



WASHINGTON
PHYSICIANS
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RESPONSIBILITY

FRACKED GAS INFRASTRUCTURE:

A THREAT TO HEALTHY COMMUNITIES

A Special Report and Recommendations to the Governors of Oregon and Washington
by
Oregon Physicians for Social Responsibility
and
Washington Physicians for Social Responsibility

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EXECUTIVE SUMMARY

Introduction

- Six major fracked gas¹ infrastructure projects are proposed in Oregon and Washington, including pipelines, refineries, liquefaction, and export facilities.
- The locales targeted for these developments are economically stressed and suffer a disproportionate burden of underlying morbidity and mortality.
- The new gas infrastructure threatens to degrade the health of these communities.
- Massive increases in greenhouse gas emissions associated with the infrastructure would also contribute significantly to climate change.

Climate Change and Health

- Regional climate change effects include drought, floods, extreme weather events, forest fires, sea-level rise, and ocean acidification.
- Climate change related adverse health effects include traumatic injury, death, heart disease, lung disease, infectious disease, heat-related disorders, stress, and mental health disorders.
- Those most susceptible to the ill effects of climate change include low income and immigrant persons, communities of color, babies, pregnant women, the elderly and those with chronic disease.

Communities at Risk

- Communities targeted for gas infrastructure development have lower median household incomes and higher unemployment rates.
- Residents also suffer higher rates of overall mortality, premature mortality, cancer, cardiovascular disease, and lung disease.
- Nearly all targeted communities are rated as those most vulnerable to climate change.
- Tribal communities would suffer disproportionate impacts on their traditional economic, spiritual, and cultural practices.

¹ The major share of so-called natural gas entering the Pacific Northwest, the chief component of which is methane gas, is extracted through the unconventional process of hydraulic fracturing or “fracking.” Throughout this document it will be referred to as “fracked gas.”

Air Pollution

- The full extent of air pollution due to the fracked gas industry is under-researched and inadequately understood due to a lax regulatory environment, inadequate air quality monitoring, and industry secretiveness.
- Documented toxic emissions from fracked gas transport and processing facilities include diesel particulate matter, nitrogen oxides, carbon monoxide, volatile organic compounds, polycyclic aromatic hydrocarbons, formaldehyde, ozone, and heavy metals.
- These air toxics are linked to cancer; cardiovascular, pulmonary, neurological, hormonal and developmental disorders; and poor pregnancy outcomes.

Water Pollution

- Local economies are dependent on abundant clean and fresh water for human consumption, agriculture and livestock, manufacturing, transportation, energy production, and recreation.
- Fracked gas infrastructure consumes massive quantities of water while discharging thousands of chemicals, with known adverse health effects, including cancer, into waterways and drinking water systems.
- Pipeline construction and operation can increase turbidity, remove riparian vegetation and increase stream temperatures, increasing the risk of harmful algae blooms and loss of drinking water.
- Construction and operation of pipelines and processing plants and/or related dredging degrade aquatic habitat for commercially and culturally important fish, shellfish, and other wildlife.

Noise Pollution

- Fracked gas infrastructure is associated with high levels of both intermittent and continuous noise.
- Exposure to high levels of noise is linked to hearing loss, hypertension, reduced learning and productivity, hormonal disruption, and heart disease.
- Construction activities are exempt from noise regulation in both Oregon and Washington.

Natural and Human-caused Disasters

- Fracked gas and its products are highly flammable and explosive; gas pipelines have a particularly poor safety record.

- Fracked gas infrastructure in the Pacific Northwest is uniquely vulnerable to the risks of earthquake, tsunami, inundation, and wildfire.
- Fires, explosions, and vapor clouds lead to traumatic injury and death as well as toxic releases into air and water.

Occupational Health and Safety

- The gas industry is exempt from disclosing the chemicals they use and from most federal statutes protecting worker health and safety.
- Workers in the fossil fuel industry are exposed to myriad health risks and are killed on the job at rates four to seven times higher than other industries.
- Workers in the fracked gas industry are vulnerable to industrial accidents, exposure to benzene, hydrogen sulfide and other toxins, silicosis, and exposure to radiation and noise.

Temporary Labor Camps

- Temporary labor camps associated with fracked gas facilities impose outsized impacts on local infrastructure, public services, and public health through increases in crime, drug use, assaults, kidnapping, sex trafficking, and sexually transmitted infections.
- Native American communities, especially women and girls, have suffered disproportionately from these impacts.

Health Effects of Hydraulic Fracturing (Fracking)

- Most of the gas piped into Oregon and Washington is fracked gas.
- The fracking process degrades the environment of surrounding communities through toxic contamination of air and water with hundreds of chemicals with known associations to cancer, heart and lung disease, developmental disorders, and poor pregnancy outcomes.

INTRODUCTION

Planet Earth, according to the October 2018 special report from the Intergovernmental Panel on Climate Change (IPCC),² has now already warmed by 1.0° C above pre-industrial levels. The report, by the United Nations body for assessing the science related to climate change, reiterates the need to limit global warming to 1.5° C to avoid rendering large swaths of the world uninhabitable with devastating effects on human health and well-being.

But according to a January 2019 report by Oil Change International, “Between now and 2030, the United States is on track to account for 60 percent of world growth in oil and gas production, expanding extraction at least four times more than any other country.”³ Independent researchers drew on industry and governmental data sources to make the case that this level of production would prohibit achieving the IPCC goal of 1.5° C global warming.⁴

The Pacific Northwest figures large in the gas sector’s plans for transporting, refining, processing, liquefying, and exporting fracked gas and its products. The fracking boom in the U.S., along with growing Canadian extraction of gas, has produced an abundant supply of cheap gas⁵ which has outstripped domestic markets, leading corporate owners to seek overseas markets, primarily in Asia. To the gas industry, the West Coast is ideally situated for the development of processing and export facilities. Six separate proposals in Oregon and Washington, if brought to completion, would entail massive increases in global fracked gas consumption and greenhouse gas (GHG) emissions and would accelerate the pace of global warming.^{6 7 8} This unprecedented expansion of fracked gas infrastructure on the lands, waterways, and coastlines of the Pacific Northwest presents unacceptable risks to the health of our communities, both local and global.

² (Intergovernmental Panel on Climate Change, 2018)

³ (Trout, January, 2019)

⁴ (Mutitt, 2016)

⁵ (U.S. Energy Information Administration, n.d.)

⁶ (DePlace E. &, 2018)

⁷ (Erickson, Towards a Climate Test for Industry: Assessing a Gas-based Methanol Plant, 2018)

⁸ (Stockman & McGarry, Jordan Cove and Pacific Connector Pipeline Greenhouse Gas Emissions, 2018)

The Projects

Proposals for new fracked gas infrastructure include:

- Jordan Cove Liquefied Natural Gas (LNG) project, also known as the Jordan Cove Energy Project, in Coos Bay, Oregon, which proposes to receive up to 1.2 billion cubic feet of gas per day and export up to 7.8 million metric tons of LNG annually to markets in Asia.⁹ The LNG facility would be located on the north spit of Coos Bay, 7.5 miles upstream from the mouth of the channel. Less than a quarter mile across the waterway lies the town of North Bend and the Southwest Regional Airport. The 500-acre parcel of land on which the facility and terminal would be sited also lies on the traditional territory of the Coos Tribe, Siletz Tribe and others.
- Jordan Cove LNG includes construction of the Pacific Connector Gas Pipeline (PCGP), a three-foot diameter, 229-mile pipeline through four rural counties in southwest Oregon, which would transport up to 1.2 billion cubic feet of fracked gas per day to the Jordan Cove facility. The pipeline would stretch between the town of Malin in Klamath County to Jordan Cove in Coos County, slashing through pristine wilderness areas of southwest Oregon, multiple drinking watersheds, as well as hundreds of farms, ranches, and small towns and the traditional territories of many tribes, including the Klamath, Yurok, and Karuk tribes who oppose the project. Eminent domain would need to be deployed to force hundreds of local landowners to accommodate the pipeline.
- Curzon Energy coal bed methane extraction wells, which involve an unconventional extraction process distinct from hydraulic fracturing. Curzon owns 47,000 acres of coalbed gas accumulations in rural Coos County where they have drilled 5 wells and laid 4 miles of pipeline.¹⁰ As of December 2018 the project has been suspended due to lower than expected yields.¹¹ However, an April 2019 report to investors states that deeper drilling and exploration in Coos County is proceeding.
- Kalama Methanol Refinery, the world's largest methane to methanol refinery in the Port of Kalama, Washington, which would produce up to 3.6 million tons of methanol annually for export to China.^{12 13} The company, Northwest Innovation Works (NWIW), also proposes a

⁹ (Draft Environmental Impact Statement for the Jordan Cove Energy Project, 2019)

¹⁰ (Curzon Energy, n.d.)

¹¹ (Proactiveinvestors, 2018)

¹² (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

methanol refinery of similar size in Port Westward, Oregon.¹⁴ The refinery in Kalama would be sited on the Columbia River at the north end of the Port of Kalama Marine Park, about 2 miles from downtown Kalama and less than 1 mile from residences. The project includes construction of a new 3-mile pipeline, the Kalama Lateral Pipeline.

- The second NWIW proposed methanol refinery would be constructed at Port Westward, in the Columbia River Estuary, which includes juvenile salmon habitat. It could be located about 8 miles away from the town of Clatskanie and in the midst of prime agricultural land.
- Pacific Coast Fertilizer, a proposed fertilizer plant in Longview, Washington, would utilize 50 million cubic feet of methane per day to produce anhydrous ammonia-based fertilizer for local markets.¹⁵ The plant would be located on the Mint Farm Industrial Park which lies in close proximity to residential neighborhoods.
- Puget Sound LNG in Tacoma, Washington, which would produce up to 500,000 gallons of LNG per day for use primarily as a domestic commercial marine fuel.^{16 17} The facility is being constructed on 33 acres of the Blair-Hylebos Peninsula in the Port of Tacoma, directly on top of traditional and culturally important Puyallup Indian tribal lands. The site is also adjacent to 3 sites still undergoing clean-up processes related to historic industrial contamination. The project will require construction of 5 miles of connecting gas pipelines.

A map illustrating the locations of these facilities can be found [here](#).

The gas industry also hopes to expand local residential and commercial markets for gas through smaller projects like the Williams Company upgrade of the North Seattle Lateral Pipeline. This seemingly modest project would have the potential to increase carbon pollution in Washington State by as much as 5%, while attracting less regulatory attention.¹⁸

No hydraulic fracturing (fracking) wells are currently operational or proposed in either Oregon or Washington. According to the U.S. Energy Information Administration neither Oregon

¹³ (Draft Supplemental Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, 2018)

¹⁴ (Zimmer-Stucky, 2018)

¹⁵ (DePlace E. &, 2017)

¹⁶ (Final Environmental Impact Statement: PSE LNG, 2016)

¹⁷ (Draft Supplemental Environmental Impact Statement: Proposed Tacoma Liquefied Natural Gas Project, 2018)

¹⁸ (DePlace E. , Small Seattle Pipeline Expansion would mean Big Carbon Pollution Increase , 2019)

nor Washington has significant gas reserve potential for fracking.¹⁹ Oregon has only one gas producing site near the town of Mist in Columbia County, which deploys conventional drilling to extract gas from porous sandstone. The Snake River Basin is thought to be another source of gas reserves. Three permits have been issued for conventional gas drilling in the area, but no drilling has taken place.²⁰

No gas has been produced in the state of Washington for decades.²¹ However, the Pacific Coal Region lies along the western and eastern flanks of the Cascade Range, extending from Canada into southern Oregon.²² The coal beds are known to contain methane, which could be extracted through an unconventional process called coal bed methane extraction. Coal bed methane extraction does not entail injection of fracking fluids under pressure, but does result in accumulation of many of the same toxic fluids and presents similar problems with aquifer and groundwater contamination. The only proposed unconventional gas extraction project in the Pacific Northwest is Curzon's coal bed project, noted above. Figure 1 illustrates the location of the coal beds and currently permitted projects in Oregon.

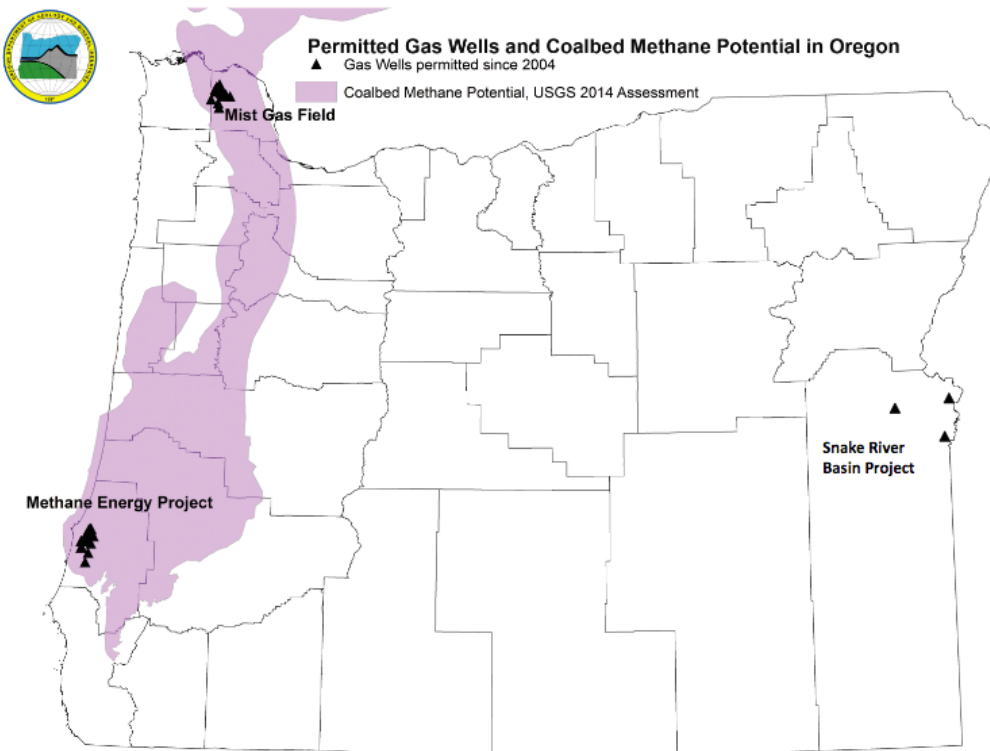
¹⁹ (U.S. Energy Information Administration, n.d.)

²⁰ (Oregon Department of Geology and Mineral Industries, 2019)

²¹ (Washington State Department of Natural Resources)

²² (U.S. Environmental Protection Agency, 2004)

Figure 1



Oregon's only producing gas field, near the town of Mist in northwest Oregon, has been producing gas from a sandstone reservoir since 1980. The reservoir is so permeable that hydraulic fracturing has never been required to economically produce gas. The US Geological Survey recently published an assessment of coalbed methane gas potential. Hydraulic fracturing may be required to develop those resources.

In 2019, the Oregon Legislature passed a 5-year moratorium on fossil fuel fracking, which was signed by the governor on June 17th, 2019.²³ The moratorium exempts coalbed extraction wells with existing permits, like the Curzon project. Also in 2019, the Washington Legislature passed a permanent ban on fracking, which the governor has signed into law.²⁴

The Corporations

The corporate entities behind fracked gas infrastructure proposals claim that jobs and tax revenue would benefit host communities.^{25 26 27 28} Rarely, if ever, do their calculations include the economic losses and human suffering associated with the projects through toxic contamination of air, land and water; human-caused and natural disasters; displacement of economic activities such as

²³ (Oregon State Legislature, n.d.)

²⁴ (Washington State Legislature, n.d.)

²⁵ (Jordan Cove LNG, n.d.)

²⁶ (North West Innovation Works, n.d.)

²⁷ (Pacific Coast Fertilizer, n.d.)

²⁸ (Puget Sound Energy, n.d.)

fishing, recreation, and tourism; desecration of culturally and historically significant sites; and loss of habitat and despoliation of the environment. All of these deleterious effects are associated directly or indirectly with increased sickness and death in affected communities.

Corporate sponsors additionally claim that the net effect of these projects would be a *decrease* in global greenhouse gas emissions,^{29 30 31 32} an assertion challenged by several independent scientific researchers.^{33 34 35 36 37 38 39 40} Intentionally or not, companies frequently base their claims on outdated or corporate-sponsored data. For example, the [lifecycle analysis](#) of methane emissions for the Kalama methanol refinery, paid for by NWIW, uses the 2007 [global warming potential metric](#) (GWP) of 25,⁴¹ which was scientifically recalculated and updated by the IPCC in 2018 to 34.⁴² The NWIW sponsored analysis also employs a methane [fugitive emission](#) rate of 0.32%, while the most recent science places the figure at 2.3% or higher.⁴³

Similar misleading metrics were applied in the lifecycle analysis (LCA) of Puget Sound LNG included in the 2019 Final Supplemental Environmental Impact Statement (FSEIS), which employed, for example, only a 100-year time frame for estimating GHG effects of methane rather than including a time frame of 20 years.⁴⁴ This in itself reduces the apparent GWP of methane by nearly threefold. The erroneous metrics and unrealistic assumptions result in analyses that are deeply flawed and a gross underestimate of the actual impact of the facilities on global warming.

The lifecycle analysis for Kalama’s methanol refinery additionally asserts that 100% of the refined methanol would replace dirtier coal in the manufacture of plastics in China, a claim that is impossible to support.⁴⁵ At the same time the chairman of the Chinese parent company of Northwest Innovation Works told Reuters that the company wants to “drive use of methanol as a transportation

²⁹ (Hoard, 2018; Ecology and Environment, Inc, 2019)

³⁰ (Northwest Innovation Works, n.d.)

³¹ (Pacific Coast Fertilizer, n.d.)

³² (Ecology and Environment, Inc, 2019)

³³ (Erickson, Towards a Climate Test for Industry: Assessing a Gas-based Methanol Plant, 2018)

³⁴ (Mutitt, 2016)

³⁵ (Stockman & McGarry, Jordan Cove and Pacific Connector Pipeline Greenhouse Gas Emissions, 2018)

³⁶ (Trout, January, 2019)

³⁷ (DePlace E. , 2016)

³⁸ (Byrnes, 1990)

³⁹ (Sanders, 2012)

⁴⁰ (Stockman, Burning the Gas 'Bridge-fuel' Myth, 2017)

⁴¹ (Erickson, SEI Comments on Kalama DSEIS, 2108)

⁴² (Intergovernmental Panel on Climate Change, 2018)

⁴³ (Alvarez, 2018)

⁴⁴ (Ecology and Environment, Inc, 2019)

⁴⁵ (DePlace E. &-D., 2018)

fuel for cars and ships” in China.⁴⁶ In early 2019 Columbia Riverkeeper came into possession of documents that revealed how NWIW is selling the project to investors as a source of fuel for China, not for use in the plastics industry.⁴⁷ The evidence calls into question the entire lifecycle analysis for the project and illustrates the company’s willingness to mislead or outright lie to the local community and regulators.

Citizens in Tacoma have faced the additional aggravation of both public and private entities that are reluctant to or outright refuse to share information about the LNG facility, which is already under construction in the heart of their community without the proper permits in place.⁴⁸ Tarika Powell, an environmental lawyer and researcher with Sightline Institute, testified in court about this issue and related violations of the public’s “right to know.”⁴⁹ Much farther south, Oregon’s Department of Environmental Quality (DEQ) took Jordan Cove LNG to task for failing to respond to their requests for specific information.⁵⁰

The fossil fuel industry is notorious for promoting misleading and erroneous information.⁵¹ Perhaps not all the corporations seeking a toehold in the Pacific Northwest engage in duplicity, utilize outdated science, or withhold information, but they have amply demonstrated a lack of ethics, transparency, and integrity. Communities in Oregon and Washington are justifiably wary of partnering with them.

The gas industry is, in addition, a poor investment for communities to make. Supply is at an all-time high and prices at an all-time low. The record amount of gas produced over the past decade has been at a loss and gas companies are in debt.^{52 53} The industry’s attempt to force prices up by increasing demand, that is, by expanding their markets in Asia through export from west coast terminals, will only backfire. As gas prices go up, they will not be able to compete with cheaper renewable energy sources, whose prices continue to fall.⁵⁴ Local communities would then be stuck with dirty and unprofitable infrastructure, saddling their economies with the costs of decommissioning and clean-up.

⁴⁶ (Aizhu, 2017)

⁴⁷ (Solomon, 2019)

⁴⁸ (Hanchard, 2017)

⁴⁹ (Powell T. , Sightline Testifies at Hearing for Tacoma LNG Protesters, 2018)

⁵⁰ (Oregon Department of Environmental Quality, 2018)

⁵¹ (Hope, 2019)

⁵² (Mikulka, The Inevitable Death of Natural Gas as a 'Bridge Fuel", 2019)

⁵³ (Mikulka J. , 2019)

⁵⁴ (Mikulka, The Inevitable Death of Natural Gas as a 'Bridge Fuel", 2019)

The fracked gas industry has capitalized on decades of de-regulation, tax favors, and weakening of both the public sector and citizen rights to flood the market with cheap gas, accelerate the pace of global climate change, and degrade our health and well-being. Local communities targeted for new fracked gas infrastructure are confronted with a false choice between a healthy economy and a healthy environment. In fact, the two go hand-in-hand, but the fracked gas industry has no contribution to make to either.

The Communities

Proposed projects could directly harm hundreds of thousands of persons, including:

- Hundreds of farms, ranches, and small towns in rural SW Oregon
- North Bend and Coos Bay Oregon, which have yet to recover from the collapse of the fisheries and timber trade
- Residents of prime agricultural land around Port Westward, Oregon
- Port towns of Kalama and Longview, which struggle to find their economic footing
- The city of Tacoma, still in recovery from its toxic industrial past
- Native American communities of both Oregon and Washington

Almost without exception, the port cities and towns and rural areas targeted for fracked gas infrastructure development are those which have been left behind in the economic expansion following the Great Recession of 2008. Compared to statewide averages, these locales are characterized by higher unemployment rates, lower median household incomes, and a disproportionate burden of morbidity and mortality, including cancer, heart, and lung disease; people in these communities are sicker and they die younger. All of these locales are, or were, places of stunning natural beauty and abundant natural resources like native forests, wildlife, fish, shellfish, and clean water.

Native American communities would bear additional adverse impacts on their cultural heritage and traditional economic activities. Many tribal nations of both Oregon and Washington are deeply opposed to projects constructed on tribal lands that impact their livelihoods and threaten their ways of life.

Private landowners in the path of the Pacific Connector Gas Pipeline would also face devaluation of their property, environmental degradation of their lands, and increased risks of fire, explosion, and toxic spills. For the pipeline to be built, property would need to be seized from

reluctant landowners through declarations of eminent domain. In its 2016 denial of the pipeline project, the Federal Energy Regulatory Commission concluded that the public benefits of the project did not justify the use of eminent domain.⁵⁵

Most of these communities are desperate for jobs and tax revenue and are understandably eager for economic development. Economic prosperity is a necessary condition for healthy communities. Any benefits of fossil fuel infrastructure, however, represent short-term economic gains at most. If benefits come at all, they would be at the expense of short- and long-term economic losses, environmental degradation, increased global warming, and increased rates of sickness and death.

The construction and operation of these facilities alone would exact a toll including:

- Toxic pollution of air, water, and land
- Noise pollution
- Increased risk of natural and human-caused disasters
- Occupational health and safety risks
- Adverse impacts of large, temporary encampments of workers

These targeted communities have the most to lose. They are among the areas where the adverse health impacts of climate change will hit the hardest. In addition, local authorities lack resources and expertise to adequately evaluate the welter of technical data presented in the proposals. When debates are dominated by technical issues, more fundamental issues become obscured. Who benefits? Who loses? Who assumes the risks to safety and health? How do these projects square with local cultures, values, and ways of life? These are questions that are too often lost or ignored, but they are the questions basic to the future communities want to build for themselves.

A Just Transition

The precautionary principle of public health holds that when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.⁵⁶

⁵⁵ (Federal Energy Regulatory Commission, 2016)

⁵⁶ (Vu, 2017)

In accordance with the precautionary principle, the American Public Health Association has called for a cessation of all unconventional (which includes fracking) gas and oil exploration and development. The APHA notes that: “In contrast to the precautionary principle employed through most of Europe, the United States employs a risk-based approach wherein, in most cases, companies utilizing unconventional drilling and its associated technologies are issued drilling permits and extraction is conducted before there is a full understanding of potential risks to the environment and human health.”⁵⁷

The states of Oregon and Washington are uniquely positioned to put the brakes on the expanded production and export of fracked gas. Gas that cannot be processed and exported or otherwise brought to market is gas that is no longer profitable to produce. State resources and policies should alternatively aim at a just transition to clean and renewable energy, sources that impose far less risk to health and safety. (U.S. Environmental Protection Agency, n.d.)

The EPA defines environmental justice as the “fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. This goal will be achieved when everyone enjoys the same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.”⁵⁸

A just transition means ensuring that nobody is left behind in the shift from fossil fuels to a clean energy economy. It includes deep investments in clean and green economic opportunities for stressed and at-risk communities. A just transition would include:

- Dedicating funds to help communities affected by climate change
- Government support for workers who lose their jobs in the phase-out of fossil fuel facilities
- Upgrading and weatherization of existing buildings to achieve energy efficiency, safety, and affordability
- Repairing and upgrading public infrastructure such as bridges, roadways, and water systems
- Building or upgrading power grids to provide efficient and affordable electricity
- Investing in renewable power sources
- Supporting family farming and investing in sustainable farming

⁵⁷ (American Public Health Association, 2018)

⁵⁸ (U.S. Environmental Protection Agency, n.d.)

- Investing in public transit and zero-emission vehicle infrastructure and manufacturing
- Restoring ecosystems through land preservation and reforestation
- Cleaning up existing hazardous waste and abandoned sites

Oregon and Washington are two of eighteen states that signed on to the U.S. Climate Alliance, pledging to “accelerate new and existing policies to reduce carbon pollution and promote clean energy deployment.”⁵⁹ Allowing the Pacific Northwest to become a national hub for processing and shipment of fracked gas and its products flies in the face of this pledge. Promotion of fracked gas only delays the necessary transition to clean energy.⁶⁰ Expansion of fracked gas infrastructure locks communities into decades of dependence on fossil fuel that crowds out development of cleaner, safer alternatives.⁶¹

The adverse effects of global climate change are already upon us and will only worsen in the coming years in the absence of vigorous and sustained reductions in GHG emissions. The effects will land hardest on the youngest, the oldest, the sickest, and most economically stressed among us. These same individuals and communities should not be forced out of economic necessity to tie their futures to a polluting and dying fossil fuel industry.

Climate change mitigation, on the other hand, would produce immediate health benefits for our communities.⁶² Promoting healthy communities is a key strategy toward mitigation of, preparation for, and recovery from climate-related events and disasters. Denying the fracked gas industry access to our lands and our waterways is a necessary step toward building the healthy communities that will help ensure our future prosperity.

⁵⁹ (United States Climate Alliance: About Us, n.d.)

⁶⁰ (Staddon P L, 2015)

⁶¹ (Trout, January, 2019)

⁶² (Vossler M. , Thomas, Kitchell, Idzerda, & Cornett, 2018)

RECOMMENDATIONS

Oregon Physicians for Social Responsibility and Washington Physicians for Social Responsibility oppose any expansion of transport, storage, or shipment of fracked gas within our states on the basis of very serious, credible threats to the health of our residents. Further, we call upon the governors of Washington and Oregon, as well as agencies in both states, to deny permits that facilitate the expanded production, transport, storage, and/or handling of fracked gas. Our commitment as health professionals to improving the health of the public and achieving equity in health status demands that we clearly and unequivocally communicate the urgent need to transition away from fossil fuels to clean and equitable renewable energy sources.

We further endorse the many recommendations of the American Public Health Association regarding all activities associated with unconventional (fracked) gas,⁶³ including:

- No new development of fracked gas infrastructure.
- A strategic phase-out of existing fracked gas infrastructure, consistent with CO2 reduction goals and minimization of harm to communities economically dependent on fracked gas infrastructure.
- Requirements that energy companies disclose and receive approval for all chemicals proposed for use in fracked gas infrastructure.
- Monitoring of air, soil, and water quality impacted by ongoing fracked gas activities, during the period of phase-out and following shut-down, until recovery is achieved.
- Establishment of a registry for active surveillance of community and worker health affected by fracked gas-related activities.
- Immediate cessation of fracked gas activities if negative human health or environmental effects are observed, until further evidence indicates that operations can be safely resumed.

⁶³ (American Public Health Association, 2018)

CLIMATE CHANGE AND HEALTH

Analyses of current scientific evidence predict the following impacts of climate change on the Pacific Northwest:^{64 65 66 67}

- An overall warming trend
- More extreme heat events
- Significant loss of snowpack
- Increased drought
- Increased flooding
- Higher intensity and increased distribution of wildfires
- Sea-level rise
- Increased ocean acidity

These effects will have wide-ranging impacts on the health and well-being of Pacific Northwest communities, as summarized in Figure 2 from the Fourth National Climate Assessment (NCA4).⁶⁸

⁶⁴ (May, 2018)

⁶⁵ (Hamilton, 2009)

⁶⁶ (Vynne, 2011)

⁶⁷ (Snover, 2013)

⁶⁸ (Ebi, 2018)

Figure 2

Social, Economic, and Environmental Impacts of Climate Change

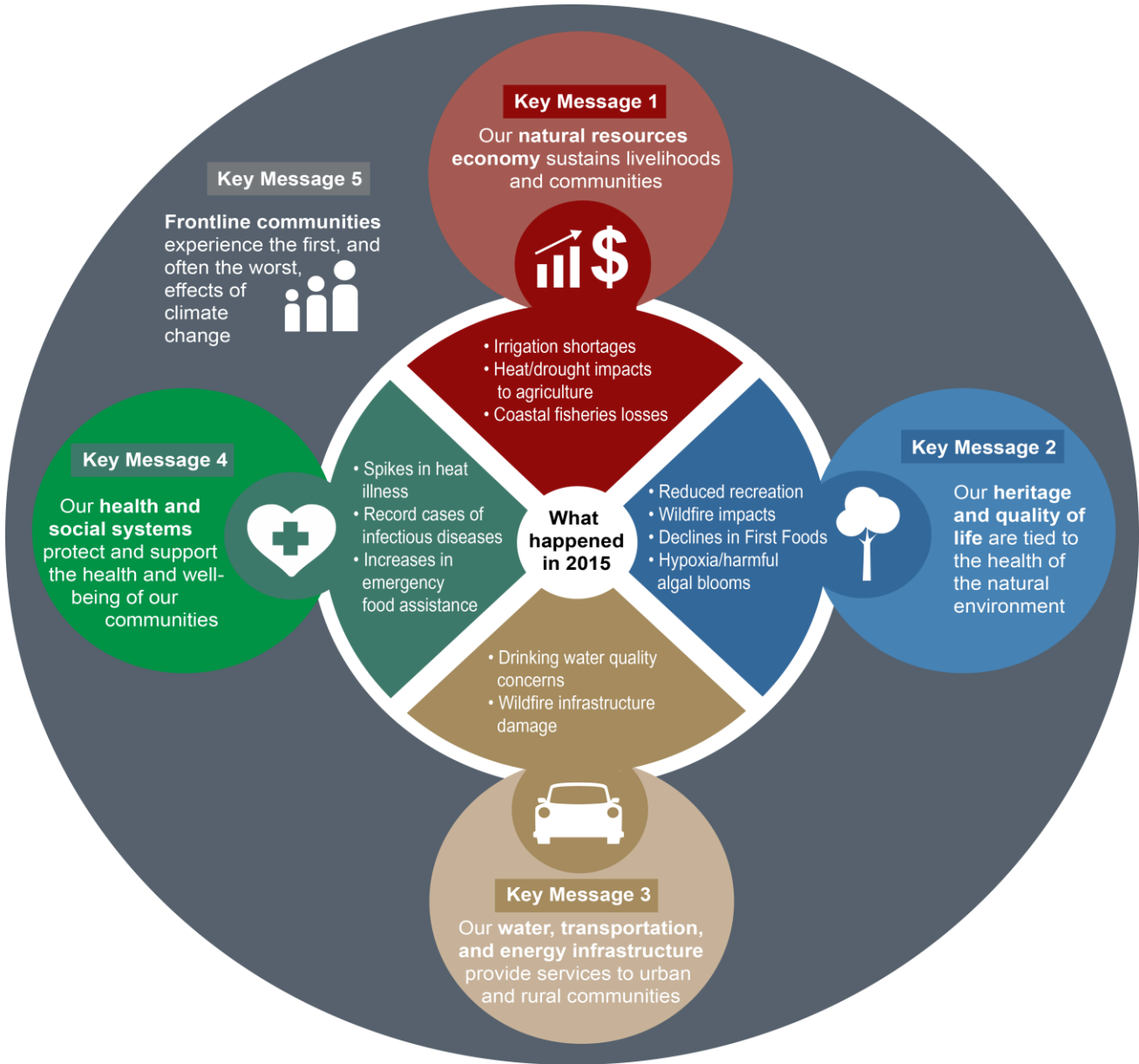
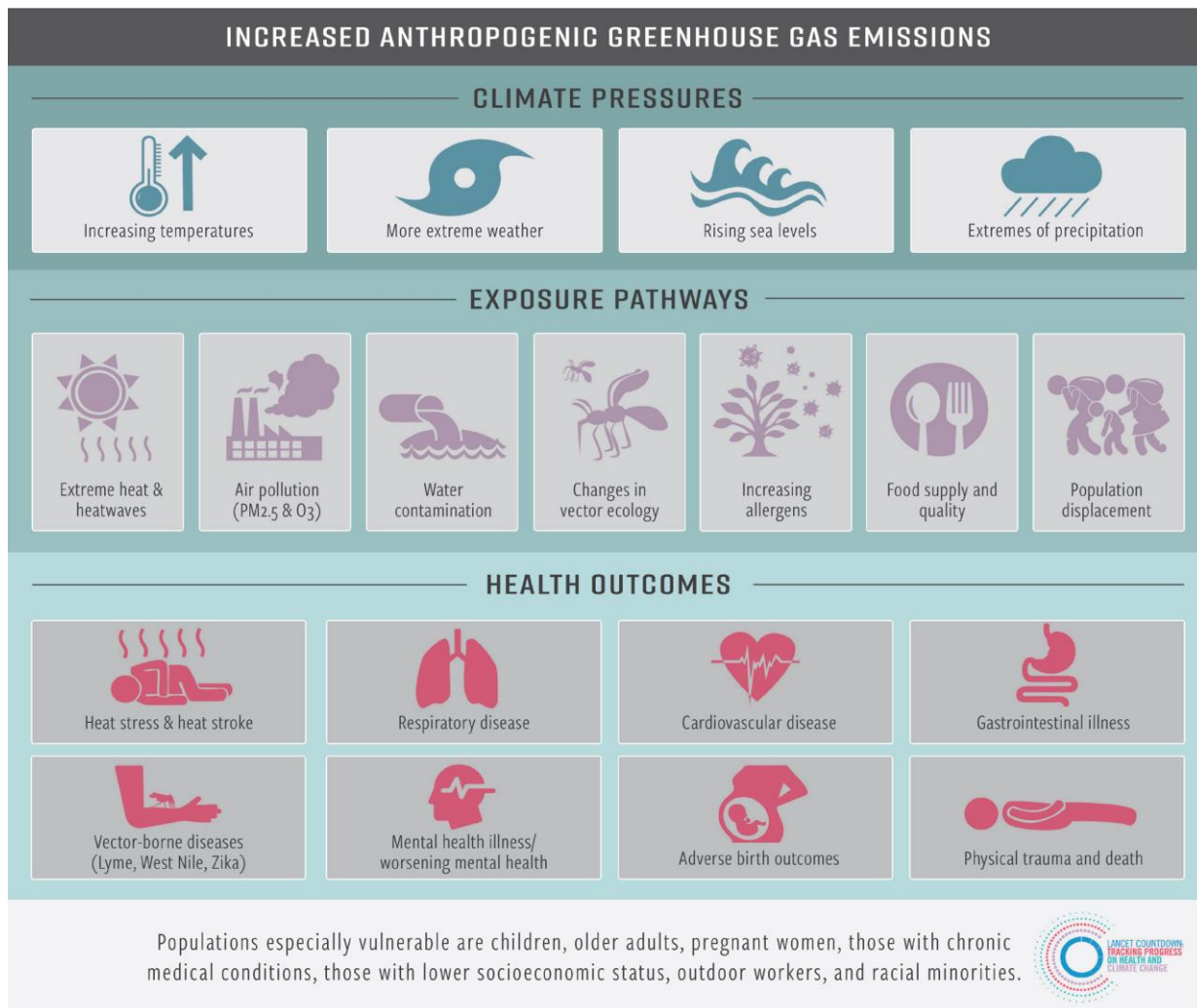


Figure 3 from the Lancet Countdown on Climate Change and Health⁶⁹ summarizes the effects of climate change on health outcomes.

Figure 3
Health Effects of Climate Change



Multiple studies have identified those persons and communities most at risk for adverse outcomes of climate change in Oregon and Washington.^{70 71 72 73 74 75} Table 1, adapted from these reports, summarizes the major health risks of climate change and the populations most at risk.

⁶⁹ (Salas, 2018)
⁷⁰ (Ebi, 2018)
⁷¹ (Salas, 2018)
⁷² (Haggarty B. e., 2014)

Table 1: Climate Change Health Effects and Susceptible Populations: Pacific Northwest

	Outcomes	Susceptible Populations
Heat related illness	Heat rash, heat cramps, heat exhaustion, heat stroke	Very young and very old, pregnant women, people with chronic disease, socially isolated, houseless, outdoor workers
Heat related death	Heart attack, stroke, renal failure, heat stroke, respiratory failure	Very young and very old, people with chronic disease, socially isolated, houseless, outdoor workers
Heat related violence	Homicide and intentional injury	Children and young adults especially in communities with pre-existing higher rates of interpersonal violence
Heat related air pollution and ozone formation	Chest pain, coughing, throat irritation, exacerbation of emphysema, bronchitis and asthma, cancer and cardiopulmonary death	Children, those living in areas with pre-existing air pollution, persons with pre-existing cardiac and respiratory conditions
Drought related food insecurity	Hunger and malnutrition	Low income, communities of color, pregnant women, children
Smoke pollution from wildfires	Asthma, bronchitis, pneumonia, cardiopulmonary disease, motor vehicle crash, injuries, death	Very young and very old, those with pre-existing respiratory and cardiac disease, vehicle operators, passengers
Drought and heat related harmful algal blooms	Toxic contamination of drinking water affecting liver, skin, gastrointestinal tract, nervous system	Residents dependent on affected water systems
Wildfires	Accidental injury and death	Those who live or work in fire-prone areas
Heavy rains	Accidental injury and death	Those who live, work or attend school near or on unstable slopes, including houseless
Flooding	Accidental injury and death, water borne disease, exposure to toxins	Those who live, work or attend school in low lying areas, including houseless
Weather related increase in mold, pollens and other allergens	Exacerbation of asthma and allergic rhinitis	Those with pre-existing allergic disorders
Infectious disease	Vector borne disease, food and water borne disease, fungal disease	Low income, those with pre-existing chronic disease, very young and very old, immune-compromised
Stress related to extreme weather events	Anxiety, depression, suicide, substance abuse, violence	Those with pre-existing mental health disorders and pre-existing socioeconomic stressors
Stress from weather-related displacement	Anxiety, depression, suicide, substance abuse, violence	Low income, residents of flood- and fire-prone areas, coastal communities

⁷³ (Haggarty B. , 2015)

⁷⁴ (Washington Environmental Health Disparities Map, n.d.)

⁷⁵ (Snover, 2013)

COMMUNITIES AT RISK

Malin is a tiny farming town near the border with California in Klamath County, Oregon, a community of about 800 persons, which grew up on the cattle and timber trade. Grains and potatoes, along with cattle, are now the principle commercial crops. (All population figures cited are from the 2017 US Census Bureau population estimates.⁷⁶) As the crow flies it's about 200 miles west and north, across public, private, and tribal forests, ranches, and farms to the closely related coastal towns of Coos Bay and North Bend, where some 26,000 people make their home. After white settlement, the local economy was based on the timber and fishing industries, which fell into decline in the late twentieth century. The last major lumber mill closed in '89. Since then the main economic activities have been tourism and recreation, remnants of the timber and fishing trades and agriculture.

Much farther north, lies the Columbia River Port of Kalama. The port is among the busiest on the west coast⁷⁷ and is a key economic engine of the town, which is home to 2,700 persons. About a dozen miles downstream sits Longview, another former lumber town of nearly 40,000 persons. Like North Bend, Longview has struggled to recover from the late 20th century decline in the timber trade as well as the closure of an aluminum mill. Across the river on the Oregon side and another 15 miles downstream is the rural town of Clatskanie, population 1,800. The Port of Columbia County administers Port Westward, an industrial port on the salmon-bearing river. This is primarily farm and forest country.

Farther north yet on the southern reach of Puget Sound lies the city of Tacoma, home to 213,000 people. The city has a mixed economic base of industrial, transport, manufacturing, tourist, retail and service sectors, including a busy container-handling port, many high-tech companies, an oil refinery, and a paper and pulp mill. Two Superfund sites with ongoing clean-up activities, the unfortunate legacy of its industrial past, are located on Commencement Bay within the city.

These are the communities, historically dependent on rich natural resources, that are now targeted by the fracked gas industry. What they also have in common are depressed economies with higher rates of poverty and unemployment compared to statewide averages. Local governments are cash-strapped. Their residents suffer higher rates of death and disease (see Tables 2 through 6

⁷⁶ (United States Census Bureau, n.d.)

⁷⁷ (World Port Source, n.d.)

below). Most suffer additional burdens of toxic industrial and commercial waste and pollution. They are some of the region's most vulnerable locales to adverse effects of climate change.

Native American Communities

Living within these locales are also a number of Native American communities. Across the country tribal communities often find themselves frontline communities, those places first and hardest hit by the deleterious effects of the fossil fuel industry and its associated climate change effects. Proposed fracked gas infrastructure would have an out-sized effect on these communities. Adverse impacts on the spiritual and traditional ways of life are not trivial. They result in emotional harm, in addition to economic harm, both of which degrade quality of life and lead to increases in morbidity and mortality.

Sovereign tribal nations in both Oregon and Washington have registered complaints about the failure of corporate and governmental entities to adequately consult the tribes about impacts on their lands, waters, people, cultural and spiritual practices, and sacred grounds. A 2019 report from the Government Accountability Office validated those allegations⁷⁸ The GAO report verified what House Natural Resources Chairman Raúl Grijalva (D-Ariz.) has long heard from tribal nations. "Avoiding discussions until after decisions are made is not consultation," Grijalva said.⁷⁹

Six tribal nations, including the Confederated Tribes of the Grand Ronde Community of Oregon; the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians; the Klamath Tribes (Klamath, Modoc, and Yahooskin); the Yurok Tribe; the Karuk Tribes; and the Cow Creek Band of Umpqua Tribe of Indians, have filed motions to intervene in the Jordan Cove project, citing potential excavation and destruction of important burial and other sacred sites.^{80 81} They note potential habitat destruction due to construction and operation of the facility and the threat to traditional fishing and shellfish harvesting activities of the tribes. Five federally recognized tribes oppose the project, including the Klamath Tribes, the Yurok Tribe, the Karuk Tribe and the Tolowa Dee-Ni. In March of 2019 the Siletz Tribe also voted to formally oppose the Jordan Cove project and pipeline, citing multiple environmental concerns: "We really cannot support a project that's potentially this degrading to the environment and to sensitive habitat for several species, and could compound the

⁷⁸ (U.S. Government Accountability Office, 2019)

⁷⁹ (Yachnin, 2019)

⁸⁰ (Confederated Tribes of Coos, Lower Umpqua & Siuslaw Indians, 2013)

⁸¹ (Klamath Tribes Tribal Council, 2017)

disastrous effects of a Cascadia earthquake. We don't believe this project will continue our tradition of being good stewards of our land, which we need to protect in all ways that we can.”⁸²

The Puyallup Indian Reservation is located directly south of Puget Sound LNG. The Puyallup Indian Tribe opposes Puget Sound LNG, citing concerns over pollution of water, unearthing toxic contaminants in the soil, and further degradation of local fish habitat which has already suffered the toxic effects of prior industrial activities.⁸³ ⁸⁴ Affiliated Tribes of Northwest Indians⁸⁵ and the National Congress of American Indians⁸⁶ also oppose this and other fracked gas projects.

Climate Change Susceptibility

The U.S. Global Change Research Program is a federal program mandated by Congress to conduct scientific assessments of the global environment. They determined that vulnerability to the adverse health effects of climate change depend on three factors: exposure, sensitivity, and adaptive capacity, which are illustrated in Figure 4.⁸⁷ All three factors are at play in the cities, towns, and rural locales that would host new fracked gas infrastructure.

⁸² (The News Guard, 2019)

⁸³ (350 Tacoma, 2018)

⁸⁴ (Mapes, 2018)

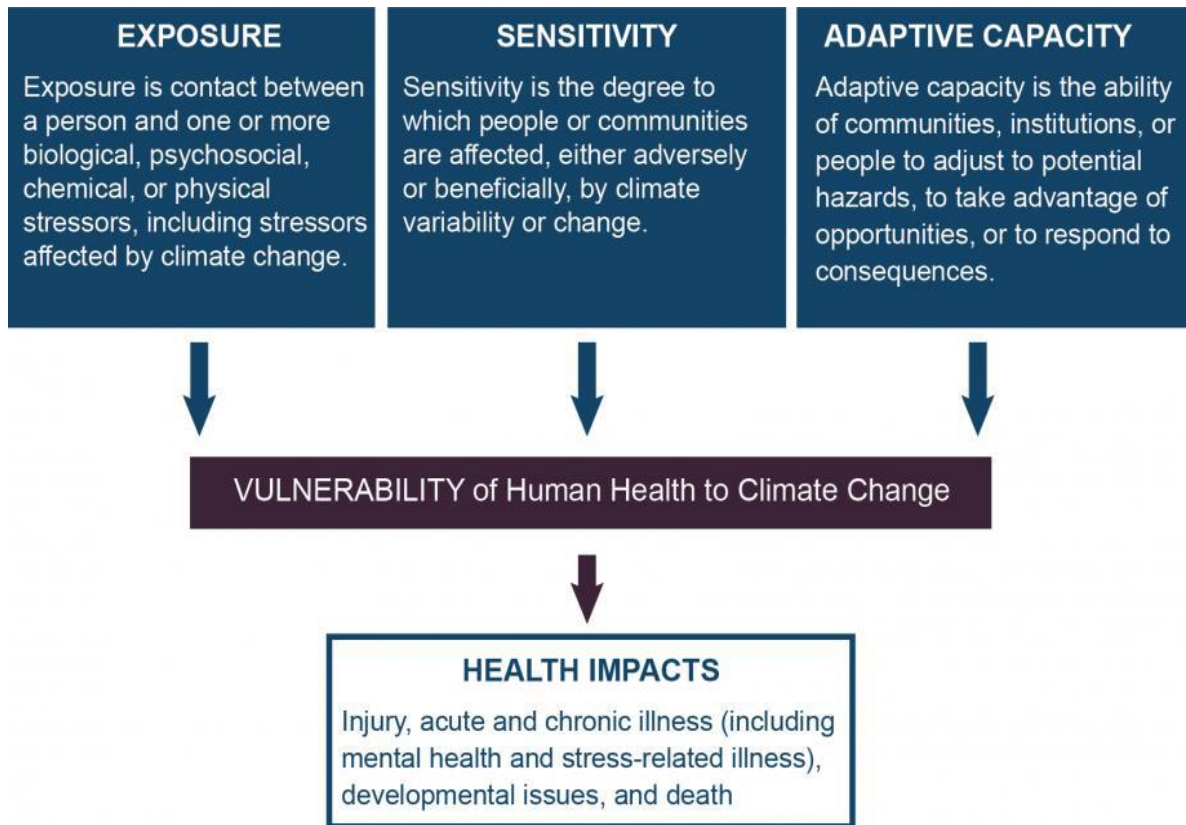
⁸⁵ (Indian Country Today, 2017)

⁸⁶ (National Congress of American Indians, 2018)

⁸⁷ (Crimmins, 2016)

Figure 4

Climate Change Susceptibility



Researchers at Portland State University combined demographic variables of income, race, education, employment, and age with exposure variables to toxic air pollution.⁸⁸ The resulting index score identifies communities by census tract in Oregon that are most at risk to the effects of climate change. In Figure 5 the vulnerability index score is given as a percentage; a higher percentage reflects greater vulnerability.

⁸⁸ (Zapata, 2017)

Figure 5

Census Tracts Most Vulnerable to Climate Change in Oregon

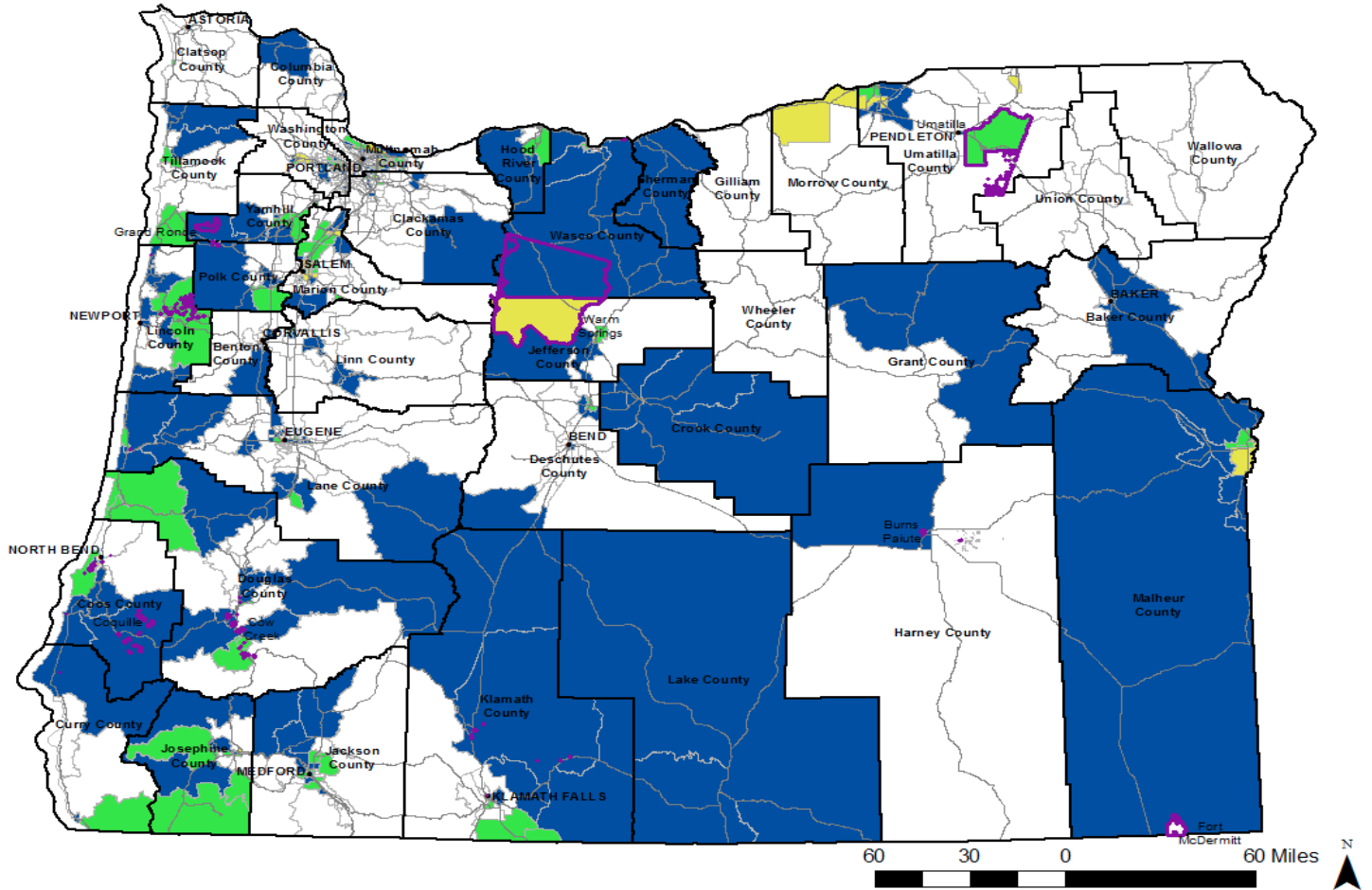


Figure 5: Top 10%, 25%, and 50% of Census Tracts Most Vulnerable to Climate Change in Oregon. GIS data source: US Census Bureau and State of Oregon. Index scores are based on data from: U.S. Census American Community Survey (ACS) 2011-2015 5- year estimates and the National Air Toxics Assessments (NATA) 2011. Purple indicates Indian reservations, village, and towns.



Figure 6 identifies economically distressed areas and the top 50% of Census Tracts Based on the Vulnerability Index. Figure 7 overlays this map with the location of already existing greenhouse gas emitting facilities.

Figure 6
Economically Distressed Areas of Oregon

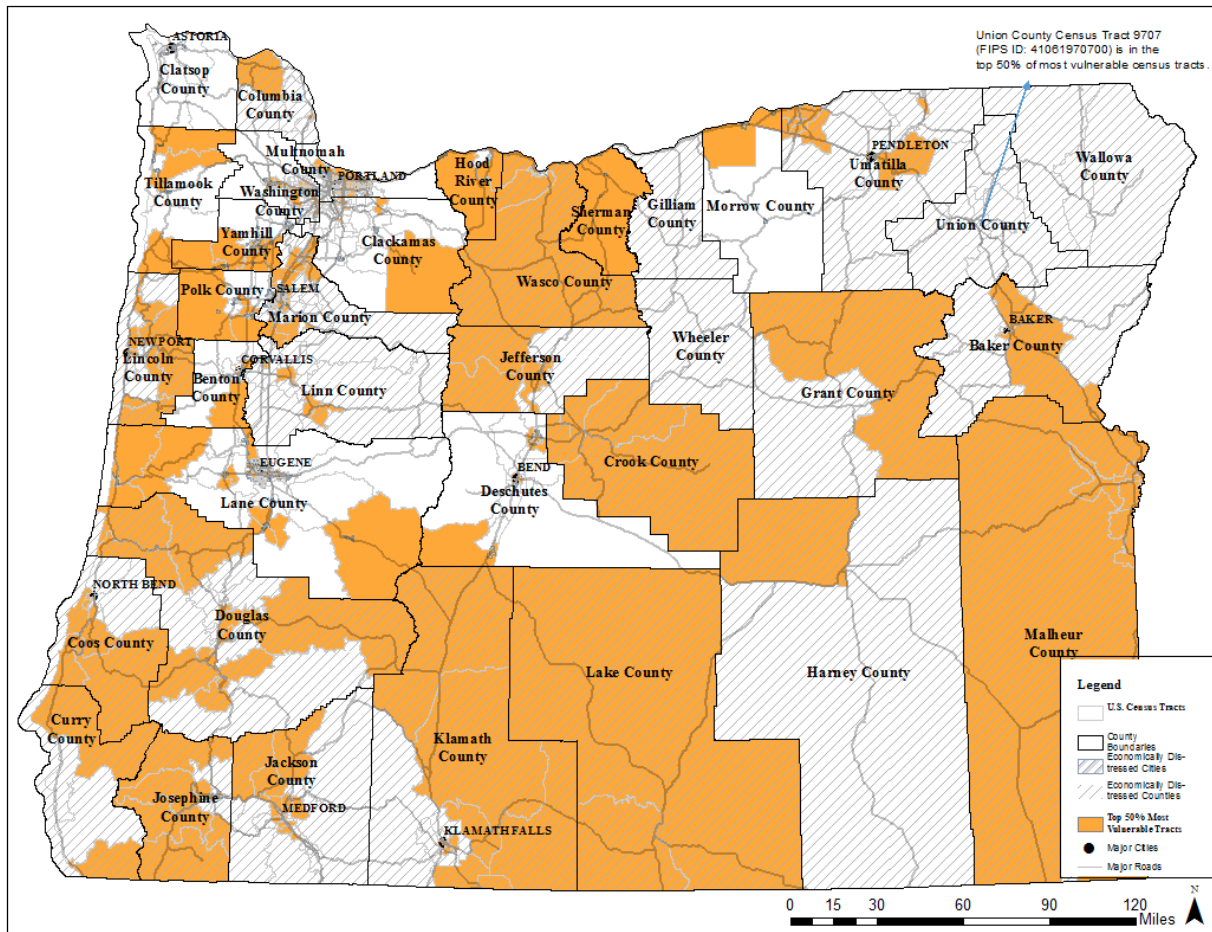


Figure 6: Economically Distressed Areas and Top 50% of Census Tracts Based on Vulnerability Index. GIS data source: US Census Bureau and State of Oregon. Index scores are based on data from: U.S. Census American Community Survey (ACS) 2011-2015 5- year estimates and the National Air Toxics Assessments (NATA) 2011.

Figure 7

Distribution of Greenhouse Gas Emitting Facilities in Oregon

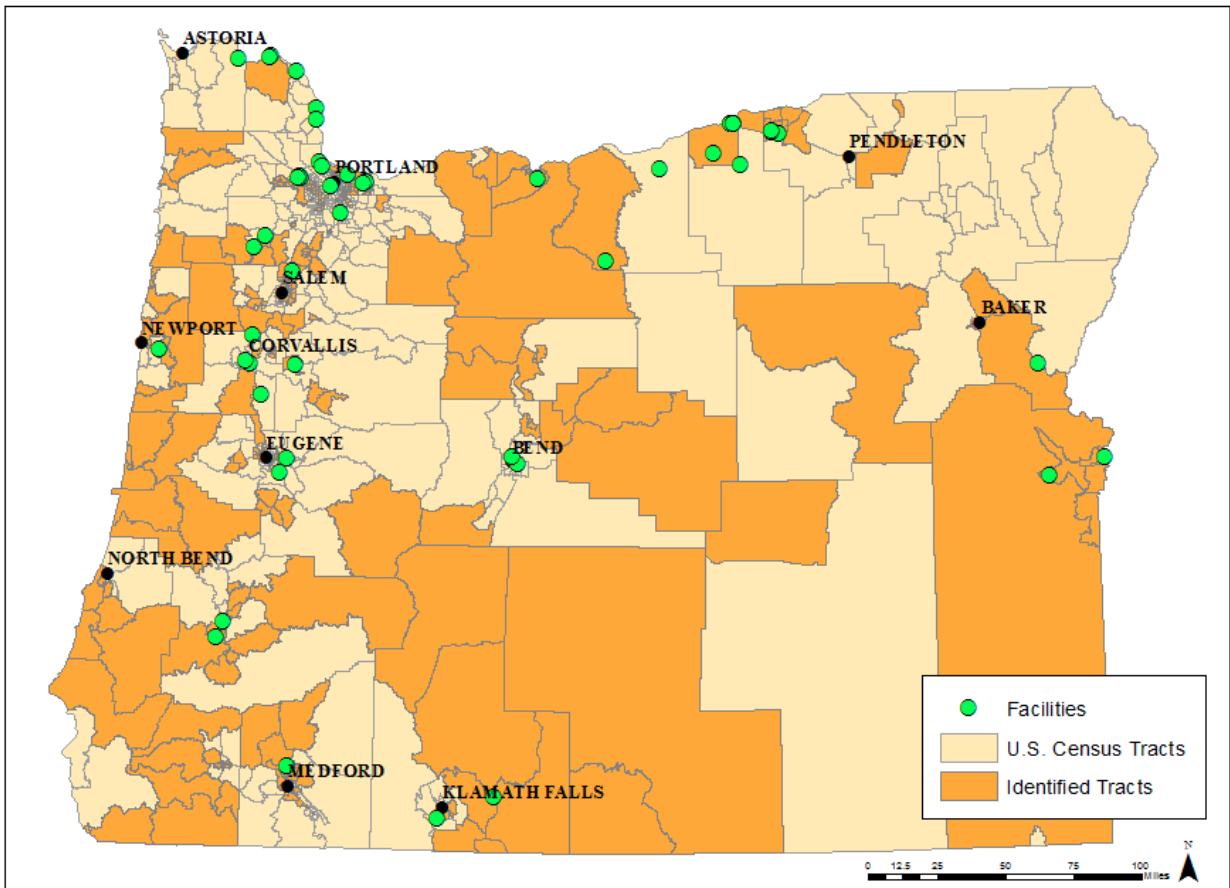


Figure 7: Distribution of Greenhouse Gas Emitting Facilities in Relationship to U.S. Census Tracts Identified as Most Vulnerable to Climate Change. All facilities with Air Quality Permits from the Oregon Department of Environmental Quality that produced over 25,000 metric tons of CO₂e emissions in 2015. Data source: Oregon Department of Environmental Quality 2015 Greenhouse Gas Facility Emissions (2017b). Most vulnerable to climate change census tracts include the top 50% of census tracts with the highest vulnerability index score.

The Washington Tracking Network similarly identified those communities in Washington most vulnerable to climate change based on a vulnerability index.⁸⁹ This index combined nineteen variables in four areas:

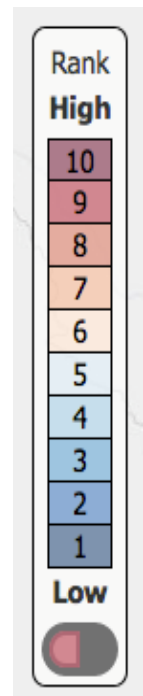
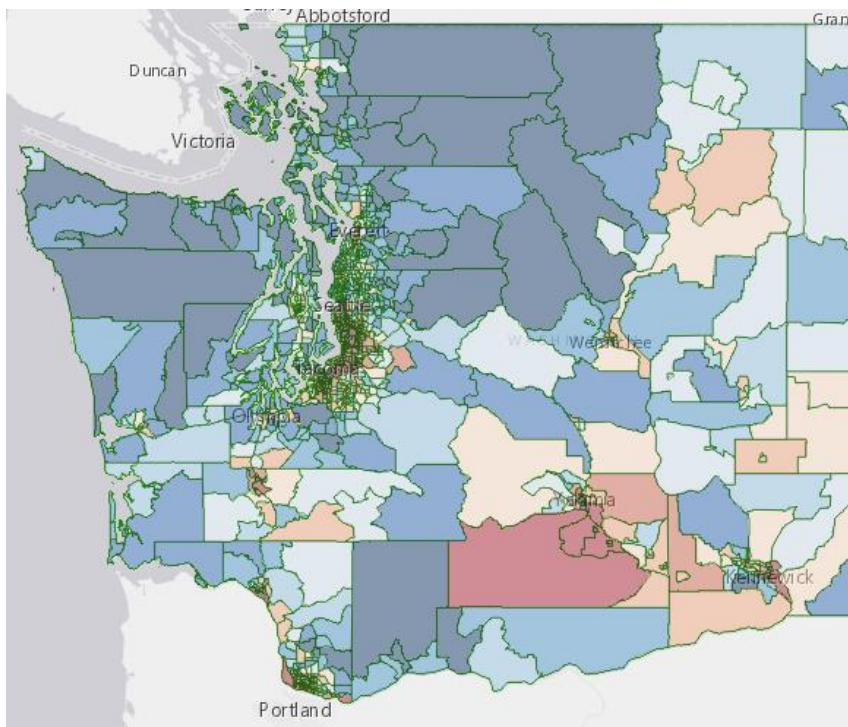
- *Environmental Exposures:* nitrous oxides; diesel emissions; ozone concentration; particulate matter; proximity to heavy traffic roadways; toxic release from facilities

⁸⁹ (Washington Environmental Health Disparities Map, n.d.)

- *Environmental Effects*: lead risk from housing; proximity to hazardous waste treatment, storage, and disposal facilities; proximity to superfund sites; proximity to Risk Management Plan facilities; wastewater discharge)
- *Sensitive Populations*: death from cardiovascular disease; low birth weight
- *Socioeconomic Factors*: limited English; no high school diploma; poverty; race - people of color; transportation expense; unaffordable housing; unemployed

Figure 8 depicts Washington State as a whole.

Figure 8
Washington State: Climate Change Vulnerability Index



Figures 9 and 10 zoom in on Pierce and Cowlitz Counties respectively, where three major fracked gas projects are currently proposed or are in progress. In Figure 9, the Port of Tacoma (the site for the LNG facility) is located on the finger-like peninsulas jutting out into Puget Sound in the middle of the map.

Figure 9
Tacoma: Climate Change Vulnerability Index

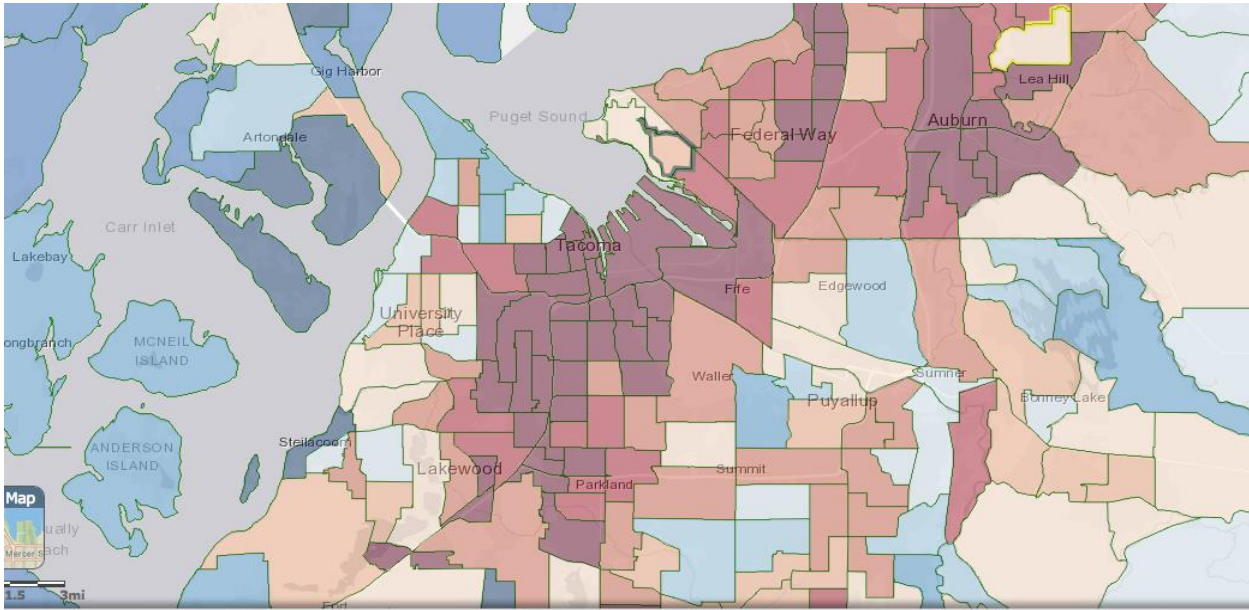
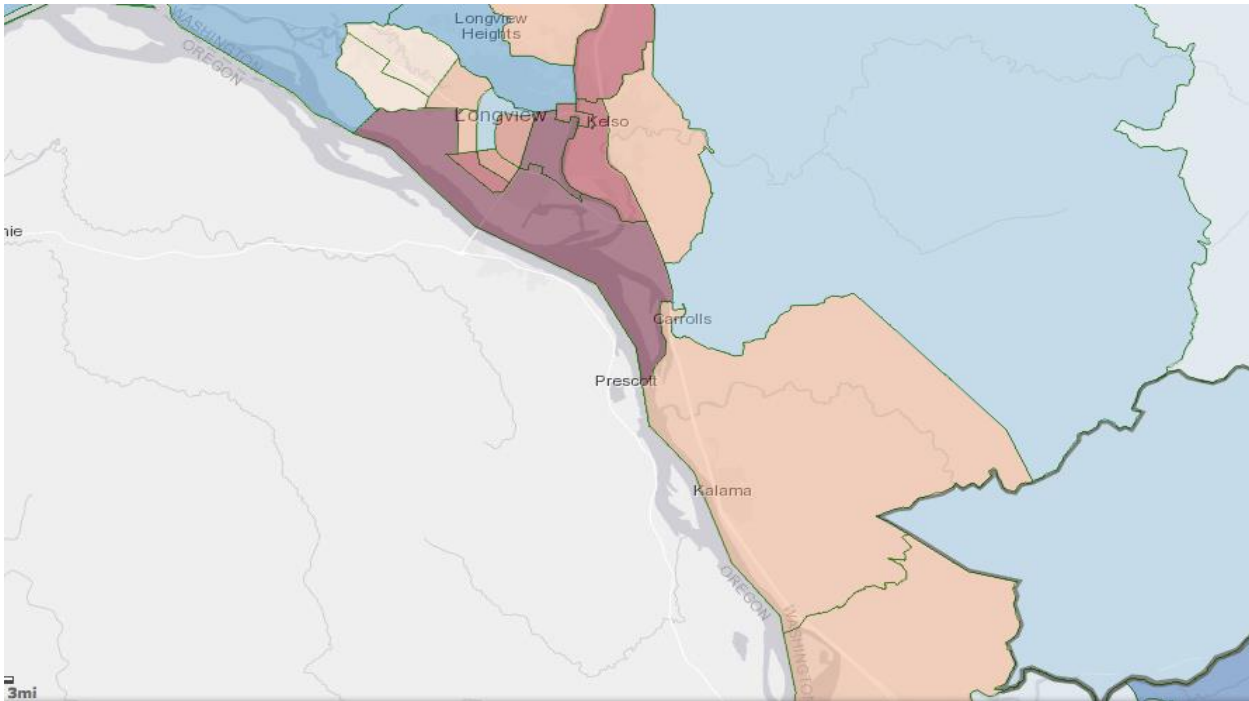


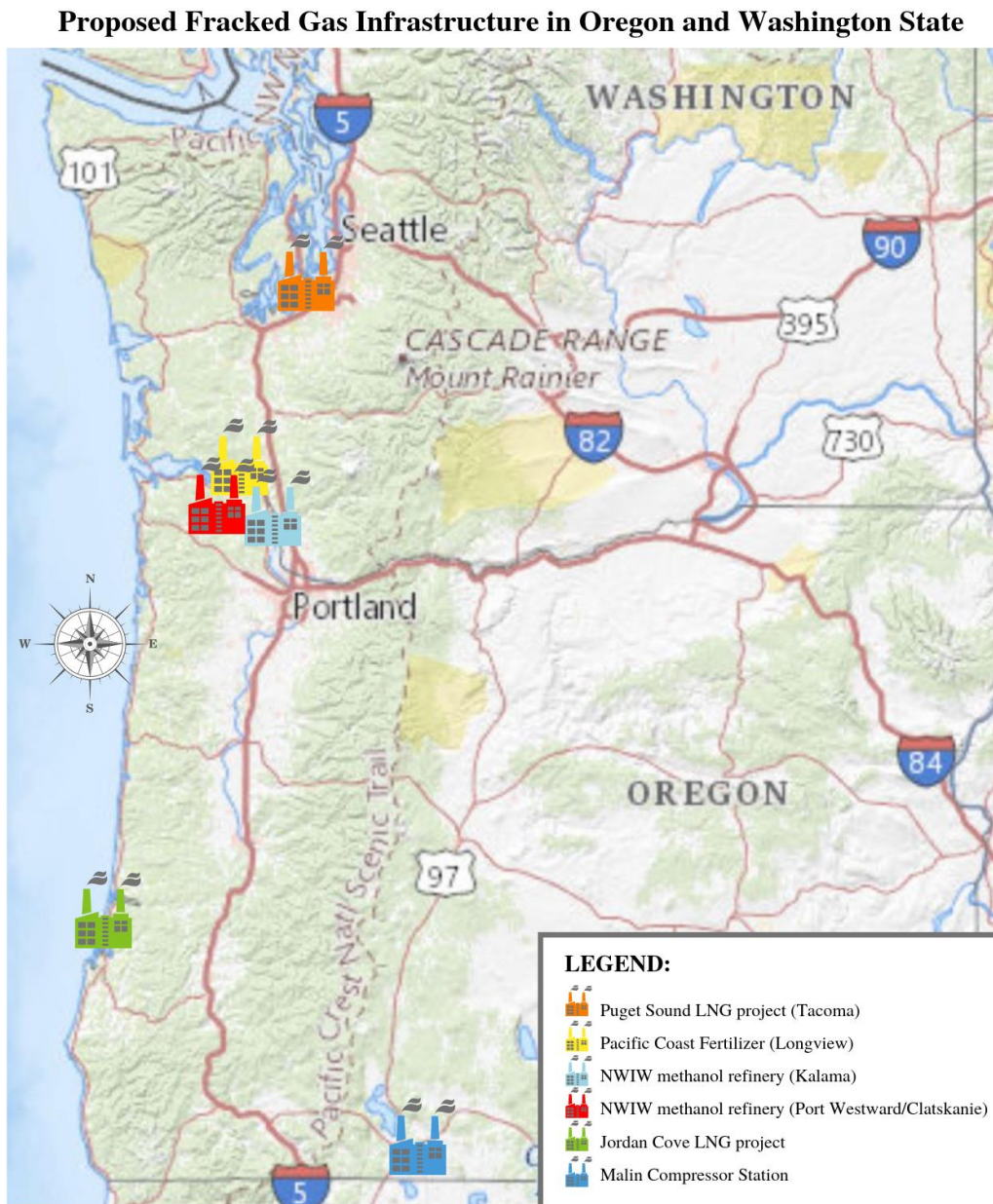
Figure 10
Kalama and Longview: Climate Change Vulnerability Index



Social and Economic Profiles of Regions at Risk

Figure 11 maps the location of currently proposed major fracked gas infrastructure in Oregon and Washington.

Figure 11 Proposed Fracked Gas Infrastructure Oregon and Washington



Underlying map sourced from USGS
(<https://viewer.nationalmap.gov/advanced-viewer/>)

The counties where new fracked gas infrastructure is proposed have some of the worst social, economic, and health profiles compared to statewide averages, especially Cowlitz County (Pacific Coast Fertilizer and Kalama methanol refinery), Coos County (Jordan Cove LNG) and Klamath County (PCGP).

The affected counties tend to have small populations of immigrants or persons of color with the exception of Klamath County, which has a large Native American and Latinx population.

Table 2: Demographics: Race, Ethnicity, Language⁹⁰ (2017 Population Estimates)							
	% Non-Hispanic African American alone	% American Indian and Alaskan Native alone	% Asian alone	% Native Hawaiian /Other Pacific Islander alone	% Hispanic or Latino	% Non-Hispanic White alone	% Who Do Not Speak English at Home
Oregon State	2.2%	1.8%	4.7%	0.4%	13.1%	75.8%	15.2%
Columbia	0.6%	1.5%	1.1%	0.2%	5.2%	88.5%	4.0%
Coos	0.8%	2.9%	1.3%	0.3%	6.5%	85.2%	5.1%
Douglas	0.5%	2.1%	1.1%	0.2%	5.9%	87.8%	3.8%
Jackson	0.9%	1.6%	1.5%	0.4%	12.9%	80.9%	9.5%
Klamath	1.0%	4.9%	1.2%	0.2%	13.1%	77.8%	8.3%
Multnomah	6.0%	1.4%	7.9%	0.7%	11.6%	69.9%	20.0%
Washington State	4.2%	1.9%	8.9%	0.8%	12.7%	68.7%	19.1%
Cowlitz	1.0%	2.0%	1.6%	0.4%	9.0%	83.7%	7.3%
Pierce	7.5%	1.7%	6.7%	1.7%	10.9%	67.0%	14.2%

⁹⁰ (U. S. Census Bureau, n.d.)

Each of these counties has higher rates of unemployment and lower high school graduation rates, as depicted in Table 3.

Table 3: Social and Economic Factors				
	Unemployment*	Median Household Income**	Persons in Poverty ***	High School Graduation****
Oregon State	3.9%	\$56,119	13.2%	75%
Columbia	4.9%	\$57,449	12.3%	73%
Coos	5.3%	\$40,848	19.9%	58%
Douglas	5.2%	\$44,023	14.9%	64%
Jackson	4.8%	\$48,688	14.3%	75%
Klamath	6.3%	\$42,531	19.2%	72%
Washington State	4.3%	\$66,174	11.0%	81%
Cowlitz	5.6%	\$49,804	16.4%	79%
Pierce	4.9%	\$63,881	10.2%	84%

*Oregon Unemployment, 11/18⁹¹; Washington Unemployment, 11/18⁹²

** 2013-2017, in 2017 dollars⁹³

*** Percentage of persons living in poverty from the Small Area Income and Poverty Estimates⁹⁴

**** Percentage of ninth-grade cohort that graduates in 4 years, 2014-2015⁹⁵

⁹¹ (State of Oregon Employment Department, n.d.)

⁹² (Employment Security Department: Washington State, n.d.)

⁹³ (U. S. Census Bureau, n.d.)

⁹⁴ (U. S. Census Bureau, n.d.)

⁹⁵ (Robert Wood Johnson Foundation, n.d.)

Adult and child mortality are higher in nearly every locale. Infant mortality is particularly high in Klamath County.

Table 4: Mortality ⁹⁶			
	Premature Age-adjusted Mortality*	Child mortality**	Infant Mortality***
Oregon State	310	40	5
Columbia	330	30	#
Coos	420	50	#
Douglas	390	60	6
Jackson	330	40	4
Klamath	390	60	9
Washington State	290	40	5
Cowlitz	390	50	5
Pierce	330	50	5

*Premature age-adjusted mortality: Number of deaths among residents under age 75 per 100,000 population (age-adjusted) 2010-2013.

**Child mortality: Number of deaths among children under age 18 per 100,000, 2010-2013.

***Infant Mortality: Number of all infant deaths (within 1 year), per 1,000 live births. 2006-2012

no data available

⁹⁶ (Centers for Disease Control and Prevention: National Center for Health Statistics, n.d.)

Over all death rates are higher in targeted counties, sometimes strikingly so, and especially for cancer, heart and lung disease, and suicide (a marker for community socio-economic stress).

Table 5: Oregon: Age-adjusted Death Rate per 100,000, by County⁹⁷ *

	All Causes	All Cancer	Heart Disease	Stroke	Chronic Lung Disease	Diabetes	Homicide	Suicide
State Total	834.1	198.4	191.8	68.8	49.1	66.6	3.3	15.0
Columbia	940.3**	228.7**	214.1**	74.3	58.4	66.4	2.3	18.7
Coos	949.9**	224.1**	226.3**	66.4	59.9**	78.8**	4.7	22.6**
Douglas	905.5**	209.5	203.0	63.0	62.4**	78.5**	3.4	16.7
Jackson	830.8	199.0	186.4	71.5	51.4	61.3	3.3	20.4**
Klamath	947.3**	204.8	217.6**	56.4**	70.5**	79.1**	4.6	23.3**

* Age-adjusted death rate per 100,000 population, 2017

** Statistically significant difference

Table 6: Washington: Age-adjusted Death Rate per 100,000, by County *

	All Causes	All Cancer	Major Cardiovascular Disease	Chronic Lung Disease	Diabetes	Homicide	Suicide
State Total	690.0	157.0	187.6	39.9	22.5	3.4	15.6
Cowlitz	820.0	189.5	202.4	64.1	36.7	#	24.2
Pierce	760.0	170.3	205.8	46.5	22.9	4.9	17.6

*Age-adjusted death rates per 100,000 population, 2015⁹⁸

data unavailable

Note: measures of statistical significance not available

These are locales that are already experiencing the deadly intersections of depressed economies, environmental degradation, and ill health. Fracked gas infrastructure will not bring the hoped-for economic prosperity necessary for healthy communities. It will only further degrade living conditions.

⁹⁷ (Oregon Health Authority, n.d.)

⁹⁸ (Washington State Department of Health, n.d.)

Stress and Mental Health

Often neglected in the discussion of impacts on communities targeted for major fracked gas infrastructure development is the associated psychological stress. Mental health impacts arise from proposals to build fracked gas infrastructure due to uncertainty of risks to health, life, property, security, sense of well-being, and inability to plan for the future. Noise exposures during construction and operation of fracked gas terminals also have the potential to increase stress and exacerbate mental health disorders among workers and nearby residents.

The threat of loss of land and property through eminent domain puts people in the path of proposed pipelines into long-term limbo, having to wait for many years to determine whether a project will go through. While they wait, they are reluctant to make changes or improvements to their homes, are unable to plan for the future, and are confronted with impossible decisions about whether to sell or lease right of way to their land, whether to leave or stay. Many poorer communities have been divided by the prospect of windfall profits for some but not all of the community. Confounding the profit motive is the threat of damage to health, environment, ecosystem supports, and cultural values. Threats of accidents or toxic releases increase concerns about the location of schools, hospitals, residences, and other businesses.

Residents of communities experiencing large influxes of temporary labor are caught between the lure of jobs and the threat of physical harm from toxic emissions to air and water, or from accidental releases, explosions, and fires. Added to those uncertainties, temporary labor influxes put stress on the resources of communities such as fire, police, and health care, and infrastructure such as roads, water, and sewage systems. Communities are faced with unforeseen burdensome expenses, with further loss of comfort and well-being.

For Native American communities, the prospect of loss of valued resources and traditional values after centuries of forced migration and marginalization is a source of increased mental and physical stress. Furthermore, increases in violence, assault, and disappearances among Native American women and girls have been documented near fossil fuel infrastructure projects. Threats to well-being, safety, and security are threats to mental as well as physical health and marginalized communities, including tribal nations, are disproportionately affected by these adverse impacts.⁹⁹

⁹⁹ (Hayes, 2018)

AIR POLLUTION

Toxic air pollutants (TAPs), also known as hazardous air pollutants, are agents known or suspected to cause cancer or other serious health effects, such as lung and heart diseases, adverse effects on reproduction, or birth defects. They are often measured by lifetime cancer risk and respiratory hazard index. As the scientific understanding of TAPs has evolved, levels considered “safe” have consistently gone down. The standards for U.S. air quality have been set under considerable influence of industry and the standards set by the World Health Organization are often significantly lower and more protective.

Current National Ambient Air Quality Standards (NAAQS), established by the U.S. Environmental Protection Agency (EPA), cover only six air pollutants, known as criteria air pollutants: nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO), ozone, particulate matter (PM₁₀ and PM_{2.5}), and lead.¹⁰⁰ Fracked gas installations are known emitters of many of these air pollutants and many others. Ambient air quality standards do not exist for these additional pollutants, though Oregon DEQ has ambient benchmarks for some of them.

Safe levels of air pollutants are often assumed to fit all persons. Estimates of risk may be based solely on healthy adult exposure with no consideration for differences due to gender, race, age, size or pre-existing health conditions. In addition, emissions for any one air pollutant may comply with air quality standards, but that single pollutant benchmark fails to take into account the cumulative effects of exposure to several pollutants at once (which is by far the usual case) or how one pollutant might increase the power or the effect of another. For example, the potency of airborne carcinogens is increased when they are adsorbed onto fine particulate matter and transported through the lungs to the blood and brain and placenta. Stating that the levels of exposure are below a particular standard is not the same as saying the risk of harm is not increased. Any amount of exposure to a carcinogen increases the risk of cancer. Lastly, for some air pollutants no level of exposure exists which does not harm human health. A prime example is fine particulate matter (PM₁₀ and PM_{2.5}), a major pollutant associated with fracked gas infrastructure which causes a host of health problems.

In 2010 the American Heart Association (AHA) revised and reissued its position on fine particulate matter: “The overall evidence is consistent with a causal relationship between particulate

¹⁰⁰ (U.S. Environmental Protection Agency, 2015)

matter 2.5 exposure and cardiovascular morbidity and mortality. This body of evidence has grown and has been strengthened substantially... [and] because the evidence reviewed supports that there is no safe threshold, it appears that public health benefits would accrue from lowering PM2.5 concentrations even below present-day [EPA standards] ... to optimally protect the most susceptible populations.”¹⁰¹ The American College of Obstetricians and Gynecologists along with the American Society of Reproductive Medicine;¹⁰² the American Academy of Pediatrics;¹⁰³ and the World Health Organization¹⁰⁴ have also issued statements calling for prompt action to revise air quality standards and reduce public exposure to toxic air pollutants, especially particulate matter.

Beyond extraction, every stage of fracked gas transport, storage, combustion, refinement, and processing is responsible for levels of air pollutants that threaten public health. Common air toxics produced over the life-cycle of fracked gas include:

- *Volatile organic compounds* (VOC), organic chemicals that form vapors easily. VOCs contribute to the formation of ozone and smog.
- Ground level *ozone*, formed from nitrogen oxides (NO_x) and VOCs. While ozone is a key constituent of the upper atmosphere, ground level ozone is created by human activities (largely the combustion of fossil fuel) and is a constituent of smog.
- *Particulate matter* (PM), tiny particles of solid or liquid suspended in a gas. The burning of fossil fuels (particularly diesel) in vehicles, power plants, and industrial processes generates significant amounts of particulate matter. PM is often referred to by size: PM10 and PM2.5.
- *Nitrogen oxides* (NO_x), expelled from high temperature combustion. They can be seen as a brown haze above or as a plume downwind of cities.
- *Carbon monoxide* (CO), a colorless and odorless gas. It is a product of combustion of fuel such as gas, coal, or wood.
- *Formaldehyde*, a VOC that is listed by the International agency for Research on Cancer (IARC) as a known cause of nose and throat cancer.

¹⁰¹ (Brook, 2010)

¹⁰² (American College of Obstetricians and Gynecologists, 2013)

¹⁰³ (Kim, 2004)

¹⁰⁴ (World Health Organization, 2013)

- *Benzene*, also a VOC, a colorless, flammable liquid with a sweet odor. Benzene is a natural part of crude oil and gasoline (and therefore motor vehicle exhaust), as well as cigarette smoke. It is classified by IARC as a known carcinogen.
- *Polycyclic aromatic hydrocarbons* (PAH), a particular type of volatile organic compound produced by the thermal decomposition of organic matter, such as in engines and incinerators or when biomass burns in forest fires. It is a prime carcinogen in cigarette smoke. Examples of PAHs include naphthalene and benzo[a]pyrene, which is classified by the IARC as a known carcinogen.

In both Oregon and Washington air quality is monitored primarily for particulate matter in the larger cities and towns, industrial sites, and transportation corridors.¹⁰⁵ ¹⁰⁶ Very few sites monitor for carbon monoxide, nitrogen oxides, sulfur dioxide, ozone, or lead. Toxic air pollutants rarely monitored. In Oregon, no air quality monitoring stations exist in Coos or Columbia Counties.

¹⁰⁵ (Oregon Department of Environmental Quality, 2019)

¹⁰⁶ (Washington State Department of Ecology, n.d.)

Table 7 summarizes the key health effects of toxic air emissions associated with fracked gas.

Table 7: Health Effects of Air Pollutants Associated with Fracked Gas Infrastructure	
Air Pollutant	Health Effects
Volatile organic compounds	Cancer, watery eyes, coughing, nausea, skin irritation, eye, nose and throat irritation, frequent headaches, damage to the liver, kidney and central nervous system
Ozone	Lung damage, inflammation of the lining of the lung, chest pain, coughing, throat irritation, worsening of bronchitis, emphysema, and asthma
Particulate matter	Strokes, heart disease, autism, attention deficit hyperactivity disorder, Alzheimer's Disease, lung cancer, worsening of bronchitis, emphysema, and asthma
Nitrogen Oxides (NO _x)	Lung inflammation, increased lung infections
Carbon Monoxide	Short term: headache, dizziness, nausea; unconsciousness and death (at high levels of acute exposure) Long term: heart disease
Formaldehyde	Nasopharyngeal cancer, watery eyes, burning in eyes, nose and throat, wheezing, nausea, skin irritation
Benzene	Cancer: acute myelogenous leukemia, other blood cancers (leukemias and lymphomas), anemia, myelodysplastic syndrome
Polycyclic Aromatic Hydrocarbons	Testicular, skin and colon cancer, cataracts, kidney and liver damage, birth defects, developmental disorders, hormonal disruption

Table 8 summarizes types of fracked gas infrastructure with best documented emissions of air pollutants and is not an inconclusive list.

Table 8: Air Pollutants Associated with Fracked Gas Infrastructure						
	Particulate Matter	Volatile Organic Compounds	Ozone	NO_x	CO	Other
Compressor stations; pipelines	yes	yes (formaldehyde, benzene, hexane)	unknown	yes	yes	sulfur dioxide, lead
LNG facilities	yes	yes	yes	yes	yes	unknown
Methanol refining	yes	yes (benzene, formaldehyde, PAHs)	unknown	unknown	yes	ammonia, nickel
Ammonia production facilities	yes	yes	unknown	yes	yes	unknown

Jordan Cove LNG

The air quality status of the local environment is unknown. According to the JCEP Final Environmental Impact Statement (FEIS), the closest monitoring sites for criterion air pollutants are in Eugene and Lane County. For all monitored air pollutants, emissions at the plant are expected to fall well below NAAQS.¹⁰⁷

The LNG facility will also emit Hazardous Air Pollutants. In the Coos Bay area ambient levels of HAPs were last measured in 2005, in terms of lifetime cancer risk, and again in 2011, using the respiratory hazard index. Levels were found to be low, although no safe levels have been established for these hazardous air pollutants. The 2017 JCEP Resource Report 9 notes that the LNG

¹⁰⁷ (Office of Energy Projects: Federal Energy Regulatory Commission, 2019)

terminal will be a source of HAPs, emitting 8.1 tons per year and 3.1 tons per year of n-hexane, a known neurotoxin as well as many others including benzene, formaldehyde, polycyclic aromatic hydrocarbons, arsenic, cadmium, and mercury.¹⁰⁸

Compressor Station of the Pacific Connector Gas Pipeline

Compressor stations provide the force which propels gas through pipelines. They emit significant amounts of air pollution, both from the operation of the engine which powers the pump as well as from venting. When the pressure in the pipeline exceeds levels meant to ensure safety (by not creating dangerous pressure on the pipeline), the contents of the pipeline are vented intentionally and directly into the ambient air. Fugitive leaks may occur as well. Compressor stations and meter stations, which also vent methane, VOCs and PM, are often located every 40 to 100 miles along fracked gas pipelines. A meter station is proposed for Coos County as part of the Jordan Cove LNG project. The Klamath Compressor Station for the Pacific Connector Gas Pipeline would be located in a rural area with 16 homes in the vicinity. Two compressor stations related to existing large pipelines are already located near this proposed compressor station.

In New York State a study on the health effects of the emissions from 18 fracked gas compressor stations found that, collectively, these sites released 40 million pounds of 70 different contaminants over a 7-year period (the seventh largest point source of air pollution in the state for that time period). The largest emissions (by volume) were nitrogen oxides, carbon monoxide, volatile organic compounds (VOC), formaldehyde and particulate matter.¹⁰⁹

Studies of gas compressor stations in Pennsylvania and New York demonstrated that compressors emitted highly variable plumes of methane that spread downwind and were measurable a full mile away at levels that could expose nearby residents, especially during temperature inversions.¹¹⁰ High levels of methane, especially in an enclosed space, can cause suffocation, loss of consciousness, headache and dizziness, nausea and vomiting, weakness, and loss of coordination.

High levels of formaldehyde were found near compressor stations in Arkansas, Pennsylvania, and Wyoming. Formaldehyde is a byproduct of incomplete combustion from the gas-fired engines. It is also created when fugitive methane, which escapes from compressor stations, is exposed to sunlight. Other hazardous air pollutants detected near compressor stations in this study were benzene

¹⁰⁸ (Jordan Cove LNG, 2017)

¹⁰⁹ (Russo, 2017) https://www.albany.edu/about/assets/Complete_report.pdf

¹¹⁰ (Payne, 2017) doi: 10.1016/j.scitotenv.2016.12.082

and hexane. One air sample collected near a compressor station in Arkansas contained 17 different volatile compounds.¹¹¹

According to the JCEP Resource Report 9, monitoring stations in proximity to the proposed route focus primarily on monitoring of PM10 and PM2.5 (related to particulate matter emissions from wood heating in the region). No stations monitor for SO2 and NO2 in the multi-county area of southern/southwestern Oregon and northern California. Monitoring for CO was performed in Medford through 2010, after which the monitor site was closed. Per this report, NAAQS are met at the Klamath Compressor Station and along the path of the PCGP with the exception that approximately 4.3 miles of pipeline would be located within the Klamath Falls PM2.5 nonattainment area (out of compliance with NAAQ standards) and approximately 300 feet of pipeline would be located within the PM10 maintenance area (formerly out of compliance).

Hazardous air pollutants (HAPs) are also generated both with construction and operation of the Compressor Station and Pipeline, primarily formaldehyde. The JCEP Resource Report 9 states that these levels meet current standards, although no safe levels have been established.

During 2014 and 2015, Klamath Falls experienced elevated PM2.5 ambient concentrations due to wildfires in southern Oregon.¹¹² During the 2018 fire season the highest concentration of wildfires in the state was in Southern Oregon and air quality alerts were issued to residents of Klamath Falls.¹¹³ However, the DEIS for Jordan Cove does not consider cumulative effects of toxic pollution from fires with ongoing toxic emissions, particularly from compressor stations.¹¹⁴

Kalama Methanol Refinery

Methanol refining is an industrial process that emits significant amounts of air pollution. Methanol itself is toxic when ingested or inhaled. It affects the nervous system, particularly the optic nerve, and is the toxin responsible for the cases of blindness from drinking homemade spirits (moonshine). Principle TAPs from the refinery would include nitrogen oxides, sulfur dioxide, carbon monoxide, and VOCs. PM2.5 emissions from the refinery are particularly worrisome because no safe level exists for these pollutants.

¹¹¹ (Macey, 2014) doi: 10.1186/1476-069X-13-82

¹¹² (Jordan Cove LNG, 2017)

¹¹³ (Linares, 2018)

¹¹⁴ (Office of Energy Projects: Federal Energy Regulatory Commission, 2019)

According to the FEIS, all toxic air emissions beyond the industrial site itself would fall within limits set for Washington State. Within the physical confines of the operation, however, the levels of PM_{2.5} would exceed standards by five-fold. (Table 4.6¹¹⁵) The emission estimates assume the use of Ultra-Low Emissions (ULE) technology which, according the FEIS, is expected to decrease the emissions of GHGs and toxic air pollutants.

Two possible technologies for producing methanol from methane are considered in the Final Environmental Impact Statement. Combined reformer (CR) technology is currently deployed in all large-scale methane to methanol refineries worldwide. The alternative proposed for the Kalama methanol plant is ULE, which would reduce PM_{2.5} emissions by about 60%. However, while ULE technology has been used to produce other chemicals from methane, it is a new technology for methanol production and has only been deployed in one small methanol plant in Australia. It has never been applied at any full-scale methanol production facility. Table 9 (reproduced from the FEIS¹¹⁶) displays total expected annual emissions from normal facility operations, based on the two different technologies.

Pollutant	Combined Reformer	Ultra-Low Emissions
nitrogen oxides (NO _x)	124 tons/year	75 tons/year
carbon monoxide (CO)	584 tons/year	72 tons/year
particulate matter (PM)	161 tons/year	64 tons/year
sulfur dioxide (SO ₂)	46 tons/year	46 tons/year
volatile organic compounds (VOC)	105 tons/year	54 tons/year

¹¹⁵ (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

¹¹⁶ (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

Diesel exhaust is another source of concern. During construction and operation of the terminal, diesel exhaust emissions will arise from construction and support vehicles, generators, and marine vessels servicing the terminal. It is composed of various pollutants including VOCs, NO_x, and PM_{2.5} and is carcinogenic. But to estimate cancer risk of diesel emissions at the refinery the FEIS drew on a 2002 EPA statement that “human-response data [related to diesel exhaust] are considered too uncertain to derive a confident quantitative estimate of cancer unit risk.”¹¹⁷ In fact, in 2012 the IARC (World Health Organization) upgraded its classification of diesel particulate matter to a known and certain carcinogen.¹¹⁸

Anhydrous Ammonia

Anhydrous ammonia (NH₃) is a common nitrogen containing fertilizer used in industrial agriculture to promote rapid plant growth. Its agricultural use results in significant contributions to worldwide GHG emissions. NH₃ is also used as a refrigerant and is a key chemical in the illicit production of methamphetamine. Numerous thefts of NH₃ have occurred for the purposes of producing methamphetamine resulting in leaks and releases due to improper handling and storage.

Exposure to anhydrous ammonia can cause severe eye, nose and throat irritation, breathing difficulty, wheezing, chest pain, pulmonary edema (fluid build-up in the lungs), burns, blisters, and frostbite. According to The Centers of Disease Control and National Institute of Occupational Safety and Health, exposure is fatal at concentrations as low as 300 parts per million.

The production of ammonia is energy intensive and accounts for 1-2% of worldwide energy use and 3% of worldwide greenhouse gas emissions.¹¹⁹ But Cornell University and the Environmental Defense Fund recently released a study demonstrating that methane gas emissions from fertilizer plants are “vastly underestimated” and may be as much as 100 times higher than the self-reported estimates of the industry.¹²⁰ This industrial process also releases other types of air pollution.

The proposed Pacific Coast Fertilizer plant, which would be sited in Longview, Washington’s Mint Farm Industrial Park, would produce anhydrous ammonia using fracked gas. The Draft EIS (DEIS) is expected in the spring of 2019. However, toxic emissions would be similar to

¹¹⁷ (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

¹¹⁸ (International Agency for Research on Cancer, 2012)

¹¹⁹ (Lehigh University, 2018)

¹²⁰ (Garris, 2019)

the Dyno-Noble Fertilizer plant in nearby St Helens, Oregon, which emits particulate matter, nitrous oxides, carbon monoxide, and VOCs.¹²¹ The proposed Longview plant is expected to produce four to six times as much fertilizer per year, compared to the Dyno-Noble plant, with a proportional increase in the amount of toxic emissions.

Puget Sound LNG

Toxic emissions, as modeled for the Puget Sound LNG FEIS, do not exceed the critical statutory thresholds for air pollution.¹²² For reasons elaborated above this does not ensure that air quality would not be degraded and harmful to both workers and the community. Emissions from construction, which include stirring up contaminants in the earth from prior industrial activities, would create a toxic mix of nitrous oxides, carbon monoxide, sulfur dioxide, PM2.5, volatile organic compounds, and other toxic air pollutants (TAP).

Operations of the facility would result in emissions from the pretreatment heater, enclosed ground flare, emergency flare, LNG vaporizer, 1600KW backup diesel generator as well as fugitive emissions from pipelines and storage tanks and refrigerant leaks and losses. These emissions would include the same pollutants as listed above for construction, plus sulfuric acid.

Tacoma-Pierce County was out of compliance with National Ambient Air Quality Standards (NAAQS) for PM2.5 for several years. Compliance was attained in March of 2015 (daily PM2.5 = 33 micrograms per cubic meter/one-year average; threshold for non-compliance = 35).¹²³ As this same report notes, however, serious adverse health effects are experienced at levels below the NAAQS. The LNG facility would only add to this problem.

Methane has been promoted as a “clean” fuel for maritime vessels, particularly in comparison to diesel. But measurements of the gaseous and particulate emissions of a cruise ferry on the Baltic Sea using a dual-fuel engine showed that LNG is not such a clean fuel for ships.¹²⁴ Methane made up about 85 percent of the vessel’s hydrocarbon emissions. Particulate emissions showed substantial amounts of volatile and nonvolatile particles, both of which are hazardous to human health.

¹²¹ (Oregon Department of Environmental Quality)

¹²² (Final Environmental Impact Statement: PSE LNG, 2016)

¹²³ (Washington State Department of Ecology, 2016)

¹²⁴ (Anderson, 2015)

WATER AND LAND POLLUTION

Clean, fresh water is one of the most important and abundant natural resources in the Pacific Northwest. It is also one of the region's features that attracts the gas industry, which requires staggering amounts of water for construction and operation of its infrastructure, especially refineries. At the same time, the infrastructure threatens to pollute and degrade watersheds and waterways that communities and wildlife rely upon. Adverse impacts on land are closely related and include loss of farmlands, wetlands, and forest and despoilment of the natural beauty of the Pacific Northwest.

Oregon and Washington economies are highly dependent on reliable water and water systems for human consumption, agriculture and livestock, manufacturing, transportation, energy production, and recreation. Clean water is essential to our environmental health, for trees and vegetation, wetlands, aquatic life, and human health. Drought related to climate change has already negatively impacted lands and water systems in the Pacific Northwest.

As noted by the Oregon Department of Environmental Quality, "Many studies have shown that it is more cost-effective to prevent pollution in the environment than to remove it through treatment or to implement restoration."¹²⁵ Reducing or eliminating pollutants through protection and prevention can:

- lower treatment and maintenance costs for public water providers
- improve long-term viability of groundwater drinking water sources
- reduce the need for equipment replacement or upgrades
- reduce risks associated with many contaminants (including ones known to be toxic, persistent, and/or bio-accumulative)
- promote long-term assurances of a safe and adequate drinking water supply
- help protect property values and preserve the local and regional economic growth potential
- enhance public confidence in their drinking water
- reduce the need for expensive treatment in both surface water and groundwater

Alternatively, pollution of drinking water associated with fracked gas infrastructure may saddle water providers and ratepayers with costly new monitoring and treatment systems.

¹²⁵ (Oregon Department of Environmental Quality Environmental Solutions: Watershed Management Section, 2018) <https://www.oregon.gov/deq/FilterDocs/SurfaceWaterResourceGuide.pdf>

Pacific Connector Pipeline

The proposed Pacific Connector Pipeline (PCP) has vast potential to degrade water quality and quantity on public, private, and tribal land for drinking water and other beneficial uses. The project would directly harm approximately 480 Oregon rivers and streams by clearcutting through riparian areas, building new roads to access these rivers, damming and diverting water, cutting trenches and laying a 36-inch pipeline directly through riverbanks and riverbeds. Horizontal drilling beneath the wild and scenic Rogue, Umpqua, Coquille, Coos, and Klamath Rivers could result in pollution of waters with toxic drilling fluids. At least twelve public drinking water sources are located in watersheds to be transected by the proposed pipeline. (See Appendix III for detailed information.)

The pipeline would slash a 95-foot wide swath through forest, ranch, and farm land and would also cross the popular recreational hiking trail, the Pacific Crest Trail. Clear cuts along the trail and elsewhere would be permanently maintained by cutting and spraying fertilizers, herbicides and pesticides.

During construction, testing of the pipeline to determine if it will hold gas would utilize enormous quantities of fresh water in areas that are designated as drought affected. For example, the Klamath Basin and those who rely on Klamath water (irrigators, tribal communities, endangered species, wildlife refuges, and associated wildlife) already experience extreme strain on water resources. Testing could require over 60 million gallons of fresh water. If the project re-uses water to test multiple segments of pipe, it would still consume at least 16 million gallons of water.¹²⁶ Discharged test water would be contaminated with materials used to construct the pipeline.

According to the Oregon DEQ and the Oregon Health Authority, water contamination “depends on three major factors: 1) the occurrence of a land use/activity that releases contamination, 2) the location of the release, and 3) the hydrologic, ecological, and/or soil characteristics in the source area that allow the transport of the contaminants to the waterbody and thereby the intake.”¹²⁷

Human factors affecting water quality include:

- All activities and facilities within riparian areas
- Road locations and conditions, especially stream crossings, and roads near streams, on steep slopes, and with drainage systems connected to the stream network

¹²⁶ (Draft Environmental Impact Statement for the Jordan Cove Energy Project, 2019)

¹²⁷ (Oregon Department of Environmental Quality Environmental Solutions: Watershed Management Section, 2018)

- Stormwater runoff from contaminated lands, for example, with high phosphorus or nitrogen content
- Recently managed forestland which has been harvested, replanted, and treated with herbicides.
- Quarries, construction, and other industrial sites
- Hazardous material sites
- Solid waste landfill sites

Each of these factors is associated with the proposed pipeline.

Some landscapes are more sensitive to disturbances and contamination has greater potential to impact the water supply.¹²⁸ Sensitive areas include:

- Riparian areas
- Springs, seeps, and wetlands
- Steep slopes (>70-85%)
- Floodplains
- Areas with high soil erosion or runoff potential, for example, disturbed or bare soil
- High water table areas
- Areas of high soil permeability
- Areas within 1000 feet of rivers and streams.

The proposed pipeline would pollute streams, wetlands and riverbeds; blast rock and hillsides; clear-cut and destroy vegetation in each of these sensitive areas within municipal watersheds. Potential adverse impacts include:

- increased water temperature from loss of forest cover and riparian area buffers
- increased erosion from loss of forest cover and riparian areas leading to increased sediment and turbidity
- increased use of chlorine due to higher turbidity levels, leading to increased chemical by-products that carry their own health risks
- contamination of water and soil by oil, lubricants, and chemicals
- movement of non-native species into watersheds on tires of vehicles, on boats, and equipment

¹²⁸ (Oregon Department of Environmental Quality Environmental Solutions: Watershed Management Section, 2018)

- fires due to construction and blasting accidents and rupture or failure of the pipeline
- wildfire leading to pipeline explosion leading to larger wildfire
- water contamination through accidental application of fire suppressants/retardants
- post-fire slope failures, debris flows, landslides, increased turbidity, loss of drinking water, increased cost for replacement of drinking water, increased costs for water treatment
- disruption of surface water connection with groundwater (from blasting and water diversions)
- disruption of groundwater connection with wells and surface water (from blasting and water diversions)
- contamination of water by herbicides like picloram (to maintain right-of-way free of vegetation on and near the pipeline route) which could persist in the groundwater for years
- contamination of water by intensive use of fertilizers to re-plant cleared area around pipeline
- increased incidence of harmful algal blooms

Construction and operation of the pipeline would also degrade habitat for aquatic life, especially the endangered Coho salmon, with negative impacts on fishing and traditional activities of tribal communities. Habitat degradation would occur through loss of forest canopy, removal of riparian vegetation, decreased summer flows, warming of water, and addition of fertilizers/nutrients to encourage re-growth of vegetation on certain properties following installation of the pipeline.

These same effects would increase risk of harmful algal blooms (HAB). According to the Centers for Disease Control and Prevention, HAB can produce toxins that cause illness in people, companion animals, livestock and wildlife.¹²⁹ Exposures to the toxins can occur when people or animals have direct contact with contaminated water by:

- Swimming
- Breathing in aerosols (tiny airborne droplets or mist that contain toxins) from recreational activities or wind-blown sea spray

¹²⁹ (Centers for Disease Control and Prevention, n.d.)

- Swallowing toxins by drinking contaminated water or eating contaminated fish or shellfish

Human and animal illnesses and symptoms vary depending on the nature and length of exposure and the particular HAB toxin involved. Common toxins include cyanotoxins which can be toxic to the nervous system, liver, skin, or the gastrointestinal tract. No human deaths in the United States have been caused by cyanotoxins; however, companion animal, livestock, and wildlife deaths caused by cyanotoxins have been reported throughout the United States and the world.¹³⁰

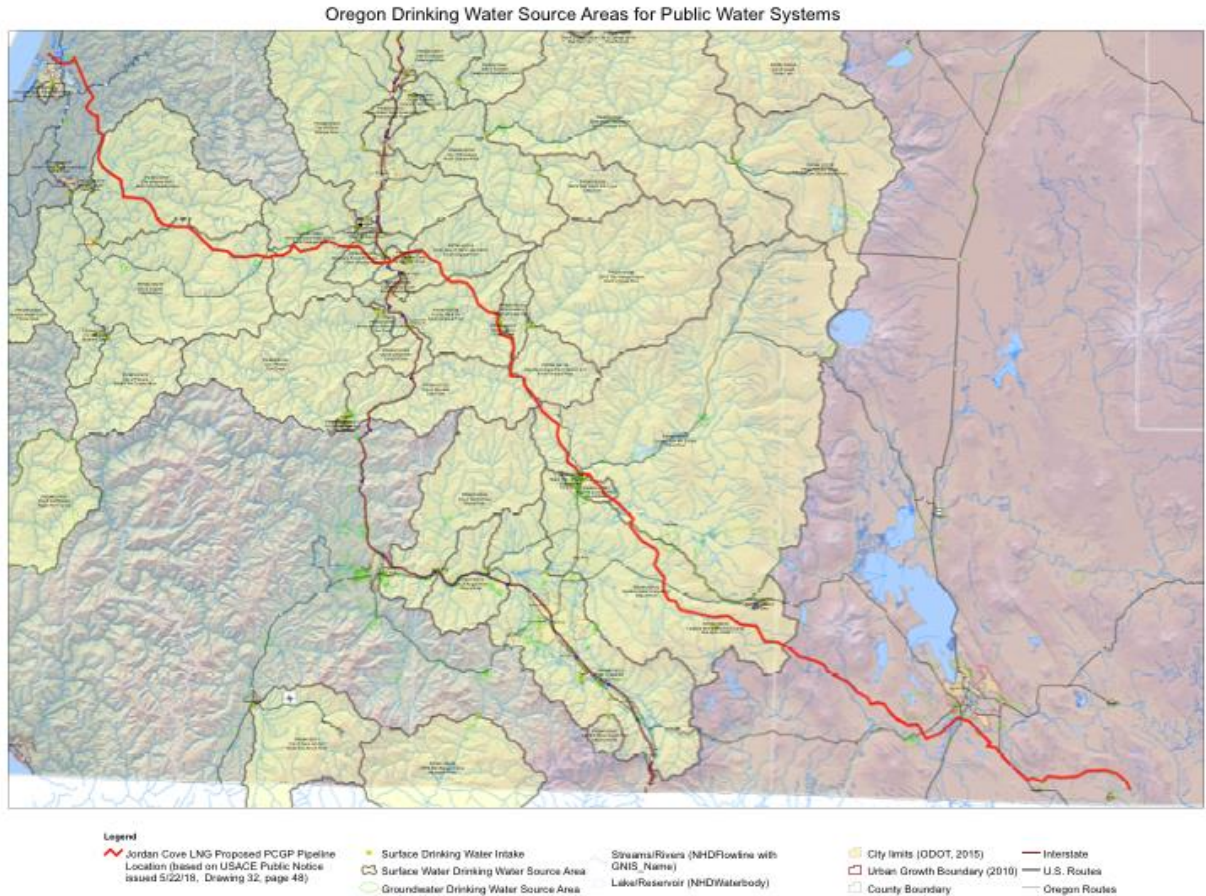
During the summer of 2018, a state of emergency was declared by Governor Brown when the drinking water supply for the City of Salem was tainted by HABs. Eight drinking watersheds in SW Oregon that would be transected by the PCGP are today at risk for HAB.¹³¹ The construction and maintenance of the proposed Pacific Gas Connector Pipeline would greatly exacerbate that risk.

The following map illustrates the course of the proposed pipeline and the many drinking watersheds that would be directly disturbed and degraded by the project. Many more drinking water sources could be damaged if a fire associated with the PCP were to start in a small watershed, jump a ridge and burn out of control within and/or beyond the larger Rogue, Umpqua, Coquille, Klamath or Coos watersheds.

¹³⁰ (Centers for Disease Control and Prevention, n.d.)

¹³¹ (Oregon Health Authority, 2018)

Figure 12
Pacific Connector Gas Pipeline and Drinking Water Sheds



According to the Jordan Cove DEIS, “If a groundwater supply is affected by the Project, Pacific Connector would work with the landowner to provide a temporary supply of water; if determined necessary, Pacific Connector would provide a permanent water supply to replace affected groundwater supplies.”¹³² The same claim is made for mitigation for a temporary or permanent loss of surface water supplies. Replacement of a permanently contaminated aquifer or surface water drinking source would, however, require trucking in bottled water or piping it in from an alternative source. This would be costly, difficult, and in some cases impossible. It would represent a permanent erosion of quality of life as well as significant reduction in land value. Lack of an affordable and reliable source of clean water renders a landscape uninhabitable over the long term.

¹³² (Draft Environmental Impact Statement for the Jordan Cove Energy Project, 2019)

Jordan Cove LNG

Construction and operation of the terminal would require massive dredging operations in the Coos Bay Estuary, which is critical habitat for Coho salmon and is home to thriving oyster farms, traditional shellfish gathering areas, as well as other aquatic and estuarine life. Dredging and disposal of dredged material will increase turbidity, degrade the shoreline and the bay and negatively impact habitat in the area.

The project would remove roughly 6 million cubic yards from the Coos Bay Estuary. A related channel deepening project would increase the overall dredging to 18 million cubic yards in the estuary, and would be one of the largest dredging proposals in Oregon's history.¹³³ Suspended sediment will make the water murky and increase turbidity. Dredging of this scope would stir up contaminated sediments from past industrial activities, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), heavy metals, petrochemicals, pesticides and other persistent and toxic contaminants. These could enter the food chain, accumulate in the tissues of animals and fish and present significant health risks to people consuming these foods. Contaminated sediments also pose a major threat to shellfish such as oyster beds, a major local industry.

Endangered Oregon Coast Coho salmon would be negatively impacted. Impacts on one stock of salmon can degrade fishing throughout Southern Oregon and Northern California, threatening loss of livelihood and food source to communities in the region. Diminished access to salmon and shellfish would especially harm tribal nations and their protected resources, exacerbating injustices to these and other communities that rely on aquatic resources for their livelihoods.

LNG vessel traffic in Coos Bay would further interfere with ocean-based fisheries.¹³⁴ The Dungeness crab fishery is consistently the most valuable single species commercial fishery in Oregon, making the crustacean's well-being of special significance to the economy of Coos Bay and the State of Oregon itself.¹³⁵ According to Professor Sylvia Yamada, Assistant Professor of Senior Research in the Department of Zoology at Oregon State University, Coos Bay is a crucial "nursery" habitat for the Dungeness crab.¹³⁶ The highest number of juvenile crabs are found in soft sediments and eel grass beds of estuaries, where the young crabs find food and shelter from predators.

¹³³ (Oregon Department of Environmental Quality, n.d.)

¹³⁴ (Rogue Climate, 2019)

¹³⁵ (Knoder, 2018)

¹³⁶ (Yamada, 2019)

Not only would the turbidity during the construction phase of the LNG terminal negatively impact the ecological community, the ongoing dredging to maintain the berth and shipping channels would continue to disturb the ecosystem. In a study by Professor Yamada designed to simulate a dredging operation, she found that 45 - 85% of the Dungeness crabs exposed to the operation died. Over the four-year estimated construction period, Dungeness crabs would face repeated exposure to dredging activities that could substantially increase their rates of mortality.

Michael Graybill is the former manager of the South Slough National Estuarine Research Reserve, a fisherman, and current resident of Coos Bay. He testified in public hearings in January of 2019 that individual boats involved in commercial fisheries including the Dungeness crab, salmon and pink shrimp work as a fleet.¹³⁷ When Dungeness crab season opens and weather conditions permit, the boats in the fishery head toward sea in unison. Particularly in winter, which is commercial crab season, boats at sea monitor weather conditions and the effects on the bar. In declining or marginal weather conditions, the fleet of boats reverses direction and heads together for the bar. Their safe return can consume the entire window of suitable incoming high tide conditions. When the tide reverses and begins to ebb, conditions on the bar deteriorate rapidly. Boats that miss this window are forced to ride out the storm at sea until the next high flood tide. Adding LNG ship traffic would negatively impact the existing use of the navigation channel by the fishing fleet. Closing the bar for the necessary thirty minutes over high tide to accommodate passage of an LNG carrier risks stranding one of the fishery fleet boats at sea in bad weather, a serious if not life-threatening outcome.

Coal Bed Methane Extraction

Oregon DEQ issued a Discharge Elimination System permit in 2007, which was renewed in 2012 and remains active until 2020. While in some coal bed methane (CBM) developments wastewater is reinjected back into the ground, the Coos County project is permitted to treat and then discharge wastewater into the Davis Slough five miles south of Coos Bay.¹³⁸ The discharge is contaminated with a number of hazardous chemicals that may include benzene, toluene, ethylbenzene and heavy metals including arsenic, cadmium, lead, mercury, and copper. Although

¹³⁷ (Graybill, 2019)

¹³⁸ (Oregon Department of Environmental Quality, 2018)

extraction is currently suspended, the pre-existing Curzon wells are exempt from the 2019 5-year moratorium on gas fracking in Oregon.¹³⁹

Kalama Methanol Refinery

The methane to methanol refinery would be the largest methanol plant in the world, and it would sit on the banks of the Columbia River, adjacent to wetlands and overlying the alluvial aquifer associated with the Columbia and Kalama rivers and from which the City of Kalama draws its water. The refinery will significantly impact water resources during both construction and operation.

During construction stormwater and surface runoff would be discharged into the Columbia River and adjacent wetlands, carrying sediment, debris, fuel, oil, grease, and other hazardous pollutants that could affect water quality, especially if accidental spills occur.¹⁴⁰ Dredging to accommodate shipping vessels and installation of concrete and steel pipes will cause turbidity in the Columbia River, which can be harmful to aquatic life. Dredging could also disturb sediments, releasing accumulated hazardous chemicals into the water.

During operations, real and potential adverse impacts on water resources include:

- Degradation of water quality of the aquifer due to contaminated stormwater runoff and accidental spills of methanol or other hazardous chemicals
- Increased vessel traffic on the Columbia River with increased potential for toxic spills
- Consumption of the vast quantities of fresh water

Toxic spills of bunker fuel or methanol into the Columbia from ships, as well as toxic spills at the refinery of chemicals used in producing methanol and waste products such as heavy metals could contaminate the underlying aquifer, which supplies drinking water to the thousands who live nearby. Neither the FEIS or Draft Supplemental EIS (DSEIS) seriously examine this possibility.

A healthy Columbia River basin is essential to northwest fisheries and to the Columbia River tribes who rely on the fish for food, cultural, and spiritual resources. In addition, at a time when Southern Resident killer whales are on the verge of extinction, impacts on Chinook salmon and other fisheries in the Columbia River basin must be considered.¹⁴¹ Yet the FEIS gives short shrift to the issue, mentioning fish rarely and whales not once. The FEIS concedes that increased marine traffic “would have the potential to result in cumulative impacts to wildlife and fisheries resources,

¹³⁹ (Loew, Oregon Senate passes 5-year fracking moratorium for oil, natural gas, 2019)

¹⁴⁰ (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

¹⁴¹ (Nations of Yakama, Umatilla, Warm Springs and Nez Perce, n.d.)

including increased potential for the introduction of invasive species, ship strikes, and wake stranding.”¹⁴² Despite this, the FEIS made no attempt to quantify these impacts on fisheries. It goes on to say the refinery will increase the overall risk of spills and erosion impacting not only fish, but the riparian and aquatic vegetation as well.

Endangered Southern Resident killer whales are in decline. With only 78 animals remaining, they are among our nation’s most endangered species.¹⁴³ According to the National Oceanic and Atmospheric Administration (NOAA), the threats facing the Southern Residents are reduced prey (Chinook salmon), vessel traffic, noise, and toxic contaminants and spills. These are the very impacts, identified in the FEIS, that the refinery operations would have on the Columbia River. It would indirectly harm whales by putting further pressure on their primary food source, the Chinook salmon that spawn in many western rivers, but in the greatest numbers in the Columbia. Southern Residents rely most heavily on this particular source.

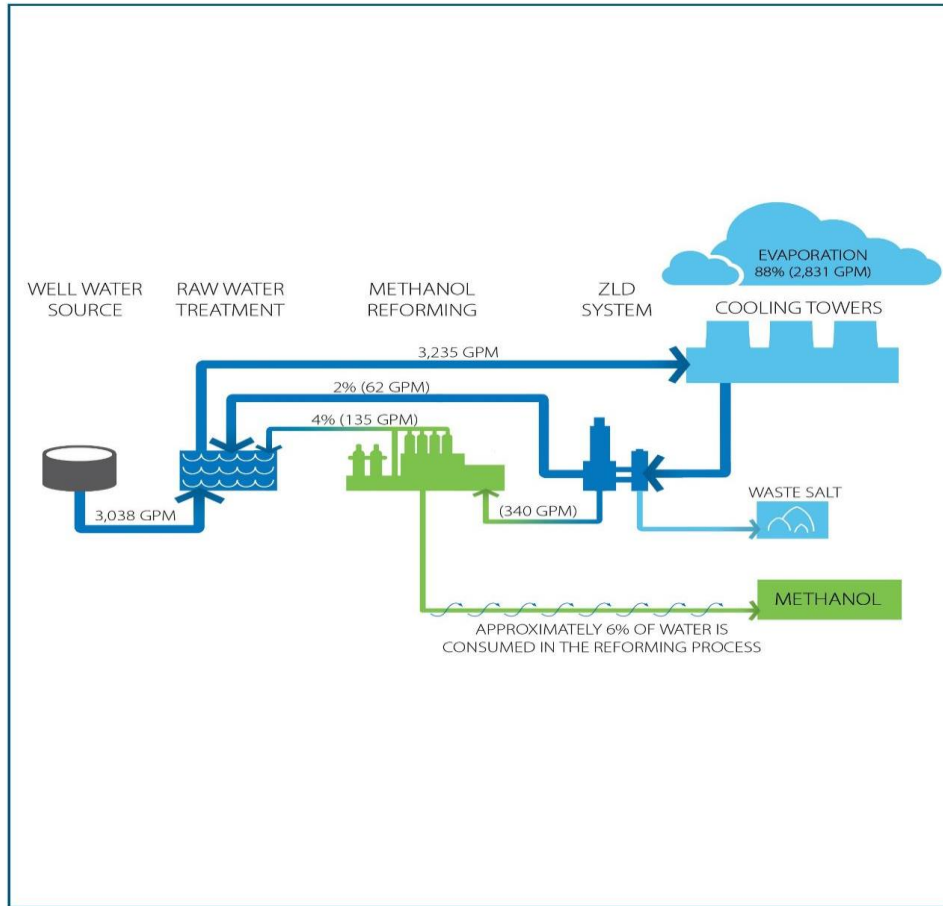
Methanol refineries consume huge quantities of fresh water. The proposed refinery at Kalama would use as much as 5 million gallons/day and would require construction of a new groundwater collector well that would dip into the underlying alluvial aquifer, the water source that supplies the City of Kalama. Nearly 90% of the water (2831 gallons/min) would be lost as evaporation from the cooling towers. The typical Kalama household of four uses 250 gal/day, and the population of Kalama is 2700, which means the refinery alone would consume more than seven times the amount of water used by the residents of Kalama.¹⁴⁴ Figure 13 illustrates the proposed industrial water use cycle. The largest share of the water used would be discharged as water vapor, which is itself a greenhouse gas.

¹⁴² (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

¹⁴³ (National Oceanic and Atmospheric Administration, 2018)

¹⁴⁴ (City of Kalama, n.d.)

Figure 13
 Kalama Methanol Plant Industrial Water Cycle



Industrial Water Cycle with Zero Liquid Discharge (ZLD)
 Figure 5-5



As conceded in the FEIS, “Groundwater levels could be affected by the operation of the proposed well, which could affect water supplies at other wells located in the alluvial aquifer.”¹⁴⁵ It concluded that water supply would be sufficient, based on tests showing that a pumping rate of up to 6,600 gallons/minute would have no discernible drawdown on the aquifer. The new well would draw at 3440 gallons/min, so the tests exceeded the proposed draw rate by less than two-fold.

According to the Climate Impacts Group, climate change in our region will bring decreased water for irrigation, fish, and summertime hydropower production; increased conflicts over water;

¹⁴⁵ (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

and increased urban demand for water.¹⁴⁶ The Fourth National Climate Assessment predicts a decrease in summer precipitation by up to 30 percent and low stream flows west of the Cascades.¹⁴⁷ The massive fresh water consumption of the methanol plant would only add to the growing pressure on water resources from drought predicted in the coming decades.

All of these concerns apply to the proposed refinery at Port Westward, which would, in addition, require a controversial re-zoning of more than 800 acres of prime agricultural land for industrial use,¹⁴⁸ which would only add to adverse impacts on agriculture predicted by current climate change science.¹⁴⁹

Longview Anhydrous Ammonia Plant

Pacific Coast Fertilizer has proposed an anhydrous ammonia manufacturing facility in Longview at the Mint Farm Industrial Park, which borders residential neighborhoods and sits a half-mile from the Columbia River. The facility will manufacture 1,650 tons of ammonia per day, consuming about 2.5 million gallons of water and discharging about 1 million gallons of wastewater.¹⁵⁰ The cooled liquid ammonia will be stored on site for subsequent delivery to west coast destinations by truck and to international markets by marine vessels, with an estimated 12 to 15 ships per year transiting the Columbia River.

The Longview ammonia facility would be located less than fifteen miles from the proposed Kalama methanol refinery, along the same stretch of the Columbia River, raising many of the same concerns. An EIS is under way for the ammonia facility, which will provide more details about its impact during construction and operation.

During construction stormwater and surface runoff would carry sediment, debris, fuel, oil, grease, and other hazardous pollutants, with the potential that these contaminants would find their way to the Columbia River and/or the aquifer, which supplies the drinking water for residents of Longview.

Operation of the facility raises similar concerns enumerated for the Kalama methanol plant, including:

¹⁴⁶ (Snover, 2013)

¹⁴⁷ (Ebi, 2018)

¹⁴⁸ (Zimmer-Stucky, Conservation Groups File Lawsuit to Protect Important Farmland, Salmon Habitat Near Controversial Columbia River Port, 2018)

¹⁴⁹ (Ebi, 2018)

¹⁵⁰ (DePlace E. &, 2017)

- impacts on water quality of groundwater due to contaminated stormwater runoff, accidental spills of ammonia or hazardous chemicals used in its manufacturing, and discharge of wastewaters, including contamination of the drinking water for local residents
- impacts on the Columbia River due to increased vessel traffic and the potential for toxic spills
- consumption of large quantities of fresh water required for ammonia manufacturing

These two facilities alone would consume 7.5 mill gallons/day, or about three times the amount of water consumed by all the residents of Longview and Kalama combined.

Anhydrous ammonia poses additional risk to the Columbia River and Northwest fisheries. Extremely small quantities of ammonia can kill freshwater fish. A small-scale tractor accident in 2016 spilled ammonia into an Indiana creek, killing at least 500 fish and in 2004 a larger ammonia pipeline spill killed 25,000 fish in a nearby Kansas creek.¹⁵¹ In 2001, a tanker spill near West Milton, Ohio created a “two-mile plume of anhydrous ammonia in Ludlow Creek,” killing 103,300 fish.¹⁵² As noted in this report by the Center for Effective Government, accidents involving ammonia plants are not rare. From 1998 to 2013, almost 1,000 accidents have occurred at 678 facilities storing large quantities of anhydrous ammonia in the United States.

Puget Sound LNG

Puget Sound Energy has begun building an unpermitted LNG facility on the Blair-Hylebos Peninsula on Commencement Bay and where the Chinook Landing Marina, owned by the Puyallup Indian Tribe, is also located. Elements of the project will cross two drainage basins and two watersheds.¹⁵³ The LNG will be used for fueling maritime vessels and other purposes.

Both construction and operation raise concerns about water pollution. As detailed in the FEIS, construction will entail substantial in-water work, including the demolition and removal of a pier, a dock, and a catwalk, and the installation of 150 piles to build a trestle and loading platform. These activities carry the risk of erosion and sedimentation, along with migration of debris and sediment, all very damaging to salmon and other marine life. Construction stormwater and surface runoff carrying sediment, debris, fuel, oil, grease, and other hazardous pollutants could find their

¹⁵¹ (DePlace E. &, 2017)

¹⁵² (Plagakis, 2013)

¹⁵³ (Final Environmental Impact Statement: PSE LNG, 2016)

way to groundwater or Commencement Bay. Existing subsurface contamination could also spread into groundwater during construction. Advisories already exist that limit the quantities of fish from Commencement Bay and nearby waters that can be safely eaten.¹⁵⁴ Further pollution would harm fish, killer whales, and other marine life, with negative consequences for the Puyallup Indian Tribe, whose land overlaps with the facility site.

Operation of the facility carries the same risks of contaminated stormwater and surface runoff. More serious risks are associated with bunkering (fueling) of vessels with LNG on the waterways, which include barge-to-ship bunkering, truck-to-ship bunkering, along with pipeline transfer of LNG. The bunkering operations entail risks of spills of the barge and truck diesel fuels, as well as a risk of an LNG spill. Marine traffic will increase, contributing to the risk of spills from collisions. Barge and truck fuels are particularly dirty, making spills or leaks especially damaging to the groundwater and Commencement Bay. The impacts on the waterways have not been fully addressed in the FEIS with respect to the Puyallup Indian Tribe activities and resources, as well as marine wildlife including fish and Southern Resident killer whales.

A major accidental spill into the waterways or Commencement Bay could happen during fueling, as a result of collision with another ship or due to intentional (e.g. terrorist) activity. The spilled LNG would create a spreading, evaporating pool that could ignite. According to the Sandia National Laboratories, a collision causing a small to medium spill would likely lead to a fire that would cause damage and injury within a half mile radius; a larger spill (e.g. due to intentional breach) would cause damage and injury more than a mile away.¹⁵⁵ These are unlikely scenarios but must be considered due to the proximity of residential areas of Tacoma and the Puyallup Tribal lands and cultural resources.

Industry and U.S. Coast Guard guidelines specify that LNG port terminals be located in remote areas of ports, not near civilians, narrow waterways, or other facilities that could produce sparks.^{156 157} The siting of the LNG facility on the Blair-Hylebos Peninsula violates each of these conditions. The U.S. Coast Guard has not yet approved the Waterway Suitability Analysis report for this facility.¹⁵⁸

¹⁵⁴ (Washington State Department of Health, n.d.)

¹⁵⁵ (Hightower, 2004)

¹⁵⁶ (Hay, n.d.)

¹⁵⁷ (U.S. Coast Guard, 2008)

¹⁵⁸ (Final Environmental Impact Statement: PSE LNG, 2016)

Tacoma's Commencement Bay was declared a Superfund site in 1983. After decades of cleanup and the recovery of critical populations of birds, fish, and other marine animals,¹⁵⁹ construction and operation of an LNG processing and bunkering facility only threatens to undo those environmental gains. Portions of the LNG site are already contaminated with industrial solvents from Occidental Chemical (OxyChem). The OxyChem Superfund cleanup is incomplete, raising concerns about whether construction activity would facilitate further water pollution from OxyChem's legacy pollution.¹⁶⁰

NOISE POLLUTION

Construction and operation of fracked gas terminals, methanol refineries, anhydrous ammonia plants, compressor stations, metering stations, and pipelines expose workers and nearby residents to high levels of noise with significant adverse health impacts. The World Health Organization (WHO) estimates that at least one million years of healthy life years are lost every year in western European countries because of environmental noise.¹⁶¹

Goines and Hagler noted in their review of noise pollution that noise violates one of the six guaranteed constitutional rights, the right of domestic tranquility. They stated "the potential health effects of noise pollution are numerous, pervasive, persistent, and medically and *socially significant*" and identified seven adverse effects of noise:¹⁶²

- hearing impairment
- interference with spoken communication
- sleep disturbances
- cardiovascular disturbances
- disturbances to mental health
- impaired task performance
- negative social behavior and annoyance reactions

¹⁵⁹ (National Oceanic and Atmospheric Administration, 2018)

¹⁶⁰ (DePlace E. , Who Should Pay for Tacoma's Last Big Cleanup?, 2017)

¹⁶¹ (World Health Organization, 2011)

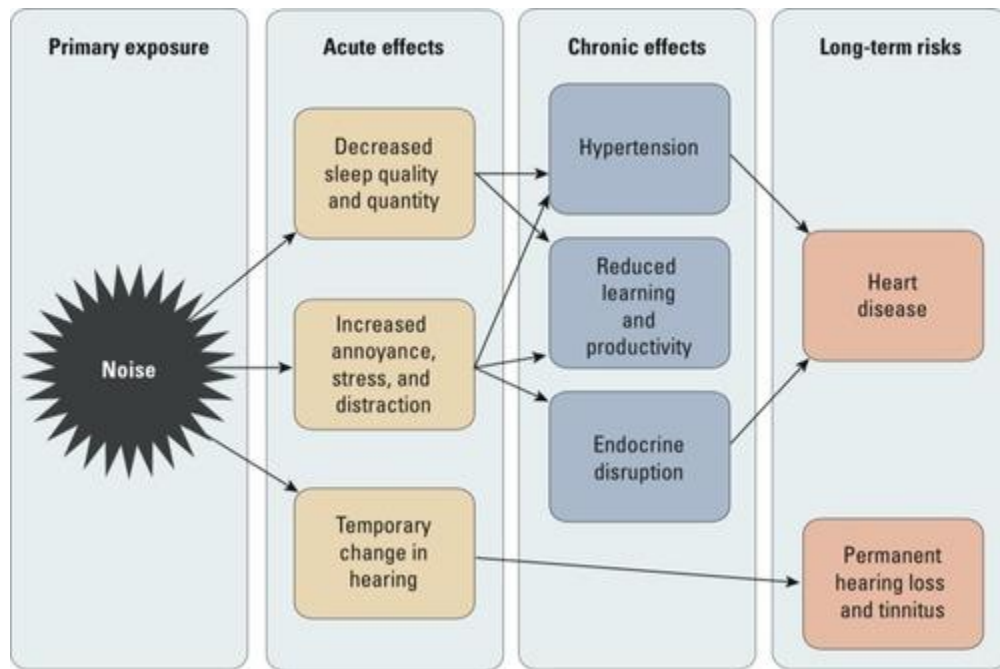
https://www.who.int/quantifying_ehimpacts/publications/e94888.pdf?ua=1

¹⁶² (Goines, 2007) <https://www.ncbi.nlm.nih.gov/pubmed/17396733>

The populations most vulnerable to these effects include those with chronic disease, fetuses, infants and young children, and the elderly.¹⁶³

Hammer, et.al. notes these effects in Figure 14.¹⁶⁴

Figure 14
Health Effects of Noise Pollution



Noise pollution adversely affects health primarily by increasing stress. Experienced as annoyance and distraction, noise activates our “fight and flight” hormones, increasing blood pressure and heart rate, ultimately causing hypertension, ischemic heart disease (angina and heart attack) and stroke.^{165 166} People in noisy environments experience a subjective habituation to noise, but their cardiovascular system does not habituate.

Noise at night similarly triggers a stress response with the same consequences. Activating the sympathetic nervous system (adrenalin), noise decreases the quality and quantity of sleep, changing the stage of sleep from deep sleep to a less restorative lighter stage.¹⁶⁷ Increased levels of stress hormones—epinephrine, norepinephrine, and corticosteroids—result in increased blood pressure,

¹⁶³ (Goines, 2007) <https://www.ncbi.nlm.nih.gov/pubmed/17396733>

¹⁶⁴ (Hammer M.S., 2014)

¹⁶⁵ (Hammer M.S., 2014)

¹⁶⁶ (Münzel, 2018)

¹⁶⁷ (Muzet, 2002)

heart rate, cardiac output, and vasoconstriction and disruption of circadian rhythms. Ultimately the health consequences are hypertension and ischemic heart disease.¹⁶⁸

- Continuous noise in excess of 30 decibels (dB) disturbs sleep. For intermittent noise, the more frequent the events the higher the likelihood of awakening.¹⁶⁹
- Sleep disturbance, characterized by difficulty in falling asleep and frequent awakenings, when experienced over a long period of time can lead to less productivity at work, greater need for health care services and increased risk of injury.¹⁷⁰
- In addition to resulting in less restful sleep, sleep disturbance due to noise has been associated with changes in the body's inability to regulate blood pressure and other changes in the cardiovascular system.¹⁷¹ The 2018 WHO Environmental Guidelines detail evidence of the cardiovascular and metabolic effects of environmental noise.¹⁷²
- Extended exposure to high noise levels can lead to inflammation and oxidative stress which can increase the risk of heart disease, such as coronary artery disease, hypertension, stroke, diabetes, and heart failure.¹⁷³
- Adverse health effects are related to total noise exposure from all sources rather than the noise from any single source.¹⁷⁴

Stress experienced by members of the community comes not only from the noise itself and disrupted sleep but from having no control over their environment. In Ohio, interviews of 34 residents living near sites of unconventional gas development reported significant psychological stress from noise pollution and, in some instances, considered moving from the area.¹⁷⁵

A version of sound, referred to as low frequency noise (LFN), since it is in a range typically not audible to most people, has also been shown to adversely affect health. A systematic review of seven observational studies between 2000 and 2015 found associations between exposure to LFN and self-reported annoyance, as well as various other symptoms including hypertension, sleep-related problems, concentration difficulties and headache, in the adult population living in the

¹⁶⁸ (Sforza E., 2004)

¹⁶⁹ (Berglund B. a., 1995)

¹⁷⁰ (Colton, 2006) <https://www.ncbi.nlm.nih.gov/pubmed/20669438>

¹⁷¹ (Berglund B. e., 1999) <https://apps.who.int/iris/handle/10665/66217>

¹⁷² (World Health Organization, 2018) <http://www.euro.who.int/en/health-topics/environment-and-health/noise/environmental-noise-guidelines-for-the-european-region>

¹⁷³ (Münzel, 2018)

¹⁷⁴ (Goines, 2007)

¹⁷⁵ (Fisher, 2018) <https://doi.org/10.1016/j.jenvp.2017.12.008>

vicinity of a range of LFN sources.^{176 177 178} WHO, in their 2018 Environmental Noise Guidelines, recommend that LFN be further studied.¹⁷⁹

Noise Regulation

Regulation of the level and duration of noise at the federal, state, and local levels is not sufficient to protect the American public from the negative health impacts of noise pollution.

- In 1972, the Noise Control Act was passed by Congress, declaring, "... it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes health and welfare."¹⁸⁰
- In 1974, the Environmental Protection Agency (EPA) estimated that nearly 100 million Americans lived in areas where the daily average noise levels exceeded those identified as being safe.¹⁸¹
- In 1982, the government abruptly terminated federal funding for the Office of Noise Abatement and Control. The lack of funds threw total responsibility for noise control to the states.^{182 183}
- The EPA recommends average outdoor noise levels < 55 dB and indoor levels <45 dB.¹⁸⁴
- The most recent WHO noise guidelines, based on systematic reviews of the current science on connections between noise and health, consider average daily exposure levels and night time specific levels based on noise from road traffic, railways, aircraft, wind turbine, and leisure activities. The guidelines recommend < 30 dBA in bedrooms at night for optimal sleeping and 40 dBA outside of bedrooms to prevent adverse health effects of noise. Daytime noise recommendations range from 45-54 dBA.¹⁸⁵ (An A-weighted sound level (dBA) is the sound level in decibels which more closely approximates the frequency response of the human ear and correlates better with subjective reactions to noise.)¹⁸⁶

¹⁷⁶ (Baliatsas, 2016)

¹⁷⁷ (Leventhal, 2004)

¹⁷⁸ (Berglund B., 1996)

¹⁷⁹ (World Health Organization, 2018)

¹⁸⁰ (Goines, 2007)

¹⁸¹ (U.S. Environmental Protection Agency, 1974)

¹⁸² (Shapiro, 1991)

¹⁸³ (Bronzaft, 2000)

¹⁸⁴ (U.S. Environmental Protection Agency, 1974)

¹⁸⁵ (World Health Organization, 2018)

¹⁸⁶ (Beranek, 1992)

- Oregon and Washington specifically exempt construction activities from noise regulations. They also may exempt the operations of the facilities, as well.^{187 188}

Jordan Cove LNG

The proposed LNG terminal would be located in Coos Bay, near the town of North Bend, the Southwest Regional Airport, residential areas, camping and recreational areas (Oregon Dunes Recreational Area). These areas already experience higher than recommended levels of noise, primarily from transportation sources. Both construction and operation of the terminal will add to the existing noise levels.

Construction is projected to take five years with the greatest noise generated in year three. (All information and data about noise sources, levels and duration is derived from Resource Report 9 submitted by JCEP to FERC June 2017.)¹⁸⁹ Noise would be generated from heavy construction equipment and vehicles, pile driving and dredging of the bay, all of which may occur simultaneously and at night. Pile driving would be the dominant noise source and would occur over a two-year period 20 hours per day, creating intermittent high intensity noise that would be intrusive, annoying, and disturbing to the local community, wildlife, and fish. Peak construction activities would result in intermittent noise levels of 129 dBA during the day and 125 dBA at night. Existing ambient noise levels are reported to range from 53-65 dBA, measured at Noise Sensitive Areas (NSA), levels which are already above recommendations, especially at night (>40-45 dB). (NSAs are those areas adjacent to a proposed activity which would be adversely affected by excessive noise levels, for example, homes, hotels, hospitals, schools and churches.) Construction activities are predicted to increase average noise levels significantly, up to 7.6 dB.

Once built the terminal will operate continuously day and night, 7 days a week, generating noise from compressors, combustion and steam turbines, and generators as well as idling tankers and ground flares. Current noise levels from vehicle traffic, recreational vehicle use, boat traffic, ocean surf, and aircraft are significant, 53-65 dBA at NSAs, measured in May 2017. These areas are residential, camping and recreational. Although it is stated in Resource Report 9, that the terminal

¹⁸⁷ (Oregon Administrative Rules)

¹⁸⁸ (Washington Administrative Code)

¹⁸⁹ (Jordan Cove LNG, 2017)

will increase noise levels minimally (0-2.9 dBA), this increase is significant, additive and unremitting, with night time noise levels above recommended levels.

Additional noise sources that were not considered in the Resource Report are dredging and channel maintenance in Coos Bay and potential extension of a runway at the Southwest Oregon Regional Airport, with a significant increase in air traffic noise.

According to Margaret Corvi, Director of the Department of Natural Resources of the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw, pile driving noise and noise from both the construction and operation of the terminal will make tribal cultural practices, such as fishing and harvesting shellfish, unattractive and decrease access to food and economic resources.¹⁹⁰ Pile driving in particular would create levels of intermittent noise significant enough to have behavioral effects on fish and marine mammals, further degrading fishing and harvesting of shellfish. It would also decrease recreational activity for both local residents and visitors to the area, with negative impacts on the local economy.

Pacific Connector Gas Pipeline and Compressor Stations

Construction and operation of the compressor station and pipeline would generate significant noise, all of which is exempted from the Oregon state noise regulations. Environmental health researchers at the University of Maryland's School of Public Health studied noise generated by a compressor station, finding that residents living near a compressor station are potentially exposed to noise levels that are higher than the recommended U.S. EPA levels of 55 dBA (outdoor/daytime) and 45 dBA (indoor/night time). They emphasize that environmental exposures from these stations, including noise, are a significant public health concern and a source of stress for nearby residents in communities like Doddridge County, West Virginia, where researchers conducted this study.¹⁹¹

The Klamath Compressor Station (KCS) would be located in a rural area with sixteen residences within a one-mile radius and will require twelve to eighteen months to build. Average combined construction noise levels at 1500 feet would be 60 dBA, well above recommended noise levels both during the day and especially at night.

KCS would operate 24 hours per day, 7 days per week, generating continuous noise levels that exceed Oregon regulations, which prohibit raising the noise level more than 10 dBA. This

¹⁹⁰ (Corvi, 2018)

¹⁹¹ (Boyle M. e., 2017)

<https://www.tandfonline.com/doi/abs/10.1080/15459624.2017.1316386?journalCode=uoh20>

would occur despite acoustical mitigation measures. Blowdowns (venting of gas) would also occur, both scheduled and emergency, generating high levels of startling intermittent noise. Two metering stations would also be located very near the KCS and generate additional noise.

Construction of the 229-mile pipeline includes Horizontal Directional Drilling (HDD) at six river crossings. Existing noise levels at five of six of these crossings are greater than 55 dBA. HDD will only add to noise levels above those recommended by the EPA. Construction of the pipeline will also include blasting which will generate very high intermittent levels of noise.

The operation of high-pressure gas transmission systems also creates continuous low and extra-low frequency soundwaves in the communities they transverse. These noises are known as “flutter” and “hum.” Low frequency noise (LFN) and vibrations are believed to cause cranial distress, ringing ears, mood swings, throat and digestive problems and psychiatric disturbances. Residential exposure to LFN may increase the adverse effects of higher frequency noise, because most walls in buildings do not attenuate LFN.

Kalama and Port Westward Methanol Refineries

Northwest Innovation Works proposes building twin methane to methanol refineries at the Port of Kalama and Port Westward along the Columbia River over a three-year period. A three-mile pipeline is also proposed for the Kalama methanol refinery. The refinery itself would be located near residential areas in both Washington and Oregon and recreational facilities (Camp Kalama). Little specific information is available for the plant at Port Westward.

Construction of the Kalama manufacturing facility and marine terminal would generate noise from typical construction activities and would be limited to daytime hours. (All information and data about noise sources, levels and duration is derived from Kalama methanol refinery FEIS.)¹⁹² It would involve pile driving, which generates much more annoying impulsive noise. Average levels overall, however, are predicted to be < 60dBA at NSAs.

Operation of the Kalama refinery would generate noise 24 hours per day, seven days per week. At the various NSAs, noise levels from operations would all be < 50 dBA and increase the existing noise levels by < 10 dBA (range 0-12). According to the FEIS, existing noise levels are 40-72 dBA. The added noise from the refinery would increase current levels by >10 dBA at only one NSA. Despite generally meeting current legal standards, the night time noise levels exceed

¹⁹² (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

recommended levels. Levels of noise, however, are legally permitted to exceed 70 dBA at the borders of the project in the industrial area.

Although in compliance with regulatory standards, construction of the Kalama refinery would generate high levels of impulsive noise, especially from pile driving. Operation of the refinery would generate significant noise levels adding to noise levels in the area, which already exceed EPA and WHO noise levels recommended at night.

Construction of the Kalama Lateral Pipeline (KLP) would generate levels of noise above current legal standards and very close to residences in Kalama, both intermittent from blasting into rock and continuous from horizontal directional drilling under I-5 and the BNSF railway.

Longview Anhydrous Ammonia Plant

Pacific Coast Fertilizer plans to build the plant over a three-year period in the Mint Farm Industrial Park, Longview Washington, in 61 acres in an area zoned for heavy industrial use. However, it is located only several thousand feet from residential neighborhoods in Cowlitz County. 42% of Longview's youth live within 1.5 miles of the proposed facility.¹⁹³

Although analysis of noise levels has not been done as yet (a full EIS is planned), operation of the facility would be continuous 24 hours per day, 7 days per week, and include loading 100-200 trucks per week.

Puget Sound LNG

This complex project is already generating noise from the construction of the terminal (without permits) on the Blair-Hylebos Peninsula in the Port of Tacoma very near the heart of the city of Tacoma.

The Puyallup Indian Tribe marina is 1,000 feet away and the nearest home is just over 2,000 feet away. (All information and data about noise sources, levels and duration is derived from the Final Environmental Impact Statement.)¹⁹⁴ The FEIS states that the existing noise environment is high and consistent with an industrial marine port. Noise levels are high both from construction work, 80-90 dBA at 50 feet away and pile driving, 100 dBA at 50 feet. The noise pollution is particularly harmful to the endangered Southern Resident killer whales.

¹⁹³ (Zimmer-Stucky, Protect Longview's Kids, Neighborhoods from Anhydrous Ammonia, 2018)

¹⁹⁴ (Final Environmental Impact Statement: PSE LNG, 2016)

No measurements are reported in the FEIS of noise levels in noise sensitive areas. The FEIS also does not quantitate noise levels for the associated construction projects: Golden Given Limit Station, updating the Frederickson Limit Station, and building two new distribution pipeline segments.

Operation of the LNG Facility and the Tote Marine Fueling system will include day and night mooring and loading of bunkering barges and the operation of pumps, compressors, vaporizers, fans, and blowers. Noise levels are not reported in the FEIS. Noise effects of the operation of Golden Given Limit Station are not reported in the FEIS, as the pipelines are expected not to generate noise because they would be underground and under functional roadways.

NATURAL AND HUMAN-CAUSED DISASTERS

Fracked gas infrastructure is extremely vulnerable to natural and human-caused disasters. Earthquakes, floods, and other events create serious risks of explosions, fires, vapor clouds, and leaks that can release toxic pollutants into air and water and harm workers and communities in the vicinity of infrastructure used to transport, process, store, and export fracked gas.¹⁹⁵

Local, state, and federal regulations create important requirements for energy companies to anticipate and prevent accidents and incidents in which workers, the environment, and other people could be harmed. As the fracked gas industry changes and adopts new technologies, however, researchers point to a lack of understanding and oversight by regulatory bodies to ensure safety.¹⁹⁶

Proposed fracked gas projects in the Pacific Northwest must be evaluated with regard to the additional risk associated with susceptibility to earthquake, tsunami, and wildfire. These projects pose significant health risks for employees, emergency responders, and nearby residents, including burns, physical injury, toxic exposure, and death.

Natural Disasters: Earthquake and Tsunami

The Pacific Northwest is vulnerable to earthquakes due to its position on the Cascadia Subduction Zone.¹⁹⁷ Experts estimate a 42% likelihood of an earthquake up to a magnitude of 9.0 in the zone within the next 50 years, an area that encompasses every proposed gas infrastructure project

¹⁹⁵ (Physicians for Social Responsibility and Concerned Health Professionals of New York, 2018)

¹⁹⁶ (Powell T. a., 2016)

¹⁹⁷ (Pacific Northwest Seismic Network)

in Oregon and Washington.¹⁹⁸ An earthquake of that magnitude would devastate the Northwest; the most severe impacts, including soil liquefaction, landslides, and tsunamis, would fall on coastal areas.¹⁹⁹ In case of a tsunami, the immense force of the initial surge would carry marine vessels, other objects and debris inland, smashing coastal buildings and structures.²⁰⁰ Weeks of inundation that could follow would compound the damage.

The volatility and potential for combustion at fracked gas processing and storage facilities makes these sites particularly vulnerable. As examples:

- Soil liquefaction has caused significant damage at other industrial port facilities in the U.S., Mexico, and other countries.²⁰¹
- The LNG/LPG (liquefied petroleum gas) storage plant in Chiba, Tokyo Bay was cracked by the 2011 Tohoku-Fukushima earthquake, producing a fireball and blaze that took 11 days to extinguish.²⁰²
- In February 2018, an earthquake shut down an LNG project in Papua New Guinea, damaging equipment and foundation supports and forcing evacuation of hundreds of workers.²⁰³

The risks of earthquake on pipelines in wildfire prone forested areas are not just destruction of infrastructure but unmanageable wildfires in remote areas resulting from the release of gas. The destruction of communities with injuries and loss of life from a magnitude 9.0 earthquake could be compounded by catastrophic fires.

Natural Disasters: Flooding and Sea-Level Rise

Many industrial ports that house fracked gas facilities will experience effects of sea-level rise due to climate change within 50 to 100 years. Estimates quantifying sea-level rises vary; however, scientists and researchers understand that these impacts will likely cause industries which operate near coastlines to adjust their infrastructure and could hinder operations significantly.²⁰⁴

Sea-level rise will impact the coasts of Oregon and Washington and their industrial port areas. A 2018 report from the University of Washington's Climate Impacts Group projects relative

¹⁹⁸ (Goldfinger, 2012)

¹⁹⁹ (Harvey, 2017)

²⁰⁰ (Venturato, 2007)

²⁰¹ (Werner, 1998)

²⁰² (French Ministry of Ecology, Sustainable Development and energy , 2011)

²⁰³ (Reuters, 2018)

²⁰⁴ (Christodoulou, 2018)

sea-level rise to reach from 1.5 to 3.3 ft in Tacoma by 2100.²⁰⁵ Their report acknowledged that earthquakes can significantly alter sea-level and cause changes in land elevation, leading to further encroachment of water and flooding issues.

In 2017, Hurricane Harvey and ensuing flooding negatively impacted oil refineries and gas storage terminals. According to a Reuters article, 27 million cubic feet of fracked gas was released due to flooding. An environmental group found that 31 additional spills at oil and gas wells, pipelines and storage tanks occurred. Because energy companies are not legally required to report wastewater spills, it is likely that the true costs of toxic spills and leakage of oil and gas were not fully accounted for.²⁰⁶

Human-caused disasters: Accidents

Fracked gas accidents are neither trivial nor rare. The majority of fires and explosions are associated with pipeline failure. Pipelines are subject to various types of internal corrosion, including “sweet corrosion,” related to CO₂, or “sour corrosion,” due to hydrogen sulfide, both of which are usually present in fracked gas and constitute the major cause of pipeline and storage tank leaks.²⁰⁷

The U.S. Department of Transportation’s Pipeline and Hazardous Materials Safety Administration recorded 858 serious incidents involving pipelines from 1996 to 2016, with 347 fatalities and 1,346 injuries.²⁰⁸ Absent meaningful regulation, the extent of pipeline leakages with explosive potential remains unknown.²⁰⁹

- In January 2019, a gas pipeline ruptured in rural Nobel County, Ohio. The 120 ft fireball destroyed one home, injuring a 12-year old boy. In the year prior, the Texas Eastern Transmission Pipeline exploded in the same county. In April 2016 that same pipeline had exploded in Salem Township, Pennsylvania, producing a 50- by 12-foot crater and a fireball that “obliterated a home, melted a road and sent a 26-year old man to the hospital with third-degree burns over 75% of his body.”²¹⁰
- On First Nation lands near Prince George, British Columbia, a 36-inch gas pipeline ruptured in October, 2018, causing a massive fire. No one was hurt, but 100 members of the Lheidli

²⁰⁵ (Miller I. e., 2018)

²⁰⁶ (Flitter E. , 2017)

²⁰⁷ (Popoola, 2013)

²⁰⁸ (US Department of Transportation: Pipeline and Hazardous Materials Safety Administration, n.d.)

²⁰⁹ (Glick, 2018)

²¹⁰ (Nobel, 2019)

T'enneh First Nation were forced from their homes and the gas supply to one million customers was threatened.²¹¹ The cause of the rupture is, as of this writing, undetermined.

- On August 9, 2018, in Midland, Texas, odorless gas leaking from a dime-sized hole in a nearby pipeline spontaneously ignited, killing a three-year old girl and seriously injuring her sister and parent.²¹²
- In 2017, a deadly explosion in Firestone, Colorado from odorless gas leaking from an out-of-use pipeline which was not fully shut off killed two people in their homes and hospitalized two more.²¹³
- In Seattle in 2016, a fracked gas line exploded injuring nine firefighters and destroying multiple businesses. When the line was shut off in 2004, it was not properly capped and gas had been flowing through it for a dozen years.²¹⁴ The explosion resulted in a \$1.5 million fine against Puget Sound Energy (PSE) for 17 violations.
- In 2012 a fracked gas pipeline ruptured and burned in Sissonville, West Virginia destroying three houses and damaging several others. According to the investigation, the surface of the pipe was heavily corroded at the point of rupture.²¹⁵
- Also in 2012 a pipeline at a compressor station near Wellington, Utah was scored by a backhoe and later burst, causing fire and explosion that destroyed the facility and injured two workers on site.²¹⁶

The most common cause of pipeline failure is internal corrosion, related to “sour corrosion” from hydrogen sulfide or “sweet corrosion” related to carbon dioxide, both of which are common contaminants of fracked gas.²¹⁷

Landslides have recently been identified as an additional cause of pipeline failure, especially when pipelines are constructed in steep and rocky terrain.²¹⁸ The advisory issued by the Pipeline and Hazardous Materials Safety Administration cited seven significant accidents related to landslides, most of which resulted in toxic releases. They included:

²¹¹ (Shore, 2018)

²¹² (Soraghan M. a., 2018)

²¹³ (Finley, 2017)

²¹⁴ (Lacitis, 2017)

²¹⁵ (National Transportation Safety Board, 2014)

²¹⁶ (Mills, 2012)

²¹⁷ (Popoola, 2013)

²¹⁸ (Pipeline and Hazardous Materials Safety Administration, 2019)

- A January 29, 2019 rupture in West Virginia following a landslide that displaced a pipeline by 10 feet.
- A 2016 spill in North Dakota caused by a landslide.
- A 2016 explosion of a gas pipeline in Montecito, California related to local floods and landslides.

Compressor stations also have explosive potential.

- On January 30, 2019 in rural Armada Township, MI, an equipment malfunction at a fracked gas compressor station caused a dramatic fire and an explosion that was felt miles away.²¹⁹
- When a compressor station north of Watford City, ND, exploded in December 2015, drywall cracked and knocked pictures off the walls of homes about a mile away. Locals described it as “like a truck had hit the house going 75 mph” or like someone “had picked up the house and dropped it.”²²⁰

Accidents and spills at LNG facilities are less common and the dynamics and hazards are poorly understood. A comprehensive review of research into the LNG production chain examined vapor production, vapor dispersion, and mechanisms of combustion, noting the “intrinsic process safety issues” of LNG. The authors described various threats to human safety, including pool fires, jet fires, and vapor cloud explosions.²²¹

A Congressional Research Service (CRS) study in 2008, when the United States was a net importer of LNG, stated that LNG infrastructure is “inherently hazardous” citing thirteen serious accidents at onshore LNG terminals.²²² According to another CRS report in 2009, certain LNG hazards are not “understood well enough to support a terminal siting approval.” Potential risks included pool fires and flammable vapor clouds. The analysis pointed out the need for additional LNG safety research,²²³ a need which was again noted as recently as 2014.²²⁴

- Less than five years ago, an explosion at the Williams Company Inc LNG facility in Plymouth, Washington injured workers and brought attention to the imprudence of siting massive gas tanks near population centers. The explosion, felt up to six miles away, sprayed shrapnel 300 yards, punctured one of the large LNG storage tanks, caused gas leaks for over

²¹⁹ (Hicks, 2019)

²²⁰ (Robinson, 2016)

²²¹ (Ikealumba, 2014)

²²² (Parfomak, 2008)

²²³ (Congressional Research Service, 2009)

²²⁴ (Ikealumba, 2014)

24 hours and required the evacuation of residents living within two miles.²²⁵ Shrapnel injured four employees and a fifth worker was hospitalized for burns. Fumes from the facility sickened local residents and emergency responders. At the time, the authorities worried that “a second blast could create a 0.75 mile ‘lethal zone’ around the plant.”²²⁶

- In 2018 LNG leaked into a space between the inner and outer walls of a storage tank at the Sabine Pass LNG export facility in Cameron Parish, Louisiana, creating cracks in the carbon steel outer tank wall that allowed gas to escape.²²⁷ Because of the potential for a catastrophic accident, threatening 500 workers and contractors at the facility, as well as nearby communities, the federal Pipeline and Hazardous Materials Safety Administration ordered the shut-down of the two tanks.

Although explosions involving methanol, a product of methane, are rare, they also occur.²²⁸

- In 2006 in Daytona Beach, FL, two employees were killed in an explosion while attempting to remove a steel canopy above a methanol storage tank.
- In 2012, a methanol ship in Malaysia exploded, presumably after it was struck by lightning.
- Again in 2012, an explosion and fire occurred while workers unloaded methanol from a train in Garland, Texas.
- An explosion in a Chinese chemical plant was triggered in 2015 when a welder ignited methanol.

Human-caused Disasters: Acts of Terrorism

The possibility of terrorist attacks against fracked gas infrastructure, especially LNG facilities, have been noted for well over a decade. In 2003, as part of a larger investigation of potential terrorist targets in wake of the 9/11 attacks, the Congressional Research Service provided a background report to the U.S. Congress on the security of LNG terminals in the United States. The CRS identified LNG tanker ships and storage infrastructure as “vulnerable to terrorism,” noting that tankers could be turned as weapons against coastal cities and that inland LNG facilities are typically located near large population centers. The CRS further noted that the public cost of security for LNG

²²⁵ (Powell T. , 2016)

²²⁶ (Schneyer, 2014)

²²⁷ (Schleifstein, 2018)

²²⁸ (Luck, 2016)

shipments, via Coast Guard escorts of tankers through coastal shipping channels, was considerable (\$40,000-\$80,000 per tanker).²²⁹ The cost, nearly two decades later, would be much higher.

The 2008 CRS study cited above identified security of tankers, terminals, and inland storage plants as issues of concern. Serious risks include pool fires with intense heat, which can occur when LNG spills near an ignition source; flammable vapor clouds that can drift until reaching an ignition source; and a rapid phase transition that can generate a flameless explosion.²³⁰ The possibility of terrorist attacks involving LNG facilities was noted again by the CRS in 2009.²³¹

Acts of terrorism that target fracked gas infrastructure, though unlikely, continue to be of concern. In a 2017 discussion of the threats of maritime terrorism, recent scenarios of an attack included the hijacking of an LNG carrier and then “exploding it as a floating bomb or utilizing it as an impact weapon against port facilities.”²³²

Jordan Cove LNG

In November 2017, the Oregon Department of Geology and Mineral Industries (DOGAMI) detailed their concerns about Jordan Cove LNG and the Pacific Connector Gas Pipeline. Because the projects would be located in a high seismic hazard area and the tsunami inundation zone, DOGAMI listed concerns about duration of shaking, soil settlement and liquefaction, landslides, tsunami scour, and tsunami debris, all of which could cause infrastructure to fail and present significant safety hazards. An additional DOGAMI concern is the potential for LNG tankers to become “ballistics in the Bay” in the event of a large earthquake and tsunami.²³³

DOGAMI maps indicate that the Jordan Cove LNG terminal would be located in a place at risk for inundation by a local tsunami and that the docking area for LNG tankers would be in an area subject to both distant tsunamis and at maximum risk in the event of a local tsunami.²³⁴ ²³⁵ In addition, road access to the spit where the LNG terminal would be located is just above sea level. Subsidence from a great earthquake could destroy vehicle access to Jordan Cove, preventing escape from a subsequent tsunami and preventing access by emergency responders. Goldfinger and

²²⁹ (Congressional Research Service, 2003)

²³⁰ (Parfomak, 2008)

²³¹ (Congressional Research Service, 2009)

²³² (Meng Wee, 2017)

²³³ (Avy, 2017)

²³⁴ (Oregon Department of Geology, n.d.)

²³⁵ (Miller C., 2013; Havens, 2019)

coauthors have concluded that the chance of a magnitude >8 earthquake in the Coos Bay area off southern Oregon in the next 50 years is 40%.²³⁶

In January 2015, Jerry Havens, professor of chemical engineering at University of Arkansas and James Venart, emeritus professor of mechanical engineering at University of New Brunswick, both experts in LNG hazards, fire science, and catastrophic explosions, commented to the Federal Energy Regulatory Commission that the proposed Jordan Cove LNG terminal exposes the public to risk of fire and explosion. The mix of refrigerants used to chill the gas and the heavy hydrocarbon impurities in pipeline gas that are stripped out and stored on-site pose a threat of catastrophic accidents involving unconfined hydrocarbon vapor cloud explosions (UVCE).²³⁷

In response to the March 2019 DEIS Dr. Havens reiterated his concern about UVCEs, noting: “If the magnitude of the possible overpressures [is] estimated using actual data (experience) available for UVCEs (rather than predicted with the FLACS theoretical model), the UVCE hazard would be clearly indicated as a serious major hazard at the [Jordan Cove facility]. *UVCEs at numerous similar heavy hydrocarbon handling/storage facilities have resulted in destruction of the facilities as well as injuries and deaths beyond the plant boundaries* [Emphasis in original].²³⁸

Of additional concern is the proximity of the proposed shipping channel and LNG facility to residential and industrial areas, which puts the safety of many people at risk. According to the March 2019 DEIS, consideration must be given to “Zones of Concern”. It states, “As LNG marine vessels proceed along the intended transit route, the estimated zones of concern would extend over resources such as residential and industrial areas, military installations, and also non-residential areas accessible to the public such as parks.”²³⁹

As mapped in the March 2019 DEIS, Hazard Zone 1 mostly overlies water and encompasses coastal areas in Charleston and Coos Bay with potential impacts to commercial vessels, recreational vessels, fishing vessels, Cape Arago Dock, North Bay Marine Industrial Park, and Roseburg Forest Products Facility.

Hazard Zone 2 covers a broader swath of coastal areas along Charleston, Coos Bay, Barview, and North Bend with potential impacts to multiple residential buildings, commercial buildings, industrial buildings, numerous RV parks, numerous recreational areas and boat launch ramps,

²³⁶ (Goldfinger, 2012)

²³⁷ (Mandel, 2016)

²³⁸ (Havens, 2019)

²³⁹ (Draft Environmental Impact Statement for the Jordan Cove Energy Project, 2019)

Marine Research Center, Charleston Marina, South Slough Bridge, Coast Guard Sector Charleston, Charleston Fire District Stations 1 and 3, Madison Elementary School, Sunset Middle School, Coos Bay Fire Department Station 2, and the Southwestern Oregon Regional Airport.

Hazard Zone 3 includes larger portions of Charleston, Coos Bay, Barview, and North Bend and includes Coast Guard Group North Bend, Railroad Bridge, Oregon Dunes Recreational Park, Southwestern Oregon Community College. Clearly, thousands of residents are at varying risks for burns, injury, and death in the event of an accident or intentional act with rupture of an LNG ship and/or related Jordan Cove storage facility and a large release of gas.

The close proximity of the Southwest Oregon Regional Airport to the LNG facility presents additional hazards. The airport serves Coos Bay and North Bend with commercial flights out of Denver and San Francisco. Daily operations include general aviation, air freight, and Coast Guard activities. The flight approach is usually over the bay and the north spit. In May 7, 2019 The Federal Aviation Administration (FAA) issued 13 Notices of Presumed Hazard for this project. According to the March 2019 DEIS, “Permanent and temporary structures at the LNG terminal as well as LNG carrier operations in the Federal Navigation Channel would exceed FAA obstruction standards and there is a potential significant impact to the safe air operations of the Southwest Oregon Regional Airport if a resolution cannot be settled between Jordan Cove and FAA.”²⁴⁰

If the resolution, which is being negotiated out of public view, does not mandate reductions in the heights of storage tanks, cranes, vessel stacks, and other structures to conform with the maximum allowed under FAA regulations, the only options would be to re-route air traffic over populated areas (a solution that is considered too risky by the Southern Oregon Regional Airport, according to the DEIS), or the addition of lights and markings on the obstructing structures, which leaves the actual hazards in place.

Though the potential for accidental collision of an aircraft into a storage tank at the facility is small, the consequences would be catastrophic. The DEIS notes that the storage tanks are not designed to withstand such an impact without perforation, which would result in fire and explosion.²⁴¹

²⁴⁰ (Draft Environmental Impact Statement for the Jordan Cove Energy Project, 2019)

²⁴¹ (Draft Environmental Impact Statement for the Jordan Cove Energy Project, 2019)

Pacific Connector Gas Pipeline

Remote and populated areas of Oregon could be impacted by earthquakes with significant damage to the pipeline and release of flammable and explosive methane gas and volatile organic compounds (VOC) to the air. The proposed pipeline would be located directly under the North Bend McCullough Bridge, the main artery and highway (Hwy 101) entering the town of North Bend. An earthquake and subsequent liquefaction could rupture that pipeline, releasing these pollutants. Any ignition source could precipitate fires.

Aside from earthquake and corrosion, naturally occurring wildfires themselves may result in pipeline damage or rupture, for example, by falling timber.

Massive and difficult to control wildfires related to pipeline failures would severely impact the dry, rugged lands and the people who live there. Fires can cause erosion, landslides, and debris flows affecting rivers and streams. Wildfires often burn out of control and damage small, large, and contiguous watersheds that support multiple beneficial uses of water. Remote areas may not be easily accessible to emergency response.

Over half the pipeline route crosses lands that are mapped by the U.S. Forest Service as having moderate to very high wildfire risk.²⁴² Firefighters United for Safety, Ethics and Ecology, (FUSEE), who oppose the project, further note that clear-cuts around the pipeline would fill in with grasses, shrubs and weeds, which ignite more easily than forest. Greater exposure to sun and wind would increase fire intensity and rate of spread, making the pipeline route into a quick-burning fuse that would allow fire to race through forested areas.

The PCGP would also be constructed in terrain subject to landslides and the construction of the pipeline itself would increase the risk of landslides, which are themselves a cause of pipeline failure.

Kalama Methanol Refinery

The Kalama methanol plant would process large quantities of fracked gas into liquid methanol. The highly flammable methanol will be stored on site in eight tanks, each capable of holding more than 8 million gallons of methanol.²⁴³

²⁴² (Firefighters United for Safety, Ethics and Ecology, 2019)

²⁴³ (Luck, 2016)

- Methanol has a very low flash point, 73 degrees F, which is the lowest temperature at which its vapors will ignite. This means that even at ambient storage temperatures, let alone hot weather or hot facility environments, a lot of vapor is produced, creating a high risk of fires or explosions. The combination of two volatile substances at the proposed plant, methane plus methanol, compounds the risk of explosions and fires.
- According to the Final Environmental Impact Statement (FEIS), sand and silt below groundwater levels at the site are susceptible to liquefaction. The FEIS estimates that liquefaction could occur as deep as 100 feet underground, which could cause soils underlying the refinery, dock and tank farm to spread and severely damage key infrastructure.²⁴⁴
- The Draft Supplemental Environmental Impact Study (DSEIS) for the Kalama project identifies seismic protections as part of construction plans; however, it states that a “ground improvement plan” will be designed as the project is being built, leaving questions about what such a plan would include and how it might protect workers and the surrounding community from consequences of a severe seismic event.²⁴⁵
- In an independent worst-case scenario analysis requested by Columbia Riverkeeper, a plane crash, terrorist attack, or a Cascadia Subduction Zone magnitude 9.0 earthquake, could rupture multiple tanks and if sparked, could possibly lead to an explosion in the remaining intact tank.²⁴⁶ If catastrophic tank failure were to occur, leaking methanol could catch fire, and the vapor, if trapped, could cause an explosion that could shatter glass as far away as Longview and Rainier, destroy buildings within a six-mile radius and cause serious injuries in Kalama.
- The facility proposed by Northwest Innovation Works is far larger than what is currently in operation anywhere in the world. Given the lack of experience with this technology and the fact that it is sited in an area at risk for both earthquakes and tsunamis, it seems prudent to consider the catastrophic, albeit unlikely, risk scenarios.

²⁴⁴ (Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, September 2016)

²⁴⁵ (Draft Supplemental Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility, 2018)

²⁴⁶ (Luck, 2016)

Puget Sound LNG

The proposed LNG plant in the Port of Tacoma will produce, store, and bunker marine vessels with LNG. The facility presents risks for fires and unconfined hydrocarbon vapor cloud explosions. Located within an urban population center, Puget Sound LNG presents grave dangers.

The plant has two close neighbors. The Port of Tacoma lies to its south and employs 10,000 people and has a resident population of 1,300.²⁴⁷ Just north is the residential neighborhood of Northeast Tacoma, with a population of 17,000.²⁴⁸ Many people live, work, and travel less than half a mile away from the plant. Also located less than 2 miles away is the Northwest Detention Center operated by U.S. Immigration and Customs Enforcement (ICE). ICE has an evacuation plan, but the plans are considered “sensitive” and have not been released even to the Tacoma Fire Department.²⁴⁹ In the event of a sudden and major disaster, like an earthquake, tsunami, and/or LNG explosion, the safe evacuation of inmates would be difficult if not impossible.

Tacoma citizens and the Tacoma News-Tribune have repeatedly requested access to safety modelling information from Puget Sound Energy (PSE), the local energy utility which promotes the LNG project. PSE refused until ordered twice by Pierce County Superior Court and sued to prevent its release.²⁵⁰ According to the FEIS in a section entitled: Thermal Radiation & Vapor Dispersion Safety Modeling, “The risks of fire and explosions have been modelled, but they are covered by a non-disclosure agreement and for security reasons are considered critical energy infrastructure and are not to be released to the public.”²⁵¹

Critics have identified multiple issues:

- A report modeling three tsunami scenarios prepared by the Washington State Department of Natural Resources found that a magnitude 7.3 earthquake could lead to a tsunami with waves enveloping the Port and reaching five kilometers into the City of Tacoma.²⁵²
- PSE points to the multilayered steel and concrete materials used to build the 149-foot, 8-million-gallon storage tank. However, local environmental researchers and advocates

²⁴⁷ (Puget Sound Regional Council, 2013)

²⁴⁸ (Northeast Tacoma, Tacoma WA Demographics, n.d.)

²⁴⁹ (Henterly, 2015)

²⁵⁰ (Martin, 2018)

²⁵¹ (Final Environmental Impact Statement: PSE LNG, 2016)

²⁵² (Venturato, 2007)

identified that a “tank-breach” scenario was not run in modeling of potential project incidents and spills, citing leaks from a similar LNG facility in Louisiana.²⁵³

- The siting study calculated that a tank fire in which the roof was destroyed could have a flame more than 200 feet high.²⁵⁴ Such a fire is impossible to extinguish, and how long such a fire could burn is unknown. The only recourse would be to evacuate the area.
- A report prepared for the City of Tacoma by Cascadia Consulting and University of Washington researchers projecting climate change impacts in Tacoma found that the industrial Tideflats area, where the Puget Sound LNG facility is located, is vulnerable to sea-level rise. It names the Port of Tacoma as vulnerable to high risk of flooding due to climate impacts and rising sea-levels. Consequently, the risk of accidental gas releases due to flooding and storm surges must be considered.
- The report additionally identified the Tideflats area as vulnerable to landslides, which poses additional risks to the LNG facility.²⁵⁵
- Ecology and Environment Inc, Global Environmental Specialists and Braemer Engineering, the firms that prepared the FEIS, recommended additional mitigation measures to "protect worker and public health and safety."²⁵⁶ Why workers and citizens would be at risk is not specified nor are the mitigation measures.
- An environmental consultant retained by the Puyallup Indian Tribe, Dr. Ron Sahu, found a number of inadequacies in the Puget Sound LNG siting study:²⁵⁷
 - The Report assumes spills or leaks will be contained in a 10-minute time frame. A 10-minute leak duration is unsupported by PSE documentation. Previous experience with an LNG facility explosion in Washington State shows that leaks can persist more than 24 hours.²⁵⁸
 - Leaks were assumed to occur only from pipelines two inches or larger.
 - The report ignored failures of refrigerant storage vessels and risks from handling refrigerants. Refrigerants are among the more volatile substances that would be stored in the facility.

²⁵³ (Hay, n.d.)

²⁵⁴ (Nunnally, 2016)

²⁵⁵ (Parvey, 2016)

²⁵⁶ (Final Environmental Impact Statement: PSE LNG, 2016)

²⁵⁷ (Sahu, 2018)

²⁵⁸ (Powell T. , Williams Companies Failed To Protect Employees in Plymouth LNG Explosion, 2016)

- The report failed to assess the possibility of a vapor cloud explosion. In 2016, longtime LNG and fracked gas industry researchers were quoted in a trade publication discussing risks from explosions and vapor clouds as understudied: “We believe these additional hazards have been discounted without sufficient scientific justification in spite of multiple international reports during the last decade of catastrophic accidents involving unconfined hydrocarbon vapor cloud explosions.”²⁵⁹
- Regarding the report’s analysis on the size of vapor barriers, Dr. Sahu noted that, “The analysis assumes that a chain link fence will provide an effective vapor barrier.”
- In their interview with E&E news, engineering professors Jerry Havens and James Venart expressed dismay at the lack of regulations and safety standards concerning vapor releases and the potential for combustion in proposed LNG facilities.²⁶⁰

Even when designed and operated safely, gas releases may occur as a part of normal LNG bunkering operations, making each operation a potential fire hazard. These gas releases present a particular danger when facilities are sited at busy ports. An analysis by Sightline Institute revealed that the Puget Sound LNG “facility would be flanked by two oil facilities on a busy industrial peninsula that is difficult to evacuate in an emergency and in close proximity to several marinas, unrelated ship traffic, and other port businesses and employees.”²⁶¹ This is in direct conflict with the recommended best practices that LNG operations be located in the most protected and secure location in the port; preferably in a remote area of the port that is not frequented by other port users.²⁶²

Given that the project site is only 30 acres (1/20 of a square mile), it is unreasonable to assume that leaks and explosions can be contained within the site. It almost certainly poses a threat beyond the site boundaries.

²⁵⁹ (Mandel, 2016)

²⁶⁰ (Sahu, 2018)

²⁶¹ (Powell T. a., 2016)

²⁶² (Society of International Gas Tanker and Terminal Operators, 2003)

OCCUPATIONAL HEALTH AND SAFETY

When fossil fuel export projects are proposed, supporters emphasize economic opportunities, particularly job creation. What is left out of the discussion is how dangerous and unhealthy these jobs can be. Workers in the fossil fuel industry are exposed to myriad health risks and are killed on the job at rates four to seven times higher than other industries.²⁶³

The many detrimental health impacts of oil and gas field work are well studied and documented, including benzene exposure;²⁶⁴ silicosis;²⁶⁵ endocrine disruption;²⁶⁶ radiation and noise exposure;²⁶⁸ exposure to hydrogen sulfide;²⁶⁹ and increased overall mortality rates, especially due to work-related motor vehicle accidents.²⁷⁰ ²⁷¹

With remarkable disregard for public health, the oil and gas industry, specifically, is exempt from disclosing the chemicals they use and from most federal statutes protecting worker, resident and environmental health, including, but not limited to, the Clean Water Act, Clean Air Act, Compensation and Liability act and the Toxic Release Inventory.²⁷² Despite high mortality rates from fire and explosion, the oil and gas industry is also exempt from OSHA regulations called process safety management (PSM), which regulate industries to prevent workplace explosions.²⁷³

Diesel emissions expose large numbers of fossil fuel workers to known respiratory hazards. The US Department of Transportation (DOT), responsible for the health and safety of interstate truck and bus drivers, has neither a standard for diesel emissions nor other health standards with explicit exposure limits.²⁷⁴ Nor does OSHA have any standard specifically for exposure to diesel exhaust.²⁷⁵ Only a small proportion of the thousands of chemicals present in the gas and particulate matter of diesel emissions is covered by OSHA standards, and most of these standards require only that specified limits not be exceeded over an 8-hour work shift. Components in the gas phase rarely

²⁶³ (AFL-CIO, 2018)

²⁶⁴ (Lombardi, 2014)

²⁶⁵ (Esswein E. e., 2014)

²⁶⁶ (Bang, 2015)

²⁶⁷ (O'Neill, 2014)

²⁶⁸ (Witter, 2014)

²⁶⁹ (Cribb, 2017)

²⁷⁰ (AFL-CIO, 2018)

²⁷¹ (Olsen, 2014)

²⁷² (Colborn, 2011)

²⁷³ (Soraghan M. , 2015)

²⁷⁴ (American Public Health Association, 2014)

²⁷⁵ (U.S. Department of Labor: Occupational Safety and Health Administration, n.d.)

exceed their limits. Their greatest potential threat comes from their adsorption onto diesel engine particulates, bringing them deep into the lungs. This exposure is unlimited and unregulated. Similarly, for environmental contaminants, components taken separately rarely exceed their limits, but their threat is increased when combined with simultaneous exposure to other contaminants.

The oil and gas industry is currently exempt from much of OSHA's noise standards as well, despite numerous health risks to workers from noise levels resulting from drilling, heavy equipment, diesel engines, and pipe-fitting operations.²⁷⁶

Fire and Explosions

According to numbers compiled by Energywire, the oil and gas industry employs less than 1% of the U.S. workforce but is responsible for nearly 10% of occupational deaths from fire.²⁷⁷ Between 2009 and 2013, the sector had the highest rate of mortality from fire and explosions of any private industry, and the second highest of all occupations, behind only firefighting.²⁷⁸

- In Seattle in 2016, a gas line exploded injuring nine firefighters and destroying multiple businesses. The line was supposed to have been shut off in 2004, but the contractors hired by Puget Sound Energy failed to properly cut and cap the line and gas had been flowing through it for 12 years.²⁷⁹
- On August 1, 2018 outside Midland, Texas, two pipelines began leaking at their intersection. Five workers from the pipeline companies, Kinder Morgan and Navitas Midstream, and two local firefighters responded to the leak by attempting to shut off the flow. A fire ignited and a series of explosions followed. All seven workers were hospitalized and one later died of his injuries. No report has yet determined the cause of the explosion.²⁸⁰ One week later a different pipeline exploded, killing a three-year old child in her home.
- The Williams Company's LNG storage facility in Plymouth, Washington is the largest in the Pacific Northwest, with two fourteen-million-gallon storage tanks. (See section "Natural and Human Caused Disasters" above for more) At eight a.m. on March 31, 2014, fracked gas inside the LNG processing station ignited, creating a series of rolling

²⁷⁶ (Witter, 2014)

²⁷⁷ (Soraghan M., 2015)

²⁷⁸ (Soraghan M., 2015)

²⁷⁹ (Lacitis, 2017)

²⁸⁰ (San Angelo Standard-Times, 2018)

explosions that fragmented equipment, sent 250 pounds of metal flying up to 900 feet away, and lit the facility on fire. Four employees were injured from the shrapnel, and one was burned. Before the explosion, plant operators had temporarily dismantled the site's safety monitors, so the plant continued to operate and leak fracked gas through the emergency. Company officials requested that employees repeatedly reenter the facility to manually shutdown dangerous equipment. Though more than a hundred emergency responders arrived on-site, they were unable to enter the facility for eight hours until the wind changed enough to drive out the flammable fracked gas. The extreme cold of LNG also made plugging the leaks time intensive: holes would freeze over until ambient temperature melted enough to begin leaking again. Despite the five injured employees, the company recorded only one injury in the official report months later because federal regulations only mandate that oil and gas producers report injuries leading to death or overnight hospital stays.²⁸¹

Deadly Gases and Airborne Hazards

The production, transport and storage of fracked gas exposes workers and adjacent communities to numerous toxic air pollutants during each stage of its life cycle: drilling, well completion and fracking; transport by rail, pipeline or ship; liquefaction, refining, processing, and storage. Airborne toxins pose more serious risks for workers, as likelihood and severity of exposure increases significantly with proximity to operations, as well as during particular stages of production.²⁸²

Common hazardous air pollutants emitted during fracked gas production, processing, and transport include, among others: volatile organic compounds (VOC) like benzene, toluene, ethylbenzene, and xylene; formaldehyde; hydrogen sulfide; carbon monoxide; sulfur oxide; diesel particulates; ozone; and radon gas.^{283 284}

²⁸¹ (Powell T. , 2016)

²⁸² (McKenzie, Human health risk assessment of air emissions from development of unconventional natural gas resources, 2012)

²⁸³ (Shonkoff S. e., 2014)

²⁸⁴ (McKenzie, Human health risk assessment of air emissions from development of unconventional natural gas resources, 2012)

Researchers in Colorado found, during the extraction process alone (fracking), companies used 944 different products, which together contained 632 different chemicals. Of these chemicals:²⁸⁵

- More than 75% affect skin, eyes, and other sensory organs, as well as respiratory and gastrointestinal systems
- 40-50% affect the brain and nervous systems
- 37% affect the endocrine system
- 25% cause cancer and mutations

Still largely unstudied on their own, these chemicals can also combine and potentially form new reactants when exposed to air, high temperatures, and other variables of the extraction process.²⁸⁶

Hydrogen Sulfide

- Hydrogen sulfide, or “sour gas”, is one of the most common and dangerous byproducts of oil and gas production, causing acute and chronic breathing issues, neurological defects, and death. It can also corrode metal, making storage dangerous. In high concentrations the gas deadens a person’s sense of smell, making it undetectable.^{287 288}
- A study in the Alberta tar sands found that of workers interviewed, 35% experienced high exposure levels, and 10% had at some point been “knocked down” (lost consciousness) by the gas.²⁸⁹
- Hydrogen sulfide is regulated in many states producing oil and gas, but according to Energy Wire’s reporting, in the years 2013 and 2014 alone, five workers died from exposure in the fracking fields. In 1975, the gas was responsible for the deaths of nine in Denver City, Texas.²⁹⁰

²⁸⁵ (Colborn, 2011)

²⁸⁶ (Kaden, 2015)

²⁸⁷ (Kaden, 2015)

²⁸⁸ (Lee, 2014)

²⁸⁹ (Hessel, 1997)

²⁹⁰ (Lee, 2014)

Volatile Organic Compounds

- Between 2010 and 2015 at least nine workers died from close proximity to hydrocarbon vapors, also known as volatile organic compounds (VOC), trapped in fracked gas storage containers.²⁹¹
- All petroleum contains potentially lethal levels of VOCs. But according to a study by the National Institute for Occupational Safety and Health (NIOSH), VOC exposure in fracked gas is more unpredictable and often more dangerously concentrated than in conventional oil and gas production.²⁹² Exposure to these trapped gases can lead to sudden loss of consciousness and death.²⁹³
- An investigation by Energywire found that one of the ways workers are taught to avoid these sudden exposures is by “testing the wind” before they open the hatch.²⁹⁴
- Workers face these risks during all routine container tests—at the fracking site, during transport, and at processing facilities.²⁹⁵

Silicosis

- Exposure to silica dust is a well-known hazard in mining, construction, sandblasting, and other industries. It is a known lung carcinogen.
- In hydraulic fracturing, intensive blasting of sand and the general lack of regulation creates conditions where silica exposure can become extremely hazardous.
- A study by NIOSH of eleven fracking sites in five states found that full-shift silica exposure exceeded the threshold for safe levels, sometimes by ten times or more. Wearing a respirator was ineffective in preventing significant exposure.²⁹⁶
- The huge amount of sand required by hydraulic fracking has led to a surge of intensive sand mining in parts of Minnesota and Wisconsin. This has in turn led to higher health risk for miners, and likely their communities as well due to the ambient silica dust released during the extraction process.²⁹⁷

²⁹¹ (Harrison, 2016) <https://www.cdc.gov/mmwr/volumes/65/wr/mm6501a2.htm>

²⁹² (Esswein E. e., 2014)

²⁹³ (NIOSH-OSHA, 2018)

²⁹⁴ (Soraghan M. , SAFETY: Poisoned by the Shale? Investigations Leave Questions in Oil Tank Deaths, 2014)

²⁹⁵ (Harrison, 2016)

²⁹⁶ (Esswein, Occupational Exposures to Respirable Crystalline Silica During Hydraulic Fracturing, 2013)

²⁹⁷ (Korfmacher, 2013) <https://doi.org/10.2190/NS.23.1.c>

- Recently, the American Thoracic Society called for greater recognition of the harm of silicosis, citing its prevalence, seriousness and yet underrepresentation in occupational health cases.²⁹⁸
- Silicosis risks will occur during construction of fracked gas pipelines, processing, and storage facilities.
- A report by researchers in Quebec found that, while all major construction projects expose workers to silica, pipeline laborers had some of the highest risks of silicosis exposure due to their frequent use of jackhammers, masonry saws, and other dust producing heavy machinery.²⁹⁹

Diesel Engine Exhaust

- Workers encounter diesel engine exhaust (DEE) from heavy machinery throughout gas production and transport. Diesel exhaust components include carbon monoxide, nitric oxide, nitrogen dioxide, sulfur oxides, and polycyclic aromatic hydrocarbons, as well as fine particulate matter.
- When NIOSH conducted a full shift study of diesel exhaust exposure at multiple fracking sites, they found the mean exposure over time (17 $\mu\text{g}/\text{m}^3$, ranging from 0.1–68 $\mu\text{g}/\text{m}^3$) near to the state of California’s maximum safe exposure level (20 $\mu\text{g}/\text{m}^3$). 10% of their measurements exceeded this limit.³⁰⁰
- DEE is a recognized carcinogen and cause of lung cancer.³⁰¹ U.K. researchers have estimated DEE to be the third largest contributor to occupationally induced lung cancer (after asbestos and silica) and estimate DEE is responsible for up to 6% of all lung cancer deaths.³⁰²
- Diesel fumes not only impact workers at close proximity, but create regionally hazardous air quality.

²⁹⁸ (Deslauriers, 2016)

²⁹⁹ (Beaudry, 2013)

³⁰⁰ (Esswein E. e., Measurement of Area and Personal Breathing Zone Concentrations of Diesel Particulate Matter (DPM) during Oli and Gas Extraction Operations, Including Hydraulic Fracturing, 2018)

³⁰¹ (Benbrahim-Tallaa, 2012)

³⁰² (Vermeulen, 2013)

Radiation

- Radon is a component of fracked gas, but its concentration levels can far exceed safe levels as a result of the extraction process. These concentrations can then travel with the gas and dissolve into the mixed fluids, or “slurry”, produced during the disposal of fracking wastes.³⁰³
- Radon will remain in the gas and disposal slurry until the radioactive isotopes fully decay, creating a long-term exposure risk for both workers and downstream consumers.³⁰⁴
- Radon is second only to tobacco as a cause of lung cancer.³⁰⁵

Noise

- These risks are higher with fracking than conventional gas production due to the greater scale and length of time when workers are exposed to noise during horizontal drilling and other unconventional extraction methods.³⁰⁶

Jordan Cove LNG

The majority of jobs offered by the Jordan Cove project will come during the short-term construction of the facility (which is true of each of the proposed fracked gas projects). In its Resource Report 1, the parent company Pembina estimates an average of 1,023 construction employees per month over a five-year construction period. Work would include pile driving and dredging of the bay, road and infrastructure construction, and building the processing facility itself.³⁰⁷

While not a definitive accounting of all occupational risks, Jordan Cove exemplifies the specific risks to workers’ health posed by projects of this scale:

- Acute and continuous exposure to diesel fumes, VOCs, and other toxic emissions from heavy construction machinery, high levels of bus and truck traffic, and the presence of two large diesel-fired generators as well as two black diesel backup generators.

³⁰³ (Steinhäusler, 2004)

³⁰⁴ (Kaden, 2015)

³⁰⁵ (Al-Zoughool, 2008)

³⁰⁶ (Kaden, 2015)

³⁰⁷ (Jordan Cove Energy Project L.P., 2017)

- Nighttime use of vehicles and heavy equipment: dredging and pile driving of the bay is expected to occur 24 hours per day over two years. Many of the workers would be temporary and come from out of county, likely commuting long distances and leading to higher risk of over-exhaustion and vehicular death.
- High noise exposure would occur from ongoing and wide use of heavy machinery.
- Silica exposure from high levels of dust produced in concrete work, dredging, and masonry.

When completed, the facility would require 180 permanent positions.³⁰⁸ Employees at the terminal will similarly experience constant high noise level exposure and possible over-exhaustion from nighttime operations. They are also at risk of acute and deadly exposure to VOCs, benzene, and methane during routine testing and maintenance of the gas storage tanks.

The greatest risk for workers at Jordan Cove comes from potential fires and explosion from unknown or unrepaired leakages, exemplified by the explosion at the William's Company LNG storage facility in Plymouth, Washington. These risks are augmented by the possibility of earthquake and tsunami.

Pembina has promised to build what they call the Southwest Oregon Regional Safety Center (SORSC) near the terminal, including a "security center" and an "emergency operations center". They have also promised to build a fire station nearby in a separate facility, staffed with industrial firefighters.

However, as the explosion in Plymouth demonstrated, significant safety issues were not necessarily mitigated by the presence of firefighters; in fact, the firefighters and trained LNG employees who responded to the situation in Plymouth could not immediately act due to continued leakage of explosive fumes. The root problem of the above case was not a lack of firefighters or emergency crews, but the degradation of storage equipment, employee error, proximity of flammables, and scale of the facility.

Pacific Connector Gas Pipeline

Pipeline construction workers will experience many of the same risks as those at Jordan Cove: high diesel fume exposure, long and irregular hours including nighttime work and commuting, continual noise pollution, and high risk of silica dust exposure from digging equipment.

³⁰⁸ (Draft Environmental Impact Statement for the Jordan Cove Energy Project, 2019)

Pipeline monitors, likewise, face what can be lethal exposure to methane, VOCs, and other noxious gasses potentially released during maintenance at compressor stations, as well as during any leak repair.

Because the PCGP will transport fracked gas in unprocessed, pressurized form there would be continuous risk of leaks and explosions. If a pipeline failure occurs, Pacific Connector employees and local emergency responders would be responsible for resolving the problem at their own risk. Pacific Connector Gas Pipeline LP writes in their “Resource Report No. 11, Reliability and Safety” that they would plan for this by sharing information with existing safety organizations. They do not, however, plan to provide emergency training in the case of gas leakage, or pay for more emergency equipment, suggesting the burden of risk will fall on local emergency responders and local jurisdictions.

In addition, in many places along the pipeline, the company has only promised to patrol and check for leaks once per year.³⁰⁹

Climate change has already dramatically increased the number and severity of wildfires in Oregon. According to Firefighters United for Safety, Ethics and Ecology (FUSEE), over half the 229-mile long pipeline would cross through lands already designated by the U.S. Forest Service as having moderated to very high wildfire risk.³¹⁰ The result will be a pipeline that functions like a quick-burning fuse, causing, in case of a spill and ignition, major wildfires in the surrounding area. Firefighters responding to the disaster would face a dangerous double-risk: the need to suppress the pipeline explosion as well as suppressing the fires that would threaten surrounding communities and themselves.

Kalama Methanol Refinery

The proposed Kalama methanol refinery would be the largest in the world, producing 3.6 million metric tons of methanol a year and consuming nearly three times as much fracked gas as Portland and Seattle combined.³¹¹ According to the Northwest Innovation Works Safety Report, the site would convert crude fracked gas to methanol and water using heat and metallic compounds to break down the gas, releasing numerous toxic waste materials, such as hydrogen sulfide.³¹²

³⁰⁹ (Jordan Cove LNG, 2017)

³¹⁰ (Firefighters United for Safety, Ethics and Ecology, 2019)

³¹¹ (DePlace E. &, 2018)

³¹² (AcuTech, 2016)

In 2014, the Chemical Safety and Hazard Investigation Board (CSB), an independent federal investigative agency, compiled a report on the hazards of methanol, finding that workers' health and safety risks include:³¹³

- Handling of catalyst material. In unprocessed form fracked gas is largely composed of methane, but conversion to the intermediary synthetic gas introduces a high percentage of carbon monoxide, a known asphyxiate. The hazards of other catalyst materials are less well known. In their Safety Report, the company acknowledges, "some of these compounds may be toxic if inhaled and some may have potential to self-heat and combust when exposed to the atmosphere under certain circumstances." Removal would depend on workers navigating a complex process of purging gasses, preventing dust kick-up, and moving through confined spaces.³¹⁴
- Acute exposure to methanol. Methanol is a known poison and can easily enter through the skin and eyes, or from ingesting contaminated food or water. High doses can cause blindness or death and a range of impacts on the central nervous system, including headaches, dizziness, lethargy, seizures, and coma.
- Chronic exposure to methanol. Repeated or chronic exposure to low levels of methanol may cause birth defects, produce inflammation of the eye (conjunctivitis), recurrent headaches, giddiness, insomnia, stomach disturbances, and visual failure. The most noted health consequences of longer-term exposure to lower levels of methanol are a broad range of effects on the eye. Inflammatory changes and irritation of the skin (dermatitis), occurs with chronic or repeated exposure to methanol.³¹⁵
- General handling of methanol. Methanol is flammable, burns easily, and has a higher density than air, so that it pools and collects near the ground following a spill. This tendency makes cleanup difficult, as the gas does not dissipate without good ventilation.
- Fire and Explosion. Methanol is widely used in a number of settings: commercial, industrial, institutional, and at home. A report compiled of known methanol incidents in thirteen countries over a fifteen-year period found that industrial workplace accidents comprised the highest percentage (31%, n=28), with fire and explosions accounting for 90% of those incidents, with 23 workers injured and 6 killed. The only higher mortality

³¹³ (Medina, 2014)

³¹⁴ (AcuTech Consulting Group, 2016)

³¹⁵ (National Institute for Occupational Safety and Health, n.d.)

rate was in transportation, with 57 fatalities in 26 incidents. One third of all incidents documented in the report had no known cause.³¹⁶

Longview Anhydrous Ammonia Plant

Pacific Coast Fertilizer’s proposed plant in Longview would employ about 100 people in the processing of fracked gas to anhydrous ammonia for nitrogen fertilizer. The Centers for Disease Control and Prevention (CDC) report that anhydrous ammonia can be extremely hazardous to work with, expanding rapidly into the air upon release.³¹⁷ Exposure to anhydrous ammonia can cause severe eye, nose and throat irritation, breathing difficulty, wheezing, chest pain, pulmonary edema (fluid build-up in the lungs), burns, blisters, and frostbite. According to the CDC and National Institute of Occupational Safety and Health, exposure is fatal at concentrations as low as 300 parts per million.

Accidents occur frequently from storage and transport of the substance. A report in 2013 found that over a fifteen-year period almost 1,000 accidents occurred at 678 facilities, with over a fifth of these facilities having multiple accidents. These resulted in 19 deaths and 1,651 injuries.³¹⁸

Puget Sound LNG

Puget Sound Energy’s proposed facility in Tacoma would be an LNG terminal for refueling ships. Called “bunkering,” this new and unregulated process depends on a number of “best case scenarios” to ensure the LNG doesn’t spill or volatilize, damaging physical structures and injuring workers.³¹⁹

A 2015 report from the American Bureau of Shipping outlines the numerous unique hazards of the fueling system, including risk of “serious injury to personnel in the immediate area if they come in contact with cryogenic liquid” and “brittle fracture damage to steel structures exposed to cryogenic temperatures”. Like all LNG terminals, gas may also release throughout the storage and transfer process, creating an ambient fire-hazard at the facility and acute risk of methane asphyxiation for workers.³²⁰ If built as proposed and without regulation, worker protection from

³¹⁶ (Medina, 2014)

³¹⁷ (Centers for Disease Control and Prevention)

³¹⁸ (DePlace E. &, 2017)

³¹⁹ (Powell T. a., 2016)

³²⁰ (American Bureau of Shipping, 2015)

these hazards would be almost entirely at the mercy of the safety plan of Puget Sound Energy and their business partners.

TEMPORARY LABOR CAMPS

Construction of oil and gas infrastructure, including processing plants, export terminals, extraction sites and pipelines, requires a large influx of labor with frequently unforeseen impacts on local communities. The influx of labor necessitates temporary housing and makes demands on local communities to provide for and adjust to the sudden increase in population and need for services. Frequent reports in the past ten years have documented burdens on local infrastructure, public services and public health and increasingly on nearby tribal communities through increases in crime, drug use, assaults, kidnapping, sex trafficking, and sexually transmitted infections (STI).

- In Williams County, North Dakota, in the Bakken Shale, increases in crime have corresponded with the flow of oil. The infusion of cash has reportedly attracted career criminals who deal in drugs, violence, and human sex trafficking. In 2014 the *Williston Herald* portrayed the rapid rise of “violent crimes that result in the immediate loss of an individual’s property, health or safety, such as murder, larceny and rape.” With fewer than 100 law enforcement personnel, crime in Williams County “has risen in kind with the county’s population, but funding, staffing and support training for law enforcement has not.”³²¹
- According to the North Dakota Health Department, the number of HIV and AIDS cases in North Dakota more than doubled between 2012 and 2014, and cases were shifting to the state’s western oil fields, where 35-40 percent of all new cases occurred. Previously, only 10 percent of cases were in that region.³²² This trend followed on the heels of an upsurge in sexually transmitted chlamydia cases in the same region. The North Dakota state director of disease control, Kirby Kruger, attributed the uptick in HIV cases to the drilling and fracking industry and attempted to spread HIV prevention messages at the

³²¹ (Bell, 2014) Retrieved from http://www.willistonherald.com/news/modernized-slavery/article_84e257d8-3615-11e4-a4f8-001a4bcf887a.html

³²² (Associated Press, 2014) Retrieved from http://billingsgazette.com/news/state-and-regional/montana/north-dakota-hiv-aids-rate-rises-with-population-growth/article_a939fed6-f737-5cfb-957f-ab800673f4d7.html

“man camps” that house young male workers in the oil industry.³²³ Human sex trafficking accompanied the fracking boom, but a shortage of medical professionals hampered response to the public health crisis, according to Kruger, who noted that it was difficult to hire nurses and medical staff who could live in the area on a public health wage.

- In 2017 the Southwest Pennsylvania Environmental Health Project established a voluntary public health registry to track and analyze impacts of shale gas development on people living near gas production facilities. According to a spokesperson, “The vast majority of independent science is looking at [shale gas development] and saying something’s not good there. We need to know more ... The findings of this registry will allow the health care community to be more informed about what problems people are experiencing when they walk into their offices.”³²⁴
- Sexually transmitted infections (STI) can increase through sexual mixing patterns associated with labor migration. A longitudinal, ecologic study was conducted from 2000–2016 in a prolific shale gas region situated in Ohio. Reported cases of chlamydia, gonorrhea and syphilis by county and year were obtained from the Ohio Department of Health. All 88 counties were classified as none, low, and high shale gas activity in each year, using data from the Ohio Department of Natural Resources. Compared to counties with no shale gas activity, counties with high activity had 21% increased rates of chlamydia and 19% increased rates of gonorrhea.³²⁵

One of the underreported effects of the fracking boom is the strain on the area’s healthcare system. Motor vehicle accidents and deaths, for example, are many times higher for oil and gas workers than workers in other industries, leading to over-burdened hospitals and emergency response services. One study found oil and gas workers died from work-related motor vehicle accidents 8.5 times more frequently than other wage and salary workers.³²⁶

The Methodist Healthcare Ministries executive report of the South Texas Community Needs Assessment describes the consequences of the fracking boom on healthcare in rural Texas counties near the Eagle field shale (EFS) area. Results include:

³²³ (Heitz D. , 2014)

³²⁴ (Hopey, 2017)

³²⁵ (Deziel N.C., 2018) <https://doi.org/10.1371/journal.pone.0194203>

³²⁶ (Retzer, 2013)

- Increased STIs (rates of chlamydia in part of the EFS area is 365 per 100,000 people— compared to a national average of 84 per 100,000).
- Increases in the number of uninsured patients, as much work in the oilfield is done by subcontractors who do not have health insurance. Additionally, workers in the industries that have grown to provide services to oil field workers are generally uninsured. At a single site in the study, the percentage of uninsured patients grew from 60 percent in 2011 to 74 percent in 2013. Across the study, self- pay, and charity cases increased 11%.
- Increases in heat exhaustion, dehydration, sleep deprivation, exposure to oil and gas spills, and accidents.
- Increase in traffic accidents. In one county, accidents increased 412% between 2009-2011. The impact on hospitals has also been described in the Bakken oil field region of North Dakota.
- Trauma services have increased in some rural areas by over 1000%. Half these trauma visits are attributed to oil field injuries, though many are drug overdose related.
- In North Dakota between 2012-2014 HIV/AIDS cases doubled. 35% occurred in the western oil fields, the site of large “man camps” which had already seen a significant increase in chlamydia cases.

Native Americans

Reports are emerging of disproportionately severe trauma to tribal communities near temporary labor camps. In January 2014, James Anaya, the United Nations special rapporteur, opened the meeting of the UN’s Permanent Forum stating: “It has become evident ... that extractive industries many times have different and often disproportionately adverse effects on indigenous peoples, and particularly on the health conditions of women.” He detailed the effects on Native American women and girls, including increased rates of STIs and HIV/AIDS, physical assault, and sexual harassment and violence. He additionally noted that “contamination of indigenous lands and natural resources resulting from extractive activities has significant implications for reproductive health, having contributed in many cases to birth defects, delayed child development and disease among community members.” In addition, he noted, the full range of health effects are yet to be

determined, igniting fears among Native Americans about the unknown intergenerational effects that the contamination will have on their communities.³²⁷

A 2016 opinion piece in the *Boston Globe* exposed the risks Native American women faced due to the Dakota Access Pipeline: “It also endangers women and girls. That’s because, in this country as around the world, extractive industries create so-called ‘man camps,’ places where male workers often work twelve-hour days, are socially isolated for weeks or months at a time, and live in trailers in parks that extend for miles. Many men retain their humanity, but as advocacy organizations like First Nations Women’s Alliance have noted, these man camps become centers for drugs, violence, and the sex trafficking of women and girls. They also become launching pads for serial sexual predators who endanger females for miles around.”³²⁸

In 2014 the U.S. Justice Department Office on Violence Against Women awarded three million dollars to five rural and tribal communities to prosecute crimes of violence against women and provide services to victims of sexual assault, domestic violence, and stalking in the Bakken Region of North Dakota and Montana.³²⁹ Rationale documented by tribal leaders, law enforcement, and the FBI included, “rapid development of trailer parks and modular housing developments often referred to as ‘man camps’; abrupt increase in cost of living, especially housing; rapid influx of people, including transients, in a previously rural and stable community; constant fear and perception of danger; and a lost way of life. Local and tribal officials and service providers reported that these changes have been accompanied by a rise in crime, including domestic and sexual violence.”³³⁰

To address the community health and safety harms linked to temporary labor camps of extractive industries, the British Columbia Ministry of Aboriginal Relations and Reconciliation funded a research project in 2017, carried out in consultation with First Nations. The project noted that “increased domestic violence, sexual assault, substance abuse, and an increased incidence of sexually transmitted infections (STIs) and HIV/AIDS due to rape, prostitution, and sex trafficking are some of the recorded negative impacts of resource extraction projects, specifically as a result of

³²⁷ (Rickert, 2014). <http://nativenewsonline.net/currents/un-special-rapporteur-oil-gas-mining-operations-brings-increased-sexual-violence/>

³²⁸ (Nagle, 2016)

³²⁹ (U.S. Department of Justice, 2014) Retrieved from <http://www.justice.gov/opa/pr/associate-attorney-general-west-announces-3-million-grants-address-violence-against-women>

³³⁰ (U.S. Department of Justice, 2014) Retrieved from <http://www.justice.gov/sites/defaultfiles/ovw/legacy/2014/04/25/fy2014-initiative-for-the-bakken-region-enhanced-services-for-victims.pdf>

the presence of industrial camps and transient work forces.” The objectives of the project were to stimulate dialogue and to develop detailed protective steps for Nations, government, and industry in advance of the initiation of planned extraction projects in the region, in order to prevent violence against women and other life changing negative effects linked to the industrial camps.³³¹

Jordan Cove LNG and Pacific Connector Gas Pipeline

Jordan Cove LNG has applied for a permit for a 2100-person temporary labor camp to be built on the north sand spit in Coos Bay during construction of the fracked gas processing plant. Access would be limited to one way in and out. Access for emergency responders and escape for visitors and personnel in case of emergencies would be inadequate and present a serious danger.

Proposed temporary housing would be serviced by new utilities including water supply and waste disposal. Will proposed utilities be adequate to handle a large influx of workers? If not, there is potential for negative impacts on the waters of Coos Bay, the estuary, and the ocean shore with the potential for contamination of soils and water as well as significant stress on the public water system by significantly increased usage. The large influx of labor will likely also place increased stress on the police, fire, and health resources of Coos Bay, North Bend, and surrounding communities.

Many temporary labor camps may be needed to build the proposed Pacific Connector Pipeline, especially in rural areas in and near tribal lands, raising concerns of increased risks to rural communities of communicable diseases, crime, drug use, assaults, and homicides. Local communities do not have the resources or the ability to protect their community members, and public health resources are insufficient to respond to the projected adverse health impacts.

HEALTH EFFECTS OF HYDRAULIC FRACTURING

Hydraulic fracturing (fracking) for gas is a remarkably dirty and dangerous industry with sometimes devastating effects on neighboring communities. The majority of the gas piped into Oregon and Washington is fracked gas, which has been extracted at substantial cost to the communities that surround fracking sites. West Coast fracked gas infrastructure would help perpetuate the development of fracking for gas that harms communities nationwide and in Canada.

³³¹ (Gibson, 2017) Retrieved from http://www.thefirelightgroup.com/thoushallnotpass/wp-content/uploads/2016/03/Firelight-work-camps-Feb-8-2017_FINAL.pdf

Health effects of fracking operations include air and water pollution, human-caused disasters, and threats to occupational health and safety. The deleterious effects of temporary labor camps associated with construction of fracked gas facilities are discussed above.

Air Pollution

Fracking for gas is associated with health-threatening levels of air pollution. Numerous studies have documented high levels of air pollutants that cause cancer as well as pulmonary and neurological diseases. Distant effects of fracking related emissions are seen as well, particularly via ground level ozone and smog.

Air pollutants include volatile organic compounds, ozone, particulate matter, nitrogen oxides, carbon monoxide, formaldehyde, benzene, and polycyclic aromatic hydrocarbons (see section [Air Pollution](#) above for further description of toxics).

Air samples gathered near fracking sites in Arkansas, Colorado, Pennsylvania, Ohio, and Wyoming were found to contain eight highly toxic chemicals. The most common airborne chemicals detected included two known human carcinogens (benzene and formaldehyde) and two potent neurotoxicants (hexane and hydrogen sulfide). In 29 out of 76 samples, concentrations far exceeded federal health and safety standards, sometimes by several orders of magnitude. Further, high levels of pollutants were detected at distances exceeding legal setback distances from wellheads to homes. Highly elevated levels of formaldehyde, for example, were found up to a half-mile from a wellhead. In Arkansas, seven air samples contained formaldehyde at levels up to 60 times the level known to raise the risk for cancer.³³²

Whole air samples collected throughout the Barnett Shale basin in Texas contained benzene, hexane, and toluene at levels two to fifty times greater than the local background and similar to those seen in other intensely drilled shale basins in Colorado and Utah.³³³

Between 2009 and 2014, ethane emissions in the Northern Hemisphere increased by about 400,000 tons annually, the bulk of it from North American oil and gas activity, according to research by an international team led by the University of Colorado Boulder. Ethane contributes to the creation of ground-level ozone pollution (smog), a known human health hazard.³³⁴

³³² (Macey, 2014) doi: 10.1186/1476-069X-13-82

³³³ (Marrero, 2016) doi: 10.1021/acs.est.6b02827

³³⁴ (Helmig, 2016) doi: 10.1038/ngeo2721

Approximately two percent of total global ethane emissions (250,000 tons of ethane/year) originate from the Bakken shale oil and gas field. These emissions directly impact air quality across North America by contributing to the formation of ground level ozone and smog. Surface-level ozone is linked to respiratory problems, eye irritation, and crop damage. Additionally, as a greenhouse gas, ethane is the third-largest contributor to human-caused climate change. Up until 2009 global ethane levels were decreasing, but have risen following the shale gas boom.³³⁵

Aerial infrared camera surveys “of more than 8,000 oil and gas wells in seven U.S. regions found that well pads emit considerably more methane and volatile organic compounds (VOC) than captured by earlier inventories. Moreover, these emissions were widely and unpredictably variable from site to site and from well to well. Over 90 percent of total airborne emissions from well pads originated with vents and hatches on aboveground storage tanks.”³³⁶

In response to health concerns by local residents, a research team from University of Cincinnati and Oregon State University found high levels of air pollution in heavily drilled areas of rural Carroll County, Ohio. Air monitors showed 32 different hydrocarbon-based air pollutants, including the carcinogens naphthalene and benzo[a]pyrene.³³⁷

Researchers found that drilling and fracking in Utah’s Uintah Basin emit prodigious amounts of volatile organic air pollutants, including benzene, toluene and methane, all of which are precursors for ground-level ozone (smog). Multiple pieces of equipment on and off the well pad, including condensate tanks, compressors, dehydrators, and pumps served as the sources of these emissions. This research shows that drilling and fracking activities are the cause of the extraordinarily high levels of winter smog in the remote Uintah basin—which regularly exceed air quality standards and are similar to that of downtown Los Angeles.³³⁸

Residential areas in intensely drilled northeastern Colorado have high levels of fracking-related air pollutants, including benzene and ozone.³³⁹ A Colorado School of Public Health study based on three years of monitoring at Colorado fracking sites found a number of toxic petroleum

³³⁵ (Kort, 2016) doi: 10.1002/2016GL068703

³³⁶ (Lyon, 2016) doi: 10.1021/acs.est.6b00705

³³⁷ (Oregon State University: Environmental Health Sciences Center, 2014)
<http://ehsc.oregonstate.edu/air/62PAH>

³³⁸ (Warneke, 2014) doi: 10.5194/acp-14-10977-2014

³³⁹ (Thompson C. R., 2014) doi: 10.12952/journal.elementa.000035

hydrocarbon air pollutants near gas wells including benzene, ethylbenzene, toluene, and xylene. These air toxics are linked to neurological and respiratory diseases and cancer.³⁴⁰

Measured levels of air pollution associated with fracking are already alarming. Research suggests additionally that emissions and associated health risks have been grossly understated due to the extensive scope of fracking and the variable nature of fracking-caused emissions. Researchers with the Southwest Pennsylvania Environmental Health Project showed that methods do not adequately measure the intensity, frequency, or durations of community exposure to the toxic chemicals routinely released from drilling and fracking activities. They found that exposures may be underestimated by an order of magnitude, as mixtures of chemicals, local weather conditions, and vulnerable populations are not taken into account.³⁴¹

Water Pollution

Contamination of water with toxic fracking fluids is widespread and well-documented in dozens and dozens of scientific studies. Contamination has affected rivers and streams, surface and groundwater, and many sources of drinking water. Hydraulic fracturing is exempt from key provisions of the Safe Drinking Water Act and fracking chemicals are protected from public scrutiny as trade secrets.³⁴² Known toxins can be legally injected into the ground near aquifers or directly into the aquifers themselves. Most states that host fracking operations do not require routine monitoring of groundwater aquifers near drilling and fracking operations.

The EPA's six-year, \$29 million study on fracking and water resources documented in detail the widespread deleterious impacts on drinking water at each stage of the fracking process.³⁴³ Contamination has resulted from spills of fracking fluid and fracking wastewater; discharge of fracking waste into rivers and streams; and underground migration of fracking chemicals, including gas, into drinking water wells. Depletion of aquifers caused by water withdrawals has also created water shortages.

According to an important compendium on fracking risks compiled by Physicians for Social Responsibility and Concerned Health Professionals of New York: "Repudiating industry claims of risk-free fracking, studies from across the United States present irrefutable evidence that

³⁴⁰ (McKenzie L. M., 2012) doi: 10.1016/j.scitotenv.2012.02.018

³⁴¹ (Brown, 2014) doi: 10.1515/reveh-2014-0002

³⁴² (Physicians for Social Responsibility and Concerned Health Professionals of New York, 2018)

³⁴³ (U.S. Environmental Protection Agency, 2016)

groundwater contamination occurs as a result of fracking activities and is more likely to occur close to well pads. In Pennsylvania alone, the state has determined that more than 300 private drinking water wells have been contaminated or otherwise impacted as the result of drilling and fracking operations over an eight-year period.³⁴⁴ The U.S. Agency for Toxic Substances and Disease Registry (ATSDR), determined that the chemical contamination of some private water wells in Dimock, Pennsylvania rendered the water unsuitable for drinking.³⁴⁵

More than 1000 chemicals have been confirmed as ingredients in fracking fluid, including dozens of known reproductive and developmental toxins. In addition, fluids contain heavy metals, radioactive elements, brine, and volatile organic compounds (VOC), which pose additional threats to surface and groundwater.

A 2017 study cited in the compendium found that “spills of fracking fluids and fracking wastewater are common, documenting 6,678 significant spills over a period of nine years in four states alone. In these states, between two and sixteen percent of wells report spills each year. About five percent of all fracking waste is lost to spills, often during transport.”³⁴⁶ In some watersheds, widespread downstream contamination has occurred with radioactive elements, heavy metals, endocrine disruptors, and toxic disinfection byproducts, which alter the ecology and chemistry of water flows, with adverse effects on aquatic biodiversity and populations of sensitive fish species, such as brook trout.

Researchers in Texas found 19 different fracking-related contaminants—including cancer-causing benzene—in hundreds of drinking water samples collected from the aquifer overlying the heavily drilled Barnett Shale.³⁴⁷ In Pennsylvania, a solvent used in fracking fluid was found in drinking water wells near fracking operations. The solvent is known to cause well casing problems.³⁴⁸ In California, state regulators admitted that they had mistakenly allowed oil companies to inject drilling wastewater into aquifers containing clean, potable water.³⁴⁹ A 2017 study found that fracking wastewater discharged into rivers and streams through treatment plants created dozens of

³⁴⁴ (Physicians for Social Responsibility and Concerned Health Professionals of New York, 2018)

³⁴⁵ (Agency for Toxic Substances and Disease Registry: CDC, 2016)

³⁴⁶ (Physicians for Social Responsibility and Concerned Health Professionals of New York, 2018)

³⁴⁷ (Hildenbrand, 2015) doi: 10.1021/acs.est.5b01526

³⁴⁸ (Llewellyn, 2015) doi: 10.1073/pnas.1420279112/-/DC Supplemental

³⁴⁹ (Long, 2015)

brominated and iodinated disinfection byproducts that are particularly toxic and “raise concerns regarding human health.”³⁵⁰

The Pennsylvania Department of Environmental Protection determined that fracking wastewater that had leaked from a storage pit contaminated groundwater and rendered a natural spring used for drinking water in Greene County undrinkable.³⁵¹ In Arkansas, researchers found that water withdrawals for fracking operations can deplete streams, threaten drinking water supplies, damage aquatic life and impact recreation.^{352 353}

Using geochemical and isotopic tracers to identify the unique chemical fingerprint of Bakken region brines (the naturally occurring salty water that lies underground and is brought to the surface through fracking), a Duke University study found that accidental spills of fracking wastewater have contaminated surface water and soils throughout North Dakota where more than 9,700 wells have been drilled in the past decade.³⁵⁴ Contaminants included salts as well as lead, selenium and vanadium. In the polluted streams, levels of contaminants often exceeded federal drinking water guidelines. Soils at spill sites showed elevated levels of radium. The study concluded that “inorganic contamination associated with brine spills in North Dakota is remarkably persistent, with elevated levels of contaminants observed in spill sites up to four years following the spill events.” In a comment about this study, lead author and Duke University geochemist Avner Vengosh said, “Until now, research in many regions of the nation has shown that contamination from fracking has been fairly sporadic and inconsistent. In North Dakota, however, we find it is widespread and persistent, with clear evidence of direct water contamination from fracking.”³⁵⁵

After residents complained about its foul taste, a 2016 study by Stanford University scientists determined that fracking fluids had contaminated the drinking water in the town of Pavillion, Wyoming.³⁵⁶ Contaminants included the carcinogen benzene and neurotoxic toluene. In the Pavillion area, operators sometimes fracked directly into underground sources of water.³⁵⁷

³⁵⁰ (Liberatore, 2017) doi: 10.1021/acs.estlett.7b00468

³⁵¹ (Niedbala, 2018) https://observer-reporter.com/news/localnews/w-va-company-fined-million-for-violations-at-well-sites/article_cc1ce344-faec-11e7-84ca-076df3832f29.html

³⁵² (Entrekin, 2018) doi: 10.1021/acs.est.7b03304

³⁵³ (American Chemical Society, 2018) <https://www.sciencedaily.com/releases/2018/01/180131095656.htm>

³⁵⁴ (Lauer, 2016) doi: 10.1021/acs.est.5b06349

³⁵⁵ (Nicholas School of the Environment, Duke University, 2016)

³⁵⁶ (DiGiulio, 2016) doi: 10.1021/acs.est.5b04970

³⁵⁷ (DiGiulio, 2016)

In an interview about the research, lead author DiGiulio said that his findings raise concerns about similar water pollution in other heavily fracked regions. “Pavillion isn’t geologically unique in the West, and I’m concerned about the Rocky Mountain region of the U.S. The impact on [underground drinking water sources] could be fairly extensive. Pavillion is like a canary in a coal mine and we need to look at other fields.”³⁵⁸ Co-author Jackson noted, “There are no rules that would stop a company from doing this anywhere else.”³⁵⁹

Other potential health impacts of water contamination from fracking include pre-term birth, pregnancy complications and childhood cancer. West Virginia researchers found endocrine-disrupting chemicals in surface waters near wastewater disposal sites.³⁶⁰ ³⁶¹ These types of chemicals can hurt the developing fetus even when present at very low concentrations. A Johns Hopkins study looked at records of 9,384 women with newborns who lived near fracking sites and found a 40% increased chance of having a premature baby and a 30% risk of having the pregnancy be classified as “high-risk”.³⁶² Premature babies accounted for 35% of infant deaths and prematurity is a known cause of life-long disabilities.

A Yale team identified 55 known or possible carcinogens that may be released into air and water from fracking operations. Of these, 20 are linked to leukemia or lymphoma.³⁶³ A 2017 Colorado study found higher rates of leukemia among both children and young adults living in areas dense with gas and oil wells.³⁶⁴

Each frack uses about 25,000 gallons of chemicals, including known human carcinogens, neurotoxins, and endocrine disrupting chemicals which contaminate water and soil. Table 9 is a partial list of commonly used chemicals and their health effects.³⁶⁵

³⁵⁸ (Banerjee, 2016) <https://insideclimatenews.org/news/29032016/fracking-study-pavillion-wyoming-drinking-water-contamination-epa>

³⁵⁹ (Jordan, 2016) <http://news.stanford.edu/2016/03/29/pavillion-fracking-water-032916/>

³⁶⁰ (Kassotis, 2016) doi: 10.1016/j.sci.tenv.2016.03.113

³⁶¹ (Bienkowski, 2016) <http://www.environmentalhealthnews.org/ehs/news/2016/april/in-w.-virginia-frack-wastewater-may-be-messing-with-hormones>

³⁶² (Casey, 2016) doi: 10.1097/EDE.0000000000000387

³⁶³ (McKenzie L. M., Childhood hematologic cancer and residential proximity to oil and gas development, 2017) doi: 10.1371/journal.pone.0170423

³⁶⁴ (Elliot, 2017) doi: 10.1016/j.scitotenv.2016.10.072

³⁶⁵ (U.S. Department of Energy)

Table 10: Hydraulic Fracturing Chemicals

Chemical	Type of Additive	Why Used	Non-fracking Uses	Health Problems
Hydrochloric (muriatic acid)	Acid	helps dissolve rock, and make cracks	swimming pool chemical, toilet bowl cleaner	severe burns to skin, GI and respiratory tract
Polyacrylamide	Reduces friction	minimizes friction in the pipes	water treatment, soil conditioner	nervous system damage, carcinogen
Methanol	Corrosion inhibitor	prevents corrosion; winterizing agent	used as solvent and in biodiesel	wood alcohol--can cause blindness and death
Ethylene glycol	Scale inhibitor	prevents scale in pipes	anti-freeze	poisonous
Glutaraldehyde	Biocide	kills bacteria that might be corrosive to pipes	disinfecting medical equipment	commonly causes throat and lung irritation, and asthma
n,n-Dimethyl formamide	Corrosion inhibitor	prevents pipe corrosions	plastics	liver damage, high blood pressure
Isopropanol	Surfactant	increases viscosity of the fluid	rubbing alcohol, glass cleaner	contact irritation, headache, dizziness
Ammonium persulfate	Breaker	delays breakdown of polymer chains	bleaching, plastics mfg.	respiratory distress, burning on contact

Noise Pollution

A review analyzing the relevant scientific literature on the potential public health impacts of ambient noise related to unconventional (fracked) oil and gas development found that “oil and gas activities produce noise at levels that may increase the risk of adverse health outcomes, including

annoyance, sleep disturbance, and cardiovascular disease.” The review included focus on vulnerable populations, including children, the elderly, and the chronically ill.³⁶⁶

In California, noise from well stimulation was associated with both sleep disturbance and cardiovascular disease in a dose-response relationship (the louder the noise, the greater the adverse effect).³⁶⁷

In cooperation with The Colorado Oil and Gas Conservation Commission, researchers at Colorado State University performed area noise monitoring at 23 oil and gas sites throughout Northern Colorado. Current noise mitigation strategies reduced noise levels. However, the reduction was not sufficient to reduce the noise below the residential permissible noise level (55 dBA).³⁶⁸

Human-caused Disasters

The fracking process itself has been shown to increase seismicity and precipitate earthquakes in communities near drilling sites.³⁶⁹ Scientists have linked surges in gas production and injections of wastewater, a key part of the fracking process, to earthquakes with magnitudes as high as 5.8 in Ohio, Arkansas, Texas, Oklahoma, Kansas, and Colorado, states with significant fracking operations.³⁷⁰ Both the U.S. Geological Survey (USGS) and state geological agencies such as the Oklahoma Geological Survey now acknowledge that earthquakes can be caused by wastewater injection. Emerging evidence suggests that risk of earthquakes can continue to rise for years after waste injection and cannot be prevented through “proper” fracking protocols or by solely limiting the rate or volume of injected fluid.³⁷¹

³⁶⁶ (Hays, 2016) doi: 10.1016/j.scitotenv.2016.11.118 (Shonkoff S. B., 2015)

³⁶⁷ (Shonkoff S. B., 2015) <http://ccst.us/publications/2015/vol-II-chapter-6.pdf>

³⁶⁸ (Radtke C., 2017) doi: 10.1080/15459624.2017.1316386

³⁶⁹ (Physicians for Social Responsibility and Concerned Health Professionals of New York, 2018)

³⁷⁰ (Physicians for Social Responsibility and Concerned Health Professionals of New York, 2018)

³⁷¹ (Physicians for Social Responsibility and Concerned Health Professionals of New York, 2018)

Bibliography

- 350 Tacoma. (2018, December 10). *What's Wrong with Puget Sound Energy's Fracked Gas Project*. Retrieved from 350 Tacoma: <https://www.350tacoma.org/pselng/>
- AcuTech. (2016, February 17). *Safety and Health Aspects*. Retrieved from Kalama Manufacturing Facility SEPA: <https://kalamamfgfacilitysepa.com/wp-content/uploads/2016/09/FEIS-Appendix-G2-Safety-and-Health-Aspects-Report.pdf>
- Adler, N. E. (2002, March/April). Socioeconomic Disparities in Health: Pathways and Policies. *Health Affairs*, 1(2).
- AFL-CIO. (2018, April 26). *Death on the Job: the Toll of Neglect*. Retrieved from AFL-CIO: American's Unions: <https://aflcio.org/reports/death-job-toll-neglect-2018>
- Agency for Toxic Substances and Disease Registry: CDC. (2016, May 24). *Health Consultation: Dimock Groundwater Site*. Retrieved from Agency for Toxic Substances and Disease Registry: CDC: https://www.atsdr.cdc.gov/hac/pha/DimockGroundwaterSite/Dimock_Groundwater_Site_HC_05-24-2016_508.pdf
- Aizhu, C. (2017, December 4). *China's CAS Plans Gas-to-methanol plant on U.S. West Coast*. Retrieved from Reuters: <https://www.reuters.com/article/us-china-usa-gas-methanol/chinas-cas-plans-gas-to-methanol-plant-on-u-s-west-coast-idUSKBN1DZ0BH>
- Alvarez, R. A. (2018, June). Assessment of Methane Emissions from the U.S. Oil and Gas Supply Chain. *Science*, 361(6398), 186-188.
- Al-Zoughool, M. a. (2008, March 26). Health effects of radon: A review of the literature. *International Journal of Radiation Biology*, 85(1).
- American Bureau of Shipping. (2015). *LNG Bunkering: Technical and Operational Advisory*. Retrieved from American Bureau of Shipping (ABS) Eagle: https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_LNG_Bunkering_Advisory.pdf
- American Chemical Society. (2018, January 31). *Potential impact of hydraulic fracturing on streams, downstream recreation, drinking water*. Retrieved from American Chemical Society: Science Daily: <https://www.sciencedaily.com/releases/2018/01/180131095656.htm>
- American College of Obstetricians and Gynecologists. (2013, October). *ACOG—The American College of Obstetricians and Gynecologists, Committee Opinion, No. 575, October 2013*. Retrieved from American College of Obstetricians and Gynecologists: <https://www.acog.org/-/media/Committee-Opinions/Committee-on-Health-Care-for-Underserved-Women/co575.pdf>
- American Public Health Association. (2014, November 18). *Preventing Environmental and Occupational Health Effects of Diesel Exhaust*. Retrieved from American Public Health Association: <https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2015/01/28/12/14/preventing-health-effects-of-diesel-exhaust>
- American Public Health Association. (2018, November 13). *The Environmental and Occupational Health Impacts of Unconventional Oil and Gas Industry*. Retrieved from American Public Health Association: <https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2019/01/28/impacts-of-unconventional-oil-and-gas-industry>
- Anderson, M. e. (2015). Particle-and gaseous emissions from an LNG powered ship. , ,. *Environmental Science & Technology*, 49, 12568–12575.
- Associated Press. (2014, October 13). *North Dakota HIV/AIDS rate rises with population growth*. Retrieved from Billings Gazette: <http://billingsgazette.com/news/state-and->

regional/montana/north-dakota-hiv-aids-rate-rises-with-population-growth/article_a939fed6-f737-5cfb-957f-ab800673f4d7.html

- Avy, B. J. (2017, November 6). *Cover Letter and Comments to Oregon Department of Energy*. Retrieved from Oregon Department of Geology and Mineral Industries.
- Babisch, W. (2005). Noise and Health. *Environmental Health Perspectives*, 113, A14–15.
- Baliatsas, C. e. (2016, July 1). Health effects from low-frequency noise and infrasound in the general population: Is it time to listen? A systematic review of observational studies. *Science of the Total Environment*, 557-558, 163-9.
- Banerjee, N. (2016, March 29). *Fracking study finds toxins in Wyoming town's groundwater and raises broader concerns*. Retrieved from InsideClimate News: <https://insideclimatenews.org/news/29032016/fracking-study-pavillion-wyoming-drinking-water-contamination-epa>
- Bang, K. e. (2015). Silicosis Mortality Trends and New Exposures to Respirable Crystalline Silica United States, 2001-2010. *Morbidity and Mortality Weekly Report*, 64(5), 117-120.
- Beaudry, C. e. (2013). Occupational exposure to silica in construction workers: a literature-based exposure database. *Journal of Occupational and Environmental Hygiene*, 10(2).
- Bell, T. (2014, September 6). *Modernized slavery*. Retrieved from Williston Herald: https://www.willistonherald.com/news/modernized-slavery/article_84e257d8-3615-11e4-a4f8-001a4bcf887a.html
- Benbrahim-Tallaa, L. e. (2012). Carcinogenicity of Diesel-Engine and Gasoline-Engine Exhausts and Some Nitroarenes. *The Lancet Oncology*, 13(7), 663-664.
- Beranek, L. L. (1992). *Noise and Vibration Control Engineering: Principles and Applications*. Cambridge, MA: John Wiley and Sons.
- Berglund B., e. a. (1996). Sources and effects of low frequency noise. *Journal of the Acoustical Society of America*, 99, 2985-3002.
- Berglund, B. a. (1995). Community Noise. *Archives of the Center/or Sensory Research*, 2(1), 195. Retrieved from <http://www.nonoise.org/library/whonoise/whonoise.htm>
- Berglund, B. e. (1999). *Guidelines for community noise*. Retrieved from World Health Organization: <https://apps.who.int/iris/handle/10665/66217>
- Bienkowski, B. (2016, April 6). *In W. Virginia, frack wastewater may be messing with hormones*. Retrieved from Environmental Health News: <http://www.environmentalhealthnews.org/ehs/news/2016/april/in-w.-virginia-frack-wastewater-may-be-messing-with-hormones>
- Boyle, M. D. (2017, April 3). *A pilot study to assess residential noise exposure near natural gas compressor stations*. Retrieved from Public Library of Science: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0174310>
- Boyle, M. e. (2017, June 2). A pilot study to assess residential noise exposure near natural gas compressor stations. *PLOS ONE*, 14(8), 659-667.
- Bronzaft, A. (2000). Noise: Combating a ubiquitous and hazardous pollutant. *Noise Health*, 2, 1–8.
- Brook, R. e. (2010, June 1). Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *121*(21), 2331-78.
- Brown, D. e. (2014). Understanding exposure from natural gas drilling puts current air standards to the test. *Reviews on Environmental Health*, 29 (4), 277-92.
- Bryan, K. (2014, August 3). *Drugs, Oilfield Work, Traffic Pushing More People through Doors of Watford City ER*. Retrieved from Grand Forks Herald:

- <https://www.grandforksherald.com/news/3316383-drugs-oilfield-work-traffic-pushing-more-people-through-doors-watford-city-er>
- Byrnes, B. (1990). Environmental Effects of N Fertilizer Use: an Overview. *Fertilizer Research*, 26(1-3), 209.
- Casey, J. A. (2016). Unconventional natural gas development and birth outcomes in Pennsylvania, USA. *Epidemiology*, 27(2), 163–172.
- Centers for Disease Control and Prevention. (n.d.). *Anhydrous Ammonia: What is the Problem?* Retrieved from Centers for Disease Control and Prevention: <https://www.cdc.gov/healthcommunication/toolstemplates/entertainmented/tips/AnhydrousAmmonia.html>
- Centers for Disease Control and Prevention. (n.d.). *Harmful Algal Bloom (HAB)-Associated Illness*. Retrieved from Centers for Disease Control and Prevention: <https://www.cdc.gov/habs/index.html>
- Centers for Disease Control and Prevention: National Center for Health Statistics. (n.d.). *CDC Wonder*. Retrieved from Centers for Disease Control and Prevention: <https://wonder.cdc.gov/ucd-icd10.html>
- Christodoulou, A. e. (2018, October 17). *Sea-level rise in ports: a wider focus on impacts*. Retrieved from Maritime Economics and Logistics: <https://link.springer.com/article/10.1057/s41278-018-0114-z>
- City of Kalama. (n.d.). *Water/Sewer/Garbage*. Retrieved from City of Kalama, WA: <http://www.cityofkalama.com/residents/water-sewer-garbage/utility-rates>
- Colborn, T. e. (2011). Natural Gas Operations from a Public Health Perspective. *Human and Ecological Risk Assessment: n International Journal*, 17(5), 1039-1056.
- Colton, H. .. (2006). *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*. Washington (DC): National Academies Press (US).
- Confederated Tribes of Coos, Lower Umpqua & Siuslaw Indians. (2013, June 20). *Motion to Intervene in Jordan Cove Energy Project*. Retrieved from Federal Regulatory Energy Commission: <https://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=13286908>
- Congressional Research Service. (2003, September 9). *Liquefied natural gas (LNG) infrastructure security: Background and issues for Congress*. Retrieved from Congressional Research Service: http://www.energy.ca.gov/lng/documents/CRS_RPT_LNG_INFRA_SECURITY.PDF
- Congressional Research Service. (2009, December). *Liquefied natural gas (LNG) import terminals: Siting, safety, and regulation*. Retrieved from Congressional Research Service: https://www.everycrsreport.com/files/20091214_RL32205_e95cb50c88dbd56a2c8f706b2d521ef7ae81ee00.pdf
- Corvi, M. (2018, June 8). Public meeting of Oregon Environmental Justice Task Force and Confederated Tribes of Coos, Lower Umpqua and Siuslaw, The Klamath Tribes, The Yurok Tribe, and The Cow Creek Band of Umpqua Tribe of Indians.
- Cribb, R. e. (2017, October 1). *That rotten stench in the air? It's the smell of deadly gas and secrecy*. Retrieved from <https://www.thestar.com/news/canada/2017/10/01/that-rotten-stench-in-the-air-its-the-smell-of-deadly-gas-and-secrecy.html>
- Crimmins, A. e. (2016). *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. Retrieved from GlobalChange: U.S. Global Change Research Program: <https://health2016.globalchange.gov/>

- Curzon Energy. (n.d.). *Coos Bay - Coal Bed Methane*. Retrieved from Curzon Energy: <http://www.curzonenergy.com/operations/asset-overview>
- DePlace, E. &. (2015, September 22). *Why China Wants Methanol from the Northwest*. Retrieved from Sightline Institute: <https://www.sightline.org/2015/09/22/why-china-wants-methanol-from-the-northwest/>
- DePlace, E. &. (2017, November 7). *A Billion-dollar Gas to Fertilizer Plant in Longview?* Retrieved from Sightline Institute: <https://www.sightline.org/2017/11/07/a-billion-dollar-gas-to-fertilizer-plant-in-longview/>
- DePlace, E. &. (2018, July 2). *What Consumes More Gas than Many of Cascadia's Cities Combined*. Retrieved from Sightline Institute: <https://www.sightline.org/2018/07/02/what-produces-more-gas-than-many-of-cascadias-cities-combined/>
- DePlace, E. &.-D. (2018, February 14). *How Northwest Methanol Is Likely Intended for China's Gas Tanks*. Retrieved from Sightline Institute: <https://www.sightline.org/2018/02/14/how-northwest-methanol-is-likely-intended-for-chinas-gas-tanks/>
- DePlace, E. (2016, June 23). *Examining Methanol's Green Claims in the Northwest*. Retrieved from Sightline Institute: <https://www.sightline.org/2016/06/23/examining-methanols-green-claims-in-the-northwest/>
- DePlace, E. (2016, October 28). *Kalama's Methanol Refinery, by the Numbers*. Retrieved from Sightline Institute: <https://www.sightline.org/2016/10/28/kalamas-methanol-refinery-by-the-numbers/>
- DePlace, E. (2017, March 22). *Who Should Pay for Tacoma's Last Big Cleanup?* Retrieved from Sightline Institute: <https://www.sightline.org/2017/03/22/who-should-pay-for-tacomas-last-big-clean-up/>
- DePlace, E. (2019, March 28). *Small Seattle Pipeline Expansion would mean Big Carbon Pollution Increase* . Retrieved from Sightline Institute: <https://www.sightline.org/2019/03/28/north-seattle-pipeline-expansion-increase-carbon-pollution/>
- Deslauriers, J. &. (2016). Silica Exposure, Silicosis, and the New Occupational Safety and Health Administration Silica Standard. *Annals of the American Thoracic Society*, 15(12), 1391-1392.
- Deziel N.C., e. a. (2018). Shale gas activity and increased rates of sexually transmitted infections in Ohio, 2000–2016. *PLOS ONE*, 13(3).
- DiGiulio, D. C. (2016). Impact to underground sources of drinking water and domestic wells from production well stimulation and completion practices in the Pavillion, Wyoming, Field. *Environmental Science & Technology*, 50(8).
- Dilawar, A. (2018, November 7). *Taxpayers May Soon Be on the Hook for a \$2 Billion Fracked Gas Refinery*. Retrieved from Pacific Standard Magazine: <https://psmag.com/environment/taxpayers-may-soon-be-on-the-hook-for-2-billion-fracked-gas-refinery>
- Draft Environmental Impact Statement for the Jordan Cove Energy Project*. (2019, March). Retrieved from Federal Regulatory Energy Commission: <https://www.ferc.gov/industries/gas/enviro/eis/2019/03-29-19-DEIS/03-29-19-DEIS.pdf>
- Draft Supplemental Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility*. (2018, November). Retrieved from https://kalamamfgfacilitysepa.com/wp-content/uploads/2018/11/DSEIS_November2018.pdf
- Draft Supplemental Environmental Impact Statement: Proposed Tacoma Liquefied Natural Gas Project*. (2018, October 8). Retrieved from Puget Sound Clear Air:

<https://www.pscleanair.org/DocumentCenter/View/3482/Draft-Supplemental-EIS-Tacoma-LNG-October-8-2018?bidId=>

- Ebi, K. e. (2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: Human Health*. Retrieved from U.S. Global Change Research Program: https://nca2018.globalchange.gov/downloads/NCA4_Ch14_Human-Health_Full.pdf
- Ecology and Environment, Inc. (2019, March 29). *Final Supplemental Environmental Impact Statement: Proposed Tacoma Liquefied Natural Gas Project*. Retrieved from Puget Sound Clean Air: <https://www.pscleanair.org/DocumentCenter/View/3616/Tacoma-LNG-FSEIS-032919?bidId=>
- Elliot, E. G. (2017). Unconventional oil and gas development and risk of childhood leukemia. *Science of the Total Environment*, 576.
- Elliott E. G., e. a. (2017). A Systematic Evaluation of Chemicals in Hydraulic-fracturing Fluids and Wastewater for Reproductive and Developmental Toxicity. *Journal of Exposure Science and Environmental Epidemiology*, 27(90).
- Employment Security Department: Washington State. (n.d.). *Monthly Employment Report*. Retrieved from Employment Security Department: Washington State: <https://esd.wa.gov/labormarketinfo/monthly-employment-report>
- Entrekin, S. e. (2018). Water stress from high-volume hydraulic fracturing potentially threatens aquatic biodiversity and ecosystem services in Arkansas, United States. *Environmental Science & Technology*, 52(4), 2349–2358.
- Erickson, P. &. (2018). *Towards a Climate Test for Industry: Assessing a Gas-based Methanol Plant*. Retrieved from Stockholm Environmental Institute: <https://www.sei.org/publications/assessing-gas-methanol-plant/>
- Erickson, P. &. (2018, December 27). *SEI Comments on Kalama DSEIS*. Retrieved from Stockholm Environmental Institute: <https://www.sei.org/wp-content/uploads/2018/02/erickson-lazarus-kalama-comments.pdf>
- Esswein, E. e. (2013). Occupational Exposures to Respirable Crystalline Silica During Hydraulic Fracturing. *Journal of Occupational and Environmental Hygiene*, 10(7), 347-356.
- Esswein, E. e. (2014). Evaluation of Some Potential Chemical Exposure Risks during Flowback Operations in Unconventional Oil and Gas Extraction: Preliminary Results. *Journal of Occupational and Environmental Hygiene*, 11(10), D174-D184.
- Esswein, E. e. (2018). Measurement of Area and Personal Breathing Zone Concentrations of Diesel Particulate Matter (DPM) during Oil and Gas Extraction Operations, Including Hydraulic Fracturing. *Journal of Occupational and Environmental Hygiene*, 15(1), 63-70.
- Federal Energy Regulatory Commission. (2016, December 9). *Order Denying Rehearing*. Retrieved from Federal Energy Regulatory Commission: <https://www.ferc.gov/CalendarFiles/20161209152707-CP13-483-001.pdf>
- Final Environmental Impact Statement: Jordan Cove Energy and Pacific Connector Pipeline Project*. (2015, September). Retrieved from Office of NEPA Policy and Compliance: <https://www.ferc.gov/industries/gas/enviro/eis/2015/09-30-15-eis.asp>
- Final Environmental Impact Statement: Kalama Manufacturing and Marine Export Facility*. (September 2016). Retrieved from <https://kalamamfgfacilitysepa.com/>
- Final Environmental Impact Statement: PSE LNG*. (2016, May 5). Retrieved from City of Tacoma: <https://www.cityoftacoma.org/cms/One.aspx?portalId=169&pageId=113675>

- Finley, B. (2017, May 2). *Deadly Firestone Explosion Caused by Odorless Gas Leaking from Cut Gas Flow Pipeline*. Retrieved from The Denver Post: <https://www.denverpost.com/2017/05/02/firestone-explosion-cause-cut-gas-line/>
- Firefighters United for Safety, Ethics and Ecology. (2019). Retrieved from The Jordan Cove Fracked Gas Pipeline: A Threat to Communities and Firefighters: <https://www.arcgis.com/apps/Cascade/index.html?appid=72a68fa5778440dbb9c3ea2a5f652279>
- Fisher, M. e. (2018, February). Psychosocial implications of unconventional natural gas development: Quality of life in Ohio’s Guernsey and Noble Counties. *Journal of Environmental Psychology*, 55.
- Flitter, E. &. (2017, September 15). *Oil and chemical spills from Hurricane Harvey big, but dwarfed by Katrina*. Retrieved from Reuters: Environment: <https://www.reuters.com/article/us-storm-harvey-spills/oil-and-chemical-spills-from-hurricane-harvey-big-but-dwarfed-by-katrina-idUSKCN1BQ1E8>
- Flitter, E. (2017, September 15). *Oil and gas spills at Harvey big, but dwarfed Katrina*., Retrieved from Reuters: <https://www.reuters.com/article/us-storm-harvey-spills/oil-and-chemical-spills-from-hurricane-harvey-big-but-dwarfed-by-katrina-idUSKCN1BQ1E8>
- French Ministry of Ecology, Sustainable Development and energy . (2011, March 11). *When Natural and Technological Hazards Collide: Overview of the Industrial Accidents Caused by the Great Tohoku Earthquake and Tsunami*. Retrieved from French Ministry of Ecology, Sustainable Development and energy : https://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/Overview_japan_mars_2013_GB.pdf
- Garris, A. (2019, June 6). *Industrial methane emissions are underreported, study finds*. Retrieved from Cornell Chronicle: <http://news.cornell.edu/stories/2019/06/industrial-methane-emissions-are-underreported-study-finds>
- Gharemani, Y. (2014, April). *Fractured Health Care: Pumping Resources Back into the Eagle Ford Shale Communities*. Retrieved from Methodist Healthcare Ministries: http://www.mhm.org/images/stories/pdf/Fractured_Healthcare_ExecSumm_FINAL.pdf
- Gibson, G. e. (2017, February 8). *Indigenous Communities and Industrial Camps: Promoting healthy communities in settings of industrial change*. Retrieved from The Firelight Group: Retrieved from http://www.thefirelightgroup.com/thoushallnotpass/wp-content/uploads/2016/03/Firelight-work-camps-Feb-8-2017_FINAL.pdf
- Glick, D. &. (2018, October 19). *The Rising Risks of the West's Latest Gas Boom*. Retrieved from High County News: <https://www.hcn.org/issues/50.18/energy-industry-how-site-workers-and-firefighters-responding-to-a-2017-natural-gas-explosion-in-windsor-colorado-narrowly-avoided-disaster>
- Goines, L. &. (2007, March). Noise Pollution: a Modern Plague. *Southern Medical Journal*, 100, 287-294.
- Goldfinger, C. e. (2012). *Turbidite Event History—Methods and Implications for Holocene Paleoseismicity of the Cascadia Subduction Zone: A USGS Professional Paper*. Retrieved from U.S. Geological Survey: Earthquake Hazards of the Pacific Northwest Coastal and Marine Regions: <https://pubs.usgs.gov/pp/pp1661f/>
- Gottlieb, B. &. (2017, February). *Too Dirty, Too Dangerous: Why Health Professionals Reject Natural Gas*. Retrieved from Physicians for Social Responsibility: <https://www.psr.org/wp-content/uploads/2018/05/too-dirty-too-dangerous.pdf>

- Graybill, M. (2019, January 30). *Oral Testimony: Public Hearing for Jordan Cove Removal-Fill Permit Application*. Retrieved from https://oregonshores.org/sites/default/files/sites/default/files/media-library/miscellaneous/dsl_comment_jordan_cove_app0060697_removal-fill_permit_1.30.19.pdf
- Haggarty, B. (2015, October). *Climate and Health Vulnerability Assessment*. Retrieved from Oregon Health Authority: <https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/CLIMATECHANGE/Documents/Social-Vulnerability-Assessment.pdf>
- Haggarty, B. e. (2014). *Oregon Climate and Health Profile Report*. Retrieved from Oregon Health Authority: <https://www.oregon.gov/oha/ph/HealthyEnvironments/climatechange/Documents/oregon-climate-and-health-profile-report.pdf>
- Hamilton, R. e. (2009). *Projected Future Conditions in the Lower Willamette River Subbasin of Northwest Oregon*. Retrieved from University of Oregon: <https://scholarsbank.uoregon.edu/xmlui/handle/1794/10737>
- Hammer M.S., e. a. (2014). Environmental noise pollution in the United States: developing an effective public health response. *Environ Health Perspectives*, 122, 115–119.
- Hanchard, J. (2017, December 1). *Tacoma liquefied natural gas plant raises permit concerns*. Retrieved from King 5 News: <https://www.king5.com/article/news/local/tacoma/tacoma-liquefied-natural-gas-plant-raises-permit-concerns/281-495040400>
- Harrison, R. (2016). Sudden Deaths Among Oil and Gas Extraction Workers Resulting from Oxygen Deficiency and Inhalation of Hydrocarbon Gases and Vapors — United States January 2010–March 2015. *Morbidity and Mortality Weekly Report*, 65, 6-9.
- Harvey, H. (2017, October 23). *Fifty simulations of ‘The Really Big One’ show how a 9.0 magnitude earthquake in Cascadia could play out*. Retrieved from University of Washington: <http://www.washington.edu/news/2017/10/23/50-simulations-of-the-really-big-one-show-how-a-9-0-cascadia-earthquake-could-play-out/>
- Havens, J. (2019, April 1). *Comments on Draft Environmental Impact Statement for the Jordan Cove Energy Project*.
- Hay, T. (n.d.). *The Case For and Against the Puget Sound Energy Liquefied Natural Gas Facility in the Port of Tacoma*. Retrieved from Todd Hay: http://toddhay.com/Inq - paperkey_14
- Hayes, K. e. (2018, June 1). Climate change and mental health: risks, impacts and priority actions. *International Journal of Mental Health Systems*, 12(28). Retrieved from <https://ijmhs.biomedcentral.com/articles/10.1186/s13033-018-0210-6>
- Hays, J. e. (2016). Public health implications of environmental noise associated with unconventional oil and gas development. *Science of the Total Environment*, 580, 448-556.
- Heitz, D. (2014, September 30). *Oil boom helps fuel surge in HIV in North Dakota*. Retrieved from HealthlineNews: <http://www.healthline.com/health-news/oil-boom-helps-fuel-hiv-surge-north-dakota-093014 - 1>
- Helmig, D. e. (2016). Reversal of Global Atmospheric ethane and Propane Trends Largely due to US Oil and Natural Gas Production. *Nature Geoscience*, 9, 490–495.
- Henterly, L. (2015, March 18). *The disaster waiting to happen at the Northwest Detention Center*. Retrieved from The Seattle Globalist: <https://www.seattleglobalist.com/2015/03/18/northwest-detention-center-tsunami-disaster-evacuation-tacoma/34981>

- Hessel, P. e. (1997). Lung Health in Relation to Hydrogen Sulfide Exposure in Oil and Gas Workers in Alberta, Canada. *American Journal of Industrial Medicine*, 31(5), 554-557.
- Hicks, M. a. (2019, December 30). *Appeals flood consumers: Use less gas after utility fire*. Retrieved from The Detroit News: <https://www.detroitnews.com/story/news/local/macomb-county/2019/01/30/no-injuries-after-fire-armada-natural-gas-facility/2721353002/>
- Hightower, M. e. (2004, December). *Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water*. Retrieved from Sandia National Laboratories: <https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2004/046258.pdf>
- Hildenbrand, Z. e. (2015). A comprehensive analysis of groundwater quality in the Barnett Shale region. *Environmental Science & Technology*, 49 (13), 8254-8262.
- Hoard, E. (2018, January 12). *Jordan Cove Opponents and Supporters Disagree on Findings of New Report*. Retrieved from The News-Review: https://www.nrtoday.com/news/environment/jordan_cove/jordan-cove-opponents-and-supporters-disagree-on-findings-of-new/article_f5217d49-22f2-5666-ac58-50d80f5b6391.html
- Hope, M. (2019, February 19). *Revealed: How the Tobacco and Fossil Fuel Industries Fund Disinformation Campaigns Around the World*. Retrieved from DESMOG: Clearing the PR Pollution that Clouds Climate Science: <https://www.desmogblog.com/2019/02/19/how-tobacco-and-fossil-fuel-companies-fund-disinformation-campaigns-around-world>
- Hohey, D. (2017, May 1). *Registry will study health impact from living near shale gas wells*. Retrieved from Pittsburgh Post-Gazette.: Retrieved from <http://powersource.post-gazette.com/powersource/consumers-powersource/2017/05/01/Registry-will-study-health-impact-from-living-near-shale-gas-wells/stories/201705010018>
- Ikealumba, W. C. (2014, April 23). Some recent advances in liquefied natural gas (LNG) production, spill, dispersion, and safety. *Energy & Fuels*, 28(6), 3556–3586.
- Indian Country Today. (2017, August 7). *Puyallup Battle LNG Facility in Tacoma*. Retrieved from newsmaven: <https://newsmaven.io/indiancountrytoday/archive/puyallup-battle-lng-facility-in-tacoma-Uas1XkEDVE-AKmnxc-cU1A/>
- Intergovernmental Panel on Climate Change. (2018, October). *Global Warming of 1.5 degrees C : Summary for Policymakers*. Retrieved from Intergovernmental Panel on Climate Change: <https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/>
- International Agency for Research on Cancer. (2012, June 12). *IARC: Diesel Engine Exhaust Carcinogenic*. Retrieved from International Agency for Research on Cancer: World Health Organization: https://www.iarc.fr/wp-content/uploads/2018/07/pr213_E.pdf
- Jordan Cove LNG. (2017, November). *Resource Report No. 11 Reliability and Safety Pacific Connector Gas Pipeline Project*. Retrieved from Jordan Cove LNG: <https://www.google.com/search?client=firefox-b-1-d&q=Resource+Report+No.+11+Reliability+and+Safety+Pacific+Connector+Gas+Pipeline+Project++201711.+Pacific+Connector+Gas+Pipeline,+LP>
- Jordan Cove LNG. (2017, September). *Resource Report No. 9: Air and Noise Quality*. Retrieved from Jordan Cove LNG: <https://www.jordancovelng.com/project/regulatory-resource-reports>
- Jordan Cove LNG. (n.d.). *The Jordan Cove Project: Safe. Clean. Reliable*. Retrieved from Jordan Cove LNG and Pacific Connector Gas Pipeline: <https://www.jordancovelng.com/project>

- Jordan Cove LNG/Pacific Connector Gas Pipeline. (2017, July). *Revised Draft JCEP Resource Report 1 – General Project Description*. Retrieved from Jordan Cove LNG/Pacific Connector Gas Pipeline: <https://www.jordancovelng.com/project/regulatory-archive>
- Jordan, R. (2016, March 29). *Stanford researchers show fracking's impact to drinking water sources*. Retrieved from Stanford News: <http://news.stanford.edu/2016/03/29/pavillion-fracking-water-032916/>
- Kaden, D. &. (2015). *Environmental and Health Issues in Unconventional Oil and Gas Development*. Elsevier.
- Kassotis, C. e. (2016). Endocrine disrupting activities of surface water associated with West Virginia oil and gas industry wastewater disposal site. *Science of the Total Environment*, 557-558.
- Kemball-Cook, S. e. (2010). Ozone Impacts of Natural Gas Development in the Haynesville Shale. *Environmental Science and Technology*, 44(24), 9357-9363.
- Kim, J. a. (2004, December). Ambient air pollution: health hazards to children. *114*(6), 1699-707.
- Klamath Tribes Tribal Council. (2017, October 20). Retrieved from https://drive.google.com/file/d/1dFNTfiSCC6i8E5OZyrmFoaO0TGps78W_/view
- Knoder, E. (2018, March 11). *Oregon's Commercial Fishing in 2018*. Retrieved from State of Oregon: Employment Department: <https://www.qualityinfo.org/-/oregon-s-commercial-fishing-in-2018>
- Korfmacher, K. e. (2013). Public Health and High Volume Hydraulic Fracturing. *New Solutions: A Journal of Environmental and Occupational Health Policy*, 23(1), 13–31.
- Kort, E. A. (2016). Fugitive Emissions from the Bakken Shale Illustrate Role of Shale Production in Global Ethane Shift. *Geophysical Research Letters*, 43, 4617–4623.
- Lacitis, E. (2017, March 29). *Puget Sound Energy will pay \$1.5M for Greenwood explosion*. Retrieved from The Seattle Times: <https://www.seattletimes.com/seattle-news/puget-sound-energy-will-pay-15m-for-greenwood-explosion/>
- Lauer, N. E. (2016). Brine spills associated with unconventional oil development in North Dakota. *Environmental Science & Technology*, 50(10).
- Lee, M. (2014, October 21). *SAFETY: "That Stuff Can Get You so Fast" -- Deadly Gas on the Rise in Oil Fields*. Retrieved from Energy Wire: <https://www.eenews.net/stories/1060007591>
- Lehigh University. (2018, July 9). *Electrochemically-produced ammonia could revolutionize food production*. Retrieved from Phys/news: <https://phys.org/news/2018-07-electrochemically-produced-ammonia-revolutionize-food-production.html>
- Leventhal, H. (2004). Low frequency noise and annoyance. *Noise Health*, 6, 59- 72.
- Liberatore, H. e. (2017). Identification and comparative mammalian cell cytotoxicity of new iodophenolic disinfection byproducts in chloraminated oil and gas wastewaters. *Environmental Science & Technology Letters*, 4(11), 475–480.
- Linares, A. (2018, July 31). *Wildfires Continue to Spread in Southern Oregon*. Retrieved from The World: https://theworldlink.com/news/local/wildfires-continue-to-spread-in-southern-oregon/article_fd897256-e87e-537c-875e-7b616e0127b1.html
- Llewellyn, G. T. (2015). Evaluating a groundwater supply contamination incident attributed to Marcellus Shale gas development. *Proceedings of the National Academies of Science*, 112, 6325-30.
- Loew, T. (2019, February 7). *Fracking ban on oil, gas development returns to Oregon Legislature*. Retrieved from The Statesmen Journal: <https://www.statesmanjournal.com/story/tech/science/environment/2019/02/07/oregon-legislature-fracking-ban-oil-gas-development/2795705002/>

- Loew, T. (2019, May 29). *Oregon Senate passes 5-year fracking moratorium for oil, natural gas*. Retrieved from Statesman Journal: <https://www.statesmanjournal.com/story/news/2019/05/29/oregon-senate-passes-5-year-fracking-moratorium/1271400001/>
- Lombardi, K. (2014, December 4). *Benzene and worker cancers: An American tragedy*. Retrieved from The Center for Public Integrity: <http://www.publicintegrity.org/2014/12/04/16320/benzene-and-worker-cancers-american-tragedy>.
- Long, J. e. (2015, July 9). *Summary report: An Independent Scientific Assessment of Well Stimulation in California*. Retrieved from California Council on Science and Technology: <http://ccst.us/publications/2015/2015SB4summary.pdf>
- Luck, M. (2016, December 10). *Risk of methanol explosion a hot topic in Kalama* . Retrieved from The Daily News: https://tdn.com/news/local/risk-of-methanol-explosion-a-hot-topic-in-kalama/article_45a048f1-438e-52d1-b688-42364bed0c5a.html
- Lyon, D. e. (2016). Aerial surveys of elevated hydrocarbon emissions from oil and gas production sites. *Environmental Science & Technology*, 50(9).
- Münzel, T. e. (2018 , March 20). The Adverse Effects of Environmental Noise Exposure on Oxidative Stress and Cardiovascular Risk. *Antioxidants & Redox Signaling*, 28(9), 873-908.
- Macey, G. P. (2014). Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. *Environmental Health*, 13(82).
- Mandel, J. (2016, June 7). *Natural Gas: Explosive LNG issues grab PHMSA's attention*. Retrieved from E&E News: <https://www.eenews.net/stories/1060038378>
- Mapes, L. (2018, April 19). *A 'monstrosity' or a step forward? Puyallup Tribe, PSE in showdown over Tacoma natural-gas plant*. Retrieved from The Seattle Times: <https://www.seattletimes.com/seattle-news/environment/puget-sound-energy-puyallup-tribe-in-showdown-over-lng-plant-on-tacoma-tideflats/>
- Marmot, M. (2007). Achieving Health Equity: From Root Causes to Fair Outcomes. *Lancet*, 370(9593), 1153-63.
- Marrero, J. E. (2016). Estimating Emissions of Toxic Hydrocarbons from Natural Gas production Sites in the Barnett Shale Region of Northern Texas. *Environmental Science & Technology*, 50 (19), 10756-10764.
- Martin, K. (2018, July 19). *PSE's gas plant studies have 'significant technical issues,' Puyallup tribe's experts allege*. Retrieved from The News Tribune: <https://www.thenewstribune.com/news/local/article215146725.html>
- May, C. e. (2018). *Impacts, Risks, and Adaptation in the United States: Northwest*. Retrieved from Fourth National Climate Assessment: <https://nca2018.globalchange.gov/chapter/northwest>
- Mazurek, J. M. (2015, June 15). *Silicosis Update*. Retrieved from NIOSH Science Blog: <http://blogs.cdc.gov/niosh-science-blog/2015/06/15/silicosis-update/>
- McKenzie, L. M. (2012). Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment*, 424, 79-87.
- McKenzie, L. M. (2012). Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources. *Science of The Total Environment*, 424, 79-87.
- McKenzie, L. M. (2017). Childhood hematologic cancer and residential proximity to oil and gas development. *PLOS ONE*, 12(2).
- Medina, E. (2014). Methanol Hazards & Safeguards: Lessons Learned From the Global Supply Chain . *Professional Safety*, 59(6), 67-74.

- Meng Wee, J. (2017). Maritime terrorism threat in Southeast Asia and its challenges. *Journal of the Singapore Armed Forces*, 43(2), 32-44.
- Mikulka, J. (2019, February 7). *Are Investors Finally Waking up to North America's Fracked Gas Crisis?* Retrieved from DESMOG: Clearing the PR Pollutions that Clouds Climate Science: <https://www.desmogblog.com/2019/02/07/north-america-natural-gas-fracking-financial-crisis-investors>
- Mikulka, J. (2019, February 22). *The Inevitable Death of Natural Gas as a 'Bridge Fuel'*. Retrieved from DESMOG: Clearing the PR Pollution that Clouds Climate Science: <https://www.desmogblog.com/2019/02/22/inevitable-death-natural-gas-bridge-fuel-renewables>
- Miller, C. (2013). *Some Notes on Subduction Earthquakes, Tsunami and LNG Terminals*. Retrieved from 350Corvallis: https://350corvallis.org/wp-content/uploads/2013/01/LNG-in-Tsunami-Zone_all.pdf
- Miller, I. e. (2018). *Projected Sea Level Rise for Washington State – A 2018 Assessment: a collaboration A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, and US Geological Survey*. Retrieved from WA Coastal Network: <http://www.wacoastalnetwork.com/files/theme/wcrp/SLR-Report-Miller-et-al-2018.pdf>
- Miller, S. M. (2013, December 10). *Anthropogenic Emissions of Methane in the United States*. Retrieved from Proceedings of the National Academy of Sciences: <https://www.pnas.org/content/110/50/20018.abstract>
- Mills, T. (2012). *Report of Investigation: Dry Canyon Compressor Station*. Wellington, Utah.
- Mutitt, G. (2016, September). *The Sky's Limit: Why the Paris Climate Goals Require a Managed Decline of Fossil Fuel*. Retrieved from Oil Change International: <http://priceofoil.org/2016/09/22/the-skys-limit-report/>
- Muzet, A. (2002). The need for a specific noise measurement for population exposed to aircraft noise during night-time. *Noise Health*, 4(15), 61–64.
- Nagle, M. &. (2016, September 29). *Sexual Assault on the Pipeline*. Retrieved from Boston Globe: <https://www.bostonglobe.com/opinion/2016/09/29/sexual-assault-pipeline/3jQscLWRcmD12cfefQTNsL/story.html>
- National Congress of American Indians. (2018, October). *Oppose the Siting of Liquefied Natural Gas Facilities in or Near Tribal Lands and Major Population Centers*. Retrieved from National Congress of American Indians: <http://www.ncai.org/resources/resolutions/oppose-the-siting-of-liquefied-natural-gas-facilities-in-or-near-tribal-lands-and-major-population-centers>
- National Institute for Occupational Safety and Health. (n.d.). *Methanol: Systemic Agent*. Retrieved from Centers for Disease Control and Prevention: National Institute for Occupational Safety and Health: https://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750029.html
- National Oceanic and Atmospheric Administration. (2018). *Commencement Bay: Hazardous Waste Site/Tacoma, WA/1920's to Present*. Retrieved from National Oceanic and Atmospheric Administration: Damage Assessment, Remediation, and Restoration Program: <https://darrp.noaa.gov/hazardous-waste/commencement-bay>
- National Oceanic and Atmospheric Administration. (2018). *Southern Resident Killer Whales and West Coast Chinook Salmon*. Retrieved from National Oceanic and Atmospheric Administration:

https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/srkw-salmon-sources-factsheet.pdf

National Transportation Safety Board. (2014, March 11). *Columbia Gas Transmission Corporation Pipeline Rupture Sissonville, West Virginia, December 11, 2012*. Retrieved from National Transportation Safety Board:

<https://www.nts.gov/investigations/AccidentReports/Reports/PAR1401.pdf>

Nations of Yakama, Umatilla, Warm Springs and Nez Perce. (n.d.). *Columbia Basin Salmonids*. Retrieved from Columbia River Inter-Tribal Fish Commission: <https://www.critfc.org/fish-and-watersheds/columbia-river-fish-species/columbia-river-salmon/>

Nicholas School of the Environment, Duke University. (2016, April 27). *Contamination in North Dakota linked to fracking spills [Press release]*. Retrieved from Nicholas School of the Environment, Duke University:

<https://nicholas.duke.edu/about/news/ContaminationinNDLinkedtoFrackingSpills>

Niedbala, B. (2018, January 16). *West Virginia company fined \$1.7 million for violations at 14 well sites in Greene County*. Retrieved from Observer-Reporter: https://observer-reporter.com/news/localnews/w-va-company-fined-million-for-violations-at-well-sites/article_cc1ce344-faec-11e7-84ca-076df3832f29.html

NIOSH-OSHA. (2018). *NIOSH-OSHA Hazard Alert: Health and Safety Risks for Workers Involved in Manual Tank Gauging and Sampling at Oil and Gas Extraction Sites. (2018)*. Retrieved from Center for Disease Prevention and Control: <https://www.cdc.gov/niosh/docs/2016-108/default.html>

Nobel, J. (2019, February 2). *The Hidden Risk in the Fracking Boom*. Retrieved from Rolling Stone: <https://www.rollingstone.com/politics/politics-features/pipeline-explosions-fracking-796569/>

North West Innovation Works. (n.d.). *Projects*. Retrieved from NW Innovation Works:

<https://nwinnovationworks.com/project/>

Northeast Tacoma, Tacoma WA Demographics. (n.d.). Retrieved from areavibes:

<https://www.areavibes.com/tacoma-wa/northeast+tacoma/demographics/>

Northwest Innovation Works. (n.d.). *Proposed Kalama Methanol Plant to Bring Dramatic GHG Reductions; Northwest Innovation Works will Mitigate 100% of In-state Emissions*. Retrieved from Northwest Innovation Works:

<https://nwinnovationworks.com/news/proposed-kalama-methanol-plant-bring-dramatic-ghg-reductions-northwest-innovation-works-mitigate-100-in-state-emissions.html>

Nunnally, D. (2016, October 10). *What experts say about PSE's secret LNG plant studies*. Retrieved from The News Tribune: <https://www.thenewstribune.com/news/local/article215146725.html>

Office of Energy Projects: Federal Energy Regulatory Commission. (2019, March). *Draft Environmental Impact Statement for the Jordan Cove Energy Project*. Retrieved from Federal Energy Regulatory Commission:

<https://www.ferc.gov/industries/gas/enviro/eis/2019/03-29-19-DEIS/03-29-19-DEIS.pdf>

O'Neill, R. (. (2014, July). *Chemicals, Dust and earths and the new rush for oil and gas*. Retrieved from Hazards Magazine.: <http://www.hazards.org/oil/fracking.htm - top>

Olsen, L. (2014, February 22). *Houston Chronicle exclusive: Drilling boom, deadly legacy*.

Retrieved from Houston Chronicle: <http://www.houstonchronicle.com/news/special-reports/article/Houston-Chroniclexclusive-Drilling-boom-5259311.php - /0>

Oregon Administrative Rules. (n.d.). *Chapter 350, Division 35 of the Oregon Administrative Rules* .

Retrieved from Oregon Administrative Rules: <https://www.oregon.gov/deq/Rulemaking/Docs/div35table1-10.pdf>

- Oregon Department of Environmental Quality. (2018, January). *Coos Bay Coal Bed Methane Project Rears Its Head Again: Research Notes, January 2018*. Retrieved from Oregon State Legislature: Committee Meeting Documents: <https://olis.leg.state.or.us/liz/2017I1/Downloads/CommitteeMeetingDocument/148844>
- Oregon Department of Environmental Quality. (2018, December 20). *Supplemental Information Request to Jordan Cove LNG*. Retrieved from Oregon Department of Environmental Quality: <https://www.oregon.gov/deq/FilterDocs/JordanCoveSupp.pdf>
- Oregon Department of Environmental Quality. (2019). *2019 Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan*. Retrieved from Oregon Department of Environmental Quality: <https://www.oregon.gov/deq/FilterDocs/AQmonitoringplan.pdf>
- Oregon Department of Environmental Quality Environmental Solutions: Watershed Management Section. (2018). *Oregon Public Water Systems Surface Water Resource Guide For Drinking Water Source Protection*. Retrieved from Oregon Department of Environmental Quality: <https://www.oregon.gov/deq/FilterDocs/SurfaceWaterResourceGuide.pdf>
- Oregon Department of Environmental Quality. (n.d.). *Facility Details: Dyno Nobel Incorporated*. Retrieved from Oregon Department of Environmental Quality: <https://www.deq.state.or.us/msd/profilerreports/traacs.asp?id=05-2042-ST-01>
- Oregon Department of Environmental Quality. (n.d.). *Jordan Cove Energy Project*. Retrieved from Oregon Department of Environmental Quality: <https://www.oregon.gov/deq/Programs/Pages/Jordan-Cove.aspx>
- Oregon Department of Environmental Quality: Water Quality Assessment Reports. (2018). *Source Water Assessment Reports*. Retrieved from Oregon Department of Environmental Quality: Water Quality Assessment Reports: <https://www.deq.state.or.us/wq/dwp/swrpts.asp>
- Oregon Department of Geology and Mineral Industries. (2019, April 23). *Senate Committee on Environment and Natural Resources: Oil and Gas Resources in Oregon*. Retrieved from Oregon State Legislature: <https://olis.leg.state.or.us/liz/2019R1/Downloads/CommitteeMeetingDocument/193623>
- Oregon Department of Geology. (n.d.). *Tsunami Evacuation Map: Coos Bay Peninsula Oregon*. Retrieved from Oregon Department of Geology: <https://www.oregongeology.org/pubs/tsubrochures/CoosBayEvac.pdf>
- Oregon Health Authority. (2018, December). *Public Water Systems susceptible to harmful algae blooms (HABs)*. Retrieved from Oregon Health Authority: Drinking Water: Rules: <https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/DRINKINGWATER/RULES/Documents/cyanotoxins/ListofSusceptibleSourcesandPWSsforPermRule-updated-12-18-2018.pdf>
- Oregon Health Authority. (n.d.). *Age-Adjusted Death Rates by County*. Retrieved from Oregon Health Authority: Death Data, Center for Health Statistics: <https://www.oregon.gov/oha/PH/BIRTHDEATHCERTIFICATES/VITALSTATISTICS/DEATH/Pages/aadeath.aspx>
- Oregon State Legislature. (n.d.). *2019 Regular Session*. Retrieved from Oregon State Legislature: Oregon Legislative Information: <https://olis.leg.state.or.us/liz/2019R1/Measures/Overview/HB2623>
- Oregon State University: Environmental Health Sciences Center. (2014). *List of 62 PAH analyzed in Carroll County, OH*. Retrieved from Oregon State University: Environmental Health Sciences Center: <http://ehsc.oregonstate.edu/air/62PAH>

- Pacific Coast Fertilizer. (n.d.). *Frequently Asked Questions*. Retrieved from Pacific Coast Fertilizer: <http://pacificcoastfertilizer.com/faqs/>
- Pacific Coast Fertilizer. (n.d.). *Nitrogen based fertilizers are an essential element and a much needed source of nutrients for growing food crops*. Retrieved from Pacific Coast Fertilizer: <http://pacificcoastfertilizer.com/faqs/>
- Pacific Northwest Seismic Network. (n.d.). *Hazard Maps*. Retrieved from Pacific Northwest Seismic Network: <https://pnsn.org/outreach/hazard-maps-and-scenarios/hazard-maps>
- Parfomak, P. W. (2008, May). *Liquefied natural gas (LNG) infrastructure security: Issues for Congress*. Retrieved from Congressional Research Service: <https://www.hsdl.org/?view&did=486464>
- Parvey, J. e. (2016, May). *Tacoma Climate Change Resilience Study*. Retrieved from City of Tacoma/Environmental Services Department: http://cms.cityoftacoma.org/Sustainability/Climate_Resilience_Study_Final_2016.pdf
- Payne, B. F. (2017). Characterization of methane plumes downwind of natural gas compressor stations in Pennsylvania and New York. *Science of the Total Environment*, 580, 1214-21.
- Pediatrics, K. J. (2004, December). Ambient air pollution: health hazards to children. *Pediatrics*, 114(6), 1699-707. Retrieved from National Institutes of Health/U.S. Library of Medicine: <https://www.ncbi.nlm.nih.gov/pubmed/15574638>
- Physicians for Social Responsibility and Concerned Health Professionals of New York. (2018, March). *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction): Fifth Edition*. Retrieved from Physicians for Social Responsibility: https://www.psr.org/wp-content/uploads/2018/04/Fracking_Science_Compendium_5.pdf
- Pipeline and Hazardous Materials Safety Administration. (2019, May 2). *Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards*. Retrieved from EENews: Environment and Energy Publishing: https://www.eenews.net/assets/2019/05/02/document_ew_01.pdf
- Plagakis, S. (2013, May 5). *Is Anhydrous Ammonia a Risk to Your Community?* Retrieved from Center for Effective Government: <https://www.foreffectivegov.org/is-anhydrous-ammonia-a-risk-to-your-community>
- Popoola, L. T. (2013). Corrosion Problems during Oil and Gas Production and Its Mitigation. *International Journal of Industrial Chemistry*, 4(1), 35.
- Powell, T. (2016, February 2). *How Industry and Regulators Kept Public in the Dark After 2014 LNG Explosion in Washington*. Retrieved from Sightline Institute: <https://www.sightline.org/2016/02/08/how-industry-and-regulators-kept-public-in-the-dark-after-2014-lng-explosion-in-washington/>
- Powell, T. (2016, June 3). *Williams Companies Failed To Protect Employees in Plymouth LNG Explosion*. Retrieved from Sightline Institute: <https://www.sightline.org/2016/06/03/williams-companies-failed-to-protect-employees-in-plymouth-lng-explosion/>
- Powell, T. (2018, February 20). *Sightline Testifies at Hearing for Tacoma LNG Protesters*. Retrieved from Sightline Institute: <https://www.sightline.org/2018/02/20/sightline-to-testify-at-hearing-for-tacoma-lng-protesters/>
- Powell, T. (2019, February 12). *Methane's 20- and 100-Year Climate Effect is Like 'CO2 on Steroids'*. Retrieved from Sightline Institute: <https://www.sightline.org/2019/02/12/methane-climate-change-co2-on-steroids/>

- Powell, T. (2019, February 12). *Studying Full Methane Life Cycle Critical to PNW Climate Policy*. Retrieved from Sightline Institute: <https://www.sightline.org/2019/02/12/study-methane-life-cycle-critical-pacific-northwest/>
- Powell, T. a. (2016, May 17). *Tacoma's Proposed LNG Plant Raises Safety Concerns*. Retrieved from Sightline Institute: <https://www.sightline.org/2016/05/17/tacomas-proposed-lng-plant-raises-safety-concerns/>
- Proactiveinvestors. (2018, December 2018). *Curzon Energy to take a step back to consider best way forward at Coos Bay*. Retrieved from Proactiveinvestors: <https://www.proactiveinvestors.co.uk/companies/news/211551/curzon-energy-to-take-a-step-back-to-consider-best-way-forward-at-coos-bay-211551.html>
- Puget Sound Energy. (n.d.). *Project Summary*. Retrieved from Tacoma LNG: <http://tacomacleanlng.com/project-summary>
- Puget Sound Regional Council. (2013). *Port of Tacoma MIC*. Retrieved from Puget Sound Regional Council: <https://www.psrc.org/sites/default/files/mic-profile-portoftacoma.pdf>
- Radtke C., e. a. (2017, August 10). Noise characterization of oil and gas operations. *Journal of Occupational and Environmental Hygiene*, 14(8), 659-667.
- Retzer, K. D. (2013). Motor vehicle fatalities among oil and gas extraction workers. *Accident Analysis & Prevention*, 51, 168–174.
- Reuters. (2018, March 4). *Earthquake knocks out Exxon's Papua New Guinea LNG project for about eight weeks*. Retrieved from Reuters: <https://www.reuters.com/article/us-papua-quake-lng/earthquake-knocks-out-exxons-papua-new-guinea-lng-project-for-about-eight-weeks-idUSKBN1GG163>
- Rickert, L. (2014, January 21). *UN Special Rapporteur: Oil, Gas & Mining Operations Brings Increased Sexual Violence*. Retrieved from NativeNewsOnline: <http://nativenewsonline.net/currents/un-special-rapporteur-oil-gas-mining-operations-brings-increased-sexual-violence/>
- Robert Wood Johnson Foundation. (n.d.). *Explore Health Rankings*. Retrieved from County Health Rankings and Roadmaps: <http://www.countyhealthrankings.org/explore-health-rankings>
- Robinson, A. (2016, January 5). *Compressor station explosion raises concerns*. Retrieved from McKenzie County Farmer: <http://www.watfordcitynd.com/?id=10&nid=3533>
- Rogue Climate. (2019 , January 30). *Comment on DSL APP0060697 (Jordan Cove Energy Project and Pacific Connector Gas Pipeline) Application for Removal-Fill Permit* .
- Russo, P. N. (2017, October 12). *Health effects associated with stack chemical emissions from NYS natural gas compressor stations, 2008-2014*. Retrieved from Institute for Health and the Environment: University at Albany: https://www.albany.edu/about/assets/Complete_report.pdf
- Sahu, R. (2018, April 11). *Issues Identified in the Tacoma LNG Siting Study Report*.
- Salas, R. N. (2018). *Lancet Countdown on Health and Climate Change: Brief for the United States*. Retrieved from Lancet Countdown: <http://www.lancetcountdown.org/media/1426/2018-lancet-countdown-policy-brief-usa.pdf>
- San Angelo Standard-Times. (2018, August 6). *Victim in Midland-Area Pipeline Explosion Was from San Angelo*. Retrieved from San Angelo Standard-Times: <https://www.gosanangelo.com/story/news/2018/08/06/victim-midland-area-pipeline-explosion-san-angelo/913903002/>
- San Angelo Standard-Times. (2018, August 6). *Victim in Midland-Area Pipeline Explosion Was from San Angelo*. *San Angelo*. . Retrieved from San Angelo Standard-Times :

<https://www.gosanangelo.com/story/news/2018/08/06/victim-midland-area-pipeline-explosion-san-angelo/913903002/>

- Sanders, R. (2012, April 2). *Fertilizer Use Responsible for Increase in Nitrous Oxide in Atmosphere*. Retrieved from UC Berkely: Berkeley News: <https://news.berkeley.edu/2012/04/02/fertilizer-use-responsible-for-increase-in-nitrous-oxide-in-atmosphere/>
- Scheck, T. &. (2016, December 13). *EPA reverses course, highlights fracking contamination of drinking water*. Retrieved from <https://www.apmreports.org/story/2016/12/13/epa-fracking-contamination-drinking-water>
- Schleifstein, M. (2018, February 10). *Sabine Pass LNG ordered to shut down leaking gas storage tanks*. Retrieved from New Orleans: The Times-Picayune: https://www.nola.com/environment/2018/02/sabine_pass_lng_ordered_to_shu.html
- Schneyer, J. e. (2014). *Blast at Liquefied Natural Gas Site Casts Spotlight on Industry Safety*. Retrieved from Scientific American/Reuters: <https://www.scientificamerican.com/article/blast-at-liquefied-natural-gas-site-casts-spotlight-on-industry-safety/>
- Sforza E., e. a. (2004). Heart rate activation during spontaneous arousals from sleep: effect of sleep deprivation. *Clinical Neurophysiology*, 115, 2442–2451.
- Shapiro, S. (1991, November). *The Dormant Noise Control Act And Options to Abate Noise Pollution*. Retrieved from Noise Pollution Clearing House: Online Library: <http://www.nonoise.org/library/shapiro/shapiro.htm>
- Shonkoff, S. B. (2015). Potential impacts of well stimulation on human health in California. In *An Independent Scientific Assessment of Well Stimulation in California*. Sacramento, CA.: California Council on Science and Technology.
- Shonkoff, S. e. (2014). Environmental Public Health Dimensions of Shale and Tight Gas Development. *Environmental Health Perspectives*, 122(8), 787–795.
- Shore, R. (2018, October 11). *B.C. pipeline rupture causes natural gas shortage, soaring gasoline prices*. Retrieved from Vancouver Sun: <https://vancouversun.com/news/local-news/enbridge-pipeline-ruptures-sparks-massive-fire-near-prince-george>
- Snover, A. K. (2013). *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers*. Retrieved from University of Washington: Climate Impacts Group: <https://cig.uw.edu/news-and-events/publications/climate-change-impacts-and-adaptation-in-washington-state-technical-summaries-for-decision-makers/>
- Society of International Gas Tanker and Terminal Operators. (2003). *LNG Operations in Port Areas: Essential Best Practices for the Industry*. Witherby & Co Ltd.
- Solomon, M. (2019, April 19). *Controversial Kalama Methanol Plant May Be Misleading Public, Regulators*. Retrieved from Oregon Public Broadcasting: <https://www.opb.org/news/article/methanol-plant-kalama-fossil-fuel-china/>
- Soraghan, M. (2014). *SAFETY: Poisoned by the Shale? Investigations Leave Questions in Oil Tank Deaths*. Retrieved from Energy Wire: <https://www.eenews.net/stories/1060007896>
- Soraghan, M. (2014). *SAFETY: The Drilling Industry's Explosion Problem*. Retrieved from Energy Wire: <https://www.eenews.net/stories/1060007532>
- Soraghan, M. (2015). *SAFETY: At Least 16 Drilling Industry Workers Died in Fires, Explosions Last Year*. Retrieved from Energy Wire: <https://www.eenews.net/stories/1060011452>
- Soraghan, M. a. (2018, September 10). *SAFETY: Pipeline in Fatal Blast Had a Dime-sized Hole in It*. Retrieved from Energy Wire: <https://www.eenews.net/stories/1060096333>

- Srinivasan, S., O'Fallon, L., & Dearry, A. (2003, September). Creating Healthy Communities, Health Homes, Healthy People: Initiating a Research Agenda on the Built Environment and Public Health. *American Journal of Public Health*, 93(9), 1446-1450.
- Staddon P L, D. M. (2015). Fracking Cannot be Reconciled with Climate Change Mitigation Policies. *Environmental Science and Technology*, 49, 8269–8270.
- State of Oregon Employment Department. (n.d.). *Local Area Unemployment Statistics*. Retrieved from State of Oregon Employment Department: <https://www.qualityinfo.org/ed-dwnl/?at=1&t1=~unemprate~y~03~2018~2018~>
- Steinhäusler, F. (2004). Radiological Impact on Man and the Environment from the Oil and Gas Industry: Risk Assessment for the Critical Group. In *Radiation Safety Problems in the Caspian Region* (pp. 129-134). Springer.
- Stockman, L. (2017, November). *Burning the Gas 'Bridge-fuel' Myth*. Retrieved from Oil Change International: <http://priceofoil.org/2017/11/09/burning-the-gas-bridge-fuel-myth/>
- Stockman, L., & McGarry, J. (2018, January). *Jordan Cove and Pacific Connector Pipeline Greenhouse Gas Emissions*. Retrieved from Oil Change International: http://priceofoil.org/content/uploads/2018/01/JCEP_GHG_Final-Screen.pdf
- The National Institute for Occupational Safety and Health. (2016, February). *NIOSH-OSHA Hazard Alert: Health and Safety Risks for Workers Involved in Manual Tank Gauging and Sampling at Oil and Gas Extraction Sites*. Retrieved from Centers for Disease Control: The National Institute for Occupational Safety and Health: <https://www.cdc.gov/niosh/docs/2016-108/default.html>
- The News Guard. (2019, April 1). *OPPOSING: Siletz Tribe opposes Jordan Cove LNG* . Retrieved from The News Guard: Lincoln City, Oregon: https://www.thenewsguard.com/news/opposing-siletz-tribe-opposes-jordan-cove-lng/article_9bc01138-54de-11e9-8933-cb0c47247a2a.html
- Thompson C. R., H. J. (2014). Influence of oil and gas emissions on ambient atmospheric non-methane hydrocarbons in residential areas of Northeastern Colorado. *Elementa: Science of the Anthropocene*, 2.
- Trout, K. a. (January, 2019). *Drilling Toward Disaster: Why U.S. Oil and Gas Expansion is Incompatible with Climate Limits*. Oil Change International.
- U. S. Census Bureau. (n.d.). *Quick Facts*. Retrieved from United States Census Bureau: <https://www.census.gov/quickfacts/fact/table/US/AGE295217>
- U. S. Environmental Protection Agency. (n.d.). *Environmental Justice*. Retrieved from United States Environmental Protection Agency: <https://www.epa.gov/environmentaljustice>
- U. S. Environmental Protection Agency. (n.d.). *Importance of Methane*. Retrieved from United States Environmental Protection Agency: <https://www.epa.gov/gmi/importance-methane>
- U. S. Environmental Protection Agency. (n.d.). *Overview of Greenhouse Gases*. Retrieved from United States Environmental Protection Agency: <https://www.epa.gov/ghgemissions/overview-greenhouse-gases>
- U.S. Coast Guard. (2008, December 22). *Guidance Related to Waterfront Liquefied Natural Gas (LNG) Facilities* . Retrieved from Homeland Security Digital Library: <https://www.hsdl.org/?abstract&did=22037>
- U.S. Department of Education. (n.d.). *ED Facts Data Files*. Retrieved from U.S. Department of Education: <https://www2.ed.gov/about/inits/ed/edfacts/data-files/index.html>

- U.S. Department of Energy. (n.d.). *Hydraulic Fracturing Fluids - Composition and Additives*. Retrieved from Geology.com: Geoscience News and Information: <https://geology.com/energy/hydraulic-fracturing-fluids/>
- U.S. Department of Justice. (2014, August 26). *Associate Attorney General West announces \$3 million in grants to address violence against women in rural and tribal communities in the Bakken Region*. Retrieved from U.S. Department of Justice: Justice News: <http://www.justice.gov/opa/pr/associate-attorney-general-west-announces-3-million-grants-address-violence-against-women>
- U.S. Department of Justice. (2014). *OVW Fiscal Year 2014 Violence Against Women Bakken Region Initiative: Enhanced response to victims application guidelines*. Retrieved from U.S. Department of Justice.: <http://www.justice.gov/sites/defaultfiles/ovw/legacy/2014/04/25/fy2014-initiative-for-the-bakken-region-enhanced-services-for-victims.pdf>
- U.S. Department of Labor: Occupational Safety and Health Administration. (n.d.). *Hazard Alert: Diesel Exhaust/Diesel Particulate Matter*. Retrieved from Hazard Alerts: https://www.osha.gov/dts/hazardalerts/diesel_exhaust_hazard_alert.html
- U.S. Department of Transportation. (1995, August 1). *Clean Air Program : summary assessment of the safety, health, environmental and system risks of alternative fuel*. Retrieved from Repository and Open Science Access Portal: <https://rosap.ntl.bts.gov/view/dot/8403>
- U.S. Energy Information Administration. (2018, November 15). *Oregon: State Profile and Energy Estimates*. Retrieved from U.S. Energy Information Administration: <https://www.eia.gov/state/analysis.php?sid=OR>
- U.S. Energy Information Administration. (2018, November 15). *Washington: State Profile and Energy Estimates*. Retrieved from U.S. Energy Information Administration: <https://www.eia.gov/state/analysis.php?sid=WA>
- U.S. Energy Information Administration. (n.d.). *Natural Gas-fired Electricity Generation Expected to Reach Record Level in 2016*. Retrieved from U.S. Energy Information Administration: <https://www.eia.gov/todayinenergy/detail.php?id=27072>
- U.S. Energy Information Administration. (n.d.). *U.S. States: State Profiles and Energy Estimates*. Retrieved from U.S. Energy Information Administration: <https://www.eia.gov/state/>
- U.S. Environmental Protection Agency. (1974). *Information On Levels Of Environmental Noise Requisite To Protect Public Health and Welfare With An Adequate Margin Of Safety*. Retrieved from U.S. Environmental Protection Agency: <https://nepis.epa.gov/Exe/ZyPDF.cgi/2000L3LN.PDF?Dockey=2000L3LN.PDF>
- U.S. Environmental Protection Agency. (1995, August 11). *Picloram: R.E.D. Facts*. Retrieved from U.S. Environmental Protection Agency: Prevention, Pesticides and Toxic Substances: https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/fs_PC-005101_1-Aug-95.pdf
- U.S. Environmental Protection Agency. (2004, June). *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*. Retrieved from U.S. Environmental Protection Agency: https://fracfocus.org/sites/default/files/publications/evaluation_of_impacts_to_underground_sources_of_drinking_water_by_hydraulic_fracturing_of_coalbed_methane_reservoirs.pdf
- U.S. Environmental Protection Agency. (2015, October). *Criteria Air Pollutants*. Retrieved from U.S. Environmental Protection Agency: https://www.epa.gov/sites/production/files/2015-10/documents/ace3_criteria_air_pollutants.pdf

- U.S. Environmental Protection Agency. (2016). *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States*. Retrieved from U.S. Environmental Protection Agency: <https://www.epa.gov/hfstudy>
- U.S. Environmental Protection Agency. (n.d.). *Environmental Justice*. Retrieved from U.S. Environmental Protection Agency: <https://www.epa.gov/environmentaljustice>
- U.S. Environmental Protection Agency Science Advisory Board. (2016, August 11). *U.S. Environmental Protection Agency Science Advisory Board review of the EPA's draft assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources. EPA- SAB-16-005*. Retrieved from Environmental Protection Agency: [https://yosemite.epa.gov/sab/sabproduct.nsf/LookupWebReportsLastMonthBOARD/BB6910FEC10C01A18525800C00647104/\\$File/EPA-SAB-16-005+Unsigned.pdf](https://yosemite.epa.gov/sab/sabproduct.nsf/LookupWebReportsLastMonthBOARD/BB6910FEC10C01A18525800C00647104/$File/EPA-SAB-16-005+Unsigned.pdf)
- U.S. Environmental Protection Agency. (n.d.). *TENORM Resources*. Retrieved from U.S. Environmental Protection Agency: Radiation Protection: <https://www.epa.gov/radiation/tenorm-resources>
- U.S. Government Accountability Office. (2007, February). *Public safety consequences of a terrorist attack on a tanker carrying liquefied natural gas need clarification*. Retrieved from U.S. Government Accountability Office: <https://www.gao.gov/new.items/d07316.pdf>
- U.S. Government Accountability Office. (2019, March). *Tribal Consultation: Additional Federal Actions Needed for Infrastructure Projects*. Retrieved from U.S. Government Accountability Office: <https://www.gao.gov/assets/700/697694.pdf>
- United States Census Bureau. (n.d.). *American Fact Finder*. Retrieved from United States Census Bureau: <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>
- United States Climate Alliance: About Us*. (n.d.). Retrieved from United States Climate Alliance: <https://www.usclimatealliance.org/about-us/>
- US Department of Transportation: Pipeline and Hazardous Materials Safety Administration. (n.d.). *Pipeline Incident 20 Year Trends*. Retrieved from U.S. Department of Transportation: Pipeline and Hazardous Materials Safety Administration: <https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends>
- Venturato, A. C. (2007, January). *Tacoma, Washington, Tsunami Hazard Mapping Project: Modeling Tsunami Inundation*. Retrieved from Pacific Marine Environmental Laboratory/National Oceanic and Atmospheric Administration: <https://www.pmel.noaa.gov/pubs/PDF/vent2981/vent2981.pdf>
- Vermeulen, R. S. (2013). Exposure-Response Estimates for Diesel Engine Exhaust and Lung Cancer Mortality Based on Data from Three Occupational Cohorts. *Environmental Health Perspectives*, 122(2), 172–177.
- Vossler, M., Thomas, M. M., Kitchell, M., Idzerda, R., & Cornett, S. (2018). *The Health Co-benefits of Climate Change Mitigation in Washington State*. Washington Physicians for Social Responsibility.
- Vossler, M., Thomas, M., Kitchell, M., Idzerda, R., & Cornett, S. (2018, February). *The Health Co-Benefits of Climate Change Mitigation in Washington State*. Retrieved from Washington Physicians for Social Responsibility: <https://drive.google.com/file/d/1dJbzjciwVQ0T8MXEzjvqRRUxXp8bfCho/view>
- Vu, W. a. (2017, August 2). *Precautionary Principle*. Retrieved from Oxford Bibliographies: <http://www.oxfordbibliographies.com/view/document/obo-9780199756797/obo-9780199756797-0046.xml>

- Vynne, S. e. (2011, January). *Building Climate Resiliency in the Lower Willamette Region of Western Oregon*. Retrieved from Resource Innovation Group's Climate Leadership Initiative: https://issuu.com/getresilient/docs/lower_will_report_1-26-11_final_lores
- Warneke, C. G. (2014). Volatile organic compound emissions from the oil and natural gas industry in the Utah Basin, Utah: oil and gas well pad emissions compared to ambient air composition. *Atmospheric Chemistry and Physics*, 14, 10977-10988.
- Washington Administrative Code. (n.d.). *Maximum Environmental Noise Levels*. Retrieved from Washington State Legislature: <https://app.leg.wa.gov/wac/default.aspx?cite=173-60>
- Washington Coastal Resilience Project. (2018). *Projected Sea Level Rise for Washington State: A 2018 Assessment*. Retrieved from Washington Coastal Network: <http://www.wacoastalnetwork.com/files/theme/wcrp/SLR-Report-Miller-et-al-2018.pdf>
- Washington Environmental Health Disparities Map*. (n.d.). Retrieved from Washington State Department of Health: Information by Location and Washington Tracking Network: <https://www.doh.wa.gov/DataandStatisticalReports/EnvironmentalHealth/WashingtonTrackingNetworkWTN/InformationbyLocation>
- Washington State Department of Ecology. (2016, December). *Report to the Legislature: Achieving Attainment with National Ambient Air Quality Standards*. Retrieved from Washington State Legislature: https://app.leg.wa.gov/ReportsToTheLegislature/Home/GetPDF?fileName=1602028_2a6d07ee-4393-4266-a54a-87646773a973.pdf
- Washington State Department of Ecology. (n.d.). *Air quality monitoring network*. Retrieved from Washington State Department of Ecology: <https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Air-quality-monitoring-network>
- Washington State Department of Health. (n.d.). *Death Tables by Topic*. Retrieved from Washington State Department of Health: <https://www.doh.wa.gov/DataandStatisticalReports/HealthStatistics/Death/DeathTablesbyTopic>
- Washington State Department of Health. (n.d.). *Puget Sound Seafood Eating Advice - Marine Area 11*. Retrieved from Washington State Department of Health: <https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories/PugetSound/MarineArea11>
- Washington State Department of Natural Resources. (n.d.). *Oil and Gas Resources*. Retrieved from Washington State Department of Natural Resources: <https://www.dnr.wa.gov/programs-and-services/geology/energy-mining-and-minerals/oil-and-gas-resources - oil-and-gas-in-washington>
- Washington State Legislature. (n.d.). *Bill Information>SB 5145*. Retrieved from Washington State Legislature: <https://app.leg.wa.gov/billsummary?BillNumber=5145&Year=2019&initiative=>
- Weber, B. e. (2014, January 19). *Rural North Dakota's Oil Boom and Its Impact on Social Services*. Retrieved from The Association for Community Organization and Social Administration: https://www.acosa.org/joomla/pdf/Weber_et_al.pdf
- Werner, S. e. (1998). Chapter Two: Experiences from Past Earthquakes. In S. e. Werner, *Seismic Guidelines for Ports*. ASCE Press.
- Witter, R. Z. (2014). Occupational Exposures in the Oil and Gas Extraction Industry: State of the Science and Research Recommendations. *American Journal of Industrial Medicine*, 57(7), 847-856.

- World Health Organization. (2011). *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe*. Retrieved from World Health Organization: Regional Office for Europe:
https://www.who.int/quantifying_ehimpacts/publications/e94888.pdf?ua=1
- World Health Organization. (2013, October 17). *World Health Organization: Outdoor Air Pollution Causes Cancer*. Retrieved from American Cancer Society: <https://www.cancer.org/latest-news/world-health-organization-outdoor-air-pollution-causes-cancer.html>
- World Health Organization. (2018). *Environmental Noise Guidelines for the European Region*. Retrieved from World Health Organization: Regional Office for Europe:
<http://www.euro.who.int/en/health-topics/environment-and-health/noise/environmental-noise-guidelines-for-the-european-region>
- World Port Source. (n.d.). *Port of Kalama*. Retrieved from World Port Source:
http://www.worldportsource.com/ports/commerce/USA_WA_Port_of_Kalama_193.php
- Yachnin, J. (2019, May 2). *Tribes: Grijalva touts bill to address 'check a box' consultation*. Retrieved from Energy and Environment News:
<https://www.google.com/search?client=firefox-b-1-d&q=what+is+e%26e+news>
- Yamada, S. (2019, January 15). *Oral Testimony: Public Hearing for Jordan Cove Removal-Fill Permit Application*. Retrieved from
https://oregonshores.org/sites/default/files/sites/default/files/media-library/miscellaneous/dsl_comment_jordan_cove_app0060697_removal-fill_permit_1.30.19.pdf
- Zapata, M. e. (2017). *Findings Brief for Equity Considerations for Greenhouse Gas Emissions Cap and Trade Legislation in Oregon*. Retrieved from Oregon Legislature:
https://www.oregonlegislature.gov/helm/workgroup_materials/WG_4_-_Marisa_A._Zapata_Findings_Brief.pdf
- Zimmer-Stucky, J. (2018, March 14). *Conservation Groups File Lawsuit to Protect Important Farmland, Salmon Habitat Near Controversial Columbia River Port*. Retrieved from Columbia RiverKeeper: <https://www.columbiariverkeeper.org/news/2018/3/conservation-groups-file-lawsuit>
- Zimmer-Stucky, J. (2018, September 11). *Protect Longview's Kids, Neighborhoods from Anhydrous Ammonia*. Retrieved from Columbia RiverKeeper:
<https://www.columbiariverkeeper.org/news/2018/9/protect-longviews-kids-neighborhoods-anhydrous-ammonia>

APPENDIX I: METHANE GAS BASICS

So-called “natural” gas is a fossil fuel formed by forces acting on organic material trapped deep beneath the surface of the earth. It is widely used for household heating and cooking, to generate electricity, and as feedstock to produce various chemicals and materials.

Fracked gas is both highly flammable and explosive.³⁷² In a confined space, such as a tank or a pipeline, and when combined with oxygen, fracked gas becomes explosive. It will burn when oxygen concentrations reach five to fifteen percent. It burns extremely hot, at a temperature of 3500° F. Exposure to fracked gas in a confined space will also cause asphyxiation.³⁷³ For this reason, the odorless gas is often artificially odorized to facilitate detection.

Up to 95% of fracked gas is composed of methane, a colorless, odorless, and highly flammable gas. Methane is one of the most ubiquitous organic compounds on earth and is present in the air we breathe. Compared to oil and coal, methane burns more cleanly, emitting virtually no nitrous oxide, sulfur dioxide, particulate matter or other pollutants. For this reason, it is often cited as a clean energy source and a bridge fuel to renewable energy, a judgment that fails to take into account the GHG effects of methane.³⁷⁴

Methane is generated and released into the atmosphere through both human activity, such as the fossil fuel industry, landfills and manure management systems, and natural or biogenic processes such as animal digestion and fermentation in oxygen-poor environments like wetlands. Human caused activity accounts for 50-65% of total U.S. emissions of methane per year.³⁷⁵ The fossil fuel industry alone accounts for 39% of emissions.³⁷⁶

Gas Extraction

Natural gas is extracted through both conventional and unconventional processes. In conventional production, wells are dug into underground basins where the gas has collected in large volumes and simply flows out through the well. Unconventional production is used to extract gas that is trapped in coal beds, sand or shale in tiny pockets or fissures. In hydraulic fracturing, or fracking, large volumes of water are mixed with sand and various chemicals and injected into wells

³⁷² (U.S. Department of Transportation, 1995)

³⁷³ (U.S. Department of Transportation, 1995)

³⁷⁴ (Stockman, Burning the Gas 'Bridge-fuel' Myth, 2017)

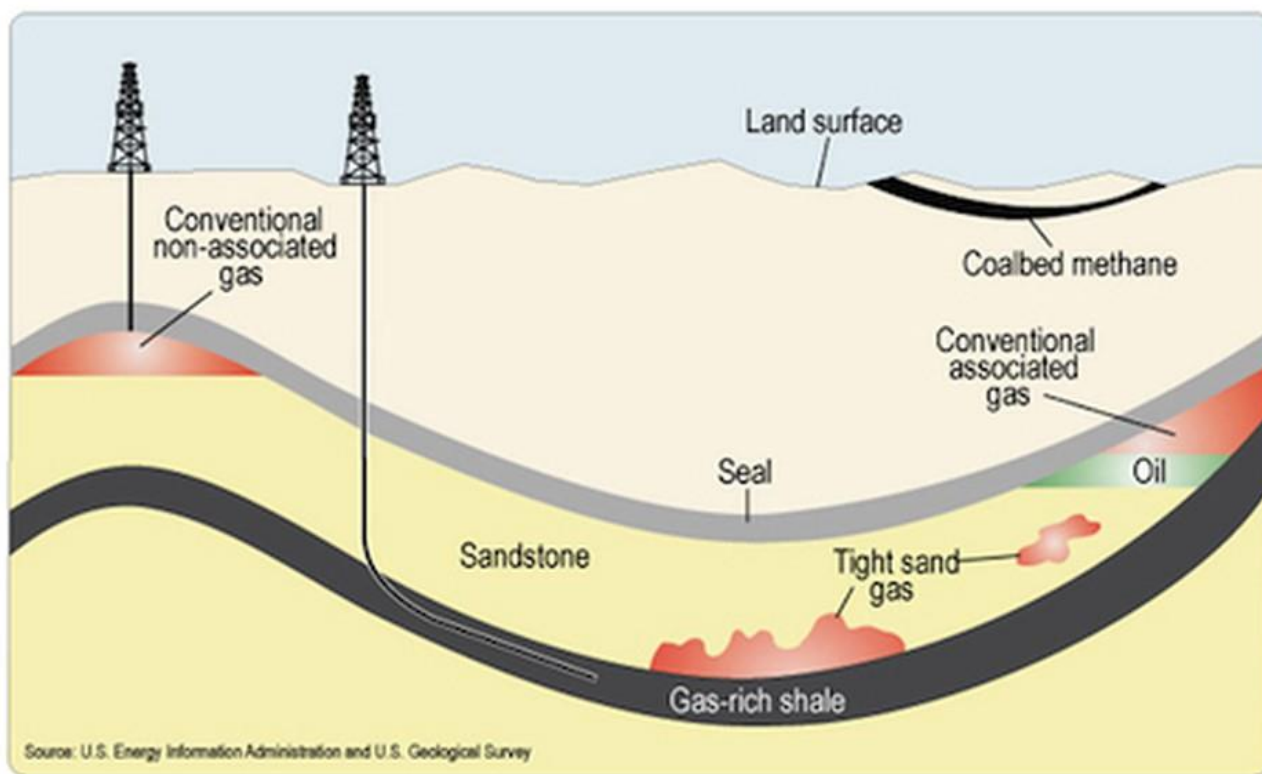
³⁷⁵ (Miller S. M., 2013)

³⁷⁶ (U. S. Environmental Protection Agency)

at high pressure to fracture or split apart the material in which the gas is embedded. This allows the gas to escape. Coal bed extraction, also an unconventional process but distinct from fracking, usually involves pumping water out of the coal bed which releases the trapped gas, but may also involve pumping chemical- and sand-laced water into the well, before pumping it back out again to release the gas.

Figure 15 illustrates some of the differences in gas extraction processes.

Figure 15
Methane Gas Deposits



Today two-thirds of gas comes from fracking, a proportion that continues to rise.³⁷⁷ Although the corporate entities behind the proposed gas infrastructure in Oregon and Washington cannot specify with any certainty, it is expected that the vast majority of the gas supplied to any new facilities in Oregon and Washington would be fracked gas from both the U.S. and Canada.

³⁷⁷ (U.S. Energy Information Administration, 2018)

Greenhouse Gas Emissions and Global Warming Potential

Methane is the second most abundant GHG³⁷⁸ after carbon dioxide (CO₂) and accounts for one-third of human-caused global GHG warming.³⁷⁹ Methane is much more effective at trapping heat than CO₂, but while CO₂ persists in the atmosphere for millennia, methane degrades into CO₂ over about twelve years.

Global warming potential (GWP) is a metric which was developed to compare the GHG effects of different gases over time compared to the same amount of CO₂. A 2018 report from the Intergovernmental Panel on Climate Change (IPCC) estimates methane's 20-year GWP value at 86 and 100-year GWP at 34.³⁸⁰ This means that a single molecule of methane traps 86 times more heat than a single molecule of CO₂ over a 20-year time period. Because of its rapid degradation compared to CO₂, its GWP is less when measured over a 100-year time frame.

When assessing the impact of a fracked gas facility on global warming it is critical to perform a lifecycle analysis. This analysis examines not just GHG emissions from the operation of the facility itself, but also the upstream extraction and pipeline transmission of the gas, the downstream export of the gas and the final use of the gas at its destination.³⁸¹

Methane emissions are both unintentional (fugitive) and intentional, such as flaring and venting. Gas companies are not legally required to report their rates of fugitive emissions, but multiple independent environmental scientists have studied the problem. The most recent peer-reviewed analysis of fugitive emissions from U.S. gas production identifies an average methane leakage rate of 2.3%.³⁸²

Liquefied Natural Gas

Natural gas can be liquefied in order to render it more compact and safer to store and transport. When cooled to -260° F the gas becomes a liquid and its volume contracts 600 times. When contained, liquefied natural gas (LNG) is neither flammable nor explosive. Structural failure of equipment, however, can result in human injury from exposure to extremely cold temperatures.³⁸³

³⁷⁸ (U. S. Environmental Protection Agency)

³⁷⁹ (Powell T. , Methane's 20- and 100-Year Climate Effect is Like 'CO₂ on Steroids', 2019)

³⁸⁰ (Intergovernmental Panel on Climate Change, 2018)

³⁸¹ (Powell T. , Studying Full Methane Life Cycle Critical to PNW Climate Policy, 2019)

³⁸² (Alvarez, 2018)

³⁸³ (U.S. Department of Transportation, 1995)

When LNG leaks or spills, it pours onto the ground like a liquid, but as soon as it warms a few degrees it re-gasifies into a vapor cloud, which slowly rises from the ground as it warms and begins to mix with oxygen. It can then explode into a fireball.

APPENDIX II: THE SOCIAL DETERMINANTS OF HEALTH

Communities in Oregon and Washington that are most susceptible to the adverse effects of climate change include communities of color, immigrants, low income persons and the houseless. These communities already bear a disproportionate burden of sickness and premature death (health outcome disparities) related to a long history of systematic socioeconomic deprivation. They very often bear the additional burden of living in unhealthy environments that are poorly prepared to withstand adverse climate events.

The most important drivers of these health outcome disparities are the social determinants of health.^{384 385} These include factors such as low education, unemployment, lack of access to health care, exposure to industrial pollutants and toxins, substandard housing, racism, poor social cohesion and political disenfranchisement. Socioeconomic status alone (defined by income and education) is a potent predictor of health outcomes.³⁸⁶

Health outcomes are determined by a complex interplay between individual and social factors. The most widely accepted model is represented in Figure 16, which is adapted from the 1991 paper for the World Health Organization on the social determinants of health by Dahlgren and Whitehead.³⁸⁷

³⁸⁴ (Adler, 2002)

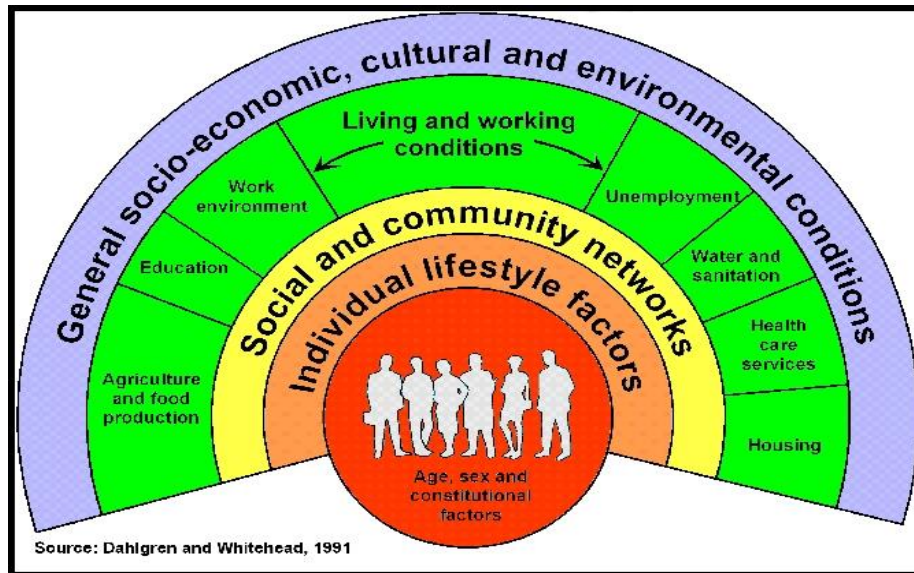
³⁸⁵ (Marmot, 2007)

³⁸⁶ (Adler, 2002)

³⁸⁷ Dahlgren and Whitehead, "Policies and Strategies to Promote Social Equity in Health."

Figure 16

Social Determinants of Health



Social and economic factors account for more than two-thirds of health outcomes.³⁸⁸ If disparities in social determinants were eliminated, disparities in health outcomes would be wiped out as well. In other words, differences in health cannot be explained away by differences in biological factors (age, gender or genetics) between those who are white alone, formally educated, financially secure and living in healthy environments and those who are not. Some researchers estimate that social, political and environmental conditions have a greater impact on well-being and longevity than either clinical care or individual behavior.³⁸⁹

Adverse impacts of climate change are a threat multiplier. They tend to stress most those communities already environmentally, socially and economically stressed. The Fourth National Climate Assessment (NCA4) noted that reducing greenhouse gas emissions would benefit the health of Americans not only in the long term, but also in the short run.³⁹⁰ The co-benefits of climate change mitigation are detailed in a report by Washington Physicians for Social Responsibility.³⁹¹

Communities can be characterized by their physical and social conditions and access to services. In a healthy community, housing units are in good repair, free of mold, vermin, lead paint and other toxics, and adequately heated and cooled. Litter, graffiti and vandalism are absent. The

³⁸⁸ Schroeder, "We Can Do Better: Improving the Health of American People."

³⁸⁹ Hernandez and Blazer, "The Impact of Social and Cultural Environment on Health."

³⁹⁰ (Ebi, 2018)

³⁹¹ (Vossler M., Thomas, Kitchell, Idzerda, & Cornett, 2018)

neighborhoods include common spaces, green spaces and an ample tree canopy. Bikeways, walkways and parks are safe and easy to access. The air and water are free of pollutants. Health clinics, schools, healthy food outlets and public transportation are all nearby. The neighbors know each other, trust each other and are willing to help out. Residents tend to remain in the neighborhood over a span of years. Crime rates are low and civic engagement is high. People are more likely to volunteer and more likely to vote.

A growing body of literature supports the hypothesis that living in a healthy neighborhood promotes mental and physical health and longevity and that poor conditions increase morbidity and premature mortality.³⁹² Improving neighborhood conditions has salutary effects on both mental and physical health.

³⁹² (Srinivasan, O'Fallon, & Deary, 2003)

APPENDIX III: WATERSHEDS IN OREGON AFFECTED BY PCGP

The Pacific Connector Gas Pipeline would require blasting and clearcutting a 75 to 95-foot right-of-way across steep terrain and through soils with high potential for erosion and landslides. It would remove trees and streamside vegetation along more than 485 Oregon streams and rivers. It would warm waters and introduce nutrients, increasing the risk of Harmful Algae Blooms (HAB). It would also increase the risks of human-caused fire and wildfire.

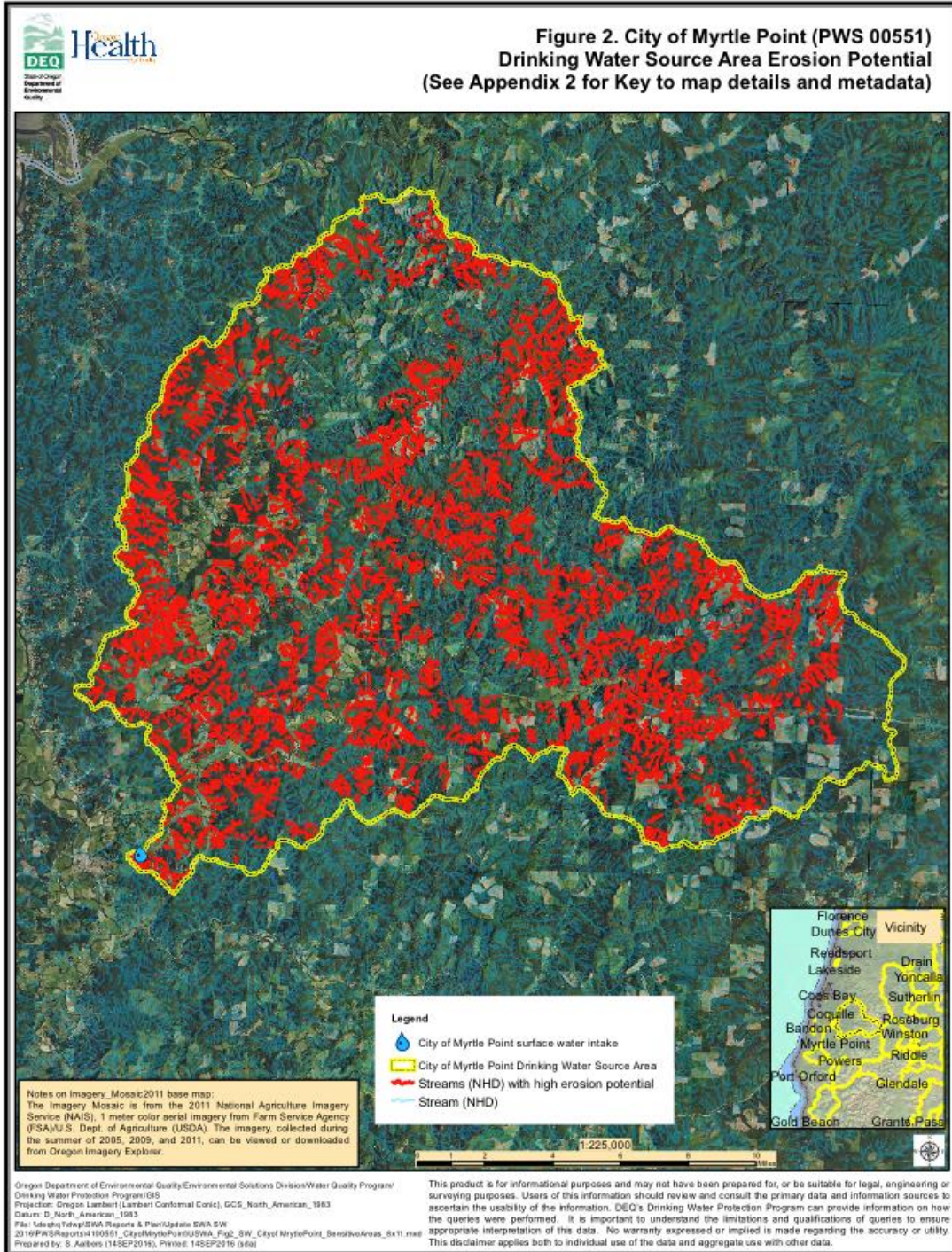
Watersheds that would be degraded by this project include, but are not limited, to those that provide water to the City of Coquille, Myrtle Point, Myrtle Creek, Medford, Eagle Point, Central Point, Jacksonville, Phoenix, Talent, Shady Cove, Anglers Cove, Tri-City JW and SA, Clarks Branch Water Association, Country View MH Estates, Lawson Acres Water Association, Glendale, Roseburg Forest Products – Dillard, Winston Dillard Water District, Tiller Elementary School, Latgawa Methodist Church Camp, Milo Academy, and Lake Creek Learning Center. Over 156,750 Oregonians rely on safe drinking water from these systems.

Many of these systems are already sensitive to contaminants of concern, including risk of erosion, turbidity, microbiological contamination, and harmful algal blooms. Many have already invested in expensive technology to clean and disinfect water.

The map below demonstrates the drinking watershed for Myrtle Point, one of the many areas in SW Oregon that is susceptible to elevated erosion potential from ground disturbance and vegetation removal and would face increased risk with construction and operation of the Pacific Connector Gas Pipeline. Steep slopes are identified for 117 miles of the proposed pipeline. 94 miles of the pipeline would be located in soils with high or severe erosion potential. Maps at this fine scale for specific watersheds are available from Oregon DEQ. Erosion leads to increased turbidity levels which can present costly challenges for human health, water treatment and water delivery.

Figure 17

City of Myrtle Point, Oregon: Drinking Water Source Area Erosion Potential



Below are excerpts from Oregon DEQ/Oregon Health Authority Source Water Assessments and/or information published by municipal water providers. Description of watersheds include sensitive areas and potential sources of contamination. In many cases they include potential pollutants from erosion and landslides, high soil permeability, stream miles in erodible soils, high soil erosion potential present, shallow landslide potential and landslide deposits. It is staggering to contemplate the damage that could be done by this massive project, the Pacific Connector Gas Project.

Medford Water Commission (PWS 4100513) provides water to Medford and provides wholesale water to cities of Eagle Point, Central Point, Jacksonville, Phoenix, Talent and the Lake Creek Learning Center

Source: Rogue River and Big Butte Springs
Jackson County
Serves 131,867 (includes those served by wholesale customers)

Oregon DEQ/Oregon Health Authority (OHA) Updated Water Source Assessment demonstrates:

A. Potential Pollutants: 8 hr time of travel in Drinking Water Source Area with 203 stream miles

- Stream miles in erodible soils: 156
- High Soil Erosion Potential: 77%
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *limited areas throughout watershed* include earth and debris slides, flows, slumps, falls and complex landslide types. (Does not include rock material landslide deposits.)

B. Potential Pollutants: Full Surface Drinking Water Source Area with 6,909 stream miles

- Stream miles in erodible soils: 5,244
- High Soil Erosion Potential: 76%
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *areas throughout watershed* include earth and debris slides, flows, slumps, falls and complex landslide types. (Does not include rock material landslide deposits.)

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Medford's Drinking Water Source Area by DEQ in June 2018:

- Previous HAB Advisory
- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Algae and aquatic weeds, pH, dissolved oxygen
- OHA DWS sampling location for cyanobacteria toxin (2011-2017)
- Waters of potential concern for HAB

C. Groundwater wells: Drinking water source area 88.68 acres

City of Coquille (PWS 4100213)

Source: Coquille River

Serves 3,866 people

Potential pollutants from erosion and landslides (See Table 1: Drinking Water Source Area Land Use and Susceptibility Analysis Summary from DEQ 2016 Source Water Assessment):

- Stream miles in erodible soils: 1,488.69 (Coquille River) 4.74 (Rink Creek)
- High Soil Erosion Potential: 41.4% (Coquille River) 99.6 (Rink Creek) (% stream miles with high erosion located within 300' of stream)
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *Multiple landslide deposits are present* and points are mapped throughout the Coquille watershed; Limited landslide/deposit near Rink Creek intake

Potential Harmful Algae Blooms (HAB) risk criteria/factors identified in City of Coquille's Drinking Water Source Area by DEQ in June 2018:

- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Dissolved Oxygen, Chlorophyll-A
- Multiple Water Quality Listings (Source: OR DEQ Water Quality Assessment (DEQ/WQ - 10/31/2014) and DEQ Source Water Assessment 2016)

Myrtle Point (PWS 4100551)

Source: North Fork Coquille River

Serves 2,600 people

DEQ/OHA Source Water Assessment 2016 (excerpts):

Potential Pollutants: 8 hr time of travel in Drinking Water Source Area with 203 stream miles

- Stream miles in erodible soils: 1,011.54
- High Soil Erosion Potential: 47% (% stream miles with high erosion located within 300' of stream)
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *Multiple landslide deposits are present* and points are mapped throughout the watershed

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Myrtle Point's Drinking Water Source Area by DEQ in June 2018:

- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Dissolved Oxygen
- Sampling point for cyanobacteria toxin (2011-2017) Multiple rivers and streams are already listed as Water Quality Limited (See Water Quality Analysis 10.31.2014)

Winston Dillard Water District (PWS 4100957)

Source: South Umpqua River

Douglas County

Serves 8,000 people

DEQ Source Water Assessment 2003 (excerpts):

There are eleven other public water systems located upstream of the Winston-Dillard intake that obtain their drinking water from the South Umpqua River or its tributaries. This source water assessment addresses the geographic area providing water to Winston-Dillard's intake (Winston Dillard's portion of the drinking water protection area) between Winston-Dillard's intake and the next upstream intake for Roseburg Forest Products.

Risks for the system, according to the Water Summary Brochure: A total of 36 potential contaminant sources were identified in Winston-Dillard's drinking water protection area. Of these, 34 are located in the sensitive areas and 29 are high-to-moderate risk sources within "sensitive areas". *The sensitive areas within the Winston-Dillard drinking water protection area include areas with high soil permeability, high soil erosion potential, high runoff potential and areas within 1000' from the river/streams. The sensitive areas are those where the potential contamination sources, if present, have a greater potential to impact the water supply.*

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Winston-Dillard's Drinking Water Source Area by DEQ in June 2018:

- Previous HAB Advisory
- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Algae and aquatic weeds, Chlorophyll-A, pH, Dissolved Oxygen
- OHA DWS sampling location for cyanobacteria toxin (2011-2017)

Roseburg Forest Products-Dillard (PWS 4194300)

Source: South Umpqua River

Douglas County

Serves 2,000 people

From 2003 Source Water Assessment Summary Brochure (excerpts):

RISKS FOR THE SYSTEM:

A total of 18 potential contaminant sources were identified in Roseburg Forest Products' drinking water protection area. Of these, 17 are located in the sensitive areas and 14 are high-to-moderate risk sources within "sensitive areas". *The sensitive areas within the Roseburg Forest Products drinking water protection area include, but are not limited to, areas with high soil permeability, high soil erosion potential, high runoff potential and areas within 1000' from the river/streams. The sensitive areas are those where the potential contamination sources, if present, have a greater potential to impact the water supply.*

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Roseburg Forest Products - Dillard Drinking Water Source Area by DEQ in June 2018:

- Previous HAB Advisory
- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Algae and aquatic weeds, Chlorophyll-A, pH, Dissolved Oxygen

Clarks Branch Water Association (PWS 4100548)

Source: South Umpqua River

Douglas County

Serves 140 people

DEQ Water Source Assessment Summary Brochure 2003 (excerpts):

RISKS FOR THE SYSTEM:

A total of 36 potential contaminant sources were identified in Clarks Branch's drinking water protection area. Of these, 35 are located in the sensitive areas and 32 are high-to-moderate risk sources within "sensitive areas." (Maps are available from the 2003 Source Water Assessment.) *The sensitive areas within the Clarks Branch drinking water protection area include, but are not limited to, areas with high soil permeability, high soil erosion potential, high runoff potential and areas within 1000' from the river/streams. The sensitive areas are those where the potential contamination*

sources, if present, have a greater potential to impact the water supply.

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Clarks Branch Drinking Water Source Area by DEQ in June 2018:

- Previous HAB Advisory
- Water Quality Limited Listing indicating the waterbody needs TMDL for Algae and aquatic weeds, Chlorophyll-A, pH, dissolved oxygen
- Waters of potential concern for HAB

Tri-City JW and SA (PWS 4100549)

Source: South Umpqua River Douglas County

Serves 3,500

Number of connections: 1,500

DEQ Source Water Assessment 2003 (excerpts):

RISKS FOR SYSTEM:

A total of 40 potential contaminant sources were identified in Tri-City Water District's drinking water protection area. Of these, 37 are located in the sensitive areas and 32 are high- to moderate-risk sources within "sensitive areas". *The sensitive areas within the Tri-City Water District drinking water protection area include, but are not limited to, areas with high soil permeability, high soil erosion potential, high runoff potential and areas within 1000' from the river/streams. The sensitive areas are those where the potential contamination sources, if present, have a greater potential to impact the water supply.*

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Tri-City JW and SA Drinking Water Source Area by DEQ in June 2018:

- Previous HAB Advisory
- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Algae and aquatic weeds, Chlorophyll-A, pH, dissolved oxygen
- OHA DWS sampling location for cyanobacteria toxin (2011-2017)

Hiland Water Co. Shady Cove (PWS 4101520)

Source: Rogue River

Serves 975 people

Due to the close proximity of intakes on the Rogue River, the following April 24, 2018 assessment of Anglers Cove/SCHWC addresses Hiland Water Co. Shady Cove.

Anglers Cove/SCHWC (PWS 01483)
Source: Rogue River
Jackson County
Serves 80 people

DEQ/OHA Source Water Assessment April 24, 2018 (excerpts):

Due to the close proximity of intakes on the Rogue River, this assessment addresses Anglers Cove/SCHWC and Hiland Water Co. Shady Cove.

Country View Mobile Home Estates also has an intake on the Rogue River upstream of these intakes and there are a number of public water systems downstream that also depend on Rogue River for their drinking water. For watersheds with more than one intake such as the Rogue Subbasin, all protection areas for intakes upstream of the water system's intake are included in their drinking water source area. Activities and impacts in upstream drinking water protection area also have the potential to impact downstream water users.

A. Potential Pollutants: 8 hour Time of Travel for Drinking Water Source Sub-Basin of Rogue

- Drinking Water Source Area: *219 sq. mi*
- Stream Miles in Drinking Water Source Area: *1,288*
- Stream Miles in Erodible Soils: *1,227*
- High Soil Erosion Potential Percent: *96%* (% stream mi with high erosion located w/in 300' of stream)
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *Limited areas throughout watershed* includes earth and debris slides, flows, slumps, falls and complex landslide types. (Does not include rock material landslide deposits.)

B. Full Source Water Source Area Rogue Basin upstream of intake

- Drinking Water Source Area: *6,229 sq. mi*
- Stream Miles in Drinking Water Source Area: *4,717*
- Stream Miles in Erodible Soils: *3,558*
- High Soil Erosion Potential Percent: *75%* (% stream mi with high erosion located w/in 300' of stream):
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *Limited areas throughout watershed* includes earth and debris slides, flows, slumps, falls and complex landslide types. (Does not include rock material landslide deposits.)

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Hiland Water Co. Shady Cove and Anglers Cove/SCHWC Drinking Water Source Area by DEQ in June 2018:

- Previous HAB Advisory
- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Algae and aquatic weeds, pH

Country View Mobile Home Estates (PWS #4100808)

Source: Rogue River plus a well
Jackson County
Serves 132 people

Oregon Source Water Assessment Report (excerpts):

In the Country View Mobile Home Estates watershed, the results of the susceptibility “analysis” include the distribution of 22 identified *high-to-moderate risk sources within the areas of highly permeable soils, high erosional soils, high runoff potential soils, and within the 1000' setback from the streams.*

A. Potential Pollutants: 8 hr time of travel in Drinking Water Source Area

- Stream miles in Drinking Water Source Area: 1,334
- Watershed Source Area: 227.86 sq mi
- High Soil Erosion Potential: 95%
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *Limited areas throughout watershed* includes earth and debris slides, flows, slumps, falls and complex landslide types. (Does not include rock material landslide deposits).

B. Potential Pollutants: Full Surface Drinking Water Source Area

- Watershed Source Area: *1,146.6 sq mi*
- Stream miles in Drinking Water Source Area: *4,613*
- Stream miles in erodible soils: *3,156*
- High Soil Erosion Potential: 68%
- Shallow Landslide Potential: *See DEQ*
- Landslide Deposits: *Limited areas throughout watershed* includes earth and debris slides, slumps, falls, and complex landslide types. (Does not include rock material landslide deposits).
- Well Protection Area: *0.51 sq mi*

Excellent maps are available in DEQ's Updated Water Source Assessment (April 2018).

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Country View MH Estates Drinking Water Source Area by DEQ in June 2018:

- Previous HAB Advisory
- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Algae and aquatic weeds, pH, dissolved oxygen
- OHA DWS sampling location for cyanobacteria toxin (2011-2017)
- Waters of potential concern for HAB

Tiller Elementary, SD #15 (PWS 4192139)

Source: South Umpqua River

Serves: 60 people

DEQ Source Water Assessment Summary 2003 (excerpts):

RISKS FOR THE SYSTEM:

A total of eighteen potential contaminant sources were identified in Tiller Elementary's drinking water protection area. Sixteen of these are located in the sensitive areas and twelve are high-to-moderate risk sources within "sensitive areas". *The sensitive areas within the Tiller Elementary drinking water protection area include areas with high soil permeability, high soil erosion potential, high runoff potential and areas within 1000' from the river/streams. The sensitive areas are those where the potential contamination sources, if present, have a greater potential to impact the water supply.*

City of Glendale (PWS 4100323)

Source: South Umpqua Subbasin: Cow Creek (permanent), Mill Creek (emergency), Section Creek (emergency)

Douglas County

Serves 872 people

2003 Source Water Assessment (excerpts):

The drinking water for the City of Glendale is supplied by three intakes located on Cow Creek, Mill Creek and Section Creek.

RISKS FOR THE SYSTEM:

A total of 45 potential contaminant sources were identified in City of Glendale’s drinking water protection area. All of these are located in the sensitive areas and 40 are high-to- moderate risk sources within “sensitive areas”. *The sensitive areas within the City of Glendale drinking water protection area include areas with high soil permeability, high soil erosion potential, high runoff potential and areas within 1000’ from the river/streams. The sensitive areas are those where the potential contamination sources, if present, have a greater potential to impact the water supply.*

Potential Harmful Algae Bloom (HAB) risk criteria/factors identified in Glendale’s Drinking Water Source Area by DEQ in June 2018:

- DEQ Water Quality Limited Listing indicating the waterbody needs TMDL for Dissolved Oxygen

Additional Threats to Drinking Water

Applications of herbicides, including picloram, to clear and maintain a right-of-way free of vegetation on and near the pipeline route increase risks to safe drinking water.

Picloram, in particular, is quite persistent in the environment. According to the EPA:³⁹³

- Picloram has a high potential to contaminate surface water by runoff from use areas.
- Picloram is highly soluble in water, resistant to biotic and abiotic degradation processes, and mobile under both laboratory and field conditions. It is stable to hydrolysis and anaerobic degradation, and degrades very slowly with half-lives ranging from 167 to 513 days.
- Eventual contamination of groundwater is virtually certain in areas where picloram residues persist in the overlying soil. Once in groundwater, picloram is unlikely to degrade, even over a period of several years.

³⁹³ (U.S. Environmental Protection Agency, 1995)