utilization measures

Hospitalizations, emergency department visits, and medication expenses represent only some of the total costs attributable to health care utilization in response to injury and illness. Expenses associated with outpatient clinic visits, for example, are also a common setting in which health care may be delivered, including for injuries and illnesses caused by wildfire smoke exposure.

In addition to direct medical costs for supplies and professional time, each of these care settings is also associated with nonmedical costs such as patient time traveling to and from the site of care, time waiting to be seen, and any uncompensated lost wages or lost leisure time necessarily taken to seek out and receive treatment.

Because not all injured or ill persons seek out health care at the same rates (or sometimes at all), health utilization measures such as these are proxy measures for the actual burden of injury and illness in society, and may therefore not reflect the full scope of costs to society of the health effects of occupational wildfire smoke exposure. The wildfire smoke rules' tangible and intangible benefits associated with prevented health effects is expected to be greater than those costs identified in this analysis.

3.3.2 Clarity of employer requirements and employee expectations

Adoption of the proposed rule would provide clarity and consistency to impacted industries. Clearly defining the responsibilities of employers removes any ambiguities and uncertainties in how they are required to act in order to protect employees exposed to wildfire smoke. In addition, employees would understand what protections they are required to receive in order to enhance their safety and health while exposed to wildfire smoke. This clarity should contribute towards better safety of workers and reduced compliance violations and/or penalties to employers.

3.3.3 Improved employee wellness at worksites

A change in wind direction can quickly increase $PM_{2.5}$ concentrations at worksites and increase the risk to employee health. Those who are trained to identify and properly respond to wildfire smoke exposure and related symptoms are less likely to suffer related injuries than employees who are not. Implementing the proposed rule with the required training components can increase employee confidence knowing they can better handle wildfire exposure situations. Knowing that their employer is required to provide prompt medical attention and must also take necessary action to address symptoms they may display which, if left unchecked, could result in immediate to long-term negative health effects, is also a positive to exposed employees. This reassurance may lead to a reduction in work anxiety and to an improvement in the health and wellness of affected workers.

3.3.4 Avoidance of pain and suffering

The accompanying psychological, mental and emotional costs of injuries (fatal and non-fatal) can have varying degrees of impact and duration on impacted families. For instance, family

members may have to shoulder the additional responsibility of providing care to the injured worker, which means a possible reduction in household income if this caregiver has to miss work days or hours as a result, or if school attendance or performance is impacted. By reducing potential and actual morbidity and mortality, unnecessary pain and suffering by both the employee and their families are avoided. The training and knowledge that employees receive about how to manage wildfire smoke exposure coupled with the exposure controls and the protective equipment that employers are required to provide, all contribute to employee protection.

In comparing the practice of monetizing the value of preventing and compensating fatalities in administrative regulations and tort law respectively, Posner et al. recommends that government agencies move in the direction of the courts and take into account factors such as dependents' pain and suffering, dread, emotional distress, and other general welfare losses (Posner 2005). They suggest, "These changes would make a dramatic difference for administrative practice, replacing the crude current effort to use a single value for statistical lives." The authors note that courts tend to award "noneconomic" damages for the deceased's pain and suffering prior to his or her death, as well as the emotional distress and loss suffered by dependents (Posner 2005).

3.3.5 Impact to productivity loss and quality of life

The costs that employers incur for medical and wage-replacement benefits of a health incident constitute the direct costs of wildfire smoke. Despite this, research has highlighted other expenses, known as uninsured or indirect costs and can include increased use of sick leave and decreased productivity resulting from workers' absence and a decline in coworkers' productivity upon the affected workers' return to work. By implementing wildfire smoke exposure controls—including supplying respirators to employees—the number of workers who sustain injuries or illness and file claims or seek out health care due to wildfire smoke can be reduced. This, in turn, can enhance the productivity of their coworkers.

Exposure to particulate matter can impact productivity through two distinct channels. Firstly, it can impair the physical functioning of the human body, leading to respiratory and cardiovascular diseases. This may reduce supply of labor, such as limiting workers' working hours, requiring them to take longer breaks or forcing them to temporarily or permanently leave the labor force. Secondly, air pollution can also affect the cognitive function of the human brain, resulting in a decline in the labor productivity, leading to reduced quality of labor output per unit of working time. In a labor market equilibrium, this effect may ultimately result in reductions in workers' unit wages as their marginal products of labor decrease (He and Ji, 2021).

Respirator use may help avert disease exacerbations triggered by wildfire smoke, and subsequently preserve quality of life which is a vital factor in pulmonary diseases like asthma and chronic obstructive disease (Ismaila 2013). Asthma adversely affects one's quality of life as it is associated with poor psychological health, compromised social functioning, reduced physical activity, and poor sleep (Cukic 2011, Song 2021, Stanescu 2019) Thus, efforts to minimize disease exacerbation will reduce the burden of disease as well as preserve quality of life. For employers, providing respirators can demonstrate that an organization values its workers' health and safety. This can boost morale and motivation, leading to increased job satisfaction and productivity.

3.3.6 Lost Work Days

Days lost from work resulting from illness, injury or impairment is considered as one of the costs attributed with wildfire smoke. This rule can add to the benefits by reducing this cost of wildfire smoke. In EPA Technical report, work loss days has been considered as one heath endpoints for main $PM_{2.5}$ benefit assessments. Different studies have discussed work loss days due to wildfire smoke. Ostro et al. estimated the impact of $PM_{2.5}$ on the incidence of work-loss days in a national sample of the adult working population living in metropolitan areas. He reported that two-week average $PM_{2.5}$ levels were significantly linked to work-loss days (Ostro, 1987). In another article, Adams et al. reported that the annual work-loss-day incidence rate associated with acute conditions per employed people was 2.8 days (Adams 1999).[46] Due to the difficulty in distinguishing the wildfire related lost work days from other incidents, and lack of other underlying data, L&I does not provide quantitative estimate of this benefit. Nevertheless, the resulting benefit of the proposed rule in reducing or avoiding the lost work days may be substantial for certain workers, especially those who are currently exposed to hazardous $PM_{2.5}$ levels with no or insufficient protections. Wage losses associated with chronic illness may lead to long-lived reductions in earning power over the course of an employee's career, resulting in further financial effects.

3.3.7 Reducing the burden of climate change

Over the past 10 years (2011-21), Washington had an average of 1,466 wildfires, which burned an average of 407,449 acres.[47] Oregon to the south had 48% more wildfires and 63% more acres burnt during this same period. During the last 5 years of that time frame the number of wildfires and acres burned in Washington increased at a rate of 9% and 72% respectively. Research projects increases in very large fires resulting from climate change across the western United States. (Wehmer et al 2017)

Implementing the proposed rule would help to alleviate certain societal costs associated with increased exposure to wildfire smoke exposure resulting from climate change. For instance, protecting workers from negative impact of exposure reduces on the strain to emergency services as well as government funded social services that these injured workers may require. With workers protected and able to continue normal life, they continue to be agents of economic activity, supporting both their individual households as well as the community at large. The uninterrupted, or reduced interruption of, spending and tax revenue received by the community and locality contributes towards the county and ultimately state level economic activity, which would have otherwise been lost due to climate change induced wildfire smoke exposures.

3.3.8 Reducing Inequities

Another benefit of the proposed rule is that it will likely provide protection for certain marginalized workers who are particularly at risk for adverse health effects due to wildfire smoke exposure. Also, cost-effectiveness researchers note how "...there is a strong ethical argument to be made that everyone's time be valued equally." and that lower wages paid to some groups "...may not reflect the true opportunity cost of their labor..." (Muennig 2016, page 97).

[46] Based on estimates from the 1996 National Health Interview Survey, Table 36.
[47] Northwest Interagency Coordination Center, Northwest Annual Fire Report, 2021.

Reducing health impacts reduces individual and population inequalities regardless of how economic impact calculations that are sensitive to wage differences may be modeled.

Outdoor workers, and in particular those of low socio-economic status are identified as "at risk" by the EPA as extended periods of time exposed to high concentrations of wildfire smoke while at work along with a higher likelihood of untreated or insufficiently treated health conditions (e.g., asthma, diabetes) could lead to increased risks of experiencing adverse health effects due to wildfire smoke.[48] In addition, migrant outdoor workers are especially impacted by factors such as documentation status, and language and cultural barriers that can affect accessing federal aid, legal assistance, and health programs and are likely to be disproportionately impacted by emerging threats, including climate change. (Castillo 2021). Specific to agricultural workers in Washington state, most are foreign born Latino males who work long hours, rotate to different employers, have completed little education, and are more likely to suffer from chronic health problems (Bethel et al 2017). These inequities may be mitigated by the proposed requirements for information and training that must be provided in a manner and language readily understood by the workers.

3.3.9 Preventing Societal Costs

Beyond the direct loss of income suffered while recovering from their injury or illness, workers with severe cases also may face impairment of their quality of life in the form of continuing physical limitations, increased usage of medical services, fear of future reinjury, and reduced capacity to perform family and social roles (Dembe 2001, Strunin and Boden 2004). In addition, there are losses borne by society as a whole such as impacts to state disability and welfare systems, loss of tax revenues, and the loss of the worker's contribution to community life (Brown 2007, Leigh 2011). Consequences of injury-related work absence may also include loss of pre-injury job, loss of seniority or loss of investment in job-specific skills. Workers may also face discrimination from potential employers following periods of injury-related absence (Strunin and Boden 2004). Such workers may fear they will be regarded by employers or co-workers as being "injury prone" or "unreliable" and that they will have more difficulty finding future employment.

Household economic losses

Economists recognize that household production, although unremunerated, creates immense value and meets important needs. Household work, including cooking, cleaning, washing, yard work, household improvements and repairs creates value. Disability due to long-term consequences from wildfire smoke can interfere with the ability to create value through home production. Rather than spending time in productive household activities, injured workers often spend their time in self-maintenance and in administrative efforts in order to secure payment for medical bills and insurance benefits. Although L&I recognizes the important role of household production to the economic and social fabric, these considerations were not included in this estimated benefit of preventing wildfire smoke related health effects.

[48] EPA, https://www.epa.gov/wildfire-smoke-course/which-populations-experience-greater-risks-adverse-health-effects-resulting#workers Which Populations Experience Greater Risks of Adverse Health Effects Resulting from Wildfire Smoke Exposure?

Community Effects When workers are injured or ill, communities suffer as well. Workers are not compensated for the full wages and benefits lost, therefore the loss of disposable income, or the portion of income that is used for consumption of goods and services, has an impact on the local and state economy. The loss of their spending and sales tax revenues has multiplier effects in the local and state economy that were not considered in the cost benefit ratio.

Prior to their illnesses and injuries, many workers are contributing members to their local communities. The value of healthy workers' volunteering and participating in committees at work, churches, schools, homeless shelters and other contributions to society could not be enumerated as financial benefits to the wildfire smoke heat rule. In some cases, wildfire smoke health effects are severe enough to lead to long-term health effects, as described in the background section. In such cases, the unquantified losses to local economies and to community participation may be substantial. Although these qualitative losses of wildfire smoke illness and injury could not be quantified and added to the measured benefits of the proposed rule, L&I emphasizes that the full costs of wildfire smoke health effects to workers and their families is much greater than the dollar value expressed in this analysis. Benefits from the prevention of wildfire smoke health effects to workers and to the State's economy as a whole of keeping workers as productive members of society are at least as important as the monetary benefits that L&I quantified.

3.3.10 Reducing incidents of asthma not requiring ED visits or hospitalizations

Asthma is one of the most common long-term diseases that affects the lungs. It affects people of all ages, and near 10% of adults and 6% of children in Washington State have current asthma.[49] Numerous studies have shown outdoor air pollution including that caused by wildfire smoke would exacerbate this health problem if the individuals with asthma breathe polluted air. In addition to the incidents analyzed in Section 3.2 that require emergency department visits or hospitalizations, the proposed measures that help reduce or prevent workers' exposure to a unhealthy level of $PM_{2.5}$ are expected to reduce other asthma related incidents for the affected workers in the state. The total benefit of this is unknown to the agency, but it is expected to be substantial given the high prevalence of asthma and the large number of workers that are affected by the rule.

[49] DOH, Asthma Data From the Washington State Behavioral Risk Factor Surveillance System, 2011 – 2016. https://doh.wa.gov/sites/default/files/legacy/Documents/Pubs//140-185-AsthmaBRFSSdata.pdf

Chapter 4: Cost-Benefit Determination

In compliance with the Administrative Procedures Act (APA) under chapter 34.05 RCW, L&I has analyzed the probable costs and benefits, quantitatively and qualitatively, associated with the proposed implementation of chapter 296-820 and 296-307 WACs.

There is an inherent level of uncertainty involved in these economic analyses. Specifically, the uncertainty comes from a number of factors including the lack of key data and information, the reliance upon certain assumptions that may be challenging to confirm, and the choice of statistical approaches to analyzing available data. While the actual cost and benefit implications of the proposed rule are unknown, the approach employed in this analysis is considered the best one within time and resource constraints, and the estimates reflected in this report are the most reasonable ones based on the available information and data at the time of this analysis.

Altogether, L&I estimates that the proposed rule would impose annual cost of $10.7 million to $14.6 million. The total quantifiable benefits of the proposed rule are estimated to be between $17.6 million and $27.8 million annually, in addition to other significant but unquantifiable benefits. Therefore, L&I concludes that the probable benefits of these rule amendments exceed their probable cost.

Chapter 5: Least Burdensome Alternative Analysis

L&I must determine whether a rule being adopted is the least burdensome of the alternative requirements that still achieves the goals and objectives of the authorizing statutes. (RCW 34.05.328(1)(e)) The authorizing statute is the WISHA, and its goals and objectives are to assure, as may reasonably be possible, safe and healthful working conditions for every man and woman working in the state of Washington. (RCW 49.17.010) Specific to harmful physical agents, including wildfire smoke exposure, WISHA mandates L&I "[p]rovide for the promulgation of health and safety standards and the control of conditions in all work places concerning… which shall set a standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity." (RCW 49.17.050(4)) L&I assessed the alternatives to elements of the adopted rules, and determined whether they met these goals and objectives. Of those that met the goals and objectives, the department determined that the adopted rules were the least burdensome version of the rule for those who are required to comply, given the goals and objectives of the law.

5.1 WAC 296-820-805 and 296-307-09805: Purpose and Scope

As described in the Background section, L&I determined that the Wildfire Smoke rule would apply to employers with workers in outdoor settings. Workers in outdoor settings have the greatest exposure to the hazard of wildfire smoke; while workers in indoor settings also experience exposure to wildfire smoke, such exposures can be significantly reduced when doors and windows are kept closed, and ventilation systems are properly used. To address the population with the greatest risk and pose the least burden, L&I decided to restrict the scope to apply to outdoor settings and to those settings that mimic outdoor settings with regard to the exposure level (i.e. vehicles without cabin air filters, indoor settings where doors and windows are kept open or are opened frequently, etc.) Additionally, L&I exempted work that falls under Chapter 296-305 WAC *Safety standards for firefighters*, as wildland firefighters have unique exposures to wildfire smoke that are partly addressed in existing rule.

5.2 WAC 296-820-815 and 296-307-09815 Identification of Harmful Exposures

As described in the Background section, these provisions require that employers determine the amount of $PM_{2.5}$ to which employees are currently exposed. This provision is necessary in order for employers to comply with the rule. There is no requirement of the frequency with which employers will need to check the air quality; rather, employers have the discretion to determine how often they will need to check the air quality in order to comply with the rule. That said, $PM_{2.5}$ data are refreshed every hour, and employers are encouraged to take advantage of the new information during changing wildfire smoke conditions. This section provides employers with the choice to use publicly available data from a list of sources in the rule, or to conduct their own monitoring using the instructions in the rule. Employers are only responsible for tracking exposures during working hours. As public entities, including EPA and Washington State Department of Ecology, provide air monitoring data via websites for free, these provisions were determined to be the least burdensome option. If employers wish to conduct their own monitoring onsite, as described by WAC 296-820-845 and 296-307-09845, the agency has provided a conversion chart between $PM_{2.5}$ and AQI within the rule.

5.3 WAC 296-820-820 and 296-307-09820: Hazard Communication

As described in the Background section, the Hazard Communication section of the Wildfire Smoke Rule requires that employers have a method to communicate with their employees regarding current smoke conditions at the worksite. It also requires a written wildfire smoke response plan.

Notifying Employees of Current Exposures

Per these provisions, employers are required to notify employees of their exposure to $PM_{2.5}$ at 5 thresholds, including:

- When at least two consecutive $PM_{2.5}$ readings are 20.5 $\mu g/m^3$ (AQI 69)
- At 35.5 $\mu g/m^3$ (AQI 101) or higher
- At 250.5 $\mu g/m^3$ (AQI 300) or higher
- At 500.4 $\mu g/m^3$ (AQI 500) or higher
- At 555 $\mu g/m^3$ (beyond the AQI) or higher

Notifying employees of their exposures is required in order to ensure that employees are aware of when they need to take action to protect themselves. Notification is of special importance at lower levels of $PM_{2.5}$ as employees may not be able to detect the smoke in the air using sensory perception; health risks may be elevated without a smell or taste of smoke in the air. Notification to employees at lower threshold levels enables L&I to achieve the goals and objectives of this rulemaking by allowing employees to take individual action to protect themselves when they may be at increased risk.

Several of the thresholds of notification additionally require that the employer take other action to protect employees, so the burden to notify employees is minimized. Employers are anticipated to have frequent contact with their employees throughout the workday as part of normal business operations; it is expected that notification to employees would or could occur alongside other communications between employers and their employees.

Employee to Employer Communication

These provisions require a two-way communication system such that employees could inform their employer of worsening air quality, the availability of controls at the worksite, and any symptoms being experienced. Due to the potential for rapid changes in air quality, a two-way communication system is needed in order for the employer to achieve compliance with other provisions in the rule, including exposure symptom response; without a two-way communication system, the employer will not be able to adequately respond to signs and symptoms of exposure. Likewise, if employees are unable to inform employers of worsening air quality or supply concerns with control measures, such as respirators, employers may inadvertently find their worksites out of compliance with other sections of the rule.

Wildfire Smoke Response Plan

A wildfire smoke response plan is essential for assisting the employer implement the provisions required by this rule and plan for how they will respond to smoke events. L&I DOSH will provide templates so that employers will be able to implement these requirements in the least burdensome manner.

5.4 WAC 296-820-825 and 296-307-09825 Information and Training

As described in the Background section, employees are required to be trained on the hazard of wildfire smoke and the provisions of this rule, similar to what is already required by the Hazard Communication Standard, Chapter 296-901 WAC. The training must be in a language and manner that employees can understand to ensure effectiveness. L&I DOSH provides a list of what is required training content, as well as expansion upon that list in Appendix A in the proposed rule. A training slide deck will be provided on the L&I website in both English and Spanish to assist employers with implementation and ensure the least burdensome approach.

Additional training is required for supervisors to ensure that employers can adequately implement the provisions in the exposure symptom response section.

5.5 WAC 296-820-830 and 296-307-09830 Exposure Symptom Response

The intention of the Exposure Symptom Response section is to ensure that employees experiencing symptoms of wildfire smoke have the ability to recover; without the opportunity to recover from symptoms of wildfire smoke, it is possible that a rapid decline in health could ensue, leading to hospitalization or death of the employee. For example, an employee suffering an asthma attack due to wildfire smoke exposure must be allowed access to an inhaler or other appropriate medical treatment without which the employee may experience severe consequences.[50]

As described in Section 2.6, employers must ensure that employees experiencing symptoms of wildfire smoke may recover from such symptoms by:

- Monitoring employees displaying symptoms to determine if medical attention is necessary;
- Allowing employees displaying symptoms to seek medical treatment, without fear of retaliation;
- Having provisions made in advance for prompt medical treatment;
- Where the current $PM_{2.5}$ is greater than 250.1 µg/m^3 (AQI 301) or more, providing a space with clean air for employee recovery.

Monitoring employees is necessary to determine that rapid declines in health do not occur. While the right to seek medical treatment without retaliation exist elsewhere, the Wildfire Smoke Rule seeks to explicitly affirm this right in the context of wildfire smoke. Employers must already have provisions made regarding the availability of first aid; provisions regarding prompt medical treatment are already part of many employers' Accident Prevention Programs. L&I has heard from a wide variety of stakeholders in the business community who acknowledge that their operations may cease once the $PM_{2.5}$ reaches 250.1 µg/m^3 or AQI 301, given the hazardous nature of the air quality. If employers choose to continue operations once the air quality reaches that threshold, employees experiencing symptoms will require clean air in order to recover from their symptoms. Given that the wildfire smoke rule does not require the use of fit-tested respirators at 250.1 µg/m^3 (AQI 301), it is possible that some employees will experience high exposures, and potentially, symptoms of wildfire smoke exposure as a result. Such employees will require a location with clean air in which to recover. This provision is the least burdensome

[50] https://www.nhlbi.nih.gov/health/asthma/attacks

alternative when compared with the option of requiring employers to implement a full respiratory protection program per Chapter 296-842 WAC including medical evaluations, fit-testing, shaving, training, and a written program. This is because L&I has determined that implementing a full respiratory protection program at $PM_{2.5}$ concentrations below 500.4 micrograms per cubic meter is currently infeasible.

5.6 WAC 296-820-835 and 296-307-09835: Exposure Controls

As described in the Background section, this section requires employers to implement effective exposure controls when the $PM_{2.5}$ reaches 35.5 $\mu g/m^3$ (AQI 101), whenever feasible. Exposure controls, also known as engineering or administrative controls, are an essential part of ensuring that employees are protected from hazards without imposing undue burden on employees through the use of personal protective equipment (PPE).

Exposure controls employed in this manner of this rule are also the least burdensome option for employers; a non-exhaustive list of exposure controls options are provided in the rule. Employers have the option to choose the exposure controls that will work best in their workplace. Implementing some of the exposure controls listed will remove the workplace from the scope of the wildfire smoke rule (i.e. moving employees to an indoor location). Implementation of exposure controls will not be feasible in every work environment; employers are not required to implement infeasible controls. Exposure controls are not required during emergency response.

5.7 WAC 296-820-840 AND 296-307-09840 Respiratory Protection

As described in the Background section, as the hazard of wildfire smoke increases, so will the respiratory protection required to protect employees. While L&I has heard from a wide variety of stakeholders stating they will shut down outdoor operations when the air quality gets poor, there are many employers that will choose to continue work or that cannot cease operations, such as emergency responders. Where work continues to occur despite high levels of wildfire smoke, the respiratory protection requirements of the wildfire smoke rule are in place to ensure minimum standards of protection for employees working in hazardous atmospheres.

Voluntary Use of Respirators

As described elsewhere in this document, there is no known concentration of $PM_{2.5}$ exposure that is known to be safe, the EPA's general air pollution health messages understate the risk to outdoor workers at a given $PM_{2.5}$ concentration, and all exposures contemplated by these wildfire smoke rules pose a serious hazard to outdoor workers, especially when considering their exposures over an entire working lifetime.

L&I has determined that it is currently infeasible, however, to require respirators be worn and a full respiratory protection program be implemented at $PM_{2.5}$ concentrations below 500.4 $\mu g/m^3$. As a policy alternative, L&I considered, but declined to advance in these permanent proposed wildfire smoke rules, requiring respirators be worn without a medical evaluation or fit-testing. L&I collected stakeholder feedback on this policy alternative in the fourth quarter of 2022. That

feedback was generally negative, for several reasons. Some stakeholders expressed concerns about how the loss of protections or even additional harm that implementing an untested and novel approach to respiratory protection would increase risks to workers. Other stakeholders expressed feasibility concerns about implementation, and shared dissatisfaction with requiring respirators be worn at the $PM_{2.5}$ concentrations contemplated by the proposal.

L&I has considered this feedback, and having evaluated the risk of additional harm to some workers created by requiring respirators without the respiratory program elements that would otherwise ensure those programs are safe and effective; as well as the feasibility concerns about implementing such a program at the $PM_{2.5}$ concentrations under consideration, L&I is responding to stakeholders by instead proposing the following less burdensome and more feasible alternatives.

At or above a concentration of $PM_{2.5}$ of 35.5 µg/m^3 (AQI 101), employers are required to provide N95 filtering-facepiece respirators to all employees for voluntary use. The employer can either directly distribute the respirator to each employee, or maintain a sufficient supply of N95s at the worksite. While L&I considered the option of requiring a full respiratory protection program at this threshold due to the hazard posed by even low levels of $PM_{2.5}$, a less burdensome alternative was selected because L&I determined implementing a full respiratory protection program at $PM_{2.5}$ concentration below 500.4 µg/m^3 is currently infeasible. .

At or above a concentration of $PM_{2.5}$ of 250.5 µg/m^3 (AQI 301), employers are required to provide N95 filtering-facepiece respirators to all employees for voluntary use. The employer must directly distribute the respirator to each employee, unlike the requirement at $PM_{2.5}$ of 35.5 µg/m^3 (AQI 101). At this threshold, the hazard to employees is increased and by directly distributing respirators to employees, use of respirators is more likely to be encouraged. As above, while L&I considered the option of requiring a full respiratory protection program at this hazardous level of $PM_{2.5}$, L&I determined that this was currently infeasible.

Required Use of Respirators

When the concentration of $PM_{2.5}$ reaches 500.4 µg/m^3 (AQI 500), which is an unusual occurrence in the State of Washington, it is anticipated that very few employers will still have employees working in outdoor environments. For those employers that plan to continue operations in these conditions, a respiratory protection program will be required per the requirements in Chapter 296-842 WAC. This is necessary to ensure that employees have minimum protections to ensure that severe adverse health outcomes are avoided by working in high levels of $PM_{2.5}$. If the concentration of $PM_{2.5}$ exceeds the AQI levels by reaching 555 µg/m^3, employers will be required to provide respirators that are able to address the intensity of the exposure at these levels. A respirator with an Assigned Protection Factor (APF) greater than 10 will be required, such as a loose-fitting powered air-purifying respirator (PAPR) or a full-facepiece air purifying respirator. Many emergency responders have already been fit-tested and cleared to wear respirators with an

APF of 10, making this provision less burdensome.

L&I considered requiring that employers shut down operations above 500.4 µg/m^3 (AQI 500) due to the hazard of wildfire smoke at these levels. However, as a least burdensome alternative, the wildfire smoke rule requires employers to implement appropriate respiratory protection at high levels of exposure, because L&I determined that it is currently feasible to implement a full respiratory protection program at 500.4 micrograms per cubic meter.

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