
# Appendix I: Environmental Health and Safety Technical Appendix

## For Programmatic Environmental Impact Statement on Green Hydrogen Energy Facilities in Washington State

By

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For the

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Attachment 1: Common Industry Standards for Industrial Facilities

# Acronyms and Abbreviations List

| | |
|---|---|
| µg/dL | micrograms per deciliter |
| 1-BP | 1-Bromopropane |
| ANSI | American National Standards Institute |
| ASME | American Society of Mechanical Engineers |
| BESS | battery energy storage system |
| BMP | best management practice |
| Cd | cadmium |
| CFR | Code of Federal Regulations |
| DDT | dichlorodiphenyltrichloroethane |
| DNR | Washington Department of Natural Resources |
| DOE | U.S. Department of Energy |
| Ecology | Washington State Department of Ecology |
| EHS | environmental health and safety |
| EMS | emergency medical services |
| EPA | U.S. Environmental Protection Agency |
| EtO | ethylene oxide |
| FIFRA | Federal Insecticide, Fungicide, and Rodenticide Act |
| GHG | greenhouse gas |
| HMTA | Hazardous Materials Transportation Act |
| IBC | International Building Code |
| IFC | International Fire Code |
| MTCA | Model Toxics Control Act |
| NFPA | National Fire Protection Association |
| NPDES | National Pollutant Discharge Elimination System |
| OSHA | Occupational Safety and Health Administration |
| PAHs | polycyclic aromatic hydrocarbons |
| PCB | polychlorinated biphenyls |
| PEIS | programmatic environmental impact statement |
| PPE | personal protective equipment |
| psig | pounds per square inch gauge |
| RCP | representative concentration pathway |
| RCRA | Resource Conservation and Recovery Act |
| RCW | Revised Code of Washington |
| SEPA | State Environmental Policy Act |
| SMR | steam-methane reforming |
| SPCC | spill prevention, control, and countermeasure |
| TCE | trichloroethylene |
| USC | U.S. Code |
| USFS | U.S. Forest Service |
| UW | University of Washington |
| WAC | Washington Administrative Code |
| WUI | wildland-urban interface |

# Summary

This technical appendix describes the environmental health and safety (EHS) conditions in the study area. It also describes the regulatory context and potential impacts and actions that could avoid or reduce impacts.

The impact analysis addressed the following types of impacts relative to EHS for each of the green hydrogen facility types evaluated in the Programmatic Environmental Impact Statement (PEIS):

- Risks from use and storage of hazardous materials at green hydrogen production facilities. Chemical and/or hazardous materials present at a green hydrogen facility during construction and operation include, but are not limited to, gaseous and liquid hydrogen, methane, sodium or potassium hydroxide, liquid natural gas, petroleum products, liquid concrete, and lithium-ion electrolyte. Risks include handling these materials and spills and exposure during incidents.
- Fire, wildfire, and explosion risks. This technical appendix considers EHS laws, regulations, and industry standards that can reduce the risks through safety, prevention, and response requirements and where there are gaps in standards.
- Worker health and safety risks such as falls, electrical exposure, loud noises, high temperatures, and strain would be similar to risks associated with other industrial facilities.

Green hydrogen facilities would have hydrogen and other flammable materials present on site that pose a risk of fire and explosion. The severity of risks would need to be assessed for each facility based on the project location, production method, and quantities of flammable materials produced or stored on site. Risk can be reduced through proper design and operations but may not be completely eliminated. Having an emergency action plan, flame and leak detection systems, and fire response equipment in place would reduce risks. Utilizing setbacks and establishing site perimeters that are nonflammable would also reduce risks. Impacts on emergency response resources during fire and explosion incidents are considered in the *Public Services and Utilities Technical Appendix*.

Findings for EHS impacts described in this technical appendix are summarized as follows:

- Through compliance with laws and permits, and with implementation of actions that could avoid and reduce impacts, most construction, operation, and decommissioning activities would likely result in **less than significant impacts** related to hazardous materials and health and safety.
- Depending on the specific location, severity, and emergency response capacity, operation activities would likely have **less than significant to potentially significant adverse impacts** from fires and explosions. The severity of risks would need to be assessed for each facility based on the project location, production method, and quantities of flammable materials produced or stored on site.

- A thermal runaway event due to damage or battery management system failure at a facility with co-located lithium-ion battery energy storage system (BESS) would likely have **potentially significant adverse impacts** related to hazardous air emissions.
- A facility may result in **potentially significant and unavoidable adverse impacts** if new ignition sources are in remote locations with limited response capabilities, or if a fire or explosion during operations spreads rapidly or impacts large areas. Determining if mitigation options would reduce or eliminate impacts below significance would be dependent on the specific project and site.

# 1 Introduction

This technical appendix describes environmental health and safety (EHS) within the green hydrogen study area and assesses probable impacts associated with and the types of green hydrogen facilities evaluated, and a No Action Alternative. Chapter 2 of the State Environmental Policy Act (SEPA) Programmatic Environmental Impact Statement (PEIS) provides a description of the types of facilities evaluated.

This section provides an overview of the aspects of EHS evaluated and lists relevant regulations that contribute to the evaluation of potential impacts.

## 1.1 Resource description

EHS refers to the risks or hazards that threaten the well-being of people or other elements of the environment. Workplace accidents or system failures can result in EHS hazards, such as fires, explosions, hazardous material spills, injury, or structural damage.

In this programmatic analysis of the construction, operation, and decommissioning of green hydrogen facilities in Washington, EHS includes the following:

- Hazardous materials including:
  - Spills or releases of chemical or hazardous materials to air, soil, or water
  - Exposure to humans
- Fire risks including:
  - General fire risk including structural fires and explosions
  - Wildfires hazards from facility activities or fires starting outside of project site boundaries
- General worker health and safety

In the study area, the following resources could have impacts that overlap with impacts to EHS. Impacts on these resources are reported in their respective technical appendices:

- **Public services and utilities:** Information on impacts to public services and utilities such as fire and emergency responses from the *Public Services and Utilities Technical Appendix* is referenced in this technical appendix when discussing hazards that would require emergency response and hazardous waste disposal.
- **Air quality and greenhouse gases:** Information on impacts from greenhouse gases from the *Air Quality and Greenhouse Gases Technical Appendix* is referenced in this technical appendix when discussing hazardous gases and airborne particulates.
- **Biological resources:** Information on wildfire risk natural features from the *Biological Resources Technical Appendix* is referenced in this technical appendix when discussing wildfire risk.
- **Water resources:** Information on surface and ground water and wetlands from the *Water Resources Technical Appendix* is referenced in this technical appendix when discussing hazardous materials impacts to waters.

- **Earth resources:** Information on soil resources from the *Earth Resources Technical Appendix* is referenced in this technical appendix when discussing hazardous materials impacts to soil.

## 1.2 Regulatory context

Table 1 summarizes the laws, plans, and policies that apply to green hydrogen facility development.

In addition to the plans, policies, and regulations listed in Table 1, there are industry and construction standards applicable to EHS (Attachment 1).

Table 1. Applicable laws, plans, and policies

| Regulation, statute, guideline | Description |
|---|---|
| **Federal** | |
| Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendments Reauthorization Act of 1986 and the Community Environmental Response Facilitation Act of 1992 | Provides a federal "Superfund" to clean up uncontrolled or abandoned hazardous waste sites as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment. |
| 33 U.S. Code (USC) 1251 et seq., Clean Water Act (CWA) | The Federal Water Pollution Control Act of 1948 was the first major U.S. federal law to address water pollution. The law was amended in 1972 and became commonly known as the Clean Water Act. The CWA establishes the basic structure for regulating pollutant discharges into waters of the United States and makes it unlawful to discharge any pollutant from a point source into those waters without a permit. |
| 42 USC 6901 et seq., Solid Waste Disposal, as amended by the Resource Conservation and Recovery Act, and the Hazardous Solid Waste Amendments of 1984 | Applicable to solid and hazardous waste generated during construction, decommissioning, and operation and maintenance. |
| Emergency Planning and Community Right-to-Know Act | Authorized by Title III of the Superfund Amendments and Reauthorization Act to help communities plan for chemical emergencies. It requires industry to report on the storage, uses, and releases of certain chemicals to federal, state, Tribal, territorial, and/or local governments. It also requires these reports to be used to prepare for and protect their communities from potential risks. |
| 42 USC 300 et seq., Chapter 6A, Safe Drinking Water Act | Principal federal law protecting drinking water for the public. Requires states to develop source water assessment programs.<br><br>Authorizes U.S. Environmental Protection Agency (EPA) administration of the Sole Source Aquifer Protection Program. |
| Resource Conservation and Recovery Act (RCRA) | Gives EPA the authority to control hazardous waste from cradle to grave. This includes the generation, transportation, treatment, storage, and disposal of |

| Regulation, statute, guideline | Description |
|---|---|
| | hazardous waste. RCRA also establishes a framework for the management of non-hazardous solid wastes. |
| Hazardous Materials Transportation Act (HMTA) of 1975 | Empowered the Secretary of Transportation to designate as hazardous material any "particular quantity or form" of a material that "may pose an unreasonable risk to health and safety or property." Hazardous materials regulations are subdivided by function into four basic areas: Procedures and/or Policies 49 Code of Federal Regulations (CFR) 101, 106, and 107. Material Designations 49 CFR 172. Packaging Requirements 49 CFR 173, 178, 179, and 180. Operational Rules 49 CFR 171, 173, 174, 175, 176, and 177. The HMTA is enforced by use of compliance orders (49 USC 1808(a)), civil penalties (49 USC 1809(b)), and injunctive relief (49 USC 1810). The HMTA (Section 112, 40 USC 1811) preempts state and local governmental requirements that are inconsistent with the statute, unless that requirement affords an equal or greater level of protection to the public than the HMTA requirement. |
| Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and Federal Food, Drug, and Cosmetic Act | FIFRA provides for federal regulation of pesticide distribution, sale, and use. All pesticides distributed or sold in the United States must be registered (licensed) by EPA. Before EPA may register a pesticide under FIFRA, the applicant must show, among other things, that using the pesticide according to specifications "will not generally cause unreasonable adverse effects on the environment." FIFRA defines the term "unreasonable adverse effects on the environment" to mean: "(1) any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide, or (2) a human dietary risk from residues that result from a use of a pesticide in or on any food inconsistent with the standard under section 408 of the Federal Food, Drug, and Cosmetic Act." |
| 49 CFR 173.185, Lithium cells and batteries | Applicable to lithium-ion batteries, including how they can be packaged and transported. |
| 49 CFR 173.159, which regulates the transportation of lead-acid batteries | Regulations on how these types of batteries may be packaged and transported. |
| National Fire Protection Association (NFPA) 855 Standards for Installation of Energy Storage Systems | Applies to facilities with co-located battery energy storage systems. |
| 29 CFR 1910.269, Electric Power Generation, Transmission, and Distribution standard | This section of the code covers the operation and maintenance of electric power generation, control, transformation, transmission, and distribution lines and equipment. |
| Occupational Safety and Health Act of 1970 | Ensures employers provide their workers a place of employment free from recognized hazards to safety and health, such as exposure to toxic chemicals, excessive noise levels, mechanical dangers, heat or cold stress, or unsanitary conditions. |
| 29 CFR 1910, Occupational Safety and Health Administration (OSHA) | Establishes OSHA, which regulates worker safety and hazards in the United States. Multiple sections would be relevant to green hydrogen facilities, including but not |

| Regulation, statute, guideline | Description |
|---|---|
| | limited to 29 CFR 1910.103 Hydrogen, 29 CFR 1910.119 Process safety management of highly hazardous chemicals, and 29 CFR 1910, Subpart I Personal Protective Equipment. |
| 29 CFR 1926, Safety and Health Regulations for Construction | Establishes health and safety regulations for construction sites to reduce the risk of injury to job site workers and the general public. |
| Clean Air Act | A comprehensive federal act that regulates air emissions and established EPA's authority to establish National Ambient Air Quality Standards to protect human health and the environment. |
| Toxic Substances Control Act/Asbestos Hazard Emergency Response Act | The Toxic Substances Control Act regulates chemicals by requiring testing and necessary use restrictions on certain chemicals. The Asbestos Hazard Emergency Response Act amended the Toxic Substances Control Act to direct the EPA to regulate asbestos hazard abatement in schools. |
| American National Standards Institute (ANSI), Design Standards | Design standards from the ANSI cover building and design standards ranging from the foundation to the structural skeleton, indoor environment considerations, and service-life calculations. |
| American Society of Mechanical Engineers (ASME), Design Standards | ASME standards are a comprehensive set of guidelines that cover the design, manufacturing, and testing of mechanical components. |
| Institute of Electrical and Electronics Engineering Guide for Substation Fire Protection (979-2012) | Design guidance, fire hazard assessment, and planning for fire protection of substations provided to substation engineers. |
| National Electric Safety Code | United States standard for the safe installation, operation, and maintenance of electric power and communication utility systems including power substations, power and communication overhead lines, and power and communication underground lines. |
| NFPA Standards (NFPA 1141 Protection for Land Development) | This standard provides requirements for the development of fire protection and emergency services infrastructure to make sure that wildland, rural, and suburban areas undergoing land use changes or land development have the resources and strategies in place to protect people and property from fire dangers and allow fire fighters to do their jobs safety and effectively. |
| NFPA Standards (NFPA 1144 Reducing Structure Ignition Hazards) | This standard provides a methodology for assessing wildland fire ignition hazards around existing structures and provides requirements for new construction to reduce the potential of structure ignition from wildland fires. |
| National Institute for Occupational Safety and Health (NIOSH) | United States federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. |
| Unified Facilities Criteria (UFC) for Fire Protection Engineering for Facilities (UFC 3-600-01) | The minimum standard for the planning and development of projects and design, construction, and commissioning documentation used for the procurement of facilities |

| Regulation, statute, guideline | Description |
|---|---|
| **State** | |
| Chapter 70.94 Revised Code of Washington (RCW), Washington Clean Air Act | These regulations secure and maintain levels of air quality that protect human health and safety, including the most sensitive members of the population, to comply with the requirements of the federal Clean Air Act, to prevent injury to plants, animal life, and property; to foster the comfort and convenience of Washington's inhabitants; to promote the economic and social development of the state; and to facilitate the enjoyment of the natural attractions of the state. |
| Chapter 70.95 RCW, Solid Waste Management Act | These regulations establish a comprehensive statewide program for solid waste handling, solid waste recovery, and recycling. |
| Chapter 70.105 RCW, Hazardous Waste Management Act | These regulations establish a comprehensive statewide framework for the planning, regulation, control, and management of hazardous waste. |
| Chapter 70.105D RCW, Model Toxics Control Act (MTCA) | MTCA funds and directs the investigation, cleanup, and prevention of sites that are contaminated by hazardous substances. |
| Chapter 173-340 Washington Administrative Code (WAC), MTCA | These regulations establish administrative processes and standards to identify, investigate, and cleanup sites where hazardous substances are located. Chapter 173-340 WAC implements MTCA in Chapter 70A.305 RCW. |
| Chapter 70.107 RCW, Washington State Noise Control Act | These regulations expand statewide efforts directed toward the abatement and control of noise. |
| Chapter 173-60 WAC, Maximum Environmental Noise Levels | These rules establish maximum noise levels and provide use standards relating to the reception of noise. |
| Chapter 90.48 RCW, Water Pollution Control Act | Sets standards to ensure the purity of all waters of the state and to work cooperatively with the federal government where interest overlaps in a joint effort to extinguish sources of water quality degradation. Grants Ecology the jurisdiction to control and prevent the pollution of streams, lakes, rivers, ponds, inland waters, salt waters, water courses, and other surface and groundwater in the state, including wetlands. Ecology uses to regulate certain activities in wetlands and waters that are non-jurisdictional under Section 404 of the CWA through the issuance of Administrative Orders. |
| Chapter 173-303 WAC, Dangerous Waste Regulations | These regulations implement Chapter 70.105 RCW and designate policies for dangerous solid waste. |
| Chapter 173-350 WAC, Solid Waste Handling Standards | These regulations set performance standards, functions, priorities, and responsibilities for solid waste. |
| Chapter 70A.214 RCW, Waste Reduction | Applicable to waste generated during construction, operation, and decommissioning of green hydrogen facilities. Establishes programs and incentives for waste reduction, recycling, and proper handling and disposal of hazardous waste. |
| Chapter 70A.218 RCW, Hazardous Waste Fees | Applicable for hazardous waste generated during construction, operation, and decommissioning of green hydrogen facilities. |

| Regulation, statute, guideline | Description |
|---|---|
| Chapter 70A.300 RCW, Hazardous Waste Management | Applicable for hazardous waste generated during construction, operation, and decommissioning of green hydrogen facilities. |
| Chapter 51-50, State Building Code adoption and amendment of the 2021 edition of the International Building Code | Establishes the Washington State Building Code's adoption of the International Building Code (IBC) which sets standards for commercial construction. This chapter also adopts NFPA 70, National Electric Code, which sets national standards for electric, and communications components installed in buildings, structures, and in open-air settings. The IBC has adopted parts of and full standards of NFPA sections including NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations, which sets construction and demolition fire safety standards. |
| Chapter 51-56 WAC, adoption and amendment of the 2021 edition of the Wildland-Urban Interface Code | The International Wildland-Urban Interface Code sets additional requirements code officials can require for structures and subdivisions located within the wildland-urban interface areas. These include a site plan, vegetation management plan, vicinity plan, fire apparatus access roads, and water supply. |
| Chapter 51-52 WAC, State Building Code adoption and amendment of the 2021 edition of the International Mechanical Code | Establishes the Washington State Building Code's adoption of the International Mechanical Code which sets standards for mechanical infrastructure in buildings and structures. This chapter also adopts several NFPA standards including NFPA 72 National Fire Alarm and Signaling Code. |
| Chapter 51-54A WAC, State Building Code Adoption and Amendment of the 2021 Edition of the International Fire Code | Establishes Washington State's adoption of the International Fire Code (IFC) and also adopts some IFC standards including NFPA 855 Standards for Installation of Energy Storage Systems relevant to battery energy storage system installation. Washington State provides amendments to each iteration of the IIFC. The current Washington State amendments to the 2021 IFC have been effective since March 15, 2024. The IFC sets standards for fire preparedness and safety. |
| Chapter 296-155 WAC, Safety Standards for Construction Work | These standards are minimum safety requirements for construction, alteration, demolition, related inspection, and/or maintenance and repair work performed in the state of Washington. |
| WAC 332-24-301, Industrial Restrictions | Applicable to construction and operations of a green hydrogen facility as it relates to wildfire risk. |
| WAC 296-24-31503, Gaseous Hydrogen Systems | Specifies design standards for gaseous hydrogen systems in Washington. |
| **Local** | |
| Comprehensive plan goals and objectives, and local codes and requirements pertaining to EHS | A local planning effort by cities and counties that provides a vision for the community and identifies steps needed to meet that vision. Many counties and cities in Washington defer to the state regulations. |

# 2 Methodology

This section provides an overview of the process for evaluating potential impacts and the criteria for determining the occurrence and degree of impact.

## 2.1 Study area

The study area for EHS includes the PEIS geographic scope of study for green hydrogen facilities (Figure 1) and surrounding areas.

The study area for the evaluation of EHS associated with the construction and operation of green hydrogen facilities would be determined by the presence (or absence) of hazardous materials, risks of fire and explosion, and health and safety risks identified during project-specific reviews. Figure 1, which shows the PEIS geographic scope of study, does not include federal lands, national parks, wilderness areas, wildlife refuges, state parks, or Tribal reservation lands, but information related to these areas is provided as context for the affected environment. For the purpose of evaluating wildfire risk, regions at risk of wildfires as defined by the U.S. Department of Agriculture and Washington Department of Natural Resources (DNR) are also considered.

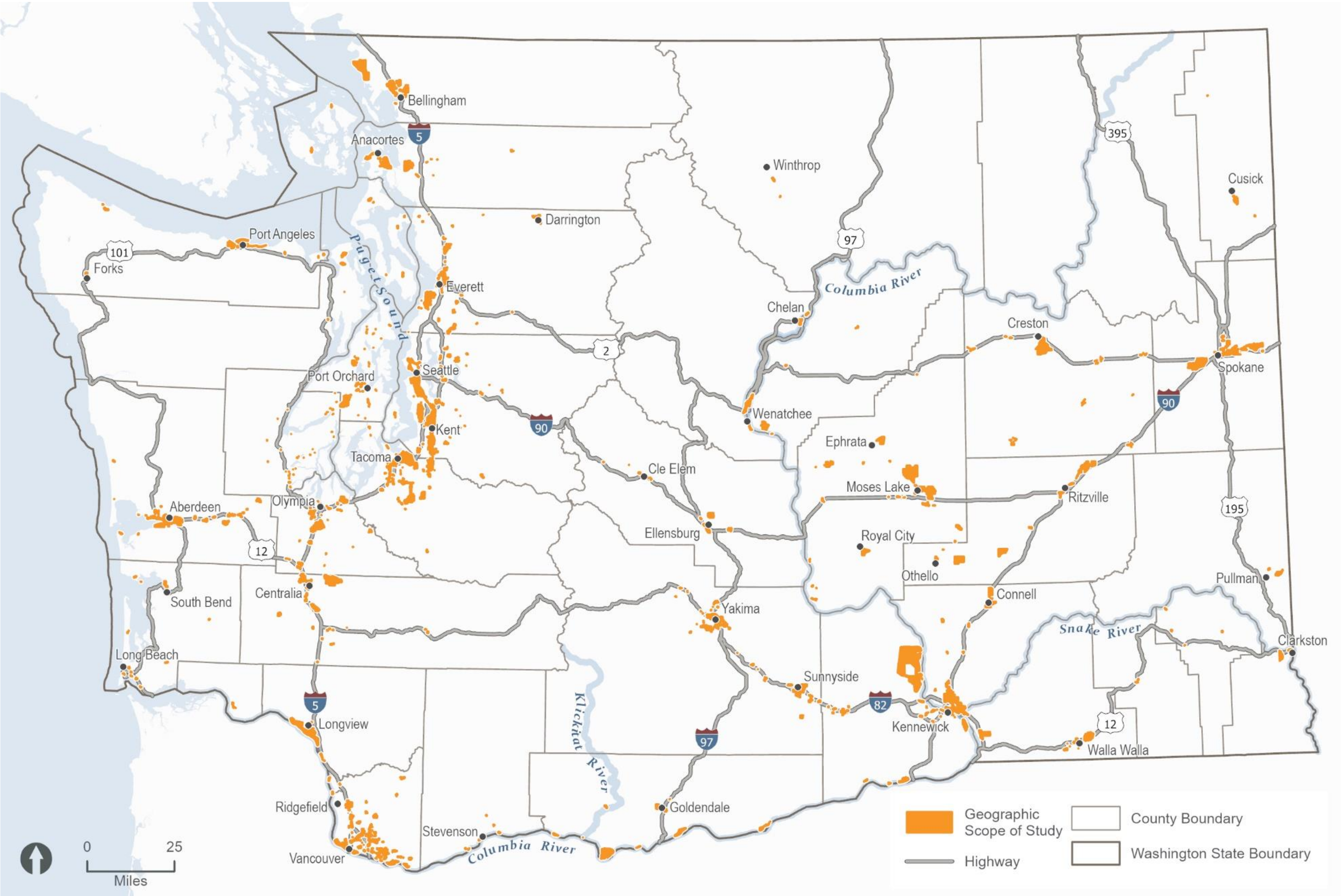


Figure 1. Green Hydrogen Energy Facilities PEIS geographic scope of study

## 2.2 Technical approach

A qualitative assessment is provided of potential existing hazards in the study area; those that may result from typical facility construction, operation, and decommissioning activities; and the potential for public exposure to hazards or hazardous materials. The approach for analyzing EHS hazards included the following steps:

1. Evaluate existing data and information from publicly available sources to generally characterize local environmental factors that could increase EHS risks.
2. Evaluate existing data and information from publicly available sources to generally characterize local populations (e.g., population size, population density, emergency response resources) to assess the level of EHS risk from a green hydrogen facility to the local population.
3. Compile information and assumptions for the types of facilities to qualitatively evaluate the EHS hazards and impacts.
4. Evaluate the impacts relative to applicable laws and regulations.

Regulations and policies were reviewed for guidelines that may impact facility design, documentation, reporting requirements, and best management practices (BMPs) for occupational safety.

The PEIS analyzes a timeframe of up to 25 years of potential facility construction and up to 50 years of potential facility operations (totaling up to 75 years into the future).

The content of this analysis also relies on other technical appendices developed for the PEIS, including those addressing air quality, water resources, public services and utilities, and transportation. Impacts to emergency response resources, including fire response and emergency medical services (EMS), are discussed in the *Public Services and Utilities Technical Appendix*.

## 2.3 Impact assessment approach

For purposes of this assessment, a **potentially significant impact** relative to EHS would occur if a facility resulted in the following:

- Release of hazardous materials to the environment that increases the risk of environmental contamination (e.g., air or water) or threats to human health and safety
- Hazard to the public or environment through transport, use, or disposal of hazardous materials or waste
- Increased risk of fire or explosion
- Increase in physical safety risks resulting in a high likelihood of harm to facility workers or the public
- Increase in wildfire risk

# 3 Technical Analysis and Results

## 3.1 Overview

This section describes the affected environment and potential EHS impacts that might occur for green hydrogen facilities analyzed in the PEIS. This section also evaluates actions that could avoid, minimize, or reduce the identified impacts, and potential unavoidable significant adverse impacts.

## 3.2 Affected environment

The affected environment represents existing conditions at the time this study was prepared. This section describes the major EHS hazards for potential facilities in the study area: hazardous materials; fire and explosion risks including wildfire risk; and worker health and safety risks. The presence of EHS hazards is associated mainly with former or existing industrial development or other development, while wildfire may be more prevalent in less-developed areas.

Emergency response is discussed in the *Public Services and Utilities Technical Appendix*.

### 3.2.1 Hazardous materials

The quantities and uses of hazardous materials vary greatly by land use. Hazardous materials can be present at industrial lands as well as commercial and agricultural land uses. Hazardous materials that could be present at businesses or other sites may include, but are not limited to, petroleum products (e.g., gasoline, diesel, or oil), heavy metals (e.g., lead, cadmium, mercury, or arsenic), pesticides, solvents, compressed gases, and batteries. Low concentrations of hazardous materials (heavy metals, petroleum products, or hydraulic fluids) may also be present along roads as a result of vehicular activity. Low concentrations of hazardous materials could also be present in isolated areas away from current or past development as a result of human activity such as illegal dumping. Hazardous airborne materials from industry and commercial use include but are not limited to carbon dioxide, carbon monoxide, sulfur dioxide, and particulate matter. Air quality and greenhouse gases existing conditions and impacts are discussed in detail in the *Air Quality and Greenhouse Gases Technical Appendix*.

The storage, use, and disposal of hazardous materials are regulated and monitored by the Washington State Department of Ecology (Ecology) under hazardous materials management programs. Sites with hazardous materials present or involved in other potentially environmentally impactful activity regulated by Ecology are listed in the Facility/Site Interaction database (Ecology 2024a). Local land use and environmental regulations may establish additional requirements on the storage and use of hazardous materials.

Industrial uses are required to be permitted to store, use, or dispose of hazardous materials and are required to document the presence of hazardous materials. Hazardous substances or materials that are commonly used in industrially zoned areas or areas zoned to support industrial uses are listed in Table 2.

Table 2. Hazardous substances or materials common to industrial lands

| Substance | Occurrence/Use | Hazard |
|---|---|---|
| Acetylene | Acetylene is a flammable gas most commonly used to fuel welding, cutting, and soldering torches. | Acetylene inhalation can cause headache, dizziness, lightheadedness, and loss of consciousness. High concentrations can displace oxygen leading to asphyxiation. Exposure to liquid acetylene can cause frostbite. Acetylene is extremely flammable. |
| Alkaline electrolysis | Alkaline electrolyzers are used in electrolysis. The contain an electrolyte fluid, commonly potassium hydroxide and sodium hydroxide. | Potassium hydroxide inhalation, ingestion, or skin and eye contact can cause eye irritation, skin irritation, respiratory symptoms, coughing, sneezing, skin burns, vomiting, and diarrhea. Sodium hydroxide is highly corrosive. Acute exposure can damage the gastrointestinal tract; cause swelling of the larynx; accumulate fluid in the lungs; cause swelling or spasms of the larynx; cause severe burns and ulcers; cause clouding of the eye and blindness; cause vomiting; cause chest and abdominal pain; cause difficulty swallowing; and cause corrosive injury to the mouth, throat, esophagus, and stomach. High doses inhaled can cause asphyxiation. Chronic exposure can lead to ulcers in the nasal passage, dermatitis, and perforation of the gastrointestinal tract. Sodium hydroxide has been classified as a carcinogen. |
| Arsenic | Arsenic is a naturally occurring element in Earth's crust that can be combined with other elements such as oxygen, chlorine, and sulfur to form inorganic compounds. Exposure usually occurs near or in hazardous waste sites or in areas with high levels of naturally occurring arsenic. | Arsenic exposure can occur through inhalation, ingestion, dermal, or eye contact. Exposure at low levels for extended periods of time can lead to skin discoloration and lesions. High exposure can cause death. |
| Asbestos | Asbestos is a naturally occurring mineral fiber that was previously commonly used in building and vehicle materials for its strength, heat resistance, and corrosion resistance. Exposure commonly occurs in manufacturing, brake and clutch servicing on cars, renovating or demolishing buildings and ships, and cleanup associated with those activities. | Asbestos fibers can be inhaled or ingested and are known to cause cancer and lung disease. |

| Substance | Occurrence/Use | Hazard |
|---|---|---|
| Asphalt (bitumen) fumes | Asphalt is a petroleum product used in road paving, roofing, siding, and concrete work. | Exposure to asphalt fumes can cause headaches, skin rash, sensitization, fatigue, reduced appetite, throat irritation, eye irritation, cough, and skin cancer. |
| Benzene | Benzene is derived from coal and petroleum and is commonly found in gasoline and other fuels. It is also used in the manufacturing of plastics, detergents, pesticides, and other chemicals. | Individuals exposed to benzene have died from leukemia. Long-term exposure may affect bone marrow and blood production. Short-term exposure to high levels of benzene can lead to drowsiness, dizziness, loss of consciousness, and death. |
| Beryllium | Beryllium is a grey metal that is lighter than aluminum and stronger than steel. It is used in the aerospace, telecommunications, information technology, defense, medical, and nuclear industries. It is commonly used as a pure metal; as beryllium oxide; or most commonly as an alloy with copper, aluminum, magnesium, or nickel. Beryllium can also be found in fly ash. | Beryllium may be inhaled or exposed to skin from the air and surfaces. Exposure can cause an immune response, resulting in the individual becoming sensitized to beryllium. Further contact after this can lead to a debilitating disease of the lungs known as chronic beryllium disease. Beryllium exposure can also cause acute beryllium disease and lung cancer. |
| 1-Bromopropane (1-BP) | 1-BP, also known as n-propyl bromide (nPB), is a solvent. It is commonly used in vapor and immersion degreasing operations for cleaning metals, plastics, and electronic or optical components; and adhesive spray applications, dry cleaning, and solvent sprays used in but not limited to asphalt production, aircraft maintenance, and synthetic fiber manufacturing. | 1-BP exposure can cause irritation to eyes, mucous membranes, upper airways, and skin; damage to the nervous system; headaches; dizziness; loss of consciousness; slurred speech, confusion; difficulty walking; muscle twitching; and loss of feeling in arms and legs. Effects can occur even after exposure has ended. |
| 1,3-Butadiene | 1,3-Butadiene is produced through processing petroleum. It is mainly used in the production of synthetic rubber but also found in smaller amounts in plastics and fuels. Common industries where exposure occurs includes synthetic elastomer (rubber and latex) production, petroleum refining, secondary lead smelting, water treatment, agricultural fungicides, production of raw material for nylon, and the use of fossil fuels. Exposure can also occur from car exhaust-polluted air and water near chemical, plastic, or rubber facilities; cigarette smoke; and ingestion of foods that are contaminated from plastic or rubber containers. | Acute exposure of low quantities can cause irritation to throat, nose, and lungs. Skin exposure can also cause frostbite. Acute exposure for high quantities can affect the central nervous system, leading to distorted blurred vision, vertigo, general tiredness, decreased blood pressure, headache, nausea, decreased pulse rate, and loss of consciousness. Chronic affects have been hard to establish due to other confounding factors, but the EPA has classified 1,3-Butadiene as a human carcinogen. |
| Cadmium (Cd) | Cd is a soft, malleable, bluish-white metal. It is commonly found in zinc | Acute inhalation of Cd can cause flu-like symptoms and damage lungs. Chronic |

| Substance | Occurrence/Use | Hazard |
|---|---|---|
| | ore but can also be found in the Cd mineral greenockite. Most Cd today is sourced from zinc byproducts and old nickel-Cd batteries. Cd is used in the production of batteries, alloys, coatings (electroplating), solar cells, plastic stabilizers, and pigments. It is also used in nuclear reactors as a neutron absorber. | exposure can cause kidney, bone, and lung disease, as well as cancer. |
| Carbon dioxide | Carbon dioxide is a colorless, odorless gas that occurs naturally in Earth's atmosphere due to cellular respiration and outgassing from Earth's crust. It is also produced during combustion. | It is considered minimally toxic from inhalation but can cause asphyxiation when it displaces oxygen. Mild exposure can cause headache and drowsiness. At higher concentrations, carbon dioxide exposure can cause rapid breathing, confusion, increased cardiac output, elevated blood pressure, and increased arrhythmias. If it displaces enough oxygen, it can cause death. |
| Carbon monoxide | Carbon monoxide is an odorless, colorless gas that is produced from combustion reactions. | Inhalation of carbon monoxide can cause carbon monoxide poisoning. Carbon monoxide poisoning can cause headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion. Continued exposure will lead to loss of consciousness and eventually death. |
| Chromium | Chromium is a grey, hard metal extracted from chromite ore. Chromium used today in the United States is extracted from recycled stainless steel or imported from other countries. It is used as an alloy for stainless steel and chrome plating; used in pigment and dye, tanning, and glassmaking industries; in reflective paints; for wood preservation; to anodize aluminum; to produce synthetic rubies; and as a catalyst in chemical manufacturing and as an isotope in medicine. | Chromium III (an oxidized form of chromium) is a commonly occurring trace element in humans but can be harmful in large exposures. Chromium VI (hexavalent chromium) is toxic and is a carcinogen to humans. It can also target the respiratory system, kidneys, liver, skin, and eyes. Common exposure occurs during the welding of alloy metals that contain chromium. |
| Concrete and cement | Concrete and cement are composite materials composed of aggregate bonded by fluid that hardens over time. They are widely used for constructing roads, buildings, and other structures. | Concrete and cement exposure can come from exposure to dust and exposure to wet concrete or cement. Dust from exposure to pre-cured concrete or cement prior to adding water, cutting or grinding concrete or cement, can irritate the eyes, nose, throat, and respiratory system, Silica in concrete can cause lung damage including silicosis and lung cancer. Exposure to wet concrete or cement can cause skin irritation or even chemical burns. Concrete and cement can contain |

| Substance | Occurrence/Use | Hazard |
| --- | --- | --- |
| | | hexavalent chromium which is described in this table. |
| Crystalline silica | Crystalline silica is a naturally occurring mineral found in Earth's crust. Sand, stone, concrete, and mortar can contain crystalline silica. It is used to make products such as glass, pottery, ceramics, bricks, and artificial stone. Respirable crystalline silica (particles 100 times smaller than ordinary sand) is created during the cutting, sawing, grinding, drilling, and crushing stone, rock, concrete, brick, block, and mortar. | Inhalation of respirable crystalline silica can increase the risk of silicosis (an incurable lung disease that can lead to disability and death), lung cancer, chronic obstructive pulmonary disease and kidney disease. |
| Dielectric fluids | Dielectric fluids are used as electrical insulators in high-voltage applications such as transformers, capacitors, cables, and switchgear. They are usually composed of highly refined mineral oil, synthetic hydrocarbons and kerosene. | Health hazards vary by manufacturer. Dielectric fluids used to contain polychlorinated biphenyls. There are no numerous manufacturers, some of which are looking into more environmentally friendly components. In general, dielectric fluids can irritate the skin, respiratory, and digestive systems. Depending on the additives, other health impacts can occur from exposure. |
| Diesel | Diesel is a common fuel used to power machinery and vehicles with internal combustion engines including construction machinery and trucks. | Inhalation of diesel vapor for short periods of time can cause nausea, eye irritation, increased blood pressure, headache, lightheadedness, loss of appetite, reduced coordination, and reduced focus. Diesel fuel contact can irritate skin. |
| Diesel exhaust | Diesel exhaust is produced during the combustion of diesel fuel and includes gases and particulate matter including solid elemental carbon and organic carbon including polycyclic aromatic hydrocarbons (PAHs). Diesel engines are used in numerous industries including transportation, mining, construction, agriculture, and manufacturing. | Some PAHs have been shown to cause cancer. Diesel exhaust exposure can also cause eye and nose irritation, headaches and nausea, and respiratory diseases. |
| Ethylene Glycol | Ethylene glycol is a colorless and odorless synthetic liquid that absorbs water. It is a common ingredient in antifreeze (used in engine coolant), hydraulic brake fluid, and ink. | Ingesting small amounts of ethylene glycol is not hazardous. At higher concentrations, when ingested, ethylene glycol breaks down in the body and forms chemicals that crystallize. In large quantities, this can damage the kidneys. It can also impact the acid/base balance in the body, affecting the nervous system, lungs, and heart. |
| Ethylene oxide (EtO) | EtO is a synthetic chemical produced in large quantities to be used as an | EtO is highly flammable and reactive. Acute exposures to EtO gas can cause |

| Substance | Occurrence/Use | Hazard |
| --- | --- | --- |
| | intermediate in the production of several industrial chemicals including but not limited to ethylene glycol, a fumigant in certain agricultural products, and a sterilant for medical equipment and supplies. | respiratory irritation and lung injury, headache, nausea, vomiting, diarrhea, shortness of breath, and cyanosis. Chronic exposure is associated with cancer, reproductive effects, mutagenic changes, neurotoxicity, and sensitization. |
| Formaldehyde | Formaldehyde is a commonly used chemical. In medical fields, it is used as a preservative in medical laboratories, as an embalming fluid, and as a sterilizer. It is used in the production of resins and as a chemical intermediate. Urea-formaldehyde and phenol formaldehyde resins are used in foam insulations, as adhesives in the production of particle board and plywood, and in the treating of textiles. | Long-term exposure at low levels of formaldehyde can cause respiratory difficulty, eczema, and sensitization. Short-term exposure at higher levels can be fatal. Formaldehyde is a known carcinogen. |
| Gasoline | Gasoline is a common fuel used in machinery and vehicles with internal combustion engines. Additives blended in with gasoline may influence its toxicity | Gasoline can cause mild irritation to the skin, eyes, and respiratory tract. Ingestion of gasoline can cause mild to severe irritation of the gastrointestinal mucosa. Inhalation of low quantities of gasoline vapor can cause flushing, reduced coordination, slurred speech, and confusion. At higher concentrations, it can cause loss of consciousness, coma, or death due to respiratory failure. Gasoline vapor is lighter than air, so it poses risk for asphyxiation if in an enclosed space. Gasoline vapor is extremely flammable. |
| Herbicides and pesticides | Herbicides and pesticides are a group of chemicals used to protect plants from pests, weeds, and disease. Widely used pesticides included organochlorine, organophosphorus, and carbamate pesticides. | Health impacts of herbicides and pesticides differ depending on the pesticide or herbicide used. Exposure can occur through skin, inhalation, or ingestion. Exposure has been linked to dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive, and endocrine effects. High exposure can result in death. |
| Hydraulic fluids | Hydraulic fluids are fluids used in machinery to transfer pressure from one point to another. They are used in transmission fluid, brake fluid, and power steering fluid. They are also commonly used in construction equipment. Three common hydraulic fluids are mineral oil, organophosphate ester, and polyalphaolefin. | Little is known about health impact of mineral oil and polyalphaolefin hydraulic fluids. There is documentation of a child ingesting mineral oil hydraulic fluid and eventually dying, as well as documentation of a worker experiencing weakness of the hands after chronic exposure of mineral oil hydraulic fluid to his hands and forearms. Certain organophosphate esters are poisonous and have been documented to cause |

| Substance | Occurrence/Use | Hazard |
| --- | --- | --- |
| | | brain, nerve, and muscle problems due to organophosphate contamination. |
| Hydrogen | Hydrogen is colorless, odorless, non-toxic and non-poisonous gas. It has a variety of industry uses including fertilizer and other chemical manufacturing, petroleum refining, food processing, metalworking, welding, window glass production, electronics manufacturing, and medical applications. | Hydrogen is non-toxic, and lighter than air, but can displace air in confined spaces leading to asphyxiation. Liquid hydrogen exposure can cause severe freeze burns. Hydrogen is highly flammable. |
| Hydrogen sulfide | Hydrogen sulfide is also known as sewer gas, swamp gas, stink damp, and sour damp and is a colorless gas that has a distinct "rotten egg" smell. It is commonly used or produced in the oil and gas, mining, tanning, pulp and paper processing, and rayon manufacturing industries. It also occurs naturally in sewers, manure pits, well water, oil and gas wells, and volcanoes. | Hydrogen sulfide is extremely flammable and toxic. It is heavier air, so it can be especially dangerous in confined spaces. Health impacts vary based on the air concentration. At 2–5 parts per million, effects can include nausea, eye irritation, headaches, loss of sleep, and respiratory issues for some asthma patients. At 1,000 to 2,000 parts per million, hydrogen sulfide is lethal. |
| Isocyanates | Isocyanates are compounds containing the isocyanate group that can react with compounds containing alcohol groups to produce polyurethane polymers. Polyurethane polymers are used in polyurethane foams used for car seats, furniture, foam mattresses, under-carpet padding, packaging materials, shoes, thermoplastic elastomers, elastane fibers, polyurethane paints, polyurethane rubber, sealants, and adhesives. | Isocyanate exposure can cause skin and mucous membrane irritation, chest tightness, difficulty breathing, and asthma. It is a known carcinogen for animals. |
| Kerosene | Kerosene is a mixture of petroleum hydrocarbons that is colorless or yellowish. It is used as fuel for oil heaters, oil lamps, stoves, and flares. It is also a component of some degreasers, pesticides, paint thinners, and jet fuel. | Kerosene exposure can irritate the skin, and eyes. Inhalation of kerosene vapor can irritate the nose and throat and cause coughing. High exposures can affect the nervous system and cause headache, dizziness, nausea, and vomiting. Very high exposure can lead to convulsions and coma. Kerosene is flammable. |
| Mercury | Mercury is a naturally occurring metal. It is used in thermometers, manometers, barometers, gauges, valves, switches, batteries, high-intensity discharge lamps, amalgams for dentistry, preservatives, heat transfer technology, pigments, catalysts, and lubricating oils. | Exposure to mercury can occur from the aforementioned products but also during mining (including gold and silver ores), transport, and production. High exposure can cause permanent kidney and nervous system damage. |

| Substance | Occurrence/Use | Hazard |
| --- | --- | --- |
| Lead | Lead is a naturally occurring malleable, blue-grey heavy metal found in Earth's crust. Today, most lead production in the United States comes from recycled scrap metal and lead-acid batteries. No operational lead mines are open in Washington State, though the Buckhorn Mountain gold mine in Okanogan County has released lead contaminants into groundwater. Lead is generally used for lead-acid batteries (commonly used in cars); ceramic glazes; as a stabilizer in plastics; and as an alloy in ammunition, pipes, cable covering, building material, solder, radiation shielding, collapsible tubes, and fishing weights. It is estimated that 6.1 million lead potable water lines exist in the United States. In 1977, lead-based paint was banned in the United States, but any building constructed before the ban could contain lead. Lead was also used as an antiknock additive and octane booster in gasoline until the mid-1980s. It is still used in high-octane piston engine airplane fuels. | Lead exposure occurs through inhalation or ingestion. Chronic exposure of lead as low as 10 µg/dL (micrograms per deciliter) of blood can impair kidney function, cause high blood pressure, cause nervous system and neurobehavioral effects, cause cognitive dysfunction later in life, and if exposed prenatally can lead to subtle cognitive effects. At 20 µg/dL, lead can cause subclinical effects on cognitive functions and impact sperm health and quality, leading to delayed conception. Exposures between 20 and 40 µg/dL can cause cognitive aging and deficits to visuomotor dexterity, reaction times, and attention deficit. Above 40 µg/dL, lead can cause headache, fatigue, sleep disturbance, joint pain, myalgia, anorexia, and constipation. Above 60 µg/dL, lead can cause convulsions, coma, anemia, peripheral neuropathy, interstitial kidney fibrosis, severe abdominal cramping, and death. |
| Lithium | Lithium is a metal used in batteries, heat transfer liquids, and metal allows. Lithium salt is used as the electrolyte for lithium-ion batteries. | Lithium contact can irritate the skin and eyes. Inhalation can irritate the skin and nose, throat, and lungs. Higher concentrations can cause fluid build-up in the lungs. Ingestion can lead to loss of appetite, nausea, vomiting, diarrhea, abdominal pain, headache muscle weakness, twitching, blurred vision, loss of coordination, tremors, confusion, seizures, and coma. Certain lithium compounds have been known to cause reproductive damage. High exposure may enlarge the thyroid and may affect kidney and heart function. |
| Lubricant oils | Lubricant oils are used in numerous types of machinery to keep moving metal parts from seizing. | Individuals that work with heavy machinery may be exposed to oil mist through their skin and respiratory tract. This can damage lungs, liver, kidneys, adrenal glands, and heart depending on exposure limits. Workers exposed to oil mist have experienced eye irritation, respiratory irritation, headache, fatigue, and higher rates of cancer, especially skin cancer. |

| Substance | Occurrence/Use | Hazard |
|---|---|---|
| Metalworking fluids | Metalworking fluids are oils and other liquids commonly used to cool and lubricate metalwork when being machined. | Metalworking fluids have been known to cause skin irritation; allergic contact dermatitis; irritation of the eyes, nose, and throat; and occasionally, breathing difficulties such as bronchitis and asthma. A rare condition known as hypersensitivity pneumonitis can be contracted from metalworking fluids. Poorly refined mineral oils were used in metalworking fluids prior to 1985 and have been associated with cancers of the larynx, rectum, pancreas, skin, scrotum, and bladder. |
| Methane | Methane or natural gas is a common fuel used for heating, cooking, and electricity generation. | Methane is non-toxic, but a methane leak in a confined space could displace air, leading to asphyxiation. Methane is highly flammable. |
| Methylene chloride | Also known as dichloromethane, methylene chloride is a volatile, colorless liquid solvent. It is used in paint stripping, pharmaceutical manufacturing, paint remover manufacturing, and metal cleaning and degreasing. | Common exposure occurs through inhalation or through skin. Effects from methylene chloride include increased risk of developing cancer; adverse effects on the heart, central nervous system, and liver; and skin or eye irritation. |
| Nitrogen | Nitrogen is an inert gas that makes up 78% of Earth's atmosphere. It is commonly used as an inserting agent to improve safety, used to clear contaminants, and used to purge air from equipment. | Nitrogen is non-toxic, and at atmospheric levels, is harmless to humans. Nitrogen inhalation can become lethal when nitrogen has displaced enough oxygen. When oxygen levels are below 16%, the body will start to react with deeper, faster breathing, and impaired coordination. These symptoms steadily get worse as more oxygen is displaced leading to fatigue. At 12.5% oxygen, permanent heart damage, nausea, and vomiting can occur. Humans can lose consciousness and die when the air is less than 10% oxygen. |
| Nitrogen oxides | Nitrogen oxides are a group of highly reactive gases that include nitrogen dioxide, nitrous acid, and nitric acid. They are generally released in exhaust from combustion reactions such as internal combustion engines. | Nitrogen oxide exposure over short periods of time can aggravate respiratory illnesses such as asthma, causing coughing and difficulty breathing, and can require hospital visits for more impacted individuals. Longer exposure can cause people to develop asthma and other respiratory illnesses. As nitrogen oxides are highly reactive, they can react to chemicals in the air to form particulates and ozone (a greenhouse gas), which can both be harmful to human health. |
| Oxygen | Oxygen is naturally present within Earth's atmosphere at about 21%. It | Oxygen is required for cellular respiration, but at high concentrations or |

| Substance | Occurrence/Use | Hazard |
|---|---|---|
| | is commonly used for resuscitation, in welding, in blast furnaces, as an oxidizer, and in many other industrial processes. | pressures, it can cause nausea, dizziness, muscle twitching, vision loss, convulsions, a loss of consciousness. Breathing pure oxygen can cause coughing and shortness of breath, and at higher exposures, can cause fluid buildup in the lungs which can lead to a medical emergency. Exposure to liquid oxygen can cause skin and eye irritation, as well as frostbite. It is an oxidizer which can cause explosions when exposed to an ignition source and flammable gas. |
| Propane | Propane is a colorless, odorless gas at room temperature. It is generally stored as a liquified gas with an odorant added. It is used as a fuel, refrigerant, solvent, and aerosol propellent. | Liquified propane is extremely cold to the touch and can cause frostbite if exposed to the skin. High concentrations of propane can displace air depleting the oxygen supply which can lead to death. Propane is a flammable gas. |
| Synthetic mineral fibers | Synthetic mineral fibers include fiberglass, mineral wool (rock and slag wool), and refractory ceramic fibers. They are inorganic fibers created from rock, clay, slag, or glass. | It is inconclusive whether synthetic mineral fibers cause respiratory disease. Testing on animals has led to certain synthetic mineral fibers being classified as carcinogens to humans. |
| Toluene | Toluene is a clear, colorless liquid that becomes vapor at room temperature. It has a sharp or sweet odor as a vapor. Toluene is used in paint, metal cleaners, adhesives, gasoline and other fuels, varnish, shellac, nail polish, rust preventatives, and printing ink. | Toluene is flammable; ignition of vapor can occur from only sparks. Toluene exposure can occur from inhalation, ingestion, contact with skin, or contact with eyes. Toluene can cause irritation to the eyes, nose, and throat; dry or cracked skin; headache; dizziness; discoordination; confusion; and anxiety. Long-term exposure can cause tiredness, reaction time reduction, difficulty sleeping, numbness in the hands or feet, and damage to the female reproductive system including pregnancy loss. If swallowed, toluene can damage kidneys and the liver. |

Sources: CSB 2003; OSHA 2004, 2014, 2024a, 2024b, 2024c, 2024d, 2024e, 2024f, 2024g, 2024h, 2024i, 2024j; 2024k, 2024l, 2024m, 2024n, 2024o, 2024p, 2024q, 2024r, 2024s, 2024t, 2024u, 2024v, 2024w, 2024x, 2024y, 2024z, 2024aa, 2024ab, 2024ac, 2024ad; DOE 2004; NJ Health 2007, 2008, 2015, 2016a, 2016b; ATSDR 2014a, 2014b, 2014c, 2015; OSHA and NIOSH 2014; Nicolopoulou-Stamati et al. 2016; Leppert 2018; CDC 2019, 2024; Nowak et al. 2019; Washington State Office of the Attorney General 2022; DNR 2024; EPA 2024d; USDA n.d; VA 2024

The use of hazardous materials associated with industrial lands largely falls under the jurisdiction of the federal Emergency Planning and Community Right-to-Know Act, which requires businesses that store hazardous materials over certain volumes to annually report the chemicals present on site to the State Emergency Response Commission, Local Emergency Planning Committees, and local fire departments for emergency planning (EPA 2024a).

Industrial lands may have areas that have been contaminated from previous activities. Active and inactive land uses that are designated as toxic substance cleanup sites are documented by Ecology's Contaminated Site Register. Ecology's Toxics Cleanup Program documents and oversees cleanups of hazardous materials including petroleum, heavy metals, pesticides, and persistent organic pollutants. Cleanup sites may contain hazardous materials that are no longer permitted, many of which are classified as persistent organic pollutants, such as dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs) (Ecology 2024b).

Within and adjacent to the geographic scope of study, there are 19 cleanup sites currently on the National Priorities List under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as Superfund sites. Many of the cleanup sites are located in western Washington. These sites have hazardous material contamination present in the soil, surface water, or groundwater. Superfund sites are detailed in Table 3.

Table 3. Superfund sites in and adjacent to the geographic scope of study

| Site name | Site description | Site location (coordinates) |
|---|---|---|
| American Lake Gardens/McChord Air Force Base | 0.5-square-mile site that was used as a disposal area for McChord Field between the 1940s and 1970s. Unknown quantities of trichloroethylene (TCE) were disposed of at the site. | Tacoma, WA (47.125°, -122.527°) |
| Boomsnub/Airco | 50-acre site where the former Boomsnub Corporation chrome-plating facility and the Messer atmospheric gas fractionation facility used to operate. Between 1967 and 1994, operations of the chrome-plating facility and illegal waste practices contaminated the soil and groundwater with volatile organic compounds and chromium. | Vancouver, WA (45.677°, -122.622°) |
| Commencement Bay, near shore/tide flats | Active seaport and 12 square miles of shallow water, shoreline, and adjacent land. The site was listed in 1983 due to widespread contamination and includes eight operational units that operate as individual cleanup sites. | Tacoma, WA (47.267°, -122.417°) |
| Commencement Bay, South Tacoma Channel | 2.5 acres that includes the South Tacoma Field and Tacoma Landfill. Since 1982, the South Tacoma Field has manufactured rail cars, repaired and maintained railcars, processed oil waste, and operated two foundries. | Tacoma, WA (47.229°, -122.471°) |
| FMC Corp. | 4-acre pesticide formulation facility that operated from 1951 to 1986. From 1952 to 1969, agricultural pesticides were disposed of in an on-site pit. | Yakima, WA (46.567°, -120.493°) |
| General Electric Co. (Spokane Apparatus Service Shop) | 5-acre site that cleaned and repaired transformers and stored transformer oils and electric-related equipment between 1961 and 1980. Transformers and other equipment contained PCBs, which were released into a dry well during cleaning, contaminating soil, groundwater, and sludge. | Spokane, WA (47.673°, -117.344°) |

| Site name | Site description | Site location (coordinates) |
|---|---|---|
| Hanford 300-Area (Department of Energy [DOE]) | 54-square-mile portion of DOE's Hanford Site used for fuel manufacturing operations at Hanford as well as experimental and laboratory facilities. The site includes an unlined liquid disposal area. | Benton County, WA (46.370°, -119.275°) |
| Harbor Island | 420-acre industrial island created in the early 1900s to support businesses that conduct commercial and industrial activities, including ocean and rail transport operations. PCBs are the most widespread contaminant. Other contaminants of concern include arsenic, PAHs, mercury, and tributyltin. | Seattle, WA (47.579°, -122.352°) |
| Hidden Valley Landfill (Thun Field) | 92-acre landfill and gravel pit operational from 1967 until 1985. | Pierce County, WA (47.095°, -122.288°) |
| Lockheed West Seattle | 33 acres of state-owned aquatic lands and Port of Seattle-owned tidelands that were contaminated by industrial sandblast grit and waste | Seattle, WA (47.584°, -122.363°) |
| Lower Duwamish Waterway | 5-mile segment of Seattle's only river, the Duwamish. The Lower Duwamish Waterway has served as a major industrial corridor since the early 1900s. Its sediment has numerous contaminants from multiple sources including stormwater runoff, wastewater, and industrial practices. The pollutants most detrimental to human health are in the sediment are PCBs, arsenic, carcinogenic polycyclic aromatic hydrocarbons, dioxins, and furans. | Seattle, WA (47.510°, -122.293°) |
| Moses Lake Wellfield Contamination | 15-square mile area that includes he Grant County International Airport (formerly the Larson Air Force Base). The base's operations and industrial activities associated with the aircraft industry contaminated soil and groundwater with gasoline, diesel, oil, PCBs, asbestos, and TCE waste. | Moses Lake, WA (47.205°, -119.316°) |
| Oeser Co. | 27-acre wood-treating facility. | Bellingham, WA (48.770°, -122.514°) |
| Pacific Car & Foundry Co. | 82-acre foundry that was operational since 1907 and 1988. The Kenworth Truck Plant opened on this location in 1993. Cleanup of underground storage tanks; electrical equipment containing PCBs; and soil containing high concentrations of total petroleum hydrocarbons, arsenic, and lead occurred between 1991 and 1997. | Renton, WA (47.489°, -122.196°) |
| Pacific Sound Resources Wyckoff Site | Former 83-acre wood treating facility. | Seattle, WA (47.582°, -122.367°) |
| Pasco Sanitary Landfill | 250-acre landfill that operated from 1972 to 1992. It operated as an open burning dump from 1958 to 1971. It received hazardous waste from 1972 and 1975. | Pasco, WA (46.255°, -119.048°) |

| Site name | Site description | Site location (coordinates) |
|---|---|---|
| Western Processing Co., Inc. | 13-acre former reprocessing plant of animal byproducts and brewer's yeast and expanded to processing industrial wastes. Hazardous wastes included electroplating wastes, waste acids (pickle liquor and battery acid), zinc dross and flue dust from steel mills, transformers, waste oils, pesticides, and spent solvents that were buried in bulk tanks and drums or put into open waste piles and lagoons. | Kent, WA (47.425°, -122.242°) |

Source: EPA 2024b.

Within the geographic scope of study, there are approximately 14,145 MTCA known or suspected contaminates sites in Washington. The MTCA list gets updated every 2 weeks. Many of the cleanup sites are located in western Washington. Superfund and MTCA sites have hazardous material contamination present in the groundwater, surface water, soil sediment, air or soil.

Following remediation or cleanup, some sites may be viable for new land uses.

### 3.2.2 Worker health and safety risks

Hazards at industrial facilities can pose risks to human health and the environment. The risks may include job site hazards for construction workers, operational risks and hazards for future workers and site occupants, inadvertent release of hazardous materials to the natural and built environment, and exposure to existing hazardous materials sites and utilities. Health hazards can include exposure to harmful substances through skin, eyes, or other tissues on the body in the form of chemical hazards (solvents, adhesives, paints, toxic dusts such as lead and silica), and physical hazards (noise, radiation heat). Common workplace hazards at industrial facilities are described in Table 4.

Table 4. Common workplace hazards at industrial facilities

| Workplace hazard | Examples |
|---|---|
| Caught in or between | • Exposed parts on machinery, equipment, or tools that can spin or rotate, cut, roll, press, or roll, press, or grip during operation, adjustment, or maintenance activities.<br>• Materials that can engulf someone like soil in excavations, silage in grain storage, or sludge. |
| Chemical or substance | • Hazardous liquids, vapor, spray, dust, or gas released into the air or on surfaces due to work activities, processes, or emergencies.<br>• Biological substances like blood, animal waste, and mold that can cause illness.<br>• Low oxygen areas or spaces caused by decay or fermentation; or by replacement gases like nitrogen. |
| Electrical | • Exposed or damaged electrical system parts such as plugs, receptacles, extension cords, and wires.<br>• Energized overhead or buried power lines. |

| Workplace hazard | Examples |
|---|---|
| | • Tools, machinery, or walking surfaces that have become energized due to contact with energized power lines. |
| Falls | • Working up high from ladders, roofs, aerial lifts, cranes, etc.<br>• Floor or roof holes, uneven surfaces, and other defects on walkways or working surfaces. |
| Fire or explosion | • Flammable liquids used around ignition sources like electric heaters, welding sparks, and open flame.<br>• Combustible organic or metal dust accumulations in and around process equipment. |
| Hit by or against | • Projectiles and flying particles.<br>• Machinery or equipment that can suddenly start up or become energized during servicing or installation due to the possible release of stored energy (e.g., pneumatic, hydraulic, electrical, thermal).<br>• Stacked or overhead items or materials that can fall or tip over and strike someone.<br>• Violent individuals committing robbery or assault.<br>• Traffic and other danger zones where forklifts, excavators, loaders, tractors, trucks, and cars operate. |
| Hot surface/environment | • Hot surfaces exposed on process equipment.<br>• Working outdoors in hot weather.<br>• Hot indoor environments like foundries or structural fires.<br>• Steam. |
| Noise | • Loud noise from machinery, compressed-air tools, or other sources. |
| Slip or trip | • Icy, wet, or oily floors and outdoor pathways.<br>• Debris, worn out carpeting, tools, or other items on floors or pathways.<br>• Uneven walking surfaces.<br>• Damaged stairs. |
| Sprain/strain | • Awkward body positions like squatting, kneeling, or reaching above shoulder level.<br>• Gripping heavy objects like cinder blocks or exerting high hand force while using tools like pruners.<br>• Heavy, frequent, or awkward lifting.<br>• Vibration when using hand tools like sanders, grinders, jackhammers, and chainsaws.<br>• Repeated motions related to production-line or keyboard work. |
| Other | • Extreme cold caused by weather, refrigerated storage rooms, liquid pressurized gases like nitrogen.<br>• Radiation from sources like x-ray equipment, microwave- or radio-frequency towers and equipment, welding arcs, and lasers.<br>• Pressure extremes present during diving, tunneling, or high elevation work. |

Source: Washington State Department of Labor & Industries 2016.

Avoidance and minimization measures and BMPs that can be implemented to either prevent or address the above workplace hazards include changing the chemicals, materials, or equipment to be safer; and changing the method or tool used to be safer or improve the location (limit access or improving ventilation). The use of personal protective equipment to protect eyes, face, feet, hands, ears, torso, and lungs and provide fall protection can be required depending on the anticipated risk (Washington State Department of Labor & Industries 2023).

### 3.2.3 Hydrogen

Hydrogen has been produced for decades using fossil fuel feedstocks. Approximately 10 million tons of hydrogen—inclusive of all production pathways—are currently produced in the U.S each year.

Almost all the hydrogen produced in the U.S. is used for refining petroleum, treating metals, producing fertilizer, and processing foods to make products like gasoline, silicon chips, and peanut butter. Most of this hydrogen is produced at or close to where it is used—typically at large industrial sites.

The major hydrogen-producing states are California, Louisiana, and Texas. In Washington, hydrogen production facilities using fossil fuel feedstocks operate to provide hydrogen for use by oil refineries.

Washington has several industrial facilities currently producing and using hydrogen, including:

- Air Liquide Hydrogen Plant, Anacortes: Produces about 2.7 billion cubic feet of high purity hydrogen from steam and natural gas each hour.
- Matheson Tri-Gas, Anacortes: Produces about 7,000 tons of hydrogen each year from steam and natural gas.
- bp Ferndale refinery, Ferndale: Capacity for 188 million cubic feet per day.
- Refineries, including Shell Puget Sound refinery in Anacortes: uses hydrogen in its processes.

Hydrogen gas is non-toxic and non-poisonous as a chemical alone (DOE 2004). This analysis considers the risks associated with handling hydrogen.

#### *3.2.3.1 Hydrogen safety and risks*

All fuels have some degree of associated risk and advantages. The health and safety risks of green hydrogen production and use are comparable to those of oil refineries, which produce and use petroleum fuels and hydrogen. Hydrogen use and production risks and advantages and representation of how each trait is applied in practice are described in Table 5.

Table 5. Hydrogen traits and implications

| Trait | Description | Implication |
|---|---|---|
| Colorless flame (risk) | When hydrogen burns, the flame is pale blue and is nearly invisible and undetectable by human senses. | Installation of hydrogen and flame detectors that quickly identify any leak and minimize the potential for undetected flames are required (DOE 2004; NREL 2015; NFPA 2023a). |
| Odorless (risk) | Human senses cannot detect the presence of gaseous hydrogen. | Installation of proper sensing equipment to prevent leaks that can lead to asphyxiation when concentrations reach high levels in confined spaces (DOE 2004; NREL 2015; NFPA 2023a). |

| Trait | Description | Implication |
|---|---|---|
| High energy content by weight, but not volume (risk) | This creates challenge for storage and is why hydrogen is compressed and stored at high pressures. | Hydrogen tanks are equipped with pressure relief devises to prevent pressure from becoming too high (DOE 2024; NFPA 2023a, 2023b). |
| Small molecule, low viscosity (risk) | This makes hydrogen prone to leakage, which can become a flammable concentration. | Proper ventilation is necessary to prevent hydrogen leak concentrations reaching a flammable concentration (DOE 2004; NREL 2015; NFPA 2023a). Hydrogen detection equipment is also necessary to identify elevated hydrogen concentrations, indicating a leak. |
| Lighter than gasoline vapor and air (advantage) | Hydrogen will disperse rapidly if released in an open environment. In a closed environment, hydrogen will concentrate at the ceiling. This reduces the risk of ignition at ground level. | Lowers the risk of fires that could harm people or buildings. Propane and gasoline vapor are heavier than air and are more likely to remain at ground level, and the risk of fires that could harm people or buildings increases (DOE 2004; NREL 2015). |
| Not toxic (advantage) | Gaseous hydrogen does not pose health or physical hazards (OSHA 2024ae). | Safer to handle than other common fuels (DOE 2024). |
| Lower radiant heat than conventional gasoline (advantage) | Air around the hydrogen flame is not as hot as a gasoline flame. | The risk of hydrogen secondary fires is lower than that of gasoline (DOE 2004). |

Note: See the subsection Hydrogen safety requirements and standards for more information on the equipment used for risk prevention.

The safe use of fuel focuses on preventing situations where the three combustion factors—ignition source (spark or heat), oxidant (air), and fuel—are present (DOE n.d.). Hydrogen has a wider flammability range and a lower ignition energy than gasoline vapor and natural gas, but hydrogen requires higher concentrations in air to ignite or explode. As Table 6 shows, the ignition energy for hydrogen is similar to that of gasoline vapor and natural gas at concentrations below 10%.

Table 6. Hydrogen, gasoline vapor, and natural gas combustion comparison

| Property | Hydrogen | Gasoline vapor | Natural gas |
|---|---|---|---|
| Flammability limits (% in air) | 4–74% | 1.4–7.6% | 5.3–15% |
| Explosion limits (% in air) | 18.3–59.0% | 1.1–3.3% | 5.7–14% |
| Ignition energy (millijoules) | 0.02 | 0.20 | 0.29 |
| Flame temperature in air (°C) | 2,045 | 2,197 | 1,875 |
| Stoichiometric mixture (most easily ignited % in air) | 29% | 2% | 9% |

Source: DOE 2004

The U.S. Department of Energy (DOE) analyzed 120 hydrogen incidents that were recorded between 1999 and 2019, revealing that 3.19% occurred at a production facility and 5.32% occurred at storage/use facilities (Yang et al. 2021). Of the hydrogen-related components that are the most prone to failure, piping/fitting/valves and storage devices would be located at green hydrogen production facilities. Probable causes of the 120 hydrogen incidents are outlined in Table 7. Damage and injuries resulting from the 120 hydrogen incidents are included in Table 8.

Table 7. Hydrogen incident probable causes

| Incident probable cause | Percentage of recorded incidents |
|---|---|
| Equipment failure | 35.78 |
| Human error | 14.22 |
| Design flaw | 12.07 |
| Failure to follow standard operating procedures | 8.62 |
| Inadequate maintenance | 8.19 |
| Incomplete operating and maintenance procedures | 5.17 |
| Deficiency in procedures | 4.74 |
| Abnormal operations | 4.31 |
| Inadequate venting design | 3.45 |
| Inadequate equipment | 3.45 |

Source: Yang et al. 2021, Table 2a

As shown in Table 7, equipment failure is the main cause of incidents, accounting for 35.7%, followed by human error (14.22%). Human error and design flaws, accounting for 14.22% and 12.07%, respectively. Human error includes incorrect disassembly, assembly, movement, and replacement. Design flaws can be in the form of sensor false alarms and short lives and early retirement of equipment.

Table 8. Hydrogen incident damage and injuries

| Damage and injury | Percentage of recorded incidents |
|---|---|
| Property damage | 41.83 |
| Minor injury | 10.27 |
| Loss of human life | 5.32 |
| Facility closure | 1.9 |
| None | 31.8 |
| Lost time injury | 6.84 |
| Facility closed until repair correction | 2.66 |

Source: Yang et al. 2021, Table 2c

Of these incidents, approximately 31% resulted in no damage or injury. Minor injuries and lost time due to injury occurred in approximately 17% of incidents, while loss of human life occurred in 5%. Injury rates for natural gas incidents and hydrogen incidents are nearly equal; however, the fatality rate of hydrogen incidents can be twice that of natural gas incidents due to the chemical properties of hydrogen which burns faster and with a higher pressure than natural gas.

#### *3.2.3.2 Hydrogen safety requirements and standards*

The safe use of any fuel and the focus on preventing situations that can cause combustion (ignition source, oxidant, and fuel) are key to prevention and safety during hydrogen production. Regulations, guidelines, and codes and standards have been established through years of hydrogen use (refer to Table 1 for a list of regulations and Attachment 1 for a list of standards and guidelines). These help reduce the risk of an incident, however, risk cannot be completely eliminated.

Systems and organizations are in place to establish codes and standards that facilitate hydrogen commercialization. Industry requirements and standard practices provide for mitigation of the hazards associated with gas or liquid hydrogen. Strict guidelines and third-party testing for safety and structural integrity are constantly evolving to become more standardized and will continue to do so over the 75-year timeframe of this study.

The initial manifestation of a safety accident in hydrogen utilization is typically leakage and diffusion (Yang et al. 2021). Engineering controls that address potential leakage and diffusion allows for the regular safe use and handling of hydrogen. These precautions assist in the prevention of hydrogen exposure and are outlined below:

- **Hydrogen leak and flame detectors** are necessary to detect leaks and fires. Ultrasonic leak detectors are used to detect the ultrasonic turbulent pressure fluctuations caused by hydrogen being released into a space. Handheld ultrasonic leak detectors can also be used to detect the source of a hydrogen leak (Zalosh and Barilo n.d.). Point gas detectors are used to detect leaks at a specific location, usually 5 meters (16.4 feet) or less in diameter. For flammable gases, like hydrogen, a point gas detector provides a measurement in percent lower explosive limit (%LEL) (DESU 2024). Hydrogen flame detectors can detect hydrogen flames that may not be visible to the naked eye and have low radiant heat, making them very hard to detect without proper equipment (H2 Tools 2024b; DOE 2004). Detection systems are required as part of National Fire Protection Agency (NFPA) 2 but are not required under 29 Code of Federal Regulations (CFR) 1910.103 or Washington Administrative Code (WAC) 296-24-31503 (NFPA 2023a). Proper inspections, done per manufacturer specifications, are important to keep sensors functioning (H2 Tools 2024b). Pressure relief systems may use reclosing devices like relief valves, non-reclosing devices like rupture discs, or a combination of both in parallel. Some systems may also be equipped with emergency blowdown systems that are operated by control systems (H2 Tools 2024d).
- **Ventilation equipment:** Any indoor facility containing hydrogen process equipment must be properly ventilated to prevent the accumulation of hydrogen in the case of a leak or spill.
- **Material compatibility:** Equipment that would be exposed to hydrogen, including pipes, storage tanks, valves, and fittings, are required by law to conform to the specifications of 29 CFR 1910.103, which includes references to American Society of Mechanical Engineers (ASME) and American National Standards Institute (ANSI) material standards. In addition, NFPA 2 and 55 have guidelines for materials used with hydrogen to prevent deterioration from exposure to hydrogen (H2 Tools 2024b):
  - Materials commonly used for hydrogen gas include austenitic stainless steels, aluminum alloys, low-allow ferritic steels, carbon-manganese ferritic steels, and copper alloys. Materials to avoid for gaseous hydrogen storage and transport

include high strength ferritic and martensitic steels; gray, malleable, and ductile cast irons; nickel alloys; and titanium alloys.
  - Materials commonly used for liquid hydrogen storage include austenitic stainless steels and aluminum alloys. For piping, it is not recommended to join copper by soldering or brazing. Aluminum alloy is approved materials for liquid and gaseous hydrogen (H2 Tools 2024c). X-ray fluorescence or spark emission spectrography are two accurate, inexpensive, and fast ways to verify metal alloys (H2 Tools 2024b). As liquid hydrogen is a cryogen, specific materials of construction are required to ensure the mechanical integrity of process equipment. As such, replacements should only be made "in kind." If the need arises to change materials, then this change must be managed.
- Maintenance and inspection of hydrogen facility components is necessary to reduce risks associated with human fatigue and neglect. Replacement components should be from the same manufacturer and should be installed per manufacturer specifications. Detectors should be tested regularly, and if determined faulty, replaced in a timely manner to avoid undetected leaks and fires (H2 Tools 2024b).

## 3.2.4 Fire and explosion risk

### *3.2.4.1 Facility fire and explosion risk*

Industrial uses commonly include flammable materials, gases, and dust. Explosions can occur when flammable gases or dusts are exposed to a heat source such as fire and an oxidizer such as oxygen (OSHA 2014; UC Irvine 2024). Explosions can also occur when fires are not properly contained and are then exposed to flammable gases or dusts. Risk of explosion is reduced through proper dust control and ignition source management when handling flammable dusts and proper fire response. The use of detection systems for flammable gases can detect leaks before they reach explosive concentrations. Proper handling and storage of flammable materials would reduce fire risks.

Hydrogen gas has a wide flammability range between 4% and 74% in air and requires 0.02 millijoule of energy to ignite at higher concentrations. At concentrations of less than 10% in air, the energy required to ignite increases to levels similar to that of natural gas or gasoline in their respective flammable ranges. Hydrogen burns with a colorless flame, making it difficult to detect that it is burning (DOE 2004). A review of 221 incidents at hydrogen facilities in the United States between 1969 and 2019 showed that 114 involved fires. Of those 114 incidents, 4 occurred at a hydrogen production facility (H2 Tools 2024a).

Facility fires and explosions can impact surrounding properties. Setbacks are minimum distances that dictate how far storage tanks must be from materials and conditions (exposure groups). Calculating a minimum setback distance requires detailed site-specific information on risk factors and exposure groups. The setback distances described in this technical appendix are provided for context and are not reflective of the site-specific risk factors and exposure groups that would be considered in the hazard analysis and risk assessment study required by NFPA. A site-specific hazard analysis and risk assessment should be used to inform siting and design.

The severity of fires and explosions would vary by incident and the quantity of hazardous materials and hydrogen on site. To identify risks to surrounding properties and setbacks, site-specific facility hazard analysis and risk assessments of fire and explosion risks are required by NFPA 55, which is adopted into the Washington International Building Code (IBC) and International Fire Code (IFC). In addition, NFPA 2, Hydrogen Technologies Code, which may or may not be codified at the local level, provides standards to reduce explosion risk. A hazard analysis and risk assessment would calculate a setback by considering the highest risk of the proposed system and potential release scenarios.

Criteria for determining setbacks are based on addressing hazards associated with hydrogen flammability and the risk of fire and explosion. The setback distances in NFPA 55 are prescribed so that the risk of fire and explosion would not present a greater risk to the public in terms of fatalities or injuries than does an existing gasoline service station (NFPA Appendix E.1).

NFPA provides minimum setbacks based on pressure (gas) or storage size (liquid) alone—it does not include risk factors, site specific characteristics, or fire resistance measures. The NFPA recommendations are for industrial application. Outside of that, NFPA specifically points to building codes. Both liquid and gas hydrogen systems and surrounding development would be required to develop to the acceptable level of safety for occupants and adjacent individuals. A site-specific hazard analysis and risk assessment study would include those factors when determining setback distances. An example of NFPA minimum setbacks based on a 15,001- to 75,000-gallon capacity liquid storage tank and gas storage with a pressure of less than 15 psig to greater than or equal to 250 psig and a pressure of less than 7,500 to greater than or equal to 15,000 psig are provided below in Table 9.

Table 9. Minimum NFPA setback distance examples by exposure group

| Exposure group | Distance (feet) Liquid hydrogen tank storage (15,001- to 75,000-gallon capacity) | Gas hydrogen tank storage (pressure of less than 15 psig to greater than or equal to 250 psig and a pressure of less than 7,500 to greater than or equal to 15,000 psig) |
|---|---|---|
| **Exposure Group 1** | | |
| Lot lines | 75 | 16 |
| Air intakes (HVAC, compressors) | 75 | |
| Wall openings | 75 | |
| Ignition sources | 50 | |
| **Exposure Group 2** | | |
| Places of assembly | 75 | 13 |
| Parked cars | 25 | |
| **Exposure Group 3** | | |
| Buildings or structure *(noncombustible or limited combustible)* | 5 | 13 |
| Buildings or structure – combustible, sprinkled [a] | 75 | |
| Flammable gas storage or systems *(above or below ground)* | 75 | |
| Stationary containers | 5 | |
| All classes of flammable and combustible liquids *(above ground and vent or fill openings if below ground)* | 100 | |
| Hazardous materials storage | 75 | |
| Heavy timber, coal or other slow burning combustible solids | 100 | |
| Wall openings (unopenable) | 50 | |
| Inlet to underground sewers | 10 | |
| Overhead wire of an electric trolley, train or bus line | 50 | |
| Below nearest overhead electrical wire | 25 | |
| Piping containing other hazardous materials | 15 | |
| Flammable gas metering and regulating stations above grade | 15 | |

Source: NFPA 55, Table 11.3.2.2 for liquid hydrogen and NFPA 2, 7.3.2.3.1.2(B)(a) for gas hydrogen
Notes:
Distance is measured from the part of the hydrogen system closest to exposure group. Does not include risk factors, site specific characteristics, or fire resistance measures.
A site-specific hazard analysis and risk assessment study would include those factors when determining setback distances.
Numbers presented in this table are for context.
A site-specific hazard analysis and risk assessment should be used to inform siting and design.
NFPA only provides recommendations up to 75,000 gallons. Above 75,000 gallons requires performance-based compliance approach with the Authority Having Jurisdiction (AHJ).
HVAC = heating, ventilation, and air conditioning.
a. Setbacks are subject to review and approval by the AHJ.

Example minimum setback distances from Table 9 for structures and materials typically found in industrial areas are displayed on Figure 2. For example, minimum setback of a liquid hydrogen tank to a lot line for a 15,001- to 75,000-gallon capacity would require a minimum distance of 75 feet (NFPA 2023b) (NFPA 55, Table 11.3.2.2).

Minimum setback of an outdoor bulk hydrogen storage system is established based on service pressure and pipe diameter. For example, distance from a compressed gas system to a lot line for a pressure of less than 15 pounds per square inch gauge (psig) to greater than or equal to 250 psig and a pressure of less than 7,500 to greater than or equal to 15,000 psig would both be a minimum of 16 feet (NFPA 55, Table 10.4.2.2.1). Minimum setbacks for other structures, such as houses, would be determined during a site-specific hazard analysis and risk assessment study and would include the risk factors, site-specific characteristics, or fire resistance measures described above, as well as other applicable local building and fire code setbacks.

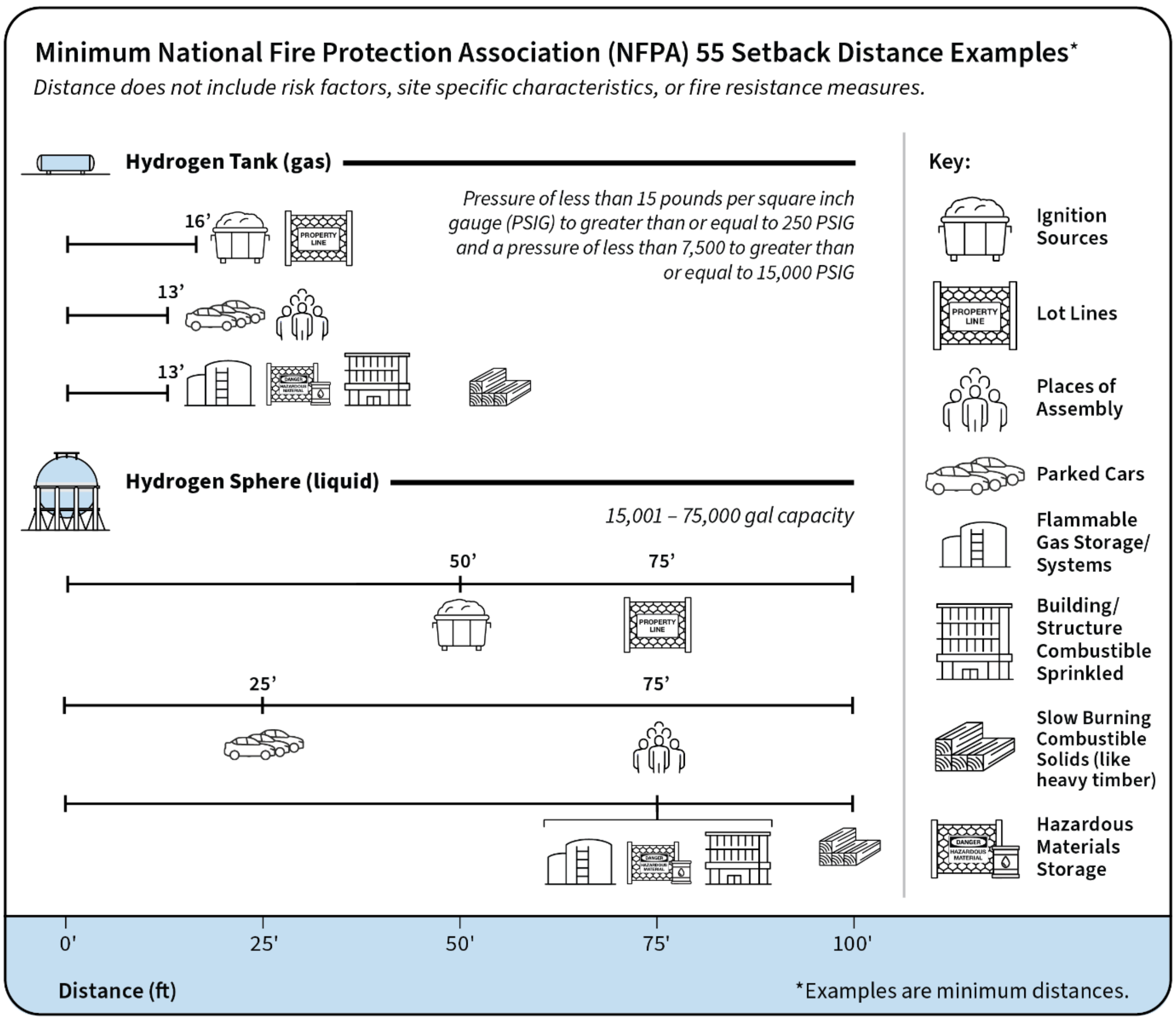


Figure 2. Minimum NFPA setback distance examples

Source: NFPA 55, Table 11.3.2.2 for liquid hydrogen and NFPA 2, 7.3.2.3.1.2(B)(a) for gas hydrogen

Using a prescribed scientific model that predicts the extent of specific hydrogen concentrations and heat fluxes, risk criteria are identified. Risk factors that can increase setback requirements include:

- Gas:
    - Storage pressure
    - Leak diameter
    - Pipe diameter
    - Distance to combustible and non-combustible equipment and infrastructure
- Liquid:
    - Use and storage of all classes of flammable or combustible liquids and combustible materials
    - Ordinary electrical equipment and other sources of ignition including process or analytical equipment
    - Intakes for ventilation, air conditioning equipment, or compressors
    - Welding or cutting operations, smoking

If there is more than one storage array with a volume greater than 400 standard cubic feet, the setback would represent each array and the maximum potential exposure (NFPA 55, Appendix H.1).

Where there are fire barrier walls, setbacks could be reduced (NFPA 6.7.3(6)). Fire barrier walls are designed have a specified fire resistance rating that limits the spread of fire. Fire barrier walls intercept flames and explosions by blocking the line-of-site between any potential leak points and exposure groups. An example of a fire barrier wall for horizontal hydrogen storage is in Figure 3, below.

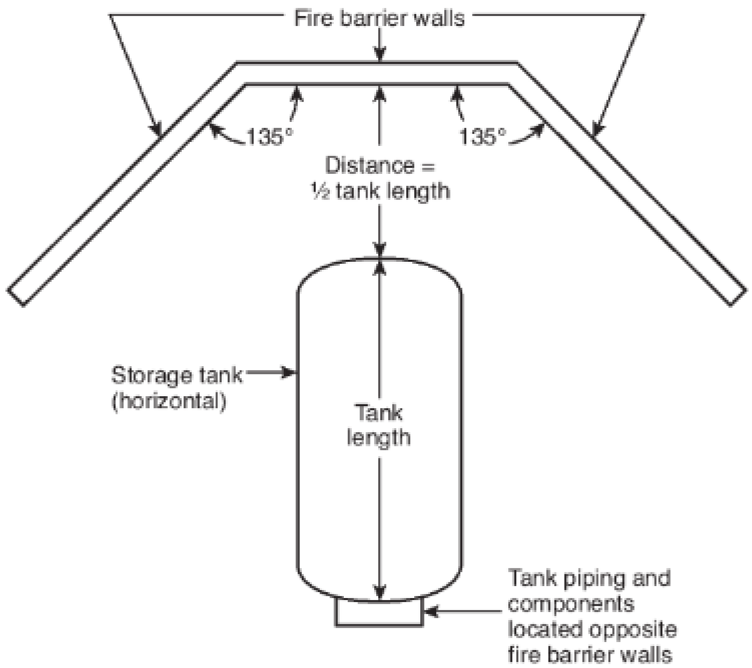


Figure 3. Schematic of three-sided fire barrier wall enclosure for horizontal hydrogen storage

Source: NFPA 2, Figure A.8.3.2.3.1.6(C)(1)(b)(vii)(b)

The permittable distance of reduction is dependent on the fire resistance rating, other fire-safety measures and specific materials (wall size, insulation, connecting angles, piping and control systems, venting, sprinklers), and the exposure group. Fire barrier walls are required to be designed and constructed in accordance with the requirements of the building code.

#### 3.2.4.2 Wildfires

Wildland fires affect grasslands, forests, and brushlands, as well as structures on or adjacent to these lands. They carry the potential for injury, loss of life, and damage. Such fires can occur from either or natural causes. The type and amount of topography (e.g., slope, elevation, and aspect), weather/climate conditions (e.g., wind, temperature, and humidity), and vegetation/fuels are the primary factors influencing the degree of fire risk and fire behavior in an area. The combination of these factors, described in more detail below, can fuel or arrest the spread of wildfire if it occurs. The sections below also discuss wildfires and air pollution, as well as climate change and fire risk.

Washington has experienced many extreme fire events in recent years, partly attributed to climate change effects and the legacy of forest fire suppression practices, and this is expected to increase in the future. The combination of longer fire seasons, population growth, declining forest health, and other changing risk factors has made wildfire considerations a top priority in the state, as outlined in the *Washington State Wildland Fire Protection 10-Year Strategic Plan* (DNR 2019). The plan recognizes the need for proactive management of the landscape and the need to prepare for expected increases in wildland fires in future years, among other considerations (DNR 2019).

Much of the study area occurs in western Washington where development is denser, and risk of wildfire is lower. There are also areas that are transitions between land and human development, known as wildland-urban interface (WUI) areas (Figure 4 and Figure 5). They have greater risk of wildfire than fully developed areas (USFA 2022).

**Topography**

Topography is the shape of the land including elevation (height above sea level), slope (the steepness of the land), aspect (the direction a slope faces), and features such as canyons and valleys. Topography can strongly influence fire behavior, including how fast a fire moves through an area; fire typically moves more quickly as it travels uphill compared to either downhill or across flat terrain. As heat rises in front of the fire, it preheats and dries upslope fuels, resulting in their rapid combustion (Bennett 2017).

Topography also influences patterns of precipitation and temperature. Washington can be categorized into geographic regions with respect to topography and the associated considerations for wildfire. The forested central Cascade Mountain region poses a relatively higher risk for extreme wildfire events compared to other parts of the state. However, due to the presence of forests, higher slopes in the mountains, and lack of requirements such as access to transmission lines and freight highway routes, almost none of these lands are included in the study area. Lands on the eastern slopes of the Cascade Range are subject to dry continental climate conditions with extreme temperatures and receive less precipitation due to the topographic rain shadow effect.

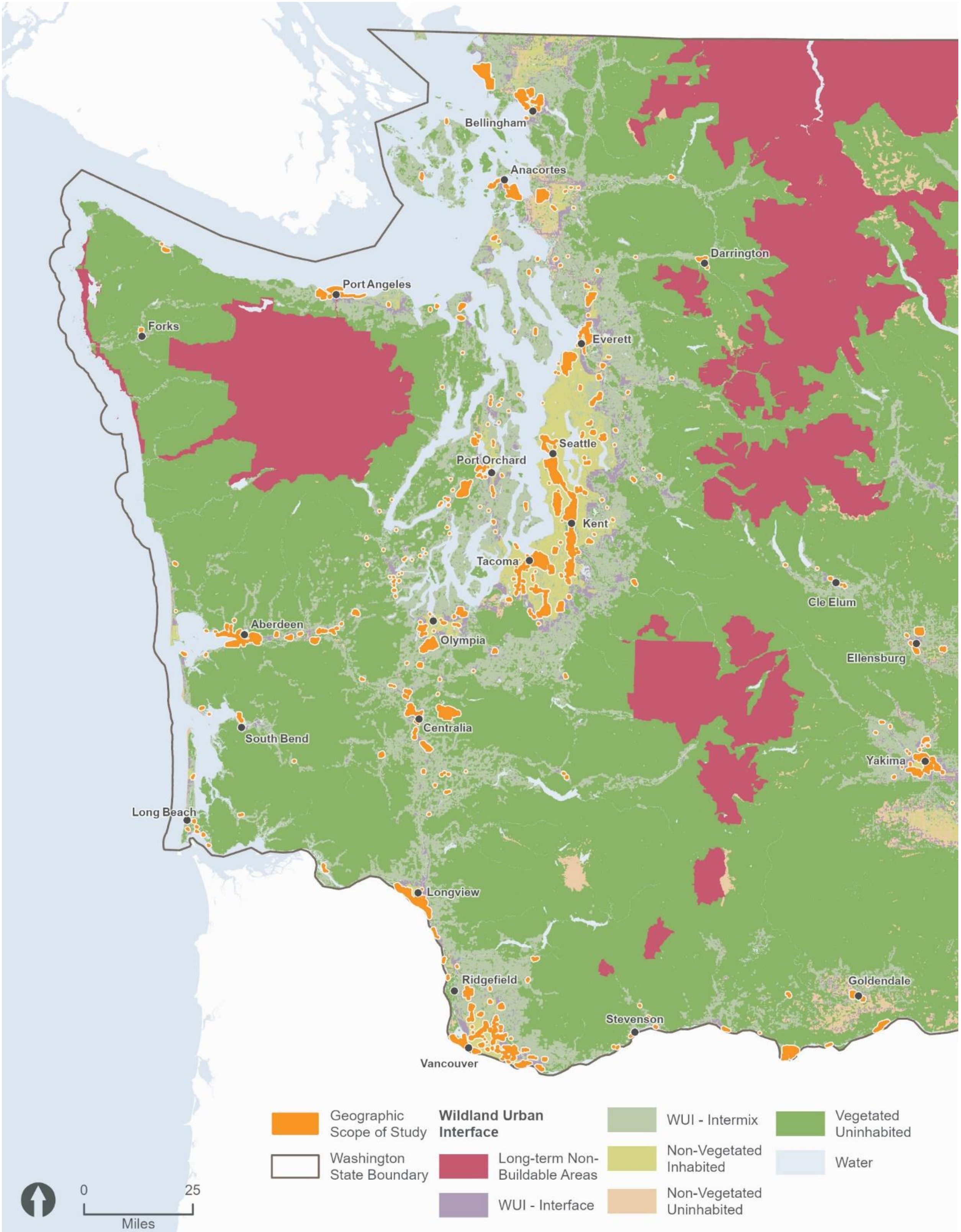

Figure 4. WUI areas in western Washington State

Source: Tonkel 2024

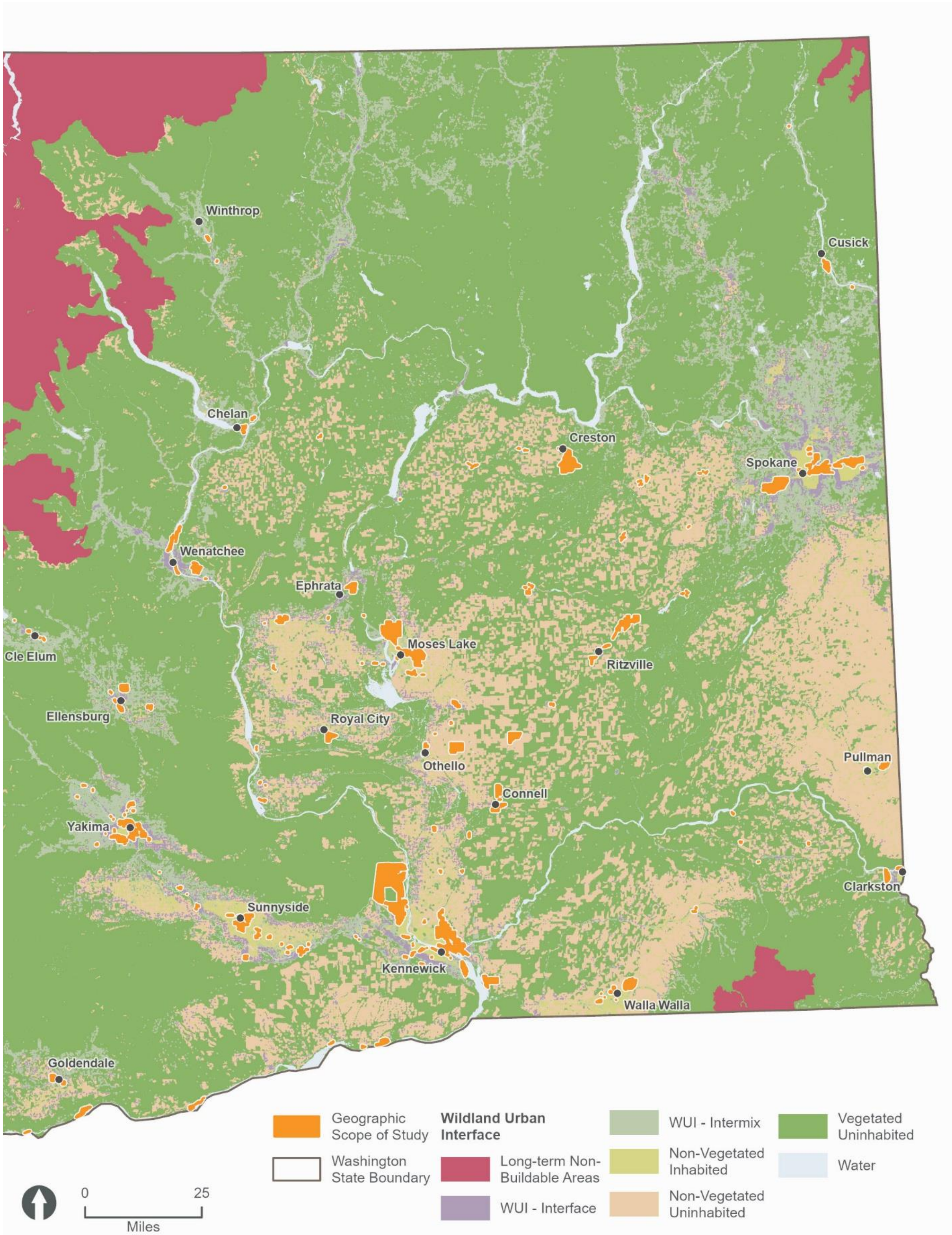


Figure 5. WUI areas in eastern Washington State

Source: Tonkel 2024

**Weather and climate**

Weather conditions such as wind, temperature, and humidity also influence fire behavior. Parts of Eastern Washington are included in the green hydrogen facilities study area. Eastern Washington is the most arid region of the state and the region with the highest fire risk. Fuels in hotter and drier temperatures are more susceptible to ignition and catch fire more readily than fuels in moister and cooler temperature conditions. Climate change also has an influence on forests and fire behavior, as prolonged drought and invasive species infestations change conditions in a way that can exacerbate fires and lead to more extreme wildfires.

The University of Washington (UW) has conducted climate resilience mapping to model wildfire risk across the state through time. The map shows the projected change in high fire danger days[1] compared to historical (1971–2000) averages. An increase in high fire danger days indicates a greater potential for wildfire danger to damage infrastructure, interrupt businesses, and affect public health and well-being (UW 2024). Although the severity of fire risk is variable across the geography of the state, with a higher number of high fire danger days in the eastern part of the state, it is notable that all counties show a moderate increase in the projected number of fire days between the years 2010 and 2039 and a significant increase in the projected number of high fire days between the years 2040 and 2069, roughly coinciding with the extended timeframe of the green hydrogen facilities. The higher greenhouse gas (GHG) scenario[2] anticipates more warming by the end of the century than the lower GHG scenario.[3] There is a notable difference in the high fire day projections in the scenario depending on the level of projected emissions, though all GHG scenarios predict a ubiquitous increase in fire days across all of Washington's counties. Additional discussion of GHG emissions is provided in the *Air Quality and Greenhouse Gas Technical Appendix*.

The regions most at risk for wildfire are the Eastern Slope of the Cascades, Okanogan Big Bend, and northeastern Washington. All of these regions include portions of the study area except for the Blue Mountains of the southeastern Palouse and the Okanogan Big Bend. Within these regions, as of 2050, the likelihood of weather and fuel conditions conducive to wildfire is projected to range from 39% to 85% depending on location and scenario. As of 2075, conditions are projected to range between 42% and 90%. A marked increase in conditions conducive to wildfire is projected to occur within the operational timeframe of the green hydrogen facilities.

[1] A high fire day is defined by UW in the context of climate resilience mapping as a day in which in which 100-hour fuel moisture (i.e., the amount of water in fuel/vegetation available for combustion) is less than the historical 20th percentile.

[2] The higher GHG emissions scenario is also referred to as the representative concentration pathways 8.5 (representative concentration pathway [RCP] 8.5) scenario or, more commonly as the "the business as usual" scenario. This scenario assumes that use of coal and other carbon-based pollutants may continue to dominate the energy sector in future years.

[3] The lower GHG scenario is also referred to as the RCP 4.5 climate modeling scenario. RCP 4.5 assumes that climate policies are invoked (or implemented) to achieve the goal of limiting emissions and radiative forcing.

**Vegetation and fuels**

Fuel is the material that feeds a fire and is a key factor in wildfire behavior. Fuel sources are diverse and include dead tree leaves, twigs, branches, and standing trees; live trees; brush; and dry grasses. Additional fuel sources can include structures such as homes, buildings, and other associated combustible materials. Natural communities in the eastern Cascades and the foothill region, as noted in the *Biological Resources Technical Appendix*, contain vegetation highly susceptible to wildfire conditions. Fire-adapted natural communities are discussed in additional detail in the *Biological Resources Technical Appendix*.

DNR has developed a mapping tool in collaboration with the U.S. Forest Service (USFS) to depict the WUI in the state. For planning purposes, the WUI can be evaluated at the county level using the mapping tool. Wildlands include many types of natural communities where roughly 50% of the ground surface is vegetated. Wildlands in the state include forests, woodlands, sagebrush-steppe, and open grasslands, among others. The WUI is often located along the fringe of urban development. To be considered WUI, development and structures must border the wildlands on at least one side. Low-density, undeveloped pockets of urban areas are referred to as wildland urban "intermix" for mapping purposes. These areas include structures surrounded on two or more sides by wildlands (Tonkel 2024).

**Wildfires and air pollution**

Smoke generated through wildfires is composed of a mixture of gaseous pollutants (e.g., carbon monoxide), hazardous air pollutants (e.g., polycyclic aromatic hydrocarbons), water vapor, and particle pollution. Particle pollution is the main component of wildfire smoke and the principal concern for public health. The wildfire crisis is considered a public health crisis; as wildfires increase in their size and severity over time, the related public health effects are anticipated to increase. As of 2024, wildland fires and prescribed fires account for 44% of the nation's primary emissions of fine particulate matter (EPA 2024c). As wildfires burn fuel, large amounts of carbon dioxide, black carbon, brown carbon, and ozone precursors are released into the atmosphere. Additionally, wildfires emit a substantial amount of volatile and semi-volatile organic materials and nitrogen oxides that form ozone and organic particulate matter. These emissions can lead to harmful exposures for first responders, nearby residents, and populations in regions that are farther from the wildfires (NOAA 2021). Exposure to these pollutants can generate asthma attacks, coughing, and shortness of breath. Refer to the *Air Quality and Greenhouse Gases Technical Appendix* for additional information about potential air contaminants.

### 3.2.5 Emergency response services

Emergency response includes law enforcement, fire departments, and emergency medical services. Impacts to emergency response services is addressed in the *Public Services and Utilities Technical Appendix*.

## 3.3 Potentially required permits

The following permits related to EHS would be required for construction, operation, or decommissioning of typical green hydrogen facilities and activities:

- **Ecology Air Operating Permit**: Required for facilities that could emit the following in a 12-month period:
  - More than 100 tons per year of any air pollutant
  - More than 10 tons per year of any hazardous air pollutant
  - More than 25 tons per year of a combination of hazardous air pollutants
- **Air Prevention of Significant Deterioration and Water Discharge Permit (Ecology or Washington State Energy Facility Site Evaluation Council):** Air and water discharge permits may be required depending on the planned level of contaminants discharged to air and whether discharge to waters of the state is proposed.
- **U.S. Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Construction Stormwater General Permit (administered by Ecology)**: Disturbance of greater than 1 acre requires coverage under the NPDES Construction Stormwater General Permit. The applicant must show discharge points, treatment methods, and erosion control BMPs to receive coverage under this permit. If discharging to stormwater or wastewater utility infrastructure, the provider must also be identified.
- **NPDES Industrial Stormwater General Permit (Ecology/EPA):** Required to operate sites with certain industrial activities that could discharge stormwater pollutants to surface waters of the state or certain facilities that have the potential to be significant contributors of pollutants or may be expected to cause a violation of any water quality standard (including groundwater standards).
- **Conditional Use Permit (local county or municipality):** Operation of a green hydrogen facility may require a use permit or a conditional use permit subject to review and approval by the jurisdiction (county or municipality) of its proposed operation. The use permit process would include review of EHS considerations.
- **Local government permits (county or municipality)**: Municipalities and counties each have their own land use process to make sure a proposed land use aligns with their zoning code and comprehensive plan. For industrial lands, EHS is taken into account so that facilities that are potentially dangerous to the public do not abut high-density residential areas.

## 3.4 Green hydrogen production facility

This section describes potential impacts of green hydrogen production facilities. For the purposes of the PEIS, the estimated footprint of a green hydrogen production facility, based on existing facilities in other areas, ranges from 1 acre to 10 acres, depending on the production method, type of storage facilities, and layout of external pipes and tanks, a parking area, and security fencing. The estimated height of structures is up to 100 feet.

A green hydrogen production facility would typically include a connection to the electricity grid to power all, or a portion of, the facility's equipment needs and buildings. Facilities typically connect to the main transmission line through distribution lines that can be up to 100 feet and the between 1 and 8 miles in length, which would be determined by the project developer based on the distance between a selected site and existing electricity grid infrastructure. This technical appendix includes evaluation of impacts associated with distribution line connections to main transmission lines.

Off-site access roads may be needed to connect a facility to the existing state routes. Most of study area is less than 10 miles from a state route (63% within 1 mile and 99% within 10 miles). If needed, the project developer would determine the length of off-site access road needed, based on the distance between a selected site, existing road infrastructure, and coordination with state and local departments of transportation.

### 3.4.1 Impacts from construction and decommissioning

Construction would require a temporary workforce of approximately 10 to 100 employees. Activities could include using, storing, and dispensing hazardous materials and fuel for vehicles and equipment on site. There may be flammable or combustible materials, compressed gases, and fuels used. Welding and other activities may involve open flames. Hazardous materials for operation would be brought onto the site during construction in preparation for operation. Decommissioning would include a temporary workforce and activities and materials similar to those for construction.

#### *3.4.1.1 Hazardous materials*

Construction and decommissioning would introduce hazardous materials that could impact the surrounding environment, workers, and the public. Hazardous materials used during construction would be typical of most industrial facility construction and include solids, fluids, and gases. Table 10 describes anticipated hazardous materials used in construction of a facility similar in type and scale of a 10-acre site.

Table 10. Common hazardous materials potentially present during construction of a typical industrial facility

| Material | Use | Approximate volumes stored/generated on site |
|---|---|---|
| Fuels: diesel, gasoline, kerosene, and propane | Vehicles, construction machinery, generators, and maintenance equipment | <5,000 gallons |
| Other petroleum fluids such as lubricating oils, hydraulic fluids, brake fluids, and fuels; coolants and battery electrolytes | Vehicles, construction machinery, generators, and equipment maintenance | <3,500 gallons |
| Compressed gases: oxygen, acetylene, and nitrogen | Welding, cutting, and purging | <6,000 cubic feet |
| Solvents and cleaning agents | Cleaning, maintenance, and preparing surfaces for paint or other treatment | <1,000 gallons |

| Material | Use | Approximate volumes stored/generated on site |
|---|---|---|
| Paints, primers, thinners, corrosion control coatings, sealants, and adhesives | Weatherproofing and preservation of equipment and structures, other construction and maintenance processes | <500 gallons |
| Herbicides and pesticides | Vegetation and insect control | <25 gallons |
| Battery electrolytes | Vehicle and equipment batteries | <250 gallons |
| Dielectric fluids (transformer oil) | Anti-conductive insulation for electric components, such as wires | <10,000 gallons |
| Concrete, cement, asphalt | Paving, building structures, retaining walls | 1,570–13,186 cubic yards |

Workers could be exposed to any of the materials discussed in Table 10. Fuels, hydraulic fluids, coolant, and other petroleum products and fluids would be present in most construction machinery and vehicles using an internal combustion engine or using hydraulic systems. Fuels and hydraulic fluids may be stored on site as well, and exposure could occur during refueling. Compressed gases would be stored on site for the use in welding, cutting, and purging. Exposure to these could occur during these activities or if a storage tank leak were to occur. Solvents and cleaning agents could be stored on site for cleaning purposes. Exposure to these could occur during cleaning and surface prep for finishing. Following prepping of surfaces, workers could be exposed to chemicals contained in paints, primers, and other finishes while applying them to surfaces on the site or if someone were to spill one of these products. Battery electrolyte exposure would be unlikely, unless batteries were damaged. Dielectric fluid exposure could occur to anyone working with high-voltage components on the site. Concrete, cement, and asphalt would be used for surfacing, but are unlikely to be used for structures. Exposure could occur during paving. Herbicides and pesticides may be used to kill noxious weeds on the site or to protect landscaping on the site.

Improper handling of the materials listed in Table 10 could release hazardous materials into the environment, increasing the risk of environmental contamination and leading to health and safety risks to construction workers and members of the public within the vicinity of a proposed green hydrogen production facility. Washington State's MTCA dictates the handling and cleanup of these types of hazardous materials. Releases would need to be contained, assessed, and remediated, with hazardous waste transported and disposed of in compliance with state and federal regulations.

A spill prevention, control, and countermeasure (SPCC) plan would be required if more than 1,320 gallons of fuel is stored on site to reduce the risk of hazardous materials entering navigable waters. An SPCC plan would include requirements for remediation materials needed on site and a procedures list of actions to take if a spill occurs, including secondary containment. Secondary containment requirements are an additional layer of protection to prevent leaks or spills from the primary containment layer. Any storage of liquid bulk containers (any container with a capacity of 55 gallons or more) and oil-filled equipment would require a secondary means of containment (40 CFR 122). An SPCC plan would also include personal protective equipment (PPE) requirements for individuals attending to spills to reduce the risk of exposure to potentially harmful substances. Contaminated soil and other hazardous materials contained would need to be disposed of properly. The developer and contractor would need to coordinate with local disposal facilities to properly dispose of contaminated material. Impacts to water quality are discussed in the *Water Resources Technical Appendix*, and impacts to soil resources are discussed in the *Earth Resources Technical Appendix*.

Airborne pollutants such as dust, fumes, and aerosolized particles would increase due to construction of a green hydrogen production facility. Most, if not all, construction vehicles and heavy machinery would likely use internal combustion engines, which produce exhaust that includes particulate matter. Air quality emissions are analyzed in the *Air Quality and Greenhouse Gases Technical Appendix.* Dust can impact visibility for the surrounding community and pose health risks to workers and the general population when inhaled. Common dust reduction methods include spraying water on exposed dry soil and creating containment structures and systems for construction activities that produce a lot of dust. Construction materials like solvents and cleaning agents produce fumes that are potentially harmful to humans and the environment. PPE would be worn by construction workers using these materials to reduce exposure. Proper storage, including reducing exposure of materials to extreme temperatures, would reduce the risk of leaks. Fumes do not usually pose a risk to the public unless leaks occur that release large quantities into the air. Some of the materials listed in Table 10 are flammable. Fire risk is discussed in Section 3.4.1.2.

Construction activities may encounter contaminated sites that have previous hazardous materials such as underground chemical storage tanks and asbestos-containing materials and building material. Damaging an underground storage tank could cause leaks that could contaminate soil, groundwater, and surface water. Impacts to water quality are discussed in the *Water Resources Technical Appendix*, and impacts to soil resources are discussed in the *Earth Resources Technical Appendix*. Conducting a site assessment prior to any construction work would help evaluate potential on-site hazards. Plans could be implemented based on findings to avoid risks of exposure and release.

Hazardous materials associated with construction and green hydrogen production (discussed below in Section 3.4.2) could be present at the site during decommissioning. Decommissioning could involve a higher risk of releasing hazardous materials due to degradation or dismantling of facility components. Part of the process would be removing some of the safeguarding features designed to reduce risks.

Accidents or failures during construction or decommissioning that could result in the release of hazardous materials are rare, and if they do occur, they are unlikely to happen at a scale that could result in risk of environmental contamination or an increase in threats to human health and safety. Through compliance with laws and permits, and with implementation of actions that could avoid and reduce impacts, construction and decommissioning activities would likely result in **less than significant impacts** related to release of hazardous materials.

#### 3.4.1.2 Worker health and safety

Site characterization and construction activities would present health and safety risks similar to those that are present on other industrial construction sites. Occupational health and safety hazards associated with the construction and site characterization of green hydrogen production facilities could include:

- Falls from facility structures
- Collisions with construction vehicles
- Exposure to electricity
- Exposure to hazardous materials (see Section 3.4.1.1)
- Exposure to the elements, including extreme conditions, and sunlight
- Fire and explosions (see Section 3.4.1.2)
- Exposure to high-temperature materials
- Exposure to high-volume construction noises

Facilities would follow Occupational Safety and Health Administration (OSHA) regulations, which establish required safety protocols, risk reduction measures, and limitations on potential exposure to specific hazards. Occupational health and safety regulations specific to the construction, operation, and decommissioning of industrial facilities are detailed under the Occupational Safety and Health Act.

Additional health and safety requirements would be established during site-specific facility-level planning to address hazards specific to the facility or site. These would address:

- Crane and hoist safety
- Electrical resources
- Fall resources
- Heat and cold stress
- Lockout and tagout

Occupational health and safety risks that could vary by geography include exposure to the elements and smoke associated with wildfire.

The types of occupational health and safety impacts that could occur during decommissioning would be comparable to those that could occur during construction. Decommissioning could involve a higher risk of exposure to hazardous materials, electricity, or fire due to degraded or malfunctioning facility components.

While accidents could occur, laws, regulations, and industry standards are in place to prevent health and safety hazards in the workplace, including regulations specific to green hydrogen production facilities. These requirements would be supplemented by facility- or site-specific health and safety plans. Through compliance with laws and permits, and with implementation of actions that could avoid and reduce impacts, construction and decommissioning activities would likely result in **less than significant impacts** related to worker health and safety.

#### 3.4.1.3 Fire and explosions

**General fire and explosions**

Fire and explosion risks during construction and decommissioning include activities or materials that could cause or feed fire or explosions, such as flammable hazardous materials and vegetation.

The hazardous materials listed in Table 10 such as petroleum products and solvents are flammable and pose a fire risk. Proper handling and storage of flammable materials would reduce fire risks. Fires could be started from ignition of flammable materials that have spilled. Construction activities such as welding, saw cutting, and soldering can create sparks that can ignite flammable materials. Vehicles and pieces of machinery used during construction would have internal combustion engines. Malfunction of these machines could result in internal combustion, and machinery could catch fire. Vegetation on or adjacent to green hydrogen production facility construction sites could serve as fuel for fires.

Explosions can occur from flammable dusts and gases reacting with a heat source and oxidizer. Flammable compressed gases, petroleum product fumes, and dust would likely be present during construction of a green hydrogen production facility. Fires could lead to explosions if not contained properly. Improper dust control and flammable gas storage could also lead to explosions.

Construction crews would be required to review and comply with NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations as required by the IBC (adopted in Washington State under Chapter 51-50 WAC). NFPA 241 provides information related to proper storage of equipment and materials that are flammable, processes to avoid and address fire hazards, utilities, and fire protection equipment (NFPA 2022a).

BMPs for reducing fire risk include developing a fire safety program prior to construction or demolition; removing accumulated flammable waste material, debris, and dust from structures and their vicinity after each work shift; not obstructing access to existing fire hydrants; and having internal combustion engine equipment exhaust face away from combustible materials. Standards in NFPA 241 are designed to reduce the risk of ignition of flammable materials by putting in safeguards that limit the availability of ignition sources within the vicinity of flammable materials (NFPA 2022b).

In addition, construction crews would be required by law to abide by 29 CFR 1926, which sets construction safety standards for construction projects in the United States. Title 29 CFR 1926 Subpart F sets fire protection and prevention standards including flammable liquids, liquified petroleum gas, and temporary heating devices. Typical measures found in this subpart are fire extinguisher standards set by the NFPA, setbacks for flammable materials and liquids, and maintenance of proper ingress and egress. Chapter 296-155 WAC sets similar construction standards for projects in Washington State. Fire protection and prevention standards required by law in Washington are set in Part D.

Through compliance with laws and permits, and with implementation of actions that could avoid and reduce impacts, construction and decommissioning would likely result in **less than significant impacts** related to fire and explosion risk.

**Wildfires**

Potential wildfire impacts associated with site characterization, construction, and decommissioning consist of those related to the risk factors described in Section 3.2.4.2, combined with activities described previously under general fire risk. Construction of green hydrogen production facilities would generate ignition risks that require careful management, especially in areas of high fire risk. Wildfires could also spread to a green hydrogen production facility construction site and be exacerbated by the presence of flammable materials on site. With climate change, fire risk is anticipated to increase throughout the state (UW 2024). Where construction is proposed in WUI or intermix areas, wildfires could spread to urban areas. Proactive coordination with emergency managers, facility planning, and compliance with OSHA and NFPA requirements would reduce construction-related risks.

Through compliance with laws and permits, and with implementation of actions that could avoid and reduce impacts, construction and decommissioning activities would likely result in **less than significant impacts** related to wildfire risk.

### 3.4.2 Impacts from operation

Green hydrogen facilities would be operated 24 hours per day, 7 days per week. Larger facilities are expected to have one to three staff on site 24 hours per day, 7 days per week. Smaller facilities would have limited staffing hours with remote operation. In addition to on-site staff to perform routine testing of hydrogen systems for any leaks, fires, or other hazards, monitoring systems would be in place on site. Maintenance could include excavation of utility or transmission lines, which could require in-water work.

The potential impacts from operation would vary depending on the type of production technology used and quantities of materials present. Green hydrogen production facilities using electrolysis would produce hydrogen using electricity to split water molecules into hydrogen and oxygen molecules, as described in Section 2.3.1 of the PEIS. Electrolyzers may contain hazardous alkaline solutions. Hazards from electrolysis include risk of hydrogen leak and ignition, alkaline solution spill and exposure, and general industrial work hazards.

Steam-methane reforming (SMR) uses renewable natural gas and high-temperature steam, which react with the presence of a catalyst to produce hydrogen, carbon monoxide, and a small amount of carbon dioxide, as described in Section 2.3.2 of the PEIS. Carbon monoxide and steam react further to produce carbon dioxide and hydrogen. To purify the hydrogen and carbon monoxide mixture, a process called pressure swing absorption is used, which requires an absorbent material such as zeolites, molecular sieves, or activated carbon (Pearson 2021) Zeolites are common absorbents used as supplements and in industrial processes and can be harmful if ingested in large quantities or if they are suspended in air in large quantities. Activated carbon is not harmful. Hazards from SMR include risk of hydrogen leak and ignition, exposure to heavy metals (nickel as a catalyst), exposure to zeolites, natural gas leak and ignition, carbon monoxide poisoning, exposure to nitrogen oxides, and general industrial work hazards.

In pyrolysis, methane is heated and decomposed to create solid carbon and gaseous hydrogen, as described in Section 2.3.3 of the PEIS. Several decomposition methods are used for pyrolysis, including thermal cracking, which uses extreme heat; thermocatalysis, which incorporates a catalyst; plasma, which uses microwave discharges at atmospheric pressure; liquid metal; and molten salt. Molten salt is commonly used in industrial settings and may pose heat or chemical burn-related risks, if not properly contained. Hazards from pyrolysis include risk of hydrogen leak and ignition, exposure to heavy metals, exposure to high-temperature materials, natural gas leak and ignition, and general industrial work hazards.

Bio-gasification uses heat, steam, and oxygen to convert biomass into hydrogen and other products, as described in Section 2.3.4 of the PEIS. To produce hydrogen, the biomass is partially burned in the presence of a catalyst to produce carbon dioxide, which reacts with the carbon-based matter to form carbon monoxide. Hazards from bio-gasification include risk of hydrogen leak and ignition, carbon monoxide exposure, exposure to other byproducts depending on feedstock, and general industrial work hazards.

Hazardous materials used or produced in these processes are discussed in Section 3.4.2.1, and fire risks are discussed in Section 3.4.2.3. Air emissions are discussed in the *Air Quality and Greenhouse Gases Technical Appendix*.

#### 3.4.2.1 Hazardous materials

Operating a green hydrogen production facility would involve the production, use, and storage of hazardous materials. Different hazardous materials could be present depending on the production method, but hydrogen would be present at all facilities.

Depending on the production method, different hazardous materials may be used for production (inherently in the equipment) or stored (in barrels or tanks on site). Table 11 details hazardous materials, their purposes, and lower and upper bound estimates.

Table 11. Hazardous materials used, stored, or produced during operation of a green hydrogen facility

| Material | Purpose | Lower bound (1-acre) estimate | Upper bound (10-acre) estimate |
|---|---|---|---|
| Methane (gas) | Used for SMR production method | 135,000 cubic feet used on site per day of operation.<br><br>In equipment (pipes, etc.) used for production. No storage tanks on site. | 1,350,000 cubic feet used on site per day of operation.<br><br>In equipment (pipes, etc.) used for production. No storage tanks on site. |
| | Used for pyrolysis production method | 2,000,000 cubic feet used on site per day of operation. | 20,000,000 cubic feet used on site per day of operation. |

| Material | Purpose | Lower bound (1-acre) estimate | Upper bound (10-acre) estimate |
|---|---|---|---|
| | | In equipment (pipes, etc.) used for production. No storage tanks on site. | In equipment (pipes, etc.) used for production. No storage tanks on site. |
| Alkaline electrolyzers (usually potassium hydroxide and sodium hydroxide) (solid or liquid) | Stored for electrolysis production method | 1,000 gallons of alkaline electrolyzer fluid stored. | 30,000 gallons of alkaline electrolyzer fluid stored. |
| Hydrogen (gas or liquid)<br><br>Note: could also be stored on-site once produced. | • Electrolysis production<br>• SMR production<br>• Pyrolysis production<br>• Bio-gasification production | • 900 kg/day produced<br>• 10,000 kg/day produced<br>• 1,000 kg/day produced<br>• 10,000 kg/day produced | • 9,000 kg/day produced<br>• 100,000 kg/day produced<br>• 10,000 kg/day produced<br>• 100,000 kg/day produced |
| Nickel (solid) | In catalyst required in green hydrogen production facilities using SMR or methane pyrolysis facilities using thermocatalysis | Proprietary equipment. Volumes contained within a catalyzer are not published for hydrogen production. | Proprietary equipment. Volumes contained within a catalyzer are not published for hydrogen production. |
| Biomass gassifiaction byproducts (solid) | Moisture, ash (solid carbon), carbon dioxide, hydrogen, nitrogen, chlorine, sulfur, or oxygen | Potential byproducts, estimates are not available. | Potential byproducts, estimates are not available. |

### Methane

Methane or natural gas is a required feedstock for both SMR and methane pyrolysis. It can also be released as an emission during methane pyrolysis. Methane is non-toxic, but a methane leak in a confined space could displace air, leading to asphyxiation. Methane is flammable and could increase fire risk as discussed in Section 3.4.2.2. Methane is also a GHG. GHG impacts are discussed in the *Air Quality and Greenhouse Gases Technical Appendix*. Methane leaks are preventable through proper maintenance and detection systems that could be utilized at a green hydrogen production facility.

### Alkaline

An alkaline electrolyzer is required for electrolysis, which also requires an electrolyte. It is common to use potassium hydroxide and sodium hydroxide. Electrolytes can come in solid or liquid form. Potassium hydroxide is less harmful to humans. Inhalation, ingestion, and skin and eye contact are common forms of exposure that can cause eye irritation, skin irritation, respiratory symptoms, coughing, sneezing, skin burns, vomiting, and diarrhea (CDC 2019).

Sodium hydroxide exposure typically occurs in the same manner as potassium hydroxide. It is strongly corrosive. Acute exposure can damage the gastrointestinal tract; cause swelling or spasms of the larynx; accumulate fluid in the lungs; cause severe burns and ulcers; cause clouding of the eye and blindness; cause vomiting; cause chest and abdominal pain; cause difficulty swallowing; and cause corrosive injury to the mouth, throat, esophagus, and stomach. High doses inhaled can cause asphyxiation. Chronic exposure can lead to ulcers in the nasal passage, dermatitis, and perforation of the gastrointestinal tract. Sodium hydroxide has been classified as a carcinogen (ATSDR 2014a). Liquid electrolytes pose a risk of spill, especially when they need to be replaced. Proper handling and spill prevention measures, including secondary containment measures, would be in place to reduce these risks, and reduce the risks of contaminating soil, surface water, and groundwater (see *Water Resources Technical Appendix* and *Earth Resources Technical Appendix*). Workers handling electrolytes would be equipped with proper PPE such as gloves, coveralls, and goggles. Spent potassium hydroxide or sodium hydroxide solutions are considered a corrosive hazardous waste when the pH is greater than 12.5 (40 CFR 261, Subpart C). Coordination with local waste facilities would be required to dispose of spent electrolyte solutions.

**Hydrogen**

At temperatures above -423 degrees Fahrenheit, hydrogen is a gas. Hydrogen gas is non-toxic and non-poisonous and because it is a gas at atmospheric temperature and pressure, it cannot contaminate surface water and groundwater. Hydrogen is lighter than air and diffuses rapidly, so asphyxiation is unlikely unless a leak were to occur in a confined space. Hydrogen is also flammable (DOE 2004). Leak and asphyxiation risk can be greatly reduced with detection systems described in Section 3.2.3.2. Fire risks from hydrogen are discussed in Section 3.4.2.2.

Hydrogen risks to human health and safety generally come from exposure to liquid hydrogen. Liquid hydrogen could be stored on site prior to transport. Liquid hydrogen is stored in a double-walled, vacuum-insulated cryogenic storage tank, and needs to be cryogenically frozen. Proper maintenance of cryogenic liquefaction systems and storage tanks, as well as redundant safety features, would reduce the likelihood of liquid hydrogen exposure. Liquid hydrogen exposure to humans can cause severe freeze burns, which can be lethal. In addition to proper maintenance and redundant design features, operators who work around liquid hydrogen should wear PPE to reduce the risk of exposure.

Hydrogen can embrittle metals, leading to metal piping fracturing and leakage. The metals listed in Section 3.2.3.2 are suggested to reduce the risk of pipe failure and leakage. Improper care of hydrogen piping can lead to leaks, which, if they go undetected in confined spaces, can cause asphyxiation. Title 29 CFR 1910.103 sets federally required standards for components that come into contact with hydrogen and would be required in development of a green hydrogen production facility. This code includes ASME and ANSI material standards. NFPA 55 includes standards for materials used for hydrogen transport and storage and is required to be followed in Washington. Though not legally binding everywhere, NFPA 2 also includes standards. In addition, in Washington State, WAC 296-24-31503(1)(c) must also be followed for all gaseous hydrogen piping systems. This subsection of code refers to ANSI standards as well for piping.

**Other hazardous materials**

Other hazardous materials associated with green hydrogen production that are present, as inherent in equipment or a byproduct, but not stored or produced are nickel and biomass gasification byproducts.

***Nickel***

A nickel-based catalyst would be required in green hydrogen production facilities using SMR or methane pyrolysis facilities using thermocatalysis. Nickel is a naturally occurring element and can be found in trace amounts in food, water, soil, and air. Acute exposure to higher quantities of nickel has caused lung damage, kidney damage, gastrointestinal distress, pulmonary fibrosis, and renal edema. Chronic exposure has been known to cause dermatitis, eczema symptoms, and respiratory impacts including asthma (EPA 2000). Nickel is considered an essential element for mammals, but at high levels it is considered a carcinogen (OSHA 2023).

Nickel is entirely contained in pellet form within the catalyst inside the reformer tubes. It would not be stored on site or released from the reformer tubes during hydrogen production. The catalyst would be replaced once every 5 to 6 years as part of routine maintenance. Nickel would be disposed of as part of the process of disposing of the catalyst. Catalysts can be disposed of through reuse to produce new catalysts and other useful materials, recycling through recovery of metals or the treatment of spent catalysts for safe disposal.

Failure to dispose of or handling of reformer tubes could lead to accidental release of nickel, leading to required spill prevention measures to avoid potential soil, groundwater, and surface water contamination. The operator would need to consult with local disposal facilities and review local and federal disposal standards for nickel-based catalysts to avoid contaminating the site and surrounding area. Impacts to water quality are discussed in the *Water Resources Technical Appendix*, and impacts to soil resources are discussed in the *Earth Resources Technical Appendix*.

***Biomass gasification byproducts***

Solid byproducts from biomass would be dependent on the feedstock. State law requires biomass used for green hydrogen production to come from solid organic fuels, including wood, forest, or field residues, or from dedicated energy crops that do not include wood pieces that have been treated with chemical preservatives. Based on these feedstocks, the potential waste from biomass can include moisture, ash (solid carbon), carbon dioxide, hydrogen, nitrogen, chlorine, sulfur, or oxygen.

As stated above, biomass-gasification hazardous materials would need to be assessed at the project level, as each facility would have a unique feedstock and process. Scrubbers would be used to remove these compounds before expelling the product and waste, so with proper maintenance, most of these compounds would not come in contact with workers. Scrubbers would be enclosed, and potential failure would be detected when water pooling is evident in the hazardous spill containment vessels placed below the scrubber as part of spill prevention measures. Contaminated water from spill containment would be treated on site to NPDES requirements or routed to a wastewater treatment plant (see *Water Resources Technical Appendix*). Biomass gasification byproducts would require secondary containment systems, which would be based on the configuration, size and needs of the facility. Operators would need to analyze their feedstock to address hazardous material concerns, but generally exposure to humans would occur only from a redundancy failure where the scrubber and enclosure of the scrubber both failed causing gas and liquids to leak. Biomass-gasification plant equipment is generally placed outside, so leaks into confined spaces are unlikely.

Through compliance with laws and permits, and with implementation of actions that could avoid and reduce impacts, operation activities would likely result in **less than significant impacts** related to hazardous materials.

#### *3.4.2.2 Worker health and safety*

The types of occupational health and safety hazards during operation would be similar to those present during construction. While the types of hazards that people could be exposed to remain the same during operation, the risk of exposure would decrease in conjunction with a decrease in the scale and intensity of on-site labor during operations (up to three employees) compared to construction. In particular, the risk of falls from facility structures, vehicle collisions, and exposure to high-volume noises would be greatly reduced during typical operation and on-site maintenance. While accidents could occur, laws, regulations, and industry standards are in place to prevent health and safety hazards in the workplace.

Following OSHA guidelines for work in industrial facilities would greatly reduce the risks of health impacts, including severe injury and death. Providing workers with proper safety measures like PPE, harnesses, and trainings would also greatly reduce risk.

While accidents could occur, laws, regulations, and industry standards are in place to prevent health and safety hazards in the workplace, including regulations specific to green hydrogen facilities. These requirements would be supplemented by facility- or site-specific health and safety plans.

Through compliance with laws and permits, and with implementation of actions that could avoid and reduce impacts, operation activities would likely result in **less than significant impacts** related to worker health and safety.

#### *3.4.2.3 Fire and explosions*

**General fire and explosions**

Green hydrogen production facilities would have hydrogen present on site, which is highly flammable. Depending on the production method, green hydrogen production facilities could also have the following flammable or combustible substances on site: methane, oxygen, and biomass. Biomass flammability would depend on the source of biomass. Oxygen, while not flammable, is highly combustible and can cause explosions from hydrogen or methane fires (DOE 2004). Methane gas is flammable at levels of 5% to 15% by volume in air (NIH 2016).

Activities involving regular maintenance of a green hydrogen production facility may include periodic electrical repair, welding, and equipment use and fueling. These activities could also increase fire danger.

Having an emergency action plan, working flame and leak detectors, and working fire suppressant systems would reduce the risk of fires spreading. Fires could get out of control if these safeguards are not in place. Fires caused from any of these fuel sources could ignite hazardous materials described in Section 3.4.2.1. Burning these materials would release hazardous fumes and/or particulate matter into the air that would be hazardous to workers, the public, and the surrounding environment. Spreading fires would first pose a risk to any on-site staff but could pose a risk to the public if they were to spread off-site. Utilizing setbacks and site perimeters that are nonflammable would reduce this risk.

Fire safety would be key to reducing risks. Following IFC as required by Chapter 51-54A WAC and NFPA guidelines (which are required by law where jurisdictions adopt and codify) in design, handling of flammable materials, and other operations would significantly reduce risks. Having proper detection systems in place and fire extinguishers readily available would help reduce the risk of fires getting out of control. Since hydrogen burns with a colorless flame, specialized detections systems would need to be used.

**Hydrogen and methane explosions**

Hydrogen explosions cannot occur with pure hydrogen; an oxidizer such as oxygen must be present. Hydrogen combined with oxygen can explode when the concentration of oxygen is between 10% and 41% in air and the concentration of hydrogen is between 18.3% and 59% (DOE 2004). Methane can explode at levels above 5.5% in air (NIH 2016). It is impossible for either methane or hydrogen to explode when they are isolated away from an oxidizer. Operators would have to adhere to WAC 296-24-31503 for gaseous hydrogen systems and 29 CFR 1910.103 for gaseous and liquefied hydrogen systems, which include regulations to safeguard hydrogen systems including requiring detectors and establishing setbacks to reduce mixing. Section 3.4.2.1 describes the setback requirements based on a site-specific hazard analysis and risk assessment, which are required by NFPA 55.

Unintended hydrogen and methane releases could cause fire and explosion. If a fire or explosion were to occur, it could result in property damage and injury or loss of life on-site. These impacts may also extend beyond the facility boundary. The severity of these impacts would vary by the type of incident and land uses of the surrounding properties, as well as emergency response capabilities. Hydrogen and methane explosion risk can be reduced, but may not be completely eliminated, through compliance with regulations requiring the proper siting, design, and operations according to NFPA 55 requirements. Compliance with these requirements is necessary for building and operation permit approval and operational inspections to minimize fire and explosion incident severity and consequence.

In addition, NFPA 2, which may or may not be codified locally, provides standards to reduce explosion risk. As stated above, explosions require a flammable gas like hydrogen to mix with an oxidizer and be ignited. Due to hydrogen's low density, it is nearly impossible for hydrogen explosions to occur in an open-air environment. Providing required setbacks between flammable materials and maintaining gas leak and flame detectors are ways to limit destruction and loss of life from explosions. A hazard analysis and risk assessment study would be required during site design to identify ignition and exposure factors and apply setbacks.

Depending on the specific location, severity, and emergency response capacity, operation activities would likely have **less than significant to potentially significant adverse impacts** from fires and explosions. The severity of risks would need to be assessed for each facility based on the project location, production method, and quantities of flammable materials produced or stored on-site.

**Wildfires**

Like with construction, green hydrogen production facilities would generate ignition risks that require careful management, especially in areas of high wildfire risk. Wildfires could also spread to a green hydrogen production facility and be exacerbated by the presence of flammable materials on site. With climate change, fire risk is anticipated to increase throughout the state (UW 2024). Where operation is proposed in WUI or intermix areas, wildfires could spread to urban areas. In these areas, facilities could use non-flammable ground cover (e.g., gravel or pavement) surrounding the facility and flammable materials, irrigate perimeter landscaping, and monitor local wildfires using publicly available data such as the Fire Information Resource Management System US/Canada wildfire geographic information system map (NASA and USFS 2024).

Proactive planning and compliance with OSHA and NFPA requirements would reduce operation-related risks that could otherwise threaten workers or spread to surrounding urban or wildland areas.

Depending on the specific location, severity, and emergency response capacity, there is potential that operation activities would likely have **less than significant to potentially significant adverse impacts** of wildfire due to risk of ignition.

### 3.4.3 Actions to avoid and reduce impacts

Site-specific mitigation actions would be developed during facility-specific reviews and permitting for each facility proposed in the future. Implementation of various plans designed to proactively address safety and hazards before they rise to emergency situations would alleviate impacts on workers, the general public, and the environment from EHS risks. An evaluation of potential facility-specific impacts on workers, the public, and the environment from EHS risks should consider the siting and design parameters, regulatory requirements, plans and procedures intended to reduce impacts, and other mitigation measures identified in Sections 3.4.3.1 through 3.4.3.3.

#### 3.4.3.1 Siting and design considerations

The following siting and design considerations could be taken into consideration to alleviate impacts to workers, the public, and the environment from EHS risks:

- Site and design facilities to include appropriate setbacks based on project-specific hazard analysis and risk assessment (required by NFPA 55).
- Design facilities with safety systems such as hydrogen heater, hydrogen leak sensors and flame sensors, fire extinguishers, automatic fire suppression system, and employee alarm system.
- Design per NFPA 55 requirements with a defensible space clearance around the site perimeter fencing and structure, particularly buildings, to serve as a fire, explosion, and spill break.
- Comply with applicable design and safety standards from the following associations for construction and operation:
    - ASME
    - National Standards Institute – Environment, Health, and Safety Management System Standards
    - ASTM – Industrial Hygiene Standards and Safety Standards
    - NFPA
    - Underwriters Laboratory
    - Institute of Electrical and Electronics Engineers

#### 3.4.3.2 Permits, plans, and best management practices

The following permits, plans, and BMPs could be taken into consideration to alleviate impacts to workers, the public, and the environment from EHS risks:

- Develop and implement an emergency action plan to address worker health and safety, standards concerning potential release of hazardous materials, and fire and explosion prevention and control. This plan would provide safety guidelines and procedures for potential emergency-related incidents during the project's construction, operation, and decommissioning. Develop the plan in coordination with local fire and emergency service providers. Use the project-specific hazard analysis and risk assessment study required by NFPA 55. The plan must meet applicable laws and codes, such as:
    - WAC 463-60-352(2) through 463-60-352(4), which address fire and explosion, hazardous materials release, and safety standards compliance
    - WAC 463-60-352(6), which describes emergency plans to ensure public safety and environmental protection
    - IFC and IBC as required by Chapter 51-54A WAC
- Develop and implement an SPCC plan to prevent spills during construction and operation of a facility and to identify measures to expedite the response to a release if one were to occur. This plan would include procedures for containing spills, cleaning spills, disposing of spilled materials, and notifying the appropriate authorities. The plan would be prepared in consultation with Ecology and pursuant to the requirements of 40 CFR 112, Sections 311 and 402 of the Clean Water Act, Section 402 (a)(1) of the federal

Water Pollution Control Act, Chapter 173-307 WAC, and RCW 90.48.080. Any cleanup efforts would meet the standards of Chapter 173-340 WAC, MTCA Cleanup Regulations.

- Develop and implement a hazardous materials and waste management plan to address the selection, transport, storage, and use of all hazardous materials. This plan would include information on construction, operation, and decommissioning and information on local emergency response and public safety authorities. This plan would also address the characterization, on-site storage, recycling, and disposal of all resulting wastes.
- Develop and implement a noxious weed or vegetation management plan to prevent the establishment of non-native, invasive species on the facility and roads to reduce fuel loads as an aid in wildfire management.
- Develop and implement an operational health and safety plan to inform employees and others on site regarding what to do in case of emergencies, including rapid shutdown procedures, the locations of fire extinguishers and nearby hospitals, telephone numbers for emergency responders, first aid techniques, and readily accessible material data safety sheets for all on-site hazardous materials:
  - Provide training in safe hydrogen-handling practices to employees.
  - Train facility maintenance staff to operate additional engineering controls to enable safe use.
- Develop a fire protection and prevention plan in coordination with local emergency response departments.
- Provide the Hydrogen Safety for First Responders course to first responders and emergency medical personnel.
- In compliance with RCW 17.10.140, use only herbicides that are approved by EPA for use in Washington State.
- To prepare for possible lightning strikes, implement lightning-protection measures to protect generators and other associated ground equipment as well as to reduce the potential for wildfires or other damage to the equipment.
- Equip construction vehicles with fire extinguishers, spark arrestors, and heat shields, as appropriate.
- Establish roads before accessing the site to minimize vehicle contact with grass.
- Use diesel construction vehicles instead of gasoline vehicles, where feasible, to prevent potential ignition of brush or other flammable materials by catalytic converters.
- Prohibit vehicles from idling in grassy areas.
- Restrict the use of high-temperature equipment in grassy areas.
- Install lightning-protection measures to protect generators and other equipment.
- Install fire-protection equipment in accordance with Washington State fire code.
- Notify the local fire district of construction plans and provide access to facility equipment.
- Monitor wildfire activity during project construction and operations and, if necessary, modify activities, change the schedule, cease construction operations, or remove equipment.
- Prevent and control potential wildfires and structure fires inside the facility with trained staff who have 24-hour access to the site.

- Locate refueling areas away from surface water locations and drainages and on paved surfaces; add features to direct spilled materials to sumps or safe storage areas where they can be subsequently recovered.
- Allow only authorized personnel within the boundaries of the green hydrogen facility.
- Do not permit smoking or other open flames within or in the vicinity of any area where hydrogen is stored or handled.
- Provide appropriate PPE for all personnel who handle hazardous materials or materials that have come in contact with hazardous materials. Hazardous materials include (1) hydrogen in enclosed piping systems or containers and (2) materials that have come in contact with liquid hydrogen or hydrogen vapor.
- Provide procedures to all employees who work in areas where they could be exposed to liquid hydrogen regarding what to do when someone is exposed to liquid hydrogen.

#### *3.4.3.3 Additional mitigation measures*

The following mitigation measure could be considered to alleviate impacts to workers, the general public, and the environment from EHS risks:

- Create a robust emergency response plan using NFPA 2800 for worst-case scenario hazards described in Sections 3.4.1 and 3.4.2 that includes plans for notifying emergency response, notifying the public, and planning for evacuation.
- Where NFPA guidelines are not required by law, follow NFPA guidelines, specifically NFPA 2, Hydrogen Technologies Code.

## 3.5 Green hydrogen production facility with co-located battery energy storage system (BESS)

This section describes potential impacts of green hydrogen production facilities with up to two co-located BESS containers. The BESSs would be used to balance loads or to provide up to 15% of power in case of an outage or power quality deviation. One BESS would provide 2.85 megawatts of electricity for 4 hours (a capacity of 11.4 megawatt hours or 11,400 kilowatt hours). Each container would be approximately 60 by 12 feet wide and 10 feet tall.

Co-location of BESSs introduces additional hazardous materials and fire risk management considerations, as described below. Additional discussion regarding public services and utilities impacts related to BESS is provided in the *Public Services and Utilities Technical Appendix*.

### 3.5.1 Impacts from construction, operation, and decommissioning

Co-located BESSs introduce the following hazards and risks:

- The BESS would result in the presence of additional hazardous materials on site that could ignite, spill, or otherwise require specialized response, cleanup, and remediation following an accident.
- Battery fires require specialized response training for first responders due to ignition risks with these hazardous materials.

- The BESS could increase the risk of structural fire or exacerbate wildfires.
- Battery fires can be difficult to extinguish and can easily reignite above certain temperatures.

Thermal events are very rare for BESSs. Lithium-ion batteries from the BESS would contain toxic chemicals that could be hazardous in the event of a system failure, which could result in the battery leaking. If the batteries overheat or are damaged, they could leak toxic gases, including hydrogen fluoride, hydrogen chloride, hydrogen cyanide, and carbon monoxide. Attempts to extinguish battery fires with water, which manufacturers typically advise against, could increase exposure to toxic chemicals through smoke, vapor, or contaminated runoff (ACP 2023). Toxic chemical leaks from battery failures are rare.

A BESS can create hazards for worker health and safety and firefighters and emergency responders, with the possibility of explosions, flammable gases, toxic fumes, water-reactive materials, electrical shock, corrosives, and chemical burns. The risk of hazardous materials leaks from batteries in the BESS could increase during operation compared to construction, due to the increased potential for batteries to leak or ignite when overheating from energy storage.

Should a thermal runaway event occur, it can result in release of toxic materials. Battery incidents can be difficult to extinguish, and some battery types can reignite above certain temperatures after being put out. Once a fire has self-extinguished, there may be releases of flammable or toxic gases including hydrogen fluoride, hydrogen chloride, hydrogen cyanide, and carbon monoxide. Spraying water on smoke or vapor released from the battery, whether burning or not, may cause skin or lung irritation. This is one additional reason for allowing the battery to burn in a controlled manner.

A fire could result in the release of toxic air emissions. These air plumes can extend beyond the site and affect nearby workers or communities. As part of the risk assessment for a facility, the potential distances would be identified and include incident response planning. This distance will vary based on the site and would be done during project-level review.

The site should be entered only by trained firefighters or emergency responders wearing full protective gear. For additional information pertaining to lithium-ion BESS incidents, including guidance for first responders, see Attachment 1 of the *Public Services and Utilities Technical Appendix*.

Battery unit installation or replacement should follow manufacturers' specifications for spacing and clearance distances. Further, a BESS generally comes equipped with remote alarms for operations personnel and emergency response teams, including voltage, current, or temperature alarms from the battery management system. Other protective measures include ventilation, overcurrent protection, battery controls to operate the batteries within designated parameters, temperature and humidity controls, smoke detection, and maintenance in accordance with manufacturers' guidelines.

For additional information pertaining to lithium-ion BESS incidents, including guidance for first responders, see the *Public Services and Utilities Technical Appendix,* Attachment 1.

WAC 51-54A-0322 includes requirements for storage of lithium-ion and lithium metal batteries. Permits are required for when more than 15 cubic feet of batteries are accumulated. A fire safety plan is required and must include emergency responses to be taken upon detection of a fire or possible fire. Where required by the fire code official, a technical opinion and report complying with IFC Section 104.8.2 shall be prepared to evaluate the fire and explosion risks associated with the storage area and to make recommendations for fire and explosion protection. The report shall be submitted to the fire code official and shall require the fire code official's approval prior to issuance of a permit. In addition to the requirements of IFC Section 104.8.2, the technical opinion and report shall specifically evaluate the potential for deflagration of flammable gases released during a thermal runaway event. Similar to facilities without a BESS, MTCA would dictate the handling and cleanup of these types of hazardous materials.

Specialized advance planning and procedures for enhanced fire response training would be required to ensure that green hydrogen facilities with co-located BESSs do not generate hazards for the public or emergency responders. Proactive planning and compliance with requirements would reduce risks of wildfire ignition and spread. An emergency response plan would specify emergency response measures to be taken upon detection of a possible fire, and adherence to setback distances (in siting and design) would reduce risks of a fire spreading. The Washington State Patrol, Ecology, and representatives from industry and local fire protection districts are studying electric vehicle fires, which could result in additional best practices for battery incident response risk reduction.

Similar to green hydrogen production facilities, decommissioning of facilities would include disposal of solid and hazardous waste. While most, if not all, materials that comprise lithium-ion batteries are recyclable, they are often disposed of as hazardous waste due to a lack of recycling service providers for batteries (Gignac 2020). Because of the growing use of lithium-ion batteries for energy storage and other purposes, the EPA has proposed rules to establish waste management regulations specific to the batteries and is undertaking efforts to advance industry capacity for battery recycling (EPA 2023). In 2023, Washington State adopted regulations under Chapter 70A.555 RCW, requiring battery manufacturers to collect and recycle small batteries, with a mandate that the Washington State Legislature assess and recommend options for collection and end-of-life management of large batteries, such as those used in BESS (Ecology 2023).

While the outcomes of these battery disposal regulations are uncertain, implementation of a statewide large battery collection and recycling system could greatly reduce impacts on local hazardous waste management capacity. Regardless of whether the batteries are recycled or disposed of as hazardous waste at their end of useful life, the batteries would be stored, handled, and transported in accordance with either hazardous waste regulations or battery-specific disposal standards, which would reduce the risk of releases of hazardous material.

#### 3.5.1.1 Impact summary

Impacts on worker health and safety would be similar to findings for green hydrogen production facilities above, with additional fire risk and risks to emergency responders associated with BESS operation.

Most impacts related to hazardous materials would be similar to findings for green hydrogen production facilities described above. If a thermal runaway event due to damage or battery management system failure were to occur, facilities with lithium-ion BESS would likely have **potentially significant adverse impacts** due to hazardous air emission risks associated with the BESSs.

### 3.5.2 Actions to avoid and reduce impacts

The actions to avoid and reduce impacts described in Section 3.4.3 would be applicable. Additional actions relative to the BESSs are described below.

#### 3.5.2.1 Siting and design considerations

- BESSs should be designed and sited in a manner consistent with the current IBC and NFPA Standards to minimize overheating and enable clearing of hazardous gases in the event of battery leaks or thermal runaway events. They must also comply with the latest Washington State Building Code Council regulations for batteries.
- Setback distances allowing for emergency accesses and management or removal of dry vegetation would also reduce risks of explosion and potential release of hazardous materials. If there is a thermal runaway event, the required setback distances would also prevent spread from one container to another.

#### 3.5.2.2 Additional mitigation measures

The following mitigation measures specific to BESS safety training and emergency response are recommended.

Fire protection, prevention, and detection measures and design features should be implemented in accordance with the current Washington Fire Code, including providing redundant separate methods of failure detection. An emergency response plan should be developed in advance of construction to train local emergency response personnel on hazards specific to BESSs during development and operation of the facility to include the current NFPA 855 Standards for Installation of Stationary Energy Storage Systems. The plan would be completed in accordance with industry guidance and existing state regulations, such as those governing public health and safety, hazardous materials business plans, and emergency response plans and procedures. The content of the emergency response plan would need to comply with existing state regulations and be developed in consultation with applicable emergency response jurisdictions and the energy storage system supplier. The plan would also define the roles, responsibilities, and training for local first responders.

Additional mitigation measures include the following:

- Develop and implement fire protection, prevention, and detection measures and design features in accordance with NFPA 855 Standards for Installation of Energy Storage Facilities and the current Washington Fire Code, including requirements for providing redundant separate methods of BESS failure detection. In addition, the developer should develop an emergency response plan in advance of construction.
- Develop and implement comprehensive training programs and safety protocols for personnel involved in BESS operations and maintenance.
- Develop and implement regular maintenance schedules and inspections for BESS components to ensure optimal performance and early detection of potential issues.
- Develop and implement detailed emergency response plans specific to BESS operations to mitigate the consequences of potential damage or failure of battery management systems.

## 3.6 Green hydrogen storage facility (gas or liquid form)

This section describes potential impacts of green hydrogen production facilities with hydrogen storage. A green hydrogen storage facility could store hydrogen in gas or liquid form. Gaseous hydrogen would be stored in stationary, aboveground, cylindrical storage systems, each of which employs different construction materials to achieve maximum working pressure ratings. Liquid hydrogen would be stored in double-walled, vacuum-insulated cryogenic storage tanks. In general, liquid hydrogen storage requires a smaller area to store the same capacity of gaseous hydrogen, although it requires the addition of a liquefaction system.

Green hydrogen storage facilities would be standalone facilities and could be located at a transport terminal or be sited at an end-use location such as an industrial facility or fueling facility. Impacts to workers, the general public, and the environment from EHS risks described in Sections 3.4 and 3.5 would generally apply to green hydrogen storage facilities, albeit less severe, as these facilities would not produce hydrogen and have risks associated with the processing methods. Liquid hydrogen would be stored in double-walled, vacuum-insulated cryogenic storage tanks, with capacities ranging from 10,000 to more than 1,000,000 cubic feet. Gaseous hydrogen would be stored in a stationary, aboveground, cylindrical or spherical tank and stored between 350 and 700 bar gauge (5,000 to 10,000 psi gauge). While there could be higher concentrations of liquid hydrogen at a green hydrogen storage facility, the same BMPs and precautions described previously would reduce the risk of liquid hydrogen exposure, fire, and explosion risks.

### 3.6.1 Impacts from construction, operation, and decommissioning

Both liquid and gaseous hydrogen storage pose similar fire and explosion risk to those described in Sections 3.4 and 3.5. Storage tanks pose no risk of fire and explosion unless a leak causes hydrogen to mix with an oxidizer and there is an ignition source present. Liquid hydrogen storage tanks contain denser hydrogen, which could provide more fuel for a fire or explosion. NFPA 55 includes different proposed setbacks for liquid and gaseous hydrogen storage as described in Section 3.4.2.1. Because of the density of liquid hydrogen, setbacks for liquid hydrogen are greater than setbacks for gaseous hydrogen tanks.

In addition, 29 CFR 1910.103 requires safety relief valves if tanks are over-pressurized and setbacks for hydrogen tanks that account for the distance where people congregate, locations where flammable material is stored, locations near oxidizers, and other hazards. Storage tanks would generally be outside, but any indoor storage tanks are required to be in well-ventilated areas in accordance with 29 CFR 1910.103.

Depending on the specific location, severity, and emergency response capacity, operation activities would likely have **less than significant to potentially significant adverse impacts** from fires and explosions. The severity of risks would need to be assessed for each facility based on the project location and quantities of flammable materials produced or stored on site.

### 3.6.2 Actions to avoid and reduce impacts

Actions to avoid and reduce impacts described in Section 3.4.3 are applicable to green hydrogen storage facilities, including requirements to follow NFPA 55 guidelines and to site and design based on a project-specific hazard analysis and risk assessment. That assessment would include appropriate setbacks for gaseous and liquid hydrogen storage systems.

## 3.7 No Action Alternative

Under the No Action Alternative, agencies would continue to conduct environmental review and permitting for green hydrogen facilities under existing laws on a project-by-project basis. The potential impacts would be similar to the impacts for the types of facilities described above for construction, operation, and decommissioning, depending on facility size and design, and would range from **less than significant impacts to potentially significant adverse impacts**.

## 3.8 Unavoidable significant adverse impacts

A facility may result in **potentially significant and unavoidable adverse impacts** if new ignition sources are in remote locations with limited response capabilities, or if a fire or explosion during operations spreads rapidly or impacts large areas. Determining if mitigation options would reduce or eliminate impacts below significance would be dependent on the specific project and site.

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# Attachment 1: Common Industry Standards for Industrial Facilities

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|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ACI | American Concrete Institute |
| AFBMA | Anti-friction Bearing Manufacturers Association |
| AGA | American Gas Association |
| AGMA | American Gear Manufacturers Association |
| AHRI | Air-conditioning, Heating, and Refrigeration Institute |
| AI | Asphalt Institute |
| AISC | American Institute for Steel Construction |
| AISI | American Iron and Steel Institute |
| AMCA | Air Moving and Conditioning Association |
| ANSI | American National Standards Institute |
| API | American Petroleum Institute |
| ASCE | American Society of Civil Engineers |
| ASHRAE | American Society of Heating, Refrigeration and Air Conditioning Engineers |
| ASME | American Society of Mechanical Engineers |
| ASNT | American Society of Nondestructive Testing |
| ASTM | ASTM International |
| AWS | American Welding Society |
| AWWA | American Water Works Association |
| CAG | Compressed Air and Gas Institute |
| CFR | U.S. Code of Federal Regulations |
| CGA | Compressed Gas Association |
| CMMA | Crane Manufacturers Association of America |

| | |
|---|---|
| CRSI | Concrete Reinforcing Steel Institute |
| CTI | Cooling Tower Institute |
| DOE | Department of Energy |
| EJMA | Expansion Joint Manufacturing Association |
| EPRI | Electric Power Research Institute (Note: Contractor is only required to follow the EPRI standards specifically listed in this Specification) |
| FERC | Federal Energy Regulatory Commission |
| HEI | Heat Exchange Institute |
| HI | Hydraulic Institute |
| ICEA | Insulated Cable Engineers Association |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| IES | Illuminating Engineers Society |
| ISA | International Society of Automation |
| ISO | International Standards Organization |
| WSBC | Washington State Building Code |
| MBMA | Metal Building Manufacturers Association |
| MSS | Manufacturers Standardization Society of the Valve and Fittings Industry |
| NAAMM | National Association of Architectural Metal Manufacturers |
| NACE | National Association of Corrosion Engineers |
| NAFM | National Association of Fan Manufacturers |
| NAIMA | North American Insulation Manufacturers Association |
| NBBPVI | National Board of Boiler and Pressure Vessel Inspectors |
| NEC | National Electric Code |
| NERC | North American Electric Reliability Corporation |
| NEMA | National Electrical Manufacturers Association |
| NFPA | National Fire Protection Association |

| | |
|---|---|
| OSHA | Occupational Safety and Health Administration |
| PFI | Pipe Fabrication Institute |
| PPI | Plastic Pipe Institute |
| SDIS | Steel Deck Institute Standards |
| SJIS | Steel Joint Institute Standard |
| SMACNA | Sheet Metal and Air-conditioning Contractors National Association |
| SSPC | Society of Protective Coatings |
| TEMA | Tubular Exchanger Manufacturers Association |
| UL | Underwriters Laboratories |