Chapter 22 Greenhouse Gases

Words in **bold** and acronyms are defined in Chapter 32, Glossary and Acronyms.

This chapter describes greenhouse gases and how the project alternatives could affect greenhouse gas emissions.

22.1 Affected Environment

Greenhouse gases (GHGs) are chemical compounds found in the earth's atmosphere that absorb and trap infrared radiation as heat. Global atmospheric GHG concentrations are a product of continuous emission (release) and removal (storage) of GHGs over time. In the natural environment, this release and storage is largely cyclical. For example, through the process of photosynthesis, plants capture atmospheric carbon as they grow and store it in the form of sugars. When plants decay or are burned, the stored carbon is released back into the atmosphere, available to be taken up again by new plants (Ecological Society of America 2008). In forests, the carbon can be stored for long periods of time, and because they are so productive and long-lived, forests have an important role in carbon capture and storage and can be thought of as temporary carbon reservoirs. There is also a large amount of GHGs stored deep underground in the form of fossil fuels, and soils store carbon in the form of decomposing plant material and serve as the largest carbon reservoir on land.

Human activities such as deforestation, soil disturbance, and burning of fossil fuels disrupt the natural cycle by increasing the GHG emission rate over the storage rate, which causes a net increase of GHGs in the atmosphere. When forests are permanently converted to farmland, for example, or when new buildings or roads displace vegetation, the GHG storage capacity of the disturbed area is reduced. Carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) emissions increase when soils are disturbed (Kessavalou, et al. 1998), and burning fossil fuels releases GHGs that have been stored underground for thousands of years and cannot be readily replaced. The resulting buildup of heat in the atmosphere from increased GHG levels increases temperatures, which causes warming of the planet through a greenhouse-like effect (U.S. Energy Information Administration [EIA] 2009).

The principal GHGs emitted into the atmosphere through human activities are CO_2, CH_4, N_2O, and fluorinated gases, such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) (EPA 2015a).

- **Carbon dioxide** is the major GHG emitted (EPA 2015a; Houghton 2010). CO_2 enters the atmosphere from activities such as land use changes, the burning of fossil fuels (e.g., coal, natural gas, oil, and wood products), and the manufacturing of cement. CO_2 emissions from the combustion of coal, oil, and gas constitute 84 percent of all U.S. GHG emissions (EPA 2015a). Before the industrial revolution, CO_2 concentrations in the atmosphere were roughly stable at 280 parts per million. By 2010, CO_2 levels had increased to 390 parts per million, a 40 percent increase, because of human activities (EPA 2015b).
- **Methane** is emitted during the processing and transport of fossil fuels, through intensive animal farming, and by the degradation of organic waste. Concentrations of CH_4 in the atmosphere have increased more than 2.5 times that of preindustrial levels (EPA 2015b).

- **Nitrous oxide** is emitted during agricultural and industrial activities and during the combustion of fossil fuels and solid waste. Atmospheric levels of N_2O have increased 18 percent since the beginning of industrial activities (EPA 2015b).
- **Fluorinated gases**, including HFCs, PFCs, and SF_6, are synthetic compounds emitted through industrial processes. They sometimes replace ozone-depleting compounds such as chlorofluorocarbons (CFCs) in insulating foams, refrigeration, and air conditioning. Fluorinated gases, particularly SF_6, are often used in substation equipment. SF_6 is used as an electrical insulator in high-voltage substation equipment such as circuit breakers, transformers, and ground switches. Although fluorinated gases are emitted in small quantities, fluorinated gases can trap more heat than CO_2 and are considered gases with a high global warming potential (EPA 2015a).

Total human-caused GHG emissions were the highest in human history from 2000 to 2010 and reached 49 gigatons of **carbon dioxide equivalent (CO_2e)** per year in 2010 (Intergovernmental Panel on Climate Change [IPCC] 2014). Annual GHG emissions grew on average by 1.0 gigaton of CO_2e (2.2 percent) per year from 2000 to 2010 compared to 0.4 gigaton of CO_2e (1.3 percent) increase per year from 1970 to 2000. Growing levels of these GHGs could increase the Earth's temperature by between 2.0 and 11.5 degrees Fahrenheit by 2100 (EPA 2015a). In the Pacific Northwest Region, an increase in annual temperature between 3.3 and 9.7 degrees Fahrenheit may occur between 2070 and 2099, depending on future total global emissions of GHGs (Mote et al. 2014).

This increase in Earth's temperature may cause accelerated melting of artic sea ice and glaciers, decreased periods of ice cover on lakes and rivers, changes in hydrology from early melting and decreased snow packs, changes in growing seasons and plant hardiness zones, changes in surface water characteristics, and increased extreme weather (Melillo, et al. 2014). All of these changes could have a ripple effect on agricultural production, human health, public infrastructure, water supplies, hydropower generation, and terrestrial, aquatic, and marine ecosystems. While models predict atmospheric concentrations of all GHGs and temperatures will increase over the next century due to human activity, the extent and rate of change from an individual project or action is difficult to predict, especially on a global scale.

To lessen BPA's system contribution to GHG emissions, BPA developed a climate change roadmap (BPA 2008), which included the adoption of a new Strategic Business Objective and a Key Agency Target related to climate change. The climate change roadmap identified measuring BPA's overall GHG emissions as a key starting point for BPA to manage its overall GHG footprint. As a result, BPA started collecting GHG data in 2009 to complete an inventory of existing GHG emissions. The GHG reporting serves as a benchmark for quantifying reductions in GHG emissions from various activities and functions and helps BPA to quantify the value of potential remedies for reducing emissions, estimating the costs of changing current practices and prioritizing future GHG emission reduction actions. In 2009, BPA became a founder and member of The Climate Registry, a nonprofit collaboration that sets standards to calculate, verify and report GHG emissions. BPA has completed and published a GHG inventory for 2009, 2010, 2011, and 2012. The Climate Registry has been third-party verified and is publically available.

In 2012, BPA's system-wide direct emissions from stationary and mobile combustion and fugitive sources totaled 88,524 metric tons of CO_2e (The Climate Registry 2013). These direct emissions were calculated from the use of vehicles, air transportation, building operation, and transmission line operation. The GHG emissions reported to The Climate Registry also includes a quantification of the SF_6 emissions from BPA facilities. In addition to reporting SF_6 emissions to The Climate Registry, BPA joined the USEPA's SF_6 Emission Reduction Partnership in 1999, which includes voluntarily reporting of SF_6 emissions.

Models predict that atmospheric concentrations of all GHGs will continue to increase over the next century, but the extent and rate of change is difficult to predict, especially on a global scale.

22.2 Environmental Consequences

General impacts that would occur for the action alternatives are discussed below. Impacts would be similar for all action alternatives.

22.2.1 Impact Levels

Impacts would be **high** where project activities would cause the following:

- Estimated GHG emissions or sequestration losses exceed 4 million metric tons of CO_2e, the approximate GHG emissions from a major industrial combustion source (e.g., a 500-MW coal-fired generation facility).

Impacts would be **moderate** where project activities would cause the following:

- Estimated emissions exceed the annual Mandatory Reporting of Greenhouse Gases threshold outlined by the EPA, or 25,000 metric tons of CO_2e, but are below the level of a baseload (500-MW) coal-fired generating facility. Assuming an average emission factor of 2,100 CO_2e per megawatt hour (MWh) from coal consumption for electric generation, a 500-MW coal-fired generation facility would emit about 4 million metric tons of CO_2e annually (EIA 2000). The annual emission or sequestration loss range with a moderate impact would be between 25,000 and 4 million metric tons of CO_2e.

Impacts would be **low** where project activities would cause the following:

- Estimated GHG emissions do not exceed the annual Mandatory Reporting of Greenhouse Gases threshold of 25,000 metric tons of CO_2e as outlined by the EPA.

No impact would occur where project activities would not create GHG emissions or sequestration losses.

22.2.2 Impacts Common to Action Alternatives

Direct GHG emissions from non-generating utility projects, such as this one, are primarily limited to vehicle and equipment emissions, and the impacts to GHG concentrations from these projects are typically low. The ongoing operation of new substation equipment could cause SF_6 emissions if it leaked from the newly installed equipment. Tree removal does not immediately emit GHGs and is not considered a direct emission, though tree removal could cause a permanent loss of a carbon storage reservoir.

GHG emission estimates were calculated for the action alternatives using currently accepted guidance and methodologies developed by the EPA and Climate Registry, and are described below. Each action alternative would contribute to atmospheric GHG concentrations from the following sources:

- During construction, through the use of gasoline and diesel powered vehicles, including cars, trucks, construction equipment, and helicopters, and through soil-disturbing activities and vegetation removal (i.e., conversion of a forested area to an access road or cleared transmission line right-of-way)
- During operation and maintenance, through the use of gasoline and diesel powered vehicles and helicopters for routine patrols of the transmission line right-of-way, maintenance work (i.e., vegetation management, site-specific repairs of roads and transmission line towers), emergency maintenance, and environmental resource review

In general, GHG emissions are inventoried for CO_2, CH_4, N_20, and high-**global warming potential** (GWP) gases in terms of CO_2e, which is computed by multiplying the mass of the gas being measured (e.g., CH_4) by its estimated GWP (e.g., CO_2 =1, CH_4 =25, N_20 =298). For the proposed project, estimated emissions were calculated for each GHG based on project activities and converted to CO_2e, based on the GWP of the GHG emitted. The contributions from each gas were then combined to get the overall estimated CO_2e emissions. These calculations were done for both project construction and project operation and maintenance.

22.2.2.1 Construction

Direct GHG emissions come from construction workers commuting to and from the site, operating construction equipment (e.g., dozers, augers, backhoes, graders, heavy-duty trucks, and front-end loaders), and helicopter operation. To ensure that the potential contributions to GHG concentrations from the project are adequately considered, the conservative analysis was based on the following assumptions:

- Emissions were calculated based on a five-year (60-month) construction period.
- An average of 45 vehicles (e.g., standard pick-up trucks) per day would be needed to transport all construction personnel, with an average round trip distance of 100 miles per vehicle, per day.
- An average of two vehicles (e.g., standard pick-up trucks) per week would be needed to transport BPA staff to the project site, with an average round trip distance of 100 miles per vehicle.
- The fuel economy of a standard pick-up truck was estimated at 17 miles per gallon (mpg).
- An average of two helicopter round trips per day would be made for 20 months, with an estimated fuel economy of 4 mpg and an average round trip distance of 100 miles.
- An average of 40 pieces of 250-horsepower construction equipment would be operating at full power for eight hours per day, five days per week.

Estimation of GHG emissions from non-tree vegetation and soil disturbance was not included in this analysis. Research has shown that these emissions are short-lived and return to background levels within several hours (Kessavalou et al. 1998; Aalde et al. 2006). Carbon that would be stored in removed vegetation would be offset by the growth and accumulation of carbon in soils and new vegetation. Given that the methodology used to estimate vehicle emissions was overestimated, the low levels of GHG emissions from temporary soil disruption that would occur are considered to be accounted for in the overall construction emission rates.

Table 22-1 displays estimated GHG emissions for those construction activities that contribute to GHG emissions.

Summary of GHG Contributions

The assumptions described above were used to estimate the overall GHG emissions for the projects proposed construction period (see Table 22-1). While all GHG emissions can be considered important in that they contribute to global GHG concentrations and climate change, the total estimated CO_2e emissions from the project would be very low compared to emissions from significant industrial combustion sources and other regional sources.

To provide context of the relative contribution level these GHG emissions represent, the EPA's mandatory reporting threshold for annual GHG emissions is 25,000 metric tons of CO_2e. This threshold is about equal to the amount of CO_2 generated by operating 4,400 passenger vehicles per year. This threshold requires federal reporting of GHG emissions, but does not require any other action (EPA 40 Code of Federal Regulations [CFR] Parts 86, 87, 89 et al.).

Construction would cause an estimated 60,571 metric tons of CO_2e emissions over a five-year period (see Table 22-1) or 18,586 CO_2e metric tons per year during the construction period, which would be roughly equivalent to the output of 3,913 passenger vehicles per year.

Table 22-1 Estimated Greenhouse Gas Emissions from Construction Activities[1]

Estimated GHG Emissions from Construction of the Action Alternatives	CO_2 Emissions (in CO_2e Metric Tons)	CH_4 Emissions (in CO_2e Metric Tons)	N_2O Emissions (in CO_2e Metric Tons)	Total CO_2e[2] Emissions (in Metric Tons)
Peak construction transportation	3,056	2,472	11,506	17,033
BPA employee transportation	2,716	2,197	10,227	15,141
Helicopter operation	181	4	1	185
Peak construction equipment operation	60,110	75	386	60,571
Annualized average emissions over 60-month construction period	13,213	950	4,424	18,586

Notes:

1. Ozone is not included as O_3 emissions from transmission line corona would be small, temporary, and localized.
2. CH_4 and N_2O emissions have been converted into units of CO_2e using the IPCC GWP factors of 25 GWP for CH_4 and 298 GWP for N_2O (EPA 2014a).

Sources: EIA 2009, EPA 2011a

22.2.2.2 Operation and Maintenance

GHG emissions would also occur during operation and maintenance of the line, roads, and substations. To provide a conservative analysis and ensure that the potential contributions to GHG concentrations from the project are adequately considered, analysis was based on the expected annual occurrence of approximately 60 routine patrols, 160 routine maintenance work visits, 40 emergency maintenance visits, eight natural resource reviews, and two aerial inspections via a helicopter. The helicopter and vehicles would most likely access the transmission line from the Portland or Vancouver metro area. The average round trip would be about 100 miles. While annual variations would likely occur, operation and maintenance activities were conservatively assumed to be generally consistent over a 50-year period, the effective operating life of a transmission line.

During operation of the new substation, the Castle Rock and Sundial substations' equipment could cause GHG emissions by using SF_6 as an electrical insulator in 25 breakers with six bushings each (total of 150 bushings at ultimate buildout). The breakers would have 1,645 pounds of average nameplate capacity (total volume of gas). BPA's overall annual SF_6 leakage rates have ranged from 0.6 to 1.4 percent (1 percent average) during the 2010 and 2013 reporting periods. The overall system-wide leakage rate includes leaks from equipment with a wide range of ages and equipment subject to corrosive environmental conditions such as corrosive salt water fog. As equipment ages and seals deteriorate, leakage rates typically increase. BPA monitors and repairs excessively leaking equipment as they are detected.

For the purposes of this analysis, the SF_6 leakage rate was assumed to be 1 percent of nameplate capacity per year. Many manufacturers guarantee no or minimal leakage rates for new equipment (Blackman et al. 2006) and BPA required a manufactured leakage rate of less than 0.5 percent annually on all new equipment. Therefore, the 1 percent assumed leakage rate is likely a conservative estimate.

Summary of GHG Contributions

Operation and maintenance of the right-of-way, transmission line, and access roads would cause an estimated 3,578 CO_2e per year (see Table 22-2), which would be roughly equivalent to the output of 753 passenger vehicles a year for all subsequent years of operations and maintenance.

Table 22-2 Estimated Greenhouse Gas Emissions from Operation and Maintenance[1]

Estimated GHG Emissions from the Action Alternatives	CO_2 Emissions	CH_4 Emissions (in CO_2e Metric Tons)	N_2O Emissions (in CO_2e Metric Tons)	SF_6 Emissions (in CO_2e Metric Tons)	Total CO_2e[2] Emissions (in Metric Tons)
During Annual Operations and Maintenance	721	222	2,636	--	3,578
During Annual Substation Operation and Maintenance	--	--	--	4,253	4,253
Annualized Average Emissions[3] Over 50 Years	721	222	2,636	4,253	7,831

Notes:

1. Ozone is not included as O_3 emissions from transmission line corona would be small, temporary, and localized.
2. CH_4 and N_2O emissions have been converted into units of CO_2e using the IPCC GWP factors of 25 GWP for CH_4 and 298 GWP for N_2O (EPA 2014a).
3. Annual averages are based on the assumption that the effective operating life of the transmission line is 50 years.

Sources: EIA 2009, EPA 2011a

Operation and maintenance of substation equipment would cause an estimated 4,253 CO_2e per year, which would be roughly equivalent to operating 895 passenger vehicles a year for all subsequent years. Averaging the direct contribution to GHGs over the operating life of the project (50 years) would cause an average annual GHG emissions of about 7,831 metric tons of $C0_2$e (1,649 passenger vehicles). Given this relatively low level of annualized emissions, the impact on global GHG concentrations from project operations and maintenance would be **low**.

22.2.2.3 Tree Sequestration Reduction

Based on the carbon cycle, trees act as temporary carbon reservoirs. Peak solid carbon storage occurs when a tree is fully mature. Alternatively, minimum solid carbon storage may occur when a forested area is permanently converted to a non-forested area, such as farmlands.

Project construction would remove trees for right-of-way and new towers, substations, and new and improved access roads, permanently converting land within the cleared area to a non-forested land use. Essentially, the cleared area is permanently maintained at the minimum level of carbon storage.

All action alternatives would have the potential to lose sequestration potential. Central Alternative using Central Option 1 would lose the most (813,464 metric tons CO_2e) and West Alternative using West Option 1 would lose the least (226,803 metric tons CO_2e) (see Table 22-3). These estimates assume that removed trees are at full maturity and would remain in that state to provide full sequestration potential. This estimate is conservative as most of the removed trees are not at full maturity (e.g. at full sequestration potential) and many trees would not have reached maximum maturity through natural attrition or other human-related disturbances. Most of the action alternatives cross lands managed for timber harvest so most of the trees are not at maximum maturity and never will be. Because sequestration losses for each action alternative are between the 25,000 CO_2e and 4 million CO_2e threshold, impacts on GHG concentrations from tree removal would be **moderate**.

Table 22-3 Estimated Greenhouse Gas Storage Potential of Removed Trees

Tree Clearing Activity	Mature Forest[1]		Forest[2]		Production Forest[3]		Total CO_{2e} Storage Loss (metric tons)[4,5]
	Acres	Total CO_{2e} Storage Loss (metric tons)[4]	Acres	Total CO_{2e} Storage Loss (metric tons)[4]	Acres	Total CO_{2e} Storage Loss (metric tons)[4]	
West Alternative	23	23,698	285	213,598	0	0	237,296
West Option 1	N/C	N/C	-14	-10,493	N/C	N/C	-10,493
West Option 2	+5	+5,151	-10	-7,495	+9	5,970	+3,626
West Option 3	+3	+3,091	+27	+20,236	+21	13,929	+37,256
Central Alternative	12	12,364	228	170,878	910	603,603	786,845
Central Option 1	N/C	N/C	+1	+750	+39	+25,869	+26,619
Central Option 2	+5	+5,152	+35	+26,232	-76	-50,411	-19,027
Central Option 3	+3	+3,091	+53	+39,722	-175	-116,077	-73,264
East Alternative	10	10,303	163	122,163	961	637,431	769,898
East Option 1	+5	+5,512	+13	+9,743	-56	-37,144	-22,250
East Option 2	-6	-6,182	+21	+15,739	N/C	N/C	+9,557
East Option 3	N/C	N/C	-6	-4,497	+22	+14,593	+10,096
Crossover Alternative	37	38,122	239	179,123	588	390,020	607,265
Crossover Option 1	-1	-1,030	+16	+11,991	N/C	N/C	+10,961
Crossover Option 2	+1	+1,031	+2	+1,498	N/C	N/C	+2,530
Crossover Option 3	+1	+1,031	+28	+20,985	+16	+10,613	+32,628

Notes:

1. Mature forest calculation based on regional estimate of timber volume and carbon stocks for Douglas fir stands at full maturity forest (125 years) in Pacific Northwest, West – 281 tons of carbon stock per acre.
2. Forest calculation based on regional estimate of timber volume and carbon stocks for Douglas fir stands 75 years in age in Pacific Northwest, West – 204.4 tons of carbon stock per acre.
3. Production forest calculation based on regional estimate of timber volume and carbon stocks for Douglas fir stands in high productivity sites with high-intensity management, estimated 55 year rotation cycle in Pacific Northwest, West – 180.9 tons of carbon stock per acre.
4. All calculations assume that 100 percent of the carbon stored would be converted to CO_2.
5. The sum of individual entries may not match totals depicted due to rounding.

22.2.3 Recommended Mitigation Measures

Mitigation measures included as part of the project are identified in Table 3-2. Mitigation measures related to air emissions in Table 3-2, and such measures in Chapter 21, Air Quality, would help reduce contributions of the action alternatives to greenhouse gases. BPA is considering the following additional mitigation measures to further reduce contributions of the action alternatives to greenhouse gases. If implemented, these measures would be completed during or immediately after project construction unless otherwise noted.

- Install any new SF_6-filled substation breakers with a manufacturer-guaranteed leakage rate no greater than 0.5 percent per year for the life of the breaker.

- Continue BPA's SF_6 monitoring process to calculate and report, in compliance with EPA requirements, the quantity of SF_6 leaked from BPA substation equipment annually.

22.2.4 Unavoidable Impacts

Unavoidable impacts would include slight increases in GHG emissions.

22.2.5 No Action Alternative

The No Action Alternative would have **no** GHG impacts because no new transmission lines, towers, access roads, or substations would be constructed. Impacts from operation and maintenance of existing lines and substations would continue unchanged.

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