King County Comprehensive Plan
Workplan Action 20: Fossil Fuel Risk Bonds Report

June 30, 2022

King County

I. Contents

II. Workplan Text

This report responds to the 2020 update to the 2016 King County Comprehensive Plan, Ordinance 19146, Attachment A, Workplan Action 20: Fossil Fuel Risk Bonds.[1]

Action 20: Fossil Fuel Facilities Risk Bonds. As part of the 2020 Comprehensive Plan update, policies and regulations related to fossil fuel facilities were adopted. More work is needed to address the potential impacts of fossil fuels and fossil fuel facilities and related uses on the environment and human health. To accomplish this, this Workplan Action item directs:

A. Preparation of a Fossil Fuel Risk Bond evaluation, that will include, at a minimum:

1. An economic risk assessment of fossil fuel facilities and related uses, and climate change. The assessment shall include recommended policy language or development regulations that directs an update to this evaluation on a periodic basis when significant new information is available, and shall quantify the expected annualized costs to County finances, the County's economy, and County households over the next fifty years associated with several categories of risks:

   a. For fossil fuel facilities and related uses, the assessment shall address risks associated with catastrophic explosions of storage and transfer facilities, refineries, oil and gas train derailments, gas pipeline ruptures and explosions, fuel tanker spills and explosions, pollution of air and water, brownfields, and abandoned infrastructure.

   b. For climate change, the assessment shall address economic risks associated with changes in the frequency and severity of wildfires, floods, storms, drought, infestations of exotic diseases and pests, and other natural hazards. The assessment shall also address costs associated with the implementation of climate action policies and plans, as well as investing in adaptation measures.

2. An evaluation of the adequacy of existing financial assurance mechanisms in reducing the County's economic and financial risks associated with fossil fuel facilities and related uses, and climate change. Title 27A of the King County Code, "Financial Guarantees" already contains mechanisms for obtaining financial assurances before attempting potentially dangerous development activity. However, there is currently no language in Title 27A that requires financial assurances specifically for fossil fuel facilities and related uses. Such measures could include surety and performance bonds, letters of credit, third party trust funds, insurance, corporate guarantees, and others. The evaluation shall compare risk exposure for the County, with the maximum likely coverage of that risk by these mechanisms, and shall include recommendations for additional financial assurances or other measures that need to be adopted to minimize risks.

B. Drafting and transmittal of any necessary legislation that establishes or modifies Comprehensive Plan policies and development regulations, that will implement the recommendations of the Fossil Fuel Risk Bond evaluation.

- *Timeline:* The Fossil Fuel Risk Bond evaluation and any necessary legislation making Comprehensive Plan and/or King County Code changes shall be transmitted to the Council for consideration by June 30, 2022.

[1] Ordinance 19146, Attachment A. [LINK]. Page 12-25 .

- *Outcomes:* The Executive shall file with the Council the Fossil Fuel Risk Bond evaluation and, if warranted, a proposed ordinance(s) with recommended code and/or policy updates.
- *Leads:* Office of Performance, Strategy and Budget, Department of Natural Resources and Parks, and Department of Local Services - Permitting Division.

III. Executive Summary

This report broadly defines fossil fuel risk bonds and their intent; identifies what types of fossil fuel facilities can be developed in unincorporated King County under its permitting jurisdiction; conducts a high-level economic risk assessment of these fossil fuel facilities; discusses climate change costs; and concludes with recommendations for King County action.

FFRBs are financial assurance mechanisms that ensure the negative impacts of fossil-fuel facility development or operation is borne by the owner or operator of the facility and not transferred to public agencies or the public at large. They are not limited to bonds but include a broad range of mechanisms that can provide this fiscal protection, including surety and performance bonds, letters of credit, third party trust funds, insurance, and corporate guarantees. As the term "bond" in FFRBs has caused some confusion, the report limits the use of the term "FFRBs," and focuses on the broader context of "financial assurance mechanisms" instead.

Although there are many fossil-fuel operations to which financial assurance mechanisms might apply, the facility types that can be constructed in unincorporated King County and fall under King County's permitting jurisdiction – barring changes to the current state or federal regulatory structure – are relatively few. The following fossil fuel facilities meet these criteria and are viable to evaluate for financial assurance mechanisms applications in unincorporated King County, namely a(n):

- Thermal (gas) electric power plant
- Liquefied natural gas (LNG) plant
- Oil terminal

The report evaluates the potential impacts of these facilities in terms of explosions, air and water pollution, brownfields, and oil spills. Impacts associated with pipelines, train derailments, and fuel tanker spills are not evaluated extensively as these facilities or incidents fall outside King County's permitting jurisdiction or incident control (see Appendix B).

Of the potential evaluated risks, the analysis found sufficient evidence of past high-cost incidents to propose requiring proof of adequate financial coverage for explosions from any of the three types of facilities that could be built in unincorporated King County and fall under its permitting jurisdiction. Since 2004, there have been at least four explosions worldwide with costs exceeding $1 billion in damages and repair in facilities producing or storing LNG and oil.[2,3,4,5] Similarly, while thermal energy plant explosions are rare, natural gas incidents overall are more common. One of these explosions, at an oil facility, was in the U.S. with listed costs of $1.5 billion.[6] Separately, a 2019 explosion at an oil refinery

[2] U.S. Chemical Safety and Hazard Investigation Board (CSB), "Final Investigation Report: Caribbean Petroleum Tank Terminal Explosion and Multiple Tank Fires," Report No. 2010.02.I. PR, October, 2015. [LINK]. Accessed 10/12/2021. Page 95.

[3] Ghanmi, Lamine, "Algeria halts production at gas complex hit by blasts and fire," the Arab Weekly, April 7, 2019. [LINK]. Accessed 10/12/2021.

[4] CSB, "Final Investigation Report: Refinery Explosion and Fire," Report No. 2005-04-I-TX, March 2007. [LINK]. Accessed 5/21/2022. Page 17.

[5] Parraga, Marianna, "Chronology: Pump collapse, leak caused Venezuela refinery blast," Reuters, September 9, 2013. [LINK]. Accessed 10/6/2021.

[6] CSB, Report No. 2005-04-I-TX, ibid. Page 17.

resulted in costs of $750 million and both bankruptcy and closure of the refinery.[7,8] Explosions can occur at both new and existing facilities, typically from operator error or aging assets.[9] Also, although many of these facilities are developed or operated by businesses with significant financial assets, it is not guaranteed that every company that might develop such facilities will have the ability to pay the full costs that might be incurred from a potential explosion. Were such an explosion to occur locally, potential cost impacts range from $34.6 million to $2.18 billion; averaging these over 50 years, costs would range from $690,000 to $43.6 million annually (for more on costs related to explosions, see report section A.1.a and Appendix D).

Research on LNG plants and oil terminals found sufficient evidence of potential impacts associated with site contamination that could lead to the creation of new brownfield impacts, especially in cases of fossil fuel facility bankruptcy and subsequent closure and abandonment. LNG plants primarily handle materials that would evaporate as gases and not result in residual soil impacts. However, other substances that could be handled onsite could result in contamination impacts if spilled, including aqueous ammonia, hexane, isopentane, pentane, diesel, and oils. Oil terminals have the potential for contamination from spills; the largest potential contaminant of concern would be petroleum products. Although brownfield liability remains with the property owner, if a property owner enters bankruptcy and abandons the facility, either state or local assumption of remediation could result in public cost impacts. An average estimate of this potential cost based on industrial cleanup activities is roughly $3 million for one site cleanup; over 50 years, it would average $60,000 annually in costs.[10]

The assessed fossil fuel facilities can result in other negative community impacts surrounding a development site beyond explosions or brownfields, including nitrogen oxide (NOx) or mercaptan air pollution; NOx deposition in waterways or thermal wastewater impacts; or oil spills. Requiring proof of financial coverage to address these impacts is not recommended at this time for one or multiple reasons, described in the report and summarized below, including:

- Technology to mitigate the impacts may be available and could potentially be required through the State Environmental Policy Act;
- There may be multiple contributors to some types of pollutants beyond a fossil fuel facility, and accurately defining how to assess impacts and require cost-coverage would be logistically and potentially legally challenging at this time; or
- There may be other regulatory mechanisms in place already requiring adequate fiscal coverage.

While not applicable for long-term pollution issues, when mitigating for specific incidents or environmental releases, the costs of these impacts are unlikely to exceed the cost-coverage required for a facility explosion given the higher costs associated with explosions (reviewed on the previous page).

Local governments seeking to require financial assurances against the risk of fossil fuel explosion can build on the existing frameworks of federal and state regulations that require financial assurances

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[7] Marsh JLT Specialty, "100 Largest Losses in the Hydrocarbon Industry 1974-2019," March 2020. [LINK]. Accessed 11/24/2021. Page 26 (pdf 28).

[8] Maykuth, Andrew, "Bankrupt Philadelphia Energy Solutions blames 'mislabeled' pipe for big blast that led to refinery's closure," Philadelphia Inquirer, March 3, 2021. [LINK]. Accessed 12/29/2021.

[9] Marsh JLT Specialty, "100 Largest Losses…," ibid. [LINK]. Accessed 12/2/2021.

[10] Wilson, B.H. et al., "Remediation of Petroleum-Contaminated Sites," Presented at NGWA Remediation Conference, New Orleans, LA, November 30, 2004. [LINK]. Value conversions used BLS, "CPI Inflation Calculator." [LINK]. Accessed 2/1/2022.

against oil spills. Rather than requiring a specific type of financial mechanism, such as a bond or insurance coverage, oil spill regulations allow a variety of financial mechanisms to be used and combined – so long as the total coverage provided is adequate to cover a "worst-case" spill. Based on research conducted for this report, it is recommended that requiring financial assurance to cover a fossil fuel facility explosion be modeled on the oil spill financial assurance model established in federal and state regulation, allowing multiple financial assurance mechanisms. Research conducted for this report did identify past issues with self-bonding in the fossil fuel industry when facilities undergo bankruptcy filings. Accordingly, it is recommended that self-bonding not be accepted as a financial assurance mechanism to cover identified financial risks associated with potential explosion or site contamination.

Existing County code does not currently require financial assurances to address explosion costs from fossil fuel facilities. Research conducted for this report identified legislative models at the state and federal level for requiring financial assurances against fossil fuel facility impacts. These models are generally agnostic as to the form of financial mechanism provided. However, research conducted for this report found multiple types of financial coverage that could be provided by a fossil fuel facility to address facility impacts, including insurance, worker's compensation, bonds, letters of credit, third-party trust funds, and corporate guarantees (for more information see Appendix F).

Another FFRB option would be to develop a natural hazard risk fund that receives an assessed surcharge on large industrial facility operations against wider pollutant impacts, such as on greenhouse gases (GHGs) against the projected costs of climate change and its associated hazards, for example. However, Washington recently passed legislation that would pre-empt pursuit of an FFRB-natural hazard risk fund for climate change for large emitters. Specifically, the Climate Commitment Act (CCA) contains two features that affect consideration of establishing a natural hazard risk fund, namely that the CCA:

- Creates a cap-and-trade system to regulate the largest GHG-emitting entities in the state starting in 2023, and that will regulate 75 percent of Washington state GHG emissions.[11,12]
- Disallows local permitting agencies from requiring additional GHG mitigation from covered entities if they comply with the CCA.[13]

For these reasons, developing a FFRB natural hazard risk fund is not recommended.

Report development did not include a comprehensive climate change cost analysis over the next 50 years to King County and households within the County. Estimating this cost would be a formidable undertaking, requiring a range of skills and careful evaluation of many variables in both the natural and built environment; a defensible estimate would require an external consultant group. Attempting such an evaluation without appropriate time and consideration could also yield a figure that is inaccurate or extremely understated (i.e., too low), weakening a future pursuit to hold large emitters accountable for climate change impacts, should the County ever pursue such a course of action. Additionally,

[11] WA Legislature, "Final Bill Report E2SSB 5126," Ibid. [LINK]. Pages 1, 6. Also see, "Session Law. Certification of Enrollment: Engrossed Second Substitute Senate Bill 5126," Filed May 18, 2021. [LINK]. Accessed 6/15/2021. Page 24, Section 10 (a).

[12] Ecology, "Chapter 173-446 WAC – Climate Commitment Act Program Rulemaking," Presentation, November 8, 2021. [LINK]. Slide 11. Accessed 5/21/2022.

[13] Washington State Legislature, "Session Law. Certification of Enrollment: Engrossed Second Substitute Senate Bill 5126," Filed May 18, 2021. [LINK]. Accessed 5/21/2022. Page 54 (pdf page 55). For additional review of recent Washington State regulations affecting this issue, see the report generated under Comprehensive Plan Workplan Action 21: Greenhouse Gas Mitigation, transmitted to the County Council in June 2022, concurrent with this report.

Washington state has recently passed a range of statewide legislation that would affect pursuit of an FFRB-natural hazard risk fund to apply to large GHG-emitters against the cost of climate change, such as within the Climate Commitment Act; see the report generated under Comprehensive Plan Workplan Action 21: Greenhouse Gas Mitigation for discussion on such regulations. [14,15] However, this report does note that the City of Tacoma retained assistance to develop a high-level climate change cost assessment that included impacts to human life, infrastructure, and property. The assessment estimated that the cost of inaction would result in over $3 billion in damages by 2050.[16] Additionally, Appendix K provides a University of Washington Climate Impacts Group review of what factors should be considered in evaluating climate change cost impacts.

This report concludes with the recommendation that King County amend the King County Code to require that fossil fuel facility developments provide proof of adequate financial responsibility to cover the costs of a worst-case facility explosion and to cover costs from potential brownfield site contamination. This proof should be provided at application or prior to key permits for facility construction, reviewed every five years during operation, and be determined by a study of potential damages validated by a third party at the owner's expense. The costs should include potential damages that could result to structures, the natural environment and public infrastructure, as well as the potential loss of life and injury to persons onsite and to members of the public. In keeping with the model established by state and federal oil spill regulation, the report recommends allowing fossil fuel facility developers to submit multiple types of fiscal mechanisms to cover potential explosion and site contamination costs, with the exclusion of self-bonding due to its insufficient coverage in cases of insolvency. As directed by Workplan Action 20, a proposed ordinance reflecting these recommendations has been transmitted by the Executive to the Council concurrent with this report.

[14] Washington State Legislature, "Session Law. Certification of Enrollment: Engrossed Second Substitute Senate Bill 5126," Filed May 18, 2021. [LINK]. Accessed 5/21/2022. Page 54 (pdf page 55). For additional review of recent Washington State regulations affecting this issue, see the report generated under Comprehensive Plan Workplan Action 21: Greenhouse Gas Mitigation, transmitted to the County Council in June 2022, concurrent with this report.

[15] Transmitted to the County Council in June 2022, concurrent with this report.

[16] City of Tacoma, "2030 Climate Action Plan - City of Tacoma," last updated December 2021. [LINK]. Accessed 5/21/2020. Page 16

IV. Background

Department Overview: The Department of Local Services (DLS) provides services to rural and urban unincorporated areas, including maintaining County roads and bridges, issuing permits, managing long-range community planning, and providing economic development support. The DLS Permitting Division provides land use planning services and development permitting review to the residents of rural and urban unincorporated King County. Permitting Division support services include green building public outreach; building and land use code review; and policy review to improve green building attainment.

The Department of Natural Resources and Parks (DNRP) supports sustainable, livable communities and a clean and healthy natural environment. It works to foster environmental stewardship and strengthen communities by providing regional parks; protecting the region's water, air, land and natural habitats; and reducing, safely disposing of and creating resources from wastewater and solid waste.

The Regional Planning Section within the Office of Performance, Strategy and Budget (PSB) is responsible for coordinating updates to the King County Comprehensive Plan, Countywide Planning Policies, and VISION 2050. It coordinates the County's participation in the Growth Management Planning Council and other regional bodies. Regional Planning also provides growth forecasting and demographics services to County departments and the region and supports and facilitates annexations of remaining urban unincorporated areas to cities.

Key Historical Context: King County Code (K.C.C.) currently restricts the geographic areas (or "zones") where fossil fuel facilities may be developed. These facilities (such as an LNG plant or oil terminal discussed in this section) may be built in industrially zoned areas as a special use if located on properties within the Urban Growth Area (UGA).[17]

However, zoning restrictions apply differently to thermal electric power plants in unincorporated King County. The K.C.C. fossil fuel facility definition does not include a non-hydroelectric generation facility, which is defined as, "an establishment for the generation of electricity by nuclear reaction, burning fossil fuels or other electricity generation methods, excluding renewable energy."[18,19] Such facilities may be built in any zone under a special or conditional use permit with varying restrictions.[20] For potentially viable facilities reviewed in this section, only thermal electric power plants would fall under the definition of non-hydroelectric generation facility and therefore could be built in non-industrial zones or in zones outside the UGA. Where the term "fossil fuel facility" is used in this report, it refers broadly to facilities that make use of fossil fuels (and includes thermal (gas) electric power plants, liquefied natural gas (LNG) plants, and oil terminals), rather than its K.C.C. definition.

Key Current Context: This report is guided by multiple King County planning documents and policies, including the:

- 2020 King County Strategic Climate Action Plan (SCAP), is a five-year blueprint for County climate action, integrating climate change into all areas of County operations and guiding work with King County cities, partners, communities, and residents. SCAP Priority Action GHG 3.8.3

[17] See King County Code (K.C.C.) 21A.08.100.A. Regional land uses, and B. 15 under Development Conditions. [LINK]. Accessed 12/1/2021.
[18] K.C.C. 21A.06.532. [LINK]. Accessed 12/1/21.
[19] K.C.C. 21A.06.805. [LINK]. Accessed 12/1/21.
[20] K.C.C. 21A.08.100.A. Regional land uses. [LINK]. Accessed 12/1/2021.

commits the County to partner with other interested parties on the countywide commitment to clean energy resources, striving to phase-out fossil fuel use.[21]

- King County Equity and Social Justice Strategic Plan is a six-year blueprint that guides the County's pro-equity policy direction, decision-making, planning, operations, services, and workplace practices to advance equity and social justice within County government and in partnership with communities. This plan prioritizes public health, with a focus on addressing disproportionate health impacts for Black, Indigenous, and People of Color (BIPOC) communities.[22]
- King County Comprehensive Plan (KCCP), is the long-range guiding policy document for all land use and development regulations in unincorporated King County, and for regional services throughout the County including transit, sewers, parks, trails, and open space. Multiple related policies are referenced in the KCCP including:[23]
    - F-344b "King County should advocate for environmental reviews of proposed oil terminals and other related fossil fuel facilities in Washington State to assess and mitigate for area-wide, cumulative risks and impacts to public safety…"
    - F-344d "King County land use policies, development regulations, and permitting and environmental review processes related to fossil fuel facilities shall be designed to: a. protect public health, safety, and welfare; b. mitigate and prepare for disasters; c. protect and preserve natural systems; d. manage impacts on public services and infrastructure…"
    - F-344e "King County shall thoroughly review the full scope of potential impacts of proposals for new, modified, or expanded fossil fuel facilities…"
    - F-344h "King County shall establish a periodic review process for fossil fuel facilities…"

In addition to the existing policy context and direction outlined above, King County evaluates and assesses the regulation and impacts of fossil fuel use in unincorporated King County. These efforts include:

- 2020 Comprehensive Plan Update Workplan items, such Action 21: Greenhouse Gas Mitigation.[24]
- Participating in rulemaking activities for state regulations, including current rulemaking for the Washington state Climate Commitment Act (CCA), and Governors Directive 19-18 Greenhouse Gas Assessment for Projects (GAP).[25]

Report Methodology: Report development was supported and guided by a King County workgroup formed of members from the King County Executive Office, PSB, DNRP, the Prosecuting Attorney's Office (PAO), and DLS. The PAO has reviewed and provided guidance on this report. Additional report research and development was led by DLS, with support by PSB and DNRP. Report recommendations were supported by all entities of the workgroup.

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[21] King County, "2020 Strategic Climate Action Plan," May 2021. [LINK]. Accessed 1/18/2022. Page 102.

[22] King County, "Equity and Social Justice Strategic Plan, 2016-2022." [LINK]. Accessed 1/18/2022. Page 31 (pdf page 33).

[23] King County, "2016 King County Comprehensive Plan," Updated July 24, 2020. [LINK]. Accessed 1/18/2022. Pages 9-54 through 9-57 (pdf pages 488 through 491).

[24] Transmitted to the County Council in June 2022, concurrent with this report.

[25] See Washington state Climate Commitment Act. [LINK]; Greenhouse Gas Assessment for Projects Rule [LINK]. Accessed 5/21/2022.

The workgroup also retained the services of the University of Washington Climate Impacts Group (UW CIG) advising on the factors local governments should consider when evaluating the costs of climate change, as there is little research on how to apply this topic in the context of local jurisdictions such as counties and cities. The UW CIG product, "Understanding the Cost of Climate Change: A Guide for Local Actors" is included in Appendix K.

Notably, research conducted for this report did not identify many scholarly articles on the topic of Fossil Fuel Risk Bonds (FFRBs). FFRBs are a relatively new concept pioneered by a 2016 paper by Dr. John Talberth and Daphne Wysham at the Center for Sustainable Economy.[26] Consequently, research for this document focused on reports and data from government agencies, professional organizations, and nonprofits; communication with various government agencies; and review of past King County documentation. Specifically, King County documentation includes review of the 2018 Fossil Fuels and Facilities Study conducted in support of the 2020 Comprehensive Plan Update.[27] Draft report materials and draft proposed legislation topics were also reviewed with local communities and nonprofits as noted in Appendix J. Report and proposed legislation development were also reviewed for equity impacts (for more information see report section V.B. Legislation that implements the recommendations of the Fossil Fuel Risk Bond evaluation). Acronyms used throughout this report are listed in Appendix A.

[26] Talberth, John and Daphne Wysham. "Fossil Fuel Risk Bonds," May 2016. [LINK] Accessed 1/22/21.

[27] King County, "Fossil Fuels and Facilities Study: In response to Ordinance 18866 and Comprehensive Plan Scoping Motion 15329," 2019-RPT0109, July 26, 2019. [LINK]. Accessed 12/16/21.

V. Report Requirements

This report section is organized to address direction called for in Comprehensive Plan Workplan Action 20: Fossil Fuel Facilities Risk Bonds (FFRBs). The report broadly defines FFRBs and other financial assurance mechanisms; identifies what types of fossil fuel facilities can be developed in unincorporated King County under its permitting jurisdiction; conducts a high-level economic risk assessment of fossil fuel facilities; discusses climate change costs; and concludes with recommendations for King County action. The following items are reviewed in this section:

A. Fossil Fuel Risk Bond evaluation
    1. Economic Risk Assessment of Fossil Fuel Facilities and Related Uses, and Climate Change
        a. Economic Risk Assessment for Fossil Fuel Facilities and Related Uses
        b. Economic Risk Assessment for Climate Change
    2. Evaluation of the Adequacy of Existing Financial Assurance Mechanisms
B. Legislation that Implements the Recommendations of the Fossil Fuel Risk Bond Evaluation

A. Fossil Fuel Risk Bond Evaluation

A primary objective of this report is evaluating the adequacy of existing financial assurance mechanisms in reducing the County's financial risk from fossil fuel facility development in unincorporated King County and, if warranted, recommend additional measures to minimize risk. This effort was initiated to evaluate financial assurance mechanisms under the umbrella term "fossil fuel risk bonds."

The phrase FFRBs can be misleading. Although "bonds" is included in this phrase, FFRBs are not limited to bonds. Publications by Dr. John Talberth and Daphne Wysham at the Center for Sustainable Economy groups FFRBs into two categories:

1. Conventional financial assurance or financial coverage mechanisms: Instruments that provide financial backing, such as insurance or bonds, for specific fossil-fuel based facilities and the associated risks of infrastructure failure.[28]
2. Climate or natural hazard risk funds: A surcharge-based fund to address the pervasive risks from climate change and its associated hazards. This mechanism form accounts for the multiple entities that contribute climate change pollutants.[29]

A majority of this report focuses on evaluating County risk and needs associated with conventional financial coverage mechanisms (climate or natural hazard risk funds are addressed towards the end of the report – see report section V.A.1.b.) The embedded use of the term "bond" in FFRBs has caused some confusion in the application of this research, as the range of financial assurances included under the term of FFRBs extends beyond bonds (for example, it can refer to insurance, letters of credit, etc.). Therefore, this report limits the use of the term "FFRBs," and focuses on the broader context of "financial assurance mechanisms" instead. Broadly speaking, FFRBs refers to multiple types of financial assurance mechanisms retained specifically against the increased risks from fossil fuel facilities; when FFRBs are referred to in this report, this is the context in which such references should be interpreted.

[28] The terms "financial assurance" and "financial coverage" are used interchangeably in this report. "Financial coverage" is used more to describe these mechanisms in the report's executive summary, as this is the more common or layman way to refer to these mechanisms (i.e., insurance and bonds). "Financial assurance" is used more in the technical review or body of this report, as it is the more common term used in academic assessments and among statutes reviewed in research conducted for this report.

[29] Talberth, John and Daphne Wysham. "Fossil Fuel Risk Bonds," May 2016. [LINK] Pg. 8. Accessed 1/22/21.

1. Economic Risk Assessment of Fossil Fuel Facilities and Related Uses, and Climate Change

Research for this report revealed a wide array of discrete fossil-fuel operations to which FFRBs might apply, and a wide range of regulations and fiscal assurances for each type of operation. However, not each of these fossil fuel operations occurs within King County and, barring changes to the current state or federal regulatory structure, many will not be developed in unincorporated King County under the County's permitting jurisdiction as reviewed in this section and Appendix B.[30]

The permitting authority for some projects may fall to the Washington state Energy Facility Site Evaluation Council (EFSEC). The EFSEC was created in 1970 to provide a "one stop" siting and permitting agency for large energy projects, centralizing large energy facility evaluation and oversight within one state agency.[31] Once a facility is sited through the EFSEC and obtains a Site Certification Agreement, then the EFSEC becomes the issuing agency for any state or local facility permits, pre-empting King County permitting jurisdiction.[32] The EFSEC oversees the siting of thermal electric power plants that are 350 megawatts or greater, new oil refineries or large existing facility expansions, and underground natural gas storage fields. For facilities under its jurisdiction, EFSEC has been delegated authority by the United States Environmental Protection Agency (U.S. EPA) to issue permits under the Federal Water Pollution Control Act and the Federal Clean Air.[33] The ESFEC responsibilities are listed in the Revised Code of Washington (RCW) Chapter 80.50.[34] A full listing of fossil fuel projects falling under EFSEC jurisdiction can be found on the ESFEC's certification process page.[35]

Research conducted for this report identified King County's permitting authority. For example, based on state regulation such as EFSEC authority (reviewed above) and federal limitations reviewed in Appendix B, several types of facilities either cannot be built within unincorporated King County or, if built, they would not be under the jurisdiction or permitting authority of King County. In the instances where such facilities would not be under the jurisdiction of the County, the County would be unable to require additional financial assurances from the developers of those facilities. Such facilities include coal mines, oil refineries, underground natural gas or propane storage, hydraulic fracturing (fracking) wells, crude oil transport by oil tanker or rail, and natural gas pipelines. The circumstances and regulation limiting King County permitting authority for these facilities varies depending on facility type. See Appendix B for examples and discussion of these facilities.

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[30] The state Energy Facility Site Evaluation Council (EFSEC) is the designated permitting authority for several types of fossil fuel projects, as reviewed in this section; changes to state law would be required for King County to have permitting authority for projects currently designated for EFSEC review projects. Similarly, varying federal laws bar local government regulation of some types of fossil fuel facilities, such as the Pipeline Safety Act and commerce clause applications for natural gas pipelines; these federal laws would have to be altered in order for local governments to require additional financial assurances from pipeline developers, for example (see 49 USC 60102 [LINK]; U.S. Constitution, Article I, Section 8, Clause 3. [LINK]. Accessed 4/29/2022). For more information see Appendix B.

[31] Washington State EFSEC, "Washington State EFSEC, "Certification Process," 2019. [LINK]. Accessed 5/21/2022.

[32] Ami Kidder, EFSEC Siting and Compliance Manager, Washington State Utilities Transportation Commission, email with author on 6/29/2021.

[33] Washington State EFSEC, "About EFSEC," September 19, 2019. [LINK]. Accessed 12/1/2021.

[34] Revised Code of Washington Chapter 80.50 [LINK]. Accessed 5/21/2022.

[35] Energy Facility Site Evaluation Council (EFSEC), "Energy Facilities," last updated September 19, 2019. [LINK]. Accessed 5/21/2022.

Rather than reviewing all fiscal assurance mechanisms applicable to all fossil fuel facilities, this report narrows the field of inquiry by clarifying which types of fossil fuel facilities exist, or are likely to be proposed for development, within King County that would also fall under its permitting jurisdiction. Research conducted for this report indicates that the following fossil fuel facilities meet these criteria, and are viable to evaluate for FFRB applications:

- Thermal (gas) electric power plant
- Liquefied natural gas (LNG) plant
- Oil terminal

The following subsections provide background on each of the types of fossil fuel facilities that can be developed in unincorporated King County and provides context for how these facilities may fall under its permitting jurisdiction.

Thermal (Gas) Electric Power Plant

A thermal (gas) power plant is a facility that burns natural gas to heat water and create water vapor to drive a steam turbine, which in turn generates electricity.[36] Puget Sound Energy (PSE) and Seattle City Light (SCL), the only utilities providing electricity services within King County, do not have fossil-based power generation facilities sited within unincorporated King County.

- SCL does not have fossil-based power generation facilities in its power supply portfolio.[37]
- PSE owns fossil-based power generation facilities, but these are all located outside King County. This includes PSE's partial ownership of the Colstrip generating plant in Montana, as well as nine natural gas-fired power (also called thermal energy) plants in Whatcom, Pierce, Cowlitz, and Klickitat counties.[38]

If a new thermal electric power plant were proposed in unincorporated King County, the County would potentially have permitting jurisdiction depending on the size of the proposed facility. The EFSEC has siting control for thermal electric power plants 350 megawatts (MW) or greater in size.[39] However, since none of PSE's existing thermal energy plants to date exceed this threshold, it is possible that a new plant could be proposed that would fall under King County jurisdiction. PSE's current thermal electric power plants and their generating capacities are listed in Table 1.

Table 1. PSE Thermal Plants and Generating Capacity[40]

Name	County	Notes	Built	Size (MW = megawatt)
Encogen	Whatcom	Acquired in 1999	1993	165 MW[41]
Ferndale	Whatcom	Acquired in 2012	1994	270 MW[42]
Frederickson	Pierce	*Acquisition year not provided*	1981	147 MW[43]

[36] Afework, Bethel, et. al., "Natural gas power plant," University of Calgary, Energy Education, February 24, 2019. [LINK]. Accessed 4/27/2022.
[37] Seattle City Light (SCL), "Media Information," [LINK]. Accessed 4/22/2021.
[38] Puget Sound Energy (PSE), "Thermal Power." [LINK]. Accessed 4/21/2021.
[39] Energy Facility Site Evaluation Council (EFSEC), "About EFSEC," last updated September 19, 2019. [LINK]. Accessed 11/30/2021.
[40] PSE, "Thermal Power." Ibid.
[41] PSE, "Encogen Generating Station." [LINK]. Accessed 6/30/2021.
[42] PSE, "Ferndale Generating Station." [LINK]. Accessed 6/30/2021.
[43] PSE, "Frederickson Generating Stations." [LINK]. Accessed 6/30/2021.

Name	County	Notes	Built	Size (MW = megawatt)
Frederickson One	Pierce	Acquired 49.85% in 2004	2002	275 MW[44]
Fredonia	Skagit	Four generating units	1980s; 2001	316 MW[45]
Goldendale	Klickitat	Acquired in 2007	2004	277 MW[46]
Mint Farm	Cowlitz	*Acquisition year not provided*	2008	310 MW[47]
Sumas	Whatcom	*Acquisition year not provided*	1993	125 MW[48]
Whitehorn	Whatcom	Two units updated 2006, 2008	1981	147 MW[49]

Liquefied Natural Gas (LNG) Plant

LNG plants, also called LNG facilities, are not uniform in type or size. Broadly, an LNG plant is a facility that can cool and store (or thereafter thaw) gaseous methane into a condensed liquid state, shrinking its volume by 600 times and enabling reduced storage space and easier transport.[50] Facilities are typically focused on either cooling, storage, and transport (exporting LNG either locally or internationally) or receiving LNG to store or thaw back to a gaseous state and transport (importing). Most of the research in this report focuses on exporting LNG facilities, but the topics discussed could apply to either import or export facility types. Facility size is affected by the amount of LNG proposed for processing. A currently proposed LNG plant in the City of Tacoma, for example, would "produce approximately 250,000 to 500,000 gallons LNG daily, and store up to 8 million gallons of LNG on site."[51] The proposed location is on two parcels totaling roughly 33 acres in size.[52]

If an LNG plant were proposed for development it would fall under the K.C.C. definition of a fossil fuel facility, and hence would be an allowed use within unincorporated King County and trigger the need for permits from the County. The currently-proposed LNG plant in the City of Tacoma is again a useful example – the project's Final Environmental Impact Statement (FEIS) lists the federal, state, and local permits and approvals required of the project. This FEIS listing includes that the City of Tacoma is the State Environmental Policy Act (SEPA) lead agency, and is also responsible for issuing Shoreline, Wetland, Floodplain Development, Clear and Grade, and Building permits for the project, among others.[53]

Although the above review indicates that the County could have some permitting jurisdiction if a new LNG plant were proposed in unincorporated King County, in some cases the state could assume

[44] PSE, "Frederickson Generating Stations." [LINK]. Accessed 6/30/2021.
[45] PSE, "Fredonia Generating Station." [LINK]. Accessed 6/30/2021.
[46] PSE, "Goldendale Generating Station." [LINK]. Accessed 6/30/2021.
[47] PSE, "Mint Farm Generating Station." [LINK]. Accessed 6/30/2021.
[48] PSE, "Sumas Generating Station." [LINK]. Accessed 6/30/2021.
[49] PSE, "Whitehorn Generating Station." [LINK]. Accessed 6/30/2021.
[50] Cook-Clarke, William, et. al, "Liquefied Natural Gas," University of Calgary, Energy Education, February 24 ,2019. [LINK]. Accessed 4/27/2022.
[51] Ecology and Environment, Inc. "Puget Sound Energy Proposed Tacoma Liquefied Natural Gas Project Final Environmental Impact Statement," September 30, 2015. [LINK]. Accessed 4/27/22. Page I (pdf page 5).
[52] It appears previously separate parcels have been consolidated in this project. See Ecology and Environment, Inc. Ecology and Environment, Inc. "Puget Sound Energy Proposed Tacoma Liquefied…," Ibid. [LINK]. Accessed 11/30/21. Pages I, 2-23 (pdf pages 5, 71). Also, Pierce County, "Public GIS" tool, E 11th St. and Taylor Way, Parcels 5000350041 and 2275200532. [LINK]. Accessed 4/27/22.
[53] Ecology and Environment, Inc. Ecology and Environment, Inc. "Puget Sound Energy Proposed Tacoma Liquefied…," Ibid. [LINK]. Accessed 11/30/21. Page IV.

permitting authority. The Washington state EFSEC has siting control for facilities with the capacity to receive LNG in the equivalent of over 100 million standard cubic feet of natural gas per day.[54] Once a facility is sited through the EFSEC and obtains a Site Certification Agreement, then the EFSEC becomes the issuing agency for any state or local facility permits, pre-empting King County permitting jurisdiction.[55] The Tacoma LNG plant will, "produce 250,000 gallons of LNG a day. A storage tank at the plant would hold 8 million gallons of LNG."[56] These figures translate to a production of 33,500 cubic feet per day, with a storage tank capacity of roughly one million cubic feet.[57] Although it is questionable if the creation and storage of LNG onsite would be classified as "receiving LNG" such that EFSEC authority would apply, processing for the proposed Tacoma facility still falls significantly short of the volumes that would trigger potential EFSEC oversight. As such, if a similarly sized facility were proposed in unincorporated King County, and if it were of a type that fell under the K.C.C. fossil fuel facility definition and outside of EFSEC regulation, it would be within King County jurisdiction for similar permits as the proposed facility in the City of Tacoma.

Oil Terminals

Oil terminals, also called oil depots, are frequently developed in conjunction with an oil refinery – and development of oil refineries are unlikely to fall under King County permitting jurisdiction (see Appendix B).[58,59] There are also no existing oil refineries in unincorporated King County, but one could theoretically be developed in the future. As such, King County could potentially have permitting jurisdiction of an oil terminal that was proposed to be either:

- Added to an oil refinery developed previously as a separate project, if the oil terminal did not receive more than 50,000 barrels per day (which would trigger EFSEC review); or
- Developed as a stand-alone oil terminal, in which case EFSEC review does not apply.[60]

When an oil terminal is not connected to a refinery, it is typically developed as a marine oil terminal to transport oil to ships and tankers, and/or potentially connected to rail lines, such as Vancouver Energy's proposal for an oil terminal along the Columbia River that was rejected in 2018 by the EFSEC.[61,62,63] As there are industrially-zoned areas both along rail lines and along the Duwamish River within the UGA, such zoning could theoretically allow an oil terminal development within unincorporated King County that could fall under the County's permitting jurisdiction.

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[54] Revised Code of Washington (RCW) 80.50.020(12)(c). [LINK]. Accessed 11/30/21.

[55] Ami Kidder, EFSEC Siting and Compliance Manager, Washington State Utilities Transportation Commission, email with author on 6/29/2021.

[56] Ruud, Candice, "Tacoma LNG plant faces delay as clean air agency orders extra scrutiny," the News Tribune, January 25, 2018. [LINK]. Accessed 6/30/2021.

[57] One gallon of LNG is 0.134 cubic feet (250,000 x 0.134 = 33,500). See Energy Transfer, "Properties and Characteristics of LNG." [LINK]. Accessed 11/30/21. Page 2.

[58] IFC Inflow, "Oil Depots." [LINK]. Accessed 12/1/2021.

[59] Maritime Manual, "What Are Oil Terminals?" last updated August 7, 2021. [LINK]. Accessed 12/1/2021.

[60] Washington State EFSEC, "Certification Process," 2019. [LINK]. Accessed 12/1/2021.

[61] The Maine Department of Environmental Protection (MDEP) groups all marine-adjacent terminals under this heading, whether or not they are connected to processing or refining facilities. See MDEP, "Marine Oil Terminals." [LINK]. Accessed 12/1/2021.

[62] Maritime Manual, "What Are Oil Terminals?" ibid.

[63] Anderson, Rick, "How forces combined again in Washington state to reject yet another oil terminal," Los Angeles Times, February 4, 2018. [LINK]. Accessed 12/1/2021.

a. Economic Risk Assessment for Fossil Fuel Facilities and Related Uses

This section explores the range of costs and risks from fossil fuel facilities associated with:

i. Catastrophic explosions
ii. Pollution of air and water
iii. Brownfields and abandoned infrastructure
iv. Oil spills

This section considers each of the above risks for facilities that are both allowed uses in unincorporated King County and fall under King County permitting jurisdiction, namely an LNG plant, thermal electric power plant, and an oil terminal as outlined above. See Appendix B for rationales on fossil fuel facilities that were not analyzed.

The economic risks of a potential new fossil fuel facility would vary based on the nature of the fossil fuel facility proposal and its siting. Facility size, operations, proximity to homes and businesses and the future zoning potential of the surrounding landscape all influence the potential economic risks from fossil fuel facilities. Given the inherent limitations of exploring economic risks in the absence of these details, this section provides a high-level overview of the typical risks of various types of facilities, and factors influencing the potential range of cost impacts.

i. Catastrophic Explosions

This report section reviews the economic risk of explosions associated with a potential new fossil fuel facility proposal in unincorporated King County. This report does not review potential pipeline explosions. While there is a significant extent of pipeline in Washington state and within King County, the County does not have jurisdiction to regulate pipelines (see Appendix B).[64] This section provides a review of natural gas explosion events), as both LNG plants and thermal electric power plants are inherently dependent on natural gas for their operations. Oil terminals still pose explosion risks, as detailed in this section. Subsections also reviews contributing cost factors from an explosion and the range of those costs; modeling issues in risk projections; and that explosion incidents may occur at both new and aging facilities.

Reviewing the frequency of fossil fuel releases and explosions, and how they are tracked in the United States (U.S.), provides context for potential explosion risks – starting with natural gas. From 2001 to 2020 there were over 5,000 natural gas and LNG release "incidents" considered reportable within the U.S. These incidents resulted in 237 fatalities, over 1,000 hospitalizations and roughly $5.9 billion in costs, equating to 250 incidents, 11 fatalities, and 54 injuries annually in the U.S.[65] This statistic covers incidents from both industrial facilities and pipelines according to the below reporting requirements and does not cover incidents in residences or most businesses; other sources provide insight into some of these arenas, though this topic is outside the scope of this report.[66]

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[64] As of 2014, there were 1,895 miles State Gas Transmission pipelines, and 22,070 miles State Gas Distribution pipelines within Washington State. Source: Pipeline Safety Trust, "Local Government Guide to Pipelines," Washington State. 2014. [LINK] Accessed 4/16/2021. Page 57.

[65] Pipeline and Hazardous Materials Safety Administration (PHMSA), "All Reported Incident 20 Year Trend;" data derived by subtracting hazardous liquids from all incidents. [LINK]. Accessed 10/5/2021.

[66] The 2018 National Fire Protection Association report estimates that 4,200 home fires start with natural gas ignition per year, causing an average of 40 deaths annually, and local fire departments respond to 340 gas or LP-Gas leaks per day with no ignition. Source: National Fire Protection Association (NFPA), "Natural Gas and Propane Fires, Explosions and Leaks Estimates and Incident Descriptions," 2018. [LINK]. Accessed 10/6/2021. Page 1.

The U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA) tracks "incidents" of gas releases. The PHMSA defines an "incident" as a release of gas from a pipeline or an underground natural gas storage facility (UNGSF), or a release of liquefied natural gas (LNG), liquefied petroleum gas, refrigerant gas, or gas from an LNG facility, and that results in one or more of the following:

- A fatality, or personal injury necessitating overnight hospitalization;
- Property damage of $122,000 or more, excluding the cost of gas lost;
- Unintentional gas loss of three million cubic feet or more;
- An event resulting in an emergency shutdown of an LNG facility or a UNGSF; or
- An event that is significant in the judgment of the operator.[67, 68]

Some industry observers have argued this federal data collection method does not represent the true extent of danger that gas leaks represent (both as an explosive risk and otherwise) due to the makeup of reporting criteria.[69] A 2016 Sightline article reviewed potential flaws in this federal data collection process as it covered a 2014 LNG explosion at Plymouth LNG in Plymouth, Washington, 30 miles south of the Tri-Cities area.

> *"Shortly after 8:00 a.m. on March 31, 2014, gas processing equipment at Plymouth LNG exploded into a towering, mushroom-shaped cloud. Nearby residents saw flames shoot into the air, and people living three to six miles from the plant could feel the explosion. The blast sent 250 pounds of debris and shrapnel flying as far as 300 yards, damaging buildings and equipment and puncturing one of the large LNG storage tanks. Shrapnel injured four of the fourteen employees on duty, and a fifth worker was hospitalized for burns."*[70]

Although the explosion had 100 emergency responders on scene; caused nausea in people up to a quarter-mile away; and led to an evacuation within two miles of the facility due to an ongoing vapor leak that lasted over 24 hours, this accident was reported as "one injury," because only one of the injured workers required overnight hospitalization.[71] Additionally, because the LNG evaporated directly from equipment, and did not touch the ground prior to evaporation, it is not tracked as a "spill" of LNG, only an evaporation of gas.[72]

Despite data reporting overlaps with pipeline incidents, or potential gaps in reporting, PHMSA reporting helps contextualize the potential frequency and severity of incidents at different types of fossil fuel facilities. Research conducted for this report found that, of the facility types that could be constructed in

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[67] These criteria apply to what is commonly defined as "natural gas," as opposed to including "gasoline" or petroleum. While 49 CFR § 191.3 defines gas as, "natural gas, flammable gas, or gas which is toxic or corrosive" (which is not definitive), 49 CFR § 191.1 – Scope notes this federal code, "…prescribes requirements for the reporting of incidents… by operators of underground natural gas storage facilities and natural gas pipeline facilities…" See U.S. Code of Federal Regulations (U.S. CFR), Title 49, Subtitle B, Chapter 1, Subchapter B, Part 191. [LINK]. Accessed 10/5/2021.

[68] "Property damage of $122,000 or more, excluding the cost of gas" criteria was set at $50,000 until 2021, providing some historical variability in what incidents were reported. See PHMSA, "Pipeline Facility Incident Report Criteria History," January 11, 2021. [LINK]. Accessed 10/5/2021.

[69] Powell, Tarika, "How Industry and Regulators Kept Public in the Dark After 2014 LNG Explosion in Washington," February 8, 2016. [LINK]. Accessed 10/6/2021.

[70] Powell, Tarika, "How Industry…," ibid. [LINK]. Accessed 10/6/2021.

[71] Powell, Tarika, "How Industry…," ibid. [LINK]. Accessed 10/6/2021.

[72] Powell, Tarika, "How Industry…," ibid. [LINK]. Accessed 10/6/2021.

unincorporated King County and fall under its permitting authority, the primary facility connected with explosion concerns would be an LNG facility. This determination is due to gaseous product handling onsite and specific incidents listed in Table 2 following this narrative section. Explosions at oil terminals and thermal electric power plants are not as frequent but still occur; explosion risk at these facility types is discussed below:

- Oil terminal incidents are rare, but incidents at a similar facility type – oil refineries – are not. Research conducted for this report did not discern an option to select PHMSA incident reporting only related to oil terminals. However, a review of the U.S. Chemical Safety and Hazard Investigation Board (CSB) open and closed investigations revealed multiple oil refinery incidents of a comparatively serious nature (i.e., higher levels of fatalities and injuries; see Appendix C).[73] Some explosions occurred due to processes that might easily occur at oil terminals as well, such as overfilling tanks with gasoline.[74] Although an oil *refinery* would likely not be under King County jurisdiction if proposed in the unincorporated area (see Appendix B), an oil *terminal* may still fall under King County permitting jurisdiction. Similarly, an oil terminal could be located adjacent to a refinery (regardless of which jurisdiction originally permitted that refinery), potentially increasing the volume of volatile or explosive compounds were an incident to occur.[75]
- Thermal energy plant explosions are rare but have occurred. As recently as May 2021, an explosion occurred at the Russel City Energy Center combined-cycle facility in Hayward, California. This incident led to a one-mile evacuation around the plant and an estimated $100 million in damages.[76] Although the incident stemmed from the steam turbine, rather than one of the two gas turbines onsite, the natural gas fuels used onsite increased the potential for a large explosion.[77] Another natural gas explosion in 2021 occurred at a Corpus Christi, Texas, power plant, leaving one dead.[78] While natural gas explosion incidents specifically at thermal energy plants are rare, PHSMA reporting shows that natural gas incidents overall are relatively common; as such, these incidents are considered applicable to thermal energy power plants, based on research conducted for this report.[79]

Research conducted for this report indicates that an explosion from accumulated flammable vapors is one of the larger explosion dangers for LNG facilities, oil terminals, and thermal energy plants.[80] A vapor

[73] U.S. Chemical Safety and Hazard Investigation Board (CSB), "Investigations." [LINK]. Accessed 5/12/2020.

[74] For example, the Caribbean Petroleum Tank Terminal Explosion that damaged over 300 homes and businesses resulted from an overfilled gasoline tank. See: U.S. CSB, "CSB Releases Draft Investigation Report into 2009 Explosion and Fire at Caribbean Petroleum Terminal Facility in Puerto Rico; Report Finds Inadequate Management of Gasoline Storage Tank Overfill Hazard," June 11, 2015. [LINK]. Accessed 9/7/2021.

[75] AOC Petroleum Support Services LLC, "United States Fuel Resiliency, Volume I. U.S. Fuels Supply Infrastructure, Infrastructure Characterization: Final Report," Prepared for the Office of Energy Policy and Systems Analysis, U.S. DOE, September 2014. [LINK].. Accessed 10/8/2021. Page 64.

[76] City of Hayward, "Russel City Energy Center," last updated July 19,2021. [LINK]. Accessed 10/11/2021.

[77] City of Hayward, Ibid. [LINK]. Accessed 10/11/2021.

[78] Howley, Christopher, "Natural gas explosion leaves one person dead," Corpus Christi Caller Times, June 19, 2021. [LINK]. Accessed 10/11/2021.

[79] See "Serious Incident 20 Year Trend," which displays incident data related to incidents that "include a fatality or injury requiring in-patient hospitalization." Source: PHMSA, "Serious Incident 20 Year Trend;" data on gas distribution, gathering, and transmission system types. [LINK]. Accessed 6/2/2022.

[80] A 2009 congressional report on LNG facilities states, "…there appears to be consensus as to what the most serious hazards are…" and immediately explores two hazard categories, namely pool fires and flammable vapor

cloud explosion (VCE) can occur when flammable gas or vapor mixes with air and finds ignition, typically in a confined or congested area that condenses the gas to a combustible state.[81] Explosions can occur from substances naturally in a gaseous state, or from flammable vapors emitted by liquid compounds. Some of the larger recorded incidents at fossil fuel facilities stem from this type of explosion, with notable incidents in recent years catalogued in Table 2 below; selected examples are VCEs with high numbers of fatalities, injuries, high damage costs; explosions in Washington state are also included.

Table 2. Fossil Fuel Facility VCEs in the Last 20 Years (Since 2002)

Year, Place	Incident Description
2004, Algeria	The Skikda LNG facility experienced an LNG pipeline leak that ignited, resulting in one of the worst petrochemical plant fires in Algeria in 40 years.[82] The incident caused the deaths of 27 persons, injured 74 persons, and $1 billion to rebuild the facility.[83,84]
2005, Buncefield, England	Gasoline storage tank safeguards failed and petrol overflowed through roof vents, pooling and forming a vapor cloud. Forty minutes later the cloud ignited, with a blast that measured 2.4 on the Richter scale heard 125 miles away; 43 persons were injured. 20 storage tanks were engulfed in the fire, which took 180 firefighters four days to extinguish.[85] Companies were fined roughly $13.5 million, which the prosecution considered too lenient.[86] Total incident costs were estimated to be $1.5 billion.[87]
2005, Texas City, TX, U.S.	Safeguards on a component tower failed and was overfilled, resulting in spillage and vapor cloud creation.[88] This explosion at the British Petroleum (BP) America Refinery left 15 persons dead; injured another 180 persons; destroyed 13 trailers; damaged another 40 trailers and 70 vehicles; and damaged houses 0.75 miles away.[89,90] Financial losses exceeded $1.5 billion. Roughly 43,000 persons were ordered to shelter-in-place.[91] Subsequent incidents at the same facility cost $30 million in plant property damage; the facility has had 39 fatalities in its 32 years of operation as of

clouds. Source: Congressional Research Service (CRS), "Liquefied Natural Gas (LNG) Import Terminals: Siting, Safety, and Regulation," December 14, 2009. [LINK] Page 5. Accessed 10/11/2021.

[81] Kim, Seong Wook, "Vapor Cloud Explosion Modeling - Estimated Maximum Loss of Tank Farms," Gen Re reinsurance blog October 5, , 2016. [LINK]. Accessed 10/11/2021.

[82] Schoch, Deborah, "Blast Traced to LNG Leak," Los Angeles Times, February 23, 2004. [LINK]. Also, Romero, Simon, "Algerian Explosion Stirs Foes of U.S. Gas Projects," New York Times, February 12, 2004. [LINK]. Accessed 10/12/2021.

[83] Oil & Gas Journal Editors, "Algerian LNG complex explosion caused by gas pipeline leak," Oil & Gas Journal, February 18, 2004. [LINK]. Accessed 10/12/2021.

[84] Ghanmi, Lamine, "Algeria halts production at gas complex hit by blasts and fire," the Arab Weekly, April 7, 2019. [LINK]. Accessed 10/12/2021.

[85] BBC News, "How the Buncefield fire happened," July 16,2010. [LINK]. Accessed 10/12/2021.

[86] BBC News, "Firms ordered to pay almost £10m over Buncefield blast," July 16, 2010. [LINK]. Accessed 10/11/2021.

[87] CSB, "Final Investigation Report: Caribbean Petroleum Tank Terminal Explosion and Multiple Tank Fires," Report No. 2010.02.I. PR, October, 2015. [LINK]. Accessed 10/12/2021. Page 95.

[88] U.S. Chemical Safety and Hazard Investigation Board (CSB), "Final Investigation Report: Refinery Explosion and Fire," Report No. 2005-04-I-TX, March 2007. [LINK]. Accessed 10/12/2021. Page 21, 22.

[89] CSB, Report No. 2005-04-I-TX, ibid. [LINK]. Page 306.

[90] Lees, Frank, "Lees' Loss Prevention in the Process Industries," 4th Ed., August 17, 2012. [LINK]. Accessed 12/29/21. Page 3083.

[91] CSB, Report No. 2005-04-I-TX, ibid. [LINK]. Page 17.

Table 2. Fossil Fuel Facility VCEs in the Last 20 Years (Since 2002)

Year, Place	Incident Description
	2007.[92] In 2012, BP sold the refinery to help pay for the 2010 Deepwater Horizon spill cleanup.[93]
2009, Puerto Rico	The Caribbean Petroleum Tank Terminal Explosion resulted from gasoline overflow of a tank, with a resulting VCE that registered 2.9 on the Richter scale, engulfing 17 tanks in a fire that took two and a half days to extinguish.[94] The fire resulted in three injuries, and damaged 300 homes and businesses within 1.25 miles; approximately 139 homes required repairs, and six were demolished.[95] There were $16.6 million of additional costs recorded, including $5 million in damages to Fort Buchanan; $3.4 million from FEMA to support response efforts; and $8.2 million for environmental liabilities.[96] The U.S. EPA assumed cost coverage for additional cleanup activities.
2010, Anacortes, WA, U.S.	The Tesoro Refinery Fatal Explosion and Fire resulted from a heat exchanger rupture, releasing hydrogen gas and naphtha (a flammable liquid hydrocarbon) that ignited causing an explosion and an intense-heat fire that burned for three hours. Seven personnel died within 22 days of the incident due to serious burns.[97]
2012, Venezuela	Loose bolts on a gas pump led to a VCE at the Amuray Oil Refinery, 80 persons injured, 3,400 structures destroyed or damaged, and $1.84 billion in losses.[98,99,100,101,]
2015, Richmond, CA, U.S.	A crude oil component pipe rupture and leak led to a vapor cloud formation. Nineteen employees were within the vapor cloud; one was engulfed during ignition but was protected from the fireball due to firefighting gear. A shelter-in-place was issued for three cities. A total of 26 persons were injured, including 20 that were hospitalized in the weeks following the incident out of 15,000 community members that sought treatment for ailments including breathing problems, chest pain and headaches.[102]
2019, Philadelphia, PA, U.S.	The Philadelphia Energy Solutions Refinery Explosion and Fire resulted from a vapor cloud ignition, in turn igniting a butylene, isobutane and butane container. The resulting explosion catapulted a 38,000-pound vessel across a river and released 5,239

[92] CSB, Report No. 2005-04-I-TX, ibid. [LINK]. Page 306.
[93] France-Presse, Agence, "BP to Sell Texas City Refinery to Rival Oil Firm," Industry Week, October 8, 2012. [LINK]. Accessed 12/29/2021.
[94] CSB, "Final Investigation Report: Caribbean Petroleum Tank Terminal Explosion and Multiple Tank Fires," Report No. 2010.02.I. PR, October, 2015. [LINK]. Accessed 10/12/2021. Page 22, 54.
[95] CSB, "Final Investigation Report: Caribbean Petroleum …" ibid. [LINK]. Page 9, 32.
[96] CSB, "Final Investigation Report: Caribbean Petroleum …" ibid. [LINK]. Page 30, 32.
[97] U.S. CSB, "Investigation Report: Catastrophic Rupture of Heat Exchanger (Seven Fatalities)," May 1, 2014. [LINK]. Accessed 10/085/2021. Page 1, 24.
[98] Rosati, Andrew, "What was behind Venezuela's deadly oil refinery explosion?," The Christian Science Monitor, September 16, 2013. [LINK]. Accessed 10/12/2021.
[99] Englund, Will, "Engineers raise alarms over the risk of major explosions at LNG plants," Washington Post, June 3, 2021. [LINK]. Accessed 9/7/2021.
[100] Parraga, Marianna, "Chronology: Pump collapse, leak caused Venezuela refinery blast," Reuters, September 9, 2013. [LINK]. Accessed 10/6/2021.
[101] Lopez, Virginia, "Venezuela oil refinery explosion: Chávez denies warnings were ignored," The Guardian, August 26, 2012. [LINK]. Accessed 12/29/2021.
[102] U.S. CSB, "Final Investigative Report: Chevron Richmond Refinery Pipe Rupture and Fire," January 28, 2015. [LINK]. Accessed 10/08/2021. Page 1, 2.

Table 2. Fossil Fuel Facility VCEs in the Last 20 Years (Since 2002)

Year, Place	Incident Description
	pounds hydrofluoric acid, a deadly industrial chemical.[103] Reported losses were estimated at $750 million; the incident led to bankruptcy of the facility, permanently closing the largest and oldest refinery of its kind on the east coast.[104,105]

An expanded list of incidents beyond the summaries provided in Table 2 is provided in Appendix C. At least four of the explosions above shows worldwide costs exceeding $1 billion per incident in damages and repair of facilities alone (not all scenarios above have available cost estimates; for ones that do, not all have estimates for damages and repairs). One of these explosions was in the U.S. (2005 Texas City BP America Oil Refinery), with listed costs of $1.5 billion from the incident. Not among the above four, the 2019 Philadelphia Energy Solutions Refinery Explosion led to bankruptcy of the refinery – adding credence to the possibility of fossil fuel facility developments having inadequate fiscal resources to cover its debts to creditors following a catastrophic event.

It should be noted that the above catalogue includes a wider range of facility types than could be built in unincorporated King County, perhaps biasing reviewers towards more extreme conclusions than if facilities were assessed by their individual facility types. However, as all of the facilities that may be built in unincorporated King County and fall under the jurisdiction of King County permitting may experience a VCE, this wide view is instructive for demonstrating the potential risk from a VCE that could occur at thermal (gas) electric power plants, liquefied natural gas (LNG) plants and oil terminals.

Range of Possible Cost Contributors

Predictions on the cost of a VCE, were an explosion to occur, will likely be inaccurate even when site-specific variables are known, much less specific information about the nature of an explosion – for instance, the judge overseeing damage claims for the fatality-free Buncefield explosion commented that, "had the explosion happened during a working day, the loss of life may have been measured in tens or even hundreds."[106] Regardless, the following table provides summarized cost estimates on the potential local VCE incident were one to occur, based on an expanded analysis provided in Appendix D.

Table 3. VCEs: Estimated Range of Costs

Cost Category	Lowest Estimate Above $0	Highest Estimate
	All values in millions, rounded.	
Fatalities	$17.5	$554.6
Injuries	$0.1	$9.6
Property Damage & Other Claims	$17.0	$1,612.0
Large Property Damage Claims Included in property damage total above	*$17.0*	*$360.0*
Total Range of Costs	**$34.6**	**$2,176.2**

[103] Phillips, Susan, Dana Bate, "Faulty, old pipe caused PES refinery explosion, sending a bus-size piece of debris flying across Schuylkill," PBS WHYY, October 16, 2019. [LINK]. Accessed 9/7/2021.

[104] Marsh JLT Specialty, "100 Largest Losses in the Hydrocarbon Industry 1974-2019," March 2020. [LINK]. Accessed 11/24/2021. Page 26 (pdf 28).

[105] Maykuth, Andrew, "Bankrupt Philadelphia Energy Solutions blames 'mislabeled' pipe for big blast that led to refinery's closure," Philadelphia Inquirer, March 3, 2021. [LINK]. Accessed 12/29/2021.

[106] BBC News, "Firms ordered to pay almost £10m over Buncefield blast," July 16, 2010. [LINK]. Accessed 10/12/2021.

Were such an explosion to occur locally, potential cost impacts range from $34.6 million to $2.18 billion; averaging these over 50 years, costs would range from $690,000 to $43.6 million annually (for more on cost estimates related to an explosion, see report Appendix D). It should be noted that the above may not fully represent the costs associated with fees, fines, and criminal penalties. Although such fines have been assessed for incidents, sometimes in the tens of millions of dollars, such costs are incurred by the facility operators and would not be a cost incurred by the public.

The remainder of this section reviews modeling issues with projecting risks associated with explosions, and reviews incident occurrence at both new and old facilities.

Modelling Issues with Risk Projections

New fossil fuel facility risk projections – and the estimated fiscal assurances needed to cover the cost of those risks – ultimately rely on computer models to approximate incident impacts. The adequacy of current risk modeling has been debated in research papers, for both VCEs and thermal radiation from fossil fuel facility projects generally, and LNG projects specifically. A 2009 Congressional Research Service paper commented on this issue with LNG Hazard Models:

> *"Federal siting standards specifically require computer modeling of thermal radiation and flammable vapor cloud exclusion zones (49 C.F.R. §§ 193.2057, 2059).32… LNG hazards models simulate complex physical phenomena and are inherently uncertain, relying on calculations and input assumptions about which fair-minded analysts may legitimately disagree. Even small differences in an LNG hazard model have led to significantly different conclusions. Referring to previous LNG safety zone studies, for example, FERC noted in 2003 that "distances have been estimated to range from 1,400 feet to more than 4,000 feet for [hazardous] thermal radiation.""*[107]

Compared to other fossil fuel facility types, LNG incidents could be considered relatively rare, which potentially reduces the risk associated with those facilities. However, the lack of incidents in recent history makes it challenging to assess the adequacy of the models in predicting impacts against real-life explosions. If there is a tendency for current models to under-predict the explosion impacts, it would in turn increase the risk were an incident to occur.[108]

Analysts have also pointed out that the larger LNG-VCE risk may not be from the liquified natural gas leaking and transforming back to a gaseous state, but from the refrigerants used to initially chill the gas.

> *"The threat of a vapor cloud explosion comes from the heavier hydrocarbons an export terminal relies on to chill the natural gas so deeply that it turns into a liquid, which is then loaded onto ships for sale abroad… A typical export terminal might have 50 tons of refrigerants on site, consisting of some combination of ethylene, propane, isobutane, isopentane or hexane. A leak at a moment when there is no wind is the most dangerous because the vapor that forms as the liquid evaporates won't disperse. It will gather in a cloud that grows until the leak stops or all the liquid spills… Various heavier-than-air hydrocarbons, including gasoline, act in similar fashions and can be used for modeling risks. One difference, though, is that refrigerants are*

[107] CRS, "Liquefied Natural Gas (LNG) Import…," ibid. [LINK] Page 7. Accessed 12/28/2021.
[108] CRS, "Liquefied Natural Gas (LNG) Import…," ibid. [LINK] Page 8, 9. Accessed 12/28/2021.

more volatile than gasoline and exist naturally in a gaseous state, so up to 100 percent of a leak could be expected to form a vapor cloud."[109]

Researchers are still learning how fossil fuel facility explosions play out in real-life, and there are continuing concerns that existing VCE modeling is inadequate. For example, a 2019 paper was still struggling to understand how the 2005 Buncefield explosion could have generated some of the compressive pressures it achieved.[110] One British study found that a VCE could be between 15 to 20 times more powerful than what the models predicted.[111] One article specifically addresses the Flame Acceleration Simulator (FLACS) software developed by Gexcon, and the results of the VCE sub-model (dubbed "Q9") stating that, "Q9 systematically underpredicts" the force of vapor explosions.[112] Another article also found issues with the Q9 approach, noting that the results were, "strongly dependent on the modelling choices made by the model user and that the validity of the Q9 approach needs to be tested more thoroughly."[113] Specific issues that have been raised regarding modelling and VCEs include:

- Failure to model nil-wind (no wind) scenarios, often due to the challenge of modeling such scenarios; the 2009 Puerto Rican and 2012 Venezuelan VCEs occurred in nil-wind conditions.[114]
- Perimeter vapor barriers, intended to keep gasses from migrating off-site towards inhabited areas, can lead to onsite gas build-up, increasing both the explosive force and radius of a blast.
- Assuming a central point of ignition in the blast radius, rather than assuming a homogenous gas distribution, which can sharply increase "overpressures" (or the force of blast waves) and consequent building damage and fatality levels. Models currently do not account for this phenomenon. [115,116,117]

Some of these issues were raised in a 2016 joint engineering workshop held by the PHMSA and British Health and Safety Executive (HSE), though analysis conducted for this report finds that to date, no regulatory changes have occurred as a result of this workshop[118] PHMSA stated in mid-2021 that updates to LNG facility rules are one of its top priorities in the near future, especially in light of the bipartisan PIPES act of 2020.[119] However, it should be noted the PIPES act imposes requirements on

[109] Englund, Will, "Engineers raise alarms over the risk of major explosions at LNG plants," Washington Post, June 3, 2021. [LINK]. Accessed 9/7/2021.

[110] Johnson, Michael et al., "Vapour Cloud Explosions – The Evidence for Deflagration to Detonation Transition," Chemical Engineering Transactions, Vol. 77, 2019, pages 697-702. [LINK]. Accessed 12/28/2021.

[111] Englund, Will, "Engineers raise alarms…" ibid. [LINK]. Accessed 12/28/21.

[112] Tam, Vincent, Felicia Tan, and Chris Savvides, "A Critical Review of the Equivalent Stoichiometric Cloud Model Q9 in Gas Explosion Modelling," *Eng.* 2, no. 2: 156-180. Article belongs to the Special Issue Valorization of Material Wastes for Environmental, Energetic and Biomedical Applications. [LINK]. Accessed 12/28/2021.

[113] Stewart, Jim and Simon Gant, "A Review of the Q9 Equivalent Cloud Method for Explosion Modelling," March 2019. [LINK]. Accessed 12/08/2021.

[114] Atkinson, Graham, et al., "A review of very large vapour cloud explosions: Cloud formation and explosion severity," Journal of Loss Prevention in the Process Industries, Volume 48, July 2017, Pages 367-375. [LINK]. Also, Chamberlain, Geoffrey, Elaine Oran, Andrzej Pekalski, "An Analysis of Severe Vapour Cloud Explosions and Detonations in the Process Industries," Chemical Engineering Transactions, Vol. 77; ISBN 978-88-95608-74-7, 2019. [LINK]. Accessed 1/6/2022.

[115] Englund, Will, "Engineers raise alarms…," ibid. [LINK]. Accessed 12/28/2021.

[116] National Oceanic and Atmospheric Administration (NOAA), "Overpressure Levels of Concern," last updated April 17, 2019. [LINK]. Accessed 12/29/2021.

[117] Englund, Will, "Engineers raise alarms…," ibid. [LINK]. Accessed 12/28/2021.

[118] Englund, Will, "Engineers raise alarms…," ibid. [LINK]. Accessed 12/28/2021.

[119] Englund, Will, "Engineers raise alarms…," ibid. [LINK]. Accessed 12/28/2021.

pipelines, and that PHSMA does not appear to be obligated to update regulations for LNG facilities other than pipelines under that act.[120] As such, it is uncertain if VCE modelling concerns will be addressed in federal modelling requirements or best practices in the near future.

Overall, although modelling is necessary to illustrate the potential magnitude of an explosion event, the variability of modelling outcomes and its sensitivity to minor input changes makes predictions about the specifics of a single event highly uncertain. Independent review of modelling outcomes for specific projects would improve outcome accuracy and certainty. In addition, any explosion modeling would optimally consider nil-wind scenarios; both natural gas and refrigerant onsite volumes; the potential impact of vapor barriers; and hopefully undertake efforts to incorporate homogenous gas distributions in a leak rather than a central point of ignition in a VCE, though this last may be especially challenging given current modeling limitations.

Incidents Can Occur at Both New and Old Facilities

When a new facility is initially proposed, it is common for developers or industry experts to laud its technological advancements in comparison to older facilities. However, incidents can occur at both newer and older facilities. In a review of the 100 largest hydrocarbon industry losses from 1974 – 2019, global insurance broker and risk advisor JLT Marsh noted that in the initial decade of facility operation, most losses are caused by operator error, "…such as not following operating or permit-to-work procedures."[121,122] However:

> *"As plant operations experience develops, the number of losses reduces, until age takes its toll and there is a steep rise in both loss frequency and magnitude in plants more than 30-years-old, creating a skewed "bath-tub curve." In older plants, mechanical-integrity-related failures account for 65% of losses. Failure of piping becomes increasingly more prevalent as plants age. (Overall, not accounting for age of plant, piping failure accounts for 60% of mechanical integrity losses.)"*[123]

This insight underscores the need for adequate fiscal coverage for fossil facilities not only at their initial development, but for ongoing, continual affirmation of adequate fiscal coverage throughout facility life, as causal risk shifts from operators to aging machinery and components.

Lastly, the financial health of fossil fuel facility operators is not uniform, such that some companies have multiple operations and funds to cover incident costs, whereas other companies may be startup operations with fewer assets and financial resources to address incidents. The ability of some or several companies to cover incident costs should not be mistaken as an ability of all fossil fuel companies to cover incident costs. As this topic is not as central to the directed analysis for this report, more information can be found in report Appendix H.

ii. Pollution of Air and Water

This report section reviews the economic risk of air and water pollution associated with a potential new fossil fuel facility proposal in unincorporated King County. Risks are evaluated for facilities that may be

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[120] Hopkins, George, "The PIPES Act Of 2020: What Regulated Entities Need To Know," JD Supra, February 2, 2021. [LINK]. Accessed 12/28/2021.

[121] Marsh, "About Marsh." [LINK]. Accessed 12/2/2021.

[122] Marsh JLT Specialty, "100 Largest Losses in the Hydrocarbon Industry 1974-2019," March 2020. [LINK]. Accessed 12/2/2021. Page 20

[123] Marsh JLT Specialty, ibid. [LINK]. Accessed 12/2/2021. Page 20.

proposed for development and fall under King County permitting jurisdiction, namely an LNG plant, a thermal electric power plant and an oil terminal.

Air Pollution

This subsection provides general assessment of the air pollution impacts of a thermal electric power plant, an LNG plant, and concludes with oil terminals. It should be noted that the following assessments do not address facility greenhouse gas (GHG) emissions or impacts; impacts related to climate change are addressed in report section V.1.b.

Thermal Electric Power Plants

This subsection on thermal electric power plant air emissions focuses on the primary emission of concern, namely nitrogen oxide; its environmental and human health impacts; and evolving technological options that might address this pollutant concern. There is also discussion of mercaptan, a common natural gas additive which can be of concern near some natural gas facilities.

The air pollutants resulting from thermal electric power plants are challenging to isolate, as most air pollution reporting is generally grouped with other fossil-fuel combusting electricity generation, or focused on GHG emissions as opposed to other air pollutants – though comparative analyses exist. [124,125] Some studies and observers note the reduced nitrogen oxide, sulfur dioxide and GHG emissions of natural gas-fired power plants compared to coal-power plants.[126] Others have pointed out that since coal is one of the most emission-generating forms of producing energy, the comparative benefits of these reductions are not impressive.[127] However, "the combustion of natural gas produces negligible amounts of sulfur, mercury, and particulates" compared to other fossil fuels (though natural gas does undergo varying levels of desulphurization depending on its end-use).[128,129] The remaining primary air pollutant of concern from natural-gas fired power plants is nitrogen oxide (one type of NOx), which rapidly transforms into nitrogen dioxide (NO_2) once released into the air.[130,131] NOx stands for multiple types of oxides of nitrogen, including both nitrogen oxide and nitrogen dioxide.[132] Lastly, additional research conducted for this report revealed concerns with the gas additive methyl mercaptan, reviewed at the end of this subsection.

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[124] United States Environmental Protection Agency (EPA), "Power Plant Emission Trends," last updated October, 2021. [LINK]. Accessed 1/4/2022.

[125] Nitrous oxide (N_2O) accounts for roughly 7 percent of U.S. GHG emissions, staying in the atmosphere for 114 years once emitted; it is 300 times more powerful as a GHG pollutant than carbon dioxide (Source: United States Environmental Protection Agency (U.S. EPA), "Overview of Greenhouse Gases," last updated November 19, 2021. [LINK]). Examples of a GHG-focus in nitrogen dioxide impact assessments include: Hajny, Krisian, et al., "Observations of Methane Emissions from Natural Gas-Fired Power Plants," Environmental Science & Technology, 2019, 53, 15, 8976–8984, June 24, 2019. [LINK]. Also, U.S. Energy Information Agency (EIA), "Natural Gas Explained," last updated December 8, 2021. [LINK]. Accessed 1/4/2019.

[126] Fischer, Douglas, "Switch to Natural Gas Slashes Power Plant Pollution," Scientific American, The Daily Climate, January 9, 2014. [LINK]. Also, U.S. EIA, "Natural gas explained," las updated December 8,2021. [LINK]. Accessed 1/3/2022.

[127] Specht, Mark, "No, natural Gas Power Plants are Not Clean," Union of Concerned Scientists (UCS), The Equation, November 9, 2018. [LINK]. Accessed 1/3/2022.

[128] UCS, "Environmental Impacts of Natural Gas," June 19, 2014. [LINK]. Accessed 1/4/2021.

[129] Gazpack, "Desulfusization." [LINK]. Accessed 1/4/2021.

[130] UCS, "Environmental Impacts of Natural Gas," ibid. [LINK]. Accessed 1/4/2022.

[131] UCAR Center for Science Education, "Nitrogen Oxides," 2017. [LINK]. Accessed 1/4/2022.

[132] EPA, "Basic Information about NO2," last updated June 7, 2021. [LINK]. Accessed 1/10/2022.

The U.S. EPA notes the following impacts from nitrogen dioxide pollution:

> *"Breathing air with a high concentration of NO2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO2.*
>
> *NO2 along with other NOx reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system… NO2 and other NOx interact with water, oxygen and other chemicals in the atmosphere to form acid rain. Acid rain harms sensitive ecosystems such as lakes and forests… [Additionally,] NOx in the atmosphere contributes to nutrient pollution in coastal waters…"*[133]

The impacts of nitrogen emissions nationally are of concern as natural-gas power generation has increased; thermal electricity plants now produce between 35 to 37 percent of energy in the U.S.[134]

The costs of nitrogen emission are not easy to estimate and would be challenging to localize to a single fossil fuel facility without site-specific information, especially when compared to other background contributors of nitrogen dioxide pollution, such as automobile traffic.[135] However, some potential cost impacts of issues, to which nitrogen dioxide emission contribute, are estimated below:

- Asthma costs the U.S. $80 billion annually, with prescription drugs contributing the largest share of per-person costs.[136]
    - Asthma-related mortality costs $29 billion per year, representing 3,168 deaths annually.
    - Missed school and workdays costs $3 billion annually.
    - The per-person cost for asthma medical care alone was estimated at $3,266 per year.[137] Considering that of the 25 million U.S. residents with asthma, 28 percent of them are children, and assuming an average life expectancy of 79 years, which would mean the following per-person, lifetime costs depending on the age of contracting asthma:[138,139]
        - 8 years $232,000
        - 20 years $193,000
        - 30 years $160,000
        - 40 years $127,000
        - 50 years $95,000

[133] U.S. EPA, "Basic Information about NO_2," last updated June 7, 2021. [LINK]. Accessed 1/4/2022.
[134] U.S. EIA, "Short-Term Energy Outlook: Electricity," December 7, 2021. [LINK]. Accessed 1/4/2022.
[135] Specht, Mark, "No, Natural Gas Power Plants…," ibid. [LINK]. Accessed 1/4/2022.
[136] Inserro, Allison, "CDC Study Puts Economic Burden of Asthma at More Than $80 Billion Per Year," American Journal of Managed Care, January 12, 2018. [LINK]. Accessed 1/4/2022.
[137] Inserro, Allison, "CDC Study…," ibid. [LINK]. Accessed 1/4/2022.
[138] Holland, Kimberly, "The Differences Between Childhood and Adult-Onset Asthma," Healthline, last updated August 5, 2019. [LINK]. Accessed 1/4/2022.
[139] Ortaliza, Jared, et al., "How does U.S. life expectancy compare to other countries?" September 28, 2021. [LINK]. Accessed 1/4/2022.

        - 60 years $62,000
    - NOx emissions also contribute to the formation of ground-level ozone, which can also cause severe respiratory problems.[140]
- Although acid rain has not generated as many recent headlines as it did from 1970 to 1990, it continues to be an environmental concern, with more focus on nitrogen emissions as a contributing factor compared to its previous emphasis on sulfur dioxide.[141] Recent commentors on the issue note that the U.S. is still recovering from the impacts of acid rain in the past, though as a current concern it is more prevalent in China and India.[142] As such, the financial impacts of acid rain are not evaluated in this report.
- Nutrient pollution in coastal (and fresh) water sources from deposits of atmospheric nitrogen was once a notable concern. Increased nutrient loads can lead to eutrophication, or algal blooms that consume oxygen in water; the low-oxygen waters can kill fish and degrade their natural habitat and can also contribute to acidification of waters following algal die-off.[143] A 1994 U.S. Geological Survey report estimated that as much as 54 percent of the nitrogen emitted from fossil-fuel burning plants was deposited through rain back in U.S. watersheds. The impact of this deposition was comparatively larger in the northeast, as the greater agricultural activity in the Western U.S. contributed proportionately more nitrogen from fertilizer runoff.[144] Regardless, various nonprofit entities tracking local water body quality have noted decreases in estimated atmospheric nitrogen deposition contributing to local eutrophication. For instance, the Chesapeake Bay Program Partners noted:

    > *"Pollution from nitrogen oxides is decreasing in response to the Clean Air Act. In 2000, nitrogen oxides accounted for three-quarters of the airborne nitrogen that was polluting the Bay, and they were a big contributor to ground-level ozone pollution. By 2017 nitrogen oxides accounted for half of airborne nitrogen pollution, with ammonia accounting for the remaining half."*[145]

In Washington state, the Department of Ecology (Ecology) estimates that there are 77,400 metric tons of atmospheric nitrogen emitted annually across all counties within Puget Sound. Of these, 77 percent of emissions stem from transportation, 13 percent stems from the built environment (10,000 metric tons), nine percent is from agriculture and seven percent is from point sources of pollution.[146] One can roughly estimate a thermal energy plant's potential contribution to atmospheric nitrogen contribution in comparison to background nitrogen levels, using the below assumptions.

- 1.7 pounds (lbs.) of nitrogen oxides are generated per megawatt-hour (MWh).[147]

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[140] National Energy Technology Laboratory (NETL), "8.7. Nitrogen Oxides (NOX) Emissions." . [LINK]. Accessed 1/10/2022.

[141] Tenneson, Michael, "Sour Showers: Acid Rain Returns--This Time It Is Caused by Nitrogen Emissions," Scientific American, June 21, 2010. [LINK]

[142] Ogden, Leley, "The Bittersweet Story of How We Stopped Acid Rain," BBC: Future, August 6, 2019. [LINK]. Also, Fountain, Henry and John Schwartz, "Have We Passed the Acid Test?" New York Times, May 2, 2018. [LINK]. Accessed1/4/2022.

[143] National Oceanic and Atmospheric Administration (NOAA), "What is eutrophication?" [LINK]. Accessed 1/6/2022.

[144] Puckett, Larry, "Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States," U.S. Geological Survey (USGS) Water-Resources Investigations Report 94-4001. [LINK]. Accessed 1/4/2022.

[145] Chesapeake Bay Program, "Air Pollution." [LINK]. Accessed 1/4/2022.

[146] Washington State Department of Ecology (Ecology), "Story Map of Nitrogen in Puget Sound: Nitrogen Sources & Pathways, Atmosphere." [LINK]. Accessed 1/4/2022.

[147] U.S. EPA, "Air Emissions," last updated December 28, 2007. [LINK]. Accessed 1/4/2022.

- An average natural gas plant is approximately 800 MW in size, with an average capacity factor (i.e., hours in use) of 56.3 percent, such that it operated for 4,932 hours out of the 8,760 hours in a year.[148,149]

Based on the above, a new thermal energy plant could conceivably result in in 3,945,600 MWh generated. This would equate to 6,707,520 lbs. of nitrogen oxides emitted, or roughly 3,000 metric tons of nitrogen oxide emissions (roughly 3.6 percent of the total revised atmospheric nitrogen emissions in Puget Sound). This would not equate to the equivalent contribution to local eutrophication impacts, as multiple sources contribute to eutrophication beside atmospheric deposition; and eutrophication contributors will vary depending on the water body and the surrounding specifics of that site. [150] The costs of eutrophication will also vary depending on the site and surrounding revenue streams. One impacted water body can result in millions of costs from various impacts, including tourism and recreation losses; commercial fishing; local property values; human health; drinking water treatment; mitigation; and restoration.[151]

Although a new thermal electric power plant has the potential to emit significant levels of nitrogen dioxide, technology for such facilities is continuing to evolve and may reduce future levels of nitrogen pollution – either following combustion, or even removing nitrogen in advance. Previous thermal power plants have employed a variety of post-combustion NOx reduction applications.[152] An evolving technology is proposing removing nitrogen prior to combustion. One notable project exploring this application has been featured in both national and international assessments, namely the 50 megawatt (MW) thermal electricity demonstration project by NET Power in La Porte, Texas which first fired in 2018 and in 2021 had its first successful delivery to the electric grid.[153] Rather than burning a traditional mix of fuel and air, which is 78 percent nitrogen and 21 percent oxygen, the NET Power plant first uses an air separation unit to produce pure oxygen, setting the nitrogen aside in reserve and virtually eliminating NOx emissions.[154,155] NET power asserts this technology could potentially also have no air pollutants overall when combined with carbon sequestration.[156] If this technology is more widely adopted, it presents another option that would address NOx pollution concerns associated with thermal electric power plants. More information on the NET power project, and generally on carbon sequestration, can be found in report Appendix I.

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[148] U.S. EIA, "Power blocks in natural gas-fired combined-cycle plants are getting bigger," February 12, 2019. [LINK]. Accessed 1/4/2022.

[149] U.S. EIA, "Average utilization for natural gas combined-cycle plants exceeded coal plants in 2015," April 4, 2016. [LINK]. Accessed 1/4/2022.

[150] Selman, Mindy and Suzie Greenhalgh, "Eutrophication: Sources and Drivers of Nutrient Pollution," World Resources Institute, June 30, 2009. [LINK]. Also, Chislock, Michael et. al, "Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems," Nature Education Knowledge 4(4):10, 2013. [LINK]. Accessed 5/24/2022.

[151] U.S. EPA, "A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution," EPA 820-F-15-096, May 2015. [LINK]. Accessed 1/6/2020.

[152] NETL, "8.7. Nitrogen Oxides (NOX) Emissions," ibid. [LINK]. Accessed 1/10/2022.

[153] Patel, Sonal, "Breakthrough: NET Power's Allam Cycle Test Facility Delivers First Power to ERCOT Grid," Power, November 18, 2021. [LINK]. Accessed 1/3/2022.

[154]National Aeronautics and Space Administration (NASA), "10 Interesting Things About Air," September 12, 2016. [LINK]. Accessed 1/3/2022.

[155] Roberts, David, "That natural gas power plant…" ibid. [LINK]. Accessed 1/3/2022.

[156] NET Power, "Home," last updated 2021. [LINK]. Accessed 1/3/2022.

Given the considerations described above, accurate, defensible pricing of NOx would be challenging given other NOx emitters and the challenge of identifying the NOx impacts from a single facility compared to existing, background NOx pollution. Evolving technology options could also potentially eliminate or reduce nitrogen pollution at the outset of a project. Additionally, the understanding of how nitrogen emissions specifically affect Puget Sound nutrient pollution and local health is still evolving. Therefore, this report does not recommend requiring financial assurance mechanisms against NOx pollution at this time. However, as the local impacts of nitrogen emission may become clearer, evaluating additional financial mechanisms to address NOx pollution may be warranted at a future date.

A final pollutant of concern associated with the delivery of natural gas is mercaptan, a class of chemical including sulfur and mercury added to odorize gas (natural gas is mostly methane, which is odorless by itself).[157] Although public-facing information from the U.S. Energy Information Agency (EIA) has described mercaptan as a "harmless chemical," this likely only refers to the small dosage a person might be exposed to during typical daily activities given reports of negative impacts in other exposure scenarios (mercaptan is added to natural gas or methane so as to provide it with odor).[158] One form of the chemical, methyl mercaptan or methanethiol, has been involved in releases with harmful effects.[159] The Centers for Disease Control (CDC) notes that methanethiol is, "highly irritant when it contacts moist tissues such as the eyes, skin, and upper respiratory tract. It can also induce headache, dizziness, nausea, vomiting, coma, and death."[160]

Research conducted for this report found three incidents related to mercaptan since 2008, which are reported on in Table 4 due to their relationship fossil fuel facilities dealing with natural gas, or if the incident helps illustrate the potential impacts of a mercaptan release.

Table 4. Mercaptan Release Incidents

Year, Place	Incident Description
2008, Eight Mile, Alabama, U.S.	Lightning struck an underground supply line to a mercaptan tank at a natural gas facility owned by Sempra Energy in Eight Mile, Alabama; it has since been purchased by Mobile Gas. [161,162] Although 40 cubic yards (1,080 cubic feet) of soil were removed, residents started complaining of a rotten egg smell in 2011 due to what was later determined as groundwater contamination.[163] Over 1,300 residents have noted symptoms such as nosebleeds, respiratory distress, nausea, vomiting, seizures, vision problems and hypertension; 14 lawsuits were filed representing hundreds of residents.[164] Remediation of the spill continued into 2020.[165]

[157] Penn, Ivan, "'We cannot breathe:' A poor Alabama town has lived with the rotten egg stench of gas for 8 years," Los Angeles Times, October 15, 2016. [LINK]. Accessed 1/12/2022.
[158] U.S. EIA, "Natural gas explained," last updated December 2, 2021. [LINK]
[159] Penn, Ivan, "'We cannot breathe…" ibid. [LINK].Accessed 1/12/2022.
[160] Centers for Disease Control (CDC) – Agency for Toxic Substances and Disease Registry (ATSDR), "Medical Management Guidelines for Methyl Mercaptan," CAS# 74-93-1, UN# 1064, page last reviewed January 12, 2017. [LINK]. Accessed 1/12/2022.
[161] Alabama Department of Environmental Management (ADEP), "Eight Mile Alabama Mercaptan Release Update as of December 2021," December, 2021. [LINK]. Accessed 1/13/2022.
[162] Penn, Ivan, "'We cannot breathe…" ibid. [LINK]. Accessed 1/13/2022.
[163] ADEP, "Eight Mile Alabama…" ibid. [LINK]. Accessed 1/13/2022.
[164] Penn, Ivan, "'We cannot breathe…" ibid. [LINK]. Accessed 1/13/2022.
[165] ADEP, "Eight Mile Alabama…" ibid. [LINK]. Accessed 1/13/2022.

Table 4. Mercaptan Release Incidents

Year, Place	Incident Description
2014, La Porte, Texas, U.S.	Methyl mercaptan was responsible for the deaths of four workers and the injury of a fifth at a DuPont chemical plant in La Porte, Texas.[166] The spill resulted in federal indictment of a chemical company and a former employee, with trial pending; the insecticide production unit where workers died was permanently closed in 2016.[167]
2015, Porter Ranch, CA, U.S.	A 2015 blowout at the Aliso Canyon underground gas-storage field near Porter Ranch, California released over 100,000 tons of methane and other chemicals into the air; it was the largest natural gas leak in U.S. history.[168,169] Over 35,000 plaintiffs filed lawsuits for damages and health impacts, which included rashes, headaches, bloody noses, and coughing up blood; there have also been concerns with potentially increased rates of cancer.[170,171,172] Officials said mercaptans were responsible for the symptoms, though other chemicals could be at fault.[173] There is also virtually no research on sustained mercaptan exposure.[174] In 2021, Aliso Canyon operators offered a $1.8 billion settlement, though roughly 97 percent of the 36,000 plaintiffs need to sign to conclude the settlement. Despite this history, the California Public Utilities Commission voted to approve expanding the facility in 2021.[175]

While mercaptan exposure can be concerning, it may not be as much of an issue at thermal electricity plants combusting natural gas for the following reasons:

- Larger quantities of mercaptan are kept at facilities that add mercaptan to odorize gas, such as at main storage facilities.[176] Plants that combust natural gas would not require mercaptan to odorize gas, as gas would already arrive odorized, reducing the potential volumes for exposure to mercaptan.
- There are technologies supporting mercaptan removal at various plants using natural gas.[177]

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[166] Widener, Andrea, "Four Killed At DuPont Plant," c&en, November 20, 2014. [LINK]. Accessed 1/12/2022.

[167] Lozana, Juan, "DuPont, Ex-Worker Indicted for Plant Gas Leak That Killed 4,"Associated Press, U.S. News, January 19, 2021. [LINK]. Accessed 1/12/2022.

[168]Grigoryants, Olga, "6 years after disastrous Aliso Canyon gas leak, officials vote unanimously to expand facility," Los Angeles Daily News (LA DN), last updated October 27, 2020. [LINK]. Accessed 1/13/2022.

[169] Tat, Linh, "Five years after Aliso Canyon gas leak, public health is at the heart of the tug-of-war," LA DN, January 25, 2016. [LINK]. Accessed 1/13/2022.

[170] Chou, Elizabeth, "A massive legal fight still hangs over the Aliso Canyon gas leak, five years later," LA DN, October 23, 2020. [LINK]. Accessed 1/13/2022.

[171] Song, Lisa, "Mercaptans in Methane Leak Make Porter Ranch Residents Sick, and Fearful," Inside Climate News (ICN), January 25, 2016. [LINK]. Accessed 1/13/2022.

[172] Chou, Elizabeth, "A massive legal fight…" ibid. [LINK]. Also, Torres, Chris, "Porter Ranch residents suffer negative health effects following Aliso Canyon gas leak," Daily Sundial, March 3, 2021. [LINK]. Accessed 1/13/2022.

[173] Song, Lisa, "Mercaptans in Methane…," ibid. [LINK]. Accessed 1/13/2022.

[174] Song, Lisa, "Mercaptans in Methane…," ibid. [LINK]. Accessed 1/13/2022.

[175] Grigoryants, Olga, "6 years after…," ibid. [LINK]. Accessed 1/13/2022.

[176] Afework, Bethel et al., "Mercaptan," University of Calgary, Energy Education, 2018. [LINK]. Also, Elgas, "LPG – Propane Gas Smell: Ethyl Mercaptan – What Does Natural Gas Smells Like," December 8, 2021. [LINK]. Accessed 5/31/2022.

[177] Judd, B, "Mercaptan removal rate exceeds 99% at Canadian gas plant," Oil and Gas Journal, Volume 91:33, 1993. [LINK]. Also, Journal of Petroleum Technology (JPT), "Hybrid Solvent Helps Ease Bottlenecking in Natural-

- None of the above examples are from a thermal electricity plant. The Aliso Canyon leak, one of the more significant gas releases in recent history, came from a facility type where a large volume of stored gas could be released, and from a relatively complex leak scenario originating hundreds of feet underground.[178] A leak from a thermal electricity plant would be easier to fix through detection and repair protocols, using valves to cut off gas prior to delivery at the leak site.[179]

As such, mercaptan is not considered an air pollutant of concern for thermal electricity plants.

In summary, potential nitrogen dioxide air emissions from thermal electricity plants could be a cause for concern; mercaptan exposure could be a concern but is less of a consistent emission issue than NOx for this facility type. Overall, many of the issues to which NOx pollution contributes have multiple sources, which would make it challenging to pursue economic coverage for those impacts. Additionally, the above-referenced technologies provide a means of mitigating emissions, which could be required as part of a project SEPA or Environmental Impact Statement (EIS) process. Hence an additional financial assurance mechanism to address air emissions from thermal electricity plants is not anticipated to be needed at this time.

Liquefied Natural Gas (LNG)

This subsection on LNG air emissions focuses on the primary concern associated with LNG plants, namely emissions of nitrogen oxides, with an additional overview of potential impacts from LNG regasification.

There are a variety of air pollutants that can result from an LNG project, including nitrogen oxides (NOx), particulate matter (PM), volatile organic compounds (VOC), sulfur dioxide (SO2), carbon monoxide (CO), and hazardous air pollutants (HAP)."[180] Unfortunately, research conducted for this report was unable to find many assessments of the absolute or relative emission levels from the plants used to create LNG to evaluate this impact, as most research is focused on emissions from combusting LNG fuels for mobile uses, or at stationary sites such as a power plant.[181,182]

Based on some available environmental improvements LNG plants pursue and critiques of existing gas-fired power plants, one of the primary air pollutants of concern for LNG facilities are NOx emissions. Concerns of NOx emissions from LNG plants are also substantiated by the use of nitrogen in LNG

Gas Plant," March 31, 2018. [LINK], and Bloemendal, Gerrit, et al., "Capture and convert - handling mercaptans in hydrocarbon streams," Digital Refining, December 2008. [LINK]. Accessed 1/12/2022.

[178] Anderson, Scott, "Preventing Future Aliso Canyon-Sized Gas Leaks – the Importance of Well Integrity," Environmental Defense Fund (EDF), Energy Exchange blog, January 28, 2016. [LINK]. Accessed 1/13/2022.

[179] EPA, "Leak Detection and Repair," October, 2007. [LINK] Accessed 1/13/2022.

[180] EPA, "EPA's Liquefied Natural Gas Regulatory Roadmap," November 2006. [LINK]. Accessed 9/8/21. Page 5.

[181] Particularly in the shipping industry. See Afin, Yinka and David Ervin, "An assessment of air emissions from liquefied natural gas ships using different power systems and different fuels," Journal of the Air & Waste Management Association, 58(3), pages 404-411, March, 2008. [LINK]. Also, Pavlenko, Nikita, et al., "Working Paper 2020-20, The climate implications of using LNG as a marine fuel," International Council on Clean Transportation (ICCT), 2020. [LINK]; Swanson, Christina and Amanda Levin, "Sailing to Nowhere: Liquefied Natural Gas is Not an Effective Climate Strategy," Natural Resources Defense Council (NRDC), R-20-08A, December, 2020. [LINK]. Accessed 1/6/2022.

[182] Chang-won, Lim, "POSCO Energy demonstrates plasma treatment to reduce NOx at LNG power plant," Aju Business Daily, August 13, 2020. [LINK]. Accessed 1/6/2022.

production, including use of the reverse Brayton cycle with nitrogen applied in refrigeration to liquefy gas.[183,184,185] Nitrogen oxide can also be used for other LNG plant functions beyond refrigeration, including helping maintain fueling arms for marine vessels, and purging pipelines prior to flaring.[186] Although purging reduces some pollutants, nitrogen is not fully eliminated during the flaring process.[187] However, dry low NOx (DLN) or dry low emission (DLE) technologies may be applied to lower NOx emissions.[188,189,190] The general impacts of NOx pollution, and its range of fiscal impacts, is reviewed in the previous subsection addressing air pollution from thermal electric power plants.

This report does not detail the comparative benefits of LNG fuels for shipping versus other fuels to a great extent, as the report scope is assessing the impact of new fossil fuel facilities, not the subsequent vehicles they might fuel once mobilized. However, there are some salient points of how LNG shipping fuel may or may not affect local air quality. For instance, some reports and research note that the switch to LNG fuels for ships may provide local air quality benefits, including a possible 93 percent reduction in particulate matter (PM) and 92 percent in NOx from switching from diesel to LNG. This might be especially important for, "port communities where high NOx levels drive ozone levels above the federal standards."[191] However, it is also important to note that:

- These benefits are only comparing emissions from fuels, and do not include plant operations.
- Only a portion of fuels are expended in port; a majority of fuel is expended during shipping, so emission benefits are not solely derived while a ship is in-port.
- Such benefits in emissions would only occur if LNG-fueled ships are replacing diesel-fueled ships. If LNG fueling is adding on to existing diesel shipping and does not lead to a net reduction in diesel ship visitation, local air quality benefits would not be achieved.

In addition to the process of creating LNG, there may be spills of LNG at plants onsite that might result in releases of air emissions. LNG must be cooled to -161 degrees Celsius to achieve a liquid state. If spilled,

[183] McQue, Katie, "QP to spend $200 million on emissions reduction technology for LNG expansion project," S&P Global, June 30, 2021. [LINK]. Accessed 1/6/2022.

[184] Clean Air Council, "Action Items: Tell AMS to Reduce Smog-Causing Pollution from PGW's Richmond LNG Plant," 2021. [LINK]

[185] Kochunni, Sarun and Kanchan Chowdhurry, "LNG boil-off gas reliquefaction by Brayton refrigeration system – Part 1: Exergy analysis and design of the basic configuration," Energy, Volume 176, pages 753-764, June 1, 2019. [LINK]. Also, Chang, H.M. et al., "Modified Reverse-Brayton Cycles for Efficient Liquefaction of Natural Gas," Cryocoolers 17, 2012. [LINK], and Joseph Pak, "Nitrogen expansion cycle enhances flexibility of small-scale LNG," Gas Processing & LNG, 2012. [LINK] Accessed 1/10/2022.

[186] Ecology and Environment, Inc., "Proposed Tacoma Liquefied Natural Gas Project Final Supplemental Environmental Impact Statement," Prepared for Puget Sound Clean Air Agency (PSCAA), March 29, 2019. [LINK]. Accessed 1/10/2022. Page 2-4,

[187] Agrebe, Azeez, "Natural Gas Flaring – Alternative Solutions," World Journal of Engineering and Techology, Volume 5, February 2017. [LINK]. Also, U.S. EIA, "Natural Gas Explained," last updated December 8, 2021. [LINK], and Emam, Emam, "Gas Flaring in Industry: An Overview," Petroleum and Coal, Vol. 57 (5), 532-555, December, 2015. [LINK]. Accessed 1/10/2022.

[188] General Electric (GL) Gas Power, "DLN 2.6 combustion system upgrades for F-class turbines," 2021. [LINK]

[189] Kawaski, "New Gas Turbine Combustion Technology for Record Low NOx Emissions," December 16, 2009. [LINK]. Accessed 1/10/2022.

[190] Siemens, "LNG Fuel Flexibility in Siemens' Land-Based Gas Turbine Operations," Electric Power Conference, May 1-3, 2007. [LINK]. Also, Ozawa, Y., "Low NOx combustion technology for LNG combined cycle power plant," January 2001. [LINK]. Accessed 1/10/2022.

[191] California Air Resources Board (CARB), "Local Air Benefits by Switching from Diesel Fuel to LNG on a Marine Vessel," March, 2020. [LINK]. Accessed 1/10/2022.

LNG will naturally re-gasify on its own, leaving no residue.[192] While initially heavier than air, LNG vapors will rise above ground-level once the LNG vapors reach -106.7 degrees Celsius, and thereafter will disperse.[193] This process poses some dangers, including:

- Gas vapors in the immediately vicinity of a spill can displace air and lead to asphyxiation, though this threat diminishes as the vapors rise in warming temperature.[194,195]
- If an area surrounding a potential leak has spatial obstacles, increasing vapor confinement and congestion, a vapor cloud explosion can result (for VCE impacts, see report section V.A.1.a.i). If the spill occurs in an unconfined environment, the vapor clouds may result in a flammable plume that will burn back to the LNG leak source until the leak isolated, the LNG supply is exhausted, or surrounding air dilutes the vapors below the flammable limit.[196]

The impacts of LNG regasification to methane are primarily associated with VCE risk, or as a greenhouse gas contributor to climate change (for more on climate change see report section V.A.1.b).

Overall, potential nitrogen dioxide air emissions from an LNG plant could be a cause for concern. However, many of the issues to which NOx pollution contributes have multiple sources, which would make it challenging to pursue economic coverage for those impacts. Additionally, some technologies provide a means of mitigating emissions that could be required as part of a project SEPA or EIS process. Hence an additional financial assurance mechanism to address this impact is not anticipated to be needed at this time.

Oil Terminals

Much of the air emissions information from facilities handling oil and gasoline focuses on refineries, rather than storage facilities alone. Stand-alone storage facility evaluations can also be co-mingled with other petroleum-related bulk storage products, such as heated storage of asphalt.[197] However, a 2021 report from the State of Maine's Department of Environmental Protection (DEP) evaluating aboveground petroleum storage tank emissions provides a useful, appropriately focused reference that emphasizes the impacts of Volatile Organic Compounds (VOC) and Hazardous Air Pollutants (HAP):

> *"The main pollutant of concern from petroleum storage facilities is VOC. VOC comprise a large class of carbon-containing compounds which participate in atmospheric photochemical reactions. A few compounds are specifically excluded from this definition, including carbon monoxide and carbon dioxide… HAP, also known as toxic air pollutants or air toxics, are those pollutants that are known or suspected to cause cancer or to have other serious health effects, such as reproductive system effects or birth defects, or that are known or suspected to have*

[192] CRS, "Liquefied Natural Gas (LNG) Import…," ibid. [LINK]. Accessed 1/11/2022. Page 6.
[193] Connecticut Department of Energy and Environmental Protection (C-DEEP), "What is LNG?" last updated May, 2021. [LINK]. Accessed 1/11/2022.
[194] USCG-OES & Tetra Tech, Inc. "Final Environmental Impact Statement for the Port Delfin LNG Project Deepwater Port Application, Volume I: Main Text," Docket No.. USCG-2015-0472, November 2016. [LINK].. Accessed 1/11/2022. Page 4-69 (pdf page 326).
[195] CRS, "Liquefied Natural Gas (LNG) Import…," ibid., page 5. Accessed 1/11/2022.
[196] USCG-OES & Tetra Tech, Inc. "Final Environmental Impact Statement for the Port Delfin …" ibid. [LINK]. Accessed 1/11/2022. Page 5-2 (pdf page 503).
[197] Shankman, Sabrina and Julia Kane, "Noxious Neighbors: The EPA Knows Tanks Holding Heavy Fuels Emit Harmful Chemicals. Why Are Americans Still at Risk?" ICN, April 18, 2021. [LINK]. Accessed 1/3/2021.

adverse environmental effects. Like emissions of VOC, emissions of HAP from petroleum storage facilities come from evaporative losses of the product being stored or transferred."[198]

The report extensively reviews the products stored, types of storage facilities, methods for controlling emissions and means to measure emission impacts. The report concluded that:

- Gasoline storage: VOC emissions are highly regulated at the state and federal level, and that additional controls would likely not result in meaningful emission reductions.
- Distillate Fuel: Some new requirements might be warranted for storage tanks over 39,000-gallons in size.
- Residual oil and asphalt: VOC mitigations are typically lacking, though there were options to reduce VOCs/HAPs that warranted further investigation.[199]

Although potential VOC/HAP air emissions from oil terminals can be a cause for concern, the above-referenced Maine DEP report reviewed multiple means of mitigating emissions that could be required as part of a project SEPA or EIS process. Such requirements could provide mitigation of the listed air impacts, such that an additional financial assurance mechanism to address that impact is not anticipated to be needed at this time.

Water Pollution

The water pollution subsection provides general assessment of the water pollution impacts of thermal electric power and LNG plants and concludes with oil terminals. As potential water pollution impacts are more limited when compared to possible air pollution impacts, this section is not broken out into subsections according to fossil fuel facility type (unlike the previous air pollution section). The below assessments do not address the possible impacts of oil spills, which are addressed in report section V.A.1.a.iv.

The primary source of water pollution related to thermal power plants comes from procuring natural gas at its source, or the groundwater and surface water concerns associated with drilling or hydraulic fracturing to release trapped gas or oil (also called fracking).[200] These contaminants are typically from spills or inappropriate injection of fracturing fluids, or the discharge or inappropriate disposal of fracturing wastewater or waste materials.[201] As hydraulic fracturing is not allowed in Washington state, these concerns – while important – would not affect waters surrounding a fossil fuel development site in unincorporated King County.

Beyond issues with procuring natural gas, LNG plants, and thermal energy plants have overlapping water pollution issues, namely NOx deposition and thermal wastewater impacts. There are some concerns with nitrogen dioxide air pollution deposition in waterways; for more on NOx pollution impacts and costs, see report section V.A.1a.ii on air pollution from thermal electric power plants. Most other water-related assessments of gas-fired power plants focus on their reduced water consumption compared to

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[198] Maine Department of Environmental Protection (DEP), "Measurement and Control of Emissions from Aboveground Petroleum Storage Tanks," January 1, 2021. [LINK]. Accessed 1/3/22. Page 6.

[199] Maine DEP, ""Measurement and Control of Emissions…," Ibid. Page 95.

[200] UCS, "Environmental Impacts of Natural Gas," ibid. [LINK]. Also, Green America, "Natural Gas: Why is it Dirty." [LINK], and, Palmer, Brian, "Natural Gas 101," NRDC, November 15, 2021. [LINK]. Accessed 1/6/2022.

[201] U.S. EPA, "Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States. Executive Summary," Office of Research and Development, EPA/600/R-16/236ES. 2016. [LINK]. Accessed 4/27/22.

coal power plants.[202] There are potential impacts with both thermal energy and LNG plants causing thermal water pollution, or wastewater released to water bodies at a higher temperature than intake waters. Thermal wastewater discharges can, "alter the local fishery composition, aquatic macroinvertebrate (bugs) communities, and aquatic plant communities."[203] Thermal pollution in waterways can also decrease oxygen supply for a variety of biota (also called hypoxia), causing fish die-off.[204] However, various studies have noted that recirculation water systems, dry cooling (refrigerant) systems or a combination of seawater and air-cooled technology can reduce thermal wastewater impacts. [205,206,207,208] Some barges and support vessels visiting LNG facilities can also take in cooling water for vessel boilers; although chemicals are not added to the waters, these discharge waters from some ships can also temporarily raise surrounding water body temperatures.[209]

Research conducted for this report did not find much assessment of the economic impacts of thermal water pollution. However, one study on an EPA 2012 data release showed, "not only that the benefits of closed-cycle cooling outweigh the costs by more than 3:1, but also that closed-cycle cooling provides a greater net social benefit ($13 billion at a three percent discount rate) than any other option considered by the EPA."[210]

Separate from thermal energy plants, LNG plants may have a spill of LNG on nearby waters, but this would not result in water pollution impacts. As noted previously, LNG must be cooled to -161 degrees Celsius to achieve a liquid state; once achieved, it is odorless, colorless, and floats on water.[211] If spilled,

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[202] Climate Central, "Water Use Declining as Natural Gas Grows," June 30, 2015. [LINK]. Also, Kondash, Andrew, Dalia Patino-Echeverri, and Avner Vengosh, "Quantification of the water-use reduction associated with the transition from coal to natural gas in the US electricity sector," Environmental Research Letters, Volume 14, Number 12, December 4, 2019. [LINK]. Accessed 1/10/2022.

[203] Public Service Commission (PSC) of Wisconsin, "Environmental Impacts of Power Plants," [LINK]. Page 8. See also, Whited, Melissa, Frank Ackerman and Sarah Jackson, "Water Constraints on Energy Production: Altering our Current Collision Course," Prepared for the Civil Society Institute, September 12, 2013. [LINK]. Accessed 1/10/2022. Page vii.

[204] Rosen, Marc, et al., "Evaluating the Thermal Pollution Caused by Wastewaters Discharged from a Chain of Coal-Fired Power Plants along a River," Sustainability, Volume 7, pages 5920-5943, may 13, 2015. [LINK]. Accessed 1/11/2022. Page 5922.

[205] Bakshi, Bhavik, Brent Sohngen & Khanal Sami, "Final Report: Addressing the Water-Energy Nexus of Fossil Power Generation by Considering Technological, Agro-Ecological, and Economic Options in the Muskingum Watershed," Ohio State University, July 18, 2019. [LINK]. Page 15; see also U.S. EIA, "2018: Form EIA-923 detailed data," Schedule 8D. Cooling System Information, 2018. [LINK]. Accessed 1/11/2022.

[206] Vaca-Jimenez, S., W. Gernems-Leenes, and S. Nonhebel, "The water footprint of electricity in Ecuador: Technology and fuel variation indicate pathways towards water-efficient electricity mixes," Water Resources and Industry, Volume 22, 100112, 2019. [LINK]. Accessed 1/11/2022.

[207] U.S. Coast Guard (USCG) Office of Operating & Environmental Standards (OES) & Tetra Tech, Inc. "Final Environmental Impact Statement for the Port Delfin"ibid. [LINK]. Accessed 1/11/2022. Page ES-7 (pdf page 10).

[208] Fricko, Oliver et al., "Energy sector water use implications of a 2 °C climate policy," Environmental Research Letters, Volume 11 (034011), March 4, 2016. [LINK]. Page 3, and, Fleishli, Steve and Becky Hayat, "Power Plant Cooling and Associated Impacts," NRDC, IB: 14-04-C, April, 2014. [LINK]. Page 3. Accessed 1/11/2022.

[209] Federal Energy Regulatory Commission (FERC), "Gulf LNG Liquefaction Project FEIS," Docket No. CP15-521-000, April 2019. [LINK]. Accessed 1/11/2022. Page 4-27 (pdf page 123).

[210] Fleishli, Steve and Becky Hayat, "Power Plant Cooling and Associated Impacts," NRDC, IB: 14-04-C, April, 2014. [LINK]. Accessed 1/11/2022. Page 6.

[211] C-DEEP, "What is LNG?" ibid.. [LINK]. Accessed 1/11/2022.

LNG will naturally re-gasify on its own, leaving no residue.[212] There is a temporary safety concern in the immediate area of an LNG spill, as the extreme cold of LNG once liquefied, and even as it re-gasifies, can injure people or damage equipment through direct contact, though a pool fire is a more probable outcome of a spill.[213]

> *"If LNG spills near an ignition source, evaporating gas will burn above the LNG pool. The resulting "pool fire" would spread as the LNG pool expanded away from its source and continued evaporating. A pool fire is intense, burning far more hotly and rapidly than oil or gasoline fires. It cannot be extinguished—all the LNG must be consumed before it goes out. Because an LNG pool fire is so hot, its thermal radiation may injure people and damage property a considerable distance from the fire itself*."[214]

While LNG spill impacts may be concerning, they do not result in residual impacts as a source of water pollution.

For the other fossil fuel facility of interest in this report, oil terminals, the primary water pollution of interest would be oil from an oil spill. For more on this topic, see report section V.A.1.a.iv.

Overall, although cited water pollution impacts do contribute to environmental issues, those issues again have multiple contributors (i.e., thermal pollution from energy plants, thermal pollution from barges), which would make it challenging to pursue economic coverage for those impacts. Additionally, there is technology available to help mitigate water pollution impacts that could be required as part of a project SEPA or EIS process. As such, this report recommends that not requiring an additional financial assurance mechanism to address this impact at this time.

iii. Brownfields and Abandoned Infrastructure

The U.S. EPA provides the following overview on its Brownfields & Land Revitalization Program:

> *"A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. It is estimated that there are more than 450,000 brownfields in the U.S. Cleaning up and reinvesting in these properties increases local tax bases, facilitates job growth, utilizes existing infrastructure, takes development pressures off of undeveloped, open land, and both improves and protects the environment."*[215]

The U.S. EPA has also assessed some of the benefits from redeveloping brownfield sites, including that:

- Car trips and car use decreases, "since brownfield sites tend to be in densely developed, centralized areas redevelopment," reducing the vehicle miles traveled (VMT). As such, redeveloping brownfields:
  - Reduces residential VMT from new growth by 25 to 33 percent, and
  - Reduces job-related VMT from new growth by nine to 10 percent.
- It improves water and air quality from improved stormwater and reduced vehicle travel.
- Residential property values increase between five to 15 percent within 1.29 miles of a brownfield site once it redevelops.

[212] CRS, "Liquefied Natural Gas (LNG) Import…," ibid. [LINK]. Accessed 1/11/2022. Page 6.
[213] CRS, "Liquefied Natural Gas (LNG) Import…," ibid. [LINK]. Accessed 1/11/2022. Page 5
[214] CRS, "Liquefied Natural Gas (LNG) Import…," ibid. [LINK]. Accessed 1/11/2022. Page 5.
[215] U.S. EPA, "Overview of EPA's Brownfields Program," last updated July 26, 2021. [LINK]. Accessed 1/11/2022.

- Between $29 to $97 million in additional annual tax revenue for local governments following cleanup, between, "2 to 7 times more than the $12.4 million EPA contributed to the cleanup of those brownfields."[216]

Although the costs and impacts of brownfields has been reviewed generally, research conducted for this report found that assessments of legacy brownfields from the fossil fuel industry tend to focus on transforming facilities in the coal industry, either coal mines or coal-fired power generation facilities.[217,218] As such, research conducted for this report found little specific information on brownfield impacts, pollutants, and both impact and remediation costs associated specifically with the types of fossil fuel facilities on which this report is focused.

Regardless, this report section reviews the projected economic risk of brownfields and abandoned infrastructure associated with a potential new fossil fuel facility proposal in unincorporated King County. Risks are evaluated for facilities that may be proposed for development and fall under King County permitting jurisdiction, namely an LNG plant, thermal electric power plant and an oil terminal.

Liquified Natural Gas (LNG) & Thermal Electric Power Plants

This subsection provides general assessment of potential impacts of brownfields specifically from an LNG plant and a thermal electric power plant. The topic of brownfields captures the extent of abandoned infrastructure that might fall under King County permitting jurisdiction, however some review of abandoning pipelines is provided in the next subsection assessing brownfield impacts with oil terminals.

Research conducted for this report did not find much assessment of the issue of LNG plants contributing to the development of brownfields. This may be affected by several factors:

- LNG facility growth in the U.S. has surged in recent years; in 2014, the U.S. was a net gas *importer* of roughly five billion cubic feet per day (Bcf/d), and by the end of 2021, the U.S. was a net *exporter* of eleven Bcf/d; in January 2022, the U.S. became the top exporter of LNG.[219,220] Given LNG project growth in the U.S., there is little LNG facility abandonment occurring, which would contribute to the scarcity of LNG facility abandonment assessments.
- LNG export projects are sometimes considered a good candidate project to redevelop existing brownfields as they fare better economically than their greenfield counterparts, though this assessment appears largely directed towards existing LNG site expansion or transitioning

[216] U.S. EPA, "Brownfields Program Environmental and Economic Benefits," last updated June 8, 2021. [LINK]. Accessed 1/11/2022.
[217] Buchsbaum, Lee, "Turning Brownfields into Greenfields: From Coal to Clean Energy," Power, November 1, 2015. [LINK]. Accessed 1/11/2022.
[218] Trabish, Herman, "Are utilities missing out on the opportunity to use old coal sites for solar?" Utility Dive, March 8, 2018. [LINK]. Accessed 1/11/2022.
[219] U.S. EIA, "U.S. natural gas net trade is growing as annual LNG exports exceed pipeline exports," August 16, 2021. [LINK]. Accessed 1/13/2022.
[220] Stapczynski, Stephen and Sergio Chapa, "US becomes world's top LNG exporter…," ibid. [LINK]. Accessed 1/13/2022.

underutilized LNG import sites to an export site.[221] Still, this overall attitude appears to be echoed internationally with Qatar and Australian LNG development trends.[222]

- LNG is not, itself, defined as a hazardous substance in the United States Code (USC) and U.S. EPA brownfield funding, which may also reduce funding for LNG cleanup activities, and reporting on, funded LNG brownfield cleanup projects, and thereby reduce the number of published LNG brownfield assessments.[223]
- Lastly, brownfield mitigation typically focuses on liquid spills, or chemicals that consolidate to a liquid state. In contrast, LNG facilities focus on gaseous chemical processing, and LNG itself – if spilled – rapidly returns to a gaseous state as it warms. Although brownfield assessments do review possible air pollutants, they focus on indoor air environments of a facility.[224] Such air pollutants may be sourced from residual air pollutants from past building operations or building materials, or from vapor intrusion into a facility from outdoor soils, groundwater or subsurface vaporization.[225] Besides LNG itself, review of EIS materials of LNG facilities noted that several chemicals used onsite are gaseous and would not result in soil or water contamination that could cause vapor intrusion issues later. These include:
    - Butane[226]
    - Ethane[227]
    - Ethylene[228]
    - Liquid nitrogen (returns to a gaseous state at room temperature)[229]
    - Propane[230]

As LNG brownfields are not currently widespread, and the nature of their operations does not include the same volumes of onsite liquid handling that could result in soil and water contamination when compared to other types of industrial facilities, this may explain the lack of literature specifically on LNG-brownfield concerns.

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[221] Evans, Caroline, "Sempra CEO Says LNG Construction Costs Rising, while Tellurian Looking to Boost Haynesville Output," Natural Gas Intelligence, August 6, 2021. [LINK], also Songhurst, Brian, "LNG Plant Cost Reduction 2014 – 2018," Oxford Institute for Energy Studies (OIES), OIES Paper NG137, October 2018. [LINK] and Meyer, Dustin, "U.S. LNG Accelerates Shifts in the Global Marketplace," American Petroleum Institute, April 26, 2019. [LINK]. Accessed 1/13/2022.

[222] Russel, Clyde, "Qatar's LNG brownfield trumps Petronas' greenfield hopes: Russel," Reuters, July 26, 2017. [LINK], and

[223] U.S. EPA, "Brownfields ACRES Frequent Questions – Definitions," last updated June 9, 2021. [LINK] Accessed 1/14/2022.

[224] U.S. EPA, "Brownfields Road Map to Understanding Options for Site Investigation and Cleanup, Sixth Edition." EPA Office of Land and Emergency Management, 542-R-17-003, [LINK]. Accessed 1/14/2022. Pages 20, 26 (pdf pages 23, 29).

[225] U.S. EPA, "Brownfields Road Map…," ibid. Page 34 (pdf page 37). Also, the Interstate Technology & Regulatory Council Brownfields Team, "Vapor Intrusion Issues at Brownfield Sites," December 2003. [LINK]. Page iii (pdf page 6). Accessed 1/14/2022.

[226] Verified this chemical is gaseous at room temperature at National Library of Medicine (NLM), "Butane," National Institute of Health (NIH). [LINK]. Accessed 1/14/2022.

[227] Verified this chemical is gaseous at room temperature at the editors of Encyclopaedia Britannica, "ethane," Britannica, September 26, 2013. [LINK]. Accessed 1/14/2022.

[228] Verified this chemical is gaseous at room temperature at Carvey, Francis, "ethylene," Britannica, March 8, 2019. [LINK]. Accessed 1/14/2022.

[229] Utah State University Environmental Health & Safety, "Liquid Nitrogen." [LINK]

[230] For See FERC, "Gulf LNG Liquefaction…," ibid. [LINK]. Accessed 1/14/2022. Page 4-156 (pdf page 252).

Despite the lack of brownfield assessments specific to LNG plants, there are some liquid chemicals used at LNG plants that could be involved in spills, and that do not quickly phase-change to a gaseous state, and hence could contaminate soils or water bodies. These are reviewed below:

- Aqueous ammonia:[231] Aqueous ammonia biodegrades in soil, though it would still require cleanup if spilled; ammonia can cause fish kills in aquatic systems.[232,233,234]
- Diesel or hot oils — Spills of petroleum products are reviewed in the following section.
- Hexane[235] — Hexane is categorized as a volatile organic compound (VOC) and a hazardous air pollutant (HAP).[236,237] The primary concerns from a spill would be exposure dosages that can have a neurotoxic effect, and the danger of fire or explosion.[238]
- Isopentane[239] — Isopentane biodegrades in soil, and can be toxic in aquatic systems.[240]
- Pentane — Can be toxic in, and cause long-term damage to, aquatic systems.[241]

Surrounding storage of the above chemicals are typically equipped with protection features to help catch spills such as containment troughs and curbs.[242] Although spills of these chemicals can be concerning when they occur, most do not appear to be connected with substantial brownfield

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[231] Proposed for use in Gulf LNG Liquefaction project. See FERC, "Gulf LNG Liquefaction…," ibid. [LINK]. Accessed 1/14/2022. Page 4-156 (pdf page 252).

[232] Tanner Industries Inc., "Aqua Ammonia: (SDS) Safety Data Sheet," 2016. [LINK]. Accessed 1/14/2022.

[233] Oregon Department of Environmental Quality (ODEQ), "Strategy Recommendations: NFA Decision Document, Wilbur-Ellis Aqua Ammonia Spill," ECSI Site ID: 2583, September 6, 2000. [LINK] also, while nonhydrous ammonia is not the same as aqueous ammonia, both require cleanup (though aqueous is less concentrated; see EPA, "1998 EPCRA 313 Q&A, Question # 450," 1998. [LINK]), the Minot train derailment that spilled almost 150,000 gallons of anhydrous ammonia cost $8 million in environmental remediation; see National Transportation Safety Board, "Derailment of Canadian Pacific Railway Freight Train 292-16 and Subsequent Release of Anhydrous Ammonia Near Minot, North Dakota January 18, 2002," March 9, 2004. [LINK] Page vi, (pdf page 8).

[234] U.S. EPA, "Ammonia," CADDIS Volume 2, last updated January 21, 2021. [LINK]. Accessed 1/14/2022.

[235] Chemical cited for use in LNG facilities in Englund, Will, "Engineers raise alarms…" ibid. Verified this chemical is liquid at room temperature at CDC-ATSDR, "n-Hexane," CAS#110-54-3, page last reviewed February 10, 2021. [LINK]. Accessed 1/25/2022.

[236] CDC-ATSDR, "n-Hexane," ibid. [LINK]. Accessed 1/25/2022.

[237] U.S. EPA, "Initial List of Hazardous Air Pollutants with Modifications," last updated January 5, 2022. [LINK]. Accessed 1/25/2022.

[238] U.S. EPA, "Hexane Hazard Summary," last updated January 2000. [LINK] and VelocityEHS, "Understanding the Hazards of Hexane," November 19, 2014. [LINK]. Accessed 1/25/2022.

[239] Verified this chemical is liquid at room temperature at Cameo Chemicals, "Isopentane," 2016. [LINK] and New Jersey Department of Health, "Hazardous Substance Fact Sheet: Isopentane," January 2009. [LINK]. Page 1. Source: Ecology and Environment, Inc. "Puget Sound Energy Proposed Tacoma Liquefied…," Ibid. [LINK]. Page 2-3 (pdf page 51). Accessed 1/14/2022.

[240] European Commission Joint Research Centre, "n-pentane," Special Publication I.03.152, 2003. [LINK]. Accessed 1/14/2022. Page 7 (pdf page 13).

[241] Verified this chemical is liquid at room temperature at NLM, "Pentane," NIH. [LINK]. Accessed 2/14/2022.

[242] Ecology and Environment, Inc. "Puget Sound Energy Proposed Tacoma Liquefied…," Ibid. [LINK]. Accessed 1/14/2022. Page 2-8 (pdf page 56).

issues to date, as most of these chemicals are not included among the top contaminants of concern reported for brownfield cleanups in the U.S., which the EPA lists in the following order:[243]

- Lead
- Petroleum
- Asbestos
- Polycyclic aromatic hydrocarbons (PAHs)
- Other Metals
- Volatile Organic Compounds (VOCs)
- Polychlorinated Biphenyls (PCBs)
- Arsenic

The one exception is hexane, which is categorized as a VOC.

Additional contaminants less commonly reported as part of brownfield cleanups include:[244]

- Cadmium
- Chromium
- Dioxin
- Mercury
- Pesticides

Although the chemicals stored in liquid form that could be involved LNG facility spills are not connected with typical brownfield contaminants, the potential impacts of identified potential spill chemicals indicates potential financial risks, especially if spills occur near aquatic systems. This risk could be compounded if a facility enters bankruptcy (this topic is addressed again later in this section).

Thermal electric plants are reviewed in this same subsection on LNG facilities as both facility types primarily address natural gas. Similar to LNG plants, research conducted for this report did not find much assessment of the issue of thermal electric power plants contributing notably to the development of brownfields. In general, also similar to LNG, thermal electricity plants primarily deal with gaseous fuels, which overlap with LNG plant observations that the majority of chemical volumes handled at the facility cannot spill onto the ground and lead to residual site contamination. Though there are potentially other liquid chemicals used at thermal energy plants that can spill and cause contamination, research conducted for this report could not find this concern reported on decisively in the literature.

Research conducted for this report did find generation of some low-level radioactive material associated with thermal electric power plants at decommissioning, though this waste is addressed through state regulatory pathways. A 2017 report addressing solid waste byproducts from plant decommissioning noted that gas-fired plants will have to address,

> *"…byproducts from air pollution controls and chemical waste, including the scale, sludge, and scrapings removed from the generator, tanks, and pipelines, that may contain radioactive*

[243] U.S. EPA, "Environmental Contaminants Often Found at Brownfield Sites," EPA S60F19007, September 2019. [LINK]

[244] U.S. EPA, "Common Types of Brownfields and their Contaminants," last updated June 16, 2021. [LINK]. Accessed 1/14/2022.

elements. However, there is little public information about the cost of different decommissioning options for… gas facilities."[245]

Radioactive wastes can be referred to as naturally occurring radioactive material (NORM) – though in Washington state these are tracked as naturally-occurring and accelerator-produced radioactive material (NARM) waste.[246] The federal Low-level Radioactive Waste Policy Amendments Act of 1985 gave states responsibility for disposing of their low-level radioactive waste and encouraged states to enter into compacts for disposal at common disposal facilities.[247] Washington state joined the Northwest Interstate Compact for low-level radiation waste management, ratified by Congress in 1985.[248] Washington state requires NARM generators to obtain a permit for disposal, and to complete disposal within Washington state.[249] As such, any NARM wastes generated from a new thermal electric power plant would be required to obtain a state permit, and those wastes would be required to be disposed of at the sole, authorized U.S. Ecology-operated facility in Richland, Washington.[250]

Given the above review, research conducted for this report did not find notable brownfield impacts associated with thermal electric power plants. This report does not recommend require additional financial assurances for brownfield impacts with thermal electric power plants at this time.

However, there are concerns with LNG plants potential for brownfield site contamination, as some material spills could damage aquatic systems if not contained; the estimated cost of this potential impact is reviewed subsequently under Regulations and Remediation Funding. However, in light of the above review, this report recommends advance planning around potential onsite hazards and facility decommissioning and requiring financial assurance against this potential risk.

Oil Terminals

This subsection reviews potential brownfield impacts from oil terminals. Oil terminal brownfield concerns cover both general potential site contaminants, as well as specific review of petroleum contamination or oil spills inland from navigable waters. For review of the impacts of oil spills on navigable waters, see the following section on oil spills. This section also reviews regulations addressing brownfield concerns and estimated cost impacts. Although pipelines generally do not fall under King County permitting jurisdiction (see Appendix B), some review of abandoning pipelines is also provided at the end of this subsection.

Research conducted for this report found that site contamination profiles (i.e., contaminant types and loads) are often reviewed in literature separate from their remediation costs – such that there are

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[245] Brown, Marilyn et al., "Solid Waste from the Operation and Decommissioning of Power Plants," Oak Ridge National Laboratory, Prepared for the US Department of Energy (DOE), ORNL/SPR-2016/774, January 5, 2017. [LINK]. Accessed 1/11/2022. Page iv (pdf page 9).

[246] Washington State Department of Health (DOH), "NARM: Naturally-Occurring and Accelerator-Produced Radioactive Material." [LINK]. Note: this is distinct from Technologically Enhanced NORM (TENORM) wastes associated with drilling and fracturing. See U.S. EPA, "TENORM: Oil and Gas Production Wastes," updated February 7, 2022. [LINK]. Accessed 2/14/2022.

[247] U.S. Nuclear Regulatory Commission (U.S. NRC), "Low-Level Waste Disposal." [LINK]. Accessed 2/14/2022.

[248] Northwest Interstate Compact, homepage. Last Updated 2019. [LINK]. Accessed 2/14/2022.

[249] Washington Administrative Code (WAC) 264-249-020; WAC last updated 12/12/16. [LINK]. Accessed 2/14/2022.

[250] U.S. NRC, "Low-Level Radioactive Waste (LLRW) Disposal Facilities," last updated May 10, 2018. [LINK]. Accessed 2/14/2022.

profiles of site contamination, and there are estimates or records of cleanup costs, but it is challenging to find the two in tandem. Unsurprisingly, petroleum and petroleum-related contaminants are common at oil terminals. Lead has been found at several sites, though lead has also been traced to historical uses of lead in products including leaded gasoline, such that lead contamination may not result from storing modern petroleum products.[251] Chlorinated solvents, heavy metals and VOCs have been found at oil terminals, but these contaminants are not universally found, and may sometimes be associated with other product storage and handling conducted at terminal sites. The profiles in Table 5 help to demonstrate the range of potential contaminants that may be found at oil terminals.

Table 5. Oil Terminal Brownfield Contamination Examples

Year, Place	Brownfield Contaminant Description
2011, New York, U.S.	A former bulk petroleum terminal in Cold Spring Harbor ceased operations in 2003, with demolition mostly completed by 2005. Site assessments began in 2002, and between 2009 and 2010, both petroleum- and lead-impacted soils were removed. The site received regulatory closure in 2011.[252]
2013, Indiana, U.S.	The former Shell Bulk Oil Terminal in Indianapolis was demolished in1996, but evaluation in 2012 found VOCs in the groundwater, for which remediation was recommended.[253]
2021, Oregon, U.S.	The former Chevron Bulk Plant in Astoria, the size of roughly two city blocks, entered into a voluntary cleanup agreement in 2004. Contaminants covered a wide range, including gasoline, diesel, petroleum-based solvents, oil and grease, BTEX, PAHs and lead. [254] Other metals are present and could be, "from waste oil, the bulk petroleum, or as naturally occurring metals that could be mobilized through changes in oxidation/reduction potential caused by petroleum decomposition." Some chlorinated solvents and total petroleum hydrocarbons (TPH) have been detected on the site before, though solvents have not been detected in recent years.[255]
2021, Washington, U.S.	The former Time Oil Company Petroleum Terminal in Seattle underwent remediation on its 10.5-acre site for petroleum hydrocarbons, chlorinated solvents, and heavy metals. The site will be redeveloped as an industrial-office campus and wet/dry marina facility. Remediation projected to finish by 2021.[256]

Petroleum products are a common contaminant for oil terminals, and for brownfield site generally. Of the estimated 450,000 brownfield sites in the U.S., roughly half or 225,000 of them are suspected to be impacted by petroleum.[257] Approximately 75 percent of these are associated with commercial land uses and 20 percent are industrial; many petroleum contamination sites are associated with leaking

[251] U.S. EPA, "Lead Remediation at Brownfields Sites," EPA 901-F-20-004, December 2020. [LINK]. Accessed 5/31/2022.
[252] Roux, "Former Bulk Petroleum Terminal; Major Petroleum Company, New York," 2011. [LINK]. Accessed 1/14/2022.
[253] Indiana Finance Authority (IFA), "Community Involvement/Relations Plan, Former Shell Bulk Oil Terminal Facility," July 2013. [LINK]
[254] BTEX refers to benzene, toluene, ethylbenzene and xylene. PAH refers to polycyclic aromatic hydrocarbons
[255] ODEQ, "Environmental Cleanup Site Information (ECSI) Database Site Summary Report - Details for Site ID 1402, Chevron Bulk Plant (Former) – Astoria," last updated January 14, 2022. [LINK]. Accessed 1/14/2022.
[256] Canterra Development Group LLC., "Former Time Oil Company, Seattle, WA." [LINK]
[257] U.S. EPA, "Petroleum Brownfields," last updated January 21, 2022. [LINK]. Accessed 1/27/2022.

underground storage tanks (USTs) at old gas stations.[258,259] This report does not review USTs in great detail, as petroleum products are typically only stored underground at retail locations (which are not reviewed in this report), whereas aboveground storage tanks (ASTs) are used for bulk crude and refined oil storage.[260]

For Washington state specifically, there are 13,700 brownfield sites with known or suspected contamination. Of these, 7,400 sites have been cleaned up and require no further action, roughly 4,000 sites are in an interim clean-up stage, and 2,300 still require additional action.[261] Between 200 to 300 new sites are discovered or reported to Ecology annually, and approximately 240 sites complete cleanup every year (and average of one cleanup every 1.5 days).[262] Approximately 85 percent of these sites are suspected of petroleum contamination.[263] This rate of cleanup indicates there is not a net reduction in brownfield sites in Washington state year-to-year, as brownfields are identified at roughly the same rate they are remediated. This also indicates that the need for brownfield funding in any given year exceeds demand.

Regulations and Remediation Funding

This subsection reviews brownfield regulation and liability as established under federal and state law and explores remediation costs; mitigation pathways when facilities undergo bankruptcy; and existing cost-coverage options with Washington state. Regulation and funding of brownfield remediation at the federal and state level includes review of the federal Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA; commonly called "Superfund"), and the Washington state Model Toxics Control Act (MTCA).[264]

Under CERCLA, brownfield contamination liability stays with the owner or operator or a property, though local governments such as King County are generally exempt from liability even when they acquire the property.[265,266] Judicial decisions for MTCA have narrowed liability further at the state level,

[258] U.S. EPA, "Opportunities for Petroleum Brownfields," EPA 510-R-11-002, July 2011. [LINK] Accessed 1/27/2022. Page 4 (pdf page 7).

[259] U.S. EPA, "Petroleum Brownfields," ibid. [LINK]. Note: Although the U.S. EPA has an Office of Underground Storage Tanks (OUST), mitigation of federally-regulated USTs are often managed by state programs, and are often ineligible for EPA Brownfields funding because they do not meet EPA funding criteria. Source: U.S. EPA, "Opportunities for Petroleum…," ibid. [LINK]. Page 3 (pdf page 6). Accessed 1/27/2022.

[260] Burclaff, Natalie, "Oil and Gas Industry: A Research Guide," Library of Congress, 2005; last updated September 2021. [LINK]. Accessed 1/27/2022.

[261] Washington State Department of Ecology (Ecology), "Model Toxics Control Act." [LINK]. Accessed 1/27/2022.

[262] Ecology, "Model Toxics Control Accounts Biennial Report of Expenditures: 2017-2019 Biennium," Publication 19-09-045, November 2019. [LINK]. Accessed 1/28/2022. Page 8 (pdf page 32)

[263] Ecology, "Model Toxics Control Accounts Biennial Report of Expenditures: 2017-2019 Biennium," Publication 19-09-045, November 2019. [LINK]. Accessed 1/28/2022. Page 8 (pdf page 32)

[264] Ecology, "Model Toxics Control Act." [LINK]. Also, U.S. EPA, "Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Federal Facilities," last updated March 28, 2022. [LINK]. Accessed 5/21/2022.

[265] U.S. EPA, "Superfund Landowner Liability Protections," last updated December 16, 2021. [LINK]. Accessed 2/14/2022.

[266] U.S. EPA, "State and Local Government Activities and Liability Protections," last updated July 13, 2021. [LINK]. Accessed 2/14/2022.

wherein operator liability requires active involvement in operational decisions at a facility.[267] As such, if an oil terminal were to result in a brownfield site at the end of facility life, the terminal owner or operator would be responsible for site cleanup; the owner and operator can be, but are not always, the same entity. However, were the owner and operator to go bankrupt such that neither would complete site remediation, the property could become abandoned. In such cases, a public entity could choose to pursue cleanup (which is discussed more later in this subsection). Most CERCLA and MTCA funds have limited availability when the liable property owner can pay for cleanup.

Although CERCLA was originally funded by petroleum and chemical producers, it has since moved to reliance on public tax funds. When CERCLA was originally enacted in 1980, it authorized excise taxes on petroleum and chemical feedstocks to pay for Superfund cleanups; when reauthorized in 1986, taxes were expanded to include chemical derivatives. Most taxes were assessed per ton of product, though there was also a Superfund tax on corporate income (previously referred to as the Corporate Environmental Income Tax) of 0.12 percent on alternative minimum taxable income in excess of $2 million.[268] However, these taxing authorities lapsed at the end of 1995, and the remaining revenues from those taxes were expended by the end of fiscal year 2003.[269] Current Superfund revenues come from a variety of sources though the primary source of funding is the U.S. Treasury, and hence the public tax base. Comparatively small amounts of additional revenues come from recouped cleanup costs borne by the federal government, fines and revenues for CERCLA violations, private voluntary settlement funds and interest on existing fund balances.[270]

While CERCLA funding can address most hazardous waste and is a primary federal regulation on brownfields, most CERCLA funding specifically cannot be used to remediate petroleum waste under the so-called "petroleum exclusion," as crude oil products are not classified as hazardous under CERCLA.[271] In contrast, the U.S. EPA's Office of Brownfields and Land Revitalization (OBLR) awards brownfields grants for the assessment and cleanup of petroleum brownfields, prioritizing relatively low risk releases. This funding stream was created through the Small Business Liability Relief and Brownfields Revitalization Act in 2002, which modified the brownfield definition under CERCLA to include potential petroleum contamination, enabling the application of some funds for petroleum remediation.[272,273] Research conducted for this report could not find much assessment of this act or the OBLR. However, the funding provided through OBLR and related programs are disproportionate

[267] Winkes, Augustus and David Weber, "Legal Whipsaw in Washington Sawmill Case: State Supreme Court Decision Fundamentally Changes the Scope of Liability Under the Model Toxics Control Act," the national Law Review, Volume 11, No. 45.June 22, 2018. [LINK].

[268] CRS, "Comprehensive Environmental Response, Compensation, and Liability Act: A Summary of Superfund Cleanup Authorities and Related Provisions of the Act," updated June 14, 2012. [LINK]. Accessed 1/27/20220. Page 20 (pdf page 24)

[269] CRS, "Comprehensive Environmental …," ibid. [LINK]. Accessed 1/27/20220. Pages 20,21 (pdf pages 24, 25)

[270] CRS, "Comprehensive Environmental …," ibid. [LINK]. Accessed 1/27/20220. Page 21 (pdf page 25)

[271] Locan, Jeffrey et. al., "Natural Gas and the Transformation of the U.S. Energy Sector," Joint Institute for Strategic Energy Analysis (JISEA), U.S. DOE National Renewable Energy Laboratory (NREL), NREL-TP-6A50-55538, November 2012. [LINK]. Page 48 (pdf page 64). Also, Kelly, Erin, "CERCLA and the Exemption of the Oil and Gas Industry," Kleinman Center for Energy Policy, BLOG, July 6, 2021. [LINK]. Accessed 2/14/2022.

[272] US.S EPA, "Petroleum Brownfields," last updated February 1, 2022 [LINK]. Accessed 2/14/2022.

[273] Johnson, Keith, "Overview of the Small Business Liability Relief and Brownfields Revitalization Act," Poyner Spruill LLP, January 1, 2004. [LINK]. Accessed 2/14/2022.

to the need, given the roughly 220,000 existing brownfields with petroleum contamination. Since 2002, the U.S. EPA has annually awarded $23 million for petroleum brownfield cleanups.[274,275]

In contrast to CERCLA, Washington state's MTCA program is still funded by taxes on petroleum and chemical producers; research conducted for this report did not find funding restrictions related to petroleum contamination. MTCA, which was passed in 1988 and became law in 1989, directs the investigation, cleanup, and prevention of hazardous substances contamination on sites in Washington State.[276] The primary MTCA revenues come from a hazardous substances tax (HST) on chemicals, pesticides, and petroleum products. Approximately 95 percent of MTCA revenues are sourced from HST funding, with the remainder coming from penalties on polluters for cleanups and Ecology oversight during the cleanup process; the HST also supports 40 percent of Ecology's base operating budget.[277,278] Per biennium, $50 million of HST revenues from petroleum products is deposited in the state Motor Vehicle Fund for transportation stormwater efforts. The remaining HST revenues from petroleum products are deposited into state MTCA accounts.[279] From 2017-2019,

- Approximately 70 percent of MTCA funds expended were on cleanup actions, whereas 30 percent were expended on investigations.
- About 69 percent of direct site-specific cleanup investments went to "highly ranked sites" based on, "the amount and type of contaminants present, and how easily contaminants could come into contact with people and the environment."[280]

Additional cleanup activities in Washington can be funded by appropriations from the state's Cleanup Settlement Account (CSA). Brownfields may also theoretically receive funding from the state Brownfields Redevelopment Trust Fund (BRTF) Account, though this funding has not been allocated so far, potentially influenced by MTCA revenue shortfalls.[281,282]

There are a range of MTCA loans and grants only available to local governments for funding, reviewed in Table 6.

Table 6. MTCA Loans and Grants

	Funding Available *per biennium*	**Award Limit**	**Match Required**
Integrated Planning[283]	1,200,000	$200,000 *single site*	None
Independent Remedial Action[284]	1,000,000	$300,000	50%

[274] Johnson, Keith, "Overview of the Small Business Liability Relief …," ibid. [LINK]. Accessed 2/14/2022.
[275] U.S. EPA, "Petroleum Brownfields," ibid. [LINK]. Accessed 2/14/2022.
[276] Ecology, "Model Toxics Control Act." [LINK]. Accessed 1/28/2022.
[277] Ecology, "Hazardous Substance Tax." [LINK]. Accessed 1/28/2022.
[278] Ecology, "Model Toxics Control Act." [LINK]. Accessed 1/28/2022.
[279] Ecology, "Hazardous Substance Tax." [LINK]. Accessed 1/28/2022.
[280] Ecology, "Model Toxics Control Accounts Biennial…," ibid. [LINK]. Accessed 1/28/2022. Page 6 (pdf page 30)
[281] Ecology, "Model Toxics Control Accounts Biennial…," ibid. [LINK]. Accessed 1/28/2022. Page 17 (pdf page 41)
[282] Ecology, "Redevelopment Opportunity Zones & Brownfield Redevelopment Trust Fund Accounts in Washington State: 2013–2017," publication No. 18-09-048, January 2018. [LINK]. Accessed 1/28/2020. Page 1 (pdf page 9)
[283] Ecology, "Integrated Planning Grants." [LINK]. Accessed 1/28/2022.
[284] Ecology, "Independent remedial action grants." [LINK]. Accessed 2/1/2022.

Table 6. MTCA Loans and Grants

	Funding Available *per biennium*	**Award Limit**	**Match Required**
Oversight Remedial Action[285]*	Varies	None	10% –50%
Area-wide Groundwater Investigation[286]	Varies	$500,000	None
Safe Drinking Water Action[287]	Varies	None	10% –50%

**Oversight remedial action can be issued in the form of both grants and loans. Other funding issued as grants.*

Both state and local governments may "acquire" a brownfield property involuntarily through bankruptcy, tax delinquency, abandonment or other circumstances. While such local governments are excused from liability for the pollution under CERCLA when the government entity did not cause its contamination, when local governments acquire a property through such actions as pursuing the property from tax delinquency, for instance, they may still become the property owners.[288,289] In such cases, governments may choose to undertake activities to address remediation to make such properties viable for resale. Were King County to "acquire" a brownfield site under such circumstances from such a fossil fuel development, these remediation activities could impose costs on the County.

Whether undertaken by a private or public entity, typical cost impacts associated with brownfield remediation are not always clear, based on research conducted for this report. Some cost reporting may only discuss the cost portion that was grant-funded, or remediation costs are bundled with redevelopment or land acquisition costs. Costs can also vary based on site characteristics, as well as the type and amount of contamination. The following examples help demonstrate the range of costs reported on in literature.

Table 7. Brownfield Remediation Cost Examples

Place	**Brownfield Cleanup Cost Description**
Rhode Island, U.S.	The cleanup of a former oil terminal at the Old State Pier property included capping and phytoremediation to transform the site into a new riverfront park. Remediation cost $2.2 million.[290,291]
Rhode Island, U.S.	The former Lincoln Lace & Braid factory had pollution from petroleum, metals, and VOCs, with pollutants spreading to the nearby river. Remediation cost $1.2 million.[292]

[285] Ecology, "Oversight remedial action grants & loans." [LINK]. Accessed 2/1/2022.
[286] Ecology, "Area-wide groundwater investigation grants." [LINK]. Accessed 1/28/2022.
[287] Ecology, "Safe drinking water action grants." [LINK]. Accessed 1/28/2022.
[288] CRS, "Comprehensive Environmental …," ibid. [LINK]. Accessed 1/27/2022. Page 14 (pdf page 18)
[289] Local Housing Solutions, "Foreclosure and disposition of tax-delinquent properties." [LINK]. Accessed 2/11/2022.
[290] Fuss & O'Neil, "Festival Pier Remediation and Redesign." [LINK]. Also, U.S. EPA, " Brownfields Success Story: Festival Pier (State Pier), Pawtucket, Rhode Island," EPA 560-A-19-005, April 2019. [LINK]. Accessed 2/14/2022.
[291] Note: Value converted from $991,000 in 2014 dollars to 2021 value using used Bureau of Labor Statistics (BLS), "CPI Inflation Calculator." [LINK]. Source: Carini, Frank and ecoRI News Staff, "Opportunity Knocks where Toxins Hide," EcoRI News, October 30, 2014. [LINK]. Accessed 2/14/2022.
[292] Note: Value converted from $991,000 in 2014 dollars to 2021 value using used Bureau of Labor Statistics (BLS), "CPI Inflation Calculator." [LINK]. Source: Carini, Frank and ecoRI News Staff, "Opportunity Knocks where Toxins Hide," EcoRI News, October 30, 2014. [LINK]. Accessed 2/14/2022.

Table 7. Brownfield Remediation Cost Examples

Place	Brownfield Cleanup Cost Description
East Hartford, Connecticut, U.S.	Approximately 30 acres previously used for petroleum storage were purchased by Goodwin College for expansion. The site had petroleum, PAH, VOC, and lead contamination. Total cost for remediation and redevelopment estimated at $198 million.[293]
Chicago, Illinois, U.S.	A 2009 fiscal analysis of Chicago brownfield redevelopment options provided pricing for various projects. The assessment cited a cost range of $660,000 to $33 million for individual projects – bundling the remediation and land assembly costs.[294]

One 2004 study of 112 sites tracked by the EPA with cost information found that the mean average cleanup cost was roughly $400,000 ($600,000 today) for all sites and $1.9 million ($2.8 million today) for industrial sites.[295] This estimate of roughly $3 million is the closest appropriate average cost estimate for an industrial brownfield site cleanup in lieu of clearer cost assessments in literature, and without additional site- and contaminant-specific information.

The following summarizes oil terminal brownfield financial risk to King County, based on the above review. Although oil terminals do present a brownfield risk, this risk is moderated by federal and state regulation that ties remediation liability to site owners and operators. In such cases, public costs are limited. However, the risk of costs falling on the public increase in cases where the owner and operator enter bankruptcy and are unable to pay for remediation. In such cases, King County would have the option of pursuing remediation of the property, though it would not be obligated to do so; other public actors such as a state agency may also pursue action. In such cases, various grants could be pursued; some of those grants (such as those associated with MTCA) are funded by taxes levied on petroleum and chemical company products, such that incurred public costs could potentially be reduced. However, MTCA funding is in high demand, and other grants or public funding may need to be secured to achieve remediation. Regardless of whether a local government or state government pursued site remediation, the remediation of a bankrupt or abandoned brownfield costs would still consume taxpayer dollars in such cases. An average estimate of this potential cost based on industrial cleanup activities is roughly $3 million. Averaged over 50 years, this would equate to $60,000 annually in costs.

In light of the above review, this report recommends advance planning around potential onsite hazards and facility decommissioning and requiring financial assurance against this potential risk. There are examples of required decommissioning planning for other fossil fuel facilities in the state that were reviewed in research conducted for this report to inform recommended legislation. For more on this topic, see the Existing Federal and State Models for Additional Regulation subsection in report section V.a.2.

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[293] Note: Value converted from $115 million in 2010 dollars to January 2022 value using BLS, "CPI Inflation Calculator." [LINK]. Source: U.S. EPA, "Opportunities for Petroleum Brownfields," ibid. [LINK]. Page 11 (pdf page 14). Accessed 2/14/2022.

[294] S.B. Friedman & Company, "Fiscal Analysis of Brownfield Redevelopment," Memo to Chicago Metropolitan Agency for Planning, March 10, 2009. [LINK]. Accessed 2/14/2022.

[295] Wilson, B.H. et al., "Remediation of Petroleum-Contaminated Sites," Presented at NGWA Remediation Conference, New Orleans, LA, November 30, 2004. [LINK]. Value conversions used BLS, "CPI Inflation Calculator." [LINK]. Accessed 2/1/2022.

Separate from the above analysis, although King County does not have permitting jurisdiction over pipelines, their transport of oil or gas to a site might be of concern as an ancillary abandoned infrastructure impact. However, current federal regulation has controls in place that should address contamination of soils or residual leaks from pipelines onsite:

> *"Abandonment of crude oil and natural gas pipelines are regulated by the Pipeline and Hazardous Materials Safety Administration, a U.S. Department of Transportation agency, under Code of Federal Regulations Title 49 Subchapter D Part 192 and 195. The rule requires that abandoned oil and gas pipelines first be "disconnected from all sources and supplies" of gas and oil and then be cleaned using pressure-enhanced pipeline draining. Usually, part of the pipeline will be removed to allow modifications and the remaining pipe is filled with grout or other inert materials. Surfaces are then restored usually with a backfill process using existing material that is not contaminated including gravel, sand, silt, clay, and soil."*[296]

iv. Oil Spills

This report section reviews the economic risk of oil spills associated with a potential new fossil fuel facility proposal in King County. This report does *not* review the impact of train derailments, as King County does not have jurisdiction to require additional financial assurances of rail lines (see Appendix B). Fuel tanker spills are *also not* assessed, as King County would not be the lead incident responder for a spill from an oil tanker (see Appendix B), though the cost of in-water spills is reviewed below to some extent due to a potential spill from a stationary source, such as from an oil terminal.

An oil spill in a navigable water body is treated differently than an oil spill on land in terms of: the potential costs and impacts of a spill; which federal administrative bodies are involved; the level of funding that may be available for clean-up; and whether that funding is sourced from the polluters or the public tax-base. As such, this section addresses oil spills on navigable waters separately from spills on land. Oil spills on land could also contribute to a brownfield impact; brownfields are addressed in the previous subsection.

Navigable Waters

This subsection first reviews the federal regulation of oil spills on navigable waters, as this process helps clarify liability, the process for cleanup of oil spills on navigable waters, and the extent of financial coverage for an oil spill in navigable waters. This subsection then discusses the costs of such spills. The following subsection helps distinguish how spills in navigable waters differ from spills on land.

Between 1989 and 1990, the Exxon Valdez Oil Spill and several additional incidents spilled 19 million gallons of oil in Alaska and along the U.S. coastline. These incidents propelled passage of the Federal Oil Pollution Act (OPA) of 1990, which modified the Federal Water Pollution Control Act, also known as the Clean Water Act.[297,298] The OPA codified that the parties responsible for oil spill pollution are liable for all costs associated with cleanup operations, though there are caveats in OPA execution (included in the below review).[299] The OPA also helped establish the framework of oil spill responses, supported by

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[296] Brown, Marilyn et al., "Solid Waste from the Operation…," ibid. [LINK]. Accessed 1/11/2022.

[297] NOAA – Office of Response and Restoration (ORR), "It Took More Than the Exxon Valdez Oil Spill to Pass the Historic Oil Pollution Act of 1990," August 18, 2015. [LINK]. Accessed 12/7/2021.

[298] U.S. EPA, "Overview of the Discharge of Oil Regulation ("Sheen Rule")," last updated January 14, 2021. [LINK]. Accessed 1/26/2022.

[299] NOAA-ORR, "Who Pays for Oil Spills," September 15, 2015. [LINK]. See also, 33 U.S.C. §2702 (1990). [LINK]. Accessed 12/7/2021.

private funding, and required oil storage facilities and vessels to submit large spill or discharge response plans to the Federal government.[300] After an oil spill incident, the following occurs:[301]

- The U.S. Coast Guard sets up an immediate funding source for federal, state, and tribal agencies that will support oil spill cleanup, to pay for agency response efforts.
    - Among these agencies, the National Oceanic and Atmospheric Administration (NOAA) provides coastal restoration, addressing environmental impacts following cleanup.
- If the polluter is deemed liable for the spill, they must reimburse all expenses to the fund established by the U.S. Coast Guard, up to their liability limit under the law of $75 million per incident.[302,303] On average, it takes four years to reach a settlement for oil spill damages. [304]
- If the polluter is not liable, or the polluter is liable and reaches its liability limit, cleanup cost coverage is provided by the Oil Spill Liability Trust Fund, accrued primarily from taxes on domestic oil production and imports.[305]
    - The National Pollution Funds Center (NPFC, under the U.S. Coast Guard) was created to manage the Oil Spill Liability Trust Fund.[306]
        - Although the U.S. Coast Guard has noted that the NPFC also appropriates funding to various federal agencies supporting administration of the OPA, the Oil Spill Liability Trust Fund cannot cover employee salaries or operating expenses according to 2002 to 2005 changes in allowed funding allocations.[307,308]
        - As such, salaries, expenses, and training of emergency response staff, restoration experts, and administrative staff may not be fully covered by the federal funding program; cost coverage of these expenses typically relies on the public tax base.[309]

OPA limits Oil Spill Liability Trust Fund expenditures to $1 billion per incident, of which no more than $500 million may be paid for natural resource damages; there is also a $633 million per-incident limit when incidents originate from onshore facilities, and a $137 million per-incident limit for offshore facilities.[310]

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[300] U.S. Environmental Protection Agency (EPA), "Summary of the Oil Pollution Act," last updated September 28, 2021. [LINK]. Accessed 12/7/2021.

[301] NOAA-ORR, "Who Pays for Oil Spills," ibid. [LINK]. Accessed 12/7/2021.

[302] NOAA-ORR, "Who Pays for Oil Spills," ibid. [LINK]. Accessed 12/7/2021.

[303] King, Rawle O., "Deepwater Horizon Oil Spill Disaster: Risk, Recovery, and Insurance Implications," Congressional Research Service (CRS), July 12, 2010. [LINK]. Accessed 12/7/2021. Page ii.

[304] NOAA-ORR, "Who Pays for Oil Spills," ibid. [LINK]. Accessed 12/7/2021.

[305] NOAA-ORR, "Who Pays for Oil Spills," ibid. [LINK]. Accessed 12/7/2021. Note: additional fund revenues come from, "interest earned on Treasury Securities held by the Fund, successful cost recoveries, and fines and penalties." Source: U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019: Report to Congress," February 25, 2020. [LINK]. Accessed 12/7/21. Page 12.

[306] U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019…," ibid. [LINK]. Accessed 12/7/2021. Page 2.

[307] U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019…," Ibid. [LINK]. Accessed 12/7/2021. Page 2.

[308] U.S. Government Accountability Office (GAO), "U.S. Coast Guard National Pollution Funds Center: Improvements Are Needed in Internal Control Over Disbursements," GAO-04-340R, January 13, 2004. [LINK]. Accessed 12/7/2021.

[309] NOAA-ORR, "Who Pays for Oil Spills," ibid. [LINK]Accessed 12/7/2021.

[310] U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019…," Ibid. [LINK]. Accessed 12/7/2021. Page 2, 4.

As established previously in this report, the only fossil fuel facility that could be developed in unincorporated King County that would handle large volumes of fossil-based oils, and fall under County permitting jurisdiction, would be an oil terminal, considered an "onshore facility" to federal regulators.

Research conducted for this report indicates that federal financial assurance mechanisms are sufficient to address the costs of an onshore facility oil spill, such as from an oil terminal. Oil spill data from the past 30 years since OPA's passage indicated that the highest onshore facility cost was approximately $43 million in 2019 dollars, which is below the federal $633 million liability limit for this facility type.[311]

It should be noted that Coast Guard reporting did not include the $1.2 billion Enbridge Energy pipeline spill in this average, as it is a high-cost outlier in incident costs.[312] Compared to other onshore oil spill incidents, the Enbridge pipeline event was roughly 28 times as expensive as the next most-expensive incident in onshore oil spill history. This exclusion is also appropriate for the purposes of this report because oil pipelines are a facility type that would not fall under King County permitting jurisdiction. However, details of the spill are provided to help understand the potential ceiling of costs from such an incident.

In 2010 an oil pipeline ruptured over a wetland near Marshall, Michigan, releasing over one million gallons of oil, blackening almost 36 miles of Kalamazoo River.[313,314] Considered the largest inland oil spill in U.S. history, the incident necessitated the permanent relocation of 150 families, and cost Canada-based Enbridge $1.21 billion in cleanup costs, exceeding the $650 million insurance policy it had for the pipeline in case of rupture.[315,316] This includes, "$551.6 million spent on response personnel and equipment, $227 million on environmental consultants and $429.4 million on professional, regulatory, and other costs. The company estimates it has $219 million in spill costs yet-to-be-paid." [317] Six years after the incident, Enbridge Energy entered into a consent decree settlement in which it did not admit negligence, but did pay $177 million in fines, including $61 million in penalty fees paid directly into the Oil Spill Liability Trust Fund.[318]

It should also be noted that Washington state has additional financial responsibility requirements for oil spills under Chapter 88.40 RCW and Chapter 317-50 Washington Administrative Code (WAC).[319] This includes requirements for onshore or offshore facilities, though specific amounts are not identified; Ecology has leeway to determine the amount based on the site, operations, and projected spill impacts.[320] Comparing the potential additional fiscal coverage of state regulation was not explored further given the determination of probable sufficiency for financial responsibility under federal rule.

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[311] U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019…," Ibid. [LINK]. Accessed 12/7/2021. Page 6.
[312] U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019…," Ibid. [LINK]. Accessed 12/7/21. Page 6.
[313] Sabin Center for Climate Change Law, "Kalamazoo River Oil Spill," Columbia Law School, 2015. [LINK]. Accessed 1/13/2022.
[314] McGowan, Elizabeth and Lisa Song, "The Dilbit Disaster: Inside The Biggest Oil Spill You've Never Heard Of, Part 1," ICN, June 26, 2012. [LINK]. Accessed 1/13/2022.
[315] McGowan, Elizabeth and Lisa Song, "The Dilbit Disaster…," ibid. [LINK]. Accessed 1/13/2022.
[316] Devereaux, Brad, "Kalamazoo River oil spill timeline after 6 years, billion-plus dollars spent," Michigan Live, May 21, 2019. [LINK]
[317] Ellison, Garret, "New Price Tag for Kalamazoo River oil spill cleanup: Enbridge says $1.21 billion," Michigan Live, April 3, 2019. [LINK]. Accessed 1/13/2022.
[318] Lynch, Jim, "Enbridge to pay $177M for oil spills," Detroit News, July 20, 2016. [LINK]
[319] RCW Chapter 88.40 [LINK] and WAC Chapter 317-50 [LINK]. Accessed 12/8/2021
[320] ECY, "Financial responsibility for oil spills." [LINK]. See also RCW 88.40.030. [LINK]. Accessed 12/8/2021.

Washington state also has oil spill financial responsibility requirements for vessels based on vessel type, size and the volume of fuel or cargo.[321] These were not reviewed to evaluate the level of added financial responsibility compared to federal requirements, if any, as King County does not have permitting jurisdiction over such vessels.

Lastly, it should be noted that the above spill regulations would apply to wide range of petroleum-based products that could be stored at an oil terminal; although not explored in this report, these regulations also apply to spills of non-petroleum oils. OPA requires that spills be reported whenever a discharge:

- Causes a sheen or discoloration on the surface of a waterbody;
- Violates applicable water quality standards; and
- Causes a "sludge or emulsion to be deposited beneath the surface of the water or on adjoining shorelines."[322]

On Land

This subsection focuses on the regulatory distinctions between oil spills on water versus oil spills that are inland (i.e., not along the coastline) of navigable waters. For a more in-depth review of such inland oil spills, including their impact and cost, see the previous report section on brownfields.

Unfortunately, the jurisdiction of the Oil Protection Act (OPA) and the related Oil Spill Liability Trust Fund (OLSTF) can sometimes be challenging to differentiate from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly called the Superfund) when it comes to oil spills.[323] The primary difference is that the OPA/OLSTF applies to spills of oils in navigable U.S. waters and the adjoining shorelines, and CERCLA applies to the cleanup of multiple types of hazardous wastes, typically with on-land sites.[324,325] CERCLA funds also cannot be used to clean up petroleum wastes by itself due to federal exclusions of petroleum from consideration as a "hazardous waste," and can only be applied if the petroleum is mixed with other wastes classified as hazardous.[326]

Although not comprehensive, Table 8 below summarizes some of the differences between the OPA and related OLSTF administered by the U.S. Coast Guard, and the CERCLA and related Superfund administered by the U.S EPA.

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[321] ECY, "Financial responsibility for oil spills." [LINK]. Accessed 12/8/2021.

[322] U.S. EPA, "Overview of the Discharge of Oil Regulation ("Sheen Rule")," last updated January 14, 2021. [LINK]. Accessed 1/26/2022.

[323] Orlando, Michael, "Maritime Pollution: Mixing OPA and CERCLA Makes for Foul Waters," International Risk Management Institute, January 2003. [LINK]. Accessed 1/14/2022.

[324] U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019…," ibid. [LINK]. Accessed 12/7/21. Page 2 (pdf page 5).

[325] U.S. EPA, "Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Federal Facilities," last updated February 16, 2021. [LINK]. Accessed 1/26/2022.

[326] CRS, "Comprehensive Environmental Response, Compensation, and Liability Act: A Summary of Superfund Cleanup Authorities and Related Provisions of the Act," updated June 14, 2012. [LINK]. Accessed 1/27/20220. Page 5 (pdf page 9)

Table 8. How are OPA and the OSLTF Different from CERCLA and Superfund?

	OPA & OSLTF	CERCLA & Superfund
Year Law Enacted	1990	1980
Type of Pollution Covered	Oil spills & threats of spills into U.S. navigable waters; usually sudden events requiring immediate response.	Hazardous substances, pollutants & contaminants; often result of newly discovered past pollution with response requiring extensive planning & public participation.
Fund Administrator	NPFC, Coast Guard	EPA (NPFC administers only the Coast Guard use of Superfund resources)
Uses of Fund	Spill response and cleanup Claims for removal costs and damages, including natural resource damages Appropriations by Congress	Short-term removals when prompt response is required Long-term remedial response actions Appropriations by Congress
Source of Funds	Per-barrel oil tax Transfers from other funds Cost recovery Interest on Fund balance Fines & penalties	Chemical & petroleum industries tax (expired 1986) Cost recovery Annual Congressional appropriations

This table is substantially identical to a table provided by the U.S. Coast Guards' National Pollution Funds Center (NPFC) on its OPA Frequently Asked Questions webpage.[327] Also, as noted previously, see the previous report subsection on brownfields – oil terminals for additional review of the impact and cost of inland oil spills and petroleum contamination.

b. Economic Risk Assessment for Climate Change

Greenhouse gas emissions from human activities are rapidly increasing the amount of heat-trapping greenhouse gases in the atmosphere, driving changes in the global climate system that have wide-ranging impacts for King County government, local communities, and the Puget Sound region. This section reviews how climate change has affected, and is anticipated to affect, the region; considerations in developing a climate change economic risk assessment; and how a climate change economic risk assessment could potentially intersect with FFRB legislation.

Climate change is already changing the Pacific Northwest region. Since 1900, average annual air temperature in the Puget Sound region has increased 1.3 degrees Fahrenheit. Heavy rain events are getting heavier while there is a long-term decline in snow and ice in the Cascades and Olympic mountains. The sea level is rising and ocean chemistry is changing in ways that are harmful to local marine species like shellfish and juvenile salmon.[328] Studies have shown that crop pests and disease are migrating 1.6 miles annually from current territories, following the rate of climate warming.[329] Climate change can also exacerbate pest outbreaks – for instance, the vegetable crop pest Fall Armyworm has

[327] U.S. Coast Guard (US CG), " Oil Pollution Act (OPA) Frequently Asked Questions," ~2017. [LINK]. Accessed 1/14/2022.
[328] King County, "2020 Strategic Climate Action Plan,"(SCAP) May 2021. [LINK]. Page 29. Accessed 5/21/2022.
[329] Barford, Eliot, "Crop pests advancing with global warming," Nature, September 1, 2013. [LINK]. Accessed 5/21/2022

had increased outbreaks influenced by a warming climate.[330] Exotic diseases are of increasing concern due to climate change influencing vector migration, such as the zika virus, dengue fever, malaria, and Lyme disease.[331] West Nile virus, first detected in the US in 1999, is now the most common mosquito-borne disease in the US, with a warming climate linked to accelerated mosquito development, biting rates, and disease incubation.[332] Although these trends are more evident nationally, they are anticipated to be seen more locally as climate change progresses.[333] Wildfire smoke events from unusually large and damaging Northwest wildfires are also becoming more prevalent. In June 2020, the Pacific Northwest experienced an unprecedented heat wave that killed 33 people in King County and 100 statewide.[334] Early research found that the event would have been "virtually impossible" without climate change.[335]

Some climate change impacts will emerge over time as a result of evolving climate conditions, such as warming temperatures, rising sea levels, and declining snowpack. Other impacts will be experienced more suddenly in the form of extreme events such as flooding, heat waves, wildfire or drought. While these types of extreme events are not new to the Puget Sound region, climate change affects the frequency, intensity, and duration of extreme events, creating new challenges for how to manage risks, including:

- Damage to public and private infrastructure
- Economic disruption
- Increased demands on emergency services
- Reduced asset life and/or performance
- Disruption to public services
- Increased risks to public health
- Disproportionate impacts on frontline communities
- Increased challenges meeting environmental goals
- Changes in capital finance and insurance markets

The figures in Appendix G help illustrate some of the broader environmental trends anticipated in the region resulting from climate change, and the interconnected natural and constructed systems that will be impacted by an increasingly changing climate.

This report does not conduct a cost assessment of climate change impacts on King County finances, its economy, and County households over the next 50 years associated with the above categories of risks as this task would require expertise and resources beyond current staffing and funding allocations. Assessing the costs of climate-related impacts is a new and complex field of economics that has largely

[330] Anders, Caroline, "Battalions of armyworms are chomping up fields across the nation — sometimes overnight," Washington Post, September 17, 2021. [LINK]. Also, Gerdeman, Beverly, "PEST ALERT: Armyworm Outbreaks in Western Washington," Washington State University, Wahtcom Ag Monthly, Volume 6 Issue 9. [LINK]. Accessed 5/21/2022

[331] Climate Nexus, "Climate Risk and Spread of Vector-Borne Disease." [LINK]. Accessed 5/21/2022.

[332] U.S. EPA, "Climate Change Indicators: West Nile Virus," July 21, 2021. [LINK]. Accessed 5/21/2022.

[333] King County, "Blueprint for Addressing Climate Change and Health," 2020. [LINK]. Accessed 5/21/2022. Page 13 (pdf page 16)

[334] State total for June 26-July 2. See Washington State Dept of Health (DOH), "Heat Wave 2021." [LINK]. Accessed 2/10/2022.

[335] See Philip et al. (in review)., "Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021," Earth System Dynamics preprint esd-2021-30, entered review November 12, 2021. [LINK]. Accessed 2/10/2022.

been focused, to date, on global- and national-scale impacts. The complexity of assessing King County cost impacts from climate change would require more time, technical expertise, and financial resources than allowed for by current project parameters. Conducting such a cost estimate without appropriate expertise may also raise future legal issues. Were King County to seek damages or financial compensation from GHG emitters at a later date to address the costs of climate change, an incomplete cost impact estimate (or an estimate that was too low) could negatively impact the success of future legal action. However, to help guide future work on this issue, King County collaborated with the UW Climate Impacts Group (CIG) to review the key concepts and foundational science to studying the economics of climate change, and to identify proven methods for economic valuations of climate impacts on a local government scale.

The CIG study noted that economic assessments have primarily been used to weigh and compare *relative* risk across varying climate impacts, geographies and/or socioeconomic contexts. In that sense, the assessments function as a decision-support tool for understanding which assets and communities are most vulnerable *relative to other assets and communities* and for allocating resources accordingly, rather than providing definitive climate change cost estimates. The CIG study also identified a range of scientific, economic, ethical, and methodological decisions that require careful consideration prior to undertaking a climate change economic risk assessment. These decisions include:

- The economic assessment's purpose;
- The organization's risk tolerance and risk assessment parameters;
- Which climate scenarios will be used as the basis for assessing future risk;
- How the organization wants to handle assumptions about socioeconomic factors such as population growth, rate of urbanization, changes in the built environment and economic development;
- What types of costs are relevant the assessment (e.g., direct versus indirect costs; market impacts versus non-market impacts) and what valuation methods will be used to define these costs; and
- What discount rate(s) will be used to understand the value of future costs and benefits relative to today.

The resulting report of this effort is included in Appendix K.

Although this report does not conduct a cost assessment of climate change impacts, other recent local assessments help illustrate the potential scale of some climate-related costs. In November 2021, the City of Tacoma released a new Climate Action Plan that included a high-level assessment of the economic costs of climate change impacts for the City of Tacoma and the benefits and costs of different adaptation actions. Assessed benefits included impacts to human life, infrastructure and property, assessed costs included staffing, materials, capital infrastructure, plan development, and technology. [336] Using a discount rate of 2.5 percent, the assessment found that the cost of inaction would result in over $3 billion in damages by 2050 (in the next 30 years). King County will be meeting with Tacoma staff and their consulting teams in 2022 to learn more about the study parameters, cost, and limits.

In addition to financial assurance options discussed previously in the report body that apply to discrete fossil fuel facility risks, another option for requiring a financial assurance or FFRB would be to develop a natural hazard risk fund. Such a fund could be established to receive an assessed surcharge on large

[336] City of Tacoma, "2030 Climate Action Plan - City of Tacoma," last updated December 2021. [LINK]. Accessed 5/21/2020. Page 16

industrial facility operations against GHGs emitted based on the projected costs of climate change and its associated hazards. However, Washington has recently passed a range of statewide legislation that may pre-empt pursuit of an FFRB-natural hazard risk fund for climate change for large emitters. Specifically, the Climate Commitment Act (CCA) contains two features that affect consideration of establishing a natural hazard risk fund, namely that the CCA:

- Creates a cap-and-trade system to regulate the largest GHG-emitting entities in the state, or those emitting 25,000 metric tons of GHGs per year starting in 2023, which mirrors the GHG reporting threshold to the federal government.[337,338] The CCA is estimated to regulate 75 percent of Washington state GHG emissions.[339]
- Disallows local permitting agencies from requiring additional GHG mitigation from covered entities if they comply with the CCA.[340]

Accordingly, this report does not recommend instituting a natural hazard risk fund that assesses a surcharge on large GHG-emitting entities in King County at this time.

2. Financial Assurance Mechanisms

Workplan Action 20 required an evaluation of the adequacy of existing financial assurance mechanisms in reducing the County's economic and financial risks associated with fossil fuel facilities and related uses, and climate change. This section first reviews the current status of financial assurances in the existing King County Code (K.C.C.), and then discusses models for requiring additional financial assurances from fossil fuel facilities.

Existing King County Financial Assurance Requirements for Fossil Fuel Facilities

K.C.C. Title 27A Financial Guarantees contains mechanisms for obtaining financial assurances before initiating potentially dangerous development activity. K.C.C. Title 27A establishes the following:

- Financial guarantees include funds, cash deposits, surety bonds or other approved mechanisms "to ensure timely and proper completion of improvements, to ensure compliance with the King County Code, and/or to warranty materials, quality of work of the improvements and design." Financial guarantees also include performance, maintenance, and defect guarantees.[341]
- Financial guarantees primarily apply to construction sites and building development, ensuring that requirements for those sites and buildings are completed according to code.
    - K.C.C. Title 27A requires financial guarantees to improvement types regulated by the following K.C.C. Titles:
        - Title 9 Surface Water Management

[337] WA Legislature, "Final Bill Report E2SSB 5126," Ibid. [LINK]. Pages 1, 6. Also see, "Session Law. Certification of Enrollment: Engrossed Second Substitute Senate Bill 5126," Filed May 18, 2021. [LINK]. Accessed 6/15/2021. Page 24, Section 10 (a).

[338] United States (U.S.) Department of Energy (DOE), "U.S. EPA Releases Greenhouse Gas Reporting Rules." [LINK]. Accessed 3/28/2022.

[339] Ecology, "Chapter 173-446 WAC – Climate Commitment Act Program Rulemaking," Presentation, November 8, 2021. [LINK]. Slide 11. Accessed 5/21/2022.

[340] Washington State Legislature, "Session Law. Certification of Enrollment: Engrossed Second Substitute Senate Bill 5126," Filed May 18, 2021. [LINK]. Accessed 5/21/2022. Page 54 (pdf page 55). For additional review of recent Washington State regulations affecting this issue, see the report generated under Comprehensive Plan Workplan Action 21: Greenhouse Gas Mitigation, transmitted to the County Council in June 2022, concurrent with this report.

[341] K.C.C. 27A.20.050. [LINK]. Accessed 12/6/2021.

        - Title 14 Roads and Bridges
        - Title 16 Building and Construction Standards
        - Title 19A Land Segregation[342]
        - Title 21A Zoning
    - In addition to the above titles, research conducted for this report also reviewed the below K.C.C Titles for matches to the terms "bond," "fiscal" and finan" (the root for finance and financial), including:
        - Title 2 Administration
        - Title 2A Administration
        - Title 4A Revenue and Financial Regulation
        - Title 20 Planning
        - Title 23 Code Compliance
        - Title 27 Development Permit Fees

Review of these K.C.C. titles identified multiple financial guarantee requirements for private development projects for construction and site remediation, but all K.C.C. Title 27A-related requirements were tied to completing building and site development features. There were no specific financial guarantees listed for development of fossil fuel facilities, or additional financial guarantees or fiscal assurances for fossil fuel facility operations following the completion of construction (see Appendix D for identified financial guarantee requirements for the construction of development projects that can be privately funded).

It should be noted that there are several non-fiscal requirements for new, modified or expanded fossil fuel facilities that include extensive analysis, public engagement and location requirements, including minimum distances from schools and places of assembly.[343]

It should also be noted that there are financial requirements in the K.C.C. that apply outside of the building construction process, but these also do not apply to fossil fuel facility operations, including:

- Operational requirements: K.C.C Title 6 Business Licenses and Regulations require some financial assurances to obtain and maintain a business license, such as a required $10,000 surety bond for businesses operating novelty amusement devices (K.C.C 6.04.060) and private security businesses (K.C.C 6.24.190; 6.24.210); a conditional bond amount for closing out sales (K.C.C. 6.16.100); and a $1,000 bond for heating, air-conditioning, and ventilation system installers (K.C.C. 6.32.030).[344]
- Event requirements: K.C.C Title 17 Fire Code includes requirements for a permitted event (the public display of fireworks) of providing a bond or certificate of insurance for $1 million before a fireworks permit is issued (K.C.C. 17.11.040).[345]

[342] Codified in 1995, K.C.C. 27A.30.010 addresses various titles or their "successors" and cites Title 19; Per Ordinance 13694 [LINK], K.C.C. Title 19A succeeds Title 19. See K.C.C. Chapter 27A.30 [LINK]. Accessed 12/6/2021.

[343] K.C.C. 21A.08.100 [LINK]. Accessed 12/7/2021.

[344] K.C.C. Chapter 6.04 [LINK]; K.C.C. Chapter 6.24 [LINK]; K.C.C. Chapter 6.16 [LINK]; and K.C.C. Chapter 6.32 [LINK]. Accessed 12/6/2021.

[345] K.C.C. 17.11.040 [LINK]. Accessed 12/6/2021.

As such, current King County regulations do not provide additional financial assurances for the operation of fossil fuel facilities, or catastrophic events occurring therein, beyond what is required by state or federal law.

Existing Federal and State Models for Additional Regulation

Although King County does not require additional financial assurances specifically from fossil fuel operators, there are state regulations on financial assurances for fossil fuel facilities impacts that were reviewed in research conducted for this report and that inform report recommendations. These serve as models for how to potentially develop local requirements of financial assurances against the facility impacts explored in this report, such as the risk from explosions, and what to potentially require in remediation planning for potential hazardous substance contamination, such as might occur in brownfields.

Washington state requires proof of financial responsibility for multiple types of fossil fuel operations, such as requiring proof that a responsibly party is able to pay for the costs from:

- An oil spill from barges and commercial vessels as well as onshore and offshore facilities,[346]
- An oil spill or accident from railroad transports of crude oil,[347] and
- Decommissioning, closure, and post-closure of coal-fired electric generation facilities.[348]

Although not researched as thoroughly for this report, there are also requirements for proof of financial responsibility at the federal level for various fossil fuel facilities, including against oil spills.[349]

The above regulatory examples have both shared and unique attributes that informed report recommendations on how the County should address requiring financial assurance against fossil fuel facility impacts. These include the following:

- The above regulatory frameworks do not impose hard limits on the types of financial assurance mechanisms that fossil fuel facility operators may submit.
    - Some do not provide any examples of the types of financial assurances that will be accepted, such as in decommissioning of coal-fired electric generation facilities.[350]
    - Some, such as assurances against oil spills from barges, list specific types of financial assurances that will be accepted, but then provide allowance for other types:

        "Financial responsibility required by this chapter may be established by any one of, or a combination of, the following methods acceptable to the department of ecology: (1) Evidence of insurance; (2) surety bonds; (3) qualification as a self-insurer; or (4) other evidence of financial responsibility."[351]

[346] Eecology, "Financial responsibility for oil spills." [LINK]. Accessed 2/8/2022.
[347] See RCW 81.04.560. [LINK]. Accessed 2/8/2022.
[348] See RCW 80.82.010. [LINK]. Accessed 2/8/2022.
[349] Various entities in oil production are required to provide proof of financial responsibility under different sections of the federal code. For instance, offshore facilities are required to provide such proof under U.S. Code of Federal Regulations, Title 49, Subtitle B, Chapter 1, Subchapter B, Part 191. [LINK]. Accessed 2/8/2022.
[349] Note: this threshold was $50,000 until 2021.
[350] See RCW 80.82.010 (1)(b). [LINK]. Accessed 2/8/2022.
[351] See RCW 88.40.030. [LINK]. Note: Washington State financial assurances for nuclear energy facilities also list a variety of accepted financial assurance mechanisms; see RCW 70A.388.080. [LINK]. Accessed 2/8/2022.

- Some regulatory examples list factors that must be considered in a determining the amount of financial responsibility required, such as assurances against oil spills from barges:

  "An onshore or offshore facility shall demonstrate financial responsibility in an amount determined by the department as necessary to compensate the state and affected counties and cities for damages... The department shall consider such matters as the amount of oil that could be spilled into the navigable waters from the facility, the cost of cleaning up the spilled oil, the frequency of operations at the facility, the damages that could result from the spill and the commercial availability and affordability of financial responsibility."[352]

- Some regulatory examples reviewed set the amount of financial responsibility required as a flat rate, whereas others set the financial responsibility required through an assessment method.
  - Washington state directly sets the amount of financial coverage that water vessels are required to obtain, and for which their operators must provide documentation. For instance, barges carrying hazardous substances must have $5 million of financial coverage, or $300 per gross ton.[353]
  - In contrast, coal-fired electric generation facilities under other applicable closure requirements must provide financial assurance against closure costs based on a detailed decommissioning plan.[354]

The above assessment provided the guidelines that informed the development of additional financial assurance legislation per the following:

- Does not need to stipulate the full list of specific types of financial assurance mechanisms that fossil fuel facility operators may submit, though some financial assurance mechanisms may be disallowed (see more on this topic in the following subsection).
- Shall list factors that must be considered in determining the amount of financial responsibility required, which will help clarify legislative intent for both developers and the County in implementing proposed regulations.
- Shall require financial responsibility determination through an assessment method, given the breadth of possible impacts considered in this report.
  - For financial assurances against the impacts of VCEs, require certification or accreditation or those conducting the VCE assessment, as well as third-party review to ensure assessment accuracy.
  - For financial assurances against the risk of hazardous substance contamination that could result in brownfields, require a decommissioning plan with contamination cost estimates for remediation by a third party.

See report section B for more information on proposed legislation related to the recommendations in this report.

Self-Assurances

Review of the practices of self-bonding and self-insurance (or, "self-assurances") in other areas of the fossil fuel industry indicate they may not be suitable forms of financial assurance to cover the risks identified in this report. Additionally, explosions and brownfield contamination carry more risk of

[352] See RCW 88.40.025. [LINK]. Accessed 2/8/2022.
[353] See RCW 88.40.020 (1). [LINK]. Accessed 2/8/2022.
[354] See RCW 80.82.010 (1). [LINK]. Accessed 2/8/2022.

requiring public taxpayer funds to mitigate when a fossil fuel industry enters *bankruptcy*, and self-assurances become unreliable during bankruptcy. These themes are explored in this subsection in how they have affected, and been affected by, other sectors of fossil fuel industry.

The practice of self-bonding in the coal mining industry underwent a transformation from 2016 to 2018, after three of the biggest and "healthiest" coal mine operators in Wyoming's Powder River Basin (PRB) underwent insolvency.[355] The PRB is the source of 50 percent of the coal produced in the U.S. from 16 mines; four companies collectively own over half the mines, with Peabody and Arch Coal producing the most coal in the PRB as of 2019.[356] Peabody and Arch Coal were also among the companies that underwent bankruptcy in 2016 with substantial debt backed by self-bonding.[357] One article at the time noted that, "Of the roughly $2 billion in future cleanup costs facing Peabody Energy Corp, $1.47 billion of that is self-bonded and has no concrete backing."[358]

Self-bonding had been (and still is) allowed when companies can prove they are finically "healthy," allowing company operation without posting surety or collateral.[359,360]

> *"For decades, US coal companies deemed financially healthy were allowed to provide their own guarantees that they could cover the costs of returning mined land to its natural state. This assurance was based on the value of the business, meaning it could disappear if the company went bankrupt and forfeited its permits.*
>
> *"Self-bonds were considered riskier after the downturn of the coal industry. A company puts up its own assets in a self-bond to cover reclamation costs. Should the company default, those assets may no longer be available to pay for reclamation leaving a possible environmental hazard," Tarah Kesterson, the Virginia Department of Mines, Minerals and Energy's spokesperson, said in a statement. This could leave taxpayers with the financial burden of clean-up.*
>
> *At the time of the 2015-16 crash, about $3.86 billion around the industry was held in self-bonds. Over $2.4bn of this was held by companies in bankruptcy."*[361]

For coal mining, states are the regulating entities that ultimately approve or deny bonds, though in 2016 the federal Department of the Interior advised halting self-bonding for coal mining.[362,363] As PRB coal mines began to exit bankruptcy, the Wyoming state Department of Environmental quality prohibited their continued self-bonding and proposed new rules to restrict its application.[364] Specifically for

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[355] Olalde, Mark, "Crackdown on coal mine 'self-bonds' stalls under Trump," Climate Home News, March 15, 2018. [LINK]. Accessed 4/29/22.

[356] Berry, Rosalyn and Mark Morey, "Sixteen Mines in the Powder River Basin Produce 43% of U.S. Coal," EIA, August 26, 2019. [LINK]. Accessed 4/29/22.

[357] Williams-Derry, Clark, "The Collapse of Coal Self-Bonding," Sightline, March 20, 2018. [LINK]. Accessed 4/29/2022.

[358] Rucker, Patrick, "Struggling coal companies must face their cleanup costs: U.S. official," Reuters, February 23 2016. [LINK]. Accessed 4/29/22.

[359] Olalde, Mark, "Crackdown on coal mine …," Ibid. [LINK]. Accessed 4/29/22.

[360] Foley Hein, Jayni, et. al, "Self-Bonding in an Era of Coal Bankruptcy," Institute for Policy Integrity, August 3, 2016. [LINK]. Accessed 4/29/22.

[361] Olalde, Mark, "Crackdown on coal mine …," Ibid. [LINK]. Accessed 4/29/22.

[362] Olalde, Mark, "Crackdown on coal mine …," Ibid. [LINK]. Accessed 4/29/22.

[363] Rodriquez, Carlos, "DOI Advises States to Halt Coal Self-Bonding Practices," Law360, August 10, 2016. [LINK]. Accessed 4/29/2022.

[364] Rucker, Patrick, "Struggling coal companies…," Ibid. [LINK]. Accessed 4/29/22.

Peabody Energy Corp., the $1.47 billion it held in self-bonds in 2016 had dwindled to $214 million by 2018, with a further $105 million due to be converted out of self-bonding at the time.[365]

One quote summarizes the concerns with self-bonding not just for the coal mine industry, but for the fossil fuel industry generally when bankruptcy is concerned.

> *"Scott Simonton, a professor and coordinator of Marshall University's environmental science programme, researches coal bonding systems and calls self-bonds "a weakness in the system".*
>
> *"You want bonds for catastrophic events, failures in the system, bankruptcies, somebody walking away. Self-bonding just leaves much of the control with the people who could be going anyway," he said. "*[366]

In contrast to the clear concerns around self-bonding, there are mixed concerns with self-insurance, apparently due to two varying definitions in the literature. The first is its typical definition as approached by federal reviewers, where self-insurance is considered synonymous with self-bonding:

> *"In December 2017, EPA's Office of Inspector General reported that the Agency did not have the ability to determine if a company's self-insurance is valid and adequate to ensure that the cleanup of waste sites under the Comprehensive Environmental Response, Compensation, and Recovery Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA) could be completed without requiring taxpayer dollars. Now, the U.S. Government Accountability Office (GAO) reports that corporate self-insurance, **also called self-bonding**, as a tool to assure remediation of surface and underground coal mines carries too many uncertainties… self-bonding occurs under the federal Surface Mining Control and Reclamation Act (SMCRA) and is authorized by the Department of the Interior's (DOI) Office of Surface Mining Reclamation and Enforcement (OSMRE) or states authorized by the OSMRE to run the SMCRA program."*[367]
> (Emphasis added)

This terminology is potentially due to the self-bonding instrument name, commonly called a "self-insurers bond."[368]

Another definition of self-insurance is, rather than using assets as collateral, a corporate entity sets aside funds against specific risks of damages.[369] This definition of self-insurance has not drawn overt concern thus far in the same manner as the equivalent of self-bonding. Instead, it is listed as a form of insurance on which fossil fuel industries may need to increasingly rely due to increased resistance by some members of the insurance industry to provide risk coverage for new or existing fossil fuel facilities.[370]

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[365] Olalde, Mark, "Crackdown on coal mine …," Ibid. [LINK]. Accessed 4/29/22.
[366] Olalde, Mark, "Crackdown on coal mine …," Ibid. [LINK]. Accessed 4/29/22.
[367] Schillaci, William, "GAO Urging Congress to End Self-Insurance for Coal Mines," Environmental, Health, and Safety (EHS) Daily Advisor, May 15, 2018. [LINK]. Accessed 4/29/2022.
[368] International Risk management Institute (IRMI), "Self-Insurer's Bond," Glossary. [LINK]. Accessed 4/29/2022.
[369] U.S. DOE, "Insurance as a Risk Management Instrument for Energy Infrastructure Security and Resilience," March 2013. [LINK]. Accessed 4/29/22. Page 4 (pdf page 12).
[370] Chief Risk Officers (CRO) Frodum, "The Heat is On. Insurability and Resilience in a Changing Climate," January 2019. [LINK]. Page 25. Also, Bosshard, Peter, "Self-insuring coal: a desperate ploy by an industry without a future," Insure Our Future Blog," August 13, 2021. [LINK] Accessed 4/29/22.

Based on the above, this report recommends that self-bonding not be accepted as a financial assurance mechanism for potential fossil fuel facility costs, but that self-insurance (as defined by the immediately preceding paragraph) be allowed.

The direction called for in Workplan Action 20 included reviewing potential financial assurance mechanisms and the maximum likely risk coverage of each. As frameworks in other fossil fuel regulations, such as federal and state regulation on oil spills (reviewed in the previous subsection), do not impose hard limits on the types of financial assurance mechanisms employed, the existing maximum coverage levels are not included in this report. Though, in light of the above discussion, this report recommends not allowing self-bonding (or self-insurance in cases where it is synonymous with self-bonding) as an acceptable form of financial coverage to cover the risks identified in this report. A summary of other types of financial assurance mechanisms is provided in Appendix F.

B. Legislation that Implements the Recommendations of the Fossil Fuel Risk Bond Evaluation

Based on the analysis in this report, it is recommended that King County enact amendments to the King County Code requiring fossil fuel facilities to provide proof of adequate financial responsibility to cover the costs of a worst-case facility VCE and remediation of potential site contamination during its decommissioning. As directed in Workplan Action 20, a proposed ordinance implementing this recommendation has been transmitted by the Executive to the Council concurrent with this report.

The proposed legislation addresses the following:

- Proof of adequate financial responsibility is required to be provided prior to facility construction and at five-year intervals during its operation.

- VCE coverage costs shall:
  - Include potential damages that could result to structures and public infrastructure, environmental resources and functions, as well as the potential loss of life and injury to persons onsite and to members of the public.
  - Be determined by a facility-specific study of the damages that might occur during a reasonable worst-case scenario explosion from oils, gases, and refrigerants stored, used or generated within the facility. The study itself shall:
    - Be prepared by a qualified expert experienced in VCE analysis, at the developer's expense.
    - Undergo third-party validation, by a qualified entity hired upon mutual agreement of the developer and the department, at the developer's expense.
    - Include a "nil" or very low wind condition VCE scenario, and its results disclosed, and address the potential impact of vapor barriers.

- Decommissioning costs shall:
  - Be determined by a facility-specific decommissioning plan for facility closure that shall include, but not be limited to, the following:
    - Listing the hazardous substances that will be stored, handled or generated within the facility; the range of potential release volumes requiring cleanup in the event of technological or safety catchment feature failures; and whether such releases have

the potential to contaminate groundwater or surface waters on or adjacent to the site.
    - The range of cleanup activities required to address hazardous substances.
    - Detailed cost estimates to implement the decommissioning plan based on the cost of hiring a third party to conduct all activities; and
    - Methods for estimating closure costs.

- In keeping with the model established by state and federal oil spill regulations, allow fossil fuel facility developers to submit multiple types of fiscal mechanisms to cover estimated cost impacts with the exception of self-bonding, which would provide insufficient coverage in cases of potential facility bankruptcy.

Equity Impact Analysis

This report and resulting recommended legislation were reviewed for equity impacts prior to transmittal. The North Highline and Skyway-West Hill subareas both have industrial zoning near railways or the Duwamish River, which increases the possibility of fossil fuel development in these communities.[371] Both communities have greater average proportions of Black, Indigenous, and People of Color (BIPOC) populations than King County as a whole, and hence could be subject to disproportionate impacts from new fossil fuel facility developments.[372]

This and recommended legislation were reviewed against the determinants of equity identified in K.C.C 2.10.210.[373] The proposed legislation may inhibit the development of new fossil fuel facilities to some extent. This may have a negative equity impact on job creation, but is projected to have a positive equity impacts on:

- Health and human services from avoided releases of nitrogen dioxide and potential respiratory impacts.[374]
- The built and natural environment with avoided potential water quality impacts.[375]
- Community and economic development through avoided brownfield creation, and its associated impacts on residential home values.[376]
- Community and public safety through avoided impacts on perceptions of community safety associated with a potential explosion incident (for more on explosion incidents please see report section A.1.a.i).

Presentations on the potential risks of fossil fuel facilities identified in this report, and the potential for proposed legislation requiring additional financial assurances against those risks, were provided to the North Highline Unincorporated Area Council and the West Hill Community Association in February 2022. Research reviewed included the types of fossil fuel facilities that could be built in unincorporated King County and that fall under its permitting jurisdiction; the risk of potential explosion incidents and

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[371] King County IMAP, Planning layer. [LINK]. Accessed 5/21/2022.

[372] Proposed Ordinance 2022-0162 (2022 update to 2016 King County Comprehensive Plan, including the Skyway-West Hill Community Service Area and North Highline Community Service Area Subarea Plans) and supporting materials. [LINK]. Accessed 5/21/2022.

[373] K.C.C. 2.10.210. [LINK]. Accessed 5/21/2022.

[374] U.S. EPA, "Basic Information about NO_2," last updated June 7, 2021. [LINK]. Accessed 1/4/2022.

[375] NOAA, "Deepwater Horizon oil spill settlements…," ibid. [LINK]. Accessed 12/20/2021.

[376] U.S. EPA, "Brownfields Program Environmental and Economic Benefits," last updated June 8, 2021. [LINK]. Accessed 1/11/2022.

brownfield contamination; and that a proposed ordinance was under consideration that would require new fossil fuel facilities to provide proof of financial coverage for fossil fuel facility impacts. Members of the public raised no concerns regarding the nature of the proposed legislation; the proposed legislation received no public comment during the posted comment period.

VI. Conclusion

A primary objective of this report was to evaluate the adequacy of existing financial assurance mechanisms for reducing the financial risk from fossil fuel facility development in unincorporated King County and, if warranted, recommend additional measures to minimize risk. This report also provides guidance on how to assess climate change impacts and refers reviewers to the report generated under Comprehensive Plan Workplan Action 21: Greenhouse Gas Mitigation for discussion on recent related statewide regulations.[377]

After reviewing potential evaluated risks, analysis conducted for this report found there is sufficient evidence that a vapor cloud explosion (VCE) at a fossil fuel facility could yield a high-cost event for which an operating entity may not have adequate financial coverage. There is also sufficient evidence of potential site contamination that could lead to the creation of future brownfields; this risk, and the risk of VCE impacts, would be exacerbated in the event of fossil fuel facility bankruptcy and subsequent closure or abandonment. Review of existing King County code also found no specific financial guarantees required for developing or operating fossil fuel facilities beyond the completion of initial facility construction. Review of existing fossil fuel regulations identified existing state and federal regulations addressing financial responsibility for a "worst case" oil spill, which provide a useful model for requiring financial assurances against explosion incidents.

Given this, this report recommends that King County enact an amendment to the King County Code requiring fossil fuel facilities to provide proof of adequate financial responsibility to cover the costs of a worst-case facility VCE and remediation of potential site contamination during its decommissioning. As directed by Workplan Action 20, a proposed ordinance reflecting these recommendations has been transmitted by the Executive to the Council concurrent with this report.

This report supports multiple King County plans and policies, as the report recommendations increase:

- King County Strategic Plan objectives to enhance community safety, while exercising sound financial and risk management by ensuring new fossil fuel facility developments have adequate financial resources to address potential industry impacts
- Transparency and accountability for fossil fuel developers, in support of the 2020 King County Strategic Climate Action Plan (SCAP). SCAP Priority Action GHG 3.8.3 commits the County to partner with other interested parties on the countywide commitment to clean energy resources, striving to phase out fossil fuels.[378]
- Protection for Black, Indigenous, and Other People of Color (BIPOC) communities that are disproportionately likely to live close to industrially- zoned areas, in support of King County Equity and Social Justice Strategic Plan direction to prioritize public health and address where disproportionate health impacts may fall upon BIPOC communities.[379]
- Alignment with numerous comprehensive plan policies, including:[380]

[377] Transmitted to the County Council in June 2022, concurrent with this report.
[378] King County, "2020 Strategic Climate Action Plan," May 2021. [LINK]. Accessed 1/18/2022. Page 102.
[379] King County, "Equity and Social Justice Strategic Plan, 2016-2022." [LINK]. Accessed 1/18/2022. Page 31 (pdf page 33)
[380] King County, "2016 King County Comprehensive Plan," Updated July 24, 2020. [LINK]. Accessed 1/18/2022. Pages 9-54 through 9-57 (pdf pages 488 through 491)

- F-344b "King County should advocate for environmental reviews of proposed oil terminals and other related fossil fuel facilities in Washington State to assess and mitigate for area-wide, cumulative risks and impacts to public safety…"
- F-344d "King County land use policies, development regulations, and permitting and environmental review processes related to fossil fuel facilities shall be designed to: a. protect public health, safety, and welfare; b. mitigate and prepare for disasters; c. protect and preserve natural systems; d. manage impacts on public services and infrastructure…"
- F-344e "King County shall thoroughly review the full scope of potential impacts of proposals for new, modified, or expanded fossil fuel facilities…"
- F-344h "King County shall establish a periodic review process for fossil fuel facilities…"

This report acknowledges the contributions from community groups in making space in meeting calendars to discuss report research; the extensive research efforts this report could draw upon from various local governments, industry participants and academic institutions; and the multiple King County staff that assisted in report development.

VII. Appendices

A. Acronyms and Units List

AST ..... aboveground storage tank
Bbls ..... million volume in barrels
Bcf/d ..... billion cubic feet per day
BIPOC ..... Black, Indigenous and People of Color
BLS ..... Bureau of Labor Statistics
BP ..... British Petroleum
BRTF ..... Brownfields Redevelopment Trust Fund
BTEX ..... Benzene, Toluene, Ethylbenzene and Xylene
CADDIS ..... Causal Analysis/Diagnosis Decision Information System
CCA ..... Washington state Climate Commitment Act
CCS ..... carbon capture & storage
C-DEEP ..... Connecticut Department of Energy and Environmental Protection
CERCLA ..... Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CIG ..... University of Washington Climate Impacts Group
CRS ..... Congressional Research Service
CSA ..... Cleanup Settlement Account
DEP ..... State of Maine's Department of Environmental Protection
DLE ..... dry low emission
DLS ..... King County Department of Local Services
DLN ..... dry low NOx
DNRP ..... King County Department of Natural Resources and Parks
DOT ..... Department of Transportation
E&P ..... exploration and production
Ecology ..... Washington state Department of Ecology
EFSEC ..... Washington state Energy Facility Site Evaluation Council
EIS ..... Environmental Impact Statement
PA ..... U.S. Environmental Protection Agency
FEIS ..... Final Environmental Impact Statement
FID ..... Final Investment Decision
FLACS ..... Flame Acceleration Simulator
FFRB.. ..... Fossil Fuel Risk Bond
GAO ..... U.S. Governmental Accountability Office
GAP ..... Greenhouse Gas Assessment for Projects
GHG ..... greenhouse gas
HAP ..... hazardous air pollutant
HSE ..... Health and Safety Executive
HST ..... hazardous substances tax
IGU ..... International Gas Union
IOCs ..... international oil companies
K.C.C. ..... King County Code
KCDA ..... King County Department of Assessments
LNG ..... Liquefied Natural Gas
MPTA ..... million tons per annum
MCTA ..... Model Toxics Control Act

MDEP ..... State of Maine's Department of Environmental Protection
MW ..... megawatts
MWh ..... megawatt-hour
NO2 ..... nitrogen dioxide
NOAA ..... National Oceanic and Atmospheric Administration
NOx ..... multiple types of oxides of nitrogen, including both nitrogen oxide and nitrogen dioxide
NARM ..... naturally-occurring and accelerator-produced radioactive material
NORM ..... naturally occurring radioactive material
NPFC ..... National Pollution Funds Center
NRDC ..... Natural Resources Defense Council
OBLR ..... U.S. EPA's Office of Brownfields and Land Revitalization
OIG ..... U.S. Department of Transportation, Office of Inspector General
O&G ..... Oil and Gas
OLSTF ..... Oil Spill Liability Trust Fund
OPA ..... Federal Oil Pollution Act of 1990
ORR ..... NOAA Office of Response and Restoration
OSHA ..... U.S. Occupational Safety and Health Administration
OSMRE ..... U.S. Office of Surface Mining Reclamation and Enforcement
OLSTF ..... Oil Spill Liability Trust Fund
PAH ..... Polycyclic aromatic hydrocarbon
PAO ..... King County Prosecuting Attorney's Office
PCB ..... Polychlorinated Biphenyl
PCC ..... Pacific Coast Coal Company
PHMSA ..... Pipeline and Hazardous Materials Safety Administration
PM ..... particulate matter
PNW ..... pacific northwest
PRB ..... Wyoming Powder River Basin
PSB ..... King County Office of Performance, Strategy and Budget
PSE ..... Puget Sound Energy
psig ..... pounds-force square inch gauge pressure
Q9 ..... VCE sub-model
RCW ..... Revised Code of Washington
SCAP ..... Strategic Climate Action Plan
SCL ..... Seattle City Light
SEPA ..... State Environmental Policy Act
SMCRA ..... Surface Mining Control and Reclamation Act
Superfund ..... common name for CERCLA
TPH ..... Total petroleum hydrocarbons
UGA ..... Urban Growth Area
UNGSF ..... underground natural gas storage facility
USC ..... United States Code
USGS ..... U.S. Geological Survey
UST ..... underground storage tank
VCE ..... vapor cloud explosion
VMT ..... vehicle miles traveled
VOC ..... volatile organic compound
WAC ..... Washington Administrative Code

B. Fossil Fuel Facilities Not Reviewed for Potential Cost Impacts – Rationale

On a national level, recent fossil fuel projections forecast a continuing rise with production reaching new heights in 2023.[381] From 2010 onward for the pacific northwest (PNW) region, "Oregon, Washington, and British Columbia have seen serious proposals for two new oil pipelines, 10 new or expanded coal export terminals, 14 oil-by-rail facilities, and at least six new natural gas pipelines."[382]

King County has varying ability to regulate new fossil fuel facility proposals in unincorporated King County due to its jurisdictional limitations. Research conducted for this report deemed that the following facilities were either not buildable within unincorporated King County or, in the case of potential development, would likely not fall under King County permitting jurisdiction. The reasons for each of these determinations is included under the following section reviews on coal mines, oil refineries, underground natural gas storage, natural gas processing, hydraulic fracturing (fracking) wells, crude oil transport by oil tanker and rail, and natural gas pipelines. The reasoning for each of these determinations is detailed below.

Coal Mines

FFRB applications for coal mines are not detailed in this report. As of the 1990s, only one coal mine, the John Henry coal mine outside of Black Diamond remained in operation in King County (and in the state); it has since ceased operation.[383,384] King County 2020 Ordinance 19146 prohibited new coal mines within King County, and as of July 2021 the John Henry coal mine agreed to a settlement that permanently closes the mine.[385,386]

> ***Note:*** *Prior to the notice of the permanent closure of the John Henry coal mine, the below information was collected on the regulation of coal mines. The below information has been retained in case it is useful to future reviewers of this topic.*

In the U.S., coal mining operations are typically regulated by states themselves but are supported by an underlying federal legal structure. The federal Surface Mining Control and Reclamation Act (SMCRA), passed in 1977, created a program intended to temporarily regulate surface mining and reclamation until States adopted regulatory programs consistent with SMCRA requirements. SMCRA Section 101 specifies that primary regulatory responsibility should rest with the States. To achieve primary regulatory responsibility, or "primacy," a State must develop a program that meets SMCRA requirements and demonstrate it has the capability to carry out SMCRA provisions. Upon approval, the State becomes the primary regulatory authority for coal mining and exploration within its borders, with

[381] United States Energy Information Administration (EIA), "EIA expects U.S. fossil fuel production to reach new highs in 2023," January 21, 2022. [LINK]. Accessed 01/26/2022.
[382] Eric de Place and Ben Stuckart, "Setting the Record Straight on Oil Trains," October 8, 2015. [LINK]. Accessed 4/21/2021.
[383] Colin Bowser, "Reviving Coal Mining in King County," University of Washington Currents: A Student Blog, January 16, 2018. [LINK]
[384] ECY, "Pacific Coast Coal Company," [LINK]. Accessed 4/22/2021.
[385] King County Council Clerk, "Ordinance 19146," Enacted August 10, 2020. [LINK]. Accessed 2/15/2022.
[386] Puget Soundkeeper, "Black Diamond Coal Mine Agrees to Permanent Closure," July 1, 2021. [LINK]. Accessed 1/26/2022.

the federal Office of Surface Mining Reclamation and Enforcement (OSMRE) assuming an oversight role.[387]

However, not all states chose to develop a SMCRA program – currently, only 24 states have primacy under SMCRA.[388] Washington state decided not to submit for a state program, and as a result OSMRE instituted a federal regulatory program for the state of Washington in 1987.[389] OSMRE administers the program for the two permitted surface mines in Washington, neither of which is actively producing coal. It notes that both mines are covered by adequate reclamation bonds.[390] This includes the John Henry Mine in unincorporated King County, 25 miles of southeast of Seattle near the City of Black Diamond.[391] The OSMRE web page on the Washington program provides the following summary of the John Henry Mine,

> *"Pacific Coast Coal Company (PCC) has operated the John Henry No. 1 Mine since 1985. The mine consists of 480 permitted acres; 312 acres are disturbed and 21 acres have been reclaimed. From 1986 to 1999, PCC produced about 300,000 tons of bituminous coal annually. Due to poor market conditions for the sale of coal, the mine ceased production in 1999. In 2009, OSMRE ordered PCC to begin reclamation in January 2010. The order was upheld by Interior's Board of Land Appeals. OSMRE had allowed the pits to remain open and unreclaimed to accommodate PCC's intent to mine coal in the future."*[392]

Oil Refineries

Financial coverages for new oil refineries are not detailed in this report, as there is a low probability that King County would have jurisdictional authority for citing such a facility. The Washington State Energy Facility Site Evaluation Council (EFSEC) has siting and permitting control for oil refineries processing over 25,000 barrels a day. [393] It is probable that the production capacity of any new oil refinery proposals would exceed 25,000 barrels a day based on the production capacities of other refineries in the state. The Washington State Department of Ecology (Ecology) provides the locations of the five existing oil refineries currently within the state:[394]

Facility Name	**Daily Capacity** (barrels of crude oil)
BP Cherry Point in Blaine	225,000[395]
Phillips 66 in Ferndale	105,000[396]

[387] Office of Surface Mining Reclamation and Enforcement (OSMRE), U.S Department of the Interior, "Oversight of Active Surface Coal Mining." [LINK]. Also, OSMRE, "Chronology of Major SMCRA-Related Events." [LINK]. Accessed 5/21/2021.
[388] OSMRE, ibid.
[389] OSMRE, "Washington State Federal Regulatory Program," last updated May 22, 2019. [LINK]. Accessed 7/26/2021.
[390] OSMRE, "Washington State…," ibid.
[391] OSMRE, "Washington State…," ibid.
[392] OSMRE, "Washington State…," ibid.
[393] Washington State Energy Facility Site Evaluation Council, "Certification Process". [LINK]. Accessed 6/29/2021.
[394] ECY, "Oil refinery greenhouse gas standards." [LINK]. Accessed 4/22/2021.
[395] British Petroleum (BP), "Cherry Point Refinery." [LINK]. Accessed 12/1/2021.
[396] Fallas, Bernado, "Ferndale: Efficient by design, with the stars to prove it," Phillips 66 Corporate Communications, September 22, 2020. [LINK]. Accessed 12/1/21. Note: 105,000 crude per day, plus additional throughput, for a total of 121,000 barrels throughput. See: Phillips 66, "2020 Fact Book," 2020. [LINK]. Page 22.

Facility Name	**Daily Capacity** (barrels of crude oil)
Shell Oil in Anacortes	145,000[397]
Tesoro in Anacortes	120,000[398]
U.S. Oil in Tacoma	42,000[399]

As no existing facilities are currently producing less than 25,000 barrels a day it is probable that, if a new oil refinery was proposed in unincorporated King County, it would be proposed at a production capacity exceeding 25,000 barrels a day and hence fall under the EFSEC permitting process.

Underground Natural Gas Storage

The Pacific Northwest (PNW) has existing natural gas storage facilities. For instance, Puget Sound Energy's (PSE) 3,200-acre Jackson Prairie Underground Storage Facility that opened in 1970, 100 miles south of Seattle in Lewis County, can hold 44 billion cubic feet natural gas, meeting between 25 to 40 percent of the PSE's PNW peak demand.[400] The facility is the 14th largest storage reservoir in the US.[401]

The Washington state Energy Facility Site Evaluation Council (EFSEC) oversees the siting of underground natural gas storage fields.[402] Once a facility is sited through the EFSEC and obtains a Site Certification Agreement, then the EFSEC becomes the issuing agency for any state or local facility permits, pre-empting King County permitting jurisdiction.[403]

Hydraulic Fracturing (Fracking) in Oil and Gas Wells

There is no oil and gas production in Washington state; while 600 exploratory gas and oil wells have been drilled since 1900, none has ever been developed into large-scale commercial production.[404] In 2019, Washington State banned the use of hydraulic fracturing for exploration and production of oil and natural gas[405,406] Unless the law is amended in the future, the new section in Chapter 78.52 RCW represents a permanent ban.[407] FFRB applications for hydraulic fracturing in oil and gas wells are not detailed in this report.

Oil Tankers

King County does not have jurisdiction over oil spill response immediately following spills -- though incremental legacy spillage that leads to brownfield creation can have some jurisdictional intersection

[397] Shell, "Shell Puget Sound Refinery: About Us." [LINK]. Accessed 12/1/2021.
[398] Marathon, "Anacortes Refinery." [LINK]. Accessed 12/1/2021.
[399] U.S. Oil, "U.S. Oil & Refining Tacoma, WA." [LINK]. Accessed 12/1/2021.
[400] PSE, "Natural Gas Storage." [LINK]. Also, PSE, "Jackson Prairie Underground Natural Gas Storage Facility," 4153_052, June 2019. [LINK]. Accessed5/31/2022.
[401] PSE, "Natural Gas Storage," ibid.
[402] Washington State EFSEC, "About EFSEC," September 19, 2019. [LINK]. Accessed 12/1/2021.
[403] Ami Kidder, EFSEC Siting and Compliance Manager, Washington State Utilities Transportation Commission, email with author on 6/29/2021.
[404] Washington State Legislature, "Final Bill Report SB 5145," 2019. [LINK]. Accessed 4/22/2021
[405] This process is different from, but sounds similar to, hydrofracture which is typically used in groundwater supply wells to increase water flows with high pressure water injection at a smaller scale than in oil and gas field reserve production. See American Ground Water Trust, "Hydrofracking Wells," The American Well Owner, Number 2, 2003. [LINK]. Accessed 4/22/2021
[406] Washington State Legislature, Ibid.
[407] Washington State Legislature, "Certification of Enrollment Senate Bill 5145: Chapter 294, Laws of 2019," 2019. [LINK]. Accessed 4/22/2021.

(for more on this topic see report section V.A.1.a.iii. Brownfields and Abandoned Infrastructure). The governing framework for oil spills, including spills from oil tankers, is reviewed below.

> *"The governing framework for oil spills in the United States remains a combination of federal, state, and international authorities. Within this framework, several federal agencies have the authority to implement oil spill regulations. Agency responsibilities can be divided into two categories: (1) oil spill response and cleanup and (2) oil spill prevention/preparedness. Oil spill response authority is determined by the location of the spill: the U.S. Coast Guard has response authority in the U.S. coastal zone, and the Environmental Protection Agency (EPA) covers the inland zone."*[408]

The Coast Guard's oil spill response jurisdiction of the "coastal zone" is defined in regulation to include,

> *"…all United States waters subject to the tide, United States waters of the Great Lakes, specified ports and harbors on inland rivers, waters of the contiguous zone, other waters of the high seas subject to the NCP, and the land surface or land substrata, ground waters, and ambient air proximal to those waters. The term coastal zone delineates an area of federal responsibility for response action."*[409]

Globally there have been decreases in the number and average volume of oil spills from vessels. In the 1970's the average number of spills per year was 79, but by the 2010s this average had decreased to six per year. Additionally, 52 percent of the large tanker spills (over 700 tonnes) since 1970 occurred in the 1970s, versus four percent of the large tanker spills occurring in the 2010s, and one percent so far for the 2020s. This has occurred even as the total of crude oil and other tanker trade doubled its shipping tonnage from 1,500 million metric tons to approximately 3,000 metric tons in 2017.[410]

Despite these statistics, oil spills from maritime vessels still occur. For the U.S., the Federal Oil Pollution Act (OPA) requires vessel owner liability for spills of between $939,800 to $25.8 million per vessel, and between $1,100 to $3,500 per gross ton of product. However, since 1990 there have been 80 oil discharges that exceeded this liability ceiling, such that the OPA Oil Spill Liability Trust Fund must cover cleanup costs; these funds are accrued primarily from taxes on domestic oil production and imports (for more on this fund see report section V.A.1.a.iv on oil spills). Half of these incidents were from self-propelled non-tank vessels, and a third of the incidents occurred from fishing vessels. Roughly 10 percent and four percent of spills that exceeded liability limits were from single hull and double hull tank barges respectively, and single hull tank ships were responsible for approximately three percent of the discharge incidents. In all, "total removal costs and damages for these discharges since enactment of the OPA is approximately $2.2 billion…" with the Oil Spill Liability Trust Fund covering $1.5 billion in the costs.[411]

Railroads (Crude Oil) and Pipelines

King County does not have jurisdiction to require additional financial assurances to the transport of fossil fuels by pipelines or rail lines; as such, this topic is not detailed in this report. These facility types

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[408] Rameseur, Jonathon, "Oil Spills: Background and Governance," CRS, September 15, 2017. [LINK]. Accessed 5/21/2022.

[409] 40 C.F.R. §300.5 [LINK]. Accessed 5/21/2022.

[410] International Tanker Owners Pollution Federation Limited (ITOPF), "Oil Tanker Spill Statistics 2021." [LINK]. Accessed 5/21/2022.

[411] U.S. Coast Guard, "Oil Pollution Act Liability Limits in 2019…," Ibid. [LINK]. Accessed 5/21/2021. Pages 6 through 9 (pdf pages 9 through 12).

are heavily regulated at the federal level and to some degree at the state level; preemption by these authorities leaves little to no room for regulation on the local level. Preemptive authorities include the Pipeline Safety Act, the Railroad Safety Act, the Hazardous Materials Transportation Act, the Natural Gas Policy Act, the commerce clause, and the Washington state EFSEC. [412,413,414,415,416,417] Were additional protections for this facility type desired, they may need to be sought as legislative changes at the state or federal level.

Although additional local regulation for these facility types is pre-empted, research conducted for this report identified some information on crude oil transport in Washington state, detailed below.

Ecology reports on crude oil transports to, and through, Washington state though three primary means: pipelines, railcars, and water vessels (Ecology does not include estimated transports by vehicle/tanker cars in their reporting).

Table B-1: 2020 Reported Crude Oil Movement by Barrel Statewide[418]

Transportation Type	Percentage	Barrels Transported *(millions)*	Gallons Transported *(billions)*
Pipeline	38%	71.8	3.02
Rail	30%	56.9	2.39
Vessel (inbound)	32%	60.1	2.53

Ecology also provides quarterly reports on Crude Oil Movement by Rail and Pipeline within the state.[419] The below are according to the fourth quarter report for 2020.

- Pipeline: For July to December 2020, pipelines transported 40.6 million barrels (bbls) of crude oil statewide.[420] It is unknown how many gallons were moved through King County.
- Vessel: Approximately 13.8 million bbls, or 581 million gallons of crude oil were transferred by vessel in Washington state for October to December 2020; if this figure remained constant for each quarter, which would indicate approximately 55.3 million bbls, or 2.3 billion gallons of crude oil transferred by vessel for the year.[421]
- Rail: Approximately 14,373 rail cars carrying crude oil travelled through King County for October to December 2020; if this figure remained constant for each quarter, which would indicate approximately 57,000 rail cars move through King County annually, or over 1,000 rail cars a week.[422]

[412] See 49 USC 60102 [LINK]. Accessed 4/29/2022.
[413] See 49 USC, Chapter 201. [LINK]. Accessed 4/29/2022.
[414] See 49 USC, Subtitle III, Chapter 51. [LINK]. Accessed 4/29/2022.
[415] House of Representatives (HR) Bill 5289, 1978. [LINK]. Accessed 4/29/2022.
[416] See U.S. Constitution, Article I, Section 8, Clause 3. [LINK]. Accessed 4/29/2022.
[417] See RCW Chapter 80.50. [LINK]. Accessed 4/29/2022.
[418] ECY, "Crude Oil Movement by Rail and Pipeline, Quarterly Report: October 1, 2020 through December 31, 2020," January 2021. Publication 21-08-004. [LINK]. Accessed 4/22/2021. Page 11.
[419] Washington State Department of Ecology (ECY), "Ecology Publications & Forms: Crude Oil Movement Quarterly Reports," last update January 2021. [LINK]. Accessed 4/22/2021.
[420] ECY, "Crude Oil Movement by Rail and Pipeline, Quarterly Report: October 1, 2020 through December 31, 2020," January 2021. Publication 21-08-004. [LINK]. Accessed 4/22/2021. Page 9
[421] ECY, "Crude Oil Movement by Rail and Pipeline…," Publication 21-08-004. Ibid. Page 8.
[422] ECY, "Crude Oil Movement by Rail and Pipeline…," Publication 21-08-004. Ibid. Page 8.

Rail accidents involving oil transport came under increased attention in 2013 following the Lac-Megantic rail disaster, where "a runaway Montreal, Maine & Atlantic Railway train that had been left unattended derailed, spilling oil, and catching fire inside the town of Lac-Megantic in Quebec. 47 people were killed, and 30 buildings burned in the town's center. About 1.6 million gallons of oil was spilled".[423] However, investigative journalists have noted that railroads cannot refuse to carry crude oil at present.

> *"…(Railroads) operate under a "common carrier obligation," which prohibits them from refusing to haul any legally allowable load even if would be inconvenient or unprofitable. In other words, they are actually required by law to transport hazardous materials, including volatile Bakken crude oil, in unsafe legacy DOT-111 tank cars until such time as the federal regulator determines these tank cars are no longer okay to use. And if the railroad hauls it, then they are liable for it."*[424]

States have some options for increased involvement, however. Washington state requires that any railroad transporting crude oil must report how the railroad would pay to clean up a "reasonable worst-case spill" through insurance, reserve accounts, letters of credit, or other financial instruments and assets.[425] This is defined under WAC 480-62-300, which establishes a "reasonable worst case percent," which is then applied to the largest train load of crude oil moved by the company the previous year.[426],[427] It is indeterminate if the resulting cost generated towards spill cleanup would be sufficient. For more information on this topic, Sightline did a series from 2014 to 2016 called, "What Do Oil Train Explosions Cost?" that provides additional analysis. [428]

[423] The Associated Press, "A timeline of recent oil train crashes in the US and Canada," June 3, 2016. [LINK]. Accessed 4/21/2021.

[424] Eric de Place and Rich Feldman, "Risk Assessment for Railroads," May 19, 2014. [LINK]. Accessed 4/21/2021.

[425] Junejo, Samir and Eric de Place, "What Washington's New Oil-by-Rail Rules Will Tell Us," Sightline, April 13, 2016. [LINK]. Accessed 4/22/2021

[426] Defined as the (Maximum Operating Speed/65)$^{2\ (squared)}$, Washington Administrative Code (WAC) 480-62-300 (2) (e), [LINK]. Accessed 4/22/2021.

[427] WAC 480-62-300 (2) (e), ibid.

[428] Sightline, "What Do Oil Train Explosions Cost," Series, 2014-2016. [LINK]. Accessed 2/8/2022.

C. Snapshot of Injuries, Fatalities, and Damages from Large Fossil Fuel Explosions

Table C-1. Snapshot of Injuries, Fatalities, and Damages from Large Fossil Fuel Explosions Since 1944

Year	Incident Name	Location	U.S.	Source	Facility Type	Fatalities	Injuries	Notes
1944	East Ohio Gas Company Explosion[429]	Cleveland, OH	X	LNG leak[430]	LNG	131	*unknown*	Fires burned 160 acres of businesses and neighborhoods. Company paid $3.5 million in damages.[431] 10,000 persons evacuated.[432]
1966	Raunheim, Germany Explosion[433]	Germany		LNG, vapor cloud	*unknown*	1	75	Injuries primarily due to flying gas.
1973	Staten Island LNG Explosion	Staten Island, NY[434]	X	Fire within tank	LNG tank	40	3[435]	Accident not caused by LNG itself, but ignition in the tank catching damage; how ignition occurred is not stated.[436]
1979	Cove Point LNG Explosion[437]	Cove Point, MD	X	LNG leak meets electrical arc	LNG	1	1	Propelled debris 300 feet. Est. $3 million in damages.

[429] Ohio History Central, "East Ohio Gas Company Explosion," [LINK]. Accessed 10/08/2021.
[430] Sandy, Eric, "The Day Cleveland Exploded: 70 Years Later, the Unthinkable Disaster of the East Ohio Gas Co. Explosion," October 15, 2014. [LINK]. Accessed 10/08/2021.
[431] Ohio History Central, "East Ohio Gas Company Explosion," [LINK]. Accessed 10/08/2021.
[432] Sandy, Eric, ibid.
[433] Siu, Nathan et al, "Qualitative Risk Assessment For An LNG Refueling Station And Review Of Relevant Safety Issues," Idaho National Engineering and Environmental Laboratory, INEEL/EXT-97-00827 Rev., February 1999.2 [LINK]. Accessed 10/08/2021. Page 74.
[434] Zaffarano, Steve, "48 years ago: Staten Island liquefied natural gas explosion in kills 40 workers," Crosscut, February 10, 2020; Updated: February 11, 2021. [LINK]. Accessed 9/8/2021.
[435] McFadden, Robert, "43 Workers Buried in Huge Gas Tank In Explosion and Fire on Staten Island," New York Times, February 11, 1973. [LINK]. Accessed 10/6/2021.
[436] National Association of State Fire Marshals, "Liquefied Natural Gas: An Overview of the LNG Industry for Fire Marshals and Emergency Responders," 2005. [LINK]. Accessed 10/08/2021.
[437] National Transportation Safety Board, "Pipeline Accident Report – Columbia LNG Corporation Explosion and Fire of Substation, Cove Point, Maryland, October 6, 1979," April 16, 1980. [LINK]. Accessed 10/08/2021.

Table C-1. Snapshot of Injuries, Fatalities, and Damages from Large Fossil Fuel Explosions Since 1944

Year	Incident Name	Location	U.S.	Source	Facility Type	Fatalities	Injuries	Notes
1992	Brenham Salt Dome Explosion[438]	Brenham, TX	X	Volatile liquids formed vapor cloud[439]	Underground Liquefied Petroleum Gas Storage	3	21	Destroyed five houses and one mobile home; another report listed dozens of homes.[440] Damaged 50 - 60 structures.[441]
1998	Sonat Exploration Co. Catastrophic Vessel Over-pressurization	Pitkin, LA[442]	X	Over-pressurized vessel	Oil and Gas Production	4	0	Destroyed 5 vehicles and part of the facility.
2001	Hutchinson Natural Gas Explosions	Hutchinson, KS[443]	X	Natural gas	Underground Propane Store	2	*unknown*	Wellbore failed; gas migrated 9 miles; damaged 26 businesses.[444]
2003	ConocoPhillips Storage Tank Explosion and Fire[445]	Glenpool, OK	X	Refilling diesel storage tank	Gasoline and Diesel Storage	0	0	300 families evacuated, and schools closed for two days. Accident cost $2,357,483.[446]

[438] Pipeline and Hazardous Materials Safety Administration (PHMSA), "Pipeline Safety: Safety of Underground Natural Gas Storage Facilities, Final Rule," Federal Register / Vol. 85, No. 29. February 12, 2020. [LINK]. Accessed 10/6/2021. Page 3.
[439] The Eagle, "Salt Dome Explosion: 20 years later," April 7, 2012. [LINK]. Accessed 410/08/2021.
[440] The Eagle, ibid.
[441] The Eagle, ibid; ABC 13, "Salt dome explosion rocked area near Brenham on April 7, 1992." [LINK]. Accessed 10/06/2021.
[442] U.S. CSB, "Investigation Report: Catastrophic Vessel Overpressurization (4 Deaths)," September 21, 2000. [LINK]. Accessed 10/8/2021.
[443] M. Lee Allison, "Hutchinson Natural Gas Explosions: Unraveling a Geologic Mystery," Kansas Bar Association, 26th Annual KBA/KIOGA Oil and Gas Law Conference, v1, p3-1 to 3-29. 2001 [LINK]. Accessed 10/6/2021.
[444] PHMSA, "UNGS Major Incidents," last updated September 11, 2018. [LINK]. Accessed 10/7/2021.
[445] Transportation Research Board (TRB), "Pipeline Accident Report: Storage Tank Explosion and Fire in Glenpool, Oklahoma, April 7, 2003," October 13, 2004. [LINK]. Accessed 10/11/2021.
[446] TRB, ibid. Page ii, 7.

Table C-1. Snapshot of Injuries, Fatalities, and Damages from Large Fossil Fuel Explosions Since 1944

Year	Incident Name	Location	U.S.	Source	Facility Type	Fatalities	Injuries	Notes
2004	Skikda LNG accident[447]	Algeria		LNG pipeline leak[448]	LNG	27	74	Considered the worst petrochemical plant fire in Algeria in over 40 years.[449] $1 billion to rebuild the facility.[450]
2005	BP America Refinery Explosion	Texas City, TX[451]	X	Volatile liquid overflow; vapor cloud.	Refinery	15	180	Houses damaged more than 0.75 miles away; losses of $1.5 billion. 43,000 persons ordered to shelter in place.
2005	Buncefield Blast/Buncefield Fire[452]	Hemel Hempstead, United Kingdom		Gas tank overflow; vapor cloud	Oil Storage Terminal	0	43	Blast measured 2.4 on the Richter scale; was heard 125 miles away. Companies fined ~£10 ($13.5) million. Took 25 fire engines, 20 support vehicles and 180 firefighters four days to extinguish blaze.[453]
2009	Caribbean Petroleum Tank Terminal Explosion	Puerto Rico[454]		Gas tank overflow; vapor cloud	Petrol Terminal	0	3	300 homes and businesses damaged.
2010	Kleen Energy Natural Gas Explosion[455]	Middletown, CT	X	Flammable vapor	Power Plant, construction	6	50	Gas used to clear pipe during power plant construction.

[447] Oil & Gas Journal Editors, "Algerian LNG complex explosion caused by gas pipeline leak," Oil & Gas Journal, February 18, 2004. [LINK]. Accessed 10/6/2021.
[448] Schoch, Deborah, "Blast Traced to LNG Leak," Los Angeles Times, february 23, 2004. [LINK]. Accessed 10/08/2021.
[449] Romero, Simon, "Algerian Explosion Stirs Foes of U.S. Gas Projects," New York Times, February 12, 2004. [LINK]. Accessed 10/6/2021.
[450] Ghanmi, Lamine, "Algeria halts production at gas complex hit by blasts and fire," the Arab Weekly, April 7, 2019. [LINK]. Accessed 100/08/2021
[451] U.S. Chemical Safety and Hazard Investigation Board (CSB), "Final Investigation Report: Refinery Explosion and Fire," Report No. 2005-04-I-TX, march 2007. [LINK]. Accessed 10/6/21. Page 17.
[452] BBC News, "Firms ordered to pay almost £10m over Buncefield blast," July 16, 2010. [LINK]. Accessed 10/11/2021.
[453] BBC News, "How the Buncefield fire happened," July 16,2010. [LINK]. Accessed 10/11/2021.
[454] CSB, "Final Investigation Report: Caribbean Petroleum Tank Terminal Explosion and Multiple Tank Fires," Report No. 2010.02.I. PR, October, 2015. [LINK]. Accessed 9/7/2021.
[455] U.S. CSB, "Urgent Recommendations, Final Report: Kleen Energy," June 28, 2010. [LINK]

Table C-1. Snapshot of Injuries, Fatalities, and Damages from Large Fossil Fuel Explosions Since 1944

Year	Incident Name	Location	U.S.	Source	Facility Type	Fatalities	Injuries	Notes
2010	Tesoro Refinery Fatal Explosion and Fire[456]	Anacortes, WA	X	Heat exchanger rupture	Petroleum Refinery	7	0	Personnel died within 22 days of the incident due to serious burns.
2012	Amuray Oil Refinery Explosion	Venezuela[457]		Vapor cloud	Oil Refinery	47	35[458]	3,400 structures destroyed or damaged, part of refinery destroyed. $1.84 billion in losses.[459]
2014	Plymouth LNG Explosion	Plymouth, WA[460]	X	Over-pressurized Unit	LNG	0	5	Explosion felt 6 miles away. Sent 250 pounds of shrapnel 900 ft. Evacuated 2-mile radius. Concerns of a second blast "leveling" 0.75 miles around the plant.[461]
2015	Chevron Refinery Fire[462]	Richmond, CA	X	Pipe rupture and vapor cloud	Refinery	0	26[463]	19 employees engulfed in vapor cloud; one was caught during ignition but was protected from fireball due to firefighting equipment. Shelter-in-place issued for 3 cities. In the weeks after the incident 15,000 community members sought treatment for ailments including breathing problems, chest pain and headaches; 20 were hospitalized.
2015	ExxonMobil Refinery Explosion[464]	Torrance, CA	X	Gasoline Processing Unit	Refinery	0	4	Near-miss release of hydrofluoric acid, which can be fatal. Catalytic dust fell on community members; unknown potential health impacts. Currently in litigation.

[456] U.S. CSB, "Investigation Report: Catastrophic Rupture of Heat Exchanger (Seven Fatalities)," May 1, 2014. [LINK]. Accessed 10/085/2021. Page 1, 24.
[457] Englund, Will, "Engineers raise alarms over the risk of major explosions at LNG plants," Washington Post, June 3, 2021. [LINK]. Accessed 9/7/2021.
[458] Parraga, Marianna, "Chronology: Pump collapse, leak caused Venezuela refinery blast," Reuters, September 9, 2013. [LINK]. Accessed 10/6/2021.
[459] Parraga, Marianna, "Chronology: Pump collapse, leak caused Venezuela refinery blast," Reuters, September 9, 2013. [LINK]. Accessed 10/6/2021.
[460] Powell, Tarika, "How Industry and Regulators Kept Public in the Dark After 2014 LNG Explosion in Washington," February 8, 2016. [LINK]. Accessed 9/7/2021
[461] Schneyer, Joshua, Timothy Gardner, and Richard Valdmanis, "Blast at U.S. LNG site casts spotlight on natural gas safety," Reuters, April 6, 2014. [LINK]. Accessed 10/08/2021.
[462] U.S. CSB, "Final Investigative Report: Chevron Richmond Refinery Pipe Rupture and Fire," January 28, 2015. [LINK]. Accessed 10/08/2021. Page 1, 2
[463] Six employees, and twenty community members.
[464] U.S. CSB, "ExxonMobil Torrance Refinery Electrostatic Precipitator Explosion," May 3, 2017.[LINK]. Accessed 10/8/2021. Page 23, 24.

Table C-1. Snapshot of Injuries, Fatalities, and Damages from Large Fossil Fuel Explosions Since 1944

Year	Incident Name	Location	U.S.	Source	Facility Type	Fatalities	Injuries	Notes
2018	Husky Energy Refinery Explosion and Fire[465]	Superior, WI	X	Hydrocarbon-air mixing	Refinery	0	36	Evacuated part of Superior, Wisconsin.
2019	Philadelphia Energy Solutions Refinery Explosion and Fire[466]	Philadelphia, PA	X	Vapor cloud	Oil Refinery	0	5	Estimated $750 million loss led to refinery bankruptcy.[467] Largest refinery of its kind on the east coast.[468] Catapulted a 38,000-pound vessel across a river.[469] Released 5,239 pounds hydrofluoric acid.
2020	Magellan Refinery Explosion[470]	Corpus Christi, TX	X	Aboveground storage tank	Refinery	0	7	4 of the 7 hospitalized were in critical condition. 2 filed suit for claims.[471]
2021	Russel City Center Explosion[472]	Hayward, CA	X	Steam Turbine Generator Compartment	Natural Gas Power Plant	0	0	Resulted in fire; concern over 45 hydrogen tanks onsite.[473] Evacuated 1.0 mile around plant; estimated $100 million in damages.[474]

[465] U.S. CSB, "Factual Investigation Update: April 26, 2018 Husky Superior Refinery Explosion and Fire," December 2018. [LINK]. Accessed 10/08/2021. Page 1.
[466] U.S. CSB, "Fire and Explosions at Philadelphia Energy Solutions Refinery: Factual Update," October 16, 2019.[LINK]. Accessed 10/08/2021.
[467] Marsh JLT Specialty, "100 Largest Losses in the Hydrocarbon Industry 1974-2019," March 2020. [LINK]. Accessed 11/24/21. Page 26 (pdf 28).
[468] BBC News, "Explosions rock south Philadelphia in refinery fire," video description, June 21, 2019. [LINK]. Accessed 10/08/2021.
[469] Phillips, Susan, Dana Bate, "Faulty, old pipe caused PES refinery explosion, sending a bus-size piece of debris flying across Schuylkill," PBS WHYY, October 16, 2019. [LINK]. Accessed 9/7/2021.
[470] Falcon, Megan, "Seven Magellan employees injured, four in critical condition after refinery explosion," Corpus Christi Caller Times, December 5, 2020. [LINK]. Accessed 10/11/2021.
[471] Flores, Alyssa, et. al, "Lawsuit filed on behalf of two burn victims injured in Magellan tank fire," Kris 6 News Corpus Christi, December 15, 2020. [LINK]. Accessed 10/11/2021.
[472] Specht, Mark, "I Toured "The Best Damn [Natural Gas] Plant In The Fleet." Two Years Later It Exploded," CleanTechnica; August 13, 2021. Originally published by Union of Concerned Scientists, The Equation. [LINK]. Accessed 10/11/2021
[473] Jarosz, Brooks, "Turbine explosion sends heavy metal flying in Hayward, cause unknown," Fox KTVU, June 28, 2021. [LINK]. Accessed 10/11/2021.
[474] Jarosz, Brooks, ibid. [LINK]. Accessed 10/11/2021.

Table C-1. Snapshot of Injuries, Fatalities, and Damages from Large Fossil Fuel Explosions Since 1944

Year	Incident Name	Location	U.S.	Source	Facility Type	Fatalities	Injuries	Notes
2021	Calpine Co Generation Plant Explosion[475]	Corpus Christi, TX	X	Natural gas explosion	Natural Gas Power Plant	1	0	

[475] Howley, Christopher, "Natural gas explosion leaves one person dead," Corpus Christi Caller Times, June 19, 2021. [LINK]. Accessed 10/11/2021.

D. Vapor Cloud Explosion (VCE) Cost Projections

If an explosion were to occur, the below VCE cost projections will likely be inaccurate. Even when site-specific variables are known, the nature of an explosion can vary depending on where a gaseous state leak occurs, the volume gas released, weather conditions, etc.– even the day of the week or time of day an explosion occurs can drastically change potential fatality and injury levels. As such, the below projections strive to provide an understanding of the factors that may influence various costs, and provide a range of low and high costs, informed by available data and past explosion events.

The Cost of Fatalities

Wrongful death verdicts, or settlements of wrongful death cases, may result in payments ranging from $500,000 to several million dollars, with a median wrongful death jury award of $2.5 million.[476,477] Wrongful death payments can range much higher, however. Notable local examples include:

- $75 million settlement in 2002 for the deaths of two boys in the 1999 Olympic pipeline explosion in Bellingham, the largest personal injury and wrongful death settlement award in Washington state history, (an average of $35 million per wrongful death.;[478]
- $45 million settlement in 2001for the deaths of six men in the 1998 Anacortes oil refinery explosion, an average of $7.5 million per wrongful death.[479]

As these settlements were both roughly 20 years ago, using a Bureau of Labor Statistics inflation calculator and factoring in the original, individual settlement years, today these awards would be:

- $117.1 million for two deaths (an average of $58.6 million per wrongful death), and
- $71.1 million for six deaths (an average of $11.8 million per wrongful death) [480]

Wrongful death awards and settlements can also range much higher, generally. More recently, the family of an 11-year-old boy who died during the 2021 winter storms in Texas is suing for $100 million for his wrongful death.[481] Although the case is not yet decided, a $100 million is not without precedent. In 2021, a family in east Texas was awarded $730 million ($480 million jury-award, another $250 million in punitive damages) for a single-fatality wrongful death lawsuit.[482]

Predictions on the cost of fatalities, were an explosion to occur, will likely be inaccurate even when site-specific variables are known, much less specific information about the nature of an explosion – even the day of the week or time of day an explosion occurs can drastically change potential fatality levels. The judge for the 2005 fatality-free Buncefield explosion commented that, “had the explosion happened

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[476] Anidjar & Levine, “How Much Money Can I Get from a Wrongful Death Settlement?.” [LINK]. Also: Jack Bernstein, Injury Attorneys, “Average Wrongful Death Settlement,” [LINK]. Accessed 10/4/2021.

[477] $2.2 million, the average from 2017 based on 2009-2013 data, adjusted to purchasing power today based on BLS, “CPI Inflation Calculator,” ibid. [LINK]. Source: Merrill, Dave, “No One Values Your Life More Than the Federal Government,” Bloomberg, October 19, 2017. [LINK]. Accessed 11/23/2021.

[478] Puget Sound Business Journal, “Olympic Pipe Line pays $75 million to settle suit,” April 10, 2002. [LINK]. Accessed 11/23/2021.

[479] Brunner, Jim, “Settlement reached in Anacortes oil refinery explosion,” the Seattle Times, January 19, 2001. [LINK]. Accessed 11/23/2021

[480] BLS, “CPI Inflation Calculator,” ibid. [LINK]. Accessed 11/24/2021.

[481] Al Jazeera, “Family sues Texas power companies for $100m over death of boy, 11,” February 22, 2021. [LINK]. Accessed 11/24/2021.

[482] Boyum, Jamey, “East Texas family awarded $730 million in wrongful death lawsuit,” KLTV, November 22, 2021. [LINK]. Accessed 11/24/2021.

during a working day, the loss of life may have been measured in tens or even hundreds."[483] However, the following assessments may help inform the potential fiscal impacts associated with fatalities, using a median wrongful death jury award of $2.2 million.[484] The 47, 20 and seven fatalities used below are sourced respectively from the Venezuela (2012), Algeria (2004) and Anacortes (2010) incidents.

- The *range* of costs would be $0 (zero fatalities) to $117.5 million (47 fatalities)
- The *average* cost for *group* fatalities (more than one) would be $59.4 million (27 fatalities)
- The average cost for fatalities (zero to one fatalities included) would be $17.5 million (7 fatalities)

A change in the average wrongful death award could strongly influence these results. For instance, if an inflation-adjusted $11.8 million per wrongful death average was used, the projected potential fatality costs would then be as follows:

- The range of costs would be $0 to $554.6 million (47 fatalities)
- The average cost for group fatalities would be $318.6 million (27 fatalities)
- The average cost for fatalities overall would be $82.6 million (seven fatalities)

The Cost of Injuries

Injury costs will vary based on the type of explosion event, injury type, and the distance of injured individuals from an explosion event. Injury costs, and available mechanisms to cover costs, will vary based on whether injury was incurred by an employee or a member of the public, as employee injuries may be covered by worker compensation claims.

Four types of injuries typically occur in gas explosions/VCEs, namely:

- Burns,
- Fragments hitting persons (structural components, glass),
- Buildings or structures falling down, and
- Persons falling or being knocked back, subsequently hitting a falling object.[485]

Lacerations from flying glass can cause serious injuries and contribute to a significant portion of injuries during various types of explosion events.[486,487]

When injuries to employees occur, a common compensation mechanism for the injury is worker compensation claims. According to 2018 to 2019 National Council on Compensation Insurance data, worker compensation claim averages were:

- $23,768 for cuts and scrapes (such as might occur from broken glass),
- $42,008 for averaging all claims, and

[483] BBC News, "Firms ordered to pay almost £10m over Buncefield blast," July 16, 2010. [LINK]. Accessed 10/12/2021.

[484] Merrill, Dave, "No One Values Your Life More Than the Federal Government," Bloomberg, October 19, 2017. [LINK]. Accessed 11/23/2021.

[485] Bjerketvedt, Dag, Jan Roar Bakke, and Kees van Wingerden, "Gas Explosion Handbook," CMG Gexcon, 1995; mild update, 2019. [LINK]. Accessed 12/16/21. Page 115.

[486] Bjerketvedt, Dag, ibid. [LINK]. Accessed 12/16/21. Page 134.

[487] Federal Emergency Management Agency (FEMA), "Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings," Risk Management Series, December 2003. [LINK; full publication LINK]. Accessed 12/16/2021. Page 4-8.

- $58,284 for burns (for persons in close proximity to an explosion event).[488]

However, the above value only represents the amount paid out to a claimant (direct cost) and does not include additional costs for a business to process a worker compensation case (indirect costs). Indirect costs can include overtime and lost production, replacement worker training, additional human resource and administrative staff time, not to mention U.S. Occupational Safety and Health Administration (OSHA) fines and enforcement, legal costs and increased workers compensation rates.[489] Research conducted for this report indicates that the ratios of indirect costs to direct costs more than double the direct costs, range from 1.1 to 2.12.[490,491] Incorporating the indirect cost ratio into a worker compensation claim revises the fiscal impact of claims per the below.

An indirect cost ratio of 1.1 would result in average worker compensation impacts of:
- $26,145 for cuts and scrapes,
- $88,216 for all claims, and
- $122,396 for burns.

An indirect cost ratio of 2.12 would result in average worker compensation impacts of:
- $50,388 for cuts and scrapes,
- $131,065 for averaging all claims, and
- $181,846 for burns.

When injuries to members of the public occur, costs will also vary depending on the nature of the injury. It is less probable, but still possible, that members of the public will suffer from burns as such injuries tend to happen in the immediate vicinity of the ignition source, though explosions may be combined with, or catalyze, other fire starts. The public may also suffer from noxious air emissions such as in the 2015 Chevron Refinery Fire, or from broken glass. Injuries may not trigger hospital visitation; when it does occur, injuries may be minor enough that onsite treat-and-release is feasible or be serious enough to trigger hospitalization.[492]

[488] National Safety Council, "Workers' Compensation Costs." [LINK]. Accessed 11/24/2021.
[489] U.S. Occupational Safety and Health Administration (OSHA), "OSHA's $afety Pays Program." [LINK]. See Also: Optimum Safety Management, "The Real Cost of a Workplace Injury." [LINK] and OSHA Academy, "Direct and Indirect Costs of Accidents," [LINK]. Accessed 11/24/2021.
[490] OSHA, "OSHA's $afety Pays Program." [LINK]. Accessed 11/24/2021.
[491] Huang, Yueng-Hsiang et. al, "Financial Decision Maker's Views on Safety," Professional Safety, April 2009, Page 38. [LINK]. Accessed 11/24/2021.
[492] U.S. CSB, "Final Investigative Report: Chevron Richmond Refinery Pipe Rupture and Fire," January 28, 2015. [LINK]. Accessed 10/08/2021. Page 1, 2

Overall, the injury cost estimates in Table D-1 are pertinent for members of the public:

Table D-1. Average Injury Costs by Type and Stay Duration (Public Injuries)

Injury Type	Average Costs, Medical	Average Costs, All[493]
Burn – Nonfatal Overnight Hospitalization[494]	$67,000	$151,000
Burn – Treat and Release[495]	$4,800	$16,200
Cut – Nonfatal Overnight Hospitalization[496]	$62,000	$113,000
Cut – Treat and Release[497]	$3,200	$48,500
Inhalation – Nonfatal Overnight Hospitalization[498]	$51,200	$94,500
Inhalation – Treat and Release[499]	$8,000	$11,100

The average of the above "treat and release" injuries is $5,300, whereas the average cost for injuries requiring overnight hospitalization is $119,500.

As with fatalities, predictions on the cost of injuries of an explosion to occurs will likely be inaccurate even when site-specific variables are known, much less specific information about the nature of an explosion. However, the following assessments may help inform the potential fiscal impacts associated with injuries, based on information noted in Table D-2, and using a direct-costs for burns only:
The 26, 43 and 80 injuries used below are sourced respectively from the Richmond (2015), Buncefield (2009) and Venezuela (2012); the 180 injuries from the Texas City (2009) incident was not used as it appears to be an outlier among the VCEs reviewed.

Table D-2. National Average Injury Costs Applied to Past Reported VCE Injuries

		26	43	80
		Multiplied by the number of injuries above		
Public Injury		*All values rounded.*		
Treat & Release	$5,300	**$140,000**	$230,000	$424,000
Overnight Hospitalization	$119,500	$3,110,000	$5,140,000	**$9,560,000**
Workers Comp. – *Base Rate*				
Cut/Scrape	$23,768	$620,000	$1,020,000	$1,900,000
Avg. All Claims	$42,008	$1,100,000	$1,800,000	$3,360,000
Burns	$58,284	$1,500,000	$2,500,000	$4,660,000

The injury costs in the above example scenarios range from a total of $140,000 to $9.56 million. It should be noted that Washington state does require worker's compensation that is either purchased directly from the Washington state Department of Labor and Industries, or through self-insurance so

[493] "All costs" includes CDC average cost values for medical treatment, work lost and quality of life impacts, which might be achieved through legal recourse or a group settlement. This may not include potential legal fees, which would raise the average cost.
[494] Centers from Disease Control (CDC) Web-Based Injury Statistics Query and Reporting System (WISQARS) query Re: 2019 Fire/burn Nonfatal Hospitalization. See CDC WISQARS [LINK]. Accessed 12/30/2021.
[495] CDC WISQARS query Re: 2019 Fire/burn ED Treat and Release Visit. [LINK]. Accessed 12/30/2021.
[496] CDC WISQARS query Re: 2019 Nonfatal Hospitalization. [LINK]. Accessed 12/30/21.
[497] CDC WISQARS query Re: 2019 Cut/pierce ED Treat and Release Visit. [LINK]. Accessed 12/30/2021.
[498] CDC WISQARS query Re: 2019 Inhalation/suffocation Nonfatal Hospitalization. [LINK]. Accessed 12/30/2021.
[499] CDC WISQARS query Re: 2019 Inhalation/suffocation ED Treat and Release Visit. [LINK]. Accessed 12/30/21.

long as a business has a minimum $25 million in business assets.[500] However, these worker compensation funds would only provide direct cost coverage.

The Cost of Property Damage and Other Claims

Projecting the cost of property damage claims, and other types of claims not previously reviewed, can be difficult. However, using information from past explosions allows some estimate of the range of costs that might be expected in a similar scenario.

Estimating the property damage costs from a VCE incident is challenging for three main reasons.

1. When property damage and other claims are resolved by a settlement, the settlement amount and terms may not be disclosed to the public, reducing the amount of publicly available data.[501]
2. Even when the amount of a court award or settlement is disclosed to the public, the details of that award are often reported as a lump sum involving multiple parties.[502] Not only does this obscure what amounts are paid to which individuals, but the awards also may comingle costs of multiple types of damage beyond property damage. For instance, reporting on the 2005 Buncefield explosion lists the total costs of claims by individuals and businesses– but what portion of the claims are directly related to property damages versus lost business, unemployment claims, or hotel stays is unknown.[503]
3. Reporting on accidents also does not commonly disclose the number of structures that are damaged; whether they are single- or multiple-story; whether they are residential or commercial in nature; and the severity of damage. Again, the 2005 Buncefield explosion has more extensive reporting. For instance, an initial resident survey following the VCE incident had 546 respondents report damage to their property. Varying percentages or respondents reported the following types of damage:
    - Cracks in walls and ceilings 60 percent
    - Damage to window frames 49 percent
    - Broken door/door locks 42 percent
    - Broken glass 27 percent
    - Damage to roof 24 percent
    - Damage to carpets, furnishings 14 percent[504]

While more detailed than other VCE reporting, this information is not granular enough to meaningfully understand the pattern or cost of damages. A crack in the wall has a different average cost to repair ($575) than a crack in the ceiling ($875), whereas a structural crack that may affect wall integrity may cost between $3,000 to $8,000 for repairs – and a structure could have multiple cracks.[505,506,507] Similarly, "broken glass" indicates broken windows, though the above data raises issues with the survey

[500] WorkCompLab, "Workers' Compensation Insurance in Washington State." [LINK]. Accessed 11/24/21.
[501] CRS, "Liquefied Natural Gas (LNG) Import…," ibid. [LINK]. Accessed 12/28/2021. Page 11.
[502] Kroll Settlement Administration LLC, "Columbia Gas Settlement Frequently Asked Questions." [LINK]. Accessed 12/30/21.
[503] Buncefield Major Incident Investigation Board (Buncefield MIIB) "The Buncefield Incident, 11 December 2005: The final report of the Major Incident Investigation Board Volume 1," 2008. [LINK]. Accessed 12/29/2021. Page 25.
[504] Gardner, Nick, "Buncefield Social Impact Assessment Final Report," SQW, January 2007. [LINK]. Page 12.
[505] Home Garden Guides, "Cost to Repair a Crack in Drywall," last updated December 24, 2021. [LINK]
[506] Home Advisor, "How Much Does It Cost to Repair a Ceiling?" [LINK]. Accessed 12/29/2021.
[507] Remodeling Calculator, "Costs of Ceiling Repair," June 10, 2021. [LINK]. Accessed 12/29/2021.

data generally – as "damage to window frames" usually begins occurring at 0.50 pounds-force per square inch of gauge pressure (psig), whereas glass failure begins at a lower force of 0.15 psig, so it is questionable that more respondents noted window frame damage than noted broken glass.[508] The original geographic extent of the survey is also unknown, which if too small may have also affected the data, as later reporting noted that houses up to five miles away experienced broken glass and ceiling/wall cracks.[509] Even if "broken glass" refers to broken windows and the survey was accurate, the average 1,800 square foot house in the greater Seattle Metropolitan area, for instance, has approximately 17 windows.[510,511] A window repair costs $850 on average, but it is probable that houses had varying number of windows damaged depending on their proximity to the origin of the blast wave, so the cost attribution for "broken glass" cannot be determined with existing data.[512]

However, when attempting to provide a rough estimate for property damage (and related claims associated with hotel stays, lost work, etc.), the 2005 Buncefield explosion is the most suitable example from which glean data for three reasons:

1. As already mentioned, the Buncefield explosion has extensive publicly available data.
2. The incident resulted in no deaths, and only minor injuries; as fatalities can significantly affect claims and settlement costs, the absence of fatalities for this incident reduces the chance of over-reporting for claims, improving the accuracy of the data.[513]
3. Of the three major incidents where structural damage data is partially available, the Buncefield explosion is the median average example in the number of structures damaged and destroyed, as shown in the following table. Research conducted for this report did not find detailed reporting on the number of structures affected of the majority of explosion incidents, resulting in a small sample of examples.

[508] NOAA, "Overpressure Levels of Concern," last updated April 17, 2019. [LINK]. Accessed 12/29/2021.
[509] Buncefield MIIB, "The Buncefield Incident…" ibid. [LINK]. Accessed 12/30/2021. Page 10.
[510] Research conducted for this report could not find an average detached home square footage for King County, so the average detached home size for Seattle was used. Source: Seattle Office of Planning & community Development, "Housing Choices Background Report," August 2019. [LINK]. Accessed 12/29/2021. Page 7.
[511] U.S. Environmental Protection Agency (EPA), "ENERGY STAR® for Windows, Doors, and Skylights Version 6.0 Criteria Revision: Review of Cost Effectiveness Analysis," 2013. [LINK]. Accessed 12/29/2021. Page 7.
[512] Home Advisor, "How Much Does It Cost to Replace Windows?" [LINK]. Accessed 12/29/2021.
[513] Buncefield MIIB, "The Buncefield Incident…" ibid. [LINK]. Accessed 12/30/2021. Page 10.

Table D-3. VCE Incident, Structural Damages

Year, Place	Name	Structures	
		Damaged	Destroyed *(% of total)*
2005, Buncefield	Buncefield Depot	634[514]	20 - 23[515] *(3.2% - 3.6%)*
2009, Puerto Rico	Caribbean Petroleum Tank Terminal	300[516]	6 *(2%)*
2012, Venezuela	Amuray Oil Refinery	3,400[517]	0 - 257[518] *(0% - 7.5%)*

Claims for the Buncefield explosion were as follows in Table D-4.

Table D-4. Estimated Total Value of Claims[519]

Claimant Type	No. of Claims	Estimate £ Million	As USD Million (2006)[520]	As USD Million (2021)[521]
Business				
Inside site perimeter	*5*	*£103*	*$190*	*$266*
Outside site perimeter	*749*	*£488*	*$898*	*$1,259*
Businesses, subtotal	754	£591	$1,087	$1,524
Individuals	3,379	£30	$55	$77
Local Authorities	7	£4	$7	$10
Totals*	**4,140**	**£625**	**$1,150**	**1,612**

**Totals may vary due to rounding.*

[514] At least 88 businesses ("Buncefield Multi-Agency Recovery Plan," Draft 1.1, January 2006. [LINK]. Page 3) and 546 residences (Gardner, Nick, "Buncefield Social Impact Assessment Final Report," SQW, January 2007. [LINK]. Page 12). Note: This number could be closer to 836 structures, as 290 other businesses listed disruptions from the emergency response and, "minor damage" ("Buncefield Multi-agency Recovery Plan" ibid). Accessed 12/29/21.

[515] The, "premises of 20 businesses were destroyed (Creutzfeldt, Naomi and C. Hodges, "Parallel tracks in mass litigation: public and private responses to the Buncefield explosion in England," draft chapter in *Class Actions in Context: How Economics, Politics and Culture Shape Collective Litigation*, edited by D. Hensler, C. Hodges and I. Tzankova, 2016. [LINK] Page 3); additionally, three families were still living at a hotel a year after the incident ("Buncefield Social Impact Assessment Final Report," SQW, ibid. Page 13). For the 25 specific structures listing various types of damage, three private structures listed partial collapse, likely included among the above businesses. (Environmental Resources Management Ltd, "Revised land use planning arrangements around large scale petroleum depots," prepared for the Health and Safety Executive, 2007. [LINK]. Page 71). At least 12 businesses had to be relocated, and another two went bankrupt. (Al Raheem, Duaa et al., "The Buncefield Accident," Texas A&M University, December 5, 2010. [LINK]. Page 13). Accessed 12/29/2021.

[516] CSB, "Final Investigation Report: Caribbean Petroleum …" ibid. Page 9, 32.

[517] Parraga, Marianna, "Chronology: Pump collapse, leak caused Venezuela refinery blast," Reuters, September 9, 2013. [LINK]. Accessed 10/6/2021.

[518] Note: This is the number of homes constructed for affected families; it is uncertain if all homes constructed were destroyed, or just damaged enough to warrant temporary housing. Source: Parraga, Marianna, "Exclusive: Venezuela refinery could restart Friday," Reuters, August 27, 2012. [LINK]. Accessed 12/29/2021.

[519] Buncefield MIIB, "The Buncefield Incident…" ibid. [LINK]. Accessed 12/30/2021. Page 25.

[520] The incident occurred right before Christmas, 2005, and claims filings proceeded primarily in 2006 (Creutzfeldt, Naomi and C. Hodges, "Parallel tracks in mass litigation…," ibid. Page 7). The 1.84 United States Dollar (USD) value to one Great British Pound (GBP) or British pound sterling value in 2006 is the listed average closing price (Macrotrends, "Pound Dollar Exchange Rate (GBP USD) - Historical Chart." [LINK]). Accessed 12/30/2021.

[521] BLS, "CPI Inflation Calculator," ibid. [LINK]. Accessed 11/24/2021.

Although this lists the claim, and not the amounts awarded to various claimants, this depicts the perceived damages experienced by claimants and brought before the courts, noting that:

- Adjusting for inflation, as well as British and American currency values at the time of the incident, the £625 million in claims from 2005 to 2006 would be $1.6 billion in claims today.
    - Approximately 250 claims totaled roughly £20 million each ($51.8 million in 2021 USD).
    - Another 2,750 claims were for less than £10,000 ($25,800 in 2021 USD).[522]
- There were 43 injuries associated with the blast, which may be included in this claim total.
    - British HSE valued the total cost of injuries at £15,050, or at $38,000 in 2021 USD.
    - Using the average for all "treat and release" (minor) injuries outlined in Table D-2 of $5,300 per injury, another estimate of 43 total injury values would be $227,000.

  Neither of these injury values significantly affects the total $1.6 billion claim estimate.

Large property damage awards would likely be included in the total number of claims reviewed above, but some estimate can be made for their stand-alone costs using current home and property values for residential and commercial parcels. There were between 20 and 23 properties destroyed in the Buncefield incident; were a similar incident to occur following development of a fossil fuel facility in an industrial zone, the probable property types that might be affected closer to a VCE catalyst include other industrial properties, multifamily developments, and single-family homes.[523] Recent property values for these property types are reviewed in Table D-5 below.

[522] Creutzfeldt, Naomi and C. Hodges, "Parallel tracks in mass litigation…," ibid. Page 6

[523] The, "premises of 20 businesses were destroyed (Creutzfeldt, Naomi and C. Hodges, "Parallel tracks in mass litigation: public and private responses to the Buncefield explosion in England," draft chapter in *Class Actions in Context: How Economics, Politics and Culture Shape Collective Litigation*, edited by D. Hensler, C. Hodges and I. Tzankova, 2016. [LINK] Page 3); additionally, three families were still living at a hotel a year after the incident ("Buncefield Social Impact Assessment Final Report," SQW, ibid. Page 13). Accessed 12/29/2021.

Table D-5. Large Property Damage Estimates

	Average Property Value	Value for 20 Properties	Value for 23 Properties
	All values in millions, rounded.		
Single Family Home	$0.85[524]	**$17.0**	$19.6
Industrial, General	$15.7[525]	$313.0	**$360.0**
Industrial, ED-MIC*			
Option 1	$5.7[526]	$114.7	131.9
Option 2	$7.3[527]	$146.3	168.2
Apartment			
Option 1	$9.1[528]	$181.6	208.9
Option 2	$13.4[529]	$268.4	308.6

**ED-MIC stands for the East Duwamish Manufacturing Industrial Center*

Using the Buncefield example of 20 to 23 properties destroyed in the VCE incident, a similar degree of property destruction could yield between $17 million to $360 million in large property damage claims.

[524] Seattle Times, "Seattle-area home prices take biggest 12-month jump ever," September 28,2021. [LINK]. Accessed 11/224/2021.

[525] Total 2019 parcel value divided by the parcel number. King County Department of Assessments (KCDA), "Commercial Revalue 2019 Assessment Roll: Industrial Area 540," 2019. [LINK]. Accessed 12/30/2021. Page 6

[526] Total 2019 parcel value divided by the parcel number. KCDA, "Commercial Revalue 2019 Assessment Roll: Area 35," 2019. [LINK]. Accessed 12/30/2021. Page 6.

[527] 2018 mean sale price. See KCDA, "…Area 35," ibid. [LINK]. Accessed 12/30/2021. Page 6.

[528] Total 2019 parcel value divided by the regular accounts (10,128). KCDA, "Apartments Specialty Area: 100, Commercial Revalue for 2020 Assessment Roll." [LINK]. Accessed 12/30/2021. Page 3.

[529] 2020 mean sale price. KCDA, "Apartments Specialty Area…" ibid. LINK]. Accessed 12/30/2021. Page 1.

E. King County Code Search Results (K.C.C.)

Research conducted for this report reviewed King County Title section headings, followed by a word search for the words "bond," "fiscal," and "finan" (the root of finance/financial) to establish King County requirements for private developments and operators. This was undertaken to assess the requirements that are separate from, and in addition to, whatever financial assurances are required by state and federal permitting. This table summarizes K.C.C. findings matching the above search pattern, but that were disregarded as immaterial to scope of this report.

Table E-1. Financial Requirements: "Bond," "Fiscal" and "Finan" in King County Code (K.C.C.)

K.C.C. Title			
Title No.	**Name**	**Code Section No.**	**Code Citation,** or *Notes*
2	Administration		*K.C.C. Title 2A includes the words* • *"bond" 18 times. These are not cited, as they do not refer to private projects; includes references to county-issued bonds and bond ratings (2.10.400; 2.38.010; 2.42.080; 2.48.105; 2.49.170); bond recommendations for the urban arterial advisory board (2.32.130); definitions (2.49.020); and bonds in relation to civil immigration enforcement (2.15.020).* • *"fiscal" 46 times. These are not cited, as they do not refer to private projects.* • *"finan" 131 times. These are not cited, as they do not refer to private projects.*
2A	Administration		*K.C.C. Title 2A includes the words* • *"bond" zero times.* • *"fiscal" three times. These are not cited, as they do not refer to private projects.* • *"finan" five times. These are not cited, as they do not refer to private projects.*
4A	Revenue and Financial Regulation		*89 references to bonds; these only address general obligation or revenue bonds issued **by** King County (such as in 4A.503.060), and bond anticipation notes (such as in 4A.200.545).*
9	Surface Water Management		
			K.C.C. Title 9 includes the words • *"bond" 14 times. These are not cited, as they do not refer to private projects.* • *"fiscal" four times. These are not cited, as they do not refer to private projects.* • *"finan" 30 times. Only four sections are cited (below) for applicability to private projects, outside of billing rates; remaining sections are not applicable.*
		9.04.050	Drainage review – requirements. "…7. Core requirement 7: Financial guarantees and liability. All drainage facilities constructed or modified for projects, except downspout infiltration and dispersion systems for single family residential lots, must comply with the liability requirements of K.C.C. 9.04.100 and the financial guarantee requirements of K.C.C. Title 27A…"

K.C.C. Title			
Title No.	**Name**	**Code Section No.**	**Code Citation,** or *Notes*
		9.04.105	Financial guarantees authorized. "The department of local services, permitting division, or its successor, is authorized to require all applicants issued permits or approvals under the provisions of this title to post financial guarantees consistent with the provisions of K.C.C. Title 27A."
		9.04.120	Drainage facilities not accepted by King County for maintenance. "A. The person or persons holding title to the property… shall remain responsible for the facility's continual performance, operation and maintenance in accordance with the standards and requirements of the department and remain responsible for any liability as a result of these duties. This responsibility includes maintenance of a drainage facility that is… 3. Released from all required financial guarantees prior to July 7, 1980…"
		9.04.130	Hazards. Whenever the director determines that any existing construction site, erosion and sedimentation problem and/or drainage facility poses a hazard…(the) person or agent in control of said property…(shall) repair or otherwise address the cause of the hazardous situation in conformance with the requirements of this chapter... If costs are incurred and a financial guarantee pursuant to this chapter or other county requirement has been posted, the director shall have the authority to collect against the financial guarantee to cover costs incurred."
14	Roads and Bridges		
			K.C.C. Title 14 includes the words • *"bond" two times. These are not cited, as they do not refer to private projects.* • *"fiscal" zero times.* *"finan" fifteen times. These are not cited, as they either do not refer to private projects, or if they do refer to potentially private projects, they do not extend fiscal assurance requirements beyond what is already addressed in other K.C.C. sections, including primarily K.C.C. Title 27A (the latter includes K.C.C. 14.02.020; 14.28.020; 14.28.050; 14.28.060; 14.44.080; and 14.46.100)*
16	Building and Construction Standards		
		16.04.900	Conversion condominium warranty of repairs and escrow fund. "…B. Prior to conveyance of any residential unit within a conversion condominium, the declarant shall establish and maintain an account with a bank or other financial institution of the declarant's choosing, containing a sum equal to ten percent of the actual cost of making repairs required in K.C.C. 16.04.890…"

K.C.C. Title			
Title No.	**Name**	**Code Section No.**	**Code Citation,** or *Notes*
		16.04.920	Site improvement financial guarantee. "Site improvement financial guarantee refers to the financial guarantee required by Title 27A as security for the applicant's guarantee of the construction, according to approved plans and county specifications…"
		16.82.130	Violations - corrective work required. "A. If clearing or grading inconsistent with the purposes and requirements of this chapter in effect at the time of the action has occurred on a site the department shall not accept or grant any development permit or approval for the site, except any permit or approval necessary for the correction of code violations, until the applicant:… 2. Obtains department approval of a permit for the appropriate restoration or corrective action and posts any required financial guarantee."
		16.82.170	Financial guarantees authorized. "The department is authorized to require all applicants issued permits or approvals under the provisions of the title to post financial guarantees consistent with the provisions of Ordinance 12020."
19A	Land Segregation		
		19A.04.150	Financial guarantee. "Financial guarantee: a form of financial security posted to ensure timely and proper completion of improvements, compliance with the King County Code or to warrant materials, and quality of work of the improvements and design. Financial guarantees include assignments of funds, cash deposits, surety bonds and other forms of financial security acceptable to the director."
		19A.08.140	Financial guarantees. "Notwithstanding any other provision of this title, the director is authorized to require all applicants issued permits or approvals under the provisions of this title to post financial guarantees consistent with the provisions of K.C.C. Title 27A."
			19A.08.160 Minimum improvements before final recording of plat or short plan - exceptions – post of financial guarantee. "…B. The director, in consultation with the department of natural resources and parks, the department of local services, road services division, the prosecuting attorney and other affected agencies, may allow the applicant to post a financial guarantee for any identified noncritical required improvements, as determined on a project by project basis, if:…"
20	Planning		*K.C.C. Title 20 includes the words* • *"bond" two times; citations below.* • *"fiscal" four times. These are not cited, as they do not refer to private projects.* • *"finan" 13 times. These are not cited, as most do not refer to private projects. When they do, they are not for specific amounts or types of financial coverages, and are not pertinent to the larger discussion.*

K.C.C. Title			
Title No.	**Name**	**Code Section No.**	**Code Citation,** or *Notes*
		20.14.025	Covington Master Drainage Plan. "…7. Developments in the Covington Master Drainage Plan Area within one hundred feet of the ordinary high watermark of Jenkins and Little Soos Creeks shall be required to re-establish native vegetation in stream buffers where native vegetation has been destroyed or disturbed… If the department of local services, permitting division, determines that the season is inappropriate for planting, the occupancy permit can be granted, provided a bond is established for the costs of revegetation."
		20.14.070	Lower Cedar River Basin Plan and Nonpoint Pollution Action Plan. "…3. The executive shall transmit to the council for review by the transportation, economy and environment committee or its successor within sixty days of the council's adoption of the Lower Cedar River Basin and Nonpoint Pollution Action Plan, criteria for prioritizing future surface water CIP and bond program projects, and the process for early review by the Cedar River Council of projects proposed for funding in the Cedar River basin."
21A	Zoning		*K.C.C. Title 21A includes the words* • *"bond" 19 times; citations below.* • *"fiscal" zero times.* • *"finan" 55 times; XX are cited below, as the most of the remainder do not refer to private projects. Note that financial guarantee definitions are omitted.*
		21A.14.195	On-site recreation – financial guarantees for construction. "Financial guarantees for construction of recreation facilities required under K.C.C. 21A.14.180 and 21A.14.190 shall be provided consistent with K.C.C. Title 27A."
		21A.16.115	21A.16.115 Landscaping - plan design, design review, and installation. "…D. The required landscaping shall be installed no later than three months after issuance of a certificate of occupancy for the project or project phase… A financial guarantee shall be required before issuance of the certificate of occupancy, if landscaping is not installed and inspected before occupancy."
		21A.16.190	Financial guarantees. "Financial guarantees shall be required consistent with the provisions of Title 27A. This time period may be extended to one year by the director, if necessary to cover a planting and growing season." *Applies to landscaping and water use.*
		21A.22.090, 21A.24.140	Financial guarantees. "Financial guarantees shall be required consistent with K.C.C. Title 27A." *Applies respectively to mineral extraction and critical areas.*

K.C.C. Title			
Title No.	**Name**	**Code Section No.**	**Code Citation,** or *Notes*
		21A.24.100	Critical area review. "B. As part of the critical area review, the department shall review the critical area reports and determine whether… 5. Mitigation to compensate for adverse impacts to critical areas is required and whether the mitigation and monitoring plans and bonding measures proposed by the applicant are sufficient…"
		21A.24.130	Mitigation and monitoring."…E. If monitoring reveals a significant deviation from predicted impact or a failure of mitigation requirements, the applicant shall implement an approved contingency plan. The contingency plan constitutes new mitigation and is subject to all mitigation including a monitoring plan and financial guarantee requirements." *Applies to critical areas.*
		21A.24.342	Wetlands - agreement to modify mitigation ratios. "…financing or funding guarantees for the duration of the mitigation and monitoring program. At a minimum, funding guarantees must be in place until mitigation activities have met the established performance standards and have been approved by the department; and…"
		21A.24.380	Aquatic areas - specific mitigation requirements. "…E. The department may reduce the mitigation ratios…if the applicant provides a scientifically rigorous mitigation monitoring program that includes the following elements: …2. Financing or funding guarantees for the duration of the monitoring program…"
		21A.24.550	Consolidated site review for single-family residential development. "…At the time of development permit application, the department shall screen the proposal for compliance with the conditions established by the department under this section, set the conditions of permit approval and, if required, establish the mitigation financial guarantee."
		21A.25.110	Aquaculture. "V. Aquaculture structures and equipment shall be of sound construction and shall be so maintained... Where any structure might constitute a potential hazard to the public in the future, the department shall require the posting of a bond commensurate with the cost of removal or repair."
		21A.41.080	Financial guarantees. "Performance guarantees consistent with the provisions of Title 27A may be required to assure that development occurs according to the approved plan." *Applies to commercial site development permits.*
		21A.50.035	Critical areas violations - corrective work required. "A. A person who alters a critical area or buffer in violation of law shall undertake corrective work… E. Any failure to satisfy corrective work requirements established by law or condition including, but not limited to, the failure to provide a monitoring report within thirty days after it is due or comply with other provisions of an approved corrective work plan shall constitute a default, and the department may demand payment of any financial guarantees or require other action authorized by K.C.C. Title 27A or other applicable law"

K.C.C. Title			
Title No.	**Name**	**Code Section No.**	**Code Citation,** or *Notes*
27	Development Permit Feed		*K.C.C. Title 27 includes the words* • *"bond" zero times; citations below.* • *"fiscal" zero times.* • *"finan" five times; two are cited below, the rest are inapplicable.*
		27.02.050	Fee Assessment. "H. Changes in the ownership of an application or permit shall not revoke the fees incurred by the application or permit, or the requirement to post financial guarantees for permitted construction."
		27.10.570	Processing, monitoring, extending and administering the default of financial guarantees. "Fees shall be charged as follows for processing, monitoring, extending and administering the default of financial guarantees… C. Administering default of financial guarantees - annual fee 1. Road improvements $4,424.00 2. Stormwater facilities $4,424.00"
Matches for K.C.C. Title 6.Business Licenses and Regulations are reviewed in report section E. Research conducted for this report included review of K.C.C Title 18 Environmental Sustainability Program, and did not discern additional, pertinent regulations to the above discussion.			

F. Financial Assurances Summary

Regardless of regulatory requirements for financial assurance to cover specific negative events associated with fossil fuel facilities, fossil fuel facilities retain financial mechanisms to address liabilities and losses for events.[530] Within the field of Oil & Gas (O&G) lending, loans to midstream companies (that transport, process and store O&G) are structured similar to other commercial loans.[531] The Federal Deposit Insurance Corporation advises financial institutions to provide loan officers guidance on issuing O&G loans that include minimum required insurance levels covering property, liability and environmental losses.[532] However, O&G industries may retain or employ a range of financial mechanisms to cover business operations and impacts beyond insurance;. this appendix reviews some of the primary financial assurance mechanisms currently available.

Insurance

The fossil fuel facilities need to determine the level of coverage that is necessary and will decide on the types of policy options to use.

- Business Insurance/Commercial General Liability Insurance
    - This coverage protects businesses against financial loss as the result of bodily injury, property damage, medical expenses, libel, slander, defending lawsuits and settlement bonds or judgments. This is an essential insurance policy for oil and gas due to the industry's risk and litigious nature.[533]
- Commercial Umbrella
    - Umbrella and Excess insurance provide coverage for the liability of a commercial venture above a specific amount set forth in a basic policy issued by the primary insurer; or a self-insurer for losses over a stated amount; or an insured or self-insurer for known or unknown gaps in basic coverages or self-insured retentions.[534]
- Commercial Property
    - This coverage protects businesses against loss and damage of company property due to a wide variety of events such as fire, smoke, wind and hailstorms, civil disobedience, and vandalism.[535]
- Catastrophe insurance (only protects against natural catastrophes)
    - This is coverage against natural or manmade disasters that is unusually severe.[536] An event is designated a catastrophe by the industry when claims are expected to reach a certain dollar threshold, currently set at $25 million, and more than a certain number of policyholders and insurance companies are affected.

[530] The common immediate form is insurance against site accidents; see Talberth, John and Daphne Wysham. "Fossil Fuel Risk…," ibid. [LINK] Accessed 6/3/22. Page 6 (pdf page 8).

[531] Federal Deposit Insurance Corporation (FDIC), "RMS Manual of Examination Policies," Section 3.2, last updated November 2020. [LINK]. Accessed 6/3/2022. Page 3.2-17 (pdf page 17).

[532] FDIC, "RMS Manual…," ibid. Accessed 6/3/2022. Page 3.2-20 (pdf page 20).

[533] U.S Small Business Administration, "Six Common Types of Business Insurance" [Link]

[534] National Association of Insurance Commissioners (NAIC), "Umbrella and Excess" [Link] Accessed 1/17/2021.

[535] U.S Small Business Administration, "Six Common Types of Business Insurance" [Link]

[536] Insurance Information Institute, "Spotlight on – Catastrophes – Insurance Issues [Link]

- Pollution Liability Insurance/ Environmental Insurance
    - This is liability coverage of an insured to persons who have incurred bodily injury or property damage from acids, fumes, smoke, toxic chemicals, waste materials or other pollutants.[537]
- Business Interruption
    - This is insurance coverage that replaces business income lost in a disaster. The event could be, for example, a fire or a natural disaster. Business interruption insurance generally is not sold as a separate policy but is either added to a property/casualty policy.[538]

Worker's Compensation

Washington state requires worker's compensation that is either purchased directly from the Washington state Department of Labor and Industries, or through self-insurance so long as a business has a minimum $25 million in business assets.[539]

Bonds

Surety bonds can be broadly grouped under Contract and Commercial bonds, with several sub-varieties. Another group, called fidelity bonds that protect employers from employee actions such as theft, are immaterial to the scope of this report. [540] Two other bond groups, namely Catastrophe Bonds and Corporate Bonds also appear as unlikely forms of fiscal coverage for topics addressed in this report.

Surety bonds last between one and four years in length, with an option to renew (though some surety bonds can "continue until cancelled") and differ from insurance in two ways.[541] First, while verifying the validity of a claim against the bond, the bonding company may seek to remedy the situation by means other than payment. Second, the bonding company expects repayment of funds against the bond following payout and will seek to collect from the principal (the entity that retained the bond). This differs from insurance, where the insured is not responsible for funds paid out on claims.[542]

- Contract Surety Bonds include four types: namely Bid, Performance, Payment and Maintenance bonds. Aside from maintenance bonds, these apply to the construction of a facility and would not be appropriate as a financial assurance mechanism for a catastrophic event during fossil fuel facility operations.
    - Bid bonds guarantee a contractor will comply with a bid contract, stopping contractors from backing out from a bid after the work is won, and are typically required on any federal or commercial projects.[543] These bonds apply to the construction phase.
    - Performance bonds protect a project owner against performance failure by the contractor to complete specific agreements outlined in a construction contract. If bonded obligations are not fulfilled, the project owner can claim financial damage.[544] These apply to the construction phase.

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[537] National Association of Insurance Commissioners (NAIC), "Environmental Pollution Liability". [LINK] Accessed 1/17/2021.
[538] Kagan, Julia. 'What is Business Interruption Insurance, May 2021. [LINK]. Accessed 1/19/2022.
[539] WorkCompLab, "Workers' Compensation Insurance in Washington State." [LINK]. Accessed 11/24/2021.
[540] Florida Division of Consumer Services, "Bonds (Other than Bail) Overview." [LINK]. Accessed 12/8/2021
[541] Tarver, Evan, "Types of Surety Bonds: Understand the 4 Main Surety Bond Types," Huttenlocher. [LINK]. Accessed 12/13/2021.
[542] Viking Bond Service, "What is a Surety Bond?" [LINK]. Accessed 12/8/2021
[543] Tarver, Evan, "Types of Surety Bond…" ibid. [LINK]. Accessed 12/13/2021.
[544] Tarver, Evan, "Types of Surety Bond…" ibid. [LINK]. Accessed 12/13/2021.

- Payment bonds, "guarantee that a contractor will pay the necessary subcontractors, material suppliers, and labor as outlined in the contract…" and apply during the construction phase.[545]
- Maintenance bonds protect, "a project owner against financial losses due to defective workmanship or faulty materials used during a construction project."[546] Maintenance bonds are often retained for between 12 to 24 months, in which time a project owner can request fixes for problems that arise or file a claim for damages.[547]
    - These bonds apply within a relatively short period of time following completion of a construction project. If a catastrophic event occurred within the first few years following construction completion, and the event was due to faulty construction of a bonded element, these bonds could theoretically be used to address some event costs. However, this bond type is not suitable as a long-standing fiscal assurance mechanism against as catastrophic event due to its short-lived coverage period.

- Commercial Surety Bonds are, "used to guarantee performance of non-construction related contractual obligations."[548]

  "Typically, professionals who are applying for an industry-specific business license will need a commercial surety bond before a license is issued… there are over 15 different commercial surety bond types, each protecting the public against the harmful business practices of a different licensed professional."[549]

  These bonds, "cover any financial damages caused by the principal as well as government fees for any license violations."[550] As these bonds cover the activities of licensed professionals under their commercial licenses, as opposed to the failure of constructed facilities, these would not be appropriate as a financial assurance mechanism for a catastrophic event at a fossil fuel facility.
- Catastrophe (cat) Bonds are used as reinsurance, or "insurance for insurance companies."[551,552]

Additional discussion on the topics of self-bonding and self-insurance or "self-assurances" is discussed in the report body under report section V.A.2.

Letters of Credit

Letters of credit are a popular option for financial assurance. It promises that the bank will pay the amount of the letter of credit if or when the regulating authority determines it is due. Banks generally charge an annual fee of between two percent and five percent of the face value for a letter of credit. That means a letter of credit for $100,000 will usually cost $2,000 to $5,000 per year to maintain. The language for a letter of credit used as financial assurance is mandated in the law and cannot be changed, even if a client's bank wants different wording. A "standby" trust agreement is also required for this form of financial assurance.[553]

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[545] Tarver, Evan, "Types of Surety Bond…" ibid. [LINK]. Accessed 12/13/2021.
[546] Tarver, Evan, "Types of Surety Bond…" ibid. [LINK]. Accessed 12/13/2021.
[547] Tarver, Evan, "Types of Surety Bond…" ibid. [LINK]. Accessed 12/13/2021.
[548] FCA Insurance Brokers, "What is Commercial Surety?" [LINK]. Accessed 12/13/2021.
[549] Tarver, Evan, "Types of Surety Bond…" ibid. [LINK]. Accessed 12/13/2021.
[550] Tarver, Evan, "Types of Surety Bond…" ibid. [LINK]. Accessed 12/13/2021.
[551] Polacek, Andy, "Catastrophe Bonds: A Primer and Retrospective," Federal Reserve Bank of Chicago, Fed Letter No. 405, 2018. [LINK]
[552] Insurance Information Institute, "Insurance Handbook: Reinsurance." [LINK]. Accessed 12/13/2021.
[553] Department of Ecology, Financial Assurance Options, "Letter of Credit". [LINK]. Accessed 1/25/2022.

Third-Party Trust Funds

A financial assurance trust fund works like a trust fund for a child — money is deposited into an account and a Trustee invests and manages the money. If there are expenses, the Trustee can pay them if allowed. If the trust fund loses money in the market or expenses go up unexpectedly, money will need to be added to the trust fund to keep it up to date. The Trustee is typically paid to manage the trust fund. The primary downside is that all money needs to be paid into the trust fund upfront.[554]

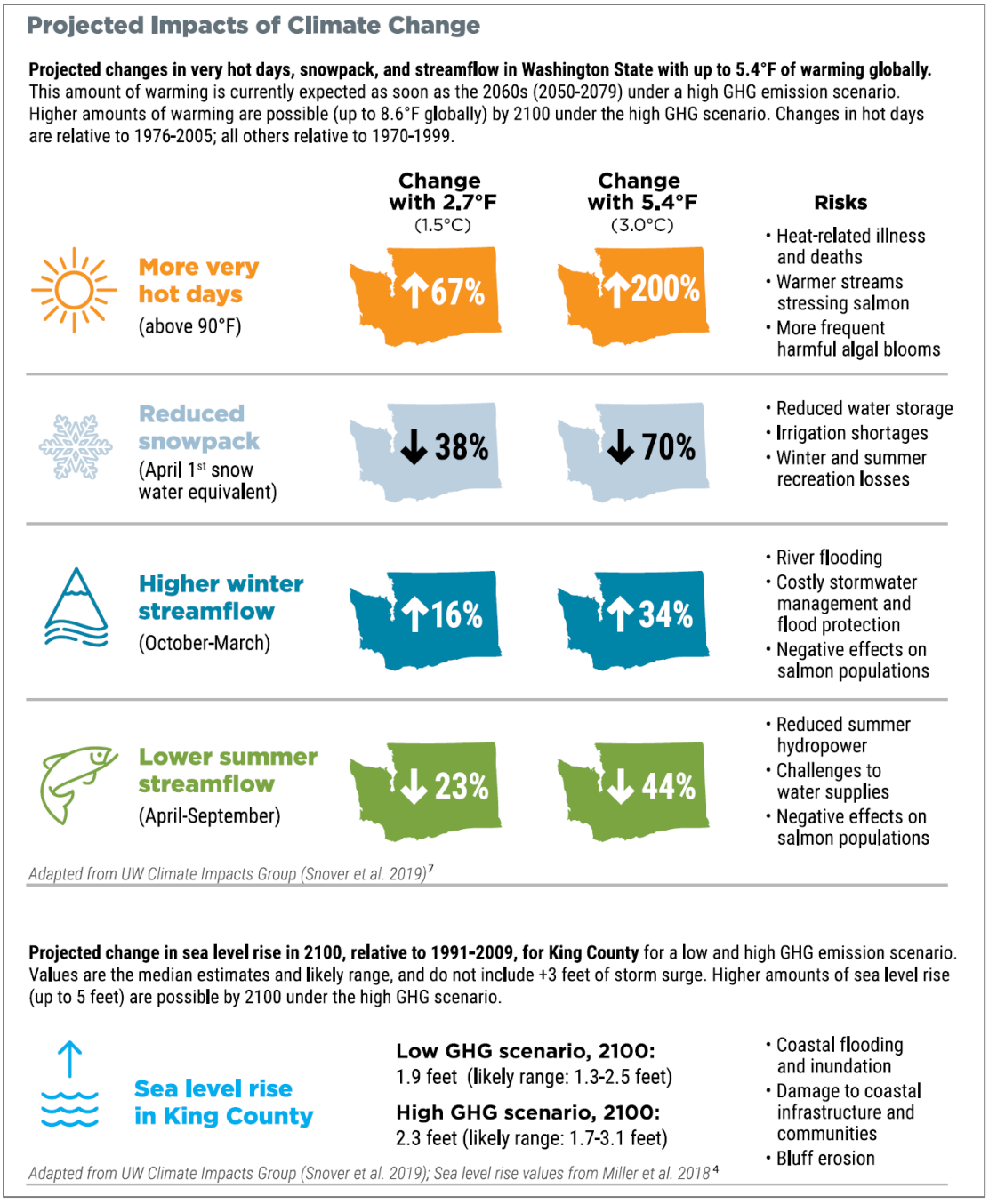
Corporate Guarantees

If a company is part of a larger corporate family, the company can have their parent company issue a corporate guarantee if the parent company can pass the financial test or a requirement to meet strict performance standards. Companies that choose this option must provide an extra document from the parent company that promises to cover the necessary expenses. Companies using the corporate guarantee for their third-party liability coverage also need an extra document from the Attorney General in their home state.[555]

[554] Department of Ecology, Financial Assurance Options, "Trust Fund". [LINK]. Accessed 1/25/2022.
[555] Department of Ecology, Financial Assurance Options, "Corporate Guarantee." [LINK]. Accessed 1/25/2022.

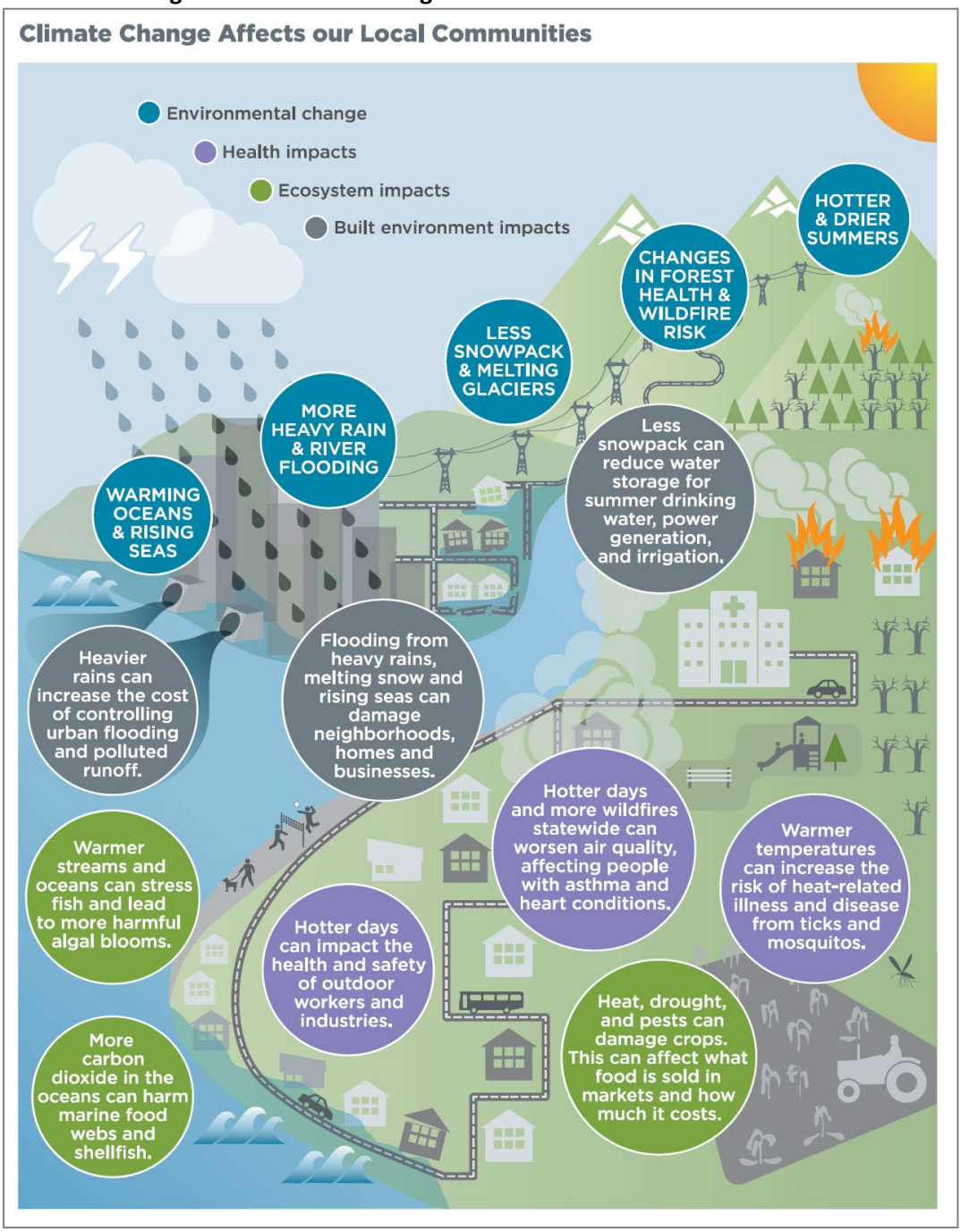
G. Anticipated Climate Change Impacts

Figure G-1. Projected Impacts of Climate Change[556]



[556] King County, "2020 Strategic Climate Action Plan,"(SCAP) May 2021. [LINK]. Page 30. Accessed 5/21/2022.

Figure G-2. Climate Change Affects our Local Communities[557]



[557] King County SCAP, ibid. [LINK]. Page 31. Accessed 5/21/2022.

H. Financial Health Review of Fossil Fuel Operators

This appendix reviews the varying types or structures of fossil fuel companies, and the varying levels of solvency of individual fossil fuel companies, including those that have proposed developing the types of fossil fuel operations that could be built in unincorporated King County and fall under its permitting jurisdiction.

Fossil Fuel Operators: Company Organization

Understanding the business structure of various fossil fuel operators can provide insight into the potential range of financial reserves available for those operators. A Library of Congress Research Guide on the oil and gas industry observes the following:

> *"The oil and gas industry is frequently divided into three segments: upstream, midstream and downstream. While each of these areas has a number of independent companies, major companies in oil and gas are often considered integrated, meaning their businesses consist of a mix of upstream, midstream and downstream activities. Companies can be private, public, or state-owned, which impacts the amount of information available."*[558]

The research guide further helps define the levels of integration that a company may have obtained.

> ***"Supermajor integrated oil and gas companies** are involved in each segment of the industry and are defined as typically having market capitalization of $100 billion or more. They are often international oil companies (IOCs).*
>
> ***Major integrated companies** are defined as typically having market capitalization of $10 billion to $100 billion.*
>
> *An **independent company** focuses on one segment of the industry and is defined as a producer who does not have more than $5 million in retail sales of oil and gas in a year or who does not refine more than an average of 75,000 barrels per day of crude oil during a given year."*[559]

Although the "independent company" definition above is focused more on oil companies, drawing a distinction between larger and smaller fossil fuel companies, with corresponding differences in potential assets and revenues, is still a useful exercise, and is explored more in the following subsection.

Operator Cost Coverage Abilities May Vary

The ability of a fossil fuel operator to cover the costs from a fossil fuel facility incident may be influenced by the type of fossil fuel facility proposed, and existing company assets at the time of development.

Some corporations that build fossil fuel facilities have multiple assets, or long-standing operational revenues, which can cover extreme cost impacts from a fossil fuel facility incident – such as supermajor integrated, or major integrated, companies as outlined in the above subsection.

Although offshore drilling facilities are not under King County permitting jurisdiction, the BP-owned Deepwater Horizon spill is a useful example of some entities' abilities to cover large cost impacts. The Deepwater Horizon spill in 2010 killed 11 people, injured 17, and released 134 million gallons in an 87-day oil spill. The spill affected 1,000 miles of coastline; spread over 40,000 square miles of the Gulf of

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[558] Burclaff, Natalie, "Oil and Gas Industry: A Research Guide," Oil and Gas Companies Section. Library of Congress, Winter 2005; updated September 2021. [LINK]. Accessed 12/20/2021.

[559] Burclaff, Natalie, "Oil and Gas Industry…, ," Oil and Gas Companies Section, ibid. [LINK]. Accessed 12/20/2021.

Mexico; caused the deaths of over 100,000 sea birds and 160,000 juvenile sea turtles; and led to an up to a 51 percent decrease in Louisiana's Barataria Bay dolphins.[560,561] To date, BP has paid over $69 billion towards the costs of the spill from multiple settlements, including the largest environmental damage settlement in U.S. history of $20.8 billion in 2016.[562,563] Some have observed that BP was worth more than $180 billion at the time of the spill, and that few other companies could have afforded the cost of the Deepwater horizon incident.[564] It is notable that the incident reduced BP stock prices, constricting its financial resources at the time of the incident, an impact that may apply to other organizations associated with future incidents.[565] However, overall, the Deepwater Horizon spill shows that some companies have adequate financial holdings to cover large costs arising from facility incidents.

The landscape of fossil fuel facility operators is not uniform, however, and the ability of one company to cover incident costs should not be mistaken as an ability of all fossil fuel companies to cover incident costs. Although fossil fuel facility developments are always in flux, there has been considerable global activity to develop LNG facilities that helps illustrate shifting developer fortunes. Some companies that initially appeared financially sound (and hence, might be able to cover incident costs) have ended up cancelling projects or entering bankruptcy (indicating impacted financial reserves or potential inability to cover incident cots). The last few years have shown multiple changes in LNG project investments, with both larger and smaller companies morphing in their degree of financial solvency; high debt loads also indicate increased financial risk to cover incidents, especially when combined with operator bankruptcy.

- The Magnolia LNG project, originally anticipated to achieve a Final Investment Decision (FID) in 2015 and start operations in 2018, has suffered a series of delays. [566] [567]
    - Original project-holder LNG Ltd. did not find investors and, following the failure of a $75 million deal to be taken private, was appointed administrators for potential insolvency (the Australian equivalent of U.S. bankruptcy).[568]

[560] Uhlmann, David, "BP paid a steep price for the Gulf oil spill but for the US a decade later, it's business as usual," The Conversation, April 23, 2020. [LINK]. Accessed 12/21/2021.

[561] National Oceanic and Atmospheric Administration (NOAA), "Deepwater Horizon oil spill settlements: Where the money went," last updated April 20, 2017. [LINK]. Accessed 12/20/2021.

[562] Schleifstein, Mark, "BP and its partners have spent $71 billion over 10 years on Deepwater Horizon disaster," April 18, 2020. [LINK]. Accessed 12/20/2021.

[563] NOAA, "Deepwater Horizon oil spill settlements…" ibid. [LINK]. Accessed 12/20/2021.

[564] Schleifstein, Mark, "BP and its partners…," Ibid. [LINK]. Accessed 12/20/2021.

[565] CNN Wire Staff, "Tony Hayward: BP not prepared for fallout, was on financial brink," CNN, November 9, 2010. [LINK]. Accessed 12/20/2021.

[566] Hydrocarbons Technology, "Magnolia LNG Export Facility, Lake Charles, Louisiana," 2015. [LINK]. Accessed 12/21/2021.

[567] An FID is the point where a company or companies that own a project announce to investors and the media that the project is progressing, as they have the funding necessary to execute the project and begin operations. This is typically determined by the company board of directors. See OilPrice.com Editorial Department, "The Complete Guide to FID's," OilPrice.com, February 23, 2020. [LINK]. Accessed 12/21/2021.

[568] Mosbrucker, Kristen, "Company behind Magnolia LNG appoints administrators, may be insolvent," the Advocate, May 5, 2020. [LINK]. Also, Woellwarth, Lydia, "LNG Limited seeks judicial advice," LNG Industry, July 1, 2020. [LINK]. Accessed 12/21/2021.

    - The project was subsequently bought by Glenfarne, which originally estimated achieving an FID by late 2021 but later pushed their FID projection back to 2023.[569] Operations are now anticipated to begin in 2026.[570]
- Three proposed LNG export terminals in the Rio Grande Valley of Texas have also experienced mixed success in financing, permitting, and addressing public opposition for proposed facilities.
    - Annova LNG announced it was abandoning development plans for the Annova LNG facility in 2021 due to LNG market changes. LNG prices dropped to record lows in 2020, with 2021 demand growth continuing at a slower pace than past years.[571,572]
    - Texas LNG, also pursued by the Glenfarne group that purchased the Magnolia LNG project, delayed their projection for making their FID in 2021 to 2022.[573]
    - Rio Grande LNG, along with Texas LNG above, has been affected by a court-order to the Federal Energy Regulatory Commission (FERC) to revisit the projects' Environmental Assessments, which did not include climate change and environmental justice impacts.[574]
- As part of Royal Dutch Shell's plan to reduce 2020 spending by 20 percent (or $5 billion), the company announced it was pulling out of the Lake Charles LNG renovation project in Louisiana, proposed to add a 16.4 million ton-annual LNG export option on to an import terminal.[575,576] Energy Transfer, the other Lake Charles LNG project partner, is continuing project development though it has stated it may reduce export goals to 11 million tons.[577,578] The project had already been granted an extension to December 2025.[579]
    - More recently in 2021, Shell has been attempting to divest its 35 percent share of the Abadi's Masela Block LNG project in Indonesia, valued at $800 million to $1 billion. Shell has failed to generate significant interest in product sales 18 months after the investment announcement. Shell may successfully exit the project if the development plan is revised, which is under consideration. Japan's Inpex, the operator, is considering adding carbon capture, utilization, and storage to the project due to growing pressure to cut emissions. The FID has been delayed two years, from 2022-2023 to 2024-2025.[580]

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[569] Naquin, Courtney, "Two Gulf Coast Fracked Gas Export Projects' Financial Investments Delayed," Sierra Club, September 24, 2021. [LINK]. Accessed 12/21/2021

[570] Bajic, Adnan, "Glenfarne gets five-year extension for Magnolia LNG," Offshore Energy, October 9,2020. [LINK]. Accessed 12/21/2021.

[571] Doherty, Liz, "Plans for Annova LNG Fracked Gas Export Terminal Ditched," Sierra Club, March 22, 2021. [LINK]. Accessed 12/21/2021.

[572] Reuters staff, "Annova stops development of Texas Brownsville LNG export project," Reuters, March 22, 2021. [LINK]. Accessed 12/21/2021.

[573] Naquin, Courtney, "Two Gulf Coast Fracked Gas Export Projects' Financial Investments Delayed," Sierra Club, September 24, 2021. [LINK]. Accessed 12/21/2021.

[574] Naquin, Courtney, "Two Gulf Coast Fracked…" ibid. [LINK]. Also, Farah, Nina, Court orders new NEPA review for Texas LNG plants," EnergyWire, August 4, 2021. [LINK]. Accessed 12/28/2021.

[575] Mann, Joshua, "Oil supermajor cuts 2020 spending by $5 billion," Houston Business Journal, March 23, 2020. [LINK]. Accessed 12/21/2021.

[576] Mosbrucker, Kristen, "Shell drops out of Lake Charles LNG project, citing coronavirus and market conditions; project downsized," the advocate, March 30, 2020. [LINK]. Accessed 12/21/2021.

[577] Mosbrucker, Kristen, "Shell drops out…" ibid. [LINK]. Accessed 12/21/2021.

[578] Lake Charles LNG, "Newsroom," last update February 2021. [LINK]. Accessed 12/21/2021.

[579] Mosbrucker, Kristen, "Shell drops out…" ibid. [LINK]. Accessed 12/21/2021.

[580] Evans, Damon, "Shell Waiting on Approval for CCS to Exit Abadi LNG," Energy Voice, December 28, 2021. [LINK]. Accessed 12/28/2021.

- Gulfport Energy Corp. filed for Chapter 11 bankruptcy and completed restructuring in 2021 with $853 million of debt.[581,582] The company had $2.5 billion total debt prior to restructuring.[583]
- Chesapeake Energy Corp. filed for Chapter 11 bankruptcy, and completed restructuring in 2021 with $1.3 billion of debt. The company had $9.1 billion total debt before restructuring.[584]
- HE Mideast Ltd announced that it was liquidating its Dubai LNG trading company in 2021, defaulting on at least $50 million of debt to LNG suppliers.[585]

Some of the above project changes may be affected due to increasingly volatile fossil fuel markets overall. Some analysts have observed that the oil and gas industry began contracting in 2014, with 2020 as a particularly impactful year.

> *"…Since the oil and gas industry began contracting in late 2014, 2020 was the worst. Forty-six exploration and production (E&P) companies representing around $53 billion in total debt filed for bankruptcy protection last year. This is around 30% of the total debt represented in bankruptcy filings since 2015, the first year Haynes and Boone began tracking data.*
>
> *"The aggregate debt (secured debt and unsecured debt) for North American oil and gas producers in 2020 was comparable to the record 2016 levels," the law firm said. "Importantly for commercial banks and other secured lenders, secured debt increased substantially from 35% in 2016 to 46% in 2020.""*[586]

For reference, secured debt refers to debt where property has been pledged as collateral for the loan, wherein the bank may repossess on the property if the debtor fails to pay their debt.[587] The above means that potentially almost half of North American oil and gas company debts are tied to their assets. If a debt were tied to a facility that suffered a catastrophic explosion, that would mean that debtor ability to pay explosion impacts would be reduced by asset loss, and the ability to pay debts associated with an explosion would be further hampered by other preexisting debts held by the operator. This also potentially raises risks associated with some financial assurance mechanisms such as self-bonding; this topic is discussed more in report section V.A.2.

Some LNG project shifts may also be due to an over-saturated market. The International Gas Union (IGU) has predicted that most LNG projects proposed for development will not be built. Compared to the current capacity of 453 million tons per annum (MPTA), there are currently 892 MPTA of

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[581] A U.S. Chapter 11 bankruptcy is where the debtor retains its assets and continues operations while developing a court-approved "plan of reorganization to keep its business alive and pay creditors over time." See Administrative Office of the U.S. Courts, Federal Judiciary, "Chapter 11 – Bankruptcy Basics." [LINK]. Accessed 12/21/2021.

[582] Gulfport Energy, "Press Release: Gulfport Energy Corporation Successfully Emerges From Chapter 11," May 18, 2021. [LINK]. Accessed 12/20/2021.

[583] Reuters staff, "Natural gas producer Gulfport Energy files for bankruptcy," Reuters, November 14, 2020. [LINK]. Accessed 12/21/2021.

[584] Kramer, Brad, "Chesapeake Energy Emerges from Bankruptcy After Financial Restructuring," February 10, 2021. [LINK]. Accessed 12/20/2021.

[585] Stapczynski, Stephen, "H-Energy's Ex-Dubai-Based LNG Trading Arm Being Liquidated," Bloomberg Law – Bankruptcy Law, Aoruk 9, 2021. [LINK]. Accessed 12/20/2021.

[586] Gonzales, Leticia, "North American E&P Bankruptcies Slow in December, but Industry Looking to Better Days," Natural Gas Intelligence (NGI), January 20, 2021. [LINK]. Accessed 12/20/2021.

[587] New York City Bar, "Bankruptcy: Types of Debt," last updated March, 2015. [LINK]. Accessed 12/28/2021.

"aspirational" LNG projects in the pre-FID stage. [588] As of 2022, the U.S. became the largest LNG exporter, followed closely by Qatar and Australia, with Russia as the fourth-largest.[589] Roughly 40 percent of the pre-FID LNG projects are in the U.S.[590] Although LNG demand has grown with China's and India's efforts to reduce coal-fired power, investors are concerned with oversupply glutting the market and dropping product prices, which some analysts have noted has been oversupplied in recent years.[591,592] The IGU has noted this may shift projects towards expansion of existing facilities (industry considers these brownfield developments), and smaller-scale developments.[593] Although a well-monied operator can open a small LNG project, this also means investments may be pursued by operators with less financial capital at the outset, which also indicates there may be increased development by operators with smaller financial reserves to cover incidents.

The above details paint a picture of the existing uncertain financial status for fossil fuel facility operators generally in some cases, and more for LNG project operators specifically. Although there are many fossil fuel facility operators who have extensive financial reserves, there is evidence of smaller investors attempting LNG project development with reduced financial reserves. Additionally, operators may be attempting to develop multiple projects simultaneously, or leverage existing assets towards additional development opportunities, which may restrict operator access to some financial coverage options in the event of an explosion incident. As such, despite the multiple financial fuel operators with extensive financial resources to cover incidents, the data shows that not every operator has this ability.

[588] Financial Post Staff, "Most of the world's proposed LNG projects unlikely to be built as investors fall out of love with natural gas," June 9, 2021. [LINK]. Note: Speculation in this area has occurred in both directions, as surging natural gas prices in late 2021 countered this predictive trend and some say have bolstered LNG project potential. Source: Zahid, Jasmin, "Insight Weekly: LNG Exports Surge; Investors Unfazed by Inflation; Neobanks Drive VC Funding," S&P Global: Market Intelligence, blog, November 23, 2021. [LINK]. Accessed 12/28/2021.

[589] Stapczynski, Stephen and Sergio Chapa, "US becomes world's top LNG exporter for first time ever," Bloomberg, Aljazeera, January 4, 2022. [LINK]. Accessed 1/13/2022.

[590] Financial Post Staff, "Most of the world's proposed LNG projects unlikely to be built as investors fall out of love with natural gas," June 9, 2021. [LINK]. Note: Speculation in this area has occurred in both directions, as surging natural gas prices in late 2021 countered this predictive trend and some say have bolstered LNG project potential. Source: Zahid, Jasmin, "Insight Weekly: LNG Exports Surge...,"ibid. [LINK]. Accessed 12/28/2021.

[591] Disavino, Scott, "For LNG developers, another year of canceled projects," Reuters, last updated May 18, 2021. [LINK]. Accessed 12/28/2021.

[592] Macdonald-Smith, Angela, "LNG glut to force US shutdowns: Fesharaki," Financial Review, December 12, 2019. [LINK]. Accessed 12/28/2021.

[593] Financial Post Staff, "Most of the world's proposed LNG projects…," ibid. [LINK]. Accessed 12/28/2021.

I. NET Power Pilot: Evaluation of Potential for Future Widespread Adoption

This appendix reviews the technology being piloted by NET Power for thermal electric plants that could reduce or remove typical NOx pollution concerns. A primary selling point of the new technology is its potential for reduced costs of associated with carbon sequestration and storage (CCS); accordingly, this section also reviews the status of CCS; why NET Power technology may provide a market advantage over current CCS costs; and the status of other proposed NET Power projects.

Primary interest in NET Power's La Porte facility has centered on its carbon sequestration process. Traditional CCS envisions an ancillary facility process to separate out carbon dioxide after combustion. While CCS is increasingly desirable in the industry, this technology has represented a "parasitic load," or a costly burden that reduces a facility's economic and energy efficiency.[594] In contrast, the NET Power facility integrates carbon-capture as part of its combustion cycle, running electric fluid turbines on pressurized carbon dioxide in water instead of on steam. After turbine generation, a heat exchanger separates the water from the carbon dioxide, which can be reused in the combustor, or repressurized to either be sold as a byproduct or stored where it will not be released into the atmosphere.[595] Carbon dioxide can be used to, "carbonate soda pop, to decaffeinate coffee and tea, to make building materials, or to enhance oil and gas extraction," also known as enhanced oil recovery (EOR).[596]

Some have observed that, rather than separating out and isolating the carbon dioxide, the challenge is actually determining where to put large quantities of carbon dioxide once collected. While a majority of operating CCS projects (16) transport the compressed carbon dioxide for EOR, the "scale of fossil fuel power generation far exceeds the ability of EOR to soak up carbon dioxide…" An observer also noted that, "…it's somewhat perverse to use avoided carbon emissions to dig up more carbon…".[597,598] Re-use of carbon dioxide is not the only alternative, however; there are currently at least five CCS facilities storing carbon in geologic formations, subsurface reservoirs or underground saline formations.[599] Although there have been concerns of the safety of storing carbon underground, recent research indicates it can be done safely and that there is adequate space for significant carbon dioxide storage.[600]

Given the NET Power integration of carbon sequestration in the plant, and so long as it can be paired with a successful carbon storage process, NET Power technology has potential to be integrated

[594] Facilities are typically concentrated in other industries, the largest grouping of which are eight CCS facilities associated with natural gas processing and liquids recovery;see Roberts, David, "That natural gas power plant with no carbon emissions or air pollution? It works." Vox, June 1, 2018. [LINK]. Such facilities separate out natural gas liquids (NGL), and sometimes also water and other contaminants, from a raw natural gas stream; see U.S. EIA, "U.S. natural gas processing plant capacity and throughput have increased in recent years," March 7, 2019. [LINK]). Accessed 1/3/2022.

[595] Roberts, David, "That natural gas power plant…" ibid. [LINK]. Accessed 1/3/2022.

[596] McMahon, Jeff, "NET Power CEO Announces Four New Zero-Emission Gas Plants Underway," Forbes, January 8, 2021. [LINK]. Accessed 1/3/2022.

[597] C2ES, "Carbon Capture," ibid. [LINK]. Accessed 1/3/2022.

[598] Roberts, David, "That natural gas power plant…" ibid. [LINK]. Accessed 1/4/2022.

[599] Center for Climate and Energy Solutions (C2ES), "Carbon Capture," [LINK]. Accessed 1/3/2022.

[600] Flude, Stephanie and Juan Alcade, "Carbon capture and storage has stalled needlessly – three reasons why fears of CO_2 leakage are overblown," The Conversation, March 4, 2020. [LINK]. Also, O'Callaghan, Jonathan, "Storing CO2 underground can curb carbon emissions, but is it safe?" Horizon, November 27, 2018. [LINK]. Accessed 1/4/2022.

mainstream – which, in addition to reducing GHG emissions, would also address nitrogen dioxide pollution from thermal energy plants.

The NET Power project is by no means the only CCS facility in existence, but it appears to be the only current project attached to thermal power generation – though more CCS projects are anticipated. There are currently 26 commercial-scale CCS projects operating, with another 21 in early development and 13 more in advanced development. Of these the 26 operating facilities, one provides storage for an LNG facility, and only two are associated with power generation facilities, namely the:

- Coal gasification Great Plains Synfuels Plant built in North Dakota in 2000; and
- Coal plant retrofit of the Boundary Dam project in Canada, built in 2014.[601]
    - Another project, NRG Petra Nova associated with coal power, was indefinitely idled in early 2021 due to the collapse of crude oil prices during the Covid-19 pandemic.[602,603,604]

Research conducted for this report indicates that roughly nine CCS projects are planned in the U.S. associated with power generation projects. Additionally, worldwide, approximately 12 CCS projects are associated with gas-fired power generation, though it is unknown how many of those projects are planned for the U.S.[605] As for NET Power, which operates as a software company licensing its technology, it has announced the technology will be used in four projects, all projected to begin power production by 2025.[606] These include:

- Coyote Clean Power, Colorado, by 8 Rivers.
- Broadwing Clean Energy Complex, retrofitting an existing carbon dioxide storage facility in Illinois, by 8 Rivers and Archer-Daniels-Midlands Co.
- Frog Lake Power Plant in Canada, by Frog Lake First Nation and KANATA.
- A still-in-exploration project in Teeside, England, with Zero Degrees Whitetail Development Ltd., an 8 Rivers subsidiary, and Singapore-based Sembcorp subsidiary Sembcorp Energy UK.[607]

These developments further support the evaluation that this technology could be used increasingly by other new developers of thermal power generation plants, and would result in reduced or negated concerns with NOx pollution.

[601] Center for Climate and Energy Solutions (C2ES), "Carbon Capture," [LINK]. Accessed 1/3/2022.
[602] C2ES, "Carbon Capture," ibid. [LINK]. Accessed 1/3/2022.
[603] Reuters, "Power plant linked to idled U.S. carbon capture project will shut indefinitely -NRG," Yahoo News, January 29, 2021. [LINK]. Accessed 1/3/2021.
[604] C2ES, "Carbon Capture," ibid. [LINK]. Accessed 1/3/2022.
[605] Fajardy, Mathilde, "CCUs in Power," International Energy Agency (IEA), November 2021. [LINK]. Accessed 1/3/2022.
[606] McMahon, Jeff, "NET Power CEO Announces Four…," ibid. [LINK]. Accessed 1/4/2022.
[607] Patel, Sonal, "Breakthrough: NET Power's Allam Cycle…" ibid. [LINK]. Accessed 1/4/2021.

J. Collaboration Activities Conducted Regarding this Report

As directed by Workplan Action 20, a proposed ordinance reflecting the recommendations of this report was transmitted by the Executive to the Council concurrent with this report. A draft of the ordinance was provided to the public and the state for review and comment prior to transmittal. Presentations were also provided to the public on research findings and recommendations. This included the following outreach activities:

- A 3-week public comment period from March 30 to April 22, 2022.
- Online posting, which included the draft legislation, information about the proposals, and the various methods for public comment.
- Email notification to Permitting's development regulation distribution list.
- Posting in the Unincorporated Area Community News, April issue 2022.
- Presentations to local community groups in 2022:
    - Four Creeks Unincorporated Area Council (UAC) (2/8)
    - West Hill Community Association (2/15)
    - Greater Maple Valley UAC (2/7)
    - North Highline UAC (2/2).

Although no comments were received in the public comment period, the Sightline Institute and the Center for Sustainable Economy provided comments on the draft report outside of the public comment period prior to report transmittal.

K. Climate Impacts Group Report, Understanding the Cost of Climate Change: A Guide for Local Actors

See attachment.

Understanding the Cost of Climate Change:

A Guide for Local Actors

Prepared for King County by:
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March 2021

COLLEGE OF THE ENVIRONMENT
UNIVERSITY of WASHINGTON

Introduction

The purpose of this review is 1) to provide an overview of key concepts and foundational science related to the study of the economics of climate change and 2) to identify proven methods for conducting economic valuations of climate impacts on a local government scale. The sections covered in this document are as follows:

1. Background

Climate change shapes society's economic and social well-being, and the economics of climate change can inform local governments in their resilience planning. The valuation of potential climate impacts allows decision-makers to better understand and prepare for varying magnitudes of risk, while cost-benefit analyses aid the design of policy instruments for both mitigation and adaptation. Additionally, chronic and acute shifts in weather and climate affect the performance of entire economic sectors, as well as the financial security of private actors and households. Despite widespread impacts, the relatively new and complex field of climate change economics has only been widely adopted in contemporary economics within the last 25 years.

While the foundational science for appraising natural and human systems was established in the 19th century, it was only in 1995 that the Intergovernmental Panel on Climate Change (IPCC)'s globally institutionalized the importance of understanding the economic and social dimensions of climate change (Cooper and Bruce, 1997). In 2008, a United States Court of Appeals decision required the federal government to account for the economic effects of climate change in regulatory cost-benefit analyses, and several state-level assessments were conducted shortly thereafter (e.g in Illinois, Maryland, New Jersey, New York, and Washington). However, in retrospect, these state assessments have been critiqued for taking an overly simplistic approach to determining the cost of impacts (Neumann & Strzepek, 2014). Furthermore, most of the existing work on the economics of climate change has been focused on global and national scale impacts while local-scale assessments remain limited.

Snapshot: National Scale Economic Assessments
Risky Business: An American Climate Prospectus

In 2014, the first national scale assessment in the United States was published through a public-private partnership, entitled "*Risky Business: An American Climate Prospectus*". This was considered a groundbreaking effort, as researchers combined the best available climate projections from IPCC's Fifth Assessment Report (AR5) and the US government's Third National Climate Assessment (NCA3), with state-of-the-art econometric analyses, private sector risk assessment tools, and cloud computing (Houser et.al, 2015). Along with insights on regionally-relevant impacts, the study identified three of the most pressing economic impacts for American businesses and governments, as follows:

- Damage to coastal property and infrastructure from rising sea levels and increased storm surge
- Climate driven changes in agricultural production and energy demand
- Impact of higher temperature on labor productivity and public health

Despite the fact that this national assessment raised concerns around the spatial and temporal aggregation of data, efforts to improve and sustain this work continue to today. In 2017, the Climate Impacts Lab, the primary research group responsible for the Risky Business report, released county-level data on median economic damages from changes in temperature, precipitation, sea levels, and storm activity. Using peer-reviewed regional and local climate projections through year 2100, the study analyzed the combined value of market and nonmarket damage across several sectors such as agriculture, crime, coastal storms, energy, human mortality, and labor.

Source: Hsiang et al., 2014

While significant scientific and technological advancement in global and national climate modeling showcase progress, climate change continues to challenge available economic techniques to its limits (Nordhaus, 2019). Key areas of concern that analysts continue to struggle with include:

- The treatment of uncertainty in human and natural systems
- The choice of the proper scenarios against which to make comparisons
- The actual valuation of specific impacts
- The aggregation of impacts over time and across differing social and economic contexts.
- Incomplete accounting

Due to the aforementioned concerns, **no economic assessment to date claims that any dollar estimate can or should be used as a definitive cost of climate change**. Rather, monetary values are a means to weigh risk relative to other climate impacts, other geographies, or across varying socioeconomic contexts. They serve as political instruments for decision-makers to understand which assets and communities are most vulnerable, and to allocate limited resources accordingly. The challenges listed above underpin the critical assumptions analysts make that ultimately shape the accuracy and relevance of their assessment. The following sections explore how local actors seeking to do an economic assessment can address these challenges.

2. Defining the Purpose of the Economic Assessment

Prior to any form of data gathering or analysis, it is critical that organizations and governments have clarity on their economic assessment's purpose. By defining key questions to be answered by the assessment, the process is given focus, scope, and direction. From choosing greenhouse gas scenarios to the type of climate models to be used, purpose helps to decide what type of information is needed and how this information will be used. For local governments, economic assessments of climate impacts are most likely to be used for the following:

- **Issue Identification or Analysis:** With this purpose, an economic assessment is used to understand the extent and nature of climate risks. Guiding questions could focus on what the most range of climate impacts that could occur, the scale of fiscal damage related to each impact, and who would bear the costs.
- **Decision-Making:** In this approach, climate-related costs are viewed relative to one another rather than as absolute values. Economic assessments can be used to guide decisions around which climate risks, communities, public infrastructure, and time-scales should be prioritized in resilience planning. While benefit-costs analysis is not within the scope of this study, this method can also be used to compare effects of mitigation or adaptation actions in relation to costs associated with a "business-as-usual" scenario.
- **Policy or Program Evaluation:** When approaching an assessment with this lens, economic costs are used to evaluate the efficacy of policies or programs. The assessment can serve as evidence that a program or policy has delivered on certain milestones, or reached high-level goals.

3. Approaching Risk and Uncertainty

Due to our limited understanding and the irresolute nature of human and natural systems, economists must navigate uncertain, imperfect, and incomplete pictures of how the world will look in the future. As a result, the identification of potential for risk always exists within a degree of uncertainty across all climate economics. One means of managing this uncertainty is to take a probabilistic approach to understanding risk-characterizing risk by the probability or likelihood of a climate-related event occurring, and the severity of its consequences (Hsiang, 2014). In a simple formula, this can be expressed as:

Risk (Loss Estimate) = Likelihood (Probability) x Severity (Consequence).

To help identify the organization's approach to risks, here are some questions to consider: *Is the organization planning for the near future, or are they looking decades ahead? Does the organization have the technical capacity and resources to plan for "tail-risk"climate events -- events that have a very low likelihood of occurring but would be catastrophic if they happened? Or are they only interested in events that are most likely to occur?* While most entities would like to understand the risks associated with every possible future, this framing allows local governments to prioritize risks and focus actions to their specific decision-making context.

4. Identifying Climate Scenarios

Identifying climate scenarios is the critical first step in developing an economic assessment. Climate scenarios provide the baseline information that help us determine climate impacts, as well as identify where our threshold for risks lie in relation to these impacts. In 2014, the IPCC published its Fifth Assessment Report (AR5) in which they adopted a set of four climate scenarios called Representative Concentration Pathways (RCP). These RCPs are labelled after a possible range of future atmospheric greenhouse gas concentrations (CO2) through the year 2100. Within the global scientific community, these scenarios are considered to be the standard baseline for developing climate models and projections for impacts such as mean temperature, precipitation, humidity and sea level rise. In order to understand the results of climate model output and analysis based on these scenarios, it is important for researchers and policy makers to understand the following assumptions associated with each of the RCPs.

Representative Concentration Pathways

- **RCP 8.5**: Assumes that fossil-fuel intensive development continues and greenhouse gas (GHG) emissions continue at the same rate as the past two centuries. RCP 8.5 is the highest of the greenhouse gas scenarios, with global temperatures projected to increase by ~4.8ºC (8.6ºF) above pre-industrial levels by century's end. Higher temperatures result in greater impacts and subsequently, greater costs.
- **RCP 6.0:** Assumes there is a modest effort to mitigate and adapt, but a heavy reliance on fossil fuels will persist. GHG emissions will gradually increase until stabilizing in the final decades of the century.
- **RCP 4.5**: Assumes a moderately low emission scenario, with substantial efforts to mitigate and adapt. GHG emissions peak by mid-century, and experience a sharp decline shortly thereafter. Global temperatures are likely to rise between 2ºC (3.6ºF) and 3ºC (5.4ºF) by century's end
- **RCP 2.6** Assumes aggressive emission reduction takes place. This scenario requires a 50% reduction in GHG emissions by 2050, relative to 1990 levels, and net zero or net negative emissions in the later decades of the century. Global temperatures are likely to rise by less than 2ºC (3.6ºF) above pre-industrial levels.

It is important to note that all scenarios will result in similar levels of warming until mid-century. Prior to mid-century, projected impacts are driven by warming that is already "in the pipeline", caused by greenhouse gases that we have already emitted (Snover et al., 2013). Since future scenarios are dependent on GHG emissions produced in the next few decades, we cannot say with certainty which scenarios are likely to occur.

Figure 1. Total greenhouse gas emissions associated with each RCP

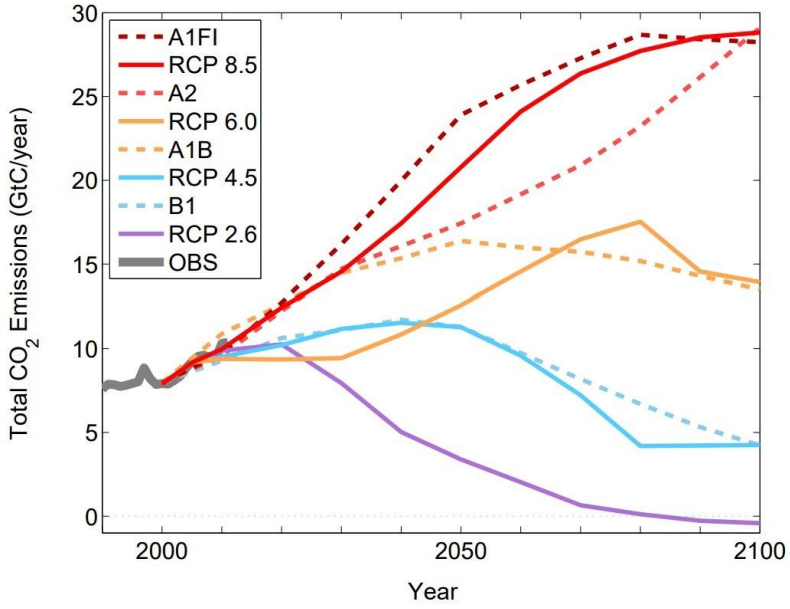

Figure 1 illustrates the projected trajectory of greenhouse gas scenarios associated with the RCPs through 2100. The grey line (OBS) represents actual emissions from the years 1990 - 2010. The dotted lines (A1F1, A2, A1B, B1) illustrate trajectories associated with a previous set of greenhouse gas scenarios that are no longer in use, but may be referenced in studies conducted before 2014.

Most studies will analyze a baseline scenario, either on its own in order to understand the cost of inaction or in comparison with lower scenarios for decision-making purposes. RCP 6.0 and RCP 8.5 are considered to be low and high baseline scenarios respectively, as they both illustrate a future in which society has a "business-as-usual" response to climate change and GHG emissions continue to increase until the century's end. More pragmatically, the choice of which RCPs to use in an assessment is often dependent on either of the following factors:

- **Data Availability:** Data used as input in climate impacts models can vary amongst RCPs and often, those seeking to do an assessment are limited to what is available for their region. For example, in the Northwest, there is a desire to be able to use RCP 6.0 more often, yet impacts data associated with this scenario is sparse. On the other hand, global and national scale assessments are often conducted with more resources and the data used is less granular. Therefore, most if not all assessments of this scale study impacts associated with the full range of scenarios.
- **Risk Tolerance:** RCPs provide a means to analyze the climate risks associated with crossing certain biophysical and human thresholds, and the choice of RCPs are often done in the interest of bracketing a range of potential impacts associated with certain levels of GHG concentrations. In this way, the choice of RCPs can be indicative of the assessor's general risk tolerance.
- **Decision-making Context:** If the economic assessment is being used as a guide for decision-making, appropriate RCPs should be chosen to suit the context. For example, it may not be as valuable or cost-efficient for local actors to analyze multiple greenhouse gas scenarios if they are only looking into the near future. This is because projected impacts will be similar across all scenarios before mid-century. Additionally, presenting costs associated with RCP 8.5 in the

later part of the century may seem too expensive relative to municipal budgets and could deter local decision-makers operating in shorter timelines.

5. Identifying Socioeconomic Scenarios

Socioeconomic Scenarios are complementary narratives that describe potential shifts in population, technological advancement, policy context, and income distribution. These scenarios are analysed with climate projections to provide a holistic picture of potential futures (Hallegatte et al, 2008; Hecht, 2013) Ha. In an economic assessment, these qualitative narratives are later translated into quantitative values, such as changes in the market price of energy or losses to gross domestic product (GDP). Given the uncertainty of how society will respond to climate change, analysts are presented with *two options:*

1) **Assess the consequences of chosen climate scenarios relative to the current economy and population.**

In this option, elements such as population and infrastructure are assumed to stay the same over the temporal scale of the assessment. Future climate projections are imposed on the present conditions of the population, economic market, and built environment. This approach is beneficial as different actors likely hold varying perspectives on how society and economy will evolve over time. However, everyone can agree on the size of the population and the structure of the economy today. Additionally, some researchers prefer this approach to separate out the economic effects of climate change from economic effects of changes in population and wealth.

2) **Attempt to predict how the economy and society will change, and assess the consequences of chosen climate scenarios relative to a hypothetical socioeconomic future.**

In this option, factors such as population, rate of urbanization, and economic development are projected out into the future. In global assessments, multiple socioeconomic scenarios are developed, considering other factors such as policy, fossil-fuel development, and socioeconomic inequality. However, this practice is uncommon in local assessments and population projections could be sufficient. If pursuing this route, local governments are also advised to conduct stakeholder engagement and seek out local expertise if projections on the rate of development and resilience of infrastructure is accurate, or if progress on policy are likely.

6. Translating Climate Impacts into Economic Values

When translating climate impacts to economic values, analysts must first understand the types of costs that would be relevant in a local-scale assessment and the methods used to define these costs. Within the context of a city or a county, there are two categories of loss to consider, as listed below (Sussman et al, 2011):

1) **Direct Losses** - The direct physical and economic losses that come as an *immediate* consequence of climate-related events. Some examples of direct losses could include the cost to repair

damaged infrastructure due to sea level rise, revenue loss in commercial fishing industries due to ecosystem disruption, or increased energy prices caused by reduction in snowpack and constrained hydropower generation.

2) **Indirect Losses** - The indirect consequences of direct losses that compound or become transparent over broader spatial and temporal scales. These indirect consequences can consist of either macroeconomic responses or broader systemic losses. Indirect losses can include the following (Halagette et al, 2008):
    - Ripple of direct economic losses to the rest of economic systems over short-term and long-term (e.g. the increased premiums for flood insurances)
    - Responses to macroeconomic shock (loss of confidence in economic actors, inequality deepening)
    - Financial constraints (low-income households unable to recover or bounce back)
    - Technical constraints (limited availability of skilled workers)
    - Impacts outside local area
    - Imports/Export of goods and service
    - Decreased property tax from depreciated home values or migration out of vulnerable areas

For direct losses, impacts can be further classified as 1) Market Impacts and 2) Non-Market Impacts which are defined below:

1) **Market Impacts** - Market impacts refer to the change in price of goods and services that are traded within an existing market. Since these goods and services are regularly bought and sold, monetary values are already defined by people's willingness to pay for it (EPA, 2014). For example, this could include the cost of rebuilding or repairing infrastructure that has been damaged by chronic coastal or riverine flooding.

2) **Non-Market Impacts -** Non-market impacts refer to goods and services that are not traded within any financial or economic market. These could also be defined as open-access resources that benefit the public, but cannot easily be quantified or expressed in monetary values (Rothman, 2003). In the field of climate change, non-market impacts typically include:

a) **Ecosystem Services** - The loss of benefits to humans provided by the natural environment or healthy ecosystems, such as the capacity of wetlands to mitigate stormwater runoff or the amount of energy savings as a result of temperature regulation provided by dense vegetation.

b) **Human Health and Well-being** - The impacts of climate events to human mortality, morbidity, and mental and emotional well-being. This could include the number of lives lost or the number of people requiring hospitalization after an extreme climate-related event such as a hurricane.

c) **Socio-Cultural Values -** The loss of physical and natural assets that may not have significant economic value, but represent social and cultural values of a specific group or population. For example, in the Northwest, salmon and other first foods hold both economic, cultural, and spiritual value for tribes and their preservation contributes to the population's overall well-being.

Figure 2. Categories of Loss

Categories of Loss	**Types of Impacts**	**Examples of Impacts**	**Methods of Valuation**	**Expressed As**
Direct Losses	Market Impacts (Section 7.1)	• Loss of Employment • Business Interruptions •	• Statistical Models • Physical Models	Quantitatively as monetary values
	Non-Market Impacts (Section 7.3)	• Ecosystem Services • Human health and well-being • Sociocultural Values	Non-Market Valuation Methods such as • Replacement Cost • Travel Cost • Hedonic Pricing • Revealed Preference • Stated Preference	Quantitatively as numbers (e.g number of lives lost, percentage of population requiring mental health support) *OR* Qualitatively as a descriptive summary of effects
Indirect Losses	Systemic Impacts and Macroeconomic Responses (Section 7.4)	• Depreciation of Assets • Increase in Taxes • Import/Export of goods and services	• Spatial Analysis • Private Sector Tools	Quantitatively or Qualitatively

7. Valuation Methods

7. 1 The Valuation of Direct Losses: Market Impacts

There are two primary models used to estimate the amount of direct physical and economic loss to a municipality or county: 1) Physical Impact Models and 2) Statistical Models. The definition for each of these methods are outlined below, along with case studies to illustrate how these models have been used in conducting local economic assessments in the past.

1. **Physical Impact Models** are spatial models that value climate risks by understanding the extent of damage on physical assets associated with a specific event. Physical Impact Models are also a common tool within the energy sector and in hazard mitigation. The physical properties of a building, such as capacity for insulation, can inform utility companies on expected energy demand associated with varying temperatures. Similarly, physical properties of a building, such as compliance to building codes, can inform ability to withstand extreme climate-related events and the anticipated extent of damage. Based on the estimated damage, researchers can infer costs with specific economic activities such as rebuilding or replacing structures, total population displaced, or amount of revenue lost due to business interruptions.

Snapshot: Physical Impact Modelling
FEMA HAZUS Model
FEMA's HAZUS model is a commonly used physical impact model for city or county scale assessments. It is a nationally standardized risk modeling tool that is made available as free GIS-based software. It is primarily used for hazard mitigation within the emergency management community and focuses on analyzing risks related to earthquakes, floods, tsunamis and hurricanes (Schneider & Schauer, 2006). The model is based on the following (Hallegatte, 2008):

- A comprehensive dataset of the exposure, i.e. the characteristics and value of the property exposed to a hazard at a fine spatial resolution;
- Vulnerability models, which relate wind speed, flooding depth and any other physical description of a disaster, to a damage ratio, which is the share of the exposure that is destroyed or damaged for a given hazard level.

Benefits of the HAZUS model include:

- The software is free and conducting an assessment with the model is relatively inexpensive. If a city or county has a Hazard Mitigation Plan in place, it's also likely that technical capacity to conduct the assessment already exists within government agencies.
- The tool was designed for mitigation and scenario modeling, meaning it can be appropriately used with forward-looking climate projections.

Limitations of the HAZUS model include:

- Out-of-the-box data provided by the model rarely provides locally relevant or accurate results. The quality of results are contingent on the quality of data users input into the model. Since HAZUS is highly customizable, using locally-developed datasets produces more accurate local results.
- The basic HAZUS model is currently limited to analyzing risks related to earthquakes, floods, tsunamis, and hurricanes. HAZUS does have the capacity to analyze wildfire risk, if specialized

fire models are integrated into the basic model. However, this requires additional time, funding, and expertise provided by fire managers (NAPA, 2001). It cannot provide estimations of losses from extreme heat.

Case Study: Physical Impact Modeling

Climate Ready Boston

In 2016, the City of Boston published Climate Ready Boston (CRB), a comprehensive citywide resilience plan which included downscaled city-level climate projections and a vulnerability assessment. Using a Physical Impact Modelling approach, the City estimated the economic cost of the three most significant climate impacts in the region:

1. Chronic Extreme Heat
2. Frequent Stormwater Flooding
3. Acute and Chronic Coastal and Riverine Flooding

While they were able to broadly understand the economic consequences associated with all three impacts, the assessment could only quantify the costs associated with coastal and riverine flooding using the HAZUS Model. This is primarily due to limitations of the HAZUS Model, specifically its limitations in analyzing certain types of risk. The physical and economic consequences of stormwater flooding were not evaluated because stormwater hazard data is not intended for use to assess individual parcels for flood impacts and are less likely to be mapped. Due to limited data, the impacts of extreme heat are expressed qualitatively and mainly refers to impacts on energy infrastructure and public and other facilities without air conditioning or that may house vulnerable populations.

In quantifying the economic consequences of coastal and riverine flooding, CRB only used three out of the four greenhouse gas scenarios in developing their downscaled climate projections: RCP 8.5, RCP 4.5, and RCP 2.6. Specifically, they chose sea level rise (SLR) scenarios that were most likely to occur within the century to focus following discussions on adaptation.

- 9” SLR with initial occurrence likely through 2030’s to 2050’s
- 21” SLR with initial occurrence likely through 2050’s to 2100’s
- 36” SLR with initial occurrence likely from 2070’s or later

They then mapped these various sea level rise scenarios over citywide building data within the HAZUS Model, in order to assess the exposure of assets associated with each scenario. By identifying the extent of damage to the built environment, they were then able to quantify the following impacts:

- **Structure Damage, Content Loss, and Inventory Loss** - Property losses are evaluated based on depth damage functions (DDFs) developed by the United States Army Corps (USACE) following Hurricane Sandy. DDF correlates the depth, duration, and type of flooding to a percentage of expected damage to a structure and its contents, including inventory. Flood depths at each structure are then cross referenced with DDFs to provide expected percent loss for each structure and its contents. This percent loss is then translated to property loss based on structure and inventory replacement costs.
- **Mental Stress & Anxiety, and Loss of Productivity** - Calculations are based on the percent share of the impacted population expected to seek mental health treatment as a result of disruption

caused by direct physical flood impacts to the structures within which they reside. Lost productivity refers to lost work productivity as a result of mental stress and anxiety alone, and it is calculated based on expected earnings lost over time as a result of decreased work productivity or performance. Both figures only consider impacts for the 30-month period following a flood event.

- **Number of People in Need of Public Shelter** - Calculations are based on expected flood depths within occupied structures, population residing in those structures, and the share of the current population within a given area that is identified as low to moderate income.

All loss estimations are reported by imposing future climate conditions on the present population and built environment. Neither population nor development are projected. However, CRB considered the disproportionate impacts to vulnerable populations by considering demographics such as age, income, disability, and english proficiency. CRB also developed their own detailed asset inventory that combines over 130 local datasets to supplement the general building stock provided by the model. Additionally, CRB convened an Infrastructure Advisory Group (IAG) to identify infrastructure assets, individual and system vulnerability, and existing resiliency measures.

2. **Statistical Models** are another approach to conducting an economic assessment of climate impacts. These models use the relationship between past climate events and economic activity in a specific sector to predict future damages (Hallegatte, 2008). For example, statistical modeling is often used in global and national scale assessments to understand the historical relationship of temperature to economic growth (Hsiang, 2014). In local-scale assessments, statistical modeling can be used with values obtained from existing literature or studies. Past or current economic costs associated with climate events are then statistically extrapolated to obtain potential costs.

Case Study: Statistical Modeling

An Overview of Potential Costs to Washington of a Business-as-Usual Approach to Climate Change

In 2009, researchers from the University of Oregon's Institute for a Sustainable Environment and ECONorthwest released a study that analyzed the cost of climate inaction to Washington households and businesses. As this study was conducted prior to IPCC's release and widespread adoption of the RCPs, an older climate scenario titled "A1F1" was used. While A1F1 is no longer commonly used, it is comparable to today's RCP 8.5, similarly functioning as a baseline scenario (See Figure 1). Researchers also factored in population growth, using rates estimated by the state through 2030 and rates provided by the US Census Bureau for the nation thereafter. The underlying assumption of this study is that human behavior, consumption patterns, and development trends will continue as they have in the past, with the purpose of illustrating economic consequences to Washington state if actions are not not taken to mitigate climate change.

This research primarily used statistical modeling methods to understand 18 climate-related costs associated with a "business-as-usual" approach to climate change, resulting in expected annual costs for three target years: 2020, 2040, and 2080. Through a literature review, researchers obtained historical data on how previous climate impacts have affected costs related to energy, fish and wildlife, flood and storm damage, food production, timber production, recreation and human health. If these values were available for years outside of the three target years, statistical interpolation or extrapolation was used to predict the relationship between impact and cost. Researchers provided caveats to this methodology, stating that the linear interpolation/extrapolation likely either underestimated or overestimated costs.

One specific example of how statistical modeling was used in this study is through the calculation of costs related to increased energy consumption caused by warming temperatures. Researchers used historical data on the relationship between temperature and indoor cooling from a 2005 Regional Assessment by the Northwest Power and Conservation Council. This original study used data from 2000, then forecasted that the average temperature for July-August would increase 2.9°C (5.2°F) by 2040 and subsequently, increase regional residential energy demand by approximately 200 MW. Washington researchers then used linear interpolation to obtain the estimated change in demand for 2020, and extrapolation for 2080. With data from a 2008 study on historical retail sales by the Energy Information Association, they then used the average monthly residential prices for July-August to estimate consumers' additional cooling costs.

7. 2 A Comparison of Valuation Methods for Direct Losses: Market Impacts

Each of the two valuation methods presented above have advantages and disadvantages. While it is possible to use both statistical modeling and physical impact modeling in the same assessment, it is important for assessors to consider the resource, data, and time requirements for each. One method may align more closely with existing efforts, and may be more strategic in terms of budget and effort. These advantages and disadvantages are summarized in the table below (See Figure 3).

Figure 3. The Advantages & Disadvantages of Two Valuation Methods for Market Impacts

Method	Advantages	Disadvantages
Physical Impact Modeling	● May be less resource-intensive. If the city or county has an existing hazard mitigation program, it is likely they have staff capacity to use this method. ● May be cost-effective. The HAZUS model is free and open-source, but other models may require more resources. ● Accounts for changes in vulnerability and adaptive capacity of the infrastructure.	● Data-intensive. Models require up-to-date, locally relevant data in order to produce relevant results. Additional data gathering or modeling, which may include interviews and focus groups with stakeholders and experts, may be required. ● Depending on the physical impact model used, there are limitations to the types of climate risks analyzed. Conducting a comprehensive assessment of multiple risks will likely require several models or mixed methods.
Statistical Modeling	● Cost-effective. It can be conducted through literature review and simple, accessible statistical models that are inexpensive to use. ● Less data requirements. Data is obtained through literature review, and simple statistical models are accessible.	● Reliance on historical data has limitations in accounting for uncertainty, as well as non-linear relationships between climate impacts and costs. ● Limited in accounting for changes in vulnerability and adaptive capacity of the built environment, as well as natural and human systems.

7.3 The Valuation of Direct Losses: Non-Market Impacts

While market impacts may be easier to quantify, non-market impacts make up the dominant share of risks and 30-80% percent of all climate-related impacts (Rothman et al, 2013). There are also several ethical considerations when assigning monetary terms to natural and human systems that analysts must consider. Putting a dollar value to a life lost and projecting how this impacts economic productivity can be seen as problematic (EPA, 2014). For this reason, thoughtful measures are required in presenting these risks. However, monetization is still necessary as it converts all dimensions of climate impacts into a single metric that policymakers can use to compare different types of risks.

While the list below is not exhaustive, it provides examples of how some methods have been used in local scale assessments in the past.

- **Hedonic Pricing:** The basic premise of this method is that the value of non-market goods and services is, to some extent, reflected in the price paid for goods and services. For example, the value of environmental conditions of where we work and live are reflected in housing prices or in labor productivity and thus, income. This can be a useful tool when attempting to appraise the economic impacts of wildfire and air quality (Tanner & Garnache, 2017).

- **Replacement Costs:** This method develops values by identifying what it would cost to replace a public good or service with a man-made system. For example, researchers from Washington State developed an economic assessment that valued the loss of snowpack by calculating the costs of constructing dams large enough to hold the equivalent volume of water that would have been retained by that snowpack (Niemi et al, 2009). While the building of new dams in the state has been limited for decades, the monetization of this ecosystem service can show the financial benefits of policies to mitigate emissions and subsequently, warming.

- **Travel Cost:** This method identifies values by identifying the costs associated with traveling to experience a specific good or service. This is specifically used to understand the effects of climate change to nature-based tourism or recreation (Halagette, 2013). It has been applied to demand estimation for forest use, hiking, biking, fishing and snow sports. Some researchers have analyzed the impact of changes in temperature on snow depth and coverage and the consequences of these changes on ski season length and the usability of ski facilities (Hamilon & Tol, 2014).

Case Study: Valuation of Non-Market Impacts - Replacement Costs

Snoqualmie Natural Infrastructure Report

The City of Snoqualmie released a report in 2020 that appraised the value of ecosystem services provided by Snoqualmie's urban forest. As a non-market public good, natural systems such as forests are often economically undervalued, if valued at all. However, they provide extensive fiscal benefits through their capacity to mitigate climate impacts, deterring costs that would otherwise be incurred building and maintaining infrastructure required for cities to adapt. For this study, the City partnered with the King County Conservation District, the Keystone Concept team, and Ecosystem Sciences and Equilibrium to assess three main ecosystem services:

1. Stormwater Retention
2. Carbon Sequestration
3. Water Quality

For these three ecosystem services alone, the study found that Snoqualmie's public forests generate somewhere between $5.8 to $7.3 Million in goods and services annually. This is not inclusive of revenue generated from their recreational or health benefits. Apart from illustrating the immense value of natural systems, this study also provides a strong argument for conservation policies and basis for economic decision-making.

The methods used in this assessment combined the spatial analysis of existing land cover, hydrologic modeling, and the use of an established ecosystem services valuation method called replacement costs. In this valuation method, market values of built systems, such as water retention and filtration infrastructure, are used to arrive at the cost of replacing an ecological system that has a similar function. This is a commonly used approach In a simple formula, this can be expressed as:

Biophysical Unit x Market Value = Economic Benefit.

For each ecosystem service analyzed, this formula is adjusted as follows:

- Stormwater Retention Benefits
    - (amount of stormwater retained by natural infrastructure/acreage of drainage basin) x (capital cost of stormwater infrastructure/storage volume)
- Carbon Sequestration Benefits
    - (sequestered ton of carbon/acre per year) x (market price of carbon/metric ton of carbon)
- Water Quality Benefits
    - (quantity of compounds filtered from water/acre per year) x (capital cost of conventional filtration infrastructure/quantity of compounds filtered)

To further understand how the above values were obtained, we can examine the valuation process for stormwater retention benefits. First, a spatial analysis of city-level datasets was employed to identify the total acreage of different types of land cover. This is necessary as bare soil and impervious surfaces have less capacity to absorb stormwater runoff, as compared to irrigated vegetation and forests. Stormwater hydrologic modeling was employed to determine the peak stormwater runoff for a defined land area. This peak runoff then informed pipe-sizing for stormwater infrastructure. Through a literature review of existing capital costs for stormwater infrastructure, the correct market values were determined.

7.4 The Valuation of Indirect Losses

Indirect losses refer to a macroeconomic response or a systemic loss, acting as a compounding consequence of direct losses due to climate change. Indirect losses indicate how direct losses are actually larger when viewed within the broader economic system, specifically in how these costs compound in relation to regional or national markets. This can be particularly challenging for local governments as it presents an issue of scale - it requires them to analyze a scope of impacts beyond their geographic area and deal with another range of uncertainties. Additionally, existing literature indicates that long-term and chronic effects have been primarily studied on a national scale and available local-scale case studies seldom include the assessment of systemic impacts.

However, focused research on specific systemic impacts do exist outside of economic assessments and could be referenced for a more comprehensive illustration of losses. For example, there has been substantial work done to understand how the increased frequency and severity of acute and chronic coastal hazards have inflated flood insurance premiums, and how this disproportionately impacts low-income homeowners. Some researchers have also explored how climate impacts contribute to property tax revenue loss.

Snapshot:
Analyzing the impacts of Sea Level Rise to Property Tax Revenues in Massachusetts

A 2018 study analyzed the systemic losses of climate impacts by exploring how sea level rise could reduce municipal budgets in the state of Massachusetts. Researchers Shi and Varuzzo developed a Geographic Information System (GIS) model that included the extent of Sea Level Rise (SLR) inundation given both aggressive and limited greenhouse gas scenarios from years 2030 to 2100, property tax data at the parcel-level, and municipal fiscal data. They then identified land parcels and buildings that would be significantly damaged with SLR, and calculated the amount of local taxes that could be impacted in one foot increments of inundation from 0 to 6 feet.

Findings indicated that at 3 ft of SLR, 1.4% or $104 million of current property taxes would be threatened across 89 coastal municipalities through the chronic inundation of over 15,000 taxable acres currently valued at $8.89 Billion. They also found that municipalities that shared the similar levels of urban development, dominant land uses, and socioeconomic characteristics also shared similar levels of revenue loss.

Source: Shi & Varuzzo, 2018

Outside of academia and government, there may also be other tools available to evaluate systemic losses. Private-sector tools can be a useful resource for understanding systemic economic consequences of climate change. In recent years, financial asset managers, investment companies and lenders have done a great deal of work to understand how climate risks create negative feedback loops between financial systems and the macroeconomy. For example, climate-related damage to assets serving as collateral for loans could create write-offs that prompt banks to restrict their lending in certain regions, which could then weaken household spending (Geraghty, 2018). Private-sector tools can also be a useful resource for understanding insured losses, such as those related to wildfires and flooding.

8. Discounting Costs

Discounting is a method used by economists to understand what future costs and benefits are worth today. It is particularly important in the field of climate change as the effects of greenhouse gas emissions are long-lasting by nature and will impact society for centuries to come. Additionally, we may incur immediate costs by investing in mitigation and adaptation today but will experience the benefits of avoided damages only decades later (Prest, 2020). Built and natural systems may also appreciate or depreciate in value over time. In an economic assessment, discounting allows analysts to compare these costs and benefits occurring in different time periods by expressing these values in present monetary terms (EPA, 2014). This is done by multiplying changes in future consumption of both market and non-market impacts by a discount rate.

The discount rate reflects time preference-how much people prefer their immediate well-being over their future well-being. It represents how much people are willing to trade savings or benefits received today for benefits they could receive in the future. Generally, if a discount rate is set to zero, future benefits are valued exactly as they are today. The higher the discount rate, the more present outcomes are valued over future ones. For intergenerational issues such as climate change, a high discount rate reflects that current generations are weighted over future generations (Prest, 2020). Currently, the common range for a discount rate is two to seven percent (2-7%). With this, there are several considerations assessors must make when choosing a discount rate and how to apply it.

- **Does the discount rate reflect current society's values?** There are two broad approaches to choosing a discount rate, reflecting either an ethical or empirical perspective of current society's values. These approaches are as follows:
    - **Prescriptive -** a discount rate that reflects how society and markets *should* trade off current and future economic benefits. It requires those conducting the assessment to make a moral or ethical judgment about the well-being of society and the health of the market at different points in time. For example, should society accept a weaker market today if it leads to a wealthier, more sustainable economy generations ahead?
    - **Descriptive -** a discount rate that reflects how society and markets *are currently* trading off current and future economic benefits. This approach is less philosophical, and relies on evidence provided by observable trends in behavior. Assessors may use existing market interest rates, such as the return on bonds or capital investments.

- **How far are you looking into the future**? **Does the discount rate reflect the values of future generations?** In general economic practice, the value of assets are typically not considered beyond 50 years. However, economists are advancing methods to address this. Currently, it is common to use a lower discount rate when using longer time horizons (Arrow, 2013). This is meant to reflect that we do not have certainty of the values of future generations or the rate of future economic growth. With this uncertainty, a lower discount rate gives weight to the unknown preferences of these future generations (Burke et al, 205; Freeman and Groom, 2016). It is also a general rule of thumb to use a discount rate that declines over time, rather than a single fixed rate across all time periods.

- **What type of assets are you attempting to value?** As discount rates are also used to reflect how assets change in value over time, it is important to understand the nature of this change for different types of goods and services. Built capital assets are known to depreciate over time, unless they are adapted or improved. On the other hand, natural infrastructure such as ecosystems tend to appreciate over time, unless human intervention causes damage. Thus, natural assets are treated with lower discount rates as compared to built assets. As an example, in the Snoqualmie Natural Infrastructure Assessment referenced above, researchers used two discount rates over 50 years - 0% to reflect the human-caused degradation of ecosystems over time, and 2.75% which is standard use for federal agencies such as the Army Corps of Engineers (Christin et al, 2020).

In the broad field of climate change economics, there is still debate amongst experts on the appropriate discount rate to use across all types of assessments. Researchers differ in their underlying philosophical understanding of society's values and subsequently, how markets behave. However, the considerations discussed provide a general guide for local assessors.

9. Conclusion

In summary, local actors that seek to conduct an economic assessment of climate impacts will need to make several decisions regarding methods and assumptions for the assessment. Scientific, economic, and even ethical uncertainties require thoughtful consideration in each step of the process. Given this, there is no single best approach for conducting a local-scale economic assessment. For local actors that have limited time and resources, it will be important to consider the existing capacity of the organization when selecting methods and defining the scope of the assessment. For example, while physical impact modeling is a more resource-intensive method of appraising direct losses, it is already well-practiced by some local governments. After climate-related events, it is a regulatory requirement for local governments to submit the cost of damage to physical infrastructure to FEMA when seeking funding. However, it is less likely that local governments have experience appraising natural infrastructure and ecosystem services and may need the assistance of outside experts and consultants. Despite the challenges involved, local-scale economic assessments of climate impacts offer a pertinent, universal means of communicating risk. Most importantly, economic assessments provide local governments with a critical tool for climate risk assessment and resilience planning.

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