APPENDIX F

LIFE-CYCLE GREENHOUSE GAS EMISSIONS

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Acronyms and Abbreviations

BNSF	Burlington Northern Santa Fe Railway
CEQ	Council on Environmental Quality
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide-equivalents
COLE	Carbon Online Estimator
gCO_2e/kWh	grams of CO2e per kilowatt-hour
GHG	greenhouse gas
kWh	kilowatt hour
LCA	life-cycle assessment
$MMTCO_2e$	million metric tons of carbon dioxide equivalent
MT	metric ton
$MTCO_2e$	metric tons of carbon dioxide equivalent
N_2O	nitrous oxide
NEPA	National Environmental Policy Act
NREL	National Renewable Energy Laboratory
USEPA	U.S. Environmental Protection Agency

Appendix F
Life-Cycle Greenhouse Gas Emissions

F.1 Introduction

This appendix provides the data and methods that support the analysis in Chapter 5, *Greenhouse Gases and Climate Change*.[1] Chapter 5 examines the direct greenhouse gas (GHG) emissions impacts associated with construction and operation of the proposed rail line, the indirect life-cycle impacts associated with downline rail traffic, international shipping of coal from the mines that would be served by the proposed rail line (hereafter referred to as *Tongue River coal*[2]), the cumulative impacts of these proposed and potentially induced mines,[3] and coal combustion.

A life-cycle approach is particularly important because the influence of the proposed rail line extends beyond the project area. Tongue River coal would displace coal and natural gas in domestic and international markets, as discussed in Appendix C, *Coal Production and Markets*. This analysis evaluates the change in life-cycle GHGs for displaced coal and natural gas to estimate the net GHG emissions.

A life-cycle analysis provides a comprehensive perspective on emissions, from production, through use, to disposal. A life-cycle perspective is particularly appropriate for a cumulative impacts analysis of GHG emissions, which have the same effect on climate change regardless of where emissions occur.

This appendix includes the following sections:

- Description of the objective and scope of the analysis.
- Overview of the approach.
- Presentation of GHG results for Tongue River coal by the direct impacts of construction and operation of the proposed rail line, and by the indirect impacts of downline rail traffic and international shipping, cumulative impacts of the proposed and potentially induced mines, and fuel combustion.
- Presentation of life-cycle GHG emission estimates for types of coal that would likely compete with Tongue River coal (competing coals or reference coals), and a comparison of the carbon-intensity of these competing coals to Tongue River coal.

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[1] This appendix provides supporting information for Chapter 5, *Greenhouse Gases and Climate Change*, of this *Draft Environmental Impact Statement for the Tongue River Railroad*. This information should not be interpreted as stand-alone information and must be read in combination with the associated chapter.

[2] Although the Tongue River is part of the Powder River Basin, for purposes of this analysis, OEA uses the term *Tongue River coal* to refer specifically to coal from areas where construction of the proposed rail line could induce new mines.

[3] The proposed mine is the Otter Creek Mine; the potentially induced mines are the Poker Jim Creek–O'Dell Creek Mines, which could be induced by the development of the proposed rail line.

- Summary of the direct GHG emissions from the proposed rail line and the net accumulated life-cycle GHG results—i.e., the net change in GHG emissions from increased production of Tongue River coal potentially induced by the proposed rail line and decreased production of other competing coals and U.S. natural gas.

F.2 Objective and Scope

The objective of this analysis is to evaluate net life-cycle GHG emissions as result of construction and operation of the proposed rail line. The scope of the analysis includes the following elements.

- **Timeframe.** OEA assessed GHG emissions over the 20-year analysis period (2018 to 2037).
- **Direct GHG emissions.** OEA assessed direct emissions from construction and operation of the proposed rail line within the project area. This includes GHG emissions produced from the materials used in construction of new track and fuel used to produce the energy consumed in construction (precombustion emissions).
- **Indirect emissions.** OEA assessed indirect emissions from downline rail traffic and international shipping (outside of the project area); from the cumulative impacts of proposed and potentially induced mines; and from the combustion of coal.
- **Geographic scope.** The geographic scope includes local emissions from construction and operation of the proposed rail line and the proposed and potentially induced mines; emissions from downline transportation and from coal and natural gas combusted in the United States, and emissions from international shipments and from coal exported and combusted in other countries.
- **Offset energy sources.** Energy sources that would likely be directly or indirectly affected by increased production of Tongue River coal include other Powder River Basin coal and Illinois Basin coal. Internationally, the proposed rail line would offset production of Indonesian, Australian, Chinese, and Colombian coals. Natural gas supplies in the United States could also be offset.

F.3 Approach

The net impact of increased Tongue River coal on global GHG emissions depends on GHG emissions from the increased volumes of Tongue River coal that are mined, transported, and combusted as a result of the proposed rail line, and the effect that this increased supply has on GHG emissions from mining, transportation, and combustion of other domestic and international coals and natural gas. Three main components are used to evaluate life-cycle GHG emissions.

- Determination of the direct GHG emissions from construction and operation of the proposed rail line and life-cycle GHG emissions from Tongue River coal that would be transported by the proposed rail line to market.
- Determination of the change in life-cycle GHG emissions of competing coals and U.S. natural gas supplies that would be displaced by the increased supply of Tongue River coal from the proposed rail line.
- Evaluation of net accumulated life-cycle GHG emissions. These are calculated as the sum of life-cycle GHG emissions from increased Tongue River coal production and reduced by the sum of life-cycle GHG emissions resulting from the displacement of other competing coals and U.S. natural gas by Tongue River coal.

OEA evaluated six primary gases: carbon dioxide (CO_2), nitrous oxide (N_2O), methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.[4] GHG emissions from these gases were evaluated as expressed as metric tons of carbon dioxide-equivalent ($MTCO_2e$) using 100-year global-warming potentials (Intergovernmental Panel on Climate Change 2007). OEA evaluated the release of stored GHGs a result of destruction of natural GHG sinks in vegetation and disturbed soils from proposed and potentially induced mines and future sequestration from reclamation.

To the extent that increased Tongue River coal production for a given scenario displaces more carbon-intensive coal from other U.S. or international sources, the GHG impact of increased Tongue River coal production would be a reduction in emissions. Alternatively, if increased Tongue River coal production for a given scenario displaces less carbon-intensive coal from other U.S. or international sources, the GHG impact of increased Tongue River coal production would be an increase in emissions.

In its revised *Draft Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in NEPA Reviews* (Council on Environmental Quality 2014), the Council on Environmental Quality (CEQ) suggests that National Environmental Policy Act (NEPA) reviews address emissions from all stages in a project's life cycle, including emissions from indirect sources, vehicles, and material supply, where feasible.[5]

With CEQ's draft guidance in mind, OEA's analysis of the life-cycle GHGs categorizes the life cycle according to direct and indirect impacts. As noted above, the direct impacts would

[4] Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are emitted primarily through industrial processes such as aluminum production, semiconductor manufacturing, and from refrigeration and in electrical transmission equipment (U.S. Environmental Protection Agency 2014). They are potent GHGs but form a minor component of emissions from processes in the coal life-cycle, which are dominated by gases associated with fossil fuel combustion (CO_2, N_2O, and CH_4).

[5] Revised in 2014, CEQ's Draft Guidance contains guidelines on how federal agencies can improve their consideration of GHG emissions and climate change effects during the evaluation of proposals for federal actions subject to NEPA review. In particular, the guidance focuses on GHG emissions resulting from proposed projects and their alternatives, as well as how climate change will affect a given project and its alternatives. The revised draft guidance suggests an annual emissions threshold level of 25,000 $MTCO_2e$ or more for a proposed action, as an indicator for agencies to consider a quantitative assessment of the associated impacts.

result from construction and operation of the proposed rail line. The indirect impacts would result from downline transport and international shipping, the cumulative impacts of proposed and potentially induced mines, and coal combustion.

Conceptually, life-cycle GHG emissions for different types of coal can be calculated by multiplying tons of coal by an appropriate life-cycle emission factor that expresses GHG emissions per ton of coal. OEA developed GHG emission factors for Tongue River Powder River Basin coal and compared these results with estimates from other competing coal sources. This allowed OEA to determine how a unit of electricity produced from Tongue River Powder River Basin coal would compare with a unit of electricity produced from competing coals that are likely to be displaced by increased Powder River Basin coal production (Section F.5, *Comparison with Life-Cycle Greenhouse Gas Emissions from Competing Coal*).

OEA used the results of the market analysis (Appendix C, Coal Production and Markets) to determine how transportation and combustion of Tongue River coal, U.S. natural gas, and other competing coals would change as a result of the proposed rail line. OEA selected six scenarios that represent the range of coal production scenarios and export terminal growth used in the market analysis, presented in Table F-1.[6] In addition to the six scenarios, two scenarios[7] in which low natural gas prices foster greater competition between natural gas and coal in the energy marketplace are compared to a No-Action Alternative with low natural gas prices.

Table F-1. Scenarios for Estimating Rail Operation and Coal Export Emissions

Scenario Description	Scenario Number[a]
Northern Alternatives	
Low coal production, zero terminal capacity growth	3
Medium coal production, medium terminal capacity growth	7
High coal production, high terminal capacity growth	11
Southern Alternatives	
Low coal production, zero terminal capacity growth	12
Medium coal production, medium terminal capacity growth	16
High coal production, high terminal capacity growth	20

Notes:
[a] Scenario numbers are assigned in Appendix C, *Coal Production and Markets*

[6] OEA modeled 21 scenarios based on three sets of variables across four analysis years (2018, 2023, 2030, and 2037): a northern alternative or southern alternative, three levels of coal production capacity (low, medium, and high), and three levels of coal export capacity in the Pacific Northwest (zero, medium, and high). Appendix C, *Coal Production and Markets,* discusses this analysis in further detail.

[7] These scenarios correspond to scenario numbers 21 and 22 in Appendix C, *Coal Production and Markets*. Both scenarios involve the northern alternatives of the proposed rail line as the higher costs of the southern alternatives prevent them from being economically viable with low natural gas prices. The first scenario represents zero terminal export growth and the second represents high export terminal growth. In both scenarios, coal production is low because the low price of natural gas increases demand for natural gas relative to coal.

Finally, OEA calculated net life-cycle GHG emissions from the proposed rail line by applying the GHG emission factors for each component of direct and indirect emissions to the volumes of Tongue River coal that would be transported by the proposed rail line. OEA compared these GHG estimates against changes in GHG emissions from U.S. natural gas and competing coal use (Section F.6, *Summary of Net Life-Cycle GHG Emissions*). From these annual estimates of net GHG emissions, OEA calculated the net accumulated life-cycle GHG emissions that would result from construction and operation of the proposed rail line between 2018 and 2037.

F.4 Direct and Indirect Life-Cycle Greenhouse Gas Results

This section presents the data, analysis, and results of the analysis of direct GHG emissions from construction and operation of the proposed rail line, and indirect life-cycle GHG emission from downline transportation, international shipping, construction and operation of proposed and potentially induced mines, and combustion of Tongue River coal.

F.4.1 Direct Impacts

F.4.1.1 Proposed Rail Line Construction

OEA modeled construction of the proposed rail line using data from two of the build alternatives; the northern 83.7-mile Tongue River Alternative and the southern 49.6-mile Decker East Alternative. These build alternatives were chosen as representative of the northern and southern build alternatives,[8] respectively, for consistency with the coal market analysis in Appendix C, *Coal Production and Markets*.

Construction of these two build alternatives would include substantial earthwork in addition to installation of tracks and other rail infrastructure. GHG emissions contributions to the life-cycle analysis would result from the combustion of fossil fuel used during construction activities. Construction activities would result in exhaust emissions from construction equipment, trucks, and workers' personal vehicles. An overview of the equipment necessary for constructing the proposed rail line and each piece of equipment's respective fuel demand and consumption is provided in Tables F-2 and F-3. Depending on the type of equipment, the fuel consumption rate depends either on the volume of earthwork needed, as shown in Table F-2, or the miles of track constructed, as shown in Table F-3.

[8] The Tongue River Alternatives, Colstrip Alternatives, Tongue River Road Alternatives, and Moon Creek Alternatives are referred to collectively as the *northern alternatives*. The Decker Alternatives are referred to as the *southern alternatives*.

Table F-2. Horsepower and Fuel Consumption Rates for Construction Equipment per Volume of Earthwork

Track and Bridge Construction Equipment	Horsepower (Non-road only)	Fuel Rate (gal/VMT or gal/hr)	Fuel Consumption (Gallons per Million Cubic Yards)
2-Ton Flatbed Truck	N/A	0.06	37
Tractor/trailer (flatbed, belly dump)	N/A	0.19	233
Caterpillar D400 Rock Truck	405	13.03	79,726
Water Truck – 4,000 gallons	N/A	2.56	7,839
Fuel/service truck	N/A	7.13	6,598
Pickup	N/A	4.08	37,419
Caterpillar 966 Loader	260	4.08	6,237
Caterpillar 140 Blade	222	6.69	20,474
CP 563E Padfoot Drum Compactor – (84”)	150	7.26	4,389
CP 563E Smooth Drum Compactor – (84”)	150	13.11	7,926
Caterpillar 815 Compactor	254	13.11	20,064
Caterpillar D6 Dozer	210	7.19	22,012
Caterpillar D9 Dozer	464	7.19	33,018
Caterpillar D10 Dozer	646	7.61	34,942
Komatsu PC 300 Excavator	254	13.03	7,874
Komatsu PC 400 Excavator	347	2.93	4,483
Caterpillar 615 Scraper	279	5.28	3,194
Caterpillar 631 Scraper	519	9.16	50,514
Rock Drill	161	0.83	594
Crawler Crane – 100 ton	350	6.69	1,137
Crawler Crane – 150 ton	500	0.00	0
Air Compressor (250 cfm)	37	3.00	4,586
Jumping Jack Compactor	161	1.72	5,252

Notes:
The fuel consumption rates for construction activities in this table are estimated per volume of earthwork needed
Sources: U.S. Environmental Protection Agency (2008) NONROAD model, (2010) MOVES model
gal/VMT = gallons per vehicle miles travelled; gal/hr = gallons per hour; N/A = not applicable

Table F-3. Horsepower and Fuel Consumption Rates for Construction Equipment per Mile of Track

Track and Bridge Construction Equipment	Horsepower (Non-road only)	Fuel Rate (gal/VMT or gal/hr)	Fuel Consumption (Gallons per Mile of Track)
Equipment			
Pettibone 360 Speed Swing – Hi-Rail	185	3.00	289
Kershaw 26-2 Ballast Regulator	161	1.72	165
Jackson 6700 Tamper	99	2.90	549
Tie Handler	464	5.80	290
Rail Clip Applicator	210	3.00	150
Ballast Consolidator	464	5.80	560
EMD SD40 Locomotive	3,000	20.91	935
EMD SD70MAC locomotive	4,000	20.91	935
Signals			
2 supervisor half-ton pickups	N/A	0.06	1
5 half-ton crew foreman pickups	N/A	0.06	2
5 one-ton crew cab pickups	N/A	0.06	2
5 utility line trucks	N/A	0.06	2
1 20-ton crane	332	5.28	28
3 tractor backhoes	93	1.24	23
Tractor-trailer combo for transport	N/A	0.06	1
Communications			
1 half-ton pickup	N/A	1,500	0
2 supervisor half-ton pickups	N/A	3,700	1
2 utility line trucks	N/A	3,700	1
1-ton crew cab pickup	N/A	1,500	0
Backhoe	93	1,500	7
Tractor-trailer combo for transport	N/A	1,500	1

Notes:
The fuel consumption rates for construction activities in this table are estimated per mile of track constructed
Source: U.S. Environmental Protection Agency (2008) NONROAD model and (2010) MOVES model
gal/VMT = gallons per vehicle miles travelled; gal/hr = gallons per hour N/A = not applicable

In addition to the fossil fuel combustion-related emissions from construction activities, construction of the proposed rail line would result in the GHG emissions associated with the upstream production emissions of key components such as steel, concrete, and gravel for the tracks and ballast system. The additional materials and energy required for bridge construction were not specifically factored into this analysis due to insufficient data on the size and span of the bridge components; emissions from construction of bridge spans were instead calculated using the same emission factors per mile of track as the rest of the rail line.

Methods and Data Sources

In order to estimate the GHG emissions from construction equipment, OEA first identified and characterized the emission sources that would result from proposed rail line construction. This was done by estimating the total railroad length of each build alternative, and then deriving the necessary volume of earthwork based on the length of the track. Total energy demand for construction activities was informed by both the length of the build alternatives and the volume of required earthwork.

Using the length and earthwork volumes for the northern and southern alternatives, OEA calculated the emissions from each source and then aggregated them. OEA estimated GHG emissions from construction equipment and construction-related motor vehicles using emission factors derived from the U.S. Environmental Protection Agency (USEPA) NONROAD 2008 (ref) model and the USEPA MOVES 2010 (ref) model, respectively. OEA also used these models to estimate the emissions of other air pollutants.

For purposes of this analysis, OEA considered the life-cycle GHG emissions associated with the upstream manufacture of reinforcing steel for the tracks, and the concrete and gravel for the ballast. First, OEA estimated the metric tons of concrete, gravel, and steel required to build both build alternatives on per-mile basis (Hill et al. 2012). These estimates represented basic track construction, since additional amounts of raw material needed for construction of bridges would be small relative to the overall length of track for each build alternative. GHG emission factors were applied to the tonnages of construction materials to estimate emissions from the manufacture of construction materials (Ecoinvent Centre 2007). The emission factors include direct GHG emissions from the manufacture of construction materials as well as emissions from the raw material inputs they are produced from (e.g., coke for steel production). The energy associated with the subsequent shaping of the raw materials into final products (e.g., the manufacture of reinforcing steel into tracks) and the transport of those finished projects to the construction site is not included in this analysis because these sources typically make up a negligible fraction of the production GHG emissions for these materials.[9]

OEA also considered GHG emissions from the loss of terrestrial carbon stored in vegetation and soils that is disturbed as a result of rail line construction and operation. To estimate the loss of above- and below-ground carbon stocks, OEA used estimates of vegetation and soil carbon storage in the study area from the Carbon Online Estimator (COLE) tool developed collaboratively by the National Council for Air and Stream Improvement and the U.S. Department of Agriculture, Forest Service. To calculate the change in carbon stocks, OEA applied estimates of the carbon stock per hectare to the hectares that would be disturbed by the right-of-way for the Tongue River Alternative and Decker East Alternative.

Results

This section presents the GHG emissions results for construction of the proposed rail line. The results in this section are used in Section F.5, *Comparison with Life-Cycle Greenhouse*

[9] In a screening estimated based on end-use transportation (or “retail transportation”) data compiled by the Bureau of Transportation (Bureau of Transportation Statistics 2013) to life-cycle emission factors for steel and concrete manufacture (Ecoinvent Centre 2007), OEA estimated that retail transportation GHG emissions account for less than 2% of production emissions for steel and 6% for concrete.

Gas Emissions from Competing Coal, to compare the carbon-intensity of Tongue River coal with other competing coals and in Section F.6, *Summary of Net Life-Cycle GHG Emissions*, to calculate net life-cycle GHG emissions from construction and operation of the proposed rail line.

The GHG emissions associated with construction of the northern alternatives were higher than for the southern alternative due to the longer route, which would require proportionally more construction activity. Tables F-4 and F-5 provide an overview of construction GHG emissions from fossil fuel combustion of both construction equipment and vehicles. Table F-6 provides the total GHG emissions from railroad construction for each build alternative.

Table F-4. GHG Emissions from Construction Activities (Per million cubic meters of earthwork)

Track and Bridge Construction Equipment	CO2 (Metric Tons)	CH4 (Metric Tons)	N2O (Metric Tons)
2 Ton Flatbed Truck	1.1	0.0	0.0
Tractor/trailer (flatbed, belly dump)	6.8	0.0	0.0
Caterpillar D400 Rock Truck	2,817.8	4.1	1.8
Water Truck – 4,000 gal	7.4	0.0	0.0
Fuel/service truck	1.6	0.0	0.0
Pickup	16.3	0.0	0.0
Caterpillar 966 Loader	607.7	0.7	0.3
Caterpillar 140 Blade	32.2	1.1	0.5
CP 563E Padfoot Drum Compactor – (84”)	4.0	0.1	0.1
CP 563E Smooth Drum Compactor – (84”)	4.0	0.1	0.1
Caterpillar 815 Compactor	49.6	0.6	0.3
Caterpillar D6 Dozer	18.5	1.1	0.5
Caterpillar D9 Dozer	121.4	3.5	1.6
Caterpillar D10 Dozer	169.1	4.9	2.2
Komatsu PC 300 Excavator	3.4	0.3	0.1
Komatsu PC 400 Excavator	11.9	0.9	0.4
Caterpillar 615 Scraper	23.6	0.3	0.1
Caterpillar 631 Scraper	308.2	4.7	2.1
Rock Drill	10.8	0.2	0.1
Crawler Crane – 100 ton	4.2	0.1	0.0
Crawler Crane – 150 ton	4.4	0.1	0.0
Air Compressor (250 cfm)	21.2	0.1	0.0
Jumping Jack Compactor	62.9	0.8	0.4

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide

Table F-5. GHG Emissions from Construction Activities Assumed (per Mile of Track Constructed)

Track and Bridge Construction Equipment	CO_2 (Metric Tons)	CH_4 (Metric Tons)	N_2O (Metric Tons)	CO_2-Equivalents (Metric Tons)[a]
Equipment				
Pettibone 360 Speed Swing – Hi-Rail	2.7	0.2	0.1	27.1
Kershaw 26-2 Ballast Regulator	0.9	0.1	0.1	22.1
Jackson 6700 Tamper	4.5	0.2	0.1	30.1
Tie Handler	20.9	0.2	0.1	52.6
Rail Clip Applicator	1.6	0.1	0.0	16.0
Ballast Consolidator	40.3	0.4	0.2	101.5
EMD SD40 Locomotive	4,105.5	1.2	0.5	4,288.8
EMD SD70MAC locomotive	5,474.0	1.6	0.7	5,718.4
Signals				
2 supervisor half-ton pickups	0.1	0.0	0.0	0.1
5 half-ton crew foreman pickups	0.3	0.0	0.0	0.3
5 one-ton crew cab pickups	0.3	0.0	0.0	0.3
5 utility line trucks	0.3	0.0	0.0	0.3
1 20-ton crane	0.7	0.0	0.0	3.1
3 tractor backhoes	0.1	0.0	0.0	2.4
Tractor-trailer combo for transport	0.2	0.0	0.0	0.2
Communications				
1 half-ton pickup	0.1	0.0	0.0	0.1
2 supervisor half-ton pickups	0.1	0.0	0.0	0.1
2 utility line trucks	0.1	0.0	0.0	0.1
1-ton crew cab pickup	0.1	0.0	0.0	0.1
Backhoe	0.0	0.0	0.0	0.7
Tractor-trailer combo for transport	0.2	0.0	0.0	0.2

Notes:

[a] CO_2-equivalent emissions are not a direct sum of CO_2, CH_4, and N_2O; each gas is weighted by a global warming potential: CO_2 = 1, CH_4 = 25, N_2O = 298 (Intergovernmental Panel on Climate Change 2007)

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide

Table F-6. Total GHG Emissions from Construction Activities, by Build Alternative

GHG Emissions	Northern Alternatives[a] (Thousand Metric Tons CO2e)	Southern Alternatives[a] (Thousand Metric Tons CO2e)
CO_2	987	794
CH_4	33	48
N_2O	173	254
Total CO_2e[b]	1,193	1,095

Notes:
[a] The northern alternatives are the Tongue River Alternatives, Colstrip Alternatives, Tongue River Road Alternatives, and Moon Creek Alternatives. The southern alternatives are the Decker Alternatives.
[b] CO_2-e emissions are calculated by weighting CO_2, CH_4, and N_2O by a global warming potential: CO_2 = 1, CH_4 = 25, N_2O = 298 (Intergovernmental Panel on Climate Change 2007)
GHG = greenhouse gas; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent

Table F-7 shows the GHG emissions associated with the upstream manufacture of raw materials for the proposed rail line's construction.

Table F-7. Upstream Material Demand and GHG Emissions for Northern and Southern Alternatives

Scenario/Emissions Source	Material Demand (Metric Tons)	Upstream Material Manufacture GHG Emissions (Thousand $MTCO_2e$)
Northern Alternatives		
Steel Demand	37,986	58
Concrete Demand	133,355	16
Gravel Demand	1,070,881	188
Scenario Total	**--**	**262**
Southern Alternatives		
Steel Demand	22,510	34
Concrete Demand	79,025	9
Gravel Demand	634,597	112
Scenario Total	**--**	**155**

Notes:
Sources: Estimated using data from Ecoinvent Centre 2007; Hill et al. 2012
$MTCO_2e$ = metric tons of carbon dioxide equivalent

Railroad track construction disturbs carbon in soil and nonsoil vegetation. For the project area where railroad construction is expected to occur, soil carbon stocks are estimated to be 38.3 metric tons of carbon per hectare and total nonsoil carbon stocks are estimated to range from 20.6 to 56.4 metric tons of carbon per hectare (National Council for Air and Stream Improvement & U.S. Department of Agriculture 2014). Therefore, the total carbon disturbance resulting from the proposed rail line could range from 58.9 to 94.7 metric tons of carbon per hectare, depending on the vegetation in place. This conservatively assumes that there is no restoration of lost above- or below-ground carbon stocks after the right-of-way is constructed.

The net carbon disturbance from construction would vary depending on the build alternative. Using the above estimates for soil carbon disturbance emissions in the project area, the emissions could range from 0.24 $MMTCO_2e$ under the southern alternatives, assuming low vegetation carbon stocks, to 0.53 $MMTCO_2e$ under the northern alternatives, assuming high vegetation carbon stocks. For reference, when compared to the lowest estimates for rail transport emissions for the northern and southern alternatives, this would be equivalent to between 2.6 and 5 percent of rail construction and operation emissions over the 20-year analysis period. Consequently, net land disturbance emissions estimates are highly variable depending on the land cover and overall represent a relatively small contribution to life-cycle GHG emissions.

F.4.1.2 Proposed Rail Line Operation

Tongue River coal would be transported on the proposed rail line through the project area (i.e. the length of the licensed build alternative until it joins the main line). This analysis considers the GHG emissions associated with diesel fuel combustion by the proposed rail line as it hauls Tongue River coal through the project area. These GHG emissions would differ based the build alternative, as well as outside factors such as coal production levels, terminal capacity growth rates, and natural gas prices.

Methods and Data Sources

Within the project area, OEA assumed that because the trains would run to and from one mine, trains would not travel the full distance over Terminus 1 and 2. OEA developed a weighted estimate for train travel within the project area for each scenario weighted by the share of coal derived from a given mine for that scenario and the distance from the beginning of that segment to the mine. For each train, the mass of the train was assumed to consist of 125 freight cars and four locomotives, weighing a total of approximately 3,706 metric tons unloaded. At maximum capacity, each freight car hauls approximately 107 metric tons of coal, for a total of 17,087 metric tons for a fully loaded train. For the purposes of calculating the change in gross metric ton kilometers, trains are assumed to conduct round trips back and forth from mines to the junction with the main line, leaving the mines fully loaded and returning empty. Therefore, OEA assumed that half of the rail traffic would consist of fully loaded coal trains and the remainder is assumed to be empty coal trains, each with four locomotives and 125 railcars.

The metric ton kilometers traveled by trains was then used to determine the diesel fuel consumption within the project area by multiplying the metric ton kilometers traveled by industry data for locomotive fuel consumption. Fuel consumption was derived from the BNSF Railway (BNSF) Annual Report on total mileage traveled and fleet-wide fuel consumption (BNSF Railway 2012). To estimate total emissions, OEA then scaled total fuel use in the project area by an emission factor for rail diesel fuel derived from the U.S. GHG Inventory and a life-cycle study from Franklin Associates that incorporated combustion and precombustion emissions for railroad diesel fuel (U.S. Environmental Protection Agency

2013, Franklin Associates 2010). An overview of the rail diesel fuel emission factor is provided in Table F-8.

Table F-8. Precombustion and Combustion Emissions for Rail Diesel Fuel

Emissions Component	GHG Emissions ($MTCO_2e$/1,000 gallons)
Pre-combustion Emissions (CO2e)	5.25
Combustion Emissions (CO2)	10.26
Combustion Emissions (CH4)	0.01
Combustion Emissions (N2O)	0.02
Total	**15.54**

Notes:
Sources: U.S. Environmental Protection Agency 2013, Franklin Associates 2010
CO_2e = carbon dioxide equivalent $MTCO_2e$ = metric tons of carbon dioxide equivalent

Results

This section presents the GHG emissions results for transportation within the project area. The results in this section are used in Section F.6, *Summary of Net Life-Cycle GHG Emissions,* to calculate net life-cycle GHG emissions from construction and operation of the proposed rail line.

Transportation of coal to the main line resulted in a variety of emissions estimates, depending on whether the northern alternative or southern alternative was constructed. Operation of the proposed rail line would result in an increase in GHG emissions in the project area but would vary according to length and terrain of the build alternative. Table F-9 summarizes the proposed rail line's traffic in the project area.

Table F-9. Rail Traffic in the Project Area

Build Alternative	Production and Export Scenario Traffic (million gross-tkm/year)		
	Low	Medium	High
Northern	3,435	4,889	7,778
Southern	1,031	2,523	5,466

Notes:
tkm/year = metric ton kilometers per year

As discussed in Section F.4.2.1, *Downline Rail Traffic and International Shipping,* the profitability of Tongue River coal, the production and export scenario, and the resulting rail traffic would determine net GHG emissions from operation in the project area. Table F-10 characterizes the annual and accumulated net GHG emissions from operation of the proposed rail line within the project area.

Table F-10. Annual and Total Net GHG Emissions from Operation of the Proposed Rail Line in the Project Area (2018–2037)

Scenario and Build Alternative	Annual Net GHG Emissions (thousand MTCO2e/year)	Total Net GHG Emissions (thousand MTCO2e)
Northern Alternatives		
Low production	44	877
Medium production	62	1,248
High production	99	1,985
Southern Alternatives		
Low production	13	263
Medium production	32	644
High production	70	1,395

Notes:
Negative GHG emissions indicate that the net traffic on downline segments will decrease as a result of Tongue River trains displacing other coal trains that had been traveling longer distances to deliver coal
GHG = greenhouse gas; $MTCO_2e$ = metric tons of carbon dioxide equivalent

F.4.2 Indirect Impacts

F.4.2.1 Downline Rail Traffic and International Shipping

Downline Rail Traffic

In order to bring Tongue River coal to power plants for domestic consumption and to the Pacific Coast or other shipping terminals for international export, the coal would be transported across 51 downline rail segments as discussed in Appendix C, *Coal Production and Markets*. The downline segments extend through the Upper Midwest to domestic markets and Great Lakes ports, as well as to the Pacific Northwest to export terminals.

In addition to the GHG emissions associated with diesel fuel combustion by locomotives hauling Tongue River coal, this analysis considers the indirect effect on rail traffic throughout the downline rail segments. Not only would overall GHG emissions be influenced by construction of the proposed rail line, they would also differ based on whether one of the northern alternatives or southern alternatives is constructed, as well as outside factors such as coal production levels, terminal capacity growth rates, and natural gas prices.

Methods and Data Sources

Using IPM®, OEA disaggregated rail traffic across 51 downline rail segments extending through the Upper Midwest and Pacific Northwest. OEA subtracted the baseline rail traffic for No-Action Alternative rail traffic scenarios from the corresponding build alternative scenarios to determine the net or additional rail traffic for each build alternative scenario. OEA used this measure of net or additional rail traffic to estimate the change in rail tonnage within each scenario by calculating the total ton-miles carried by rail throughout the 51 downline segments.

OEA calculated changes in rail metric ton kilometers by multiplying the incremental train metric tons transported per segment in each scenario by each segment's respective distance (in kilometers). For each train, the mass of the train was assumed to consist of 125 freight cars as well as 4 locomotives, weighing a total of approximately 3,706 metric tons unloaded. At maximum capacity, each freight car hauls approximately 107 metric tons of coal, for a total of 17,087 metric tons for a fully loaded train. For the purposes of calculating the change in gross metric ton kilometers, trains are assumed to conduct round-trips back and forth from mines to power plants, leaving the mines fully loaded and returning empty. Therefore, OEA assumed that half of the rail traffic would consist of fully loaded coal trains and the remainder is assumed to be empty coal trains, each with four locomotives and 125 railcars.

The change in gross-ton miles traveled along the downline segments was then used to determine the change in diesel fuel use within the rail network by multiplying the gross-ton miles traveled within the rail network by industry data for locomotive fuel consumption. Fuel consumption in the rail system was derived from BNSF's Annual Report on total mileage traveled and fleet-wide fuel consumption (BNSF Railway 2012). To estimate total emissions, OEA then scaled the change in fuel use by an emission factor for rail diesel fuel derived from the U.S. GHG Inventory and a life-cycle study from Franklin Associates that incorporated combustion and precombustion emissions for railroad diesel fuel (U.S. Environmental Protection Agency 2013, Franklin Associates 2010). The rail diesel fuel emission factor is consistent with Table F.8 in Section F.4.1.2, *Proposed Rail Line Operation*.

Results

This section presents the GHG emissions results downline rail traffic, considering changes in the rail transportation of other competing coals. The results in this section are used in Section F.6, *Summary of Net Life-Cycle GHG Emissions,* to calculate net life-cycle GHG emissions from construction and operation of the proposed rail line.

Transportation of coal to power plants and export terminals resulted in a variety of emissions estimates, depending on whether the northern alternative or southern alternative was constructed, as well as on outside factors such as export capacity and coal production. In some cases the proposed rail line's effect on downline rail segments resulted in net negative GHG emissions.

Several key factors drove these differences among the scenarios. First, transportation distances would be longer and costs to deliver the coal to market slightly higher for the southern alternatives. Therefore, while the northern alternatives would generate more immediate rail traffic, the rail traffic would displace even more traffic downline of the project area. On the other hand, the southern alternatives would result in a net increase in downline rail traffic. The results of the coal market analysis indicate that additional Tongue River coal trains would displace rail traffic on downline segments. Taking displacement into account, Tongue River coal production would increase train trips in and out of the Powder River Basin by between 0 (i.e., no net change in rail traffic) to 11.4 trains per day. Table F-11 summarizes the proposed rail line's impact on gross rail metric ton kilometers across different scenarios for downline segments.

Table F-11. Downline Rail Traffic

Build Alternative	Production and Export Scenario Traffic (million gross-tkm/year)		
	Low	Medium	High
Northern	-4,912	-7,552	-11,287
Southern	2,169	4,099	51

Furthermore, the economic viability of the Otter Creek Mine would influence the extent of rail operation. The mine is profitable at low export capacity if one of the northern alternatives is constructed, but only profitable for all years at medium and high terminal export capacity for the southern alternatives. If one of the southern alternatives is constructed and zero terminal capacity growth is assumed, the Otter Creek Mine is not economically viable in all years due to higher construction and transportation costs. Additionally, rail distances to primary markets would be longer for the southern alternatives. More information on the various coal production and transport scenarios is available in Appendix C, *Coal Production and Markets*.

Higher coal production has two market effects that influence the net GHG emissions from rail operation. The proposed rail line would facilitate the production of coal from the proposed Otter Creek Mine and could induce production from the Poker Jim Creek–O'Dell Creek and Canyon Creek deposits, resulting in increased rail traffic between these mines and power plants primarily in the Midwest. At the same time, increased transportation of Tongue River coal would offset other non-Powder River Basin coal shipments. In certain scenarios, this displacement would result in a net decrease in overall rail traffic in terms of gross metric ton kilometers.

Separately, possible increases in export capacity could increase coal exports to Asian markets, thereby increasing rail traffic to export terminals on the west coast. However, this factor actually would drive the largest decrease in downline emissions. The scenarios with the highest coal production and terminal capacity would also result in the highest displacement of downline rail traffic. According to Appendix C, *Coal Production and Markets*, export terminals are expected to be used at maximum capacity regardless of whether or not the proposed rail line is constructed. Therefore, the additional traffic to reach Pacific Northwest export terminals would displace an equivalent amount of coal shipments from further inland and thereby would drive down the net gross metric ton kilometers shipped.

Table F-12 characterizes the annual and accumulated net GHG emissions from downline rail travel resulting from the proposed rail line.

Table F-12. Annual and Total Net GHG Emissions from Operation of the Proposed Rail Line in Downline Segments (2018–2037)

Scenario and Build Alternative	Annual Net GHG Emissions (thousand $MTCO_2e$/year)	Total Net GHG Emissions (thousand $MTCO_2e$)
Northern Alternatives		
Low production	-63	-1,254
Medium production	-96	-1,928
High production	-144	-2,881
Southern Alternatives		
Low production	28	554
Medium production	52	1,046
High production	1	13

Notes:
Negative GHG emissions indicate that the net traffic on downline segments will decrease as a result of Tongue River trains displacing other coal trains that had been traveling longer distances to deliver coal
$MTCO_2e$ = metric tons of carbon dioxide equivalent

OEA also investigated immediate and downline transportation under two scenarios in which low natural gas prices would foster greater competition between natural gas and coal in the energy marketplace. In the scenario where low natural gas prices coincide with zero export terminal growth, overall train travel rises to a net positive over the no-action scenario and a slight increase in emissions (168,805 $MTCO_2e$, aggregated over 20 years). In contrast, when low natural gas prices are combined with high export terminal growth, net train travel is reduced, resulting in transportation emission reductions compared to the No Action alternative (-764,388 MTCO2e, aggregated over 20 years). This is because, in this scenario, Tongue River coal would displace other domestic coal that would have been shipped from further away for international export in the No-Action Alternative.[10]

International Shipping

As part of its coal market analysis, OEA developed assumptions regarding export terminal capacity for coal export from the Pacific Northwest. The existing coal export terminals in the Pacific Northwest are located in Vancouver, British Columbia and Prince Rupert, British Columbia. However, these terminals have limited capacity to export additional U.S.-produced coal as they are already operating close to capacity. Therefore, the export assumptions assess the impact on coal exports of new terminals that have already been proposed for construction, although their final locations and export levels have not yet been finalized. The coal market analysis in Appendix C, *Coal Production and Markets,* considered six export scenarios that would export to Asian markets—four using northern

[10] The emission estimates provided for the two low natural gas price scenarios include net GHG emissions from both the immediate, direct rail segments of the proposed rail line as well as the change in downline transportation.

alternatives and two using southern alternatives—via four proposed terminals (Gateway Pacific, Millennium Bulk, Coyote Island, and Fraser Surrey) located in Washington, Oregon and British Columbia.

Depending on export capacity growth, total export capacity available to Tongue River coal could stay at 8 million tons per year in the no-growth scenarios, to as much as 122 million tons per year by 2037 in the high-growth scenario. OEA assumed that the terminals would operate at capacity regardless of whether or not the proposed rail line is constructed (Appendix C, *Coal Production and Markets*, Chapter 8). In the No-Action Alternative, other domestic coals (including other Powder River Basin coals) would be exported to Asia. Tongue River coal would occupy a substantial share of the export capacity due to its proximity and heat content advantages over other domestic coals.

As the total metric tons of domestic exports are held constant between the build alternatives and the No-Action Alternative, the net GHG impact of coal export shipping is dependent on how Pacific Basin markets respond to exports of Tongue River coal relative to other domestic exports.

Methods and Data Sources

For scenarios in which Tongue River coal is exported to Asia, OEA selected Japan to illustrate the total transportation costs because it has historically imported more coal than any other Pacific Basin country, and is one possible destination for Powder River Basin coal exports. Shipments to terminals in Chiba, Japan, from the Pacific Northwest represent the lowest prices for ocean transport because they provide the shortest export route to Asia (see Appendix C, *Coal Production and Markets*, Chapter 4, for more detailed information about export prices). Powder River Basin coal exports to other countries such as China, Korea, or Taiwan would involve longer shipping distances by 130 to 1,500 miles.

In OEA's analysis, the gross metric tons of U.S. coal exports remain at the same level across all scenarios; consequently, Tongue River coal exports would simply displace other U.S. coal exports relative to the No-Action Alternative. In other words, the proposed rail line would affect only the *type* of coal exported, not the *amount* of U.S. coal exported. As a result, the GHG emissions from shipping U.S. coal exports would be the same, regardless of whether the proposed rail line is built or not.

For other reference coals, the change in ocean transport emissions for competing coals was calculated by scaling the average annual change in Pacific Basin and Colombian coal production in millions of tons by the distance between production sites and Chiba, Japan to calculate the net impact on in metric ton kilometers traveled. The change in metric ton kilometers of Pacific Basin and Colombian coal was multiplied by a per metric ton kilometer GHG emission factor for ocean transport derived from a life-cycle inventory database (Ecoinvent Centre 2007). The net emissions estimate for ocean transport considers the net change in emissions for the transport of Tongue River coal when it affects the amount coal produced in the Pacific Basin and distributed from major Asian coal export terminals to Asian markets.

In addition, OEA considered the emissions associated of operating coal export terminals within the greater context of international export emissions. To estimate the contribution of export terminals, OEA drew from an environmental impact assessment for the Westshore Export Terminal in Vancouver, British Columbia (Westshore Terminals 2013). The environmental impact assessment report provided emissions estimates for a scenario in which the export terminal is upgraded and expanded in 2018, which aligns with high export terminal capacity growth scenarios. From the study, OEA derived the per-unit emissions from the export terminal and scaled them by the expected coal throughput from the coal market analysis to estimate the GHG emissions.

Results

This section presents the GHG emissions results for ocean transport of coal exports transported by the proposed rail line and changes in the ocean transport of other competing coals. The results in this section are used in Section F.6, *Summary of Net Life-Cycle GHG Emissions,* to calculate net life-cycle GHG emissions.

To estimate GHG emissions from coal export terminal operation, OEA assumed GHG emissions from the Westshore Export Terminal in Vancouver would be representative of other coal export terminals on the west coast. This assumption may be conservative, as newer terminals on the west coast would likely have a lower emissions intensity, as they are able to incorporate newer, more efficient equipment. Westshore Export Terminal in Vancouver, British Columbia is expected to export 36 million metric tons of coal and emit 21,000 $MTCO_2e$ annually by 2018, or approximately 0.6 $MTCO_2e$ per thousand metric tons of coal (Westshore Terminals 2013). Based on this estimate, OEA calculated that total GHG emissions from export facilities handling Tongue River coal would be between 7 to 12 thousand $MTCO_2e$ per year (or 0.1 and 0.2 $MMTCO_2e$) from 2018 to 2037) across the two export scenarios.

OEA estimated the total exports of Tongue River coal across coal production and export scenarios (Appendix C, *Coal Production and Markets*), with the highest exports occurring in the northern and southern alternatives' high production and export scenarios. An overview of the changes in net international coal production and transport distances is provided in Table F-13. Table F-14 provides an overview of the annual and accumulated emissions associated with the ocean transport of internationally produced coals in response to the proposed rail line. The scenario numbers in Table F-13 and Table F-14 correspond to the scenario numbers in Appendix C, *Coal Production and Markets*.

These results show that the net impact on international coal production and ocean freighter travel may actually increase or decrease depending on the scenario. Differences in the heat content of the Tongue River coal would drive the differences in international coal production and transportation. For example, the relatively high energy content of Canyon Creek coal, accessed in scenarios with high Tongue River coal production, drives down the production of international coal. The price of natural gas would also influence exports: in scenarios with low natural gas prices, Tongue River coal exports are small and the overall impact of the proposed rail line on ocean transport GHG emissions compared to the No-Action Alternative is modest. This would result in only small changes in international coal production and shipping to adjust to the heat content of Tongue River coal exports.

Table F-13. Changes in International Coal Production by Scenario

Scenario	Origin	Total Change in Pacific Basin Coal Production (Million metric tons, 2018–2037)	Kilometers	Total Change in Colombian Coal Production (Million metric tons, 2018–2037)	Kilometers
3	China	0.00	3,704	-0.04	5,000
4	China	-0.01	3,704	-0.03	5,000
5	Australia	-0.49	8,334	0.06	5,000
6	N/A	N/A	N/A	-0.02	5,000
7	Indonesia	0.69	5,926	-0.08	5,000
8	Indonesia	0.50	5,926	0.07	5,000
9	China	0.00	0	-0.53	5,000
10	China, Australia, Indonesia	0.99	4,074	-0.07	5,000
11	Indonesia and Australia	3.28	7,778	0.08	5,000
12	N/A	N/A	N/A	-0.03	5,000
13	China	0.08	3,704	-0.03	5,000
14	China, Australia, Indonesia	-0.44	4,630	0.07	5,000
15	N/A	N/A	N/A	-0.05	5,000
16	China	0.03	3,704	-0.04	5,000
17	China, Australia, Indonesia	0.19	4,630	0.08	5,000
18	N/A	N/A	N/A	-0.53	5,000
19	China	-1.06	3,704	-0.07	5,000
20	China, Australia, Indonesia	-3.03	4,630	0.08	5,000
21	Indonesia and Australia	0.00	6,852	-0.04	5,000
22	Indonesia and Australia	0.07	6,852	-0.03	5,000

Notes:
These scenarios assume zero terminal growth and no change in the existing export market. More information on the various coal production and transport scenarios is available in Appendix C, *Coal Production and Markets,* Chapter 8.
N/A = not applicable

Table F-14. Annual and Accumulated Ocean Transport Emissions for International Coal Production in Response to Proposed Rail Line

Scenario	Net Transport Emissions ($MTCO_2e$/yr)	Net Accumulated Transport Emissions ($MTCO_2e$)
3	-91	-1,830
4	-77	-1,549
5	-1,665	-33,305
6	-34	-677
7	1,639	32,784
8	1,476	29,523
9	-1,167	-23,342
10	1,649	32,989
11	11,492	229,845
12	-76	-1,514
13	67	1,335
14	-731	-14,625
15	-103	-2,067
16	-38	-754
17	569	11,372
18	-1,171	-23,411
19	-1,903	-38,065
20	-6,039	-120,772
21	-79	-1,586
22	165	3,304

Notes:
$MTCO_2e$ = Metric tons of carbon dioxide equivalent

F.4.2.2 Cumulative Impacts of Mining

Proposed and Potentially Induced Mines

The proposed rail line would serve the proposed Otter Creek Mine and could induce the development of the Poker Jim Creek–O'Dell Creek deposit, which could be accessed by the Tongue River Alternatives, Colstrip Alternatives, Tongue River Road Alternatives, or Moon Creek Alternatives. The Decker Alternatives would provide access to the Canyon Creek deposit in addition to the Otter Creek Mine and Poker Jim Creek–O'Dell Creek deposits. This section assesses the GHG emissions resulting from construction of each proposed or potentially induced mine and its operation from 2018 to 2037. OEA assumed that all coal would be most efficiently extracted through surface mining because the estimated overburden ratios for the proposed and potentially induced mines are relatively low, ranging from 2.46:1 to 4.82:1. As described in Appendix C, *Coal Production and Markets*, Powder River Basin coal is almost entirely produced via surface mining technology; there is only one underground mine in the basin and additional underground mining is considered unlikely.

Table F-15 summarizes the production capacities for the low, medium, and high production scenarios for the three proposed and potentially induced mines or deposits (Otter Creek, Poker Jim Creek–O'Dell Creek, and Canyon Creek). Table F-16 summarizes the maximum production capacities for the low, medium, and high production scenarios assuming all proposed and potentially induced mines are in production. These production capacities represent the maximum annual coal production at each mine for the given production level and route alternatives and do not take into account other market impacts that could lead to lower levels of production at some mines for certain years. All coal production tonnages are presented in metric tons of mined coal. All coal transported by the proposed rail line is assumed to be transported and combusted without any additional cleaning or processing based on the market analysis described in Appendix C, *Coal Production and Markets*.

Table F-15. Production Capacities of Proposed and Potentially Induced Mine Production

Mine/Deposit	Build Alternatives	Production Scenario	Production Quantity (million metric tons of coal per year)[a]	Online Year
Otter Creek	All	Low	18.14	2018–2021[b]
Otter Creek	All	Medium	18.14	2018–2021[b]
Otter Creek	All	High	30.84	2018–2021[b]
Poker Jim Creek–O'Dell Creek	All	Low	0	--
Poker Jim Creek–O'Dell Creek	All	Medium	10.89	2023
Poker Jim Creek–O'Dell Creek	All	High	14.51	2023
Canyon Creek	Southern	Low	0	--
Canyon Creek	Southern	Medium	0	--
Canyon Creek	Southern	High	19.96	2028

Notes:
" --" denotes mines that do not enter production in a given scenario
[a] Expresses production quantity at full capacity in each scenario; production ramps up during the first two years after each mine comes online
[b] The Otter Creek Mine is assumed to come online in the calendar year after completion of the proposed rail line under each alternative. Based on the proposed rail line construction schedule, the Otter Creek Mine is expected to come online in 2018 for all alternatives when using the 24-hour, 12-month-per-year proposed rail line construction schedule. When using the non-24-hour, 8-month-per-year proposed rail line construction schedule, the Otter Creek Mine is expected to come online in: 2018 for the Tongue River Alternatives and Colstrip Alternatives; in 2019 for the Tongue River East Alternative and Colstrip East Alternatives; in 2020 for the Tongue River Road Alternative, Tongue River Road East Alternative, and Moon Creek Alternative; and in 2021 for the Moon Creek East Alternative, Decker Alternative, and Decker East Alternative.

Table F-16. Maximum Production Capacities Assuming All Proposed and Potentially Induced Mines are Productive (million metric tons of coal per year)

Year	No-Action Alternative	Northern Alternatives			Southern Alternatives		
		Production Level					
		Low	Medium	High	Low	Medium	High
2018	0	18.14	18.14	30.84	18.14	18.14	30.84
2023	0	18.14	29.03	45.36	18.14	29.03	45.36
2030	0	18.14	29.03	45.36	18.14	29.03	65.32[a]
2037	0	18.14	29.03	45.36	18.14	29.03	65.32[a]

Notes:
[a] Production capacities for the southern alternatives in the high production scenario reflect the Canyon Creek mine beginning production in 2028

Methods and Data Sources

Construction and operation of the coal deposits and mines potentially induced by the proposed rail line would result in GHG emissions from energy consumption (electricity, gasoline, and diesel fuel) for mine construction and coal extraction; direct methane emissions from surface mines; upstream emissions from the production of coal mine construction and operations equipment and materials (e.g., steel and ammonium nitrate); and upstream emissions from the production of electricity and fuels used in coal mine construction and operation.

Construction of each of the proposed and potentially induced coal deposits and mine is assumed to occur over a 30-month period based on the estimated construction period in the Otter Creek Mine permit application (Montana Department of Environmental Quality 2012). The starting year for production for the Otter Creek Mine is identified in the December Supplemental Application Filing from the Tongue River Railroad Company. Construction of the Otter Creek Mine is projected to take approximately 3 years, depending on the build alternative and construction schedule.[11] For the purposes of analysis, OEA estimated that construction of the Poker Jim Creek–O'Dell Creek deposit is projected to occur from 2020 to 2022, and the Canyon Creek deposit is projected to occur from 2025 to 2027.

TRRC expects that mine operation would begin gradually at the Otter Creek Mine. The first year of operation is expected to produce 10.89 million metric tons of coal, or about 60 percent of the anticipated permitted production of 18.14 million metric tons of coal per year. The second year of operation is expected to produce 14.51 million metric tons of coal,

[11] The Otter Creek Mine is assumed to finish construction in the same calendar year that construction of the proposed rail line is completed under each build alternative, with the Otter Creek Mine coming online the following calendar year. Based on the proposed rail line construction schedule, the Otter Creek Mine is expected to be constructed from 2015 to 2017 for all build alternatives when assuming the 24-hour, 12-month-per-year proposed rail line construction schedule. When assuming the non-24-hour, 8-month-per-year proposed rail line construction schedule, the Otter Creek Mine is expected to be constructed from 2015 to 2017 for the Tongue River Alternatives and Colstrip Alternatives; 2016 to 2018 for the Tongue River East Alternative and Colstrip East Alternative; 2017 to 2019 for the Tongue River Road Alternative, Tongue River Road East Alternative, and Moon Creek Alternative; and 2018 to 2020 for the Moon Creek East Alternative, Decker Alternative, and Decker East Alternative.

or about 80 percent of the anticipated permitted production. This gradual startup was applied similarly to both the potentially induced Poker Jim Creek–O'Dell Creek deposit and Canyon Creek deposit production rates for years 1 and 2 of mine operation. Because operation at these mines emits GHGs in proportion to the tonnage of coal mined (Spath et al. 1999, U.S. Environmental Protection Agency 2013), it is assumed the first and second years of mine operation for each mine would emit 60 percent and 80 percent, respectively, of the total GHG emissions of each mine operating at full production capacity.

Detailed data on the equipment needed for coal surface mine construction are not available. To account for this data gap, OEA used assumptions for surface mining equipment demand and energy consumption in Spath et al. (1999). OEA assumed that construction of surface mines would require 30 percent of the annual electricity, fuel, and materials needed for mine operation at full production capacity. This assumption acknowledges that similar equipment would be involved in initial mine construction, although at a reduced level compared to full-time mine operation.[12] OEA then scaled the equipment demand and energy consumption proportionally with mine capacity to account for the additional construction activities needed for larger mines.

OEA estimated the gasoline and diesel fuel consumption needed for mine operation based on the current air permit for the nearby Rosebud surface mine. OEA divided the permitted gasoline and diesel fuel consumption at the Rosebud mine by the mine's current annual coal production rate to estimate that the gasoline and diesel fuel consumption needed for to mine one metric ton of coal. The result was 0.014 gallon of gasoline and 0.303 gallon of diesel fuel per metric ton of coal mined. Since these fuel consumption factors are based on emissions limits at the Rosebud mine, they likely represent the maximum expected fuel consumption from surface mine operation. Based on estimates provided in Spath et al. (1999), OEA estimated the electricity consumption needed for mine operation to be 14.3 kilowatt hours per metric ton of coal mined.

OEA estimated the fossil fuel combustion GHG emissions from gasoline and diesel fuel using emission factors from the Bureau of Land Management (2013). OEA estimated the GHG emissions from electricity production based on the USEPA's eGRID[13] annual combustion output emissions rate for Montana (U.S. Environmental Protection Agency 2014a). In addition to emission factors for GHG emissions from gasoline and diesel fuel combustion, OEA used precombustion GHG emission factors from Franklin Associates (2010) to account for the energy requirements for extracting, processing, and transporting gasoline, diesel fuel, and fuels and materials used for electricity production.

[12] The sensitivity of mine GHG emissions to changes in this assumption are small; if annual construction GHG emissions are assumed to be equivalent to annual mine operating emissions (i.e., assuming construction emissions are equal to 100 percent, instead of 30%, of annual operation emissions), the share of construction emissions at the mining stage only increases by 4 percentage points from 2 to 6 percent.

[13] OEA used the annual combustion output emissions rate for Montana from USEPA's Emissions & Generation Resource Integrated Database (eGRID). eGRID is "a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States" updated on an annual basis. eGRID provides aggregated data by state to estimate state-level environmental impacts from electricity generation (U.S. Environmental Protection Agency 2014a).

OEA estimated the embedded emissions from operations materials and equipment per metric ton of coal production based on data in Spath et al. (1999). Operations materials were assumed to include ammonium nitrate for explosives and steel for various pieces of equipment, including stripping shovels, overburden grills, bulldozers, coal shovels, front-end loaders, coal-hauling trucks, wheel tractor-scrapers, and miscellaneous vehicles. Emissions resulting from upstream production of steel equipment and ammonium nitrate explosives were estimated based on life-cycle inventory data available from the Ecoinvent database[14] (Ecoinvent Centre 2007) for low-alloyed steel and Tovex explosives, a common explosive used by the mining industry. While demand for all mine operations materials and equipment was estimated to be proportional to the rate of coal production at each proposed and potentially induced mine, OEA also used the equipment lifetime data provided in Spath et al. (1999) to account for repurchase of end-of-life steel mine equipment during mine operation from 2018 to 2037.

OEA estimated direct surface mining and post-surface mining methane emissions from proposed and potentially induced mines per metric ton of coal mined based on emission factors for the Northern Great Plains region, including Wyoming and Montana, using data provided in USEPA's 1990–2012 GHG Inventory (U.S. Environmental Protection Agency 2013).

OEA considered GHG emissions from the loss of terrestrial carbon stored in vegetation and soils that is disturbed by of proposed and potentially induced mine construction and operation. To estimate the loss of above- and below-ground carbon stocks, OEA used estimates of vegetation and soil carbon storage in the study area from the COLE tool developed collaboratively by the National Council for Air and Stream Improvement and the U.S. Department of Agriculture, Forest Service. To calculate the change in carbon stocks, OEA applied estimates of the carbon stock per hectare to the hectares disturbed by the proposed and potentially induced mines.

The net carbon disturbance over the lifetime of the mine would depend on the ability of the land to be restored to its predisturbance state in a timely manner. During mine reclamation, soil and vegetation replacement occurs as sections of the mine are depleted of coal and no longer actively mined rather than occurring after mining for the entire tract is completed. This approach minimizes the period during which soil and vegetation will be removed from the mine acreage and therefore minimizes the avoided carbon sequestration resulting from plant growth. To account for reclamation activities, OEA applied estimates of carbon stocks following surface mine reclamation activities from a recent study (Trlica & Brown 2013) to calculate the net change in terrestrial carbon stocks.

OEA determined that several potential sources of GHG emissions from proposed and potentially induced coal mine construction and operation were negligible across the lifetime of the mines and are therefore not estimated in this analysis, such as infrastructure needed to

[14] The Ecoinvent database is a widely used source of life-cycle inventory datasets based on industrial data that have been compiled by a number of international research institutes and life-cycle assessment consultants.

bring workers and equipment to the construction site and end-of-life management of mine equipment. Similarly, based on data provided in Spath et al. (1999), OEA determined that the GHG emissions resulting from materials and energy needed for proposed and potentially induced surface mine decommissioning and reclamation are expected to be negligible relative to the GHG emissions resulting from mine construction and operation.

Results

This section presents the GHG emissions results for construction and operation of the proposed and potentially induced mines. The results in this section are used in Section F.5, *Comparison with Life-Cycle Greenhouse Gas Emissions from Competing Coal,* to compare the carbon intensity of Tongue River coal with other competing coals and in Section F.6, *Summary of Net Life-Cycle GHG Emissions,* to calculate net life-cycle GHG emissions from construction and operation of the proposed rail line.

Table F-17 provides GHG emission estimates for mine construction. OEA estimated the construction energy-related GHG emissions to be 0.011 metric ton of CO_2e per metric ton of coal production capacity (Franklin Associates 2010; Montana Department of Environmental Quality 2001; Spath et al. 1999; U.S. Environmental Protection Agency 2014a). OEA estimated the GHG emissions from manufacturing the equipment and materials used in mine operation (i.e., construction material embedded emissions) to be 0.005 $MTCO_2e$ per metric ton of coal production capacity (Ecoinvent Centre 2007; Spath et al. 1999). Using these emission factors, OEA estimated the total construction-related GHG emissions for the proposed and potentially induced mines to be 0.016 $MTCO_2e$ per metric ton of coal production capacity. This emission factor was multiplied by mine production capacity for each scenario to calculate total construction GHG emissions, shown in Table F-17.

Table F-17. Total GHG Emissions for Construction of Proposed and Potentially Induced Mines; Low, Medium, and High Production Scenarios

Scenarios and Emissions Source	Annual Construction GHG Emissions (MMTCO2e/year of construction)	Total (30-month) Construction GHG Emissions (MMTCO2e)
Low Production Scenarios (Northern and Southern Alternatives)[a]		
Construction energy	0.08	0.21
Construction material embedded emissions	0.04	0.09
Total	**0.12**	**0.30**
Medium Production Scenarios (Northern and Southern Alternatives)[b]		
Construction energy	0.13	0.33
Construction material embedded emissions	0.06	0.15
Total	**0.19**	**0.48**
High Production Scenarios (Northern Alternatives)[b]		
Construction energy	0.21	0.51
Construction material embedded emissions	0.09	0.23
Total	**0.30**	**0.74**
High Production Scenarios (Southern Alternatives)[c]		
Construction energy	0.30	0.74
Construction material embedded emissions	0.13	0.33
Total	**0.43**	**1.07**

Notes:
[a] Includes the Otter Creek (Tract 2) mine
[b] Includes the Otter Creek Mine (Tract 2) and Poker Jim Creek–O'Dell Creek deposit
[c] Includes the Otter Creek Mine (Tract 2) and Poker Jim Creek–O'Dell Creek and Canyon Creek deposits
Sources: Estimated using data from Ecoinvent Centre 2007, Montana Department of Environmental Quality 2001, Spath et al. 1999, U.S. Environmental Protection Agency2014a, 2013
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Tables F-18, F-19, and F-20 provide GHG emission estimates for mine operation. OEA used the following emission factors to estimate GHG emissions from mine operation:

- Total precombustion and combustion mine operation energy-related GHG emissions: 0.015 $MTCO_2e$ per metric ton of coal (Franklin Associates 2010; Montana DEQ 2001; Spath et al. 1999; U.S. Environmental Protection Agency 2014a).
- GHG emissions from manufacturing the equipment and materials used in mine operation (i.e., operation material embedded emissions): 0.005 $MTCO_2e$ per metric ton of coal (Ecoinvent Centre 2007; Spath et al. 1999).
- Direct methane emissions from the mine face: 0.020 $MTCO_2e$ per metric ton of coal (U.S. Environmental Protection Agency 2013).

Based on these assumptions, OEA estimates the total operation-related GHG emissions per ton of coal for the proposed and potentially induced mines to be 0.041 $MTCO_2e$ per metric ton of coal.[15] This emission factor was multiplied by coal production to estimate GHG emissions from mine operation for each scenario, as shown in Tables F-18, F-19, and F-20.

Accumulated mine operation GHG emissions through 2037 would depend on the year the mine operation begins. As noted above, depending on the proposed rail line construction schedule and build alternative, the Otter Creek Mine could begin production in 2018, 2019, 2020, or 2021. To demonstrate the range of emissions from operation of proposed and potentially induced mines, results are shown for scenarios where the Otter Creek Mine comes online in 2018 and 2021. For this analysis, the Poker Jim Creek–O'Dell Creek deposit is expected to begin production in 2023 and the Canyon Creek deposit is expected to begin production in 2028 for all southern alternatives.

Table F-18. Total GHG Emissions for Operation of Proposed and Potentially Induced Mines; Low Production Scenarios (2018–2037)

Proposed and Potentially Induced Mines	Operation Energy ($MMTCO_2e$)	Operation Material Embedded Emissions ($MMTCO_2e$)	Direct Methane from Mine Face ($MMTCO_2e$)	Total GHG Emissions ($MMTCO_2e$)
Otter Creek (Production Begins in 2018)				
Year 1 (2018)	0.16	0.06	0.22	0.44
Year 2 (2019)	0.22	0.08	0.30	0.59
Remaining Years (2020-2037)	4.93	1.76	6.66	13.35
Scenario Total (2018-2037)	**5.31**	**1.90**	**7.18**	**14.39**
Otter Creek (Production Begins in 2021)				
Year 1 (2021)	0.16	0.06	0.22	0.44
Year 2 (2022)	0.22	0.08	0.30	0.59
Remaining Years (2023-2037)	4.11	1.47	5.55	11.12
Scenario Total (2021-2037)	**4.49**	**1.60**	**6.07**	**12.16**

Notes:
Energy emissions include pre-combustion and combustion emissions.
Sources: Bureau of Land Management 2013, Ecoinvent Centre 2007, Montana DEQ 2001, Spath et al. 1999, U.S. Environmental Protection Agency 2014a, 2013.
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

[15] Emission factors do not sum exactly to the total result due to rounding differences.

Table F-19. Total GHG Emissions for Operation of Proposed and Induced Mines; Medium Production Scenarios (2018–2037)

Proposed and Potentially Induced Mines	Operation Energy ($MMTCO_2e$)	Operation Material Embedded Emissions ($MMTCO_2e$)	Direct Methane from Mine Face ($MMTCO_2e$)	Total GHG Emissions ($MMTCO_2e$)
Otter Creek (Production Begins in 2018)				
Year 1 (2018)	0.16	0.06	0.22	0.44
Year 2 (2019)	0.22	0.08	0.30	0.59
Remaining Years (2020–2037)	4.93	1.76	6.66	13.35
Mine Total (2018–2037)	**5.31**	**1.90**	**7.18**	**14.39**
Otter Creek (Production Begins in 2021)				
Year 1 (2021)	0.16	0.06	0.22	0.44
Year 2 (2022)	0.22	0.08	0.30	0.59
Remaining Years (2023–2037)	4.11	1.47	5.55	11.12
Mine Total (2021–2037)	**4.49**	**1.60**	**6.07**	**12.16**
Poker Jim Creek–O'Dell Creek				
Year 1 (2023)	0.10	0.04	0.13	0.27
Year 2 (2024)	0.13	0.05	0.18	0.36
Remaining Years (2025–2037)	2.14	0.77	2.89	5.79
Mine Total (2023–2037)	**2.37**	**0.86**	**3.20**	**6.42**
Scenario Total (2018–2037)	**7.68**	**2.75**	**10.38**	**20.81**
Scenario Total (2021–2037)	**6.86**	**2.46**	**9.27**	**18.58**

Notes:
Energy emissions include pre-combustion and combustion emissions.
Sources: Bureau of Land Management 2013, Ecoinvent Centre 2007, Montana DEQ 2001, Spath et al. 1999, U.S. Environmental Protection Agency 2014a, 2013.
MMTCO2e = million metric tons of carbon dioxide equivalent

Table F-20. Total GHG Emissions for Operation of Proposed and Potentially Induced Mines; High Production Scenarios (2018–2037)

Proposed and Potentially Induced Mines	Operation Energy ($MMTCO_2e$)	Operation Material Embedded Emissions ($MMTCO_2e$)	Direct Methane from Mine Face ($MMTCO_2e$)	Total GHG Emissions ($MMTCO_2e$)
Otter Creek (Production Begins in 2018)				
Year 1 (2018)	0.28	0.10	0.38	0.76
Year 2 (2019)	0.37	0.13	0.50	1.01
Remaining Years (2020–2037)	8.38	2.99	11.32	22.69
Mine Total (2018–2037)	**9.03**	**3.23**	**12.20**	**24.46**
Otter Creek (Production Begins in 2021)				
Year 1 (2021)	0.28	0.10	0.38	0.76
Year 2 (2022)	0.37	0.13	0.50	1.01
Remaining Years (2023–2037)	6.98	2.49	9.44	18.91
Mine Total (2021–2037)	**7.63**	**2.73**	**10.32**	**20.68**
Poker Jim Creek–O'Dell Creek				
Year 1 (2023)	0.13	0.05	0.18	0.36
Year 2 (2024)	0.18	0.06	0.24	0.48
Remaining Years (2025–2037)	2.85	1.03	3.85	7.73
Mine Total (2023–2037)	**3.15**	**1.14**	**4.26**	**8.56**
Canyon Creek (Southern Alternatives)				
Year 1 (2028)	0.18	0.07	0.24	0.49
Year 2 (2029)	0.24	0.09	0.33	0.66
Remaining Years (2030–2037)	2.41	0.89	3.26	6.56
Mine Total (2028–2037)	**2.83**	**1.05**	**3.83**	**7.70**
Northern Scenario Total (2018–2037)	**12.18**	**4.37**	**16.47**	**33.02**
Northern Scenario Total (2021–2037)	**10.79**	**3.87**	**14.58**	**29.23**
Southern Scenario Total (2018–2037)	**15.01**	**5.41**	**20.29**	**40.72**
Southern Scenario Total (2021–2037)	**13.62**	**4.91**	**18.40**	**36.94**

Notes:
Energy emissions include pre-combustion and combustion emissions.
Sources: Bureau of Land Management 2013, Ecoinvent Centre 2007, Montana DEQ 2001, Spath et al. 1999, U.S. Environmental Protection Agency 2014a, 2013
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Surface mine construction and operation disturbs carbon in soil and nonsoil vegetation, with some of this carbon restored during the mine reclamation process by replacing soil and replanting vegetation. For the region in Montana where mining induced by the proposed rail line is expected to occur, soil carbon stocks are estimated to be 38.3 metric tons of carbon per hectare[16] and total nonsoil carbon stocks are estimated to range from 20.6 to 56.4 metric tons of carbon per hectare (National Council for Air and Stream Improvement & U.S. Department of Agriculture 2014). Therefore, the total potential carbon disturbance by mining at the

[16] A hectare is a metric unit of square measure, equal to 2.47 acres.

proposed and potentially induced mines could range from 58.9 to 94.7 metric tons of carbon per hectare, depending on the vegetation in place.

A recent study found that surface mine reclamation in British Columbia, Canada led to average carbon storage of 67.7 metric tons of carbon per hectare (Trlica & Brown 2013). Using this estimate, the net carbon disturbance from reclaimed surface mines could range from a slight increase in carbon sequestration to a loss of 27 metric tons per hectare. The net carbon disturbance for the proposed and potentially induced mines would vary by the production scenario and build alternative. The largest impacts would occur under the southern alternatives, high production scenario, with net carbon disturbance for the proposed and potentially induced mines ranging from a slight increase in carbon sequestration, post-reclamation (0.5 MMTCO$_2$e) to up to approximately 1.5 MMTCO$_2$e in carbon loss.[17] For reference, this would be equivalent to approximately 3.6 percent of mine GHG emissions over the 20-year analysis period at the proposed and potentially induced mines. OEA, therefore, determined that net land disturbance emissions estimates are highly variable depending on the existing and final land cover, and overall represent a relatively small contribution to life-cycle GHG emissions.

Existing Coal Mines

The existing Spring Creek and Decker Mines are operating near the Colstrip Alternatives and Decker Alternatives, and the existing Rosebud Mine is operating near the Colstrip Alternatives. As these mines have already been constructed and are currently in operation, the GHG impacts from construction of the Spring Creek, Decker, and Rosebud Mines are outside the scope of the life-cycle GHG emissions from the proposed rail line. The proposed rail line would not be used to transport coal from these mines because each mine has access to an existing rail spur that connects to the BNSF main line and on to the power plants. There would be no transportation advantage or savings for these mines to use the proposed rail line. However, because these mines are operating near several of the proposed rail line alternatives, GHG emissions from these mine operation are included in this appendix to provide context for other similar sources of GHG emissions in the area of the proposed rail line.

Methods and Data Sources

OEA estimated GHG emissions from surface mine operation using the emission factors and data sources used for proposed and potentially induced mines.

[17] Given the total coal deposit surface areas associated with the proposed and potentially induced mines (3,091 hectares for Otter Creek, 7,265 hectares for Poker Jim Creek–O'Dell Creek, and 4,723 hectares for Canyon Creek), the net carbon disturbance from reclaimed surface mines could range from a decrease of 0.10 to an addition of 0.31 MMTCO$_2$e for Otter Creek, a decrease of 0.24 to an increase of 0.72 MMTCO$_2$e for Poker Jim Creek–O'Dell Creek, and a decrease of 0.15 to an increase of 0.47 MMTCO$_2$e for Canyon Creek.

Results

This section presents the GHG emissions results for operation of the existing coal mines. The results in this section are used in Section F.5, *Comparison with Life-Cycle Greenhouse Gas Emissions from Competing Coal* to compare the carbon intensity of Tongue River coal with other competing coals and in Section F.6, *Summary of Net Life-Cycle GHG Emissions,* to calculate net life-cycle GHG emissions from construction and operation of the proposed rail line.

In 2012, the combined production from the Spring Creek and Decker Mines was 20.2 million tons of coal, and production from the Rosebud Mine was 13 million tons of coal. Assuming constant production at these rates, Table F-21 summarizes the GHG emissions for operation of the existing mines.

Table F-21. Total GHG Emissions for Operation of Existing Mines (2018–2037)

Existing Mine / Emission Source	Annual GHG Emissions ($MMTCO_2e$/year)	Total GHG Emissions from 2018 to 2037 ($MMTCO_2e$)
Spring Creek and Decker Mines		
Operation Energy	0.28	5.53
Direct Methane from Mine Face	0.37	7.47
Mine Total	**0.65**	**13.00**
Rosebud Mine		
Operation Energy	0.18	3.56
Direct Methane from Mine Face	0.24	4.81
Mine Total	**0.42**	**8.37**
Existing Mine Total	**1.07**	**21.37**

Notes:
Energy emissions include pre-combustion and combustion emissions
Sources: Estimated using data from Bureau of Land Management 2013, Montana DEQ 2001, Spath et al. 1999, U.S. Environmental Protection Agency 2014a, 2013
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

F.4.2.3 Fuel Combustion

Whether at domestic or overseas power plants, most coal is combusted to generate power.[18] Combustion results in GHG emissions to the atmosphere.

As described above, the proposed rail line would serve the proposed Otter Creek Mine and could serve the potentially induced Poker Jim Creek–O'Dell Creek and Canyon Creek Mines. Combustion of coal produced from these mines would contribute to the accumulated GHG emissions associated with the proposed rail line. In addition, coal production and its introduction to the global coal market can increase or decrease consumption of other coals, including other U.S. coals and international coals, represented predominately by coals

[18] A very small share of coal is expected to be used for purposes other than energy combustion, such as gasification. OEA considered the GHG emissions from this portion of the coal life-cycle to be negligible.

produced in the Pacific Basin. Proposed and potentially induced coal production could also increase or decrease production and consumption of natural gas in the United States.

Methods and Data Sources

OEA analyzed the impact on consumption for each of these coal types and for natural gas, as described in Appendix C, *Coal Production and Markets.* The market analysis conservatively modeled coal production for each of the proposed and potentially induced mines without a ramp-up period following construction; this results in a higher level of estimated coal production than the more likely case that production gradually increases after mine operation commence.[19] Additionally, the market analysis found that changes in international coal production would only occur in the Pacific Basin due to changes in coal types exported out of the Pacific Northwest and Colombia. All other coal production remained the same between the proposed and no-action scenarios. Finally, the market analysis found that the majority of change in natural gas combustion would occur in the United States, with a negligible change in natural gas combustion outside of the United States. Therefore, emissions from the change in natural gas combustion are only estimated for natural gas produced and consumed in the United States.

For each scenario, OEA estimated the change in GHG emissions from coal combustion from 2018 to 2037 based on the change in the metric tons of several coal types (bituminous, lignite, subbituminous, and waste coal) produced in four regions: Tongue River coal, other Powder River Basin coal, other U.S. coal, and international coal. OEA calculated the change in GHG emissions by multiplying the change in coal production by coal rank-specific carbon content values and coal basin-specific heat-content factors. Details on these assumptions are provided in Appendix C, *Coal Production and Markets.*

Similarly, for each scenario, OEA estimated the change in GHG emissions from natural gas combustion from 2018 to 2037 based on the change in the volume of natural gas produced and consumed in the United States. OEA calculated the change in GHG emissions from natural gas combustion by multiplying the change in natural gas production by default natural gas carbon content values and heat contents. Details on these assumptions are provided in Appendix C, *Coal Production and Markets*. Finally, OEA estimated the change in natural gas precombustion GHG emissions (i.e., emissions produced from extracting, processing, and transporting natural gas) based on emission factors in a report by Franklin Associates (2010).

OEA determined that several sources of GHG emissions from the fuel combustion stage would be negligible for the proposed rail line, including power plant construction and decommissioning. Therefore, these sources were not included in this analysis. While few life-cycle assessments (LCAs) reviewed by OEA provided disaggregated estimates of the GHG emissions associated with power plant construction and decommissioning, those that

[19] As was assumed in OEA's estimates of GHG emissions from coal mines. As a result, the GHG emissions estimates from coal combustion are based on a slightly higher level of production than the GHG emission estimates at the coal mining stage.

did estimate the impacts from coal power plant construction and decommissioning estimated those sources of GHG emissions to cumulatively make-up between 0.08 and 0.64 percent of total life-cycle GHG emissions (Lenzen et al. 2006, White 1998).

Results

This section presents the GHG emissions results for combustion of the coal that would be transported by the proposed rail line and changes in the combustion of other competing coals and U.S. natural gas combustion. The results in this section are used in Section F.6, *Summary of Net Life-Cycle GHG Emissions,* to calculate net life-cycle GHG emissions.

To illustrate the range in coal combustion GHG emissions and natural gas precombustion and combustion GHG emissions impacts from 2018 to 2037, Table F-22 presents the change in global coal combustion GHG emissions.

Table F-23 presents the change in U.S. natural gas precombustion and natural gas combustion GHG emissions under six coal production and export scenarios.

- Northern alternatives with low coal production and zero export terminal capacity growth.
- Northern alternatives with medium coal production and medium export terminal capacity growth.
- Northern alternatives with high coal production high export terminal capacity growth.
- Southern alternatives with low coal production and zero export terminal capacity growth.
- Southern alternatives with medium coal production and medium export terminal capacity growth.
- Southern alternatives with high coal production and high export terminal capacity growth.

Table F-22. Change in GHG Emissions from Coal Combustion by Scenario (2018–2037)

Scenario/Emission Source	Average Annual Change in Coal Combusted (Million metric tons/year)	Average Annual Change in GHG Emissions ($MMTCO_2e$/yr)	Total Change in GHG Emissions from 2018-2037 ($MMTCO_2e$)
Low Coal Production, Zero Export Terminal Capacity Growth (Northern Alternatives)[a]			
Tongue River Coal	18.14	33.19	663.78
Other Powder River Basin Coal	-12.47	-23.20	-463.97
Other U.S. Coal	-5.77	-9.61	-192.22
Pacific Basin and Other International Coal	0.00	0.00	-0.09
Scenario Total	**-0.10**	**0.38**	**7.50**
Medium Coal Production, Medium Export Terminal Capacity Growth (Northern Alternatives)[b]			
Tongue River Coal	26.31	48.40	968.04
Other Powder River Basin Coal	-22.42	-41.21	-824.19
Other U.S. Coal	-2.26	-4.73	-94.69
Pacific Basin and Other International Coal	0.03	0.06	1.21
Scenario Total	**1.66**	**2.52**	**50.37**
High Coal Production, High Export Terminal Capacity Growth (Northern Alternatives)[b]			
Tongue River Coal	41.73	76.71	1,534.11
Other Powder River Basin Coal	-29.23	-52.90	-1,058.05
Other U.S. Coal	-8.96	-17.64	-352.89
Pacific Basin and Other International Coal	0.17	0.33	6.65
Scenario Total	**3.71**	**6.49**	**129.81**
Low Coal Production, Zero Export Terminal Capacity Growth (Southern Alternatives)[a]			
Tongue River Coal	12.82	23.44	468.88
Other Powder River Basin Coal	-9.12	-16.97	-339.37
Other U.S. Coal	-3.88	-6.01	-120.11
Pacific Basin and Other International Coal	0.00	0.00	-0.07
Scenario Total	**-0.19**	**0.47**	**9.32**
Medium Coal Production, Medium Export Terminal Capacity Growth (Southern Alternatives)[b]			
Tongue River Coal	25.67	47.21	944.20
Other Powder River Basin Coal	-21.98	-40.36	-807.19
Other U.S. Coal	-2.44	-5.19	-103.90
Pacific Basin and Other International Coal	0.00	0.00	-0.03
Scenario Total	**1.25**	**1.65**	**33.08**
High Coal Production, High Export Terminal Capacity Growth Scenario (Southern Alternatives)[c]			
Tongue River Coal	51.71	96.02	1,920.42
Other Powder River Basin Coal	-38.10	-68.93	-1,378.60
Other U.S. Coal	-10.71	-20.46	-409.13
Pacific Basin and Other International Coal	-0.15	-0.28	-5.68
Scenario Total	**2.76**	**6.35**	**127.01**

Notes:

[a] Includes proposed coal production from the Otter Creek Mine (Tract 2)

[b] Includes potentially induced coal production from the Otter Creek Mine (Tract 2) and Poker Jim Creek–O’Dell Creek deposit

[c] Includes potentially induced coal production from the Otter Creek Mine (Tract 2) and Poker Jim Creek–O’Dell Creek, and Canyon Creek deposits

$MTCO_2e$ = metric tons of carbon dioxide equivalent; $MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Table F-23. Change in GHG Emissions from Natural Gas Pre-Combustion and Combustion resulting from the Proposed Rail Line (2018–2037)

Scenario / Emission Source	Average Annual Change in Natural Gas Combusted (TBtu/year)	Average Annual Change in GHG Emissions ($MMTCO_2e$/yr)	Total Change in GHG Emissions from 2018-2037 ($MMTCO_2e$)
Low Coal Production, Zero Export Terminal Capacity Growth (Northern Alternatives)[a]			
U.S. Natural Gas Combustion	0.24	0.01	0.26
U.S. Natural Gas Pre-Combustion	NA	0.00	0.07
Scenario Total	**0.24**	**0.02**	**0.33**
Medium Coal Production, Medium Export Terminal Capacity Growth (Northern Alternatives)[b]			
U.S. Natural Gas Combustion	-7.14	-0.38	-7.59
U.S. Natural Gas Pre-Combustion	NA	-0.11	-2.13
Scenario Total	**-7.14**	**-0.49**	**-9.72**
High Coal Production, High Export Terminal Capacity Growth (Northern Alternatives)[b]			
U.S. Natural Gas Combustion	-26.58	-1.41	-28.23
U.S. Natural Gas Pre-Combustion	NA	-0.40	-7.93
Scenario Total	**-26.58**	**-1.81**	**-36.16**
Low Coal Production, Zero Export Terminal Capacity Growth (Southern Alternatives)[a]			
U.S. Natural Gas Combustion	0.13	0.01	0.14
U.S. Natural Gas Pre-Combustion	NA	0.00	0.04
Scenario Total	**0.13**	**0.01**	**0.18**
Medium Coal Production, Medium Export Terminal Capacity Growth (Southern Alternatives)[b]			
U.S. Natural Gas Combustion	-5.95	-0.32	-6.31
U.S. Natural Gas Pre-Combustion	NA	-0.09	-1.77
Scenario Total	**-5.95**	**-0.40**	**-8.09**
High Coal Production, High Export Terminal Capacity Growth (Southern Alternatives)[c]			
U.S. Natural Gas Combustion	-26.75	-1.42	-28.41
U.S. Natural Gas Pre-Combustion	NA	-0.40	-7.98
Scenario Total	**-26.72**	**-1.82**	**-36.39**

Notes:

[a] Includes proposed coal production from the Otter Creek (Tract 2) Mine

[b] Includes potentially induced coal production from the Otter Creek (Tract 2) and Poker Jim Creek–O'Dell Creek deposits

[c] Includes potentially induced coal production from the Otter Creek (Tract 2), Poker Jim Creek–O'Dell Creek, and Canyon Creek deposits

Sources: Estimated using data from Appendix C, *Coal Production and Markets* in conjunction with Franklin Associates 2010

$MTCO_2e$ = metric tons of carbon dioxide equivalent; $MMTCO_2e$ = million metric tons of carbon dioxide equivalent; TBtu = trillion British thermal units

F.5 Comparison with Life-Cycle Greenhouse Gas Emissions from Competing Coal

OEA compared life-cycle GHG emissions of Tongue River coal transported by the proposed rail line to a set of competing coals that the additional Tongue River coal is likely to displace in domestic and international markets. This section introduces the other coals and compares life-cycle GHG emission estimates from LCA literature to Tongue River coal transported by the proposed rail line. To compare different coals on a common basis, the GHG emission results are presented per unit of electricity produced from each coal.

The market analysis (Appendix C, *Coal Production and Markets*) indicated that most of the Tongue River coal would be distributed to the Upper Midwest, where it would displace coal from other U.S. mines. Appendix C, Chapter 2 notes that, historically, Powder River Basin coal has displaced eastern bituminous coal in the domestic market. If the proposed rail line is constructed, the Tongue River coal would largely displace other Powder River Basin coal. Under scenarios involving expansion of Pacific Northwest export terminal capacity (i.e., medium and high terminal capacity growth scenarios), Powder River Basin coal may also be exported to international markets; internationally, the Tongue River coal is likely to displace Australian, Indonesian, and/or Chinese coals in key Asian markets including Japan, China, and South Korea.

To determine life-cycle GHG emissions of competing coals, OEA gathered life-cycle GHG intensities for key varieties of coal from literature sources. Hundreds of LCA studies on coal have been performed around the world. In 2012, the U.S. Department of Energy's National Renewable Energy Laboratory completed its review and harmonization of coal LCA studies, the results of which are presented in the Journal of Industrial Ecology (Whitaker et al. 2012). That literature review screened 270 references, and harmonized the results from 53 studies to come up with a range of life-cycle GHG emissions varying by coal combustion technology type. Because of the extensiveness and relatively recent publication of that review, OEA relied heavily on the Whitaker et al. study for the analysis of life-cycle GHG intensities for other coals.

The Whitaker et al. 2012 study sought to standardize common parameters and boundaries from the different LCA studies for a consistent comparison of results across different studies.[20] The authors screened the life-cycle literature and eliminated studies that did not meet the standards they established for quality methods, a sufficient level of transparency, and completeness in reporting.

Among the 53 studies included in Whitaker et al. 2012, OEA narrowed down the set to studies of competing coals likely to be displaced in the United States and abroad. For the Pacific Basin studies, OEA narrowed down the set of studies and individual life-cycle GHG estimates to focus on those that explicitly referenced coals combusted in Japan, China, and South Korea, and coals that were likely imported from Australia. These coals were selected to align with the coals projected to be displaced by Tongue River coal exports in the market analysis.[21] For example, OEA included black coal estimates from Australian studies and

[20] Where feasible, Whitaker et al. (2012) took the following steps to standardize the studies: (i) they applied consistent GWP factors, (ii) they harmonized the scope of emission sources included (e.g., the authors added coal mine methane emission estimates to studies that were missing this source of GHG emissions), and (iii) they applied consistent factors for the efficiency of electricity generation plants and for carbon dioxide emissions from coal combustion.

[21] Data points on Indonesian coal were not included due to the lack of LCA studies specifically referencing Indonesian coal among the studies reviewed.

excluded estimates for brown coal, which is typically combusted at power stations near Australian coal mines rather than exported (Lenzen et al. 2006).[22] Among the U.S. studies, OEA eliminated those with results limited to coal combustion facilities in areas (e.g., the southwest and southeast regions and New York) that are unlikely market destinations for Tongue River coal. OEA also narrowed down the set of estimates to focus on a single coal-fired electricity generation technology of subcritical pulverized coal combustion to control for different technologies across the studies and excluded those results that were based on more advanced or emerging combustion technologies.[23] This eliminated variability in the technology considered to allow for a consistent comparison of life-cycle GHG emission estimates across different coal types.[24]

Table F-24 presents the full life-cycle results for the Pacific Basin and U.S. studies from the literature considered in this analysis. The results listed include those that were published by individual studies as well as the results of the Whitaker et al. system harmonization (taking into account the standardization of global warming potential, coal mine methane inclusion, and transmission and distribution loss exclusion). The additional technical harmonization steps (i.e., adjustments to thermal efficiency and coal combustion emission factor) from the Whitaker et al. 2012 study are not included in the results presented below in order to retain the variability in thermal efficiency and combustion factors among the underlying studies and coal types.

As shown in the table, the life-cycle GHGs among the Pacific Basin studies range from 975 to 1,689 grams of CO_2e per kilowatt-hour (gCO_2e/kWh) after the system boundary harmonization. The life-cycle GHGs among the U.S. studies range from 714 to 1,201 gCO_2e/kWh after the system boundary harmonization.

[22] Black coal is the second-largest commodity exported from Australia (Australian Coal Association 2014). May and Brennan 2003 indicated which estimates referred to black coal exported and not exported; OEA was thus able to exclude non-exported black coal.

[23] Results for integrated gasification combined cycle, fluidized bed, and supercritical pulverized coal combustion were excluded.

[24] Note that the Tongue River coal combustion results do take into account additional technology types as those GHG estimates are generated in a model, described in the Appendix C market analysis, that sums U.S. CO_2 emissions across power plant

Table F-24. Life-Cycle GHG Results for Competing Coals from Literature

Study	Location	Coal Type if Specified	Life-Cycle GHG Result (gCO2e/kWh) for Narrowed Set of Coal Types and Combustion Technology: As Published	Life-Cycle GHG Result (gCO2e/kWh) for Narrowed Set of Coal Types and Combustion Technology: After System Boundary Harmonization by Whitaker et al. 2012
May and Brennan 2003	Australia	Australian export black coal	1,100	1,078
Hondo 2005	Japan	Coal burned in Japan	975	975
Uchiyama 1996	Japan		990	990
Lee et al. 2004	Korea	Imported bituminous	1,001	1,023
Lee et al. 2004	Korea	Domestic anthracite	1,155	1,171
Dones et al. 2004	China		1,048–1,689	1,048–1,689
Range for Pacific Basin Studies			**975–1,689**	**975–1,689**
Dyncorp 1995	USA	Western mined coal in WA/OR market and TX market	1,201	1,201
Martin 1997	USA	U.S.-wide	1,177	1,177
Meier et al. 2005	USA	U.S.-wide	1,006–1,044	1,006–1,044
Meridian 1989	USA	Eastern bituminous	1,058	1,121
National Energy Technology Laboratory. 2010	USA	Midwestern bituminous	1,109	948
Pacca 2003	USA	Unspecified	714	714
San Martin 1989	USA	"Conventional Coal Plant"	964	1,027
Spath et al.1999	USA	Illinois No. 6. (Bituminous Coal)	760–1,045	760–1,045
Spath et al. 2004	USA	Unspecified	847	847
White 1998	USA	Average U.S. plant	874	1,037
Range for U.S. Studies			**714–1,201**	**714–1,201**

Notes:
gCO_2e/kWh = grams of carbon dioxide equivalent per kilowatt hour

F.5.1 Comparison of Results

To compare the literature results to the life-cycle GHG emission results estimated for Tongue River coal, OEA narrowed down the set of studies presented above and made additional adjustments to better harmonize with the Tongue River boundaries where feasible. The following adjustments were made.

- Eliminated studies that did not provide disaggregated results by life stage including mining, transportation, and combustion (Uchiyama 1996, Dones et al. 2004, Meier et al. 2005, Meridian 1989, Pacca 2003).

- Eliminated studies that did not report mine methane emission results (Lee 2004, San Martin 1989, White 1998).
- Added operation-related material embedded and energy-related emissions where missing based on detailed Spath et al. 1999 data.
- Separately estimated mine emissions for National Energy Technology Laboratory 2010 and presented the results alongside those reported. The results for National Energy Technology Laboratory (2010) relied on estimates from a single underground mine, the Galatia Mine in Illinois. To examine methane emissions results for a broader set of Illinois mines, OEA separately estimated underground and aboveground methane emissions from Illinois mines using the same approach used to estimate Tongue River potentially induced coal mine emissions.

F.5.1.1 Mine Emissions

OEA compared the coal mine emissions for Tongue River coal (based on the medium production scenario, northern and southern alternatives) to emissions for competing coal that could be displaced by Tongue River coal. These results were used in the calculation of net life-cycle GHG emissions (Section F.6, *Summary of Net Life-Cycle Greenhouse Gas Emissions*). The results are presented in Table F-25.

Table F-25. Mine GHG Emissions for Tongue River Coal Compared to Competing Coal

Coal Source	Median Estimate ($MTCO_2e$/metric ton of coal)
Tongue River coal	0.041
Competing coal	
Other Powder River Basin coal	0.041
Other U.S. coal	0.129
International coal	0.142

Notes:
Sources: Emissions for other U.S. coal and international coal were estimated using data from National Energy Technology Laboratory 2010, Spath et al. 1999, Dyncorp 1995, Martin 1997, May and Brennan 2003, Hondo 2005
$MTCO_2e$ = metric tons of carbon dioxide equivalent

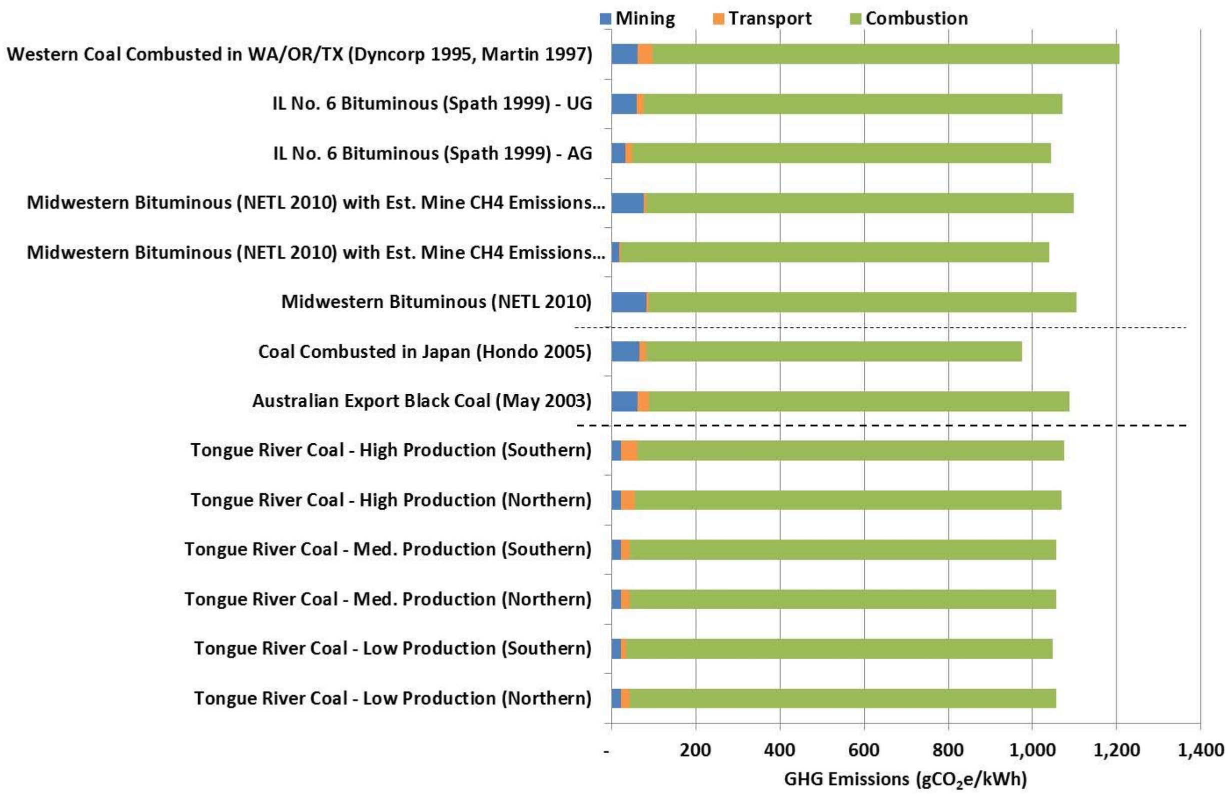
F.5.1.2 Life-Cycle Emissions

Figure F-1 provides the full life-cycle GHG emissions for Tongue River coal and competing coals per kilowatt hour of electricity produced (including mining, transportation, and end-use combustion emission sources). Tongue River coal emissions are provided in the figure for the low, medium, and high coal production scenarios for the northern and southern alternatives.

Life-cycle emissions range from a low of about 975 gCO_2e/kWh to a high of about 1,087 gCO_2e/kWh, with the value for Tongue River coal (under the medium production scenarios) at 1,048 to 1,076 gCO_2e/kWh depending on whether the northern or southern alternative is constructed. Combustion emissions dominate the life cycle, accounting for 92 to 97 percent of total life-cycle emissions across the studies included. The share of emissions from mining (i.e., mine construction, embedded material emissions, coal extraction, and mine methane emissions) varied from 2 to 8 percent among the study results included, with fugitive mine methane emissions being the largest contributor. In general, mine emissions are higher for underground mines compared to surface mines like that of the proposed Otter Creek Mine and potentially induced coal deposits.

Because the results in Figure F-1 draw from several independent LCA studies, the variation in emissions across the coal types is also influenced by differences in the life-cycle boundaries, study design, and modeling assumptions across the studies. Even so, the results demonstrate that life-cycle GHG emissions from Tongue River coal are within the range of emissions for other coals, and that for all coal types, life-cycle emissions are dominated by the coal combustion stage.

Figure F-1. Life-Cycle GHG Comparison of Tongue River Coal and Other Competing Coals/Markets



Notes:
The boundaries of the studies were harmonized where feasible. Tongue River coal scenarios include emissions from construction of the potentially induced mines allocated across mine production from 2018 to 2037; mine construction emissions contribute 0.1% of total GHG emissions. The National Energy Technology Laboratory (2010) also includes mine construction emissions. None of the other studies included mine construction emissions.
The mining results for National Energy Technology Laboratory (2010) relied on estimates from a single underground (UG) mine, the Galatia Mine in Illinois. To examine methane emissions results for a broader set of Illinois mines, OEA separately estimated UG and aboveground (AG) methane emissions from Illinois mines using the same approach used to estimate Tongue River potentially induced coal mine emissions. The results using the separate estimates of mine emissions are shown in the figure above with the labeling "Est. Mine CH4 Emissions."
Literature results reflect a single coal-fired electricity generation technology, viz., subcritical pulverized coal combustion.
Variation in combustion results between the southern and northern alternative scenarios for the Tongue River coal high production scenario is a function of the different heat contents of the coal extracted from the different potentially induced mines. The southern alternative scenarios include coal from the potentially induced Canyon Creek deposit; the northern alternative scenarios do not include Canyon Creek deposit coal. The average heat content of Tongue River coal is 17.2 MMBTU/short ton for the Otter Creek Mine, 17.5 MMBTU/short ton for the Poker Jim Creek–O'Dell Creek deposit and 18.2 MMBtu/short ton for the Canyon Creek deposit.
UG = underground mining; AG = aboveground mining; CH_4 = methane

Absent from the figure above is a Chinese coal due to lack of completeness and disaggregation in the LCA datasets. Dones et al. (2004) reports aggregated life-cycle results for coal combusted in China that range from 1,048 to 1,648 gCO2/kWh. On average, Chinese coal mines emit 33 percent more methane than the average U.S. mine due to the majority of Chinese mines being underground (U.S. Environmental Protection Agency 2012, U.S. Energy Information Administration 2014). The Chinese coal mine methane emissions profile is within the range of that for other Asian coals. Uncontrolled coal bed fires are another potentially significant source of upstream emissions from coal in China. Estimates indicate that 10 million to 200 million metric tons of coal per year are burned in these fires in China and resulting in CO_2 emissions that would range from 7 to 134 g CO_2e/kWh (Dones et al. 2007). Chinese coal production might change based on the changes in the heat content of coal exported from the United States.

F.6 Summary of Net Life-Cycle Greenhouse Gas Emissions

This section brings together the results of the analyses above to present the estimated net life-cycle GHGs that would result from construction and operation of the proposed rail line—including net GHG emissions from changes in mining, downline transportation and international shipping, and end-use combustion. The net results rely on the following two factors.

- The increased production, transportation, and combustion of Tongue River coal.[25]
- The effect of Tongue River coal on the production, transportation, and combustion of other coal consumed in the United States and international markets (as estimated by the market analysis and presented in Appendix C, *Coal Production and Markets*), namely:
    - The change in coal mine GHG emissions from the change in production of competing coals.
    - The change in rail traffic and international shipping from displacing the transportation of other coals to U.S. power plants or for international export.[26]
    - The change in coal combustion from displacing the use of other coals in power plants with Tongue River coal.

To calculate the net accumulated GHG emissions from construction and operation of the proposed rail line from 2018 to 2037, OEA added the GHG emissions estimates at each stage of the life-cycle for Tongue River coal discussed in the previous sections, the GHG emissions estimates from the change in competing coal mining, and the GHG emissions estimates from net rail traffic and net coal combustion from the market analysis in Appendix C, *Coal Production and Markets*.

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[25] GHG emissions from terrestrial soil carbon disturbance are not included in the net GHG emission estimates in order to consistently compare the life cycle GHG emissions sources from TRR coal to competing coals. The source of reference coal life cycle estimates (Whitaker et al. 2012) did not include land use change emissions because this source is not consistently captured across baseline coal studies in the LCA literature. Further, OEA found that GHG emissions from land use change at proposed and potentially induced mine sites are highly variable depending on the existing and final land cover when reclamation occurs, and net carbon stock changes from both rail line and mining disturbances amount to a small proportion of total life cycle emissions. Consequently, the results have been reported separately in the relevant sections above.

[26] GHG emissions from operation of coal export terminals are not included in the net GHG emission estimates because the market analysis found that coal terminals would operate at full capacity across all scenarios and the No-Action Alternative. Export terminal emissions will therefore be the same whether the proposed rail line is built or not. Furthermore, OEA estimated that export terminal GHG emissions from handling Tongue River coal would be between 0.1 and 0.2 $MMTCO_2e$, which is less than 0.1% of life cycle GHG emissions from Tongue River coal.

The results for Tongue River coal and the change in competing coal GHGs are provided in Table F-26. This table provides the additional GHG emissions from increased mining, transportation, and combustion of Tongue River coal in the first three columns. Next, it shows the incremental change (positive or negative) in mining, transport, and combustion of other competing coals. Table F-27 provides the change in natural gas emissions. Table F-28 sums the totals of Tables F-26 and F-27 to present the final net results by scenario.

Table F-26. Coal Accumulated and Net Life-Cycle GHG Emission Results (2018–2037)

	Tongue River Coal Emissions ($MMTCO_2e$)			Change in Competing Coal GHG Emissions ($MMTCO_2e$)			Net GHG Emissions ($MMTCO_2e$)		
	Low	**Med.**	**High**	**Low**	**Med.**	**High**	**Low**	**Med.**	**High**
Northern Alternatives									
Mining	15	21	34	-25	-24	-47	-11	-3	-13
Transport	13	19	48	-12	-18	-47	1.1	0.8	0.8
Combustion	664	968	1,534	-656	-918	-1,404	8	50	130
Total	**691**	**1,008**	**1,615**	**-693**	**-960**	**-1,498**	**-2.0**	**48**	**117**
Southern Alternatives									
Mining	15	21	42	-18	-25	-60	-2.9	-3	-18
Transport	7	18	72	-5	-15	-69	2	3	3
Combustion	469	944	1,920	-460	-911	-1,793	9	33	127
Total	**491**	**983**	**2,034**	**-483**	**-951**	**-1,923**	**8**	**33**	**112**

Notes:
Low, medium, and high refer to coal production levels and coal export capacity
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Table F-27. Natural Gas Accumulated Change in Life-Cycle GHG Emissions (2018–2037)

	Change in GHG Emissions ($MMTCO_2e$)		
Alternative	**Low**	**Medium**	**High**
Northern Alternatives			
Precombustion	0.07	-2.13	-7.93
Combustion	0.26	-7.59	-28.23
Total	**0.33**	**-9.72**	**-36.16**
Southern Alternatives			
Precombustion	0.04	-1.77	-7.98
Combustion	0.14	-6.31	-28.41
Total	**0.18**	**-8.09**	**-36.39**

Notes:
Low, medium, and high refer to production levels and coal export capacity
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Table F-28. Accumulated and Net Life-Cycle GHG Emission Results (2018–2037)

Alternative	Tongue River Coal Emissions ($MMTCO_2e$)			Change in Competing Coal and Nat Gas GHG Emissions ($MMTCO_2e$)			Net GHG Emissions ($MMTCO_2e$)		
	Low	Med.	High	Low	Med.	High	Low	Med.	High
Northern Alternatives									
Total	691	1,008	1,616	-693	-970	-1,534	-1.7	38	81
Southern Alternatives									
Total	491	983	2,034	-482	-959	-1,959	9	25	75

Notes:
Low, medium, and high refer to coal production levels and coal export capacity
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

To help interpret the net GHG emission results in Table F-28, Figure F-2 shows the results for the medium coal production and export scenario graphically.[27] GHG emissions from 2018 to 2037 for both the northern and southern alternatives are presented. The figure shows life-cycle GHG emissions from the Tongue River coal transported by the proposed rail line (left-most column) and the extent to which they displace emissions from mining, transportation, and combustion other competing coals and natural gas (stippled bars). The right-most bar shows the remaining "net" change in GHG emissions from the proposed rail line.

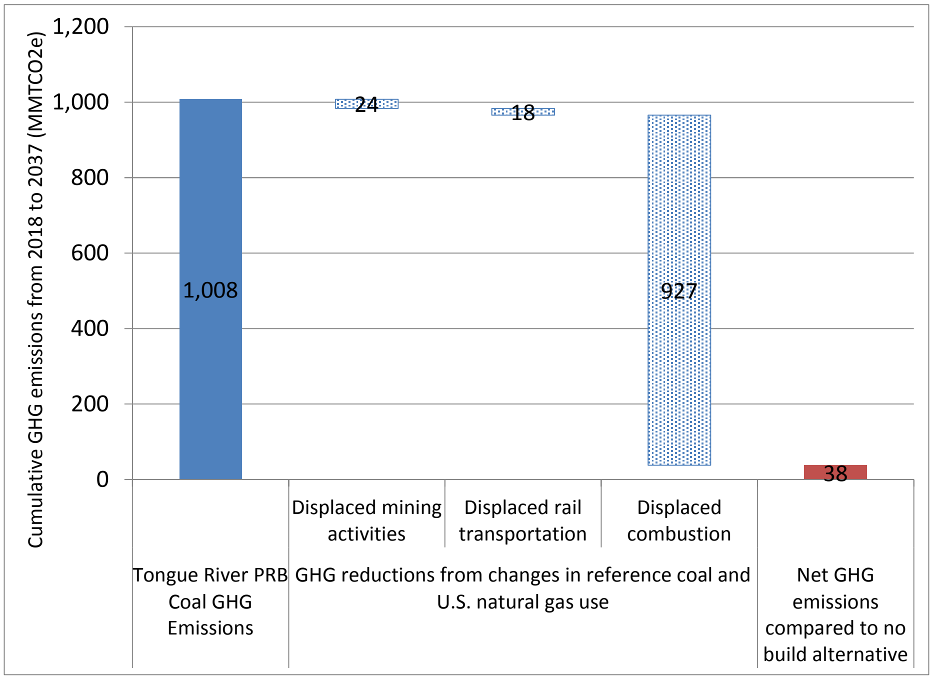
The results show that, while absolute GHG emissions from the additional Tongue River coal are between 491 to 2,034 $MMTCO_2e$ between 2018 to 2037 across the northern and southern alternatives low, medium, and high scenarios, most or all of these emissions are offset by reduced mining, transportation, and combustion of other coals and natural gas that the Tongue River coal displaces. Across low, medium, and high scenarios, accumulated net emissions from the proposed rail line range from -1.7 to 81 $MMTCO_2e$ for the northern alternatives, and from 9 to 75 $MMTCO_2e$ for the southern alternatives. The negative net result in the northern low alternative is caused by several factors. That alternative has the highest ratio of "other U.S. coal" offset per unit of Tongue River coal. Because other U.S. coal has higher mine GHG emissions that Tongue River coal, the mining offset is greatest when other U.S. coal is offset. The effect is high enough that the lower mine emissions offset the increased combustion.

It is evident from the wide ranges across the scenario results that assumptions on alternative routes, coal production levels, and export terminal capacities have a significant influence on the outcomes, not only in terms of the magnitude of net GHGs for the proposed rail line, but even whether—from a life-cycle, market-based perspective—they are positive or negative.

[27] The selection of the medium scenario in Figure F-2 is arbitrary; it was selected as a medium point between the high and low cases in order to show the results of one scenario graphically for easier interpretation.

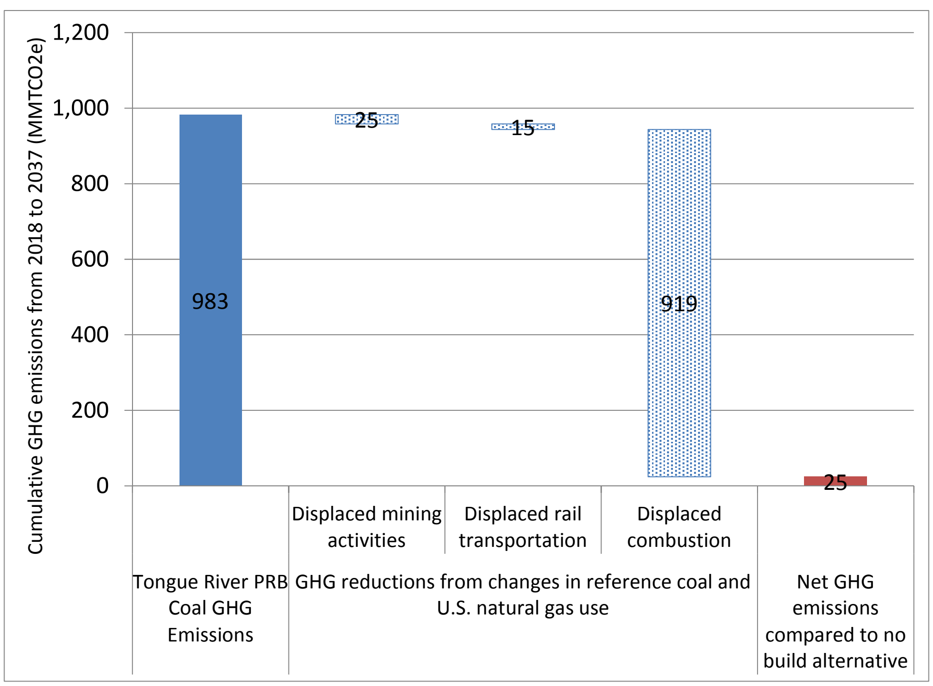
Figure F-2. Accumulated Tongue River Life-Cycle GHG Emissions, GHG Reductions from Competing Coal and Natural Gas Displacement, and Net Accumulated GHGs from the Proposed Rail Line (2018–2037)

(a) Northern Alternatives Medium Scenario



Note: The displaced combustion emissions include displaced coal combustion, natural gas combustion, and natural gas pre-combustion emissions. Net GHG emissions may not match totals due to rounding.

(b) Southern Alternatives Medium Scenario



Note: The displaced combustion emissions include displaced coal combustion, natural gas combustion, and natural gas pre-combustion emissions. Net GHG emissions may not match totals due to rounding.

F.7 Conclusions

F.7.1 Direct Greenhouse Gas Emissions

Direct emissions from construction and operation of the proposed rail line—considering just the GHGs emitted from railroad fossil fuel, combustion-related construction, and operation of the proposed rail line within the project area—would range from 80,000 to 185,000 $MTCO_2e$ per year (or 1.6 to 3.7 $MMTCO_2e$ accumulated between 2018 to 2037), depending on the build alternative and the level of coal production. The results are shown in Table F-29.

Table F-29. Direct GHG Emissions from Construction and Operation of the Proposed Project

Build Alternative	Construction Emissions (Thousand $MTCO_2e$)	Land Use Change (Thousand $MTCO_2e$)	Annual Emissions		Accumulated Emissions (2018-2037)	
			Operation Thousand $MTCO_2e$/yr	Total (Construction + Land Use Change + Operation) thousand $MTCO_2e$/yr	Operation $MMTCO_2e$	Total (Construction + Land Use Change + Operation) $MMTCO_2e$
Northern Alternatives						
Low production	1,193	330 / 532[1]	44	120	0.9	2.4
Medium production			62	144	1.2	2.9
High production			99	185	2.0	3.7
Southern Alternatives						
Low production	1,095	235 / 379[a]	13	80	0.3	1.6
Medium production			32	102	0.6	2.0
High production			70	143	1.4	2.9

Notes:
[a] Denotes low and high range of land use change emissions, depending on carbon stored in above-ground vegetation disturbed during rail line construction. The low end of the result is included in the low production scenario total; the high end of the result is included in the high production total. An average of the two is included in the medium production total.

F.7.2 Net Accumulated Life-Cycle Greenhouse Gas Emissions

Across all production and export scenarios, accumulated net emissions from the proposed rail line would range from a slight reduction of 1.7 $MMTCO_2e$ to an increase of 81 $MMTCO_2e$ for the northern alternatives, and from an increase of 9 to 75 $MMTCO_2e$ for the southern alternatives. The slight reduction for the northern alternatives, low production and export scenario, would be caused by several factors. Those build alternatives would offset more competing U.S. coal per unit of Tongue River coal. Other U.S. coal has higher mine emissions than Tongue River or Powder River Basin coal because it comes from underground mines that are high in methane. Therefore, the mine GHG missions offset would be greater when other U.S. coal is offset. The effect would be high enough that the lower mine emissions would offset the increased combustion.

F.7.3 Emissions in Context

To provide a frame of reference for these emissions estimates, OEA compared both direct and net accumulated life-cycle GHG emissions to equivalent tailpipe emissions from U.S. light-duty vehicles and to GHG emission reduction targets from several federal programs.

Direct GHG emissions from the proposed rail line would range from 80,000 to 185,000 $MTCO_2e$ per year across the scenarios. This is equivalent to adding approximately 16,800 to 39,000 passenger vehicles on the road.

Net accumulated life-cycle GHG emissions would range from a reduction of 1.7 $MMTCO_2e$ to an increase of 81 $MMTCO_2e$. On an annual basis over 20 years, the low end of the net life-cycle GHG emissions estimated by OEA is a slight GHG reduction, equivalent to taking approximately 17,600 vehicles off the road. The high end of the estimate is equivalent to the annual GHG emissions from 855,000 vehicles on the road, or less than 1 percent of the U.S. light-duty vehicle fleet in 2012.[28]

The United States has committed to reduce its GHG emissions by approximately 17 percent by 2020 from emissions in 2005 (U.S. Department of State 2010). This is equivalent to a reduction of 1,230 million metric tons in annual GHG emissions.[29] The high end of the net annual life-cycle GHG emissions estimated by OEA would be equivalent to 0.3 percent of this reduction target. The high end of the direct GHG emissions would be equivalent to just over 0.01 percent of this target.

On June 2, 2014, USEPA announced its Clean Power Plan, which is expected to reduce GHG emissions from the U.S. power sector by 30 percent compared to 2005 levels. This is equivalent to a 734 $MMTCO_2e$ reduction target.[30] The high end of the net annual life-cycle GHG emissions estimated by OEA from the proposed rail line would be equivalent to 0.6 percent of this reduction target. The high end of the direct emissions target would be equivalent to just over 0.02 percent of this target.

[28] Equivalencies based on USEPA's GHG Equivalency Calculator (available at http://www.epa.gov/cleanenergy/energy-resources/calculator.html). Looking at the net change in emissions resulting from the proposed rail line in comparison to the competing coal and natural gas scenarios, the net annual emissions would range from a decrease of 0.08 to an increase of 4.06 $MMTCO_2e$ per year for the northern alternatives and an increase of 0.43 to 3.76 $MMTCO_2e$ for the southern alternatives. In 2012, there were 111 million light-duty vehicle registrations in the United States (Oak Ridge National Library 2014).

[29] U.S. GHG emissions were 7,254 $MMTCO_2e$ in 2005 (U.S. Environmental Protection Agency 2014b).

[30] U.S. electricity generation GHG emissions were 2,446 $MMTCO_2e$ in 2005 (U.S. Environmental Protection Agency 2014b).

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