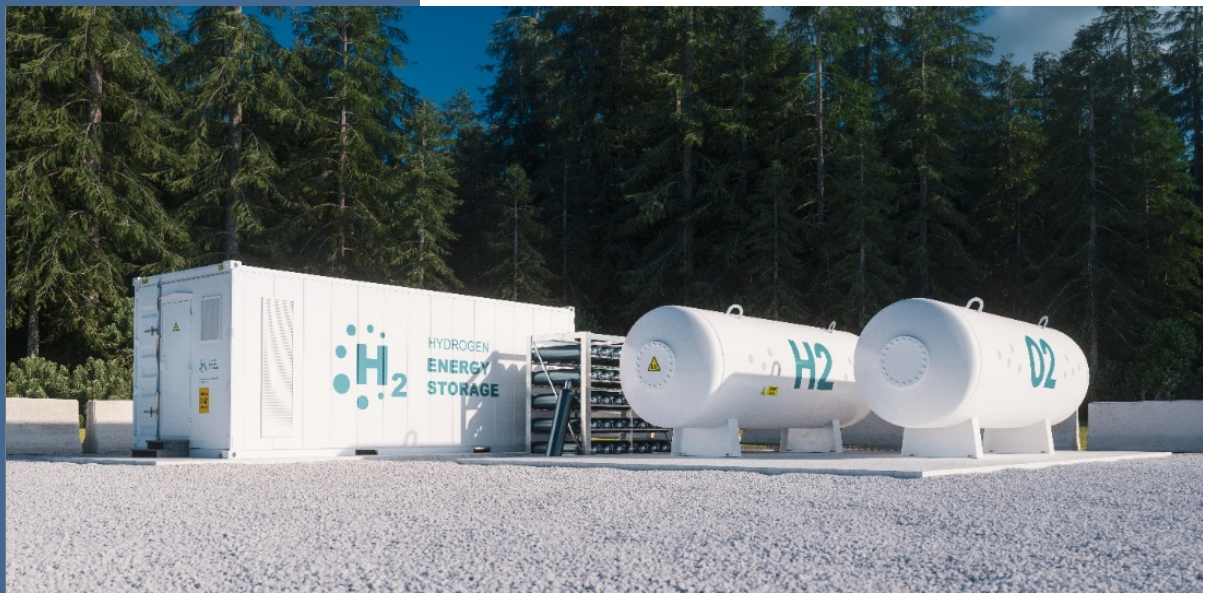

Appendix E: Air Quality and Greenhouse Gases Technical Appendix

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

By

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For the

Shorelands and Environmental Assistance Program

Washington State Department of Ecology

Olympia, Washington

June 2025, Publication 25-06-004

DEPARTMENT OF ECOLOGY State of Washington

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Acronyms and Abbreviations List

ANL	Argonne National Laboratory
AP-42	EPA Compilation of Air Pollutant Emissions Factors from Stationary Sources
BESS	battery energy storage system
BMP	best management practice
CETA	Clean Energy Transformation Act
CFCs	chlorofluorocarbons
CFR	Code of Federal Regulations
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
Commerce	Washington State Department of Commerce
CY	cubic yards
Ecology	Washington State Department of Ecology
EFSEC	Energy Facility Site Evaluation Council
EPA	U.S. Environmental Protection Agency
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Technologies
GWP	global warming potential
H_2	hydrogen gas
HAP	hazardous air pollutant
HFCs	hydrofluorocarbons
ICCT	International Council on Clean Transportation
ICE	internal combustion engine
kg	kilogram
kWh	kilowatt-hour
lb	pound
LCA	life-cycle assessment
$\mu m/m^3$	micrograms per cubic meter
MACT	Maximum Achievable Control Technology
MMBtu	metric million British thermal units
MT	metric ton(s)
MW	megawatt(s)
MWh	megawatt hours
NAAQS	National Ambient Air Quality Standards
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NETL	National Energy Technology Laboratory
N_2O	nitrous oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NOC	Notice of Construction

NSPS	New Source Performance Standards
O_3	ozone
PAHs	polycyclic aromatic hydrocarbons
Pb	lead
PEIS	Programmatic Environmental Impact Statement
PFCs	perfluorocarbons
PM_{10}	particulate matter 10 microns or less in diameter
$PM_{2.5}$	particulate matter 2.5 microns or less in diameter
POM	polycyclic organic matter
PSD	Prevention of Significant Deterioration
TAP	toxic air pollutant
RCW	Revised Code of Washington
RNG	renewable natural gas
SIP	State Implementation Plan for air quality
SF6	sulfur hexafluoride
SMR	steam-methane reforming
SO_2	sulfur dioxide
SO_x	sulfur oxide
VOCs	volatile organic compounds
WAAQS	Washington Ambient Air Quality Standards
WAC	Washington Administrative Code

Summary

This technical appendix describes the air quality and greenhouse gas (GHG) conditions in the study area. It also describes the regulatory context, methodology used, and potential impacts and measures that could avoid or reduce impacts.

This technical appendix analyzes the following key features of air quality and GHGs for each of the green hydrogen facility types evaluated in the Programmatic Environmental Impact Statement (PEIS):

- Emissions of criteria air pollutants and their precursors, hazardous air pollutants (HAPs), and air toxics
- GHG life-cycle emissions

Green hydrogen production through electrolysis would not generate direct emissions of air pollutants. Production through steam-methane reforming (SMR), pyrolysis, and bio-gasification may generate air pollutants, depending on the facility's production capacity, source of feedstock, and type and quality of production equipment. Emissions for production facilities with a battery energy storage system (BESS) would be similar to those for production facilities without a BESS. Air pollutant emissions from green hydrogen storage facilities would depend on the facility's storage capacity and the quality of liquefaction equipment. There is a potential for HAP and toxic air pollutant (TAP) de minimis thresholds to be exceeded, depending on the green hydrogen production equipment and the feedstock type and quantity. Facilities would be required by federal and state regulation to operate in a way that keeps their HAP and TAP emissions below de minimis thresholds. This could include implementing emissions control systems and best practices.

Washington's laws identify two categories of green hydrogen based on how the hydrogen is produced. "Renewable hydrogen" is produced using renewable resources both as the source for hydrogen and the source for the energy input into the production process. "Green electrolytic hydrogen" is produced through electrolysis. It does not include hydrogen manufactured using SMR or any other conversion technology that produces hydrogen from a fossil fuel feedstock. In this definition, water is the feedstock for the hydrogen, while the electricity is not a feedstock but is the input energy or process energy used in electrolysis of the water. Hydrogen produced through electrolysis will meet this definition regardless of whether the electricity is produced from renewable sources, fossil-fired generation, or any combination of these resources. The Clean Energy Transformation Act requires all electricity used in Washington to be GHG neutral by 2030 and 100% clean by 2045.

This report identifies a range of GHG life-cycle emissions using available studies and applicable carbon intensity values listed in the Washington Clean Fuels Program Rule (Chapter 173-424 Washington Administrative Code[1]) that were calculated using hydrogen pathways from the Washington Greenhouse gases, Regulated Emissions, and Energy use in Technologies (WA-

[1] https://app.leg.wa.gov/wac/default.aspx?cite=173-424

GREET) model. During construction and decommissioning, GHG emissions would be produced primarily from vehicles, equipment, and generators. GHG emissions during operations will vary based on the type of production. Life-cycle assessment (LCA) studies are not available for the pyrolysis production method. For storage facilities, converting hydrogen to liquid form requires energy to cool it to cryogenic temperatures. Project-level LCAs would need to be done to evaluate the specific source of power and end-users for a proposal.

Life-cycle GHG emissions for the different types of production are directly compared for 1 kilogram (kg) of hydrogen produced. Based on estimated life-cycle GHG emissions using LCA studies cited in this analysis and the WA-GREET model, the following GHGs are expected from the green hydrogen production methods:

- Electrolysis using average grid electricity in Washington: 12.19 kg carbon dioxide equivalent (CO_2e)/kg hydrogen gas (H_2) produced
- Electrolysis using renewable energy for electricity: 0.40–4.83 kg CO_2e/kg H_2 produced
- SMR using renewable feedstock from landfills (i.e., landfill gas): negative 51.40–11.13 kg CO_2e/kg H_2 produced, depending on the assumptions for baseline conditions
- Pyrolysis using renewable feedstock from landfills: 11.13 kg CO_2e/kg H_2 produced
- Bio-gasification using biomass feedstock: negative 1.00–5.04 kg CO_2e/kg H_2 produced, depending on the assumptions used
- Liquid storage facilities: 5.01 kg CO_2e/kg H_2 liquefied and stored

This report estimates life-cycle GHG emissions using the facility size and production assumptions in this PEIS. The production amounts vary between these. These estimates consider LCA studies and carbon intensity values established in the Washington Clean Fuel Standard rule, and the facility size assumptions used in the PEIS. Estimated annual life-cycle GHG emissions are shown in Table 1 below.

Table 1. Estimated annual life-cycle GHG emissions from hydrogen production (MT/year)

Green hydrogen production method	Life-cycle CO_2e (MT/year)
Electrolysis using average grid electricity in Washington	
Lower bound – 1,000 kg H_2/day	4,449
Upper bound – 9,000 kg H_2/day	40,044
Electrolysis using renewable energy for electricity	
Lower bound – 1,000 kg H_2/day	146 to 1,763
Upper bound – 9,000 kg H_2/day	1,314 to 15,867
SMR using renewable feedstock from landfills	
Lower bound – 2,000 kg H_2/day	-37,522 to 8,125
Upper bound – 100,000 kg H_2/day	-1,876,100 to 406,245
Pyrolysis using renewable feedstock from landfills	
Lower bound – 5,000 kg H_2/day	20,312
Upper bound – 10,000 kg H_2/day	40,625

Green hydrogen production method	Life-cycle CO_2e (MT/year)
Bio-gasification using biomass feedstock	
Lower bound – 50,000 kg H_2/day	-18,250 to 91,980
Upper bound – 100,000 kg H_2/day	-36,500 to 183,960
Liquid hydrogen storage facilities	
Lower bound – 5,000 kg H_2/day liquefaction	9,146
Upper bound – 10,000 kg H_2/day liquefaction	18,292

Note: Assumes facility operation at 365 days per year. MT = metric tons.

For comparison, if fossil fuel was used for the SMR process:

- Probable life-cycle GHG emissions for 1 kg of hydrogen produced: 11.88–12.00 kg CO_2e/kg H_2 produced
- Estimated annual life-cycle GHG emissions:
  - Lower bound (2,000 kg H_2/day): 8,672.40 to 8,760.00 MT of CO_2e per year
  - Upper bound (10,000 kg H_2/day): 433,620.00 to 438,000 MT of CO_2e per year

While hydrogen is not a GHG, its release to the atmosphere can change the abundances of methane, ozone, and stratospheric water vapor, as well as aerosols if leaked. Leakage could occur during upstream production and downstream transmission, storage, and distribution. Studies have shown that it would be important to minimize hydrogen leakages through proper maintenance and monitoring.

Findings for air quality and GHG impacts described in this technical appendix are summarized as follows:

- Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, construction, operation, and decommissioning activities would likely result in **less than significant impacts** on air quality, excluding life-cycle GHG emissions.
- Facility GHG life-cycle emissions would vary based on the type of production process used and amount of energy and feedstocks used by a facility and type of storage. In general, per kg of hydrogen produced, electrolysis using all renewable energy sources for electricity would have the lowest amount of life-cycle GHG emissions. Impacts from electrolysis, SMR, pyrolysis, bio-gasification production and storage would range from **less than significant impacts to potentially significant adverse impacts** on life-cycle GHG emissions.
- Electrolysis using fossil fuel as a source of electricity, SMR, pyrolysis, and bio-gasification production may have **significant and unavoidable adverse impacts** on life-cycle GHG emissions. Determining if mitigation options would reduce or eliminate GHG impacts below significance would be dependent on the specific project and site.

1 Introduction

This technical appendix describes air quality and greenhouse gases (GHGs) within the study area and assesses potential impacts associated with types of facilities evaluated, and a No Action Alternative, which are described in Chapter 2 of the State Environmental Policy Act Programmatic Environmental Impact Statement (PEIS).

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

1.1 Resource description

1.1.1 Fundamentals of air quality

Air quality is a measure of how clean or polluted the air is. When air quality is good, the air appears clear and contains little to no chemical pollutants or particles. Poor air quality occurs when the air contains high levels of pollutants, which can be dangerous to both human health and the environment.

Air pollution arises from various sources, both human-made and natural. Although natural sources like wind-blown dust, wildfires, and volcanoes can be substantial contributors to poor air quality, they usually do not create long-term problems. Human-made mobile sources of air pollution include cars, buses, planes, trucks, and trains. Stationary sources of human-made air pollution include power plants, oil refineries, and other industrial facilities. Area sources of human-made air pollution are localized activities or processes that emit air pollutants that can collectively contribute to poor air quality, such as agricultural activities, urban areas, and wood-burning fireplaces.

This technical appendix considers emissions of the following pollutants that impact air quality:

- **Criteria air pollutants[2] and precursors:**
  - Carbon monoxide (CO)
  - Nitrogen dioxide (NO_2)
  - Ozone (O_3):
    - Precursors[3]: Nitrogen oxides (NO_x) and volatile organic compounds (VOCs)
  - Particulate matter 10 microns or less in diameter (PM_{10})
  - Particulate matter 2.5 microns or less in diameter ($PM_{2.5}$)
  - Sulfur dioxide (SO_2)
  - Lead (Pb)

[2] Criteria air pollutants are pollutants that have National Ambient Air Quality Standards (established by the United States Environmental Protection Agency.

[3] Most criteria pollutants are directly emitted by certain activities on earth. Ozone, however, is formed in the lower atmosphere by chemical reactions with nitrogen oxides and volatile organic compounds in the presence of sunlight.

- **Hazardous air pollutants (HAPs):** Pollutants are designated as HAPs by the U.S. Environmental Protection Agency (EPA).[4] This report discusses those most relevant to green hydrogen production and storage.
- **Toxic air pollutants (TAPs):** Pollutants are designated as TAPs[5] by the Washington State Department of Ecology (Ecology). This report discusses those most relevant to green hydrogen production and storage.

1.1.2 Fundamentals of greenhouse gases

Gases that trap heat in the atmosphere are referred to as GHGs because they capture heat radiated from the sun as it is reflected back into the atmosphere from the Earth, like a greenhouse does. Increasing amounts of GHGs trap more solar radiation and decrease the amount that is reflected back into the atmosphere, resulting in an increased global average temperature and climate change impacts to people and the environment.

"Global warming" and "climate change" are common terms used to describe the increase in the average temperature of the Earth's near-surface air and oceans since the mid-20th century. Since the nineteenth century, increasing GHG concentrations resulting from human activity (such as fossil fuel combustion, deforestation, and other activities) have unequivocally caused global warming (IPCC 2023). GHGs in the atmosphere naturally trap heat by impeding the exit of solar radiation—a phenomenon sometimes referred to as the "greenhouse effect." Some GHGs occur naturally and are necessary for keeping the Earth's surface inhabitable. However, increases in the concentrations of these gases in the atmosphere during the last 100 years have trapped solar radiation and decreased the amount that is reflected back into space, intensifying the greenhouse effect and resulting in the increase of global average temperature and climate change.

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the principal GHGs. When concentrations of these gases exceed historical concentrations in the atmosphere, the greenhouse effect is intensified. CO_2 is the reference gas for climate change, because it is the GHG emitted in the highest volume. The effect that each of the GHGs has on global warming is the product of the mass of their emissions and their global warming potential (GWP). GWP indicates how much a gas is predicted to contribute to global warming relative to how much warming would be predicted to be caused by the same mass of CO_2.

GHG emissions are typically reported as metric tons (MT) of CO_2 equivalent (CO_2e). CO_2e is calculated by multiplying the mass of a given GHG's emissions by its GWP (EPA 2024a). GWP is a measure of how much 1 ton of a given GHG contributes to climate change over a certain period relative to 1 ton of CO_2 (EPA 2024b). CO_2 has a GWP of 1, but CH_4 and N_2O are substantially more potent GHGs, with 100-year GWPs of approximately 28 and 265, respectively (40 Code of Federal Regulations [CFR] 98). While CH_4 and N_2O have much higher GWPs than CO_2, CO_2 is

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[4] See the full list of HAPs here: https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications
[5] The Washington State Department of Ecology (Ecology) regulates pollutants per Washington Administrative Code 173-460-150. See the full list here: https://app.leg.wa.gov/WAC/default.aspx?cite=173-460-150.

emitted in higher quantities and accounts for the majority of GHG emissions in CO_2e, both from developments and human activity in general.

This appendix considers emissions of the following GHGs:

- CO_2
- CH_4
- N_2O
- Hydrofluorocarbons (HFCs)
- Chlorofluorocarbons (CFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF6)

This appendix also considers hydrogen emissions. While hydrogen is not a GHG, hydrogen emissions are considered because hydrogen in the atmosphere may extend the lifetime of GHGs. One study found that hydrogen has a 100-year GWP, 5 to 16 times that of carbon dioxide (UK Department for Business, Energy & Industrial Strategy 2022a). Another found that hydrogen has a 100-year GWP of 11.6 times that of carbon dioxide, which is about two-fifths as potent as methane; and the study emphasizes the importance of minimizing hydrogen leakage (Sand et al. 2023). The result of this study is yet to be vetted by the global body of experts of the Intergovernmental Panel on Climate Change.

1.1.3 Related resources

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

- **Biological resources:** Information is presented in the *Biological Resources Technical Appendix* to address potential impacts to terrestrial and aquatic species and habitats resulting from air quality and GHG impacts.
- **Water resources:** Information is presented in the *Water Resources Technical Appendix* to address potential impacts to water quality resulting from air quality and GHG impacts.
- **Environmental health and safety:** Information is presented in the *Environmental Health and Safety Technical Appendix* to address health and safety impacts of criteria air pollutants, HAPs, and air toxics.

1.2 Regulatory context

1.2.1 Air quality overview

To protect public health and welfare nationwide, the federal Clean Air Act requires that EPA establish National Ambient Air Quality Standards (NAAQS) for certain common and widespread pollutants and revise them regularly based on the latest science.

Each state must submit to EPA and the public its rules and programs that ensure that the NAAQS are attained in all areas of the state. These rules and programs comprise Washington State Implementation Plan (SIP) for air quality (EPA 2025).

EPA sets primary and secondary NAAQS for seven common “criteria pollutants” (listed in Section 1.1.1).

Most of the criteria pollutants are directly emitted. Ozone, however, is a secondary pollutant that is formed in the atmosphere by chemical reactions with NO_x and VOCs in the presence of sunlight. $PM_{2.5}$ is also directly emitted and forms in the atmosphere through chemical reactions.

The NAAQS represent maximum ambient (outdoor air) concentration levels of the criteria pollutants. The NAAQS specify different averaging times as well as maximum concentrations. The health-based NAAQS are referred to as primary NAAQS. They are set at the levels protective of human health, with an adequate margin of safety to be protective of vulnerable populations. The welfare-based NAAQS, or secondary NAAQS, are set at the levels that protect ecosystems and built environments from detrimental effects of air pollution.

Washington State has adopted its own set of Washington Ambient Air Quality Standards (WAAQS), which are equal to the NAAQS for nearly all the criteria pollutants.

After EPA sets a new or revises an existing NAAQS, it must review available air quality data and designate each area of the state as meeting or not meeting the standard. Areas that failed to meet the new or revised NAAQS are designated as “nonattainment” areas. There are no current nonattainment areas in Washington state at the time of writing this PEIS.

If an area is designated as nonattainment, the state must revise the SIP to include a plan for the area to resolve the nonattainment of the NAAQS as expeditiously as practicable, but no later than 5 years. In general, attainment plans for nonattainment areas outline specific measures to reduce ambient levels of that pollutant.

Once the air quality in the nonattainment area is improved and the state demonstrated that the improvement is permanent, enforceable, and will be maintained in the future, EPA redesignates the area to attainment and approves maintenance plans. Areas with approved maintenance plans are referred to as “maintenance area.” Oversight and air quality planning for the maintenance areas continues for at least 20 years and afterwards, the approved maintenance strategy continues to apply in the area.

There are 15 maintenance areas in Washington as of the time of writing this PEIS. To identify if a project is located in a maintenance or nonattainment area, please refer to the Air Quality Nonattainment and Maintenance Areas map (Ecology 2025).

Apart from the area designations for criteria pollutants, the federal Clean Air Act also categorizes certain geographic areas as Class I, Class II, and Class III areas:

- **Class I areas:** Under the Prevention of Significant Deterioration (PSD) program, all international parks, national wilderness areas and national memorial parks that exceed 5,000 acres, and national parks that exceed 6,000 acres are categorized as mandatory federal Class I areas. The state must prevent and remedy air quality impairments to the pristine air quality and visibility conditions. See Ecology's overview map of Class I areas (Ecology 2025).
- **Class II areas:** All other areas that attain the NAAQS are initially designated as Class II.
- **Class III areas:** Compared to Class I and II areas, Class III areas are industrialized areas and may permit a greater degree of air quality deterioration, however, they still must attain the national ambient air quality standards. There are no Class III areas in Washington.

To protect air quality in pristine Class I areas, EPA established Regional Haze Program. Washington has a SIP-approved Regional Haze Plan outlining requirements for sources.

A new emissions source must demonstrate that it will operate in compliance with all applicable federal and state air quality requirements, including emissions standards and NAAQS/WAAQS and Washington SIP. The State of Washington has established rules through Ecology for permitting new sources in both attainment and nonattainment areas of the state, or requirements may be imposed by local air authorities. Washington Administrative Code (WAC) 463-62-070[6] requires that energy facilities meet all federal and state air quality laws and regulations mentioned above. In general, if potential emissions from—or the operating capacity of—stationary sources exceed certain thresholds, approval from the applicable permitting authority is required before beginning construction. In Washington, these permits are called Notices of Construction (NOCs). New sources of air emissions in nonattainment areas must undergo more rigorous permitting and restrictions than equivalently sized sources in attainment areas. Chapter 173-400 WAC[7] establishes the requirements for review and issuance of NOC approvals for sources of air emissions.

While the ambient air quality standards place upper limits on levels of air pollution, the Prevention of Significant Deterioration (PSD) permitting regulations administered by Ecology place limits on the total increase in ambient pollution levels above baseline levels in attainment areas from the operation of large stationary sources. Allowing ambient concentration levels to increase by only a limited amount prevents "polluting up to the standard" from new and modified stationary sources and the deterioration of air quality in the area. These allowable increases are called "increments" and are smallest in Class I areas, such as national parks or wilderness areas. The rest of the country is subject to larger Class II increments. The federal Clean Air Act established mandatory Class I areas for national parks larger than 6,000 acres and national wilderness areas larger than 5,000 acres. States can choose a less stringent set of Class III increments; however, none have done so. Major (larger than a certain threshold) new

[6] https://app.leg.wa.gov/WAC/default.aspx?cite=463-62-070
[7] https://app.leg.wa.gov/wac/default.aspx?cite=173-400&full=true

stationary sources and large modifications at existing major stationary sources must meet the requirements of the PSD regulations and be issued a permit from Ecology before construction can begin. The PSD regulations also require the use of best available pollution control technology and practices, a quantitative demonstration that a stationary source would not cause or contribute to a violation of the NAAQS, and coordination with Federal Land Managers of Class I areas located near a stationary source to evaluate whether there would be an adverse impact on any air quality related values of those areas such as scenic, cultural, biological, and recreational resources.

Stationary emission sources that are not major (larger than a certain threshold) are considered minor sources. Minor sources would not trigger the requirements of PSD permitting; however, air permits or other forms of registration may still be required. Local clean air agencies administer the minor source permitting programs within their jurisdictions. Ecology manages these programs in all other areas and for certain industry categories throughout the state, regardless of local air authority jurisdiction. The EPA Region 10 issues air permits on Tribal lands. The jurisdictional areas of the local clean air agencies are (Ecology 2024a):

- Benton Clean Air Agency – Benton County
- Northwest Clean Air Agency – Island, Skagit, and Whatcom Counties
- Olympic Region Clean Air Agency – Clallam, Grays Harbor, Jefferson, Mason, Pacific, and Thurston Counties
- Puget Sound Clean Air Agency – King, Kitsap, Pierce, and Snohomish Counties
- Southwest Clean Air Agency – Clark, Cowlitz, Lewis, Skamania, and Wahkiakum Counties
- Spokane Regional Clean Air Agency – Spokane County
- Yakima Regional Clean Air Agency – Yakima County

Construction-related emissions are regulated separately under the federal Clean Air Act. WAC 173-400-110(4)[8] exempts construction activities from permitting review when the activities do not result in new or modified stationary sources.

Washington State regulates what are known as "fugitive" air emissions, which consist of any pollutants that are not emitted through a chimney, smokestack, or similar facility. For example, blowing dust from construction sites, unpaved roads, and tilled agricultural fields are common sources of fugitive particulate matter emissions, referred to as fugitive dust. WAC 173-400-040(9)(a)[9] requires owners and operators of fugitive dust sources to take reasonable measures to prevent dust from becoming airborne and to minimize emissions.

Other Washington State regulations that apply to nuisance emissions, including fugitive dust and various equipment used during construction, include the following:

- **WAC 173-400-040(3), Fallout.** No person shall cause or allow the emission of particulate matter from any source to be deposited beyond the property under direct control of the

[8] https://app.leg.wa.gov/wac/default.aspx?cite=173-400-110
[9] https://app.leg.wa.gov/wac/default.aspx?cite=173-400-040

owner or operator of the source in sufficient quantity to interfere unreasonably with the use and enjoyment of the property upon which the material is deposited.

- **WAC 173-400-040(4)(a), Fugitive Emissions.** The owner or operator of any emissions unit engaging in materials handling, construction, demolition, or other operation that is a source of fugitive emissions, if located in an attainment area and not impacting any nonattainment area, shall take reasonable precautions to prevent the release of air contaminants from the operation.
- **WAC 173-400-040(5), Odors.** Any person who causes or allow the generation of any odor from any source that may unreasonably interfere with any other property owner's use and enjoyment of their property must use recognized good practice and procedures to reduce the odor to a reasonable minimum.
- **WAC 173-400-040(9), Fugitive Dust.** The owner or operator of a source or activity that generates fugitive dust must take reasonable precautions to prevent that fugitive dust from becoming airborne and must maintain and operate the source to minimize emissions.

1.2.2 Greenhouse gas overview

In March 2008, the Washington Legislature enacted House Bill 2815, which directed Ecology to develop rules for the mandatory reporting of GHG emissions by sources that emit more than certain specified threshold amounts. These rules are codified in Chapter 173-441 WAC.[10] According to WAC 173-441-030(1)(a), any source that emits 10,000 MT of CO_2e per calendar year and is a source type identified in WAC 173-441-120 is required to report its GHG emissions to Ecology. For facilities emitting more than 25,000 MT per year, a quantitative disclosure of GHGs is required under 40 CFR 98.

In 2020, the Washington Legislature set new GHG emission limits (Revised Code of Washington [RCW] 70A.45.020[11]) to combat climate change. Under the law, the state is required to reduce GHG emissions levels as follows:

- 2020 – reduce to 1990 levels
- 2030 – 45% below 1990 levels
- 2040 – 70% below 1990 levels
- 2050 – 95% below 1990 levels and achieve net zero emissions

A law passed in 2021 expanded on a rule adopted by Ecology in 2019, establishing a program to reduce leaks from large air conditioning and refrigeration equipment, limiting the impacts for refrigeration chemicals, and requiring Ecology to recommend options for capturing HFCs when equipment reaches the end of its useful life. In 2023, Ecology adopted rules that prohibit manufacturers from using certain HFCs in new air conditioners and refrigeration equipment sold in Washington and require owners of large stationary refrigeration and air conditioning systems to report leak information to Ecology (Ecology 2024b).

[10] https://app.leg.wa.gov/wac/default.aspx?cite=173-441
[11] https://app.leg.wa.gov/rcw/default.aspx?cite=70A.45.020

The Washington Legislature set GHG emission limits (RCW 70A.45.020) to combat climate change. By 2050, the state must achieve net zero GHG emissions. RCW 19.405.060,[12] the Clean Energy Transformation Act requires all electric utilities in Washington to transition to carbon-neutral electricity by 2030 and to 100% carbon-free electricity by 2045. The Washington State Department of Commerce (Commerce) and the Washington Utilities and Transportation Commission are leading the implementation efforts.

1.2.3 Applicable laws and regulations

Table 2 lists laws, plans, and policies that are potentially applicable to air pollutants and GHG emissions from green hydrogen facilities.

Table 2. Applicable laws, plans, and policies

Regulation, statute, guideline	Description
Federal	
42 United States Code 7401 et seq., Clean Air Act	The Clean Air Act is the law that defines EPA's responsibilities for protecting and improving the nation's air quality and the stratospheric ozone layer.
40 CFR 50, National Ambient Air Quality Standards (NAAQS)	National primary and secondary ambient air quality standards. The primary standards define levels of air quality which EPA judges are necessary, with an adequate margin of safety, to protect public health. The secondary air quality standards define levels that EPA judges necessary to protect the public welfare and the environment from any known or anticipated adverse effects of a pollutant.
40 CFR 52.21, Prevention of Significant Deterioration (PSD) of Air Quality	If a new facility would be a major source of air pollutant emissions (generally, potential of 250 tons/year of a criteria pollutant or 100 tons/year for specific facility types), a PSD air permit would be required prior to construction. Ecology administers the PSD program in Washington, except for on Tribal lands or for sources under the jurisdiction of the Energy Facility Site Evaluation Council. Although this program is administered by Ecology, it requires coordination with federal partners such as EPA.
40 CFR 60, New Source Performance Standards (NSPS)	Federal emissions standards that apply to specific categories of stationary sources. The NSPS represent the minimum level of control that is required on a new or modified source. Generator engines or combustion heating equipment may be subject to the NSPS. Ecology and often local clean air agencies administer the NSPS.
40 CFR 63, National Emissions Standards for Hazardous Air Pollutants (NESHAP)	These are federal emissions standards for hazardous air pollutants from specific source categories. They generally specify the Maximum Achievable Control Technology (MACT) and/or practices that must be applied for a given source category; therefore, they are also referred to as MACT standards. Generator engines or combustion heating equipment may be subject to NESHAP. Ecology and often local clean air agencies administer the NESHAP.

[12] https://app.leg.wa.gov/RCW/default.aspx?cite=19.405.060

Regulation, statute, guideline	Description
40 CFR 98, Mandatory Greenhouse Gas (GHG) Reporting	The Greenhouse Gas Reporting Program (GHGRP) requires reporting of GHG data and other relevant information from large GHG emission sources. A total of 41 categories of emission sources are covered by the GHGRP. Facilities are generally required to submit annual reports under 40 CFR 98 if (1) direct GHG emissions from covered sources exceed 25,000 MT CO_2e per year; (2) stationary fuel combustion units at the facility have a combined maximum rated heat input capacity of 30 metric million British thermal units per hour or greater; or (3) supply of certain products would result in over 25,000 MT CO_2e of GHG emissions if those products were released, combusted, or oxidized.
40 CFR 98 Subpart P – 98.160-98.168: Hydrogen Production	Subpart P of the GHGRP requires monitoring, reporting, and recordkeeping of GHG emissions from entities that produce hydrogen and sell it as a product. It covers hydrogen production by "reforming, gasification, oxidation, reaction, or other transformation of feedstock."
40 CFR 51(W) and 40 CFR 93, General Conformity Analysis	General Conformity requires that federal agencies not take actions in nonattainment or maintenance areas that cause or contribute to violations of ambient air quality standards or interfere with goals outlined in a state or Tribal implementation plan for achieving attainment. Exemptions apply based on emissions below thresholds.
GHG Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2 (81 *Federal Register* 73478)	These rules set fuel consumption and GHG emission standards for new on-road medium- and heavy-duty vehicles and engines.
State	
Chapter 70A.15 RCW, Washington Clean Air Act	This regulation defines Ecology's and local air pollution control agencies' responsibility for protecting and improving air quality in Washington.
Chapter 70A.45 RCW, Limiting GHG Emissions	This regulation establishes GHG emission limits and reporting requirements in Washington.
Chapter 70A.65 RCW, GHG Emissions	This regulation establishes the cap and invest program in Washington.
Chapter 173-400 WAC, General Regulations for Air Pollution Sources	This chapter establishes technically feasible and reasonably attainable emissions standards and establishes rules generally applicable to the control and/or prevention of the emission of air contaminants.
WAC 173-400-040, General Standards for Maximum Emissions	This chapter outlines some general emissions standards that apply to all sources and emissions units.
WAC 173-400-99 through 173-400-105, Registration Program	Many sources of air emissions that do not require an NOC Approval instead require registration. A local clean air agency often implements its own approved version of this program.
WAC 173-400-110, New Source Review for Sources and Portable Sources	A source must apply for and be issued an NOC Approval for sources of air emissions unless exempted. Exemptions are described in the rule. A local clean air agency often implements its own approved version of this program.

Regulation, statute, guideline	Description
WAC 173-.400-720, PSD	These are the state rules for administering the PSD permitting program. If a facility would be a major source of air pollutant emissions, a PSD air permit would be required prior to construction.
Chapter 173-401 WAC, Operating Permit Regulation	Title V major sources require an Air Operating Permit. In general, the emissions threshold for each criteria pollutant is 100 tons/year potential emissions, or less in certain nonattainment areas with lower thresholds based on the severity of nonattainment.
Chapter 173-424 WAC, Clean Fuels Program Rule	Requires suppliers and consumers of certain transportation fuels in Washington to reduce and report on the carbon intensity of fuels used in the state. The rule applies to “compressed or liquefied hydrogen” (WAC 173-424-120(d)).
Chapter 173-441 WAC, Mandatory GHG Reporting	Facilities with stationary fuel combustion units emitting ≥10,000 MT CO_2e per year must report GHG emissions.
Chapter 173-444 WAC, Washington Clean Energy Transformation Act (CETA)	Establishes rules that electric utilities shall use to comply with CETA.
Chapter 173-446 WAC, Washington Climate Commitment Act	Implements the provisions of the GHG emissions cap and invest program. Generally, this applies to businesses that generate more than 25,000 metric tons of CO_2 equivalent per year.
Chapter 173-460 WAC, Controls for New Sources of Toxic Air Pollutants	Sources of toxic air pollutants must comply with these regulations.
Chapter 173-476 WAC, Ambient Air Quality Standards	Establishes maximum acceptable levels in the ambient air for particulate matter, lead, sulfur dioxide, nitrogen oxides, ozone, and carbon monoxide.
WAC 463-62-070, Construction and Operation Standards for Energy Facilities – Air Quality	States that air emissions from energy facilities shall meet the requirements of applicable state air quality laws and regulations.
Chapter 463-78 WAC, General and Operating Permit Regulations for Air Pollution Sources	Establishes maximum permissible air emissions standards and reporting requirements for emissions sources under the jurisdiction of the Washington Energy Facility Site Evaluation Council.
Local	
Local New Source Review/Air Permitting program	An NOC may be required for sources of air emissions. Local clean air agencies often have their own approved programs rather than being administered by Ecology. The Puget Sound Clean Air Agency, Southwest Clean Air Agency, Yakima Regional Clean Air Agency, Benton Clean Air Agency, and Spokane Regional Clean Air Agency are located within the study area.
Local Registration Program	Sources of air emissions that do not require an NOC may instead require registration. Local clean air agencies often have their own approved programs rather than being administered by Ecology.
Regulations from cities, counties	Green hydrogen facilities would also need to comply with city and county regulations, ordinances, and plans related to air quality and GHG emissions.

2 Methodology

This section describes 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 air quality and GHG emissions includes the PEIS geographic scope of study for green hydrogen facilities (Figure 1) and surrounding areas, which could include facilities and activities with air emissions.

Figure 1, which shows the PEIS geographic scope of study, does not include federal lands, national parks, wilderness areas, wildlife refuges and sanctuaries, state parks, or Tribal reservation lands, but information related to these areas is provided as context for the affected environment.

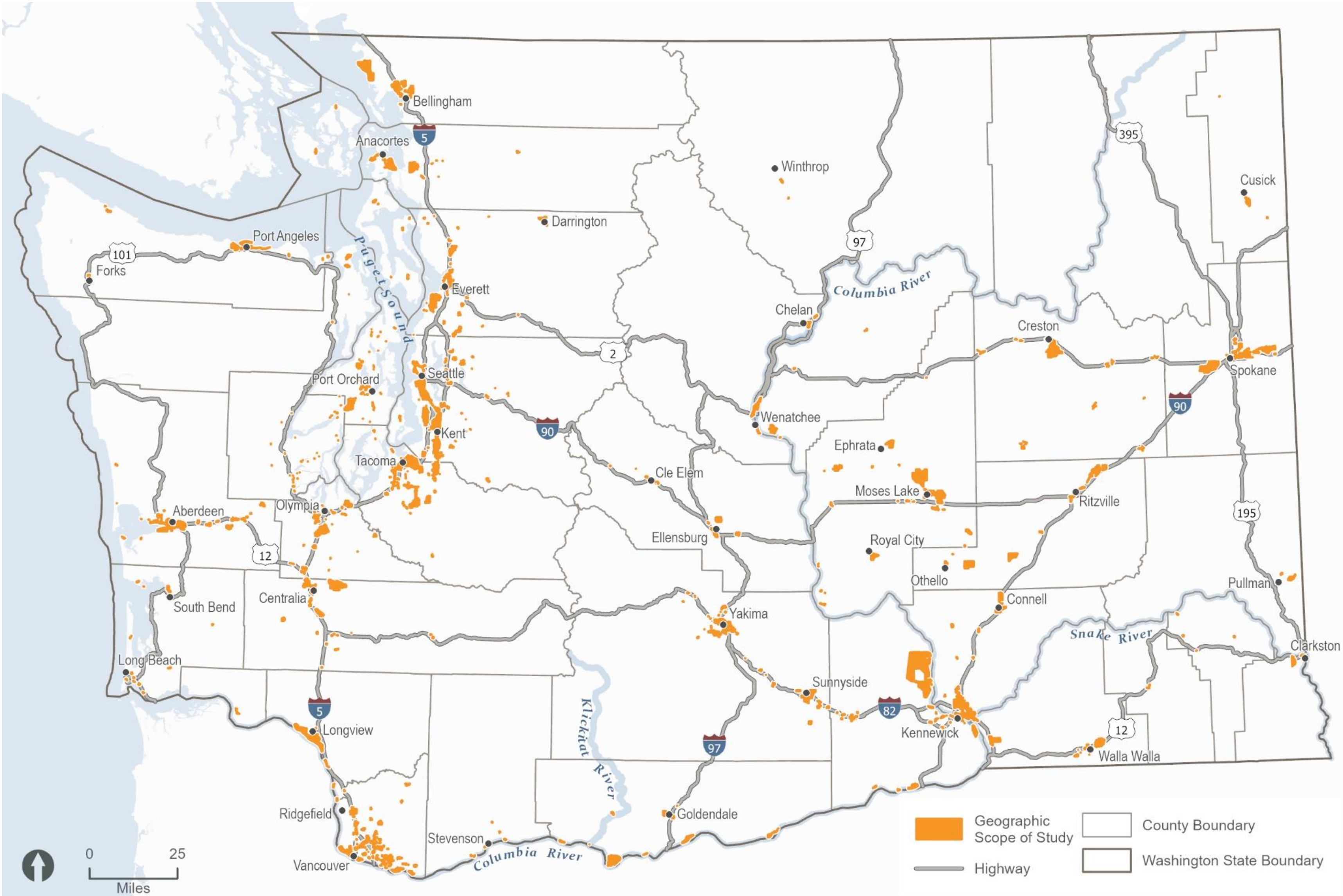

Figure 1. Green Hydrogen Energy Facilities PEIS geographic scope of study

2.2 Technical approach

The approach for analyzing air quality and GHG emissions included the following:

- Qualitatively list each type of green hydrogen facility's potential GHG and air pollutant emissions from construction, operation, and decommissioning activities, using information and assumptions about green hydrogen production, hydrogen storage, and battery energy storage systems (BESSs). Emissions are listed for each hydrogen production process evaluated in the PEIS (electrolysis, SMR, pyrolysis, and gasification). Potential emissions listed include both point source and fugitive emissions.

  HAP and TAP emissions were identified using the EPA Compilation of Air Pollutant Emissions Factors from Stationary Sources (AP-42; EPA 2023) and Santa Barbara County Approved Emission Factors for Toxic Air Contaminants (Santa Barbara County 2023). Washington state does not maintain its own set of approved emission factors specifically for TAPs. Instead, Ecology relies on a combination of EPA models, published emission factors, and other available information to estimate emissions. The approved emission factors from the Santa Barbara County Air Pollution Control District were used as a proxy for estimates of potential TAP emissions.

  To identify direct GHG emissions from hydrogen production, the following methods were used:

  - **CO_2, CH_4, and N_2O:** Argonne National Laboratory's (ANL) Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model
  - **CFCs, HFCs, PFCs, and SF6 emissions:** Identified in situations where refrigerants may be used

  To identify emissions of criteria air pollutants and their precursors, the ANL GREET model was used[13] (ANL 2023):

  - **CO, NO_x, and VOCs (precursors to O_3), and PM_{10} and $PM_{2.5}$:** Emissions of these pollutants are reported in this document per the GREET model.
  - **SO_2 and NO_2:** GREET does not specifically report NO_2 or SO_2 emissions, but it does report NO_x and sulfur oxide (SO_x) emissions. NO_2 is the primary component of NO_x, and SO_2 is the primary component of SO_x. Therefore, this document reports emissions of NO_x and SO_x per the GREET model.
  - **Pb:** Pb emissions are not listed because they would not be expected from hydrogen production, BESS, or hydrogen storage.

- Estimate GHG and air pollutant emissions factors for each hydrogen production process and storage method during operations.
- Evaluate the impacts from facility construction, operation, and decommissioning relative to applicable laws and regulations. Emissions will vary based on the type of production method or storage system used.

[13] See Attachment 1 for more information about the GREET model.

- Qualitatively list potential life-cycle GHG and air pollutant emissions, including from activities upstream and downstream of green hydrogen facilities.

To identify life-cycle GHG emissions from hydrogen production, the following methods were used:

- Review life-cycle assessment (LCA) studies to identify potential life-cycle GHG emissions factors and provide a comprehensive understanding of the GHG impacts throughout the facility's entire life cycle, which includes:
  - Potential sources of electricity for the facility (e.g., wind, solar, hydropower, fossil fuels, nuclear)
  - Common hydrogen end uses (e.g., power generation through hydrogen combustion, use in fuel cell vehicles, use in cement and metals manufacturing)
  - Available GHG emissions intensity or GHG emissions factors for these upstream and downstream activities
- Identify Washington carbon intensity values from the Washington Clean Fuels Program Rule (Chapter 173-424 WAC) that were calculated using hydrogen pathways from the Washington GREET (WA-GREET) model, which accounts for:
  - Feedstock production (e.g., growing, harvesting, or extracting raw materials)
  - Fuel processing (e.g., refining or synthesizing the fuel)
  - Transportation (e.g., moving the fuel from the production facility to the end user)
  - End use (i.e., fuel consumption)

  The carbon intensity values from the WA-GREET model do not account for emissions related to facility construction or decommissioning. The model focuses primarily on operational emissions throughout the life cycle of the fuel (e.g., green hydrogen).

Where data is available, an "emission factor" is reported. For hydrogen production, an emission factor equals the mass of a certain pollutant emitted per mass of hydrogen produced. For hydrogen storage, the emission factor equals the mass of a certain pollutant emitted per mass of hydrogen stored. Emission factors may be stated as a range to account for the fact that emissions depend on the type and quality of equipment and technology being used, and hydrogen production technologies are evolving.

Hydrogen may be emitted during production through leakages in equipment casing and pipework and through venting and purging during operation (UK Department for Business, Energy & Industrial Strategy 2022b). Hydrogen leaked to the atmosphere can act as an indirect GHG, as it can react with pollutants like methane to extend their lifetime in the atmosphere and can affect atmospheric ozone concentrations. A Columbia University study estimated that 2–4% of the hydrogen produced would be leaked (Columbia University Center on Global Energy Policy 2022). A United Kingdom study estimated a 0.52–9.20% leakage rate depending on the type of technology used (UK Department for Business, Energy & Industrial Strategy 2022b). Another study estimated a 0.10–4.00% leakage rate for the production and processing phases of electrolysis (Cooper et al. 2022).

The International Energy Agency reported in 2023, "quantitative information on hydrogen leakage remains limited" and technologies for hydrogen leakage detection are "currently insufficient as they focus on identifying large, potentially explosive leaks for safety reasons, and lack the speed and sensitivity to measure smaller leaks" (IEA 2023a).

The WA-GREET model was used to estimate the amount of hydrogen lost to the environment over the life cycle of the hydrogen production process, including from production, transportation, and end use. Leakage rates vary depending on the production method, infrastructure, and transportation. WA-GREET hydrogen leakage rates are similar across different hydrogen production methods. Based on the 2016 WA-GREET model, hydrogen leakage during liquefaction (0.3 %), transportation and distribution (1.5%), and liquid hydrogen storage (3%) can result in an overall hydrogen leakage of 4.86% for liquefied hydrogen. Assuming hydrogen production is 50% liquid and 50% gaseous hydrogen, hydrogen leakage would be 2.43%.

This analysis assumes that green hydrogen facilities do not generate electricity on site but rather receive it from electricity transmission or distribution lines.

2.3 Impact assessment approach

This analysis evaluates impacts relative to the effects of site characterization, construction, operation, and decommissioning of facilities. The actual circumstances of each facility could vary; therefore, this analysis broadly assumes that a facility would result in a potentially significant impact in any one of the following:

- **Criteria air pollutant emissions:**
  - 100 tons per year (unless the facility is in a nonattainment area, in which case the threshold would be the matching general conformity de minimis limit for that region)
  - Fugitive dust that may impact biological resources or water quality
- **HAP emissions:** 10 tons per year for a single HAP and 25 tons per year for all HAPs combined (per Clean Air Act Title V)
- **TAP emissions:** emissions above the small quantity emission rates established in WAC 173-460-150[14]

Although GHG concentrations are global and not localized, all facilities evaluated would produce GHG emissions. Life-cycle GHG emissions ranges for the facilities were derived from GHG LCAs. An LCA is a method used to assess the GHG impacts of a fuel or energy resource throughout its entire life cycle, from feedstock production to fuel use to disposal. It considers each stage of the life cycle, including extraction, manufacturing, transportation, use and end-of-life management.

[14] https://app.leg.wa.gov/wac/default.aspx?cite=173-460-150

3 Technical Analysis and Results

3.1 Overview

This section describes the affected environment and potential air quality and GHG impacts that might be caused by a green hydrogen facility. This section also evaluates measures that could avoid, minimize, or reduce the identified impacts, and describes potential unavoidable significant adverse impacts.

3.2 Affected environment

The affected environment represents existing conditions at the time this study was prepared.

3.2.1 Air quality

Air quality throughout the study area varies depending on the location. In parts of the study area with urban surroundings, air quality is generally lower than in parts with more rural surroundings.

At the time of this PEIS, all areas in Washington State meet the NAAQS set by EPA for criteria pollutants. There are 15 former nonattainment areas in Washington. Each area has an approved maintenance plan for air quality that includes specific requirements for the area. Most of the 15 areas have demonstrated attainment of the standard for which they were designated nonattainment for more than 20 years. This is an important threshold signifying successful maintenance strategies so there is no longer a need to review or revise them. At the end of 2025, there will be only two maintenance areas that are still within the 20-year planning period: Tacoma $PM_{2.5}$ and Ferndale SO_2. Washington's maintenance areas and their associated maintenance pollutants are (EPA 2024c):

- **CO:** Vancouver, Seattle-Tacoma, Spokane, and Yakima
- **PM_{10}:** Kent, Seattle, Tacoma, Olympia, Tumwater, Lacey, Wallula, Spokane County, and Yakima County
- **$PM_{2.5}$:** Tacoma
- **SO_2:** Ferndale-Intalco in Whatcom County

There are some areas of concern for particulate matter and ozone within the study area. The Tri-Cities area (Kennewick, Pasco, and Richland) is an area of concern for ozone. Sunnyside, Toppenish, and Yakima to the west are areas of concern for particulate matter, along with Omak in the north and Colville in the northeast.

Any location may experience occasional severe deterioration of air quality due to wildfires (usually July–September), depending on wind patterns and the location of the fire(s). In addition, seasonal dust storms (usually during dry periods in spring and summer), particularly in eastern and central Washington, can increase levels of particulate matter in the air, which decreases air quality leading to reduced visibility.

The study area includes industrial lands that are developed with existing industrial uses and other areas zoned for industrial uses that have not yet been developed. Existing industrial lands may include facilities and activities with associated air emissions, such as manufacturing facilities, ports, refineries, and airports. Stationary sources of air emissions include boilers, industrial processes (e.g., chemical production, energy production, waste treatment), incinerators, generators, and chemical and fuel storage tanks. Mobile sources of air emissions include internal combustion engines in trucks, construction equipment, service vehicles, aircraft, locomotives, commercial vessels, maintenance equipment, and other vehicles traveling within or near industrial lands, as well as mobile generators.

To make sure the air continues to meet air quality standards, Ecology and its partners monitor the air using Washington's Air Monitoring Network. As previously described, regulatory programs such as PSD and Chapter 173-400 WAC[15] are in place to ensure that air pollution levels do not increase to concentrations that threaten ambient air quality. Any new industrial sources of air pollution must receive an air quality permit prior to operation. The permitting programs are designed to ensure that not only are ambient air quality standards protected, but that the current levels of air quality are not substantially degraded by industrial growth.

3.2.2 GHGs

Per Ecology's most recent GHG inventory, 102.1 million metric tons of CO_2e were emitted in Washington state in 2019 (Ecology 2022). Ecology found that transportation is the largest source, at 40% of the state's GHG emissions, followed by residential, commercial, and industrial energy use at 31%, and electricity consumption (both in-state and out-of-state) at 21%.[16] The sources of the remaining 8% of emissions are agriculture, waste management, and industrial processes.[17]

An LCA analyzes GHG emissions from the full lifespan of a facility, fuel or product. An LCA GHG analysis typically covers both direct and indirect emissions of GHGs. Direct emissions refer to GHG emissions that are released directly from a facility or process. These include emissions from activities such as fuel combustion in facility equipment, industrial processes, and fugitive emissions from a facility's operation. Indirect emissions refer to GHG emissions that occur as a consequence of a facility's activities but are emitted from upstream or downstream activities, including from extracting raw materials, generating electricity used at a facility, transportation

[15] https://app.leg.wa.gov/wac/default.aspx?cite=173-400&full=true

[16] Transportation sources include on-road vehicles, marine vessels, jet fuel and aviation gasoline, rail operations, and natural gas for transportation. Washington GHG emissions from the transportation sector have been fairly constant for several years, with on-road gasoline continuing to contribute over 50% of transportation sector emissions. Marine vessel emissions include emissions from recreational, commercial, and ocean-going vessels, but exclude marine bunker fuels consumed in international waters.

[17] The industrial sector includes fugitive GHG emissions that are released during the production, processing, transmission, and distribution of fossil fuels. These emissions are typically fugitive methane due to leakage and venting from natural gas pipelines and compressor stations, and petroleum systems.

and storage of hydrogen for distribution, and manufacturing the components of a facility. A comprehensive LCA for green hydrogen facilities would typically include the emission sources in Table 3.

Washington's laws identify two categories of clean or green hydrogen based on how the hydrogen is produced:

- "Green electrolytic hydrogen" is defined in RCW 80.50.020[18] and is produced through electrolysis. It does not include hydrogen manufactured using SMR or any other conversion technology that produces hydrogen from a fossil fuel feedstock. In this definition, water is the feedstock for the hydrogen, while the electricity is not a feedstock but is the input energy or process energy used in electrolysis of the water. The source of electricity may vary but will need to meet CETA requirements and be net-zero by 2045.
- "Renewable hydrogen" is defined in RCW 80.50.020 and is produced using renewable resources both as the source for hydrogen and the source for the energy input into the production process.

Washington added "green electrolytic hydrogen" in 2022 to authorize and encourage hydrogen production facilities even if they will not rely exclusively on renewable electricity sources in the near term. Under this definition, water is the feedstock for the hydrogen, while the electricity is not a feedstock but the process energy used in electrolysis. Hydrogen produced through electrolysis will meet this definition regardless of whether the electricity is produced from on-site renewable sources, from fossil-fired generation, from unspecified grid sources, or from any combination of these resources. CETA (Chapter 19.405 RCW[19]) is Washington's clean electricity law, which requires all electricity used in Washington to be GHG neutral by 2030 and 100% clean by 2045. Under the 2030 GHG-neutral standard, a utility may use fossil-fired electricity for up to 20% of its supply under an alternative compliance mechanism.

The actual carbon intensity for green electrolytic hydrogen and other low- or zero-carbon hydrogen depends on the sources of electricity used by each production facility. The ANL GREET model is used by the U.S. Department of the Treasury to determine carbon intensity of hydrogen in order to assign 45V Production Tax Credit. U.S. Department of Energy materials regarding the GREET model show an aligned interpretation where the "feedstock" is assessed separately from "process inputs," which includes electricity. This is aligned also with the Washington Clean Fuel Program rules that show that clean fuels carbon intensity calculations will assess "feedstock" and "process energy" (WAC 173-424-900[20]).

The Washington State Department of Commerce State Energy Strategy and Green Electrolytic Hydrogen Report in 2023 found that green hydrogen and other renewable fuels are critical to reduce GHG emissions across Washington's economy, especially in sectors that are difficult to decarbonize with electrification or other pathways (Commerce 2020, 2024).

[18] https://app.leg.wa.gov/rcw/default.aspx?cite=80.50.020
[19] https://app.leg.wa.gov/rcw/default.aspx?cite=19.405
[20] https://app.leg.wa.gov/WAC/default.aspx?cite=173-424-900

For green hydrogen production and storage technologies, LCAs may vary because:

- There is much more variety in the type of raw materials and inputs that could be used during construction and operation compared to other green energy production methods (e.g., solar, wind):
  - For example, an LCA for electrolysis would depend on the specific type of electrolyzer used, an LCA for SMR or pyrolysis would depend on the source of renewable natural gas, and an LCA for bio-gasification would depend on the source of biomass.
  - All LCAs would depend on the source of electricity for the facility—whether that is electricity from a typical grid in the U.S., or electricity from Washington, where it is largely generated by nonemitting sources (EIA 2024).
  - LCA emissions estimates would also depend on whether a green hydrogen facility used compression and/or liquefaction equipment.
- There are many possible end uses for hydrogen.

While hydrogen is not a GHG, its chemical reactions can change the abundances of methane, ozone, and stratospheric water vapor, as well as aerosols if leaked. In this case, hydrogen that is leaked to the atmosphere can act as an indirect GHG (Derwent et al. 2020). Leakage could occur during upstream production and downstream transmission, storage, and distribution. Hydrogen may react with pollutants like methane to extend their lifetime in the atmosphere. Leaked hydrogen can also impact ozone concentrations, potentially harming air quality and the recovery of the ozone layer, and it can create water vapor in the atmosphere, enhancing the GHG effect. Studies have shown that it will be important to minimize hydrogen leakages (Sand et al. 2023).

Table 3. GHG emissions related to green hydrogen production

Emission source	Details related to green hydrogen facilities
Extracting raw materials to construct the components of the facility	These might include emissions from mining lithium or vanadium for batteries, or emissions from mining ore for metal.
Manufacturing the components of the facility	• For green hydrogen facilities, components that must be manufactured may include, but are not limited to: ○ Equipment such as electrolyzers, steam methane reformers, boilers, BESS, and hydrogen compression or liquefaction equipment ○ Building materials for structures (e.g., metal beams, concrete)
Extracting and producing feedstock used at the facility	• Renewable natural gas (RNG) is a feedstock for SMR or pyrolysis under the Chapter 80.50 RCW definition of "renewable hydrogen." The production of RNG may result in CH_4 and CO_2 emissions (IEA 2023b), as well as emissions of other air pollutants. The amount of CH_4 and CO_2 emissions from RNG production may vary widely based on the source of the RNG and the technology used to produce it. Per RCW 80.50.020, RNG means "a gas consisting largely of methane and other hydrocarbons derived from the decomposition of organic material in landfills, wastewater treatment facilities, and anaerobic digesters."

Emission source	Details related to green hydrogen facilities
	• Renewable biomass is a feedstock for pyrolysis or bio-gasification under the Chapter 80.50 RCW definition of "renewable hydrogen." All biomass releases GHG emissions as it decomposes. Additionally, emissions of GHGs and air pollutants may result from the process of gathering biomass and packaging it into an appropriate format for use in hydrogen production. Per RCW 19.285.030, biomass includes "(i) organic by-products of pulping and the wood manufacturing process; (ii) animal manure; (iii) solid organic fuels from wood; (iv) forest or field residues; (v) untreated wooden demolition or construction debris; (vi) food waste and food processing residuals; (vii) liquors derived from algae; (viii) dedicated energy crops; and (ix) yard waste," and biomass does not include "(i) wood pieces that have been treated with chemical preservatives such as creosote, pentachlorophenol, or copper-chrome-arsenic; (ii) wood from old growth forests; or (iii) municipal solid waste."
Generating the electricity[a] used at the facility	• Hydropower, wind, solar, and nuclear energy do not produce any direct GHG emissions, HAPs, TAPs, or criteria air pollutants during operation. • Natural gas- and coal-fired plants produce direct GHG emissions, HAP, TAP, and criteria air pollutants. • Under CETA, utilities must have net-zero emissions by 2045. Green hydrogen production facilities will likely use electricity derived from the local utility fuel mix, which is dependent on the utility's resource mix. Local utility fuel mix is tracked and reported by the Washington State Department of Commerce (Commerce 2024).
Transporting goods and employees to and from the facility	• For transportation of feedstock to a hydrogen production facility and transportation of hydrogen tanks away from a facility, the type and amount of emissions would depend on the specific transportation modes used, such as vehicles, railways, or ships, and their power source (e.g. fossil fuel, electricity, hydrogen). • Employees would typically commute in personal vehicles or public transportation, from which CO_2 emissions would be expected unless those vehicles were fully electric.
Constructing, operating, maintaining, and decommissioning the facility	These are discussed in Section 3.4 of this document.
Disposing of facility components	For example, disposing of facility components via recycling, landfill, or incineration.
End-users of green hydrogen	• Combustion for electricity generation or industrial heating: no GHG emissions. • Hydrogen fuel cell vehicles: A hydrogen fuel cell is a machine that converts hydrogen and oxygen into electricity, with water vapor and heat as the only byproducts. No GHG emissions. • Steel production: Hydrogen can be used instead of coal as a chemical reagent to turn iron ore into pig iron for steel production (RMI 2019). This process emits some CO_2 (RFF 2020; ING 2023). • Conversion to ammonia: The most common method for converting hydrogen to ammonia—called the Haber-Bosch process—emits 2.16 kilograms (kg) of CO_2e per kg of ammonia (Seyedehhoma et al. 2021). Ammonia is commonly used for manufacturing fertilizer but can also be used as a transportation fuel. • Conversion to hydrocarbon fuel: Using the Fischer-Tropsch process, hydrogen can be converted to hydrocarbon fuels, which can be used in

Emission source	Details related to green hydrogen facilities
	place of gasoline or diesel. The Fischer-Tropsch process emits CO_2 and CH_4 (NETL 2024).
Hydrogen leaks during upstream production, and downstream transmission, storage, and distribution	• Facilities and end-users may have hydrogen leaks from piping and equipment. • Leakage of hydrogen may occur during transportation and storage of hydrogen for distribution. • A UK study estimated a 0.52–9.20% leakage rate depending on the type of technology used (UK Department for Business, Energy & Industrial Strategy 2022b).

Notes:

a. “Green electrolytic hydrogen” is defined in RCW 80.50.020 and is produced through electrolysis. It does not include hydrogen manufactured using SMR or any other conversion technology that produces hydrogen from a fossil fuel feedstock. In this definition water is the feedstock for the hydrogen, while the electricity is not a feedstock but is the input energy or process energy used in electrolysis of the water. The source of electricity may vary but will need to meet CETA requirements and be net-zero by 2045. “Renewable hydrogen” is defined in RCW 80.50.020 and is produced using renewable resources both as the source for hydrogen and the source for the energy input into the production process.

b. Washington’s only coal plant, the TransAlta plan in Centralia, is scheduled to close in 2025 (Ecology 2024d).

3.3 Potentially required permits and approvals

Construction, operation, and decommissioning activities for typical green hydrogen facilities would potentially require the following permits related to air resources:

- **Air Quality Permits (Ecology, Energy Facility Site Evaluation Council [EFSEC], local agency):** These permits are required to control and manage emissions from construction and operation activities. New or modified industrial stationary sources of pollution must receive an air quality permit (NOC Approval) prior to operation. Chapter 173-400 WAC establishes the requirements for review and issuance of NOC Approvals for new or modified sources of air emissions. A fugitive dust plan may be required to demonstrate compliance with WAC 173-400-040(3) and 173-400-040(8)(a).
- **Air Operating Permit (Ecology)**: Required for facilities that could emit the following in a 12-month period:
  - More than 100 tons per year of any regulated 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
- **Clean Air Act Prevention of Significant Deterioration Permit (EFSEC, Ecology):** This permit ensures that air discharges from the facility meet state standards.
- **State Refrigerant Management Program (Ecology):** Requires facilities with refrigeration and air conditioning systems containing more than 50 pounds of refrigerant with a global warming potential of 150 or more to conduct and report periodic leak inspections, promptly repair leaks; and keep service records on site.

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 Air quality

3.4.1.1 Impacts from construction and decommissioning

The types of emissions during site characterization, construction, and decommissioning would be the same, regardless of the green hydrogen production method (i.e., electrolysis, SMR, pyrolysis, or gasification) used at the facility.

Air emissions during construction would be generated by non-road construction equipment (e.g., dozers, pavers, excavators/loaders, cranes, generator sets), haul-truck trips, on-road worker trips, vehicle travel on paved and unpaved surfaces, and fugitive dust from soil/material handling activities. The probable air quality and GHG emissions from construction are noted in Table 4.

Table 4. Emissions from construction

Type of emissions	Probable emissions
Emissions of criteria air pollutants and their precursors	• PM (fugitive dust) emissions: results from several sources – soil disturbance, transportation of soil, the wheels of vehicles/equipment/ machinery traveling over soil or gravel, and internal combustion engine (ICE) vehicle tailpipe emissions (Winkler et al. 2018) • CO, NO_2, NO_x, and VOCs: emitted from the tailpipes of ICE vehicles (Winkler et al. 2018) • SO_2: emitted from diesel-powered vehicles or equipment (Union of Concerned Scientists 2023)
HAP emissions	From diesel and gasoline internal combustion engines in construction vehicles and equipment: Acetaldehyde, acrolein, benzene, formaldehyde, 1,3-butadiene, naphthalene, and polycyclic aromatic hydrocarbons (PAHs)
TAP emissions	From diesel and gasoline internal combustion engines in construction vehicles and equipment: Acetaldehyde, acrolein, benzene, formaldehyde, 1,3-butadiene, and naphthalene
GHG emissions	CO_2, CH_4, and N_2O emitted by ICE vehicles
Hydrogen emissions	None

The amount of air pollutants and GHG emissions would depend on the following factors:

- Number of miles traveled or hours operated by vehicles, equipment, and machinery while working on site. The number of miles traveled or hours operated would depend on the size of the facility (i.e., square footage, number of structures, and configuration of structures) and amount of earth moving needed.
- Characteristics of vehicles, machinery, and non-road equipment, such as type, capacity, age, fuel, and whether they have emissions controls. For example, internal combustion engine vehicles emit more pollutants and GHGs than electric vehicles.

Emissions from green hydrogen facility construction would depend on the factors noted above. Emissions from construction were estimated for two facility footprint scenarios: 1 acre and 10 acres. Estimated maximum annual air emissions from a lower-bound (1 acre) and an upper-bound (10 acres) construction scenario are listed in Table 5. Best management practices (BMPs) would be used to reduce emissions. As shown in Table 5, construction emissions are not expected to exceed criteria pollutant thresholds. Actual emissions from construction may differ from the values presented due to variable and project-specific design characteristics.

Table 5. Estimated annual maximum criteria pollutant emissions from construction (tons/year)

Construction scenario	VOC	NO_X	CO	SO_2	PM_{10}	$PM_{2.5}$
Lower bound (1 acre)	0.32	0.82	1.08	<0.01	2.63	0.36
Upper bound (10 acres)	2.45	1.58	2.51	<0.01	10.84	1.35
Threshold	100	100	100	100	100	100
Exceeds threshold?	No	No	No	No	No	No

Source: CAPCOA 2022

Note: Emissions for each construction scenario were calculated using the California Emissions Estimator Model. Methodology and detailed emissions results are included in Attachment 2.

Air quality emissions during decommissioning would be similar to facility construction. Decommissioning emissions would be like those from other industrial facilities and would be required to comply with BMPs to be below criteria pollutant thresholds.

Through compliance with laws, permits, and with implementation of measures to avoid and reduce impacts, construction and decommissioning activities would likely result in **less than significant impacts** on air quality**.**

3.4.1.2 Impacts from operation

Vehicles and maintenance equipment/machinery

During operation, vehicles, non-road equipment, and machinery used at the facility would generate air quality and GHG emissions similar to those discussed for construction in Section 3.4.1. The types of emissions would be similar regardless of the type of green hydrogen production method used at the facility. The number of full-time employees and the use of vehicles and maintenance equipment/machinery during operation would be on a smaller scale than during construction. Therefore, vehicle and maintenance equipment/machinery activities during operation would result in fewer emissions than facility construction. BMPs would be used to reduce emissions. Operational emissions from vehicle and maintenance equipment are not expected to exceed air quality thresholds.

Building heating and cooling

During operation, building heating and cooling systems could generate air emissions. The types of emissions specifically from heating and cooling buildings (not heating and cooling related to hydrogen production) would be similar regardless of the type of green hydrogen production method used at the facility. Heating and cooling systems would be required only for administrative, storage, and other indoor areas. The size of these areas would be dependent on the size of the green hydrogen production facility and its location (e.g., a green hydrogen production facility co-located with another energy production facility may not need additional administrative space).

The amount of emissions from building heating and cooling would depend on the size of the buildings and the heating and cooling capacities at the facility. It would also depend on the heating and cooling technology, such as the types of refrigerants used in cooling systems or the use of electric rather than natural gas heating. If electric-powered heat transfer systems are used, no criteria air pollutant, HAP, TAP, or GHG emissions would be expected from the heating system. If natural gas heating systems are used, then various criteria air pollutants, HAPs, and TAPs would be expected, as well as emissions of GHGs such as CO_2, CH_4, and N_2O (EPA 2023). The discussion of GHG emissions is included in Section 3.4.2. No criteria air pollutant, HAP, TAP, or GHG emissions would be produced from the operation of cooling systems; however, CFCs, HFCs, PFCs, or SF6 would be emitted if refrigerants are leaked.

Estimated annual emissions would need to be determined during future project proposals but would be like those of other industrial facilities. Table 6 shows estimated annual air emissions from natural gas-fired boilers for select boiler sizes that may be installed at green hydrogen production facilities. BMPs would be used to reduce emissions. Emissions from operation of facility heating and cooling systems are not expected to exceed air quality thresholds.

Table 6. Estimated annual criteria pollutant emissions from industrial natural gas boiler operation (tons/year)

Facility size	Boiler capacity (MMBtu)	VOC	NO_X	CO	SO_2	PM_{10}	$PM_{2.5}$
Small	1	<0.01	0.07	0.06	<0.01	0.01	0.01
Medium	5	0.02	0.36	0.30	<0.01	0.03	0.03
Large	10	0.04	0.71	0.60	<0.01	0.05	0.05
Threshold	N/A	100	100	100	100	100	100
Exceeds threshold?	N/A	No	No	No	No	No	No

Note: Emissions calculated for natural gas-fired boiler operations at 1,500 hours per year. Methodology and emissions calculations are included in Attachment 3. MMBtu = metric million British thermal units.

Hydrogen production

Emissions from green hydrogen production depend on the production method. The sections below describe emissions from electrolysis, SMR, pyrolysis, and bio-gasification.

Electrolysis

Producing hydrogen via electrolysis does not emit any direct criteria air pollutants, HAPs, TAPs, or GHGs. Oxygen is the only byproduct.

SMR of renewable natural gas

Emissions from the SMR process occur from the reformation of methane to produce hydrogen using high heat, which could result in the release of CO_2, CO, CH_4, NO_X, and potential sulfur compounds and particulate matter. Types and quantities of air emissions from the SMR process depend on the source and chemical composition of the renewable natural gas (RNG) feedstock (i.e., proportion of CH_4, CO_2, and other trace gases), operational conditions, and hydrogen production capacity of the facility. Criteria pollutant, HAP, and TAP emissions expected from the SMR process, in terms of emission factors, i.e., mass of pollutant per mass of hydrogen produced, are listed in Table 7. GHG emissions are discussed in Section 3.4.2.

Table 7. Expected emissions from hydrogen production via SMR

Type of emissions	Probable emissions	Explanation
Emissions of criteria air pollutants and their precursors	• CO: 0.2499 g/kg H_2 • NO_x: 0.6795 g/kg H_2 • VOC: 0.2171 g/kg H_2 • PM_{10}: 0.2854 g/kg H_2 • $PM_{2.5}$: 0.2804 g/kg H_2 • SO_x: 0.0077 g/kg H_2 (ANL 2023)	Emissions may occur as gas losses from the SMR process, from the thermal decomposition process or as a result of combustion in auxiliary equipment to provide process heating.
HAP emissions	From boilers/heaters: acetaldehyde, acrolein, benzene, ethyl benzene, formaldehyde, n-hexane, naphthalene, PAHs (subset of polycyclic organic matter [POMs]), toluene, and xylenes (Santa	Emissions could occur from (1) boilers using natural gas to generate steam and (2) flares to burn vented gases.

Type of emissions	Probable emissions	Explanation
	Barbara County 2023). Probable emissions from industrial boilers for potential HAPs are listed below: • Benzene: 0.001–0.01 pound (lb)/MMBtu • Formaldehyde: 0.01–0.05 lb/MMBtu • Acetaldehyde: 0.001–0.01 lb/MMBtu (EPA 2023) From flares: Arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium, acetaldehyde, acetonitrile, acrolein, acrylonitrile, benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,1-dichloroethane, p-dichlorobenzene, 1,4-dioxane, ethyl benzene, ethyl chloride, ethylene dichloride, formaldehyde, n-hexane, hydrochloric acid, hydrogen fluoride, methyl chloroform, methylene chloride, naphthalene, PAHs (excl. naphthalene), perchloroethylene, toluene, trichloroethylene, vinyl chloride, xylenes, m-xylene, o-xylene (Santa Barbara County 2023). Probable emissions from flares for potential HAPs are listed below: • Benzene: 0.01–0.1 lb/MMBtu • Formaldehyde: 0.05–0.2 lb/MMBtu • Acetaldehyde: 0.01–0.1 lb/MMBtu • Hydrogen fluoride: 0.01–0.1 lb/MMBtu • Nickel: <0.0001 lb/MMBtu (EPA 2023)	
TAP emissions	From boilers/heaters: acetaldehyde, acrolein, benzene, ethyl benzene, formaldehyde, n-hexane, naphthalene, PAHs (subset of POMs), toluene, xylene (Santa Barbara County 2023). From flares: arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium, acetaldehyde, acrolein, benz(a)anthracene, benzene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, carbon tetrachloride, chlorobenzene, chloroform, chrysene, dibenz(a,h)anthracene, 1,1-dichloroethane, p-dichlorobenzene, 1,4-dioxane, ethyl benzene, ethyl chloride, ethylene dichloride, formaldehyde, hydrogen fluoride, indeno(1,2,3-cd)pyrene, n-hexane, methyl chloroform, naphthalene, toluene, perchloroethylene, trichloroethylene, vinyl chloride, xylenes, m-xylene, o-xylene (Santa Barbara County 2023).	Emissions could occur from (1) boilers using natural gas to generate steam and (2) flares to burn vented gases.

Criteria pollutant emissions were estimated for the lower and upper bounds of hydrogen production via SMR. A small-scale SMR facility could be capable of producing 2,000 kilograms (kg) per day, whereas a full-scale industrial SMR facility could be capable of producing 50 to 100

MT (50,000 to 100,000 kg) of hydrogen per day. Estimated annual emissions from SMR hydrogen production are listed in Table 8.

Table 8. Estimated annual criteria pollutant emissions from SMR (tons/year)

Facility capacity	VOC	NO_X	CO	SO_X	PM_{10}	$PM_{2.5}$
Lower bound – 2,000 kg H_2/day	0.17	0.55	0.20	0.01	0.23	0.23
Upper bound – 100,000 kg H_2/day	8.73	27.34	10.05	0.31	11.48	11.28
Threshold	100	100	100	100	100	100
Exceeds threshold?	No	No	No	No	No	No

Note: Assumes facility operation at 365 days per year.

Based on the estimates shown in Table 8, emissions from hydrogen production through SMR are not expected to exceed air quality thresholds for criteria pollutants listed in Section 2.3. Depending on the boiler capacity and flare size and considering the probable HAP and TAP emissions from SMR, there is potential for the HAP and TAP thresholds identified in Section 2.3 to be exceeded. Boilers are typically designed and regulated to minimize emissions of HAPs and TAPs to the environment through several mechanisms, including through the use of clean fuels (e.g., natural gas), emissions control systems (e.g., selective catalytic reduction, flue gas desulfurization, activated carbon injection, baghouse filters, electrostatic precipitators), and high-efficiency combustion. Flare systems are designed to minimize the release of HAPs and TAPs to the environment through complete combustion of excess gases and other byproducts, emissions control systems, and best practices (e.g., flare gas recovery, high-efficiency flare tips, vapor recovery systems, controlled flow rate of excess flare gas). The EPA and Ecology set limits on HAP and TAP emissions from industrial sources, including from boilers and flares. These sources are required to operate in a way that keeps their emissions below de minimis thresholds. If a source's emissions exceed the identified thresholds, facilities are often required to implement additional controls to reduce emissions of HAPs and TAPs to the environment.

Pyrolysis of renewable natural gas or biomass

The primary byproduct of hydrogen production via pyrolysis is solid carbon, but the process also produces some air emissions, which may be produced from auxiliary equipment and the thermal decomposition of organic materials. Types and quantities of air emissions from the pyrolysis process depend on the source and chemical composition of the natural gas or biomass feedstock (i.e., proportion of CH_4, CO_2, and other trace gases), operational conditions, and hydrogen production capacity of the facility. Criteria pollutant, HAP, and TAP emissions expected from the pyrolysis process are listed in Table 9.

Table 9. Expected emissions from hydrogen production via pyrolysis

Type of emissions	Probable emissions	Explanation
Emissions of criteria air pollutants and their precursors	Most significant are: • CO: 0.00693 gram (g)/kg H_2 • NO_x: 0.016493 g/kg H_2 (ANL 2023) Other criteria pollutants would be emitted in smaller quantities, generally less than 0.001 g/kg H_2 (EPA 2023).	Emissions may come from fuel-fired auxiliary equipment and thermal decomposition of organic materials.
HAP emissions	POM and VOCs. Probable emissions for potential HAPs are listed below: • Polycyclic aromatic hydrocarbons (component of POM): 0.01–0.1 g/kg feedstock • VOC – acetaldehyde: 0.01–0.05 g/kg feedstock • VOC – formaldehyde: 0.02–0.1 g/kg feedstock • VOC – methanol and other alcohols: 0.01–0.03 g/kg feedstock (EPA 2023)	VOC emissions may be a byproduct of the pyrolysis reaction.
TAP emissions	VOCs	VOC emissions may be a byproduct of the pyrolysis reaction.

Criteria pollutant emissions were estimated for the lower and upper bounds of hydrogen production via pyrolysis. A pyrolysis facility could be capable of producing 5 to 10 MT (5,000 to 10,000 kg) of hydrogen per day. Estimated annual emissions from pyrolysis hydrogen production are listed in Table 10.

Table 10. Estimated annual criteria pollutant emissions from pyrolysis (tons/year)

Facility capacity	NO_X	CO
Lower bound – 5,000 kg H_2/day	0.03	0.01
Upper bound – 10,000 kg H_2/day	0.07	0.03
Threshold	100	100
Exceeds threshold?	No	No

Note: Assumes facility operation at 365 days per year. Emissions for other pollutants (VOC, SO_X, and particulate matter) would be less than those shown for CO and NO_X and would be considered negligible.

Based on the estimates shown in Table 10, emissions from hydrogen production through pyrolysis are not expected to exceed air quality thresholds for criteria pollutants listed in Section 2.3. Depending on the feedstock quantities required for the pyrolysis reaction and considering the probable HAP and TAP emissions from the pyrolysis process, there is potential for the HAP and TAP thresholds identified in Section 2.3 to be exceeded. As identified for SMR, emissions of HAPs and TAPs to the environment could be reduced through emissions control systems, high-efficiency combustion of feedstock, and best practices. Pyrolysis facilities would be required by federal and state regulations to operate in a way that keeps their HAP and TAP emissions below de minimis thresholds. If a source's emissions exceed the identified thresholds, the facility may be required to implement additional controls to reduce emissions of HAPs and TAPs to the environment.

Bio-gasification

Emissions from the biomass gasification process occur from the incomplete combustion of biomass, which can result in emissions of CO, CO_2, CH_4, and VOCs. Emissions can also include particulate matter, sulfur compounds, and NO_X. Types and quantities of air emissions from the bio-gasification process depend on the feedstock, operational conditions, and capacity of the facility. Criteria pollutant, HAP, and TAP emissions expected from the bio-gasification process are listed in Table 11. GHG emissions are discussed in Section 3.4.2.

Table 11. Expected emissions from hydrogen production via biomass gasification

Type of emissions	Probable emissions	Explanation
Emissions of criteria air pollutants and their precursors	• CO: 0.1310 g/kg H_2 • NO_x: 0.5589 g/kg H_2 • VOC: 0.0150 g/kg H_2 • PM_{10}: 0.02069 g/kg H_2 • $PM_{2.5}$: 0.020697 g/kg H_2 • SO_x: 1.8666 g/kg H_2 (ANL 2023)	Emissions will result as a byproduct of the gasification process. Emissions may vary based on the chemical composition of the biomass used.
HAP emissions	Acetaldehyde, acetophenone, acrolein, benzene, bis(2-ethylhexyl)phthalate, bromomethane, carbon tetrachloride, chlorine, chlorobenzene, chloroform, chloromethane, 1,2-dichloroethane, dichloromethane, 1,2-dichloropropane, 2,4-dinitrophenol, ethylbenzene, formaldehyde, hydrogen chloride, naphthalene, 4-nitrophenol, phenol, propionaldehyde, styrene, 2,3,7,8-tetrachlorodibenzo-p-dioxins, toluene, 1,1,1-trichloroethane, 2,4,6-trichlorophenol, vinyl chloride, o-xylene (EPA 2023) Probable emissions for potential HAPs are listed below: • Benzene: 0.01–0.5 g/kg feedstock • VOC – acetaldehyde: 0.01–1 g/kg feedstock • VOC – formaldehyde: 0.01–0.5 g/kg feedstock (EPA 2023)	This list assumes emissions are comparable to those in AP-42 Section 1.6, Wood Residue Combustion in Boilers.
TAP emissions	Acetaldehyde, acrolein, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(j,k)fluoranthene, benzo(k)fluoranthene, carbon tetrachloride, chlorine, chlorobenzene, chrysene, dibenzo(a,h)anthracene, 1,2-dichloroethane, dichloromethane, 1,2-dichloropropane, ethylbenzene, formaldehyde, hydrogen chloride, indeno(1,2,3-cd)pyrene, naphthalene, styrene (EPA 2023)	This list assumes emissions are comparable to those in AP-42 Section 1.6, Wood Residue Combustion in Boilers.

Criteria pollutant emissions were estimated for the lower and upper bounds of hydrogen production via bio-gasification. A bio-gasification facility could be capable of producing 50 to

100 MT (50,000 to 100,000 kg) of hydrogen per day. Estimated annual emissions from bio-gasification hydrogen production are listed in Table 12.

Table 12. Estimated annual criteria pollutant emissions from bio-gasification (tons/year)

Facility capacity	VOC	NO_X	CO	SO_X	PM_{10}	$PM_{2.5}$
Lower bound – 50,000 kg H_2/day	0.30	11.24	2.64	37.55	0.42	0.42
Upper bound – 100,000 kg H_2/day	0.60	22.49	5.27	75.10	0.83	0.83
Threshold	100	100	100	100	100	100
Exceeds threshold?	No	No	No	No	No	No

Note: Assumes facility operation at 365 days per year.

Based on the estimates shown in Table 12, emissions from hydrogen production through bio-gasification are not expected to exceed air quality thresholds for criteria pollutants listed in Section 2.3. Emissions of SO_2 at the upper bound hydrogen production level would be within 25% of reaching the emissions threshold (100 tons per year). As with pyrolysis, there is a potential for the HAP and TAP thresholds identified in Section 2.3 to be exceeded, depending on the feedstock quantities required for the bio-gasification process. As identified for pyrolysis, emissions of HAPs and TAPs to the environment could be reduced through emissions control systems, high-efficiency combustion of feedstock, and best practices. Bio-gasification facilities would be required to operate in a way that keeps their HAP and TAP emissions below de minimis thresholds. If a source's emissions exceed the identified thresholds, the facility may be required to implement additional controls to reduce emissions of HAPs and TAPs to the environment.

Operation impact summary

Actual annual emissions from green hydrogen production projects may differ from the values presented above due to variable and project-specific design characteristics. Annual emissions would be calculated at the project level based on unique design prior to the permitting process and facility operations.

Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, operations activities would likely result in **less than significant impacts** on air quality.

3.4.2 GHG emissions over the lifetime of a facility

3.4.2.1 GHG emissions from construction and decommissioning

During construction, GHG emissions would be produced primarily from internal combustion engines such as those found in gas and diesel-powered vehicles and equipment, and generators. The probable air quality and GHG emissions from construction are noted in Table 13. Actual emissions from construction may differ from the values presented due to variable and project-specific design characteristics. It was estimated that construction would produce an annual maximum of between 202.8 and 689 MT CO_2e per year (CAPCOA 2022). Estimated CO_2e emissions from facility construction would be between approximately 0.0002% and 0.0007% of recorded CO_2e emissions in 2019 for the state.

Table 13. Estimated annual maximum GHG emissions from construction (MT/year)

Construction scenario	CO_2	CH_4	N_2O	CO_2e[a]
Lower bound (1 acre)	200.70	0.01	0.01	202.78
Upper bound (10 acres)	676.90	0.03	0.04	689.00

Source: CAPCOA 2022

Notes:

Emissions for each construction scenario were calculated using the California Emissions Estimator Model. Methodology and detailed emissions results are included in Attachment 3.

a. To calculate the total CO_2e, all GHGs are multiplied by their global warming potential and the results are added together. Global warming potentials are published in 40 CFR 98 (revised April 2024). The global warming potentials used to calculate CO_2e are as follows: CO_2 = 1; CH_4 = 28; N_2O = 265.

GHG emissions during decommissioning would be similar to the emissions generated from facility construction with the addition of emissions from landfill waste.

3.4.2.2 GHG emissions from operation

During operation, stationary sources of air emissions (e.g., boilers, generators) and mobile sources of air emissions (e.g., combustion engines in vehicles, non-road equipment, and machinery) at the green hydrogen production facility would produce GHG emissions. GHG emissions from vehicles, non-road equipment, and machinery would be similar to those discussed for construction in Section 3.4.2.1. The types of GHG emissions would be similar regardless of the type of green hydrogen production method used at the facility. The number of onsite employees and vehicles/equipment during operation of green hydrogen production facilities would be on a smaller scale than during construction. Therefore, GHG emissions from mobile sources would be less than those estimated for construction. Stationary sources of GHGs would likely be produced from boilers used to heat administrative, storage, and other indoor areas. Table 14 shows estimated annual GHG emissions from natural gas-fired boilers for select boiler sizes that may be installed at green hydrogen production facilities.

Table 14. Estimated annual GHG emissions from industrial natural gas boiler operation (MT/year)

Facility size	Boiler capacity (MMBtu)	CO_2	CH_4	N_2O	CO_2e[a]
Small	1	77.75	<0.01	<0.01	78.28
Medium	5	388.82	0.01	0.01	390.95
Large	10	777.73	0.01	0.01	787.98

Notes:

Emissions calculated for natural gas-fired boiler operations at 1,500 hours per year. Methodology and emissions calculations are included in Attachment 3. MMBtu = metric million British thermal units.

a. To calculate the total CO_2e, all GHGs are multiplied by their global warming potential and the results are added together. Global warming potentials are published in 40 CFR 98 (revised April 2024). The global warming potentials used to calculate CO_2e are as follows: CO_2 = 1; CH_4 = 28; N_2O = 265.

Direct GHG and hydrogen emissions can be produced directly from the hydrogen production process, from equipment operated to directly support the hydrogen production process, or from leaks in hydrogen production machinery and equipment. Direct GHG and hydrogen emissions expected from the green hydrogen production processes discussed in Section 3.4.1 are shown in Table 15. These emissions do not include the GHG emissions that may occur from auxiliary operations at a green hydrogen production facility, such as from vehicles, non-road equipment, and machinery, and from natural gas boiler operation, which is described above. The GHG emissions listed in Table 15 do not include emissions from upstream or downstream processes. Upstream and downstream GHG emissions are covered in the GHG LCA discussion in Section 3.4.2.3.

Table 15. Expected direct GHG emissions from hydrogen production process

Type of emissions	Probable emissions	Explanation
Electrolysis		
GHG emissions for electrolysis	• None	—
Hydrogen emissions for electrolysis	• 0.10–4.00% leakage rate for the production and processing phases of electrolysis (Cooper et al. 2022)	The amount of hydrogen emissions from electrolysis would depend on the facility's production capacity; the type of electrolyzer used; the number and type of valves, pumps, compressors, and piping connections; and the quality of equipment.
SMR		
GHG emissions for SMR	• CO_2: 9.378 kg/kg H_2 • CH_4: 0.0514 kg/kg H_2 • N_2O: 0.03639 g/kg H_2 (ANL 2023)	CO_2 is a direct byproduct of the SMR process. CH_4 emissions could occur due to equipment leaks or methane slip through the reactor. Auxiliary equipment such as gas-fired boilers may also contribute to GHG emissions. The type and amount of emissions may vary depending on the composition of the RNG used in the SMR process. For example, an Australian study estimated CO_2e emissions to be 3.57 kg CO_2e/kg of hydrogen for SMR using methane from a landfill, but 5.20 kg CO_2e/kg of hydrogen for SMR using biomethane from animal manure (Cho et al. 2022).
Hydrogen emissions for SMR	0.5–1% of the hydrogen produced is estimated to be leaked (Columbia University Center on Global Energy Policy 2022)	H_2 emissions may occur due to leaks from the system during operation.
Pyrolysis		
GHG emissions for pyrolysis	• CO_2: 184 g/kg H_2 • CH_4: 0.0148 g/kg H_2 (ANL 2023)	GHG emissions may result from the thermal decomposition process or from auxiliary equipment supporting the pyrolysis process.
Hydrogen emissions for pyrolysis	Some hydrogen leakage would be expected, but an emission factor is not available.	H_2 emissions may occur due to leaks from the system during operation.

Type of emissions	Probable emissions	Explanation
Bio-gasification		
GHG emissions for bio-gasification	CO_2: 26–60 kg/kg H_2, depending on the carbon content of the biomass feedstock (NREL 2018) [a]	CO_2 is a direct byproduct of gasification.
Hydrogen emissions for bio-gasification	1–2% leakage from the production and processing phases of gasification (Cooper et al. 2022)	H_2 emissions may occur due to leaks from the system during operation.

Note:

a. GREET was not used in this case. For gasification of biomass, GREET does not report the actual biogenic emissions from the gasification process, but rather assumes that CO_2 emissions from gasification equal CO_2 emissions captured during growth of biomass feedstocks.

Based on the probable emissions identified in Table 15 that could be produced directly from the hydrogen production process, the following GHGs are expected from the green hydrogen production methods:

- **Electrolysis:** 0.00 kg CO_2e/kg H_2 produced
- **SMR:** 10.83 kg CO_2e/kg H_2 produced
- **Pyrolysis:** 0.18 kg CO_2e/kg H_2 produced
- **Bio-gasification:** 26–60 kg CO_2e/kg H_2 produced

GHG and hydrogen emissions were estimated for the lower and upper bounds of hydrogen production via electrolysis, SMR, pyrolysis, and bio-gasification. Estimated annual GHG emissions from hydrogen production are listed in Table 16. The maximum direct GHG emissions that could be produced from any hydrogen production process would be from bio-gasification, which was estimated to directly produce up to 2,190,000 MT of CO_2e per year under an upper-bound (100,000 kg H_2/day) production scenario. Estimated CO_2e emissions from green hydrogen production under the upper bound bio-gasification scenario would be as high as approximately 2% of the statewide CO_2e emissions recorded for 2019. When considering the potential CO_2e emissions from other facility operations, such as vehicles, equipment, and boilers, direct GHG emissions from operating a green hydrogen production facility would be greater that what was estimated for green hydrogen production equipment alone.

Direct GHG emissions are produced from SMR, pyrolysis, and bio-gasification. Electrolysis does not directly produce GHGs. Indirect GHG emissions may occur through leakage during upstream production and downstream transmission, storage, and distribution.

Siting and design considerations, such as those listed in Section 3.4.3.2, could be implemented to reduce the potential for GHG emissions and reduce the effects from green hydrogen production on climate change. Net GHG emissions over the entire lifetime of the production process are captured as life-cycle GHG emissions, which are discussed in Section 3.4.2.3.

Table 16. Estimated direct annual GHG emissions from hydrogen production process (MT/year)

Facility capacity	CO_2	CH_4	N_2O	CO_2e[a]	H_2
Electrolysis					
Lower bound – 1,000 kg H_2/day	None	None	None	None	0.37–14.60
Upper bound – 9,000 kg H_2/day	None	None	None	None	3.29–131.40
SMR					
Lower bound – 2,000 kg H_2/day	6,845.94	37.52	0.03	7,903.60	3.65–7.30
Upper bound – 100,000 kg H_2/day	342,297.00	1,876.10	1.33	395,179.78	182.50–365.00
Pyrolysis					
Lower bound – 5,000 kg H_2/day	335.80	0.03	N/A	336.56	N/A
Upper bound – 10,000 kg H_2/day	671.60	0.05	N/A	673.11	N/A
Bio-gasification					
Lower bound – 50,000 kg H_2/day	474,500.00–1,095,000.00	N/A	N/A	474,500.00–1,095,000.00	182.50–365.00
Upper bound – 100,000 kg H_2/day	949,000.00–2,190,000.00	N/A	N/A	949,000.00–2,190,000.00	365.00–730.00

Note:

Assumes facility operation at 365 days per year.

a. To calculate the total CO_2e, all GHGs are multiplied by their global warming potential and the results are added together. Global warming potentials are published in 40 CFR 98 (revised April 2024). The global warming potentials used to calculate CO_2e are as follows: CO_2 = 1; CH_4 = 28; N_2O = 265.

3.4.2.3 GHG life-cycle assessment

Life-cycle GHG emissions from green hydrogen production were assessed using two methods. The first method was to consider published LCA studies and apply the published life-cycle GHG emissions factor to the identified lower- and upper-bound production capacities of the selected hydrogen production methods to derive probable life-cycle GHG emissions. Published LCA studies consider a range of upstream and downstream processes that could include construction and decommissioning of a facility, green hydrogen production, the source of electricity used to power green hydrogen production, transportation of the hydrogen to the end user, and the end use.

The second method used to assess life-cycle GHG emissions was consideration of the WA-GREET carbon intensities published in WAC 173-424-900. As identified in Section 2.2, the WA-GREET model considers feedstock production, fuel processing, transportation, and end use. The carbon intensity values from the WA-GREET model do not account for emissions related to facility construction or decommissioning. The model primarily focuses on operational emissions throughout the life cycle of the fuel.

GHG LCA studies

LCA studies have been published about hydrogen production methods, but they are not always applicable to the green hydrogen production methods evaluated in this PEIS, and none of them cover all the emission sources listed in Table 3. The examples below provide information to show the range of potential LCA emissions for the different types of general green hydrogen facility. Developers would need to conduct project-level LCAs based on the source of power and end-user(s).

Table 17 summarizes LCA GHG estimates from available hydrogen production LCA studies. LCA studies may include negative emissions called "carbon credits" in their analysis, which are subtracted from the total LCA emissions. Carbon credits are typically counted for emissions that are assumed to be prevented or removed from the atmosphere during the life cycle of the facility, fuel, or product. For example, when biomass is used as feedstock for hydrogen production, a carbon credit may be given because before it is harvested for feedstock, biomass removes carbon from the atmosphere through photosynthesis. LCA studies are not available for the pyrolysis production method. LCA studies are also not available for electrolysis using a mix of electricity sources that include fossil fuels.

Table 17. Hydrogen LCA studies

Publication	Hydrogen production method	LCA GHG estimate	Key limitations
Electrolysis			
International Council on Clean Transportation (ICCT) 2022	Electrolysis powered entirely by renewable energy	2.08 kg CO_2e/kg of hydrogen	• The analysis does not include construction, decommissioning, or disposal emissions (however, it does cover GHG emissions from (1) feedstock extraction, processing, and transportation, (2) hydrogen production, and (3) hydrogen transportation, compression, and combustion). • The analysis evaluates gaseous hydrogen production. • The analysis assumes that only gaseous storage is used and does not address liquid storage.
Tabrizi et al. 2023	Electrolysis powered by solar energy	1.75–4.83 kg CO_2e/kg of hydrogen, depending on the type of solar panels and location	• The analysis does not include any emissions that would occur after hydrogen production (e.g., storage, transportation) • The analysis evaluates gaseous hydrogen production.
National Renewable Energy Laboratory (NREL) 2004	Electrolysis powered by wind energy	0.97 kg CO_2e/kg of hydrogen	• The analysis is over 20 years old, and electrolysis technology has changed during that time. • The analysis does not include facility decommissioning emissions. • The analysis evaluates gaseous hydrogen production, liquefaction, and liquid hydrogen storage.
Ghandehariun and Kumar 2016	Electrolysis powered by wind energy	0.68 kg CO_2e/kg of hydrogen	• The analysis does not include decommissioning or disposal emissions.

Publication	Hydrogen production method	LCA GHG estimate	Key limitations
	in Western Canada		• The analysis is specific to alkaline electrolyzers. • The analysis assumes that only gaseous storage is used and does not address liquid storage.
ANL 2022	Electrolysis powered by either renewable or nuclear energy	Up to 0.40 kg CO_2e/kg of hydrogen, depending on the type of electrolyzer and energy source	• The analysis includes liquefaction and delivery of gaseous and liquid hydrogen. • The analysis does not include emissions from end users of hydrogen. • The analysis does not include emissions from manufacturing components such as electrolyzers.
SMR			
National Energy Technology Laboratory (NETL) 2022[a]	SMR of traditional (fossil) natural gas	12.00 kg CO_2e/kg of hydrogen	• The analysis evaluates gaseous hydrogen production. • The "cradle-to-gate" analysis does not include any emissions that would occur after hydrogen production (e.g., storage, transportation). • The analysis is specific to SMR using traditional natural gas, not RNG.
NREL 2001[a]	SMR of traditional (fossil) natural gas	11.88 kg CO_2e/kg of hydrogen	• The analysis is over 20 years old, and SMR technology has changed during that time. • The analysis is specific to SMR using traditional natural gas, not RNG. • The analysis does not include any emissions that would occur after hydrogen production (e.g., storage, transportation).
ICCT 2022	SMR of landfill gas	-51.40 kg CO_2e/kg of hydrogen	• The "well-to-wheel" LCA does not include construction, decommissioning, or disposal emissions (however, it does cover GHG emissions from (1) feedstock extraction, processing, and transportation, (2) hydrogen production, and (3) hydrogen transportation, compression, and combustion). • The analysis assumes that only gaseous storage is used and does not address liquid storage. • The large negative number estimated for LCA GHG emissions assumes that landfill RNG would be released into the atmosphere if not used for SMR, so the study gives a "carbon credit" for

Publication	Hydrogen production method	LCA GHG estimate	Key limitations
			those avoided emissions. However, landfill RNG is not always released in Washington given the state's rules controlling landfill emissions (Ecology 2024c).
ANL 2022	SMR of landfill gas	0.20 kg CO_2e/kg of hydrogen	• The "well-to-gate" analysis includes liquefaction and delivery of gaseous and liquid hydrogen. • The analysis does not include emissions from end users of hydrogen. • Similar to the ICCT study, the analysis assumes landfill GHGs would be released into the atmosphere if not used for SMR, which is not always the case, given WA rules controlling landfill emissions (Ecology 2024c). • The estimate assumes that the SMR process produces excess steam which is exported to be used elsewhere. Therefore, a natural gas boiler is not needed to create that steam and emissions from that boiler are avoided. The study gives a "carbon credit" for the exported steam, leading to a much lower LCA emissions factor than other SMR LCA studies. • The analysis does not include emissions from manufacturing components, such as SMR equipment.
Bio-gasification			
ANL 2022	Biomass gasification (specific to dried poplar)	1.70 kg CO_2e/kg of hydrogen	• The analysis includes liquefaction and delivery of gaseous and liquid hydrogen. The analysis does not include emissions from end users of hydrogen. • The analysis does not include emissions from manufacturing components, such as gasification equipment. • The analysis is specific to dried poplar (dried to 12% moisture by weight). Different kinds of biomass would have different LCA emissions.
NETL 2022[b]	Gasification of coal & biomass	-1.00 kg CO_2e/kg of hydrogen	• The analysis evaluates gaseous hydrogen production. • The analysis addresses the co-gasification of coal and biomass, rather than solely biomass.

Publication	Hydrogen production method	LCA GHG estimate	Key limitations
			• The analysis does not include any emissions that would occur after hydrogen production (e.g., storage, transportation). • The analysis estimates a negative number for LCA GHG emissions because it subtracts the CO_2 that the biomass captured from the atmosphere during its lifetime.
Hamedani et al. 2018	Gasification of biomass (forest residue - almond shells)	5.04 kg CO_2e/kg of hydrogen	• The "cradle-to-gate" analysis does not include any emissions that would occur after hydrogen production (e.g., storage, transportation). • The analysis is based on a small-scale system (1 megawatt thermal) and may not be applicable to large-scale facilities.
ICCT 2021	Gasification of biomass (forest residue)	0.72 kg CO_2e/kg of hydrogen	• The analysis evaluates compressed gaseous hydrogen only, not liquefied hydrogen. • The analysis assumes renewable energy is used in the hydrogen compression process. • The analysis does not account for leakage during the biomass gasification process.
NREL 2018[c]	Gasification of biomass (woody biomass)	2.72 kg CO_2e/kg of hydrogen	• The analysis does not account for certain upstream GHG emissions such as from biomass cultivation, feedstock transportation, and land use changes (e.g., tree and forest removal). • The analysis does not account for biogenic carbon, nor does it differentiate between fossil-derived CO_2 and biogenic CO_2 emissions, which may misrepresent the net GHG impact of the biomass hydrogen pathway.

Notes:
This table does not include LCA studies that analyzed electrolysis using electricity generated by fossil fuels. If the carbon intensity of the electricity increases (i.e., if produced using a greater percentage of fossil fuels), the carbon intensity of hydrogen production will increase.

a. LCA studies for SMR using fossil fuel feedstock are included for comparative purposes. Green hydrogen does not allow for fossil fuel as feedstock.

b. This LCA study for bio-gasification using a mixture of coal and biomass is included for comparison and to show the range of life-cycle GHG emissions that may occur from green hydrogen production using a variety of pathways. Gasification of coal does not qualify under the definition of green hydrogen.

c. The Hydrogen Analysis Production Model was run using 97% carbon capture efficiency.

Based on the probable life-cycle GHG emissions identified in Table 17, the following GHGs are expected from the green hydrogen production methods (note that life-cycle GHG emissions were not identified for pyrolysis and electrolysis using mix of sources that include fossil fuels):

- **Electrolysis using renewable energy for electricity:** 0.40–4.83 kg CO_2e/kg H_2 produced
- **SMR using landfill gas:** negative 51.40–0.20 kg CO_2e/kg H_2 produced
- **Bio-gasification using biomass feedstock:** negative 1.00–5.04 kg CO_2e/kg H_2 produced

For comparison, SMR using traditional natural gas is estimated to produced 11.88–12.00 kg CO_2e/kg H_2.

Table 18 lists the GHG emissions that were estimated for the lower and upper bounds of hydrogen production via electrolysis, SMR, and bio-gasification using the LCA GHG estimates from the studies listed in Table 17. Estimated annual direct GHG emissions from green hydrogen production alone are listed in Table 16.

The LCA GHG estimates in Table 18 account for upstream and downstream GHG emissions, including emissions from the production of energy that is used during the green hydrogen process. A full list of the emissions considered during LCA studies is included in Table 3. For green hydrogen production through electrolysis and SMR, the LCA GHG estimates would be more than those estimated for green hydrogen facility operation alone in Table 16 because of upstream GHG emissions such as those associated with the production of electricity and RNG.

For green hydrogen production through bio-gasification, life-cycle GHG estimates would be less than those estimated for green hydrogen production alone in Table 16. It was estimated that direct GHG emissions from the bio-gasification process could be up to 2,190,000 MT of CO_2e per year under an upper-bound (100,000 kg H_2/day) production scenario (see Section 3.4.2.2). The high rate of direct GHG emissions can be attributed the release of carbon from the biomass, which is converted into CO_2 during gasification. However, as shown in Table 18, the life-cycle GHG emissions for bio-gasification under the same scenario were estimated to be up to 183,960 MT of CO_2e per year. The LCA studies identified in Table 17 considered bio-gasification configurations that include CO_2 capture technologies. The CO_2 capture rates used in the bio-gasification studies were 92.5% (ANL 2022); 92.7% (NETL 2022); and 49.2% to 99.9% (ICCT 2018); and 97% (NREL 2018). In addition, the biomass feedstock used during the bio-gasification process accounts for a majority of the energy used, as was the case with the ANL study, for which 97.1% of the energy required for the facility configuration came from biomass feedstock (ANL 2022). The use of biomass for energy displaces the need for other forms of energy (e.g., natural gas, grid electricity) and the life-cycle emissions account for the reduced need for fossil fuels, which results in life-cycle GHG emissions lower than the direct GHG emissions. The NETL LCA study uses a bio-gasification configuration that also uses biomass feedstock as a source of energy and considers the life-cycle GHG emissions to be offset by using biomass as a feedstock. This is because the upstream emissions that were accounted for in the LCA study considered the uptake of CO_2 during biomass production, or the storage of CO_2 in biomass as part of the carbon cycle (NETL 2022). The Hamedani et al. 2018 study does not incorporate carbon capture technologies;

therefore, life-cycle GHG emissions for this configuration would be higher compared to configurations that include carbon capture and technologies (Hamedani et al. 2018).

Table 18. Estimated annual life-cycle GHG emissions from green hydrogen production based on previous GHG LCA studies (MT/year)

LCA GHG study (LCA GHG estimate)	Lower bound – CO_2e	Upper bound – CO_2e
Electrolysis	**1,000 kg H_2/day**	**9,000 kg H_2/day**
ICCT 2022 (2.08 kg CO_2e/kg H_2)	759.20	6,832.80
Tabrizi et al. 2023 (1.75–4.83 kg CO_2e/kg H_2)	638.75–1,762.95	5,748.75–15,866.55
NREL 2004 (0.97 kg CO_2e/kg H_2)	354.05	3,186.45
Ghandehariun and Kumar 2016 (0.68 kg CO_2e/kg H_2)	248.20	2,233.80
ANL 2022 (up to 0.40 kg CO_2e/kg H_2)	146.00	1,314.00
SMR	**2,000 kg H_2/day**	**100,000 kg H_2/day**
ICCT 2022 (-51.40 kg CO_2e/kg H_2)	-37,522.00	-1,876,100.00
ANL 2022 (0.20 kg CO_2e/kg H_2)	146.00	7,300.00
Bio-gasification	**50,000 kg H_2/day**	**100,000 kg H_2/day**
ANL 2022 (1.70 kg CO_2e/kg H_2)	31,025.00	62,050.00
NETL 2022 (-1.00 kg CO_2e/kg H_2)	-18,250.00	-36,500.00
Hamedani et al. 2018 (5.04 kg CO_2e/kg H_2)	91,980.00	183,960.00
ICCT 2021 (0.72 kg CO_2e/kg H_2)	13,140.00	26,280.00
NREL 2018 (2.17 kg CO_2e/kg H_2)	39,602.50	79,205.00

Note: Assumes facility operation at 365 days per year.

Based on the estimated annual life-cycle GHGs identified in Table 18, the following GHGs are estimated to be produced from the green hydrogen production methods annually under an upper-bound scenario (note that life-cycle GHG emissions were not identified for pyrolysis):

- **Electrolysis using renewable energy for electricity:** 15,867 MT of CO_2e per year
- **SMR using landfill gas:** 7,300 MT of CO_2e per year
- **Bio-gasification using biomass feedstock:** 183,960 MT of CO_2e per year

For comparison, SMR using traditional natural gas: 438,000 MT of CO_2e per year.

WA-GREET GHG carbon intensity values

WA-GREET 3.0 has established carbon intensities for fuels in WAC 173-424-900. This was derived from the California GREET 3.0 model. A hydrogen supplier may apply to use the applicable carbon intensity values of this rule. Table 19 identifies the WA-GREET carbon intensity values that are applicable to green hydrogen production. The exact carbon intensity value depends on factors such as the renewable energy source, the efficiency of the green hydrogen production process, and emissions from infrastructure and transportation. In general, green hydrogen produced using renewable electricity has a lower carbon intensity than green hydrogen produced using electricity derived from fossil fuels. Overall, green hydrogen is treated as a low-carbon fuel, which helps reduce the state's overall carbon intensity in transportation and energy use.

Table 19. WA-GREET carbon intensity values for green hydrogen

Fuel	Production method	Energy source/feedstock	Carbon intensity (g CO_2e/MJ)	kg CO_2e/kg H_2
Gaseous hydrogen	Electrolysis	Average grid electricity in Washington	101.57	12.19
Gaseous hydrogen	Electrolysis	Renewable solar or wind generated electricity	6.49	0.78
Gaseous hydrogen	SMR and pyrolysis	Renewable feedstock from landfills	92.77	11.13

Source: WA-GREET, WAC 173-424-900
Note: g = grams; MJ = megajoules.

Based on the probable life-cycle GHG emissions identified in Table 19 that could be produced from hydrogen production, the following GHGs are expected from the green hydrogen production methods (note that carbon intensity values were not identified for bio-gasification):

- **Electrolysis using average grid electricity in Washington:** 12.19 kg CO_2e/kg H_2 produced
- **Electrolysis using renewable energy for electricity:** 0.78 kg CO_2e/kg H_2 produced
- **SMR using renewable feedstock from landfills:** 11.13 kg CO_2e/kg H_2 produced
- **Pyrolysis using renewable feedstock from landfills:** 11.13 kg CO_2e/kg H_2 produced

Table 20 lists the life-cycle GHG emissions that were estimated for the lower and upper bounds of hydrogen production via electrolysis, SMR, and bio-gasification using the WA-GREET carbon intensity values listed in Table 19.

Table 20. Estimated annual life-cycle GHG emissions from hydrogen production based on WA-GREET carbon intensity values (MT/year)

Green hydrogen production method	Lower bound – CO_2e	Upper bound – CO_2e
Electrolysis	**1,000 kg H_2/day**	**9,000 kg H_2/day**
Average grid electricity in Washington	4,449.35	40,044.15
Renewable solar or wind generated electricity	284.70	2,562.30
SMR	**2,000 kg H_2/day**	**100,000 kg H_2/day**
Renewable feedstock from landfills	8,124.90	406,245.00
Pyrolysis	**5,000 kg H_2/day**	**10,000 kg H_2/day**
Renewable feedstock from landfills	20,312.25	40,624.50

Note: Assumes facility operation at 365 days per year.

Based on the estimated annual life-cycle GHGs identified in Table 20 using WA-GREET carbon intensity values, the following GHGs are estimated to be produced from the green hydrogen production methods annually under an upper bound scenario (note that carbon intensity values were not identified for bio-gasification):

- **Electrolysis using average grid electricity in Washington:** 40,044 MT of CO_2e per year
- **Electrolysis using renewable energy for electricity:** 2,562 MT of CO_2e per year
- **SMR using renewable feedstock from landfills:** 406,245 MT of CO_2e per year
- **Pyrolysis using renewable feedstock from landfills:** 40,625 MT of CO_2e per year

Comparison of life-cycle GHGs from electricity generation technologies
LCA studies for electricity generation technologies indicate the median life-cycle CO_2e emissions factors for coal-generated electricity is 1,001 grams CO_2e per kilowatt-hour (kWh) produced and for natural gas-generated electricity is 486 grams CO_2e per kWh produced. The median life-cycle CO_2e emissions factor for hydrogen fuel cell storage technology is 38 grams CO_2e per kWh stored (NREL 2021).

For context, Table 21 shows a comparison of estimated life-cycle CO_2e emissions from coal, natural gas, and hydrogen electricity generation technologies in terms of kWh produced or stored.

Table 21. Comparison of estimated annual LCA GHG emissions from coal, natural gas, and hydrogen electricity generation technologies

Hydrogen production capacity (H_2/day)	kWh equivalent (kWh)[a]	CO_2e (MT/yr)		
		Coal – electricity generation	Natural gas – electricity generation	Hydrogen fuel cell storage
1,000	39,400	14,395.381	546.478	0.004
10,000	394,000	143,953.810	5,464.780	0.041
50,000	1,970,000	719,769.050	27,323.900	0.205
100,000	3,940,000	1,439,538.100	54,647.800	0.410

Notes:
Assumes facility operation at 365 days per year.
a. The energy content of 1 kg of hydrogen is equal to 141.9 megajoules (higher heating value), or 39.4 kWh.

Life-cycle GHG impact summary
Using both life-cycle GHG assessment methods, the greatest life-cycle GHG emissions would be produced from SMR facilities using renewable feedstock from landfills and producing 100,000 kg H_2 per day. These facilities could have life-cycle GHG emissions up to 406,245 MT of CO_2e per year. Facility GHG life-cycle emissions will vary based on the type of production process used and amount of renewable energy used by a facility. In general, green hydrogen production through electrolysis using renewable energy for electricity would result in the lowest amount of GHGs. An LCA would need to be conducted to estimate GHGs for each project based on its specific design.

Impacts from electrolysis, SMR, pyrolysis, and bio-gasification production would likely have **less than to potentially significant adverse impacts** on life-cycle GHG emissions. The potential for GHG emissions and effects from green hydrogen production on climate change could be reduced based on siting and design considerations listed in Section 3.4.3.2.

3.4.3 Measures to avoid, reduce, and mitigate impacts

The PEIS identifies a variety of measures to avoid, reduce, and mitigate impacts. These measures are grouped into five categories:

- **General measures:** The general measures apply to all projects using the PEIS.
- **Recommended measures for siting and design:** These measures are recommended for siting and design in the pre-application phase of a project.

- **Required measures:** These measures must be implemented, as applicable, to use the PEIS. These include permits and approvals, plans, and other required measures.
- **Recommended measures for construction, operation, and decommissioning:** These measures are recommended for the construction, operation, and decommissioning phases of a project.
- **Mitigation measures for potential significant impacts:** These measures are provided only in sections for which potential significant impacts have been identified.

3.4.3.1 General measures

- **Laws, regulations, and permits:** Obtain required approvals and permits and ensure that a project adheres to relevant federal, state, and local laws and regulations.

  Rationale: Laws, regulations, and permits provide standards and requirements for the protection of resources and the PEIS impact analysis and significance findings assume that developers would comply with all relevant laws and regulations and obtain required approvals.

- **Coordination with agencies, Tribes, and communities:** Coordinate with agencies, Tribes, and communities prior to submitting an application and throughout the life of the project to discuss project siting and design, construction, operations, and decommissioning impacts, and measures to avoid, reduce, and mitigate impacts. Developers should also seek feedback from agencies, Tribes, and communities when developing and implementing the resource protection plans and mitigation plans identified in the PEIS.

  ***Rationale*:** Early coordination provides the opportunity to discuss potential project impacts and measures to avoid, reduce, and mitigate impacts. Continued coordination provides opportunities for adaptive management throughout the life of the project.

- **Land use:** Consider the following when siting and designing a project:
  - Existing land uses
  - Land ownership/land leases (e.g., grazing, farmland, forestry)
  - Local comprehensive plans and zoning
  - Designated flood zones, shorelines, natural resource lands, conservation lands, priority habitats, and other critical areas and lands prioritized for resource protection
  - Military testing, training, and operation areas
  - State-designated harbors
  - Air quality nonattainment areas

  ***Rationale*:** Considering these factors early in the siting and design process avoids and minimizes the potential for land use conflicts. Project-specific analysis is needed to determine land use consistency.

- **Choose a project site and a project layout to avoid and minimize disturbance:** Select the project location and design the facility to avoid potential impacts to resources. Examples include:
    - Minimizing the need for extensive grading and excavation and reducing soil disturbance, potential erosion, compaction, and waterlogging by considering soil characteristics.
    - Minimizing facility footprint and land disturbances, including limiting clearing and alterations to natural topography and landforms and maintaining existing vegetation.
    - Minimizing the number of structures required and co-locate to share pads, fences, access roads, lighting, etc.

  Rationale**:** Project sites and layouts may differ substantially in their potential for environmental impacts. Thoughtful selection of a project site and careful design of a facility layout can avoid and reduce environmental impacts.

- **Use existing infrastructure and disturbed lands, and co-locate facilities:** During siting and design, avoid and minimize impacts by:
    - Using existing infrastructure and disturbed lands, including roads, parking areas, staging areas, aggregate resources, and electrical and utility infrastructure.
    - Co-locating facilities within existing rights-of-way or easements.
    - Considering limitations of existing infrastructure, such as water and energy resources.

  Rationale**:** Using existing infrastructure and disturbed lands, and co-locating facilities reduces impacts to resources that would otherwise result from new ground disturbance and placement of facilities in previously undisturbed areas.

- **Conduct studies and surveys early:** Conduct studies and surveys early in the process and at the appropriate time of year to gather data to inform siting and design. Examples include:
    - Geotechnical study
    - Habitat and vegetation study
    - Cultural resource survey
    - Wetland delineation

  Rationale**:** Conducting studies and surveys early in the process and at the appropriate time of year provides data to inform siting and design choices that avoid and reduce impacts. This can reduce the overall timeline as well by providing information to agencies as part of a complete application for environmental reviews and permits.

- **Restoration and decommissioning:** Implement a Site Restoration Plan for interim reclamation following temporary construction and operations disturbance. Implement a Decommissioning Plan for site reclamation at the end of a project. Coordinate with state and local authorities, such as the Washington Department of Fish and Wildlife, county

extension services, weed boards, or land management agencies on soil and revegetation measures, including approved seed mixes. Such plans address:
  - Documentation of pre-construction conditions and as-built construction drawings
  - Measures to salvage topsoil and revegetate disturbed areas with native and pollinator-supporting plants
  - Management of hazardous and solid wastes
  - Timelines for restoration and decommissioning actions
  - Monitoring of restoration actions
  - Adaptive management measures

  Rationale**:** Restoration and decommissioning actions return disturbed areas to pre-construction conditions, promote soil health and revegetation of native plants, remove project infrastructure from the landscape, and ensure that project components are disposed of or recycled in compliance with all applicable laws and regulations.

- **Cumulative impact assessment:** Assess cumulative impacts on resources based on reasonably foreseeable past, present, and future projects. Identify actions to avoid, reduce, and mitigate cumulative impacts. Consider local studies and plans, such as comprehensive plans.

  Rationale**:** Cumulative impacts can result from incremental, but collectively significant, actions that occur over time. The purpose of the cumulative impacts analysis is to make sure that decision-makers consider the full range of consequences under anticipated future conditions.

3.4.3.2 Recommended measures for siting and design

- Design the facility and incorporate into project planning ways to minimize use of fossil fuels to reduce greenhouse gases and other air emissions.
- Consider options to reduce embodied carbon when selecting construction and operations materials and equipment.
- Optimize the hydrogen production process and implement advanced process controls to increase efficiency, reduce waste, and minimize energy use to lower potential CO_2e emissions.
- Consider state-of-the-art equipment and utilize leak monitoring and detection technology (e.g., infrared gas detectors) to minimize emissions of hydrogen and other air pollutants due to leaks in process equipment, hydrogen transportation, and storage and distribution systems (e.g., piping, pumps, tanks).

3.4.3.3 Required measures

This section lists permits and approvals, plans, and other required measures for use of the PEIS, as applicable. See Section 3.3 for more detailed information on potentially required permits and approvals.

- Air Quality Permits (Ecology, EFSEC, local agency)

- Air Operating Permit (Ecology)
- Clean Air Act Prevention of Significant Deterioration Permit (EFSEC, Ecology)
- State Refrigerant Management Program Registration (Ecology)

3.4.3.4 Recommended measures for construction, operation, and decommissioning

- Surface access roads, on-site roads, and parking lots with aggregate with hardness sufficient to prevent vehicles from crushing the aggregate and causing excessive dust. Paving could also be used on access roads and parking lots.
- Minimize vehicle and equipment exhaust emissions by:
  - Using efficient transportation routing.
  - Using hybrid or zero-emission equipment, electric maintenance trucks or service vehicles, and/or latest-model-year vehicles and equipment.
  - Maintaining vehicles and equipment in good condition.
  - Limiting engine idling time and shutting down equipment when not in use.
  - Encouraging carpooling among construction workers to minimize construction-related traffic and associated emissions.
  - Using ultra-low-sulfur diesel fuel with a sulfur content of 15 parts per million or less for all diesel engines.
  - Applying add-on pollution control technologies to construction generators.
- Implement BMPs identified in the "Guide to Handling Fugitive Dust from Construction Projects," as published by the Associated General Contractors of Washington (AGC 2009) or updated guidance recommended by the local air agency. Example measures to minimize fugitive dust emissions include:
  - Monitor wind speeds and suspend all soil disturbance activities and travel on unpaved roads during periods of high winds.
  - Use water, water-based environmentally safe dust suppression materials, or other fugitive dust-abatement measures for dust control in compliance with state and local regulations.
  - Cover construction materials that could be a source of fugitive dust during transportation or storage.
  - Limit traffic speeds on unpaved roads.
- Use offsets to reduce the amount of greenhouse gases in the atmosphere. Offset projects result in greenhouse gas reductions that are real, permanent, quantifiable, verifiable, and enforceable.

3.4.3.5 Mitigation measures for potential significant impacts

- Develop a mitigation plan to reduce the amount of GHGs in the atmosphere. The plan could include offset projects, which must result in GHG reductions that are real, permanent, quantifiable, verifiable, and enforceable. The plan should identify how the 2030, 2040, and 2050 GHG emission limits will be met and include monitoring requirements.

Rationale: A mitigation plan would reduce the amount of GHGs in the atmosphere and help meet emissions limits.

- Install hydrogen leak detection equipment to reduce risk of leakage causing indirect GHGs.

  Rationale: Hydrogen detection equipment can identify elevated hydrogen concentrations, indicating a leak.

3.5 Green hydrogen production facility with co-located 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 (MW) of electricity for 4 hours (a capacity of 11.4 megawatt hours [MWh] or 11,400 kWh). Each container would be approximately 60 by 12 feet wide and 10 feet tall. The impacts analysis of a facility with co-located BESSs would include impacts from green hydrogen production plus impacts from the BESSs.

3.5.1 Impacts from construction, operation, and decommissioning

Air quality and GHG emissions from construction, operation, and decommissioning activities associated with the BESS component of a green hydrogen production facility would be similar to, but greater than, those for green hydrogen production facilities without a BESS, described in Section 3.4. Criteria pollutant and GHG emissions from BESS construction would be in addition to those discussed in Section 3.4.

3.5.1.1 Air quality impacts

Estimated emissions from construction of a 2.85-MW BESS are shown in Table 22. Estimated emissions from construction of a BESS, when combined with the estimated emissions from green hydrogen production facility construction, are not expected to exceed criteria pollutant thresholds. If a thermal runaway event due to damage or a battery management system failure were to occur for facilities with lithium-ion BESS, there could be risk of hazardous air emissions that include toxic gases. Hazardous material risks from green hydrogen facilities and BESS are addressed further in the *Environmental Health and Safety Technical Appendix*.

Table 22. Estimated construction emissions for green hydrogen production facility with co-located BESS (tons/year)

Construction type	VOC	NO_X	CO	SO_2	PM_{10}	$PM_{2.5}$
2.85-MW BESS	0.02	0.21	0.10	0.01	0.01	<0.01
Lower-bound facility (1 acre) and 2.85-MW BESS	0.34	1.03	1.18	0.01	2.64	0.36
Upper-bound facility (10 acres) and 2.85-MW BESS	2.47	1.79	2.61	0.01	10.85	1.35
Threshold	100	100	100	100	100	100
Exceeds threshold?	No	No	No	No	No	No

Source: CAPCOA 2022
Note: Based on emissions factors per MW of development derived from published environmental impact statements produced at the project-specific level per the *State Environmental Policy Act Programmatic Environmental Impact Statement for Solar Energy Facilities in Washington State*. MW = megawatt

No emissions of criteria air pollutants, HAPs, TAPs, hydrogen, or GHGs other than those related to refrigerants are expected from BESS operation. Accidental leakage of refrigerants in air conditioning systems used for BESSs could result in minimal HAP and TAP emissions, which include emissions of CFCs, HFCs, PFCs, or SF6. Potential for HAP and TAP emissions from refrigerant leakage would be dependent on the size and number of cooling systems, maintenance practices, and the exact types and quantities of refrigerants used in cooling systems. The BMPs listed in Section 3.4.3 would be followed to reduce the potential for refrigerant leaks.

Through compliance with laws and permits and with implementation of measures to avoid and reduce impacts, construction, operation, and decommissioning of facilities with a co-located BESS would likely result in **less than significant impacts** on air quality.

3.5.1.2 GHG life-cycle assessment

LCA GHG estimates for a green hydrogen production facility with co-located BESS would be greater than those summarized in Section 3.4.2.3 for a green hydrogen production facility without a co-located BESS due to additional upstream and downstream LCA GHG emissions from the BESS. An LCA for BESS GHG emissions include material sourcing, such as extracting and processing materials (e.g., lithium, cobalt, nickel) for the batteries; manufacturing processes, including the energy and emissions associated with producing the battery cells and assembling the system; operation of the BESS; and decommissioning of the BESS, including recycling and disposal of the batteries at the end of their life. The life-cycle emissions factor for 1 kWh of delivered electricity from a lithium-ion BESS have been estimated at 1.1 to 1.7 kg (0.0011 to 0.0017 MT) CO_2e (Yudhistira et al. 2022).

The BESS at a green hydrogen facility would provide backup energy for facility operations or could be used as additional energy storage to balance loads from renewable resources with the demand of green hydrogen production. The BESS would be capable of providing 2.85 MW of electricity for 4 hours, or 11.4 MWh (11,400 kWh). The BESS would be operated intermittently, and the life-cycle GHG emissions would be between 12.54 and 19.38 MT of CO_2e each time the total energy capacity of the BESS is delivered.

GHG life-cycle emissions for a facility with co-located BESS could include an additional 1.1 to 1.7 kg of CO_2e per kWh of delivered electricity beyond the estimated emissions described in Section 3.4.2.3. These impacts on life-cycle GHG emissions are similar to those from production facilities without a co-located BESS and would likely have **less than to potentially significant adverse impacts**. The potential for life-cycle GHG emissions and effects from green hydrogen production on climate change could be reduced based on measures to avoid and reduce impacts.

3.5.2 Measures to avoid, reduce, and mitigate impacts

Measures to avoid, reduce, and mitigate impacts for BESSs are the same as those identified above for green hydrogen production facilities (see Section 3.4.3).

3.6 Green hydrogen storage facility

This section describes potential impacts of green hydrogen storage facilities. 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. The footprint of storage facilities would depend on the amount of hydrogen to be stored but would be less than 1 acre. This includes the storage tanks, separation space between tanks (if more than one), on-site access roads, and ancillary equipment.

3.6.1 Impacts from construction, operation, and decommissioning

Air quality and GHG emissions from construction and decommissioning of green hydrogen storage facilities would be similar to those for green hydrogen production facilities described in Section 3.4. Operational differences in air quality and GHG emissions for storage facilities are described below.

3.6.1.1 Air quality impacts

Compression equipment and gaseous storage
No emissions of GHGs, criteria air pollutants, HAPs, or TAPs are expected from compression equipment or gaseous hydrogen storage, assuming that compression equipment would be electric-powered (GREET 2023).

Potential emissions from the use of compression equipment and gaseous storage are hydrogen emissions. Hydrogen can leak through compressor seals, through on-site pipeline connections, and during transportation. Based on the 2016 WA-GREET model, hydrogen leakage during liquefaction (0.3 %), transportation and distribution (1.5%), and liquid hydrogen storage (3%) can result in an overall hydrogen leakage rate of 4.86% for liquefied hydrogen.

The amount of hydrogen emissions would depend on the facility's storage capacity and the quality of compression equipment. Based on a hydrogen leakage rate of 4.86% per day, a typical 1,000 kg gaseous storage may result in hydrogen leakage of up to approximately 19.6 tons per year.

Liquid tank storage

Potential emissions from liquefaction equipment and liquid hydrogen storage are listed in Table 23 (including emission factors where available). Operation of liquefaction equipment may include criteria pollutants and GHG emissions. Liquefaction equipment and liquid hydrogen storage may include hydrogen leakage into the atmosphere. Assuming liquefaction equipment is electric-powered, no HAP or TAP emissions would be expected.

Table 23. Expected emissions from liquefaction equipment and liquid hydrogen storage

Type of emissions	Probable emissions	Explanation
Emissions of criteria air pollutants and their precursors	• CO: 2.0076 g/kg H_2 • NO_x: 3.5541 g/kg H_2 • VOC: 0.5647 g/kg H_2 • PM_{10}: 0.5138 g/kg H_2 • $PM_{2.5}$: 0.2903 g/kg H_2 • SO_x 2.9718 g/kg H_2 (ANL 2023)	Criteria pollutants may be emitted from auxiliaries required to run liquefaction equipment.
GHG emissions	• CO_2: 4.7121 kg/kg H_2 • CH_4: 9.8105 g/kg H_2 • N_2O: 0.093 g/kg H_2 • CO_2e: 5.0114 kg/kg H_2[a] (ANL 2023) • CFCs, HFCs, PFCs, or SF6	CO_2, CH_4, and N_2O may be emitted from auxiliaries required to run liquefaction equipment. CFCs, HFCs, PFCs, or SF6 could be emitted due to leaks of refrigerants used in liquefaction equipment.
Hydrogen emissions	• Leakage from liquefaction equipment: 66.72 mg/kg H_2 • Leakage from liquid hydrogen storage: 3.01 g/kg H_2 (ANL 2023)	Hydrogen may leak into the atmosphere from liquefaction equipment and liquid storage tanks.

Note:

a. To calculate the total CO_2e, all GHGs are multiplied by their global warming potential and the results are added together. Global warming potentials are published in 40 CFR 98 (revised April 2024). The global warming potentials used to calculate CO_2e are as follows: CO_2 = 1; CH_4 = 28; N_2O = 265.

The amount of emissions from liquid hydrogen storage is dependent on the capacity of hydrogen liquefaction, the quality of liquefaction equipment, and the size of the liquid hydrogen storage tank. An industrial-scale liquefaction system could be capable of supporting 5–10 MT of hydrogen liquefaction per day. Table 24 shows estimated annual air emissions from liquefaction for select capacities. Emissions from liquefaction are not expected to exceed air quality thresholds.

Table 24. Estimated annual emissions from green hydrogen liquefaction

Liquefaction capacity[a]	VOC [b]	NO_X [b]	CO [b]	SO_X [b]	PM_{10} [b]	$PM_{2.5}$ [b]	CO_2 [c]	CH_4 [c]	N_2O [c]	CO_2e[c, d]	H_2 [c]
5,000	1.14	7.15	4.04	5.98	1.03	0.58	8,599.58	17.90	0.17	9,145.88	5.62
10,000	2.07	14.30	8.08	11.96	2.07	1.17	17,199.17	35.81	0.34	18,291.75	11.23
Threshold	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A
Exceeds threshold?	No	No	No	No	No	No	N/A	N/A	N/A	N/A	N/A

Notes:
Emissions calculated for liquefaction operations at 365 days per year.
a. Liquefaction capacity (kg per day).
b. Criteria pollutants (tons per year).
c. GHG (MT per year).
d. To calculate the total CO_2e, all GHGs are multiplied by their global warming potential and the results are added together. Global warming potentials are published in 40 CFR 98 (revised April 2024). The global warming potentials used to calculate CO_2e are as follows: CO_2 = 1; CH_4 = 28; N_2O = 265.

3.6.1.2 Summary of air quality impacts

Through compliance with laws, permits, and with implementation of measures to avoid and reduce impacts, construction, operation, and decommissioning activities associated with gaseous or liquid green hydrogen storage facilities would likely result in **less than significant impacts** on air quality**.**

3.6.1.3 GHG life-cycle assessment

Liquid hydrogen is stored at extremely low temperatures that often requires advanced cryogenic storage systems. Converting hydrogen to liquid form requires energy to cool it to cryogenic temperatures, and this energy input is considered when evaluating the process life-cycle efficiency.

As shown in Table 24, GHG emissions from liquefaction equipment could add up to an estimated 18,292 MT of CO_2e per year.

Impacts for hydrogen storage would range from **less than significant impacts to potentially significant adverse impacts** on life-cycle GHG emissions. Add-on pollution control technologies could reduce the life-cycle GHG emissions produced at a storage facility, and mitigation could be used to reduce the amount of GHGs in the atmosphere.

3.6.2 Measures to avoid, reduce, and mitigate impacts

Measures to avoid, reduce, and mitigate impacts for green hydrogen storage facilities are the same as those identified above for green hydrogen production facilities (see Section 3.4.3).

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

Electrolysis using fossil fuel as a source of electricity, SMR pyrolysis, and bio-gasification production may have **significant and unavoidable adverse impacts** on life-cycle GHG emissions. Determining if mitigation options would reduce or eliminate GHG impacts below significance would be dependent on the specific project and site.

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Attachment 1. GREET Model

The Argonne National Laboratory's GREET (Greenhouse gases, Regulated Emissions, and Energy use in Technologies) model was used to identify emission factors for the substances listed below.

1. Emissions of the following criteria air pollutants and their precursors:
   a. CO
   b. NO_x (precursor to O_3)
   c. VOCs (precursor to O_3)
   d. PM_{10}
   e. $PM_{2.5}$
   f. NO_x (the primary component of which is NO_2)
   g. SO_x (the primary component of which is SO_2)

2. GHG emissions:
   a. CO_2
   b. CH_4
   c. N_2O

The 2023 revision of the GREET1 Excel workbook was used. The default inputs included in the published version of the GREET 2023 model were maintained.

The emissions factors in this document reflect the direct Scope 1 emissions reported by GREET for each green hydrogen technology considered. Scope 1 represents emissions produced on site by the hydrogen production or liquefaction process; they do not include any upstream emissions from production of feedstock or electricity consumed onsite.

GREET reports direct emissions in grams per million British thermal units (g/MMBtu) of hydrogen production. Results were converted to grams per kilogram (g/kg) of hydrogen production by assuming a net heating content of 51,693 British thermal units per pound (btu/lb) for hydrogen.

The following pathways in GREET were used:

Technology	Name of GREET pathway used for criteria air pollutants	Name of GREET pathway used for GHGs
Liquefaction	L.H2 production from NA Natural Gas (Explicit) - liquification and storage assumptions	Same pathway as criteria air pollutants.
SMR	Central Plants: North American Natural Gas to Gaseous Hydrogen G.H2 Production	Same pathway as criteria air pollutants.
Pyrolysis	Central Plants: Methane Pyrolysis to Gaseous Hydrogen (Using Natural Gas)	Same pathway as criteria air pollutants.

Technology	Name of GREET pathway used for criteria air pollutants	Name of GREET pathway used for GHGs
Biomass gasification	Central Plants: Biomass to Gaseous Hydrogen, Biomass Gasification	GREET was not used in this case. For bio-gasification, GREET does not report the actual biogenic Scope 1 GHG emissions from the gasification process, but rather assumes that CO_2 emissions from gasification equal CO_2 emissions captured during growth of biomass feedstocks.

Similar to the GREET model for GHGs from biomass gasification (as noted in the table above), GREET does not report the full Scope 1 GHG emissions from the use of RNG, but rather reports lower emissions factors that account for negative emissions (or an “emissions credit”) due to the use of a biogenic fuel source. Therefore, in this report, the GREET pathway for plants using standard natural gas was used to identify more accurate Scope 1 emissions factors for SMR and pyrolysis.

Attachment 2. CalEEMod Construction Emissions

The California Emissions Estimator Model (CalEEMod) was used to calculate the estimated emissions from green hydrogen facility construction for two facility footprint scenarios: 1 acre (lower bound) and 10 acres (upper bound). Estimated maximum annual air emissions for both scenarios are listed in the table below. This attachment includes the assumptions used for each construction scenario and the detailed CalEEMod emissions reports.

Estimated annual maximum construction emissions (tons/year)

Construction scenario	VOC	NO_X	CO	SO_2	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e[a]
Lower Bound (1 acre)	0.31	0.90	1.26	0.002	2.79	0.39	233.7	0.009	0.006	235.5
Upper Bound (10 acres)	2.45	1.58	2.51	0.005	10.84	1.35	676.9	0.025	0.043	689.0

Note:

a. To calculate the total CO_2e, all GHGs are multiplied by their global warming potential and the results are added together. Global warming potentials are published in 40 CFR 98 (revised April 2024). The global warming potentials used to calculate CO_2e are as follows: CO_2 = 1; CH_4 = 28; N_2O = 265.

Assumptions – Lower Bound Construction Scenario: 1-Acre Footprint

A 1-year construction timeline was estimated for green hydrogen facility construction. A surrogate year of 2026 was used. The following assumptions were used:

- 100% of footprint would be disturbed (grading phase)
- 30% of footprint would be excavated for foundations, underground utilities, and pads (excavation/trenching phase)
- 20% of footprint would include pads for equipment/tanks/etc.
- 10% of footprint would include structures (building construction and architectural phases)
- 25% of footprint would be paved surfaces (paving phase)
- 45% of footprint (remaining of what's not buildings/pads/pavement) would be permeable surface (e.g., gravel, dirt, grass).

Site grading would occur on the entire site (approximately 1 acre or 43,560 square feet [SF]) to ensure required elevation is met. Site grading would begin in January 2026 and last approximately 1 month. Depth of grading was assumed to be 1 foot. It was assumed excavated fill would be reused on site and would not be hauled offsite.

Excavation/trenching would be required for utility installation and/or extension, building foundations, and equipment pads. Approximately 0.33 acre (14,374.8 SF) would be excavated or trenched. It was assumed equipment pads (approximately 0.2 acre or 8,712 SF) would be excavated to an average depth of 4 feet. It was assumed building foundations (approximately 0.1 acre or 4,356 SF) would be excavated to a depth of between 3 and 5 feet (average depth of 4 feet). It was assumed utility lines (approximately 250 linear feet) would be excavated to an average depth of 3.5 feet. The weighted average of site excavation depth was calculated at 3.6 feet. It was assumed excavated fill would be reused onsite and would not be hauled off site. Approximately 3,000 cubic yards (CY) of material (e.g., concrete, gravel) would be hauled onsite for equipment pads (e.g., concrete pads, hard-pack gravel pads). Excavation and trenching would begin in February 2026 and last approximately 2 months.

Construction of buildings and ancillary facilities would occur on approximately 0.1 acre (4,356 SF). Building height was assumed to be 20 feet. Construction would begin in April 2026 and last approximately 8 months. Construction accounts for installation of equipment, which would require construction worker trips, and equipment use (e.g., cranes, generator sets, welding equipment).

Architectural coatings would be applied to new buildings and ancillary facilities (approximately 0.1 acre or 4,356 SF). Architectural coating application would begin in November 2026 and last approximately 1 month.

Paving would occur on approximately 0.25 acre (1,089 SF). Paving would begin in December 2026 and last approximately 1 month.

Detailed Emissions Report – Lower Bound Construction Scenario: 1-Acre Footprint

Green Hydrogen - Lower Bound Construction Detailed Report

Table of Contents

1. Basic Project Information

1.1. Basic Project Information

Data Field	Value
Project Name	Green Hydrogen - Lower Bound Construction
Construction Start Date	1/1/2026
Lead Agency	Washington State Department of Ecology
Land Use Scale	Project/site
Analysis Level for Defaults	County
Windspeed (m/s)	5.00
Precipitation (days)	150
Location	N/A
County	N/A
City	N/A
Air District	N/A
Air Basin	N/A
TAZ	N/A
EDFZ	N/A
Electric Utility	Statewide Average
Gas Utility	User Defined
App Version	2022.1.1.26

1.2. Land Use Types

Land Use Subtype	Size	Unit	Lot Acreage	Building Area (SF)	Landscape Area (SF)	Special Landscape Area (SF)	Population	Description
General Heavy Industry	43.6	1000sqft	1.00	43,560	0.00	0.00	—	Green hydrogen production facility lower bounds (1 acre). 10% of footprint assumed to be buildings; no landscaped areas assumed.

1.3. User-Selected Emission Reduction Measures by Emissions Sector

No measures selected

2. Emissions Summary

2.1. Construction Emissions Compared Against Thresholds

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Un/Mit.	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	0.82	7.21	9.85	0.02	0.26	9.29	9.55	0.24	1.22	1.45	1,993	0.08	0.05
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	19.9	11.8	13.3	0.02	0.54	147	147	0.50	16.0	16.1	2,336	0.09	0.11
Average Daily (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	1.76	4.52	5.93	0.01	0.17	14.2	14.4	0.15	1.79	1.95	1,212	0.05	0.04
Annual (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	0.32	0.82	1.08	< 0.005	0.03	2.60	2.63	0.03	0.33	0.36	201	0.01	0.01
Exceeds (Annual)	—	—	—	—	—	—	—	—	—	—	—	—	—
Threshold	100	100	100	100	100	100	100	100	100	100	—	—	—
Unmit.	No	No	No	No	No	No	No	No	No	No	—	—	—

2.2. Construction Emissions by Year, Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Year	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily - Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
2026	0.82	7.21	9.85	0.02	0.26	9.29	9.55	0.24	1.22	1.45	1,993	0.08	0.05
Daily - Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
2026	19.9	11.8	13.3	0.02	0.54	147	147	0.50	16.0	16.1	2,336	0.09	0.11
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—

Year	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
2026	1.76	4.52	5.93	0.01	0.17	14.2	14.4	0.15	1.79	1.95	1,212	0.05	0.04
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
2026	0.32	0.82	1.08	< 0.005	0.03	2.60	2.63	0.03	0.33	0.36	201	0.01	0.01

Note: lb = pounds; MT = metric tons; yr = year.

3. Construction Emissions Details

3.1. Grading (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	1.29	11.7	12.8	0.02	0.54	—	0.54	0.50	—	0.50	2,176	0.09	0.02
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	7.55	7.55	< 0.005	0.78	0.78	35.3	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.08	0.70	0.77	< 0.005	0.03	—	0.03	0.03	—	0.03	131	0.01	< 0.005
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.27	0.27	< 0.005	0.03	0.03	2.13	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.01	0.13	0.14	< 0.005	0.01	—	0.01	0.01	—	0.01	21.7	< 0.005	< 0.005
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.05	0.05	< 0.005	0.01	0.01	0.35	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.04	0.04	0.40	0.00	0.00	5.61	5.61	0.00	1.40	1.40	98.5	< 0.005	< 0.005
Vendor	< 0.005	0.03	0.01	< 0.005	< 0.005	0.32	0.32	< 0.005	0.08	0.08	26.2	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.02	0.00	0.00	0.30	0.30	0.00	0.08	0.08	5.98	< 0.005	< 0.005

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.02	0.02	< 0.005	< 0.005	< 0.005	1.58	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	< 0.005	0.00	0.00	0.06	0.06	0.00	0.01	0.01	0.99	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.26	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.3. Building Construction (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.76	6.90	9.07	0.02	0.26	—	0.26	0.23	—	0.23	1,616	0.07	0.01
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	7.40	7.40	< 0.005	0.74	0.74	35.3	< 0.005	0.01
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.76	6.90	9.07	0.02	0.26	—	0.26	0.23	—	0.23	1,616	0.07	0.01
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	7.40	7.40	< 0.005	0.74	0.74	35.3	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.32	2.89	3.80	0.01	0.11	—	0.11	0.10	—	0.10	677	0.03	0.01
Onsite truck	< 0.005	0.02	0.01	< 0.005	< 0.005	1.83	1.83	< 0.005	0.18	0.19	14.8	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.06	0.53	0.69	< 0.005	0.02	—	0.02	0.02	—	0.02	112	< 0.005	< 0.005
Onsite Truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.33	0.33	< 0.005	0.03	0.03	2.45	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.05	0.04	0.66	0.00	0.00	1.47	1.47	0.00	0.37	0.37	155	< 0.005	0.01
Vendor	0.01	0.22	0.10	< 0.005	< 0.005	0.42	0.42	< 0.005	0.11	0.11	187	0.01	0.03
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.05	0.05	0.58	0.00	0.00	1.47	1.47	0.00	0.37	0.37	144	< 0.005	0.01
Vendor	0.01	0.24	0.10	< 0.005	< 0.005	0.42	0.42	< 0.005	0.11	0.11	187	0.01	0.03
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.02	0.02	0.24	0.00	0.00	0.55	0.55	0.00	0.14	0.14	60.9	< 0.005	< 0.005
Vendor	< 0.005	0.10	0.04	< 0.005	< 0.005	0.16	0.16	< 0.005	0.04	0.04	78.4	< 0.005	0.01
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.04	0.00	0.00	0.10	0.10	0.00	0.03	0.03	10.1	< 0.005	< 0.005
Vendor	< 0.005	0.02	0.01	< 0.005	< 0.005	0.03	0.03	< 0.005	0.01	0.01	13.0	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.9. Paving (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.60	5.41	7.22	0.01	0.22	—	0.22	0.21	—	0.21	1,121	0.05	0.01
Paving	0.03	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	7.57	7.57	< 0.005	0.79	0.79	35.3	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.03	0.31	0.42	< 0.005	0.01	—	0.01	0.01	—	0.01	64.5	< 0.005	< 0.005
Paving	< 0.005	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.26	0.26	< 0.005	0.03	0.03	2.03	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.01	0.06	0.08	< 0.005	< 0.005	—	< 0.005	< 0.005	—	< 0.005	10.7	< 0.005	< 0.005
Paving	< 0.005	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.05	0.05	< 0.005	0.01	0.01	0.34	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.06	0.06	0.64	0.00	0.00	9.68	9.68	0.00	2.42	2.42	158	< 0.005	0.01
Vendor	< 0.005	0.03	0.01	< 0.005	< 0.005	0.35	0.35	< 0.005	0.09	0.09	26.2	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.04	0.00	0.00	0.50	0.50	0.00	0.12	0.12	9.13	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.02	0.02	< 0.005	< 0.005	< 0.005	1.51	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.01	0.00	0.00	0.09	0.09	0.00	0.02	0.02	1.51	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01	0.01	< 0.005	< 0.005	< 0.005	0.25	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.7. Architectural Coating (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.12	0.86	1.13	< 0.005	0.02	—	0.02	0.02	—	0.02	134	0.01	< 0.005
Architectural Coatings	19.8	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	0.07	0.07	< 0.005	0.02	0.02	35.3	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.01	0.05	0.07	< 0.005	< 0.005	—	< 0.005	< 0.005	—	< 0.005	8.41	< 0.005	< 0.005
Architectural Coatings	1.24	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	2.22	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	< 0.005	0.01	0.01	< 0.005	< 0.005	—	< 0.005	< 0.005	—	< 0.005	1.39	< 0.005	< 0.005

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Architectural Coatings	0.23	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.37	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.01	0.01	0.12	0.00	0.00	0.29	0.29	0.00	0.07	0.07	28.8	< 0.005	< 0.005
Vendor	< 0.005	0.03	0.01	< 0.005	< 0.005	0.06	0.06	< 0.005	0.01	0.02	26.2	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.01	0.00	0.00	0.02	0.02	0.00	< 0.005	< 0.005	1.83	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	1.65	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	< 0.005	0.00	0.00	< 0.005	< 0.005	0.00	< 0.005	< 0.005	0.30	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.27	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.9. Excavation (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.29	2.61	3.89	0.01	0.08	—	0.08	0.08	—	0.08	555	0.02	< 0.005
Dust From Material Movement	—	—	—	—	—	0.01	0.01	—	< 0.005	< 0.005	—	—	—
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	7.58	7.58	< 0.005	0.79	0.79	35.3	< 0.005	0.01

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.03	0.30	0.45	< 0.005	0.01	—	0.01	0.01	—	0.01	63.9	0.01	< 0.005
Dust From Material Movement	—	—	—	—	—	< 0.005	< 0.005	—	< 0.005	< 0.005	—	—	—
Onsite truck	< 0.005	0.01	< 0.005	< 0.005	< 0.005	0.52	0.52	< 0.005	0.06	0.06	4.06	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.01	0.05	0.08	< 0.005	< 0.005	—	< 0.005	< 0.005	—	< 0.005	10.6	< 0.005	< 0.005
Dust From Material Movement	—	—	—	—	—	< 0.005	< 0.005	—	< 0.005	< 0.005	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.10	0.10	< 0.005	0.01	0.01	0.67	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.02	0.02	0.27	0.00	0.00	3.89	3.89	0.00	0.97	0.97	59.1	< 0.005	< 0.005
Vendor	< 0.005	0.03	0.01	< 0.005	< 0.005	0.37	0.37	< 0.005	0.09	0.09	26.2	< 0.005	< 0.005
Hauling	0.01	0.78	0.30	< 0.005	0.01	135	135	0.01	14.1	14.1	315	0.03	0.10
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.03	0.00	0.00	0.40	0.40	0.00	0.10	0.10	6.85	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.04	0.04	< 0.005	0.01	0.01	3.01	< 0.005	< 0.005
Hauling	< 0.005	0.09	0.03	< 0.005	< 0.005	9.32	9.32	< 0.005	0.99	0.99	70.7	< 0.005	0.01
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	< 0.005	0.00	0.00	0.07	0.07	0.00	0.02	0.02	1.13	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01	0.01	< 0.005	< 0.005	< 0.005	0.50	< 0.005	< 0.005
Hauling	< 0.005	0.02	0.01	< 0.005	< 0.005	1.70	1.70	< 0.005	0.18	0.18	11.7	< 0.005	< 0.005

4. Operations Emissions Details

4.10. Soil Carbon Accumulation by Vegetation Type

4.10.1. Soil Carbon Accumulation by Vegetation Type - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Vegetation	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—

4.10.2. Above and Belowground Carbon Accumulation by Land Use Type - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Land Use	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summ (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winte (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—

4.10.3. Avoided and Sequestered Emissions by Species - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Species	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Avoided	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequestered	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Removed	—	—	—	—	—	—	—	—	—	—	—	—	—

Species	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Avoided	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequestered	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Removed	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Avoided	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequestered	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Removed	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—

5. Activity Data

5.1. Construction Schedule

Phase name	Phase type	Start date	End date	Days per week	Workdays per phase	Phase description
Grading	Grading	1/1/2026	3/31/2026	5.00	64.0	Site grading would occur on the entire site (approximately 1 acre or 43,560 SF) to ensure required elevation is met. Site grading would begin in January 2026 and last approximately 1 month. Depth of grading was assumed to be 1 foot. It was assumed excavated fill would be reused on site and would not be hauled offsite.
Building Construction	Building Construction	10/1/2026	9/30/2028	5.00	522	Construction of buildings and ancillary facilities would occur on approximately 0.1 acre (4,356 SF). Building height was assumed to be 20 feet. Construction would begin in April 2026 and last approximately 8 months. The construction phase accounts for installation of equipment which would require construction worker trips, and

Phase name	Phase type	Start date	End date	Days per week	Workdays per phase	Phase description
						equipment use (e.g., cranes, generator sets, welding equipment).
Paving	Paving	11/1/2028	12/31/2028	5.00	43.0	Paving would occur on approximately 0.25 acre (1,089 SF). Paving would begin in December 2026 and last approximately 1 month.
Architectural Coating	Architectural Coating	10/1/2028	10/31/2028	5.00	22.0	Architectural coatings would be applied to new buildings and ancillary facilities (approximately 0.1 acre or 4,356 SF). Architectural coating application would begin in November 2026 and last approximately 1 month.
Excavation	Trenching	4/1/2026	9/30/2026	5.00	131	Excavation/trenching would be required for utility installation and/or extension, building foundations, and equipment pads. Approximately 0.33 acre (14,374.8 SF) would be excavated or trenched. It was assumed equipment pads (approximately 0.2 acre or 8,712 SF) would be excavated to an average depth of 4 feet. It was assumed building foundations (approximately 0.1 acre or 4,356 SF) would be excavated to a depth of between 3 and 5 feet (average depth of 4 feet). It was assumed utility lines (approximately 250 linear feet) would be excavated to an average depth of 3.5 feet. The weighted average of site excavation depth was calculated at 3.6 feet. It was assumed excavated fill would be reused onsite and would not be hauled offsite. Approximately 3,000 CY of material (e.g., concrete, gravel) would be hauled onsite for equipment pads (e.g., concrete pads, hard-pack gravel pads). Excavation and trenching would begin in February 2026 and last approximately 2 months.

5.2. Off-Road Equipment

5.2.1. Unmitigated

Phase name	Equipment type	Fuel type	Engine tier	Number per day	Hours per day	Horsepower	Load factor
Grading	Graders	Diesel	Average	1.00	6.00	148	0.41
Grading	Rubber Tired Dozers	Diesel	Average	1.00	6.00	367	0.40

Phase name	Equipment type	Fuel type	Engine tier	Number per day	Hours per day	Horsepower	Load factor
Grading	Tractors/Loaders/Backhoes	Diesel	Average	1.00	7.00	84.0	0.37
Grading	Excavators	Diesel	Average	1.00	8.00	36.0	0.38
Grading	Other Construction Equipment	Diesel	Average	1.00	8.00	82.0	0.42
Building Construction	Cranes	Diesel	Average	1.00	4.00	367	0.29
Building Construction	Forklifts	Diesel	Average	2.00	6.00	82.0	0.20
Building Construction	Tractors/Loaders/Backhoes	Diesel	Average	2.00	8.00	84.0	0.37
Building Construction	Generator Sets	Diesel	Average	1.00	8.00	14.0	0.74
Building Construction	Welders	Diesel	Average	1.00	8.00	46.0	0.45
Paving	Cement and Mortar Mixers	Diesel	Average	4.00	6.00	10.0	0.56
Paving	Pavers	Diesel	Average	1.00	7.00	81.0	0.42
Paving	Rollers	Diesel	Average	1.00	7.00	36.0	0.38
Paving	Tractors/Loaders/Backhoes	Diesel	Average	1.00	7.00	84.0	0.37
Paving	Paving Equipment	Diesel	Average	1.00	8.00	89.0	0.36
Architectural Coating	Air Compressors	Diesel	Average	1.00	6.00	37.0	0.48
Excavation	Excavators	Diesel	Average	1.00	8.00	36.0	0.38
Excavation	Other General Industrial Equipment	Diesel	Average	1.00	8.00	35.0	0.34
Excavation	Tractors/Loaders/Backhoes	Diesel	Average	1.00	8.00	84.0	0.37

5.3. Construction Vehicles

5.3.1. Unmitigated

Phase name	Trip type	One-way trips per day	Miles per trip	Vehicle mix
Grading	—	—	—	—
Grading	Worker	12.5	11.7	LDA, LDT1, LDT2
Grading	Vendor	1.00	8.40	HHDT, MHDT
Grading	Hauling	0.00	20.0	HHDT
Grading	Onsite truck	1.00	10.0	HHDT

Phase name	Trip type	One-way trips per day	Miles per trip	Vehicle mix
Building Construction	—	—	—	—
Building Construction	Worker	18.3	11.7	LDA, LDT1, LDT2
Building Construction	Vendor	7.14	8.40	HHDT, MHDT
Building Construction	Hauling	0.00	20.0	HHDT
Building Construction	Onsite truck	1.00	10.0	HHDT
Paving	—	—	—	—
Paving	Worker	20.0	11.7	LDA, LDT1, LDT2
Paving	Vendor	1.00	8.40	HHDT, MHDT
Paving	Hauling	0.00	20.0	HHDT
Paving	Onsite truck	1.00	10.0	HHDT
Architectural Coating	—	—	—	—
Architectural Coating	Worker	3.66	11.7	LDA, LDT1, LDT2
Architectural Coating	Vendor	1.00	8.40	HHDT, MHDT
Architectural Coating	Hauling	0.00	20.0	HHDT
Architectural Coating	Onsite truck	1.00	10.0	HHDT
Excavation	—	—	—	—
Excavation	Worker	7.50	11.7	LDA, LDT1, LDT2
Excavation	Vendor	1.00	8.40	HHDT, MHDT
Excavation	Hauling	8.93	20.0	HHDT
Excavation	Onsite truck	1.00	10.0	HHDT

5.4. Vehicles

5.4.1. Construction Vehicle Control Strategies

Non-applicable. No control strategies activated by user.

5.5. Architectural Coatings

Phase name	Residential interior area coated (sf)	Residential exterior area coated (sf)	Non-residential interior area coated (sf)	Non-residential exterior area coated (sf)	Parking area coated (sf)
Architectural Coating	0.00	0.00	65,340	21,780	—

5.6. Dust Mitigation

5.6.1. Construction Earthmoving Activities

Phase name	Material imported (CY)	Material exported (CY)	Acres graded (acres)	Material demolished (SF)	Acres paved (acres)

Paving	0.00	0.00	0.00	0.00	0.25
Excavation	3,000	0.00	1.00	0.00	—

5.6.2. Construction Earthmoving Control Strategies

Non-applicable. No control strategies activated by user.

5.7. Construction Paving

Land use	Area paved (acres)	% Asphalt
General Heavy Industry	0.25	100%

5.8. Construction Electricity Consumption and Emissions Factors

kWh per Year and Emission Factor (lb/MWh)

Year	kWh per Year	CO2	CH4	N2O
2026	0.00	185	0.02	< 0.005

Note: kWh = kilowatt hours; MWh = megawatt hours.

5.18. Vegetation

5.18.1. Land Use Change

5.18.1.1. Unmitigated

Vegetation Land Use Type	Vegetation Soil Type	Initial Acres	Final Acres
—	—	—	—

5.18.1. Biomass Cover Type

5.18.1.1. Unmitigated

Biomass Cover Type	Initial Acres	Final Acres
—	—	—

5.18.2. Sequestration

5.18.2.1. Unmitigated

Tree Type	Number	Electricity Saved (kWh/year)	Natural Gas Saved (btu/year)
—	—	—	—

6. User Changes to Default Data

Screen	Justification
Characteristics: Project Details	CalEEMod was selected as the model to estimate air emissions from construction of green hydrogen production facilities in Washington. The inputs were adjusted to account for meteorological conditions in the state of Washington.
Characteristics: Utility Information	Utility characteristics were changed to match those for Washington State. Greenhouse gas pollutant intensity factors are representative of all fuel sources for 2022 (https:/www.epa.gov/egrid).
Land Use	Green hydrogen production facility lower bound footprint is equal to 1 acre (approx. 43,560 SF). It was assumed 10% of the facility footprint would contain buildings (4,356 SF).
Construction: Construction Phases	A 1-year construction timeline was estimated for green hydrogen facility construction. A surrogate year of 2026 was used. The following assumptions were used: • 100% of footprint would be disturbed (grading phase) • 30% of footprint would be excavated for foundations, underground utilities, and pads (excavation/trenching phase) • 20% of footprint would include pads for equipment/tanks/etc. • 10% of footprint would include structures (building construction and architectural coatings phases) • 25% of footprint would be paved surfaces (paving phase) • 45% of footprint (remaining of what's not buildings/pads/pavement) would be permeable surface (e.g., gravel, dirt, grass).
Construction: Off-Road Equipment	Updated equipment inputs to match construction phases.
Construction: Dust From Material Movement	For the lower bound scenario (1 acre footprint), approximately 3,000 CY of material (e.g., concrete, gravel) would be hauled onsite for equipment pads (e.g., concrete pads, hard-pack gravel pads). It was assumed excavated fill would be reused on site and would not be hauled offsite.
Construction: On-Road Fugitive Dust	During construction, a portion of vehicle movements would occur on unpaved roads.
Construction: Paving	Paving would occur on 25% of the facility footprint (approximately 0.25 acre or 10,890 SF).
Construction: Electricity	Greenhouse gas pollutant intensity factors revised to reflect the Washington statewide average and are representative of all fuel sources for 2022 (https:/www.epa.gov/egrid)
Construction: Trips and Vehicle Miles Traveled	—

Assumptions – Upper Bound Construction Scenario: 10-Acre Footprint

A 3-year construction timeline was estimated for green hydrogen facility construction. Surrogate years of 2026 through 2028 were used. The following assumptions were used:

- 100% of footprint would be disturbed (grading phase)
- 30% of footprint would be excavated for foundations, underground utilities, and pads (excavation/trenching phase)
- 20% of footprint would include pads for equipment/tanks/etc.
- 10% of footprint would include structures (building construction and architectural coatings phases)
- 25% of footprint would be paved surfaces (paving phase)
- 45% of footprint (remaining of what's not buildings/pads/pavement) would be permeable surface (e.g., gravel, dirt, grass).

Site grading would occur on the entire site (approximately 10 acres or 435,600 SF) to ensure required elevation is met. Site grading would begin in January 2026 and last approximately 3 months. Depth of grading was assumed to be 1 foot. It was assumed excavated fill would be reused on site and would not be hauled offsite.

Excavation/trenching would be required for utility installation and/or extension, building foundations, and equipment pads. Approximately 3 acres (130,680 SF) would be excavated or trenched. It was assumed equipment pads (approximately 2 acres or 87,120 SF) would be excavated to an average depth of 4 feet. It was assumed building foundations (approximately 1 acre or 43,560 SF) would be excavated to a depth of between 3 and 5 feet (average depth of 4 feet). It was assumed utility lines (approximately 1,000 linear feet) would be excavated to an average depth of 3.5 feet. The weighted average of site excavation depth was calculated at 4 feet. It was assumed excavated fill would be reused onsite and would not be hauled offsite. Approximately 15,000 CY of material (e.g., concrete, gravel) would be hauled onsite for equipment pads (e.g., concrete pads, hard-pack gravel pads). Excavation and trenching would begin in April 2026 and last approximately 6 months.

Construction of buildings and ancillary facilities would occur on approximately 1 acre (43,560 SF). Building height was assumed to be 20 feet. Construction would begin in October 2026 and last approximately 24 months. The construction phase accounts for installation of equipment which would require construction worker trips, and equipment use (e.g., cranes, generator sets, welding equipment).

Architectural coatings would be applied to new buildings and ancillary facilities (approximately 1 acre or 43,560 SF). Architectural coating application would begin in October 2028 and last approximately 1 month.

Paving would occur on approximately 2.5 acres (108,900 SF). Paving would begin in November 2028 and last approximately 2 months.

Detailed Emissions Report – Upper Bound Construction Scenario: 10-Acre Footprint

Green Hydrogen - Upper Bound Construction Detailed Report

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5.18.2.1. Unmitigated

6. User Changes to Default Data

1. Basic Project Information

1.1. Basic Project Information

Data Field	Value
Project Name	Green Hydrogen - Upper Bound Construction
Construction Start Date	1/1/2026
Lead Agency	Washington State Department of Ecology
Land Use Scale	Project/site
Analysis Level for Defaults	County
Windspeed (m/s)	5.00
Precipitation (days)	150
Location	N/A
County	N/A
City	N/A
Air District	N/A
Air Basin	N/A
TAZ	N/A
EDFZ	N/A
Electric Utility	Statewide Average
Gas Utility	User Defined
App Version	2022.1.1.26

1.2. Land Use Types

Land use subtype	Size	Unit	Lot acreage	Building area (SF)	Landscape area (SF)	Special landscape area (SF)	Population	Description
General Heavy Industry	436	1,000 SF	10.0	435,600	0.00	0.00	—	Green hydrogen production facility upper bounds (10 acres). 10% of footprint assumed to be buildings; no landscaped areas assumed.

1.3. User-Selected Emission Reduction Measures by Emissions Sector

No measures selected

2. Emissions Summary

2.1. Construction Emissions Compared Against Thresholds

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Un/Mit.	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	1.61	12.0	20.1	0.04	0.36	238	238	0.34	25.6	25.7	5,824	0.20	0.37
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	207	16.8	20.2	0.04	0.74	33.7	34.1	0.68	6.21	6.59	5,781	0.21	0.37
Average Daily (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	13.4	8.65	13.7	0.03	0.26	59.2	59.4	0.24	7.17	7.40	4,089	0.15	0.26
Annual (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Unmit.	2.45	1.58	2.51	< 0.005	0.05	10.8	10.8	0.04	1.31	1.35	677	0.02	0.04
Exceeds (Annual)	—	—	—	—	—	—	—	—	—	—	—	—	—
Threshold	100	100	100	100	100	100	100	100	100	100	—	—	—
Unmit.	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes

2.2. Construction Emissions by Year, Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Year	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily - Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
2026	0.44	4.75	5.80	0.01	0.13	238	238	0.11	25.6	25.7	1,864	0.09	0.18
2027	1.61	12.0	20.1	0.04	0.36	33.7	34.1	0.34	6.21	6.55	5,824	0.20	0.37
2028	1.56	11.4	19.7	0.04	0.33	33.7	34.1	0.30	6.21	6.51	5,752	0.20	0.30

Daily - Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
2026	1.87	16.8	20.2	0.04	0.74	33.7	34.1	0.68	6.21	6.59	5,781	0.21	0.37
2027	1.59	12.2	19.4	0.04	0.36	33.7	34.1	0.34	6.21	6.55	5,715	0.21	0.37
2028	207	11.6	19.1	0.04	0.33	33.7	34.1	0.31	6.21	6.51	5,646	0.21	0.36
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
2026	0.78	6.96	9.13	0.02	0.25	59.2	59.4	0.23	7.17	7.40	2,326	0.09	0.14
2027	1.13	8.65	13.7	0.03	0.26	18.4	18.6	0.24	3.66	3.90	4,089	0.15	0.26
2028	13.4	7.32	11.9	0.02	0.22	16.5	16.7	0.20	3.27	3.47	3,331	0.12	0.19
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
2026	0.14	1.27	1.67	< 0.005	0.05	10.8	10.8	0.04	1.31	1.35	385	0.02	0.02
2027	0.21	1.58	2.51	< 0.005	0.05	3.36	3.40	0.04	0.67	0.71	677	0.02	0.04
2028	2.45	1.34	2.16	< 0.005	0.04	3.01	3.05	0.04	0.60	0.63	551	0.02	0.03

3. Construction Emissions Details

3.1. Grading (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	1.82	16.6	19.6	0.03	0.74	—	0.74	0.68	—	0.68	3,280	0.13	0.03
Onsite truck	< 0.005	0.10	0.04	< 0.005	< 0.005	15.1	15.1	< 0.005	1.57	1.57	70.6	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.32	2.92	3.43	0.01	0.13	—	0.13	0.12	—	0.12	575	0.02	< 0.005
Onsite truck	< 0.005	0.02	0.01	< 0.005	< 0.005	1.58	1.58	< 0.005	0.17	0.17	12.4	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.06	0.53	0.63	< 0.005	0.02	—	0.02	0.02	—	0.02	95.2	< 0.005	< 0.005
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.29	0.29	< 0.005	0.03	0.03	2.05	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.05	0.05	0.56	0.00	0.00	7.85	7.85	0.00	1.96	1.96	138	< 0.005	0.01
Vendor	< 0.005	0.03	0.01	< 0.005	< 0.005	0.32	0.32	< 0.005	0.08	0.08	26.2	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.01	0.01	0.09	0.00	0.00	1.24	1.24	0.00	0.31	0.31	24.3	< 0.005	< 0.005
Vendor	< 0.005	0.01	< 0.005	< 0.005	< 0.005	0.05	0.05	< 0.005	0.01	0.01	4.59	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.02	0.00	0.00	0.23	0.23	0.00	0.06	0.06	4.03	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01	0.01	< 0.005	< 0.005	< 0.005	0.76	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.3. Building Construction (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	1.07	9.85	13.0	0.02	0.38	—	0.38	0.35	—	0.35	2,397	0.10	0.02
Onsite truck	< 0.005	0.10	0.04	< 0.005	< 0.005	14.8	14.8	< 0.005	1.49	1.49	70.6	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.19	1.77	2.33	< 0.005	0.07	—	0.07	0.06	—	0.06	432	0.02	< 0.005
Onsite truck	< 0.005	0.02	0.01	< 0.005	< 0.005	1.57	1.57	< 0.005	0.16	0.16	12.7	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.04	0.32	0.43	< 0.005	0.01	—	0.01	0.01	—	0.01	71.5	< 0.005	< 0.005
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.29	0.29	< 0.005	0.03	0.03	2.10	< 0.005	< 0.005

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.53	0.51	5.82	0.00	0.00	14.7	14.7	0.00	3.66	3.66	1,442	0.04	0.06
Vendor	0.06	2.36	1.01	0.01	0.03	4.21	4.23	0.03	1.06	1.09	1,871	0.08	0.28
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.09	0.08	1.01	0.00	0.00	2.38	2.38	0.00	0.59	0.59	261	0.01	0.01
Vendor	0.01	0.42	0.18	< 0.005	< 0.005	0.68	0.69	< 0.005	0.17	0.18	337	0.01	0.05
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.02	0.01	0.19	0.00	0.00	0.43	0.43	0.00	0.11	0.11	43.3	< 0.005	< 0.005
Vendor	< 0.005	0.08	0.03	< 0.005	< 0.005	0.12	0.13	< 0.005	0.03	0.03	55.7	< 0.005	0.01
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.5. Building Construction (2027) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	1.03	9.39	12.9	0.02	0.34	—	0.34	0.31	—	0.31	2,397	0.10	0.02
Onsite truck	< 0.005	0.09	0.04	< 0.005	< 0.005	14.8	14.8	< 0.005	1.49	1.49	69.0	< 0.005	0.01
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	1.03	9.39	12.9	0.02	0.34	—	0.34	0.31	—	0.31	2,397	0.10	0.02
Onsite truck	< 0.005	0.10	0.04	< 0.005	< 0.005	14.8	14.8	< 0.005	1.49	1.49	69.0	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.74	6.71	9.24	0.02	0.24	—	0.24	0.22	—	0.22	1,712	0.07	0.01
Onsite truck	< 0.005	0.07	0.03	< 0.005	< 0.005	6.24	6.24	< 0.005	0.63	0.63	49.3	< 0.005	0.01

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.13	1.22	1.69	< 0.005	0.04	—	0.04	0.04	—	0.04	283	0.01	< 0.005
Onsite truck	< 0.005	0.01	0.01	< 0.005	< 0.005	1.14	1.14	< 0.005	0.11	0.12	8.16	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.52	0.34	6.18	0.00	0.00	14.7	14.7	0.00	3.66	3.66	1,525	0.02	0.06
Vendor	0.06	2.14	0.95	0.01	0.03	4.21	4.23	0.03	1.06	1.09	1,832	0.08	0.28
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.51	0.46	5.47	0.00	0.00	14.7	14.7	0.00	3.66	3.66	1,415	0.04	0.06
Vendor	0.06	2.27	0.97	0.01	0.03	4.21	4.23	0.03	1.06	1.09	1,834	0.08	0.28
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.36	0.29	3.79	0.00	0.00	9.45	9.45	0.00	2.34	2.34	1,018	0.02	0.04
Vendor	0.04	1.59	0.69	0.01	0.02	2.70	2.72	0.02	0.69	0.70	1,309	0.05	0.20
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.07	0.05	0.69	0.00	0.00	1.72	1.72	0.00	0.43	0.43	169	< 0.005	0.01
Vendor	0.01	0.29	0.13	< 0.005	< 0.005	0.49	0.50	< 0.005	0.13	0.13	217	0.01	0.03
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.7. Building Construction (2028) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.99	8.92	12.9	0.02	0.30	—	0.30	0.28	—	0.28	2,397	0.10	0.02
Onsite truck	< 0.005	0.09	0.04	< 0.005	< 0.005	14.8	14.8	< 0.005	1.49	1.49	67.3	< 0.005	0.01
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Off-Road Equipment	0.99	8.92	12.9	0.02	0.30	—	0.30	0.28	—	0.28	2,397	0.10	0.02
Onsite truck	< 0.005	0.10	0.04	< 0.005	< 0.005	14.8	14.8	< 0.005	1.49	1.49	67.4	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.53	4.79	6.94	0.01	0.16	—	0.16	0.15	—	0.15	1,286	0.05	0.01
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	4.68	4.68	< 0.005	0.47	0.47	36.1	< 0.005	0.01
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.10	0.87	1.27	< 0.005	0.03	—	0.03	0.03	—	0.03	213	0.01	< 0.005
Onsite truck	< 0.005	0.01	< 0.005	< 0.005	< 0.005	0.85	0.86	< 0.005	0.09	0.09	5.98	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.51	0.34	5.83	0.00	0.00	14.7	14.7	0.00	3.66	3.66	1,498	0.02	0.01
Vendor	0.06	2.07	0.92	0.01	0.03	4.21	4.23	0.03	1.06	1.09	1,789	0.07	0.26
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.49	0.40	5.13	0.00	0.00	14.7	14.7	0.00	3.66	3.66	1,390	0.03	0.06
Vendor	0.06	2.18	0.94	0.01	0.03	4.21	4.23	0.03	1.06	1.09	1,791	0.07	0.26
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.26	0.21	2.67	0.00	0.00	7.09	7.09	0.00	1.76	1.76	751	0.02	0.03
Vendor	0.03	1.15	0.50	0.01	0.01	2.03	2.04	0.01	0.51	0.53	960	0.04	0.14
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.05	0.04	0.49	0.00	0.00	1.29	1.29	0.00	0.32	0.32	124	< 0.005	0.01
Vendor	0.01	0.21	0.09	< 0.005	< 0.005	0.37	0.37	< 0.005	0.09	0.10	159	0.01	0.02
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.9. Paving (2028) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.94	8.83	12.8	0.02	0.33	—	0.33	0.30	—	0.30	1,970	0.08	0.02
Paving	0.15	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	0.10	0.04	< 0.005	< 0.005	15.1	15.1	< 0.005	1.57	1.57	67.4	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.11	1.04	1.51	< 0.005	0.04	—	0.04	0.04	—	0.04	232	0.01	< 0.005
Paving	0.02	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	0.01	< 0.005	< 0.005	< 0.005	1.07	1.07	< 0.005	0.11	0.11	7.93	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.02	0.19	0.27	< 0.005	0.01	—	0.01	0.01	—	0.01	38.4	< 0.005	< 0.005
Paving	< 0.005	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.19	0.19	< 0.005	0.02	0.02	1.31	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.07	0.06	0.77	0.00	0.00	13.3	13.3	0.00	3.32	3.32	209	< 0.005	0.01
Vendor	< 0.005	0.06	0.03	< 0.005	< 0.005	0.70	0.70	< 0.005	0.17	0.18	50.2	< 0.005	0.01
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.01	0.01	0.09	0.00	0.00	1.41	1.41	0.00	0.35	0.35	24.8	< 0.005	< 0.005
Vendor	< 0.005	0.01	< 0.005	< 0.005	< 0.005	0.07	0.07	< 0.005	0.02	0.02	5.91	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.02	0.00	0.00	0.26	0.26	0.00	0.06	0.06	4.10	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01	0.01	< 0.005	< 0.005	< 0.005	0.98	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.11. Architectural Coating (2028) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.11	0.81	1.12	< 0.005	0.02	—	0.02	0.01	—	0.01	134	0.01	< 0.005
Architectural Coatings	207	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	0.05	0.02	< 0.005	< 0.005	0.07	0.07	< 0.005	0.02	0.02	33.7	< 0.005	0.01
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.01	0.05	0.07	< 0.005	< 0.005	—	< 0.005	< 0.005	—	< 0.005	8.05	< 0.005	< 0.005
Architectural Coatings	12.4	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	2.03	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	< 0.005	0.01	0.01	< 0.005	< 0.005	—	< 0.005	< 0.005	—	< 0.005	1.33	< 0.005	< 0.005
Architectural Coatings	2.27	—	—	—	—	—	—	—	—	—	—	—	—
Onsite truck	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.34	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.10	0.08	1.03	0.00	0.00	2.95	2.95	0.00	0.73	0.73	278	0.01	0.01
Vendor	< 0.005	0.03	0.01	< 0.005	< 0.005	0.06	0.06	< 0.005	0.01	0.02	25.1	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.01	< 0.005	0.06	0.00	0.00	0.16	0.16	0.00	0.04	0.04	16.9	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	1.51	< 0.005	< 0.005
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	< 0.005	< 0.005	0.01	0.00	0.00	0.03	0.03	0.00	0.01	0.01	2.79	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.25	< 0.005	< 0.005

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Hauling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.13. Excavation (2026) - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Onsite	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.39	3.43	4.91	0.01	0.11	—	0.11	0.10	—	0.10	697	0.03	0.01
Dust From Material Movement	—	—	—	—	—	0.01	0.01	—	< 0.005	< 0.005	—	—	—
Onsite truck	< 0.005	0.10	0.04	< 0.005	< 0.005	15.2	15.2	< 0.005	1.58	1.58	70.5	< 0.005	0.01
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.14	1.23	1.76	< 0.005	0.04	—	0.04	0.04	—	0.04	250	0.01	< 0.005
Dust From Material Movement	—	—	—	—	—	0.01	0.01	—	< 0.005	< 0.005	—	—	—
Onsite truck	< 0.005	0.04	0.02	< 0.005	< 0.005	3.26	3.26	< 0.005	0.35	0.35	25.3	< 0.005	< 0.005
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Off-Road Equipment	0.03	0.22	0.32	< 0.005	0.01	—	0.01	0.01	—	0.01	41.4	< 0.005	< 0.005
Dust From Material Movement	—	—	—	—	—	< 0.005	< 0.005	—	< 0.005	< 0.005	—	—	—
Onsite truck	< 0.005	0.01	< 0.005	< 0.005	< 0.005	0.59	0.59	< 0.005	0.06	0.06	4.19	< 0.005	< 0.005
Offsite	—	—	—	—	—	—	—	—	—	—	—	—	—

Location	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.03	0.02	0.36	0.00	0.00	5.19	5.19	0.00	1.30	1.30	85.0	< 0.005	< 0.005
Vendor	< 0.005	0.03	0.01	< 0.005	< 0.005	0.37	0.37	< 0.005	0.09	0.09	26.2	< 0.005	< 0.005
Hauling	0.02	1.17	0.47	0.01	0.02	217	217	0.01	22.6	22.6	985	0.05	0.16
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Average Daily	—	—	—	—	—	—	—	—	—	—	—	—	—
Worker	0.01	0.01	0.11	0.00	0.00	1.67	1.67	0.00	0.42	0.42	28.5	< 0.005	< 0.005
Vendor	< 0.005	0.01	< 0.005	< 0.005	< 0.005	0.12	0.12	< 0.005	0.03	0.03	9.40	< 0.005	< 0.005
Hauling	0.01	0.44	0.17	< 0.005	0.01	46.6	46.6	< 0.005	4.96	4.97	354	0.02	0.06
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—`
Worker	< 0.005	< 0.005	0.02	0.00	0.00	0.31	0.31	0.00	0.08	0.08	4.71	< 0.005	< 0.005
Vendor	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.02	0.02	< 0.005	0.01	0.01	1.56	< 0.005	< 0.005
Hauling	< 0.005	0.08	0.03	< 0.005	< 0.005	8.51	8.51	< 0.005	0.91	0.91	58.5	< 0.005	0.01

4. Operations Emissions Details

4.10. Soil Carbon Accumulation by Vegetation Type

4.10.1. Soil Carbon Accumulation by Vegetation Type - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Vegetation	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—

4.10.2. Above and Belowground Carbon Accumulation by Land Use Type - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Land Use	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	—	—

4.10.3. Avoided and Sequestered Emissions by Species - Unmitigated

Criteria Pollutants (lb/day for daily, ton/yr for annual) and GHGs (lb/day for daily, MT/yr for annual)

Species	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Daily, Summer (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Avoided	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequestered	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Removed	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
Daily, Winter (Max)	—	—	—	—	—	—	—	—	—	—	—	—	—
Avoided	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequestered	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Removed	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
Annual	—	—	—	—	—	—	—	—	—	—	—	—	—
Avoided	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequestered	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
Removed	—	—	—	—	—	—	—	—	—	—	—	—	—

Species	ROG	NOx	CO	SO2	PM10E	PM10D	PM10T	PM2.5E	PM2.5D	PM2.5T	CO2T	CH4	N2O
Subtotal	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—

5. Activity Data

5.1. Construction Schedule

Phase name	Phase type	Start date	End date	Days per week	Workdays per phase	Phase description
Grading	Grading	1/1/2026	3/31/2026	5.00	64.0	Site grading would occur on the entire site (approximately 10 acres or 435,600 SF) to ensure required elevation is met. Site grading would begin in January 2026 and last approximately 3 months. Depth of grading was assumed to be 1 foot. It was assumed excavated fill would be reused on site and would not be hauled offsite.
Building Construction	Building Construction	10/1/2026	9/30/2028	5.00	522	Construction of buildings and ancillary facilities would occur on approximately 1 acre (43,560 SF). Building height was assumed to be 20 feet. Construction would begin in October 2026 and last approximately 24 months. The construction phase accounts for installation of equipment which would require construction worker trips, and equipment use (e.g., cranes, generator sets, welding equipment).
Paving	Paving	11/1/2028	12/31/2028	5.00	43.0	Paving would occur on approximately 2.5 acres (108,900 SF). Paving would begin in November 2028 and last approximately 2 months.
Architectural Coating	Architectural Coating	10/1/2028	10/31/2028	5.00	22.0	Architectural coatings would be applied to new buildings and ancillary facilities (approximately 1 acre or 43,560 SF). Architectural coating application would begin in October 2028 and last approximately 1 month.
Excavation	Trenching	4/1/2026	9/30/2026	5.00	131	Excavation/trenching would be required for utility installation and/or extension, building foundations, and equipment pads. Approximately 3 acres (130,680

Phase name	Phase type	Start date	End date	Days per week	Workdays per phase	Phase description
						SF) would be excavated or trenched. It was assumed equipment pads (approximately 2 acres or 87,120 SF) would be excavated to an average depth of 4 feet. It was assumed building foundations (approximately 1 acre or 43,560 SF) would be excavated to a depth of between 3 and 5 feet (average depth of 4 feet). It was assumed utility lines (approximately 1,000 linear feet) would be excavated to an average depth of 3.5 feet. The weighted average of site excavation depth was calculated at 4 feet. It was assumed excavated fill would be reused onsite and would not be hauled offsite. Approximately 15,000 CY of material (e.g., concrete, gravel) would be hauled onsite for equipment pads (e.g., concrete pads, hard-pack gravel pads). Excavation and trenching would begin in April 2026 and last approximately 6 months.

5.2. Off-Road Equipment

5.2.1. Unmitigated

Phase name	Equipment type	Fuel type	Engine tier	Number per day	Hours per day	Horsepower	Load factor
Grading	Excavators	Diesel	Average	1.00	8.00	36.0	0.38
Grading	Graders	Diesel	Average	1.00	8.00	148	0.41
Grading	Rubber Tired Dozers	Diesel	Average	1.00	8.00	367	0.40
Grading	Tractors/Loaders/Back hoes	Diesel	Average	3.00	8.00	84.0	0.37
Grading	Other Construction Equipment	Diesel	Average	1.00	8.00	82.0	0.42
Building Construction	Cranes	Diesel	Average	1.00	7.00	367	0.29
Building Construction	Forklifts	Diesel	Average	3.00	8.00	82.0	0.20
Building Construction	Generator Sets	Diesel	Average	1.00	8.00	14.0	0.74

Phase name	Equipment type	Fuel type	Engine tier	Number per day	Hours per day	Horsepower	Load factor
Building Construction	Tractors/Loaders/Backhoes	Diesel	Average	3.00	7.00	84.0	0.37
Building Construction	Welders	Diesel	Average	1.00	8.00	46.0	0.45
Paving	Pavers	Diesel	Average	2.00	8.00	81.0	0.42
Paving	Paving Equipment	Diesel	Average	2.00	8.00	89.0	0.36
Paving	Rollers	Diesel	Average	2.00	8.00	36.0	0.38
Paving	Cement and Mortar Mixers	Diesel	Average	4.00	6.00	10.0	0.56
Paving	Tractors/Loaders/Backhoes	Diesel	Average	1.00	8.00	84.0	0.37
Architectural Coating	Air Compressors	Diesel	Average	1.00	6.00	37.0	0.48
Excavation	Excavators	Diesel	Average	2.00	8.00	36.0	0.38
Excavation	Other General Industrial Equipment	Diesel	Average	1.00	8.00	35.0	0.34
Excavation	Tractors/Loaders/Backhoes	Diesel	Average	1.00	8.00	84.0	0.37

5.3. Construction Vehicles

5.3.1. Unmitigated

Phase name	Trip type	One-way trips per day	Miles per trip	Vehicle mix
Grading	—	—	—	—
Grading	Worker	17.5	11.7	LDA, LDT1, LDT2
Grading	Vendor	1.00	8.40	HHDT, MHDT
Grading	Hauling	0.00	20.0	HHDT
Grading	Onsite truck	2.00	10.0	HHDT
Building Construction	—	—	—	—
Building Construction	Worker	183	11.7	LDA, LDT1, LDT2
Building Construction	Vendor	71.4	8.40	HHDT, MHDT
Building Construction	Hauling	0.00	20.0	HHDT
Building Construction	Onsite truck	2.00	10.0	HHDT
Paving	—	—	—	—
Paving	Worker	27.5	11.7	LDA, LDT1, LDT2
Paving	Vendor	2.00	8.40	HHDT, MHDT
Paving	Hauling	0.00	20.0	HHDT
Paving	Onsite truck	2.00	10.0	HHDT

Phase name	Trip type	One-way trips per day	Miles per trip	Vehicle mix
Architectural Coating	—	—	—	—
Architectural Coating	Worker	36.6	11.7	LDA, LDT1, LDT2
Architectural Coating	Vendor	1.00	8.40	HHDT, MHDT
Architectural Coating	Hauling	0.00	20.0	HHDT
Architectural Coating	Onsite truck	1.00	10.0	HHDT
Excavation	—	—	—	—
Excavation	Worker	10.0	11.7	LDA, LDT1, LDT2
Excavation	Vendor	1.00	8.40	HHDT, MHDT
Excavation	Hauling	14.3	20.0	HHDT
Excavation	Onsite truck	2.00	10.0	HHDT

5.4. Vehicles

5.4.1. Construction Vehicle Control Strategies

Non-applicable. No control strategies activated by user.

5.5. Architectural Coatings

Phase name	Residential interior area coated (SF)	Residential exterior area coated (SF)	Non-residential interior area coated (SF)	Non-residential exterior area coated (SF)	Parking area coated (SF)
Architectural Coating	0.00	0.00	653,400	217,800	—

5.6. Dust Mitigation

5.6.1. Construction Earthmoving Activities

Phase name	Material imported (CY)	Material exported (CY)	Acres graded (acres)	Material demolished (SF)	Acres paved (acres)
Paving	0.00	0.00	0.00	0.00	2.50
Excavation	15,000	0.00	10.0	0.00	—

5.6.2. Construction Earthmoving Control Strategies

Non-applicable. No control strategies activated by user.

5.7. Construction Paving

Land use	Area paved (acres)	% Asphalt
General Heavy Industry	2.50	100%

5.8. Construction Electricity Consumption and Emissions Factors

kWh per Year and Emission Factor (lb/MWh)

Year	kWh per year	CO_2	CH_4	N_2O
2026	0.00	185	0.02	< 0.005
2027	0.00	185	0.02	< 0.005
2028	0.00	185	0.02	< 0.005

5.18. Vegetation

5.18.1. Land Use Change

5.18.1.1. Unmitigated

Vegetation Land Use Type	Vegetation Soil Type	Initial Acres		Final Acres
—	—	—	—	

5.18.1. Biomass Cover Type

5.18.1.1. Unmitigated

Biomass Cover Type	Initial Acres	Final Acres
—	—	—

5.18.2. Sequestration

5.18.2.1. Unmitigated

Tree Type	Number	Electricity Saved (kWh/year)		Natural Gas Saved (btu/year)
—	—	—	—	

6. User Changes to Default Data

Screen	Justification
Characteristics: Project Details	CalEEMod was selected as the model to estimate air emissions from construction of green hydrogen production facilities in Washington. The inputs were adjusted to account for meteorological conditions in the State of Washington.
Characteristics: Utility Information	Utility characteristics were changed to match those for Washington State. Greenhouse gas pollutant intensity factors are representative of all fuel sources for 2022 (https:/www.epa.gov/egrid).
Land Use	Green hydrogen production facility lower bound footprint is equal to 1 acre (approx. 43,560 SF). It was assumed 10% of the facility footprint would contain buildings (4,356 SF).
Construction: Construction Phases	A 3-year construction timeline was estimated for green hydrogen facility construction. Surrogate years of 2026 through 2028 were used. The following assumptions were used: • 100% of footprint would be disturbed (grading phase) • 30% of footprint would be excavated for foundations, underground utilities, and pads (excavation/trenching phase) • 20% of footprint would include pads for equipment/tanks/etc. • 10% of footprint would include structures (building construction and architectural coatings phases) • 25% of footprint would be paved surfaces (paving phase) • 45% of footprint (remaining of what's not buildings/pads/pavement) would be permeable surface (e.g., gravel, dirt, grass).
Construction: Off-Road Equipment	Updated equipment inputs to match construction phases.
Construction: Dust From Material Movement	For the lower bound scenario (1 acre footprint), approximately 3,000 CY of material (e.g., concrete, gravel) would be hauled onsite for equipment pads (e.g., concrete pads, hard-pack gravel pads). It was assumed excavated fill would be reused on site and would not be hauled offsite.
Construction: On-Road Fugitive Dust	During construction, a portion of vehicle movements would occur on unpaved roads.
Construction: Paving	Paving would occur on 25% of the facility footprint (approximately 0.25 acres or 10,890 SF).
Construction: Electricity	Greenhouse gas pollutant intensity factors revised to reflect the Washington statewide average and are representative of all fuel sources for 2022 (https:/www.epa.gov/egrid).

Attachment 3. Supplemental Calculations

Emissions factors are representative values that attempt to relate the quantity of a pollutant released with the activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant emitted per unit weight, volume, distance, or duration of the pollutant emitting activity.

Emissions from heating/boiler operation

Emissions Factors (lb/1000000 standard cubic foot[scf])

VOC	NO_X	CO	SO_X	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O
5.5	100	84	0.6	7.6	7.6	120019	2.26	2.26

Source: In most cases, these factors are simply an average of all available data of acceptable quality and are generally assumed to be representative of long-term averages for all emitters in the source category. The emission factors presented in this table are generally from the Compilation of Air Pollutant Emission Factors (AP-42) and WebFIRE (EPA's online emissions factor database).

Assumptions:

Type of Fuel: Natural Gas
Type of Boiler: Industrial
Heat Value (MMBtu/ft^3): 0.00105
Operating time per year (hours): 1,500

Formulas:

Heating Fuel Consumption ft^3 per Year

FCRC= OT * RC / HV / 1000000

FCRC: Fuel consumption for rated capacity method
OT: Operating time per year (hours)
RC: rated capacity of boiler/furnace (MMBtu)
HV: Heat value (MMBtu/ft^3)
1000000: Conversion factor

Heating Emissions per Year

HEPOL= FC * EFPOL / 2000

HEPOL: Heating emission emissions (tons)
FC: Fuel consumption
EFPOL: Emission factor for pollutant
2000: Conversion factor pounds to tons

Conversion tons to metric tons

MT/yr=tpy * 0.907185

MT/yr: Metric tons per year
Tpy: Tons per year
0.907185: Conversions factor tons to metric tons

Results:

Emissions from heating/boiler operations

Boiler capacity (MMBtu)	VOC [a]	NO_X [a]	CO [a]	SO_X [a]	PM_{10} [a]	$PM_{2.5}$ [a]	CO_2 [b]	CH_4 [b]	N_2O [b]
1	0.00393	0.07143	0.06000	0.00043	0.00543	0.00543	85.72786	0.00161	0.00161
5	0.01964	0.35714	0.30000	0.00214	0.02714	0.02714	428.63929	0.00807	0.00807
10	0.03929	0.71429	0.60000	0.00429	0.05429	0.05429	857.27857	0.01614	0.01614

[a] Criteria pollutants (tons per year).
[b] GHG (metric tons per year).

Attachment 4. Supplemental Calculations for Construction Fuel Estimates

1 acre - construction fuel use

Construction Equipment Use

Construction Phase	# days	Equipment Type	Fuel Type	Number/Day	Hours/Day	HP	Load Factor	Fuel Consumption Rate (gal/hr)	Duration Total (hrs)	Total Fuel Consumption (gal)	
Grading	22	Graders	Diesel	1	6	148	0.41	8.808	132	1162.656	
	22	Rubber Tired Dozers	Diesel	1	6	367	0.4	3.952	132	521.664	
	22	Tractors/Loaders/Backhoes	Diesel	1	7	84	0.37	1.7945	154	276.353	
	22	Excavators	Diesel	1	8	36	0.38	3.002	176	528.352	
	22	Other Construction Equipment	Diesel	1	8	82	0.42	1.7945	176	315.832	
Building Construction	153	Cranes	Diesel	1	4	367	0.29	3.3495	612	2049.894	
	153	Forklifts	Diesel	2	6	82	0.2	0.89	1836	1634.04	
	153	Tractors/Loaders/Backhoes	Diesel	2	8	84	0.37	1.7945	2448	4392.936	
	153	Generator Sets	Diesel	1	8	14	0.74	3.108	1224	3804.192	
	153	Welders	Diesel	1	8	46	0.45	1.035	1224	1266.84	
Paving	21	Cement and Mortar Mixers	Diesel	4	6	10	0.56	0.252	504	127.008	
	21	Pavers	Diesel	1	7	81	0.42	2.73	147	401.31	
	21	Rollers	Diesel	1	7	36	0.38	1.52	147	223.44	
	21	Tractors/Loaders/Backhoes	Diesel	1	7	84	0.37	1.7945	147	263.7915	
	21	Paving Equipment	Diesel	1	8	89	0.36	2.376	168	399.168	
Architectural Coating	23	Air Compressors	Diesel	1	6	37	0.48	1.872	138	258.336	
Excavation	42	Excavators	Diesel	1	8	36	0.38	3.002	336	1008.672	
	42	Other General Industrial Equipment	Diesel	1	8	35	0.34	1.7945	336	602.952	
	42	Tractors/Loaders/Backhoes	Diesel	1	8	84	0.37	1.7945	336	602.952	
Total Fuel Consumption (gallons)										19840.3885	Diesel

Worker and Vendor Trips

Construction Phase	#days	Type	Fuel Type	#one-way trips per day	one-way Trip Length	Vehicle Class	Total one-way trips	VMT	Fuel Consumption (mpg)	Fuel Consumption (gal)	
Grading	22	Worker	Gasoline	13	11.7	LDA, LDT1, LDT2	286	3346.2	21	159.3428571	
	22	Vendor	Diesel	1	20	HHDT, MHDT	22	440	8	55	
	22	Onsite Truck	Diesel	1	10	HHDT	22	220	6.2	35.48387097	
Building Construction	153	Worker	Gasoline	18	11.7	LDA, LDT1, LDT2	2754	32221.8	21	1534.371429	
	153	Vendor	Diesel	7	8.4	HHDT, MHDT	1071	8996.4	8	1124.55	
	153	Onsite Truck	Diesel	1	10	HHDT	153	1530	6.2	246.7741935	
Paving	21	Worker	Gasoline	20	11.7	LDA, LDT1, LDT2	420	4914	21	234	
	21	Vendor	Diesel	1	8.4	HHDT, MHDT	21	176.4	8	22.05	
	21	Onsite Truck	Diesel	1	10	HHDT	21	210	6.2	33.87096774	
Architectural Coating	23	Worker	Gasoline	4	11.7	LDA, LDT1, LDT2	92	1076.4	21	51.25714286	
	23	Vendor	Diesel	1	8.4	HHDT, MHDT	23	193.2	8	24.15	
	23	Onsite Truck	Diesel	1	10	HHDT	23	230	6.2	37.09677419	
Excavation	42	Worker	Gasoline	8	11.7	LDA, LDT1, LDT2	336	3931.2	21	187.2	
	42	Vendor	Diesel	1	8.4	HHDT, MHDT	42	352.8	8	44.1	
	42	Hauling	Diesel	9	20	HHDT	378	7560	6.2	1219.354839	
	42	Onsite Truck	Diesel	1	10	HHDT	42	420	6.2	67.74193548	
Total Fuel Consumption (gallons)										2910.172581	Diesel
										2166.171429	Gasoline

Notes

The construction equipment fuel usage was calculated through use of the off-road equipment assumptions utilized in the CalEEMod model run and the fuel usage calculations derived from similar studies (linked below).

https://bchd.blob.core.windows.net/docs/hlc/Appendix%20E-Construction%20Fuel%20Consumption%20Calculations1.pdf

https://www.santamonica.gov/media/Housing-Element-Update-2021-to-2029/APPENDIX%20E-ENERGY%20CAKCULATIONS.pdf

10 acres - construction fuel use

Construction Equipment Use

Construction Phase	# days	Equipment Type	Fuel Type	Number/Day	Hours/Day	HP	Load Factor	Fuel Consumption Rate (gal/hr)	Duration Total (hrs)	Total Fuel Consumption (gal)	
Grading	64	Graders	Diesel	1	8	148	0.41	8.808	512	4509.696	
	64	Rubber Tired Dozers	Diesel	1	8	367	0.4	3.952	512	2023.424	
	64	Tractors/Loaders/Backhoes	Diesel	3	8	84	0.37	1.7945	1536	2756.352	
	64	Excavators	Diesel	1	8	36	0.38	3.002	512	1537.024	
	64	Other Construction Equipment	Diesel	1	8	82	0.42	1.7945	512	918.784	
Building Construction	522	Cranes	Diesel	1	7	367	0.29	3.3495	3654	12239.073	
	522	Forklifts	Diesel	3	8	82	0.2	0.89	12528	11149.92	
	522	Tractors/Loaders/Backhoes	Diesel	3	7	84	0.37	1.7945	10962	19671.309	
	522	Generator Sets	Diesel	1	8	14	0.74	3.108	4176	12979.008	
	522	Welders	Diesel	1	8	46	0.45	1.035	4176	4322.16	
Paving	43	Cement and Mortar Mixers	Diesel	4	6	10	0.56	0.252	1032	260.064	
	43	Pavers	Diesel	2	8	81	0.42	2.73	688	1878.24	
	43	Rollers	Diesel	2	8	36	0.38	1.52	688	1045.76	
	43	Tractors/Loaders/Backhoes	Diesel	1	8	84	0.37	1.7945	344	617.308	
	43	Paving Equipment	Diesel	2	8	89	0.36	2.376	688	1634.688	
Architectural Coating	22	Air Compressors	Diesel	1	6	37	0.48	1.872	132	247.104	
Excavation	131	Excavators	Diesel	2	8	36	0.38	3.002	2096	6292.192	
	131	Other General Industrial Equipment	Diesel	1	8	35	0.34	1.7945	1048	1880.636	
	131	Tractors/Loaders/Backhoes	Diesel	1	8	84	0.37	1.7945	1048	1880.636	
Total Fuel Consumption (gallons)										87843.378	Diesel

Worker and Vendor Trips

Construction Phase	#days	Type	Fuel Type	#one-way trips per day	one-way Trip Length	Vehicle Class	Total one-way trips	VMT	Fuel Consumption (mpg)	Fuel Consumption (gal)	
Grading	64	Worker	Gasoline	17.5	11.7	LDA, LDT1, LDT2	1120	13104	21	624	
	64	Vendor	Diesel	1	20	HHDT, MHDT	64	1280	8	160	
	64	Onsite Truck	Diesel	2	10	HHDT	128	1280	6.2	206.4516129	
Building Construction	522	Worker	Gasoline	183	11.7	LDA, LDT1, LDT2	95526	1117654.2	21	53221.62857	
	522	Vendor	Diesel	71.4	8.4	HHDT, MHDT	37270.8	313074.72	8	39134.34	
	522	Onsite Truck	Diesel	2	10	HHDT	1044	10440	6.2	1683.870968	
Paving	43	Worker	Gasoline	27.5	11.7	LDA, LDT1, LDT2	1182.5	13835.25	21	658.8214286	
	43	Vendor	Diesel	2	8.4	HHDT, MHDT	86	722.4	8	90.3	
	43	Onsite Truck	Diesel	2	10	HHDT	86	860	6.2	138.7096774	
Architectural Coating	22	Worker	Gasoline	36.6	11.7	LDA, LDT1, LDT2	805.2	9420.84	21	448.6114286	
	22	Vendor	Diesel	1	8.4	HHDT, MHDT	22	184.8	8	23.1	
	22	Onsite Truck	Diesel	1	10	HHDT	22	220	6.2	35.48387097	
Excavation	131	Worker	Gasoline	10	11.7	LDA, LDT1, LDT2	1310	15327	21	729.8571429	
	131	Vendor	Diesel	1	8.4	HHDT, MHDT	131	1100.4	8	137.55	
	131	Hauling	Diesel	14.3	20	HHDT	1873.3	37466	6.2	6042.903226	
	131	Onsite Truck	Diesel	2	10	HHDT	262	2620	6.2	422.5806452	
Total Fuel Consumption (gallons)										48075.29	Diesel
										55682.91857	Gasoline

Notes

The construction equipment fuel usage was calculated through use of the off-road equipment assumptions utilized in the CalEEMod model run and the fuel usage calculations derived from similar studies (linked below).

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https://www.santamonica.gov/media/Housing-Element-Update-2021-to-2029/APPENDIX%20E-ENERGY%20CAKCULATIONS.pdf