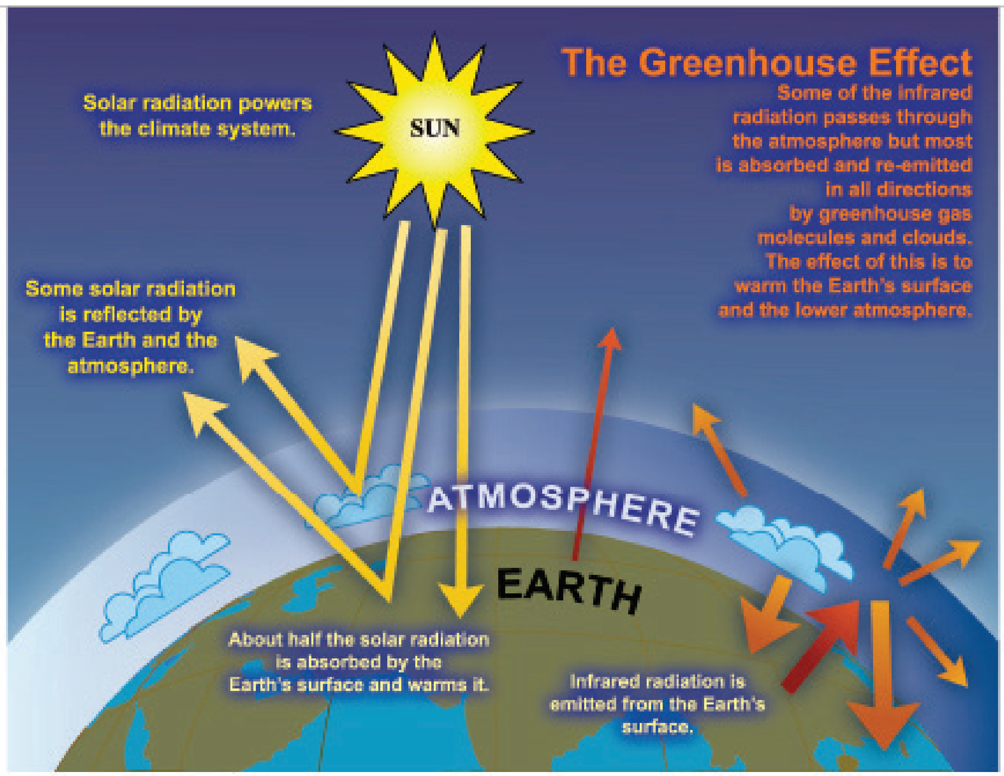
4.14 GREENHOUSE GASES AND CLIMATE CHANGE

4.14.1 Introduction

4.14.1.1 Context

The Earth maintains a temperature level that can sustain life as a result of the natural greenhouse gas (GHG) effect. Energy from the sun, in the forms of heat and light, is either immediately reflected or absorbed by the Earth's surface or, to a lesser extent, its atmosphere. In order for the Earth's heat to remain in a steady state, the incoming solar energy must, on average, remain equal to the outgoing energy radiated into space. However, some of the infrared radiation, or heat radiated outward by the Earth's surface, is absorbed by certain gases in the atmosphere and then radiated back down to the surface – effectively trapping the heat. This phenomenon of the greenhouse effect is illustrated in Figure 4.14.1-1.



Source: Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, 2007

Figure 4.14.1-1 Image of the Greenhouse Effect

Certain gases, including those that occur naturally in the atmosphere such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone, in addition to manufactured industrial pollutants such as hydrofluorocarbons (HFCs), have the ability to trap outbound radiation within the troposphere (i.e., the layer of the atmosphere closest to the surface) and keep it within the Earth's atmosphere. Collectively, these gases are called *greenhouse gases* for their ability to contribute to the greenhouse effect. GHGs are characterized in terms of their global-warming potential (GWP), a relative measure of how effective a given gas is at trapping heat and how long the gas resides within the atmosphere. This metric is commonly normalized in terms of carbon dioxide-equivalents (CO_2e) and then given a time horizon, with 1 unit of CO_2 having a 100-year GWP of 1, whereas an equivalent amount of CH_4 will have a 100-year GWP of 25 (Intergovernmental Panel on Climate Change [IPCC] 2007).

Throughout the Earth's geologic history, GHGs have been released through natural sources, such as CO_2 emitted from aerobic respiration or organic decomposition. These emissions have been generally counter-balanced by natural sinks that absorb CO_2, such as vegetation and forests, due to plant photosynthesis (which absorbs atmospheric CO_2) and absorption of CO_2 by oceans. However, since the beginning of the industrial revolution, levels of GHGs emitted as a result of human activities, commonly referred to as anthropogenic GHG emissions, have added to GHG accumulation and exacerbated the GHG effect, resulting in greater amounts of heat being trapped within the atmosphere. The anthropogenic activities that emit GHGs include the combustion of fossil fuels, industrial processes, land use change, deforestation, agricultural production, solvent use, and waste management.

According to the IPCC in its Summary for Policymakers of the Working Group I contribution to the Fifth Assessment Report (IPCC 2013)[1], warming of the climate system is unequivocal and each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. Furthermore, over the period 1880 to 2012, the globally averaged combined land and ocean surface temperature data show a warming of 0.85 degrees Celsius (1.5 degrees Fahrenheit) (IPCC 2013). This warming has coincided with increased concentrations of GHGs in the atmosphere. The IPCC, in addition to other institutions, such as the National Research Council and the United States (U.S.) Global Change Research Program (USGCRP), have concluded that it is extremely likely[2] that global increases in atmospheric GHG concentrations and global temperatures are caused by human activities.

A warmer planet causes large-scale changes that reverberate throughout the Earth's climate system, including higher sea levels, changes in precipitation, and altered weather patterns (e.g., an increase in more extreme weather events). These climate change shifts can, in turn, affect other processes and spark changes that cascade through natural systems to affect ecosystems, societies, and human health. The time horizon for many of these effects is reasonably foreseeable within the 21st century, though projections are subject to uncertainty. The amount to which these effects are attributable to any single man-made project is very small; however, given their magnitude when combined, these effects warrant discussion.

[1] The IPCC's Fifth Assessment Report will comprise a series of publications that reflect the work of three working groups: Working Group I (WG-I), which is assessing the physical scientific aspects of the climate system and climate change; Working Group II (WG-II), which is assessing the vulnerability of socio-economic and natural systems to climate change and options for adapting to it; and Working Group III (WG-III), which is assessing options for mitigating climate change. At the time of writing this Final Environmental Impact Statement, the IPCC had published its Summary for Policymakers of the WG-I contribution to the Fifth Assessment Report (IPCC 2013). The underlying main report, "Underlying Scientific-Technical Assessment" for WG-I, as well as the outputs from WG-II and WG-III, have not yet been published.

[2] IPCC attributes the likelihood of *extremely likely* to be 95 to 100 percent.

Several federal agencies are currently evaluating the science of climate change including the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. The U.S. Central Intelligence Agency (CIA), the U.S. Department of State (the Department), and the Department of Defense are addressing climate change as an important issue that may impact national security interests (CIA 2009, U.S. Department of State 2013, U.S. Department of Defense 2010).

4.14.1.2 Scope of Assessment

This section presents the relationship between the proposed Project and climate change in the following ways and as illustrated in Figure 4.14.1-2:

- **Emissions**—an assessment of the emissions of GHGs that would be associated with the proposed Project. This includes both direct and indirect emissions attributable to the construction and operation of the pipeline (see Section 4.14.2, Direct and Indirect Greenhouse Gas Emissions), as well as incremental indirect emissions associated with the lifecycle[3] of Western Canadian Sedimentary Basin (WCSB) crude oil that would be transported by the proposed Project (see Section 4.14.3, Incremental Indirect Lifecycle Greenhouse Gas Emissions, which provides a summary of Appendix U, Lifecycle Greenhouse Gas Emissions of Petroleum Products from WCSB Oil Sands Crudes Compared with Reference Crudes, containing the detailed study undertaken);
- **Contributions to Climate Change**—how the proposed Project and lifecycle GHG emissions, along with other sources of GHGs, could cumulatively contribute to climate change (see Section 4.14.4, Cumulative Greenhouse Gas Emissions and Climate Change Impacts); and
- **Proposed Project Area Effects**—an assessment of the effects that future projected climate change (e.g., temperature and precipitation changes) could have in the proposed Project area, including both effects directly on construction and operation of the proposed Project (see Section 14.4.5, Climate Change Impacts on the Proposed Project) and synergistic effects on the wider potential resource impacts of the proposed Project (see Section 14.4.6, Climate Change Impacts on the Affected Environment and Associated Impacts).

The relevant GHG and climate change considerations for alternatives to the proposed Project are presented in Section 2.2, Description of Alternatives.

For the lifecycle GHG emissions assessment, information, data, methods, and analyses used in this discussion are based on information provided in the 2011 Final Environmental Impact Statement (EIS) and the 2013 Draft Supplemental EIS, as well as new information relevant to environmental concerns that has become available since the Final EIS and Draft Supplemental EIS publication. This section also represents a new section compared to the Draft Supplemental EIS, where GHG and climate change text and sections (Sections 3.12, 4.12, 4.14, and 4.15 of the Draft Supplemental EIS) have been consolidated under one section.

[3] *Lifecycle* refers to the different stages of the WCSB oil sands-derived crudes and reference crudes, which *upstream* of the proposed Project includes extraction/mining and upgrading, and *downstream* considers refining and end-product combustion. It also includes consideration of intermediate products and wastes as well as transportation.

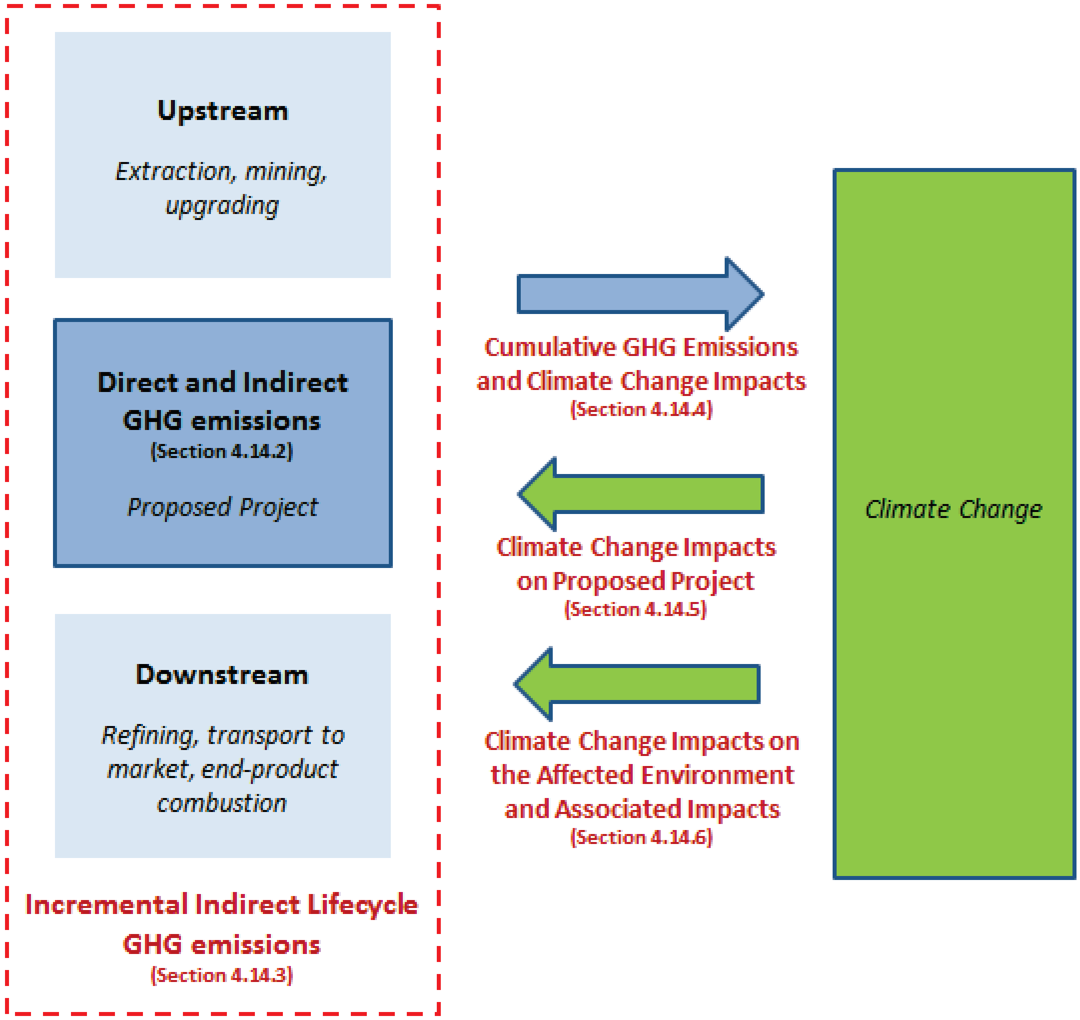


Figure 4.14.1-2 Relationship between Climate Change and the Proposed Project

4.14.1.3 Summary of Key Findings

The key findings for this section regarding GHG emissions are as follows:

- Construction GHG emissions associated with fuel and electricity use in support of construction sites, camps, and other sources such as open burning are estimated to be 0.24 million metric tons of CO_2 equivalents ($MMTCO_2e$).
- Operating emissions associated with electricity consumption (used primarily for pump stations and project infrastructure) and fugitive emissions are estimated to be 1.44 $MMTCO_2e$ per year.
- The total annual lifecycle emissions associated with production, refining, and combustion of 830,000 barrels per day (bpd) of oil sands crude oil transported through the proposed Project, as determined through this assessment, are approximately 147 to 168 $MMTCO_2e$. The

equivalent annual lifecycle GHG emissions from 830,000 bpd of the four reference crudes (representing crude oils currently refined in Gulf Coast area[4] refineries) examined in this section are estimated to be 124 to 159 $MMTCO_2e$. The range of incremental GHG emissions (i.e., the amount by which the emissions would be greater than the reference crudes) for crude oil that would be transported by the proposed Project is estimated to be 1.3 to 27.4 $MMTCO_2e$ annually[5]. This is equivalent to annual GHG emissions from combusting fuels in approximately 270,833 to 5,708,333 passenger vehicles, the CO_2 emissions from combusting fuels used to provide the energy consumed by approximately 64,935 to 1,368,631 homes for 1 year, or the annual CO_2 emissions of 0.4 to 7.8 coal fired power plants.

- The estimated range of potential emissions is large because there are many variables such as which reference crude or which study is used for the comparison.

The above estimates represent the total incremental emissions associated with production and consumption of 830,000 bpd of oil sands crude compared to the reference crudes. These estimates represent the potential increase in emissions attributable to the proposed Project if one assumed that approval or denial of the proposed Project would directly result in a change in production of 830,000 bpd of oil sands crudes in Canada (and the consequential change in production due to displacement of the reference crudes). However, as set forth in Section 1.4, Market Analysis, such a change is not likely to occur. Section 1.4 notes that approval or denial of any one crude oil transport project, including the proposed Project, is unlikely to significantly impact the rate of extraction in the oil sands, or the continued demand for heavy crude oil at refineries in the United States (based on expected oil prices, oil-sands supply costs, transport costs, and supply-demand scenarios).

The 2013 Draft Supplemental EIS estimated how oil sands production would be affected by long-term constraints on pipeline capacity (if such constraints resulted in higher transportation costs and if long-term West Texas Intermediate [WTI]-equivalent oil prices were less than $100). The Draft Supplemental EIS also estimated a change in GHG emissions associated with such changes in production. The additional data and analysis included in this Final Supplemental EIS provide greater insights into supply costs and the range of prices in which pipeline constraints would be most likely to impact production. If WTI-equivalent prices fell to around approximately $65 to 75 per barrel, if there were long-term constraints on any new pipeline capacity and if such constraints resulted in higher transportation costs, then there could be a substantial impact on oil sands production levels. This is discussed further in Section 1.4.5.4, Implications for Production.

[4] Unless otherwise specified, in this Final Supplemental EIS the Gulf Coast area includes coastal refineries from Corpus Christi, Texas, through the New Orleans, Louisiana, region. See Section 1.4, Market Analysis, for a description of refinery regions.
[5] Because the estimates of lifecycle emissions from oil sands (i.e., 147 to 168 $MMTCO_2e$) and the four reference crudes (i.e., 124 to 159 $MMTCO_2e$) both represent ranges across various studies, it is not possible to subtract the high and low bounds from each to arrive at the net emissions result. Instead, the results for oil sands crudes from one study need to be consistently compared against the results for the other reference crudes from the same study to produce the final net emissions result (i.e., 1.3 to 27.4 $MMTCO_2e$).

The key elements for this section regarding climate change are as follows:

- The GHG emission impacts of the proposed Project have been discussed with reference to other GHG emission levels and how these cumulatively contribute to climate change. Direct and indirect emissions associated with the proposed Project, as well as those of alternative actions, contribute to cumulative global GHG emissions together with those of other past, present, and reasonably foreseeable future actions. GHG emissions differ from other impact categories discussed in this Final Supplemental EIS in that all GHG emissions of the same magnitude contribute to global climate change equally regardless of the source or geographic location where they are emitted.
- Information on GHG emissions associated with the production of the oil sands crude oil in Canada are discussed in the context of total Canadian emissions, as reported by Environment Canada.
- An analysis was performed to evaluate the potential impacts of climate change on the proposed Project construction and operations. A number of sources were reviewed and cited as part of this analysis, and used to establish the projected climate changes for the proposed Project lifetime, comprising increased summer temperatures and temperature extremes, as well as increased annual precipitation, including more severe storm events. Climate conditions during the 1- to 2-year construction period would not be expected to differ much from current conditions. Keystone has represented that the proposed Project is designed in accordance with U.S. Department of Transportation (USDOT) regulations and the Pipeline Hazardous Material Safety Administration (PHMSA) Special Conditions (see Appendix B, Potential Releases and Pipeline Safety), and that these design standards are sufficient to accommodate the projected different future conditions resulting from climate change.
- Consideration has also been given to the impacts and effects that have been presented in this Final Supplemental EIS that are attributable to the proposed Project, and whether the projected climate changes could further exacerbate or influence these identified impacts and effects.

4.14.1.4 Greenhouse Gas Regulatory Requirements and Standards

In 2007, the U.S. Supreme Court ruled that GHGs are air pollutants under the Clean Air Act (CAA) and its implementing regulations (42 U.S. Code 7401 et seq., as amended in 1977 and 1990). Since that time, several state and federal regulatory programs have been implemented to address increasing levels of GHG emissions in the United States. The U.S. Environmental Protection Agency (USEPA) has promulgated regulations for GHG reporting and permitting for stationary sources. States across the United States, including those where the proposed Project would be located, have joined regional climate initiatives and adopted standards to mandate an increase in the use of renewable energy sources. These programs are described in the subsections below.

Federal Programs

Endangerment Finding and Cause or Contribute Findings

On April 2, 2007, in Massachusetts versus the USEPA, 549 U.S. 497, the Supreme Court found that GHG emissions are air pollutants within the meaning of the CAA. The Court held that the USEPA Administrator must determine whether or not emissions of GHGs from new motor vehicles cause or contribute to air pollution, which may reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision. In making these decisions, the Administrator is required to follow the language of Section 202(a) of the CAA. The Supreme Court decision resulted from a petition for rulemaking under Section 202(a) filed by more than a dozen environmental, renewable energy, and other organizations. As a result of this decision, on April 24, 2009, the USEPA proposed the Endangerment Finding and the Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the CAA. USEPA's Endangerment Finding refers to current and projected concentrations of the mix of six key GHGs (CO_2, CH_4, N_2O, HFCs, perfluorocarbons [PFCs], and sulfur hexafluoride [SF_6]) in the atmosphere threaten the public health and welfare of current and future generations (USEPA 2013d). The Administrator further proposed to find that the combined emissions of CO_2, CH_4, N_2O, and HFCs from new motor vehicles and motor vehicle engines contribute to the atmospheric concentrations of these key GHGs and hence to the threat of climate change. This is referred to as the Cause or Contribute Finding. The Endangerment Finding under Section 202(a) of the CAA was signed by the USEPA Administrator on December 7, 2009, and published in the Federal Register on December 15, 2009. The final rule became effective on January 14, 2010.

Greenhouse Gas Reporting Program

On October 30, 2009, the USEPA promulgated regulations to establish the first comprehensive reporting program, namely the Greenhouse Gas Reporting Program (GHGRP), to collect data on GHG emissions from upstream and downstream sources and suppliers. The final GHG Reporting Rule became effective on December 29, 2009. Prior to the establishment of the GHGRP, the USEPA collected voluntarily-reported emissions data from various sectors. However, these data were not comprehensive, and, in some cases, they were incomplete or inconsistent. The GHGRP requires that comprehensive, accurate, and consistent facility-level GHG data and information be made available for the purpose of using it to make well-informed policy and regulatory decisions addressing climate change

The GHGRP requires reporting of CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and other fluorinated gases, including nitrogen trifluoride and hydrofluorinated ethers. Approximately 8,000 facilities from nine sectors of the U.S. economy with 41 source categories (emission sources), accounting for about 85 to 90 percent of industrial GHGs emitted in the United States, are represented in reporting year 2012. The sectors covered by the GHGRP include, among others, petroleum and natural gas systems, refineries, and chemicals. In order to balance burden and coverage, the GHGRP establishes a reporting threshold for most reporters of 25,000 $MMTCO_{2e}$ per year emissions or supply.

The first installment of regulations promulgated in 2009 required reporters to begin collecting data starting in 2010 and to start reporting annually in 2011. Subsequent rules were promulgated in 2010, which finalized the requirements for additional sectors, including petroleum and natural gas systems (Subpart W of the GHGRP [USEPA 2013e]), to begin 2011 data collection and

2012 annual reporting. All reporters subject to the GHGRP are now required to submit annual reports in March of each year. These reports cover information collected over the previous calendar year.

The source categories that fall under the petroleum and natural gas systems sector (Subpart W of the GHGRP) include onshore and offshore petroleum and natural gas production; natural gas processing and transmission/compression; underground natural gas storage; and liquefied natural gas storage and import and export equipment. The USEPA did not propose to include the crude oil transportation segment of the petroleum and natural gas industry in this rulemaking. Crude oil transportation results in a small contribution to the total CO_2 and CH_4 fugitive and vented emissions in the petroleum and natural gas industry, with storage tanks—the largest source—already being covered under petroleum and natural gas production. Crude oil is commonly transported by barge, tanker, rail, truck, and pipeline. The combustion emissions resulting from these modes of transportation are covered in other Subparts of the GHGRP that are not applicable to the Project. Consequently, the proposed Project would not trigger GHG reporting under the GHGRP.

Greenhouse Gas Tailoring Rule

On June 3, 2010, the USEPA issued a final rule that establishes an approach to addressing GHG emissions from stationary sources under the CAA permitting programs with an effective date of August 2, 2010. The rule sets thresholds for GHG emissions that define when the CAA permits under the Prevention of Significant Deterioration (PSD) and the Title V Operating Permits programs are required for new or existing industrial facilities. The rule tailors the emissions thresholds to limit which facilities must obtain permits and covers nearly 70 percent of the national GHG emissions that come from stationary sources, including those from the nation's largest emitters (e.g., power plants, refineries, and cement production facilities).

Preconstruction permits are required of any new or modified stationary source with emissions greater than promulgated thresholds. In order to obtain such a permit, a facility must demonstrate it will use Best Available Control Technologies to minimize GHG emissions.

For sources constructed from July 1, 2011 to June 30, 2013, the rule requires PSD permitting for first-time construction projects that emit GHG emissions of at least 100,000 tons per year (tpy), even if they do not exceed the permitting thresholds for any other pollutant. In addition, sources that emit or have the potential to emit at least 100,000 tpy CO_2e and that undertake a modification that increases net emissions of GHG by at least 75,000 tpy CO_2e are also subject to PSD requirements. Additionally, for the first time, the Tailoring Rule-established operating permit requirements apply to sources based on their GHG emissions, even if they would not apply based on emissions of any other pollutant. Facilities that potentially emit at least 100,000 tpy CO_2e are subject to Title V permitting requirements. The proposed Project is not subject to PSD (see Section 3.12.2.2, Regulatory Requirements) and would have emissions of CO_2e less than the applicable thresholds for any of the stationary sources (i.e., construction camps and pump stations). Emissions from mobile sources (on-road and non-road) are not included in the emission estimates for permit applicability of a stationary source. Consequently, the proposed Project would not be subject to the federal GHG permitting rule.

On December 2, 2010, the USEPA released its guidance for limiting GHG emissions based on the CAA requirement for new and modified emission sources to employ Best Available Control Technology to limit GHGs if subject to the PSD permitting program. As a result, the guidance focuses on the process that state agencies should use as they are developing permits for individual sources to determine whether there are technologies available and feasible for controlling GHG emissions from those sources. The guidance is not a formal rulemaking and does not establish regulations, but it provides permitting authorities more detail on USEPA expectations for the implementation of its new GHG permitting requirements.

National Fuel Economy Standards

In April 2010, the USEPA and USDOT National Highway Traffic Safety Administration (NHTSA) finalized a new joint regulation for GHG emissions and fuel economy for passenger cars and light trucks for model years 2012 to 2016. This national program updates existing Corporate Average Fuel Economy (CAFE) standards, and requires model year 2016 vehicles to achieve an average of 35.5 miles per gallon. The USEPA regulates GHG emissions from passenger vehicles up to 8,500 pounds gross vehicle weight rating (plus medium-duty sport-utility vehicles and passenger vans up to 10,000 pounds).

In September 2011, the USEPA and USDOT finalized a new rule regulating fuel economy standards for commercial medium and heavy duty on-highway vehicles and work trucks (heavy-duty vehicles) for model years 2014 to 2018. The rule covered three regulatory categories of heavy-duty vehicles: combination tractors; pick-up trucks and vans; and vocational trucks, as well as gasoline and diesel heavy-duty vehicle engines.

In August 2012, the USEPA and USDOT finalized new standards for passenger cars and light trucks for model years 2017 to 2025 that will raise the average fuel economy to 54.5 miles per gallon for model year 2025 vehicles. According to the Final Rule, the new standards were designed to achieve an overall doubling of fuel efficiency for new vehicles (NHTSA 2012).

Federal Initiatives

Council on Environmental Quality's National Environmental Policy Act Guidance Document on Climate Change

On February 18, 2010, the Council on Environmental Quality (CEQ) published the *Draft National Environmental Policy Act (NEPA) Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions* for public review and comment. This draft guidance has been withdrawn from consideration, and new draft guidance is expected to be available in the near future. These guidelines would describe ways in which 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.

Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants

On February 16, 2012, the Department announced the formation of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC), a new global initiative focusing on the reduction of black carbon, HFCs, and CH_4 (CCAC 2013). The founding coalition partners are Bangladesh, Canada, Ghana, Mexico, Sweden, and the United States, together with the United Nations Environment Programme. To date, an additional 28 countries, including the European

Commission and nine individual European Union member states, as well as, numerous non-state parties and science advisories have joined the coalition. The pollutants that are the focus of this initiative have relatively short durations once emitted—on the order of a few days to a few years—but are responsible for up to one third of the global warming effects the Earth has experienced. Due to their shorter lifetime, actions to reduce emissions will quickly lower atmospheric concentrations of these pollutants, thereby yielding a relatively rapid climate response. This initiative is meant to incentivize new actions as well as highlight and build upon existing efforts, such as the Global Alliance for Clean Cookstoves, the Arctic Council, the Montreal Protocol, and the Global Methane Initiative. It is also meant to complement global actions to reduce CO_2 emissions. The Department's announcement of the Coalition specifically named sources of black carbon that pertain to the proposed Project, including diesel trucks and agricultural burning (CCAC 2013).

The President's Climate Action Plan

The President's Climate Action Plan has three key pillars: cut carbon pollution in America, prepare the United States for impacts of climate change, and lead international efforts to combat global climate change and prepare for its impacts (White House 2013). Under the carbon pollution reduction pillar, the President's Climate Action Plan measures include:

- Cutting carbon pollution from power plants;
- Promoting leadership in renewable energy by accelerating clean energy permits and expanding and modernizing the electric grid;
- Increasing long-term investment in clean energy innovation;
- Building a 21st century transportation sector by increasing fuel efficiency;
- Reducing energy bills for homes and businesses;
- Reducing other GHG emissions (such as HFCs and CH_4); and
- Providing federal leadership in GHG emissions reduction.

To prepare the United States for climate change impacts, the Obama administration plans to focus on three initiatives: building stronger and safer communities and infrastructure, including establishing local task forces on climate preparedness and supporting communities as they prepare for climate impacts; protecting the economy and natural resources, including identifying vulnerabilities of key sectors to climate change and support climate resilient investments; and providing tools using sound science to manage climate change impacts.

The Obama administration plans to lead international climate change efforts by working with other countries to take action, such as combating short-lived climate pollutants, expanding clean energy use, and cutting energy waste. The administration also plans to lead efforts to address climate change through international negotiations, including the follow-on to the United Nations Framework Convention on Climate Change.

State and Provincial Programs

Several regional and state programs have been enacted to lower GHG emissions. The Western Climate Initiative (WCI) is a regional, multi-sector, GHG reduction initiative that includes California and several Canadian provinces. The initiative has a goal to reduce regional emissions by 15 percent below 2005 levels by 2020 while simultaneously creating jobs, enhancing energy independence, and protecting human health and the environment. This program is the most comprehensive carbon-reduction strategy designed to date in North America. Participants set regional GHG targets and implement emission trading policies to reduce GHGs from the region. California, British Columbia, and Quebec have moved forward with the first of two phases of the cap-and-trade system, which began on January 1, 2012. Ontario and Manitoba are committed to implementation programs soon, but have not yet begun implementation.

The recommended cap-and-trade program has a broad scope that includes seven GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and nitrogen trifluoride). The first phase of the cap-and-trade program covers emissions from electricity generation, including imported electricity, industrial combustion at large sources, industrial process emissions, fossil-fuel consumption for transportation, and residential fuel use. Together, these sectors cover two-thirds of all emissions in the WCI region. The second phase will begin in January 2015 and expands to any transportation fuel as well as other commercial, residential, and industrial fuels not included in the initial phase. When fully implemented in 2015, the program will cover nearly 90 percent of GHG emissions in the WCI region.

The province of Alberta, Canada, has enacted legislation that regulates GHG emissions; the legislation requires that large emitters report their emissions and take mandatory actions to reduce emissions. Industry emissions that are greater than 50,000 tons must be reported annually using a specified gas reporting standard, and the emissions intensity of emissions greater than 100,000 tons must be reduced by 12 percent through the following mechanisms:

- Improving operations
- Purchasing offsets—the purchases of offsets are regulated and can be purchased from sectors that have voluntarily reduced their emissions in Alberta. Offsets are created using protocols approved by the government of Alberta and must be verified by an independent third party.
- Contribute to the Climate Change and Emissions Management Fund—firms may pay $15 per ton of emissions into the fund in order to meet the 12 percent reduction target. The fund will assist in achieving the goals of Alberta's Climate Change strategy to support the development and application of transformative technologies.
- Purchase or use Emissions Performance Credits—these credits are generated by facilities that have achieved the 12 percent mandatory reduction. Emissions Performance Credits may be sold to other facilities or banked for future use. However, they can only be used once and not in the same year they are generated (Environment and Sustainable Resource Development 2013).

The governors of Nebraska, South Dakota, and Kansas, along with nine other Midwestern governors and Manitoba, Canada, are members of the Energy Security and Climate Stewardship Platform for the Midwest. The platform lists goals for energy efficiency improvements, low-carbon transportation fuel availability, renewable electricity production, and carbon capture and storage (CCS)[6] development. In addition to goals related to energy efficiency, renewable energy sources, and biofuel production, the platform lays out objectives with respect to carbon capture and storage. In 2010, members formed a CCS task force to assist Midwest states in meeting regional goals for CCS between 2012 and 2015. The task force has compiled recommendations for priority CCS projects, analyzed key statutory and regulatory frameworks for states to consider, and reported current efforts in the Midwest with respect to CCS (Midwestern Governors Association 2013). By 2020, all new coal plants in the region are meant to capture and store CO_2 emissions. Numerous policy options are described for states to consider as they work towards these goals. The platform also lays out six cooperative regional agreements. These agreements establish a Carbon Management Infrastructure Partnership, a Midwestern Biobased Product Procurement System, coordination across the region for biofuels development, and a working group to pursue a collaborative, multi-jurisdictional electricity transmission initiative. States adopting all or part of the platform from the proposed Project area include South Dakota, Kansas, Nebraska, and North Dakota, as well as the Canadian Province of Manitoba.

On November 15, 2007, Kansas joined five other states and Manitoba, Canada, to establish the Midwest Greenhouse Gas Reduction Accord. South Dakota, three other states, and one Canadian province are observers to the process. Under the Accord, members agree to establish regional GHG reduction targets, including a long-term target of 60 to 80 percent below 2007 emissions levels, and to develop a multi-sector cap-and-trade system to help meet the targets. Other initiatives included establishing and implementing a GHG emissions reductions tracking system and implementing other policies, such as low-carbon fuel standards, to aid in reducing emissions. While the Midwest Greenhouse Gas Reduction Accord has not been formally suspended, the participating jurisdictions are no longer actively pursuing it (Center for Climate and Energy Solutions [C2ES] 2012).

In January 2009, nine Northeastern and Mid-Atlantic states formed the Regional Greenhouse Gas Initiative (RGGI) to cap annual emissions from power plants in the region as a part of a mandatory, market-based effort to reduce GHG emissions (RGGI 2009). This initiative capped emissions at 188 million metric tons of CO_2 for 2009 through 2011, and 165 million metric tons of CO_2 for 2012 through 2014 (RGGI 2012). Beginning in 2015, the initiative will reduce the cap by 2.5 percent each year through 2019. As of 2012, a total of 29 states and the District of Columbia have enacted Renewable Portfolio Standards (RPSs)[7] (Lawrence Berkeley National Lab 2012). In 2012, the total RPS account for 54 percent of total U.S. retail electricity sales. In South Dakota, House Bill 1272, which established a voluntary Renewable Portfolio objective of 10 percent by 2015, was signed into law on February 21, 2008. Montana has enacted a RPS with a goal of 15 percent renewable energy sources by 2015.

Twenty states and the District of Columbia each authorized statewide GHG emission reduction targets to be achieved by a specified date (C2ES 2013a). For example, in August 2009, the state of New York issued an Executive Order to reduce the state's GHG emissions 80 percent from

[6] Carbon capture and storage (CCS), also referred to as carbon capture and sequestration, is a technological approach aimed at preventing the release of CO_2 into the atmosphere. The technology involves capturing CO_2 produced by industrial processes and then injecting it deep into a rock formation with properties to allow permanent storage.
[7] An RPS is a regulation that requires the increased production of energy from renewable energy sources.

1990 levels by 2050. Colorado set emission targets in 2008, which was a statewide goal to reduce GHG emissions at 20 percent below 2005 levels by 2020 and 80 percent below 2005 levels by 2050.

California, Oregon, and Washington have established emission performance standards for electricity generation (C2ES 2013b). Various criteria are used as the basis for determining a performance standard. For example, the standard for a coal-fired generator could be based on *best available control technology* or follow a *lowest achievable emission rate* target. New York is in the process of starting a similar program.

Low carbon fuel standard (LCFS) policies have been adopted in California, British Columbia, and the European Union, and are in development in Oregon, Washington, and 11 states in the Northeast and Mid-Atlantic regions (C2ES 2012). These standards generally require that overall carbon values of lifecycle GHG emissions for transportation fuels decrease by up to 10 percent over the next decade, although the definition of fuels and the percent reduction over time differ across jurisdictions. More carbon-intensive fuels include those derived from crude oil sources in the WCSB, Venezuela, Nigeria, the Middle East, and California (IHS Cambridge Energy Research Associates, Inc. [IHS CERA] 2010). The impact of LCFS on the U.S. market demand for oil sands crude oil is speculative at this time since few jurisdictions have implemented these standards.

One concern regarding the adoption of LCFS policies in certain jurisdictions is that GHG-intensive crudes will simply be routed to other markets through emissions leakage or shuffling,[8] which could result in no net reduction in GHG emissions (Yeh and Sperling 2010), or even a slight increase (Barr 2010). Implementation of LCFS policies applied more widely in United States, and international markets would help mitigate the potential effect of crude shuffling and emissions leakage. Additional analysis about the potential relationship between the proposed Project and separate regulatory or market measures aimed at improving fuel efficiency or promoting alternative energy sources for crude oil is included in Section 2.2, Description of Alternatives.

[8] According to Sperling and Yeh (2009), "…a major challenge for the LCFS is avoidance of 'shuffling' or 'leakage.' Companies will seek the easiest way of responding to the new LCFS requirements. That might involve shuffling production and sales in ways that meet the requirements of the LCFS but do not actually result in any net change. For instance, a producer of low-GHG cellulosic biofuels in Iowa could divert its fuel to California markets and send its high carbon corn ethanol elsewhere. The same could happen with gasoline made from tar sands and conventional oil. Environmental regulators will need to account for this shuffling in their rule making. This problem is mitigated and eventually disappears as more states and nations adopt the same regulatory standards and requirements."

4.14.2 Direct and Indirect Greenhouse Gas Emissions

This section addresses the direct and indirect potential contributions of the proposed Project to GHG emissions associated with construction and operation of the pipeline.

4.14.2.1 Construction Emissions

The construction phase of the proposed Project would result in GHG emissions arising from the following sources or activities:

- Clearing of land in the proposed right-of-way (ROW) via machinery and open burning on some portions of disturbed land (0.5 percent of the land projected to be disturbed, based on information received from TransCanada Keystone Pipeline, LP [Keystone]);
- Backup emergency generator engines running at eight construction camps;[9]
- Indirect (off-site) electricity usage at the eight construction camps;
- On-road and non-road vehicles used for the construction of the proposed pipeline; and
- On-road and non-road vehicles used for the construction of the pump stations.

The pipeline would be constructed in Montana, South Dakota, and Nebraska simultaneously in 10 construction spreads, of which each would require an average of 6 to 8 months to complete. Eight construction camps, which would house personnel working on the construction of the proposed Project, would be powered by electricity from the local utility (grid). During upset conditions when commercial power supply is interrupted (assume 500 hours per camp), one 400-kilowatt backup emergency generator engine per camp would be used. On-road vehicles such as various types of diesel-powered trucks and non-road vehicles such as diesel-powered bulldozers and loaders would be used throughout the entire construction phase along the pipeline route and at the 20 pump stations in Montana, South Dakota, Nebraska, and Kansas (see Table 4.12-1).

For the entire duration of the construction phase, the estimated GHG emissions amount to 244,153 metric tons of CO_2e,[10] which can be seen below in Table 4.14-1. The GHG emissions

[9] The contractor yards would likely have small trailer offices connected to the grid. In comparison to the contractor camps, indirect GHG emissions associated with electricity usage at the contractor yards or elsewhere would be small and were not estimated.

[10] The IPCC developed the GWP concept to compare the ability of different GHGs to trap heat in the atmosphere over a certain period of time. GWPs are typically assessed over a time period of 100 years, although shorter or longer timeframes can also be used. The CEQ NEPA Guidance on Climate Change does not recommend the use of any particular GWP values for estimating GHGs as CO_2e. To date, federal agencies have not used one consistent set of GWP values. This Final Supplemental EIS uses the 100-year GWP values for CO_2 (1), CH_4 (25), and nitrous oxide (298) from the IPCC's Fourth Assessment Report (IPCC 2007). For comparison, the Fourth Assessment Report's 20-year GWP values are 72 for CH_4 and 289 for nitrous oxide (IPCC 2007). Because CO_2 is the predominant GHG that would be emitted during construction and operation of the proposed Project, the use of the 20-year GWP values (instead of the 100-year GWP values) would not have a significant effect on the overall CO_2e emissions calculated.

associated with the construction of the connected actions[11] are deemed minimal relative to the proposed Project, and have not been calculated.

Table 4.14-1 Estimated Direct and Indirect Construction Emissions for the Proposed Project

	Greenhouse Gas Emissions (tons)				Greenhouse Gas Emissions (metric tons)
Emission Source/Activity	**CO_2**	**CH_4**	**N_2O**	**CO_2e[a]**	**CO_2e**
Construction Camp Emergency Generators[b]	1,218	0.05	0.02	1,224	1,110
Construction Non-road (Pipeline)[c]	147,155	14.3	6.41	149,424	135,556
Construction On-road (Pipeline)[d]	5,197	0.30	0.53	5,363	4,865
Open Burning[e]	51.6	0.36	NA[f]	60.7	55.1
Construction Camp Electricity Usage (Commercial Power Supply)[g]	91,306	1.61	1.56	91,810	83,290
Construction Non-road (Pump Stations)[c]	19,360	1.99	0.89	19,676	17,850
Construction On-road (Pump Stations)[d]	1,585	0.07	0.13	1,624	1,474
Total	**265,872**	**18.7**	**9.54**	**269,182**	**244,200**

[a] CO_2e calculated used 100-year GWPs from IPCC's Fourth Assessment Report of 1, 25, and 298 for CO_2, CH_4, and N_2O, respectively (IPCC 2007).

[b] Construction camp emission estimates include eight camps (four in Montana, three in South Dakota, and one in Nebraska) with one 400-kilowatt generator engine per camp operating for a total of 500 hours (when commercial power supply is interrupted).

[c] Non-road CO_2 emission factors for diesel and gasoline fuelled equipment were derived using methodology described in Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling for Compression Ignition (USEPA 2010b) and Spark-Ignition Engines (USEPA 2010c), respectively. CH_4 and N_2O factors were taken from Table 13.6 of The Climate Registry General Reporting Protocol Version 1.1 (TCR 2008); converted from g/gal to lb/hp-hr based on a density of 7.05 lb/gal for diesel and 6.17 lb/gal for gasoline; and a brake specific fuel consumption obtained from USEPA's Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling (USEPA 2010a).

[d] On-road GHG emission factors taken from The Climate Registry - General Reporting Protocol, Version 1.1 (TCR 2008). Total miles traveled estimated based on number of equipment, daily hours of operation per equipment, each operating 6 days per week, 24 to 34 weeks (an average of 30 weeks was assumed for calculations) per spread, and an assumed 5 vehicle miles traveled per hour.

[e] CH_4 emissions from open burning were calculated using an equation from Air Pollutant Emissions associated with Forest, Grassland, and Agricultural Burning in Texas (Fraser et al. 2002): *Emissions (lb) = Emission Factor (lb/ton)* Fuel Consumption (tons/acre)* area burned (acres)*. Approximately 15,296 acres of land are expected to be disturbed in total—Montana (5,462 acres), South Dakota (5,778 acres), Nebraska (3,985 acres), Kansas (15 acres), and North Dakota (56 acres)—but area expected to be burned was assumed to be only 0.5 percent of the total acreage. Fuel load or consumption factors for hay/grass were taken from Fraser et al. 2002. Fuel load or consumption factor for tree tops and stumps were taken from USEPA AP-42 Table 13.1-1 (USEPA 1996). Values applicable to the Rocky Mountain region (MT = Region 1; SD and NE = Region 2) were used.

[f] NA = not applicable

[g] Electrical power requirement for each camp is assumed to be 1.6 megawatts. GHG emission factors were taken from USEPA's eGRID2012 version 1 data base (USEPA 2013a).

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[11] Connected actions are those that 1) automatically trigger other actions which may require environmental impact statements, 2) cannot or will not proceed unless other actions are taken previously or simultaneously, 3) are interdependent parts of a larger action and depend on the larger action for their justification.

Keystone would minimize the extent of land clearing for ROWs and expect that contractors would maintain construction equipment and vehicles in accordance with manufacturer's recommendations. Keystone would implement the following measures[12] to minimize production of GHGs during construction:

- Contractors would be required to ensure that motorized equipment is operating only when required (no unnecessary idling); this requirement would be reinforced during training of the construction workforce and during construction.
- Utilization of construction camps with associated contractor yards would reduce the overall number of personal vehicles being operated to drive to and from the construction yards each day.
- Contractors would utilize state of the art equipment to increase energy efficiency and effectiveness.
- Throughout construction, contractors would be required to conduct regular maintenance and inspections of their equipment. Deteriorated parts would be required to be promptly repaired or replaced.
- Keystone would limit the construction disturbance and land clearing to the minimum necessary to safely build the proposed Project.
- Following construction, areas disturbed during construction would be revegetated as soon as possible.

4.14.2.2 Operational Emissions

During the operation phase of the proposed Project, GHG emissions would arise from both direct (Scope 1) and indirect (Scope 2) sources. A summary of these emissions can be found in Table 4.14-2. Direct operating emissions would include minimal fugitive CH_4 emissions at connections both along the main proposed pipeline and at the pump stations. These fugitive CH_4 emissions would be emitted from approximately 55 intermediate mainline valves along the pipeline route and from the 20 pump stations. Emissions from the use of maintenance vehicles (at least twice per year) and aircraft for aerial inspection (at least once every 2 weeks) during the proposed Project operations are expected to be negligible. Indirect operating emissions from the proposed Project would be associated with electricity generation needed to power the pump stations.

The proposed Project includes 20 pump stations: six in Montana, seven in South Dakota, five in Nebraska, and two in Kansas. Each pump station would consist of four to six pumps driven by electric motors (exp Energy Services Inc. 2012). The pumps are rated at 6,500 horsepower (hp), and annual electricity usage from pump stations in Montana (1,274,317 megawatt-hour(s) per year [MWh/year]), South Dakota (1,486,703 MWh/year), Nebraska (1,061,931 MWh/year), and Kansas (424,772 MWh/year) were provided by Keystone.[13] Using USEPA's e-GRID factors for

[12] These measures would reduce GHG emissions compared to those calculated.

[13] This electricity usage has been updated from that assumed in the Draft Supplemental EIS, in which pumps were assumed to run continuously; updated information indicates that pumps would run at less than full load.

the regions in which the pump stations would be located, the indirect operating emissions for the proposed Project are estimated to be 1.44 $MMTCO_2e$[14] per year, as shown in Table 4.14-2.

Table 4.14-2 Direct and Indirect Annual Operating GHG Emissions for the Proposed Project

Emission Source/Activity	GHG Emissions (Tons/Year)				GHG Emissions (Metric Tons/Year)
	CO_2	CH_4	N_2O	CO_2e[f]	CO_2e
Fugitive Emissions (Pipeline)[a, b]	Negligible	0.001[e]	NA	0.02	0.02
Fugitive Emissions (Pump Stations)[a, c]	NA	0.08	NA	1.97	1.78
Electricity Usage (Pump Stations)[d]	1,582,304	27.5	26.9	1,591,007	1,443,352
Total	**1,582,304**	**27.5**	**26.9**	**1,591,009**	**1,443,354**

[a] Direct fugitive CH4 emissions were estimated from total organic carbon emission rates based on CH_4's typical weight fraction of 0.15 (USEPA AP-42, Section 5.2, [USEPA 2008]). Total organic carbon emission factors taken from Texas Commission on Environmental Quality's Equipment Leak Fugitives document, (Texas Commission on Environmental Quality 2008). Emission factors pertaining to Oil and Gas Production Operations for Heavy Oil <20 degrees American Petroleum Institute (API) gravity were used.
[b] Pipeline CH_4 emissions include combined fugitive emissions from approximately 55 intermittent mainline valves along the pipeline route in Montana (25), South Dakota (15), and Nebraska (15).
[c] Pump station CH_4 emissions include combined fugitive emissions from 18 pump stations along the pipeline corridor in the three states plus two pump stations in Kansas (i.e., 20 pump stations total). Each pump station was assumed to have the following components: 13 valves, and 109 flanges and connectors. There are a total of 187 pumps along the entire route, with each pump station having either 4, 5, or 6 pumps.
[d] Indirect GHG emissions from electricity usage were estimated using annual electricity usage (MWh/year) in each state and appropriate regional e-Grid emission factors (USEPA eGRID2012 version 1 database for Year 2009) (USEPA 2013a). Most parts of Montana fall under the NWPP eGRID region; however, the portion of the proposed pipeline that crosses Montana is within the MROW region.
[e] NA = not applicable
[f] Carbon dioxide equivalents (CO_2e) calculated used 100-year GWPs from IPCC's Fourth Assessment Report of 1, 25, and 298 for CO_2, CH_4, and N_2O, respectively (IPCC 2007).

As shown above, the total annual GHG emissions from the proposed pipeline operation amount to 1.44 $MMTCO_2e$ per year.[15] To put these emissions into context, the annual CO_2e emissions from the proposed Project are equivalent to CO_2e emissions from approximately 300,000 passenger vehicles operating for 1 year, or 71,928 homes using electricity for 1 year.[16] The GHG emissions associated with operation of the connected actions are deemed minimal relative to the proposed Project, and have not been calculated.

[14] This calculated GHG emissions value assumes that the pumps along the pipeline alignment operate at their full hp capacity (i.e., 6,500 hp). This is a conservative assessment because in reality very few pumps would reach their motor hp. If it was assumed that the pumps would operate on average at 90 percent of their design condition loading, and the variable speed drive would operate the pump at partial load on average 85 percent, an operating hp of 3,569 would be obtained. The GHG emissions with the pumps operating at this hp would be 0.79 $MMTCO_2e$ (55 percent of the GHG emissions noted in the text).
[15] In 2010, total U.S. GHG emissions (CO_2e from anthropogenic activities) amounted to approximately 6,822 million metric tons (USEPA 2012), which used the 100-year GWP values from IPCC's Second Assessment Report (IPCC 1996). Globally, approximately 30,326 million metric tons of CO_2 emissions were added to the atmosphere via the combustion of fossil fuels in 2010 (IEA 2012).
[16] Equivalencies based on USEPA's GHG Equivalency Calculator (USEPA 2013b).

Keystone would implement the following measures to minimize energy consumption and production of GHGs during operation of the proposed Project:

- Contractors would be required to conduct regular maintenance and inspections of their equipment, including pumps associated with pump station operations. Deteriorated parts would be required to be promptly repaired or replaced.
- The proposed Project's pump station design incorporates state of the art equipment that has been engineered and manufactured to a high level of energy efficiency. The 6,500 hp induction motors are in excess of 97 percent efficient, compared to motors used in the existing Keystone pipeline, which are 96.1 to 96.6 percent efficient. Each pump station includes a variable frequency motor drive, which is rated at 96 percent or better in efficiency. This electronic equipment provides precise flow/speed control to allow the pump to operate at the point of peak efficiency and eliminates the need for a pressure control valve, which would otherwise waste pressure and, therefore, energy. This equipment also has the added benefit of minimizing current in-rush[17] during motor starts.
- The main line pumps of the pump station have been tested at 91 to 92 percent efficiency, compared to a best efficiency range between 87.1 to 88.6 percent for the existing Keystone pipeline pumps. This high efficiency rating is achieved through a specialized manufacturing process, producing highly polished internal pump components. In addition, many of the proposed Project pump stations would have power factor correction capacitor banks installed. These banks also improve the efficiency of the utility power system to a 95 percent power factor.

Electrical power would be supplied to the pump stations by local cooperatives or utilities that determine how the power would be generated, including renewable sources (such as wind and solar power, which result in fewer GHG emissions than fossil-fuel based sources). Several proposed Project-area states have RPS that mandate power companies to generate a portion of their power from renewable sources: Montana's RPS is 15 percent by 2015, South Dakota's RPS is 10 percent by 2015, and Kansas's RPS is 20 percent by 2020. Nebraska has no RPS.

4.14.2.3 Black Carbon

The GHG emissions in Tables 4.12-1 and 4.12-2 do not include black carbon (soot), which is a climate forcing agent that is a product of incomplete combustion. Black carbon is a particle rather than a GHG, with a much shorter atmospheric lifespan on the order of 5.3 to 15 days, depending on the meteorological conditions where it is removed from the atmosphere in precipitation or through deposition, compared to the lifespan of CO_2, which is on the order of hundreds of years (U.S. Climate Change Science Program 2008, Archer et al. 2009). This Final Supplemental EIS does not include a discussion of black carbon emissions because the available science and information available suggest that they are a negligible contribution alongside the sources of GHG emissions associated with construction and operation of the proposed Project. There is no generally accepted method for summarizing and normalizing the different effects that black carbon emissions have on the climate (NHTSA 2012). This is a result of the high level of

[17] This is where motors draw several times their full load current while starting.

uncertainty regarding the total climate effect of black carbon emissions and in expressing black carbon emissions in terms of CO_2 equivalence. The climate forcing from black carbon occurs through numerous mechanisms including changes in albedo[18]—particularly when deposited on ice surfaces—increasing cloud droplet concentrations and thickening low-level clouds.

Land clearing by brush burning is also a source of black carbon emissions, although the level of burning for the proposed Project will be minimal. During burning, in addition to black carbon, a range of other pollutants also get emitted, including organic carbon (Rao and Somers 2010). The ratio of black carbon emissions to other pollutants varies by fuel and combustion environment. Black carbon and organic carbon can have different effects with respect to climate influences: black carbon tends to warm the environment by absorbing incoming and outgoing radiation, whereas organic carbon tends to reflect radiation back to space, producing a cooling effect (Bond et al. 2011, Hansen et al. 2005).[19] Compared to combustion of fossil fuels, carbon emissions from biomass burning have a much higher fraction of organic carbon than black carbon, meaning that the net overall warming effect from black carbon is likely to be negligible as the net cooling effect from organic carbon emissions largely offsets black carbon emissions (Chow et al. 2011).

Land clearing activities associated with the construction of the proposed Project will include removal and open burning of native brush along the proposed pipeline route mostly consisting of wheatgrass, deciduous trees, and prairie sand reed. The ratio of organic carbon to black carbon emitted from burning these types of vegetation is very high, roughly twice as great as from fossil fuel sources (Chow et al. 2011). The net forcing effect, consequently, is very small for these biomass sources. As a result, the net forcing from black carbon and organic carbon emissions from brush burning associated with the proposed Project's construction phase is subject to a wide range of uncertainty, but is generally unlikely to make a major net contribution to global warming.

4.14.3 Incremental Indirect Lifecycle Greenhouse Gas Emissions

This section, based on additional information and analysis in Appendix U, Lifecycle Greenhouse Gas Emissions, estimates the incremental lifecycle GHG emissions associated with WCSB crude oils that would be transported by the proposed Project compared to reference crudes that would likely be displaced. The analysis was undertaken based on a review of existing lifecycle studies and models that estimate GHG emissions and implications for WCSB oil sands-derived crudes in comparison to reference crudes currently being distributed and refined in the United States. The analysis estimated the full lifecycle GHG emissions of the WCSB crude oils and the reference crudes (see Figure 4.14.3-1). The reference crudes were selected as examples of crudes that are likely to be displaced from the U.S. crude oil market and/or the world crude oil market by increases in crude oil produced from the WCSB. Because crude oil produced in the WCSB

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[18] *Albedo* refers to the reflectivity of a surface.

[19] This does not account for brown carbon, which has an absorbing component; however, at this time, the brown carbon emissions from brush are not available. A recent study (Chung et al. 2012) suggests the radiative forcing of organic carbon (including brown carbon) is negligible over most of the United States and Canada. This could suggest that the vegetation in these regions is not a significant contributor to organic matter forcing. As this study is based on satellite observations, which do not differentiate between the sources of combustion, the Department has considered well-recognized peer-reviewed and governmental reports that are applicable to the proposed Project in its response.

generally has higher lifecycle GHG emissions than the potentially displaced reference crude oils, increases in WCSB crude oil in the U.S. (or world) market would increase overall lifecycle GHG emissions of the crude oils consumed.

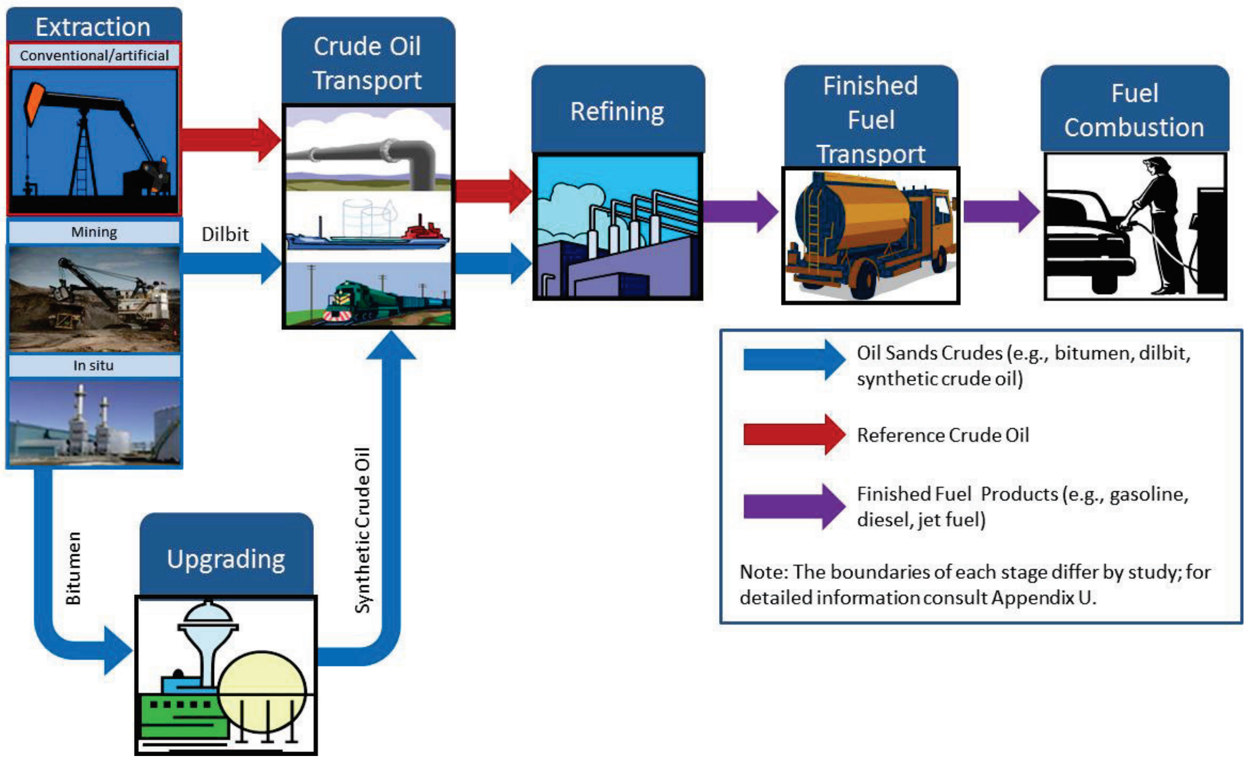


Photo Sources: Suncor Energy 2010, Shell 2009

Figure 4.14.3-1 Simplified Lifecycle of Crude Oils

The emissions associated with production, refining, and end use of the crude oil that would be transported by the proposed Project are assessed as potential indirect or cumulative effects. Indirect effects of an action include those that are caused by an action and occur later in time or farther away in distance but that are still reasonably foreseeable. Indirect effects may include growth-inducing effects. Cumulative effects are those that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions.

Section 1.4, Market Analysis, and Section 2.2, No Action Alternative, assesses whether the proposed pipeline is likely to induce growth or change (or otherwise impact) the rate of extraction in the oil sands in Canada, the refining activities in the U.S. Petroleum Administration for Defense District (PADD) 3 Gulf Coast, and end-use combustion of crude-oil derived transportation fuels. The findings from those sections form part of the broader assessment performed on GHG emissions associated with the project. This section assesses the lifecycle emissions of oil sands crude oils compared to other crude oils using existing studies, and provides a range of GHG emissions estimates.

The total capacity of the proposed Project is 830,000 bpd. Of that 830,000 bpd of capacity, up to 100,000 bpd is reserved for production from Montana and North Dakota that would be delivered to the proposed Project in Baker, Montana. The proposed pipeline may also transport conventional crude oils from Alberta, Canada, in addition to oil sands crudes. Although not all of the capacity of the proposed Project would be used to transport oil sands crude oils, however, the estimates in this section are based on 830,000 bpd of oil sands crudes to present a conservative, high-end estimate of emissions associated with crude oil that could be transported by the proposed Project.

For completeness and comparison purposes, the GHG emissions associated with land use changes attributable to the WCSB crude oil mining, and to a lesser extent *in situ* extraction methods, have also been calculated, as has the relative importance of how petroleum coke is addressed in the lifecycle analyses.

4.14.3.1 Lifecycle Analysis Framework of Fuels

Figure 4.14.3-1 illustrates the simplified crude oil lifecycle, which considers the key stages from extraction through to end-product (fuel) combustion. Consideration of all of these important stages, using a lifecycle analysis (LCA) approach, provides an opportunity for a comprehensive assessment and understanding of the direct and indirect GHG emissions associated with a given project.

The primary carbon and energy flows are those associated with the production of three premium fuel products—gasoline, diesel, and kerosene/jet fuel—by refining crude oil. In addition to the premium fuels, other secondary co-products such as petroleum coke, liquefied petroleum gas, and sulfur are produced as well. Primary carbon flows characterize most of the carbon in the system (crude is processed into premium fuel products which are combusted and converted to CO_2), and primary energy flows in the system are those involved in extracting, upgrading, refining, transporting, and combusting the crude and premium fuel products.

In addition to primary flows, there are a range of secondary energy and carbon flows and emissions to consider. Because these flows are outside the primary operations associated with fuel production, they are often characterized differently across studies or excluded from LCAs, and estimates of specific process inputs and emission factors vary according to the underlying methods and data sources used in the assessment. Examples of secondary carbon flows associated with petroleum products include the production and use of petroleum coke; non-energy uses of petroleum, such as lubricating oils, petrochemicals, and asphalt; and changes in biological or soil carbon stocks as a result of land-use change. Secondary energy flows come from sources imported into the system, such as purchased electricity or natural gas and energy required to build capital equipment and infrastructure.

Primary carbon and energy flows are integral to the economics of the oil industry and are well-defined in the LCA studies reviewed for this assessment. Secondary carbon and energy flows typically include aspects of the industry that are considered more peripheral and are therefore less well-defined in the studies. These differences in the level of definition and characterization of secondary flows limit the extent to which they can be effectively modeled in lifecycle assessments.

The boundaries applied to LCA studies influence the final GHG emissions. Different LCA boundaries can be selected, as described below in Figure 4.14.3-2; it is important that these boundary conditions are considered and understood when results are analyzed to ensure appropriate and consistent interpretation:

- Wells-to-Refinery (WTR)—considers emissions from upstream production of fuels, mining/extraction, upgrading, and transport to refinery;
- Wells-to-Tank (WTT)—considers emissions from WTR plus refining and distribution; and
- Wells-to-Wheels (WTW)—includes all stages in WTT plus emissions from fuel combustion.

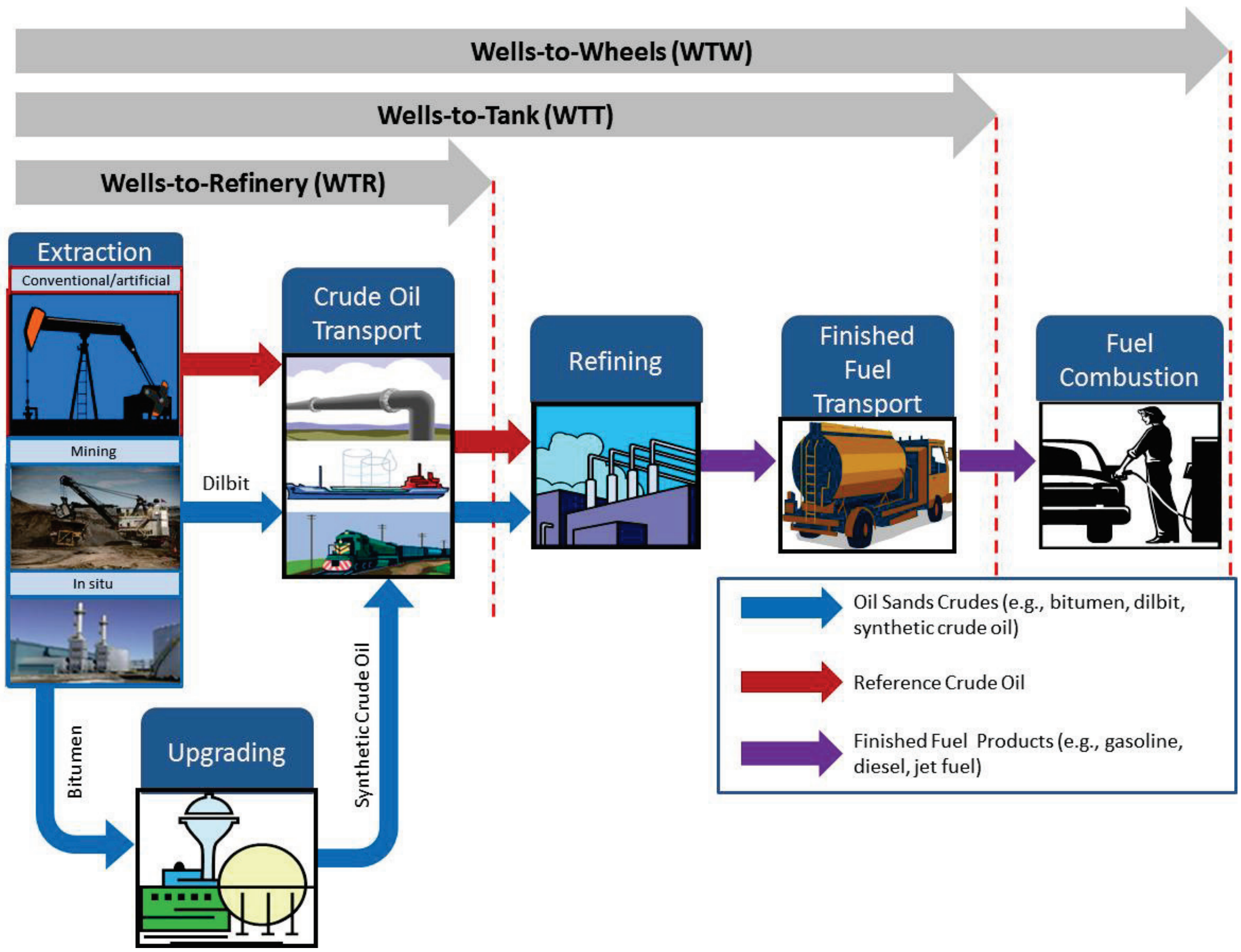


Photo Sources: Suncor Energy 2010, Shell 2009

Figure 4.14.3-2 Crude Oil Lifecycle Boundaries

A full WTW analysis of GHG emissions is an essential part of this assessment to ensure that the differences and similarities in lifecycle stages are defined and accounted for. For example, extraction techniques for crude oils differ depending upon the type of crude oil extracted, the nature of the reservoir, and the age of the reservoir. These different techniques can use substantially different amounts of energy and result in different amounts of GHG emissions. In addition, heavier hydrocarbon fractions may be removed and processed[20] at upgraders prior to transportation for some oil sands, whereas for all reference crudes, heavier hydrocarbon removal or processing occurs at the refinery stage. With respect to similarities, once the premium fuel products have been refined, the transportation and end-use combustion (and the associated GHG emissions) are the same irrespective of the original crude source.

4.14.3.2 Methodology and Approach

Review of Existing Studies

A review was undertaken of existing lifecycle studies and models that estimate GHG emissions and implications for oil sands-derived crudes in comparison to reference crudes.

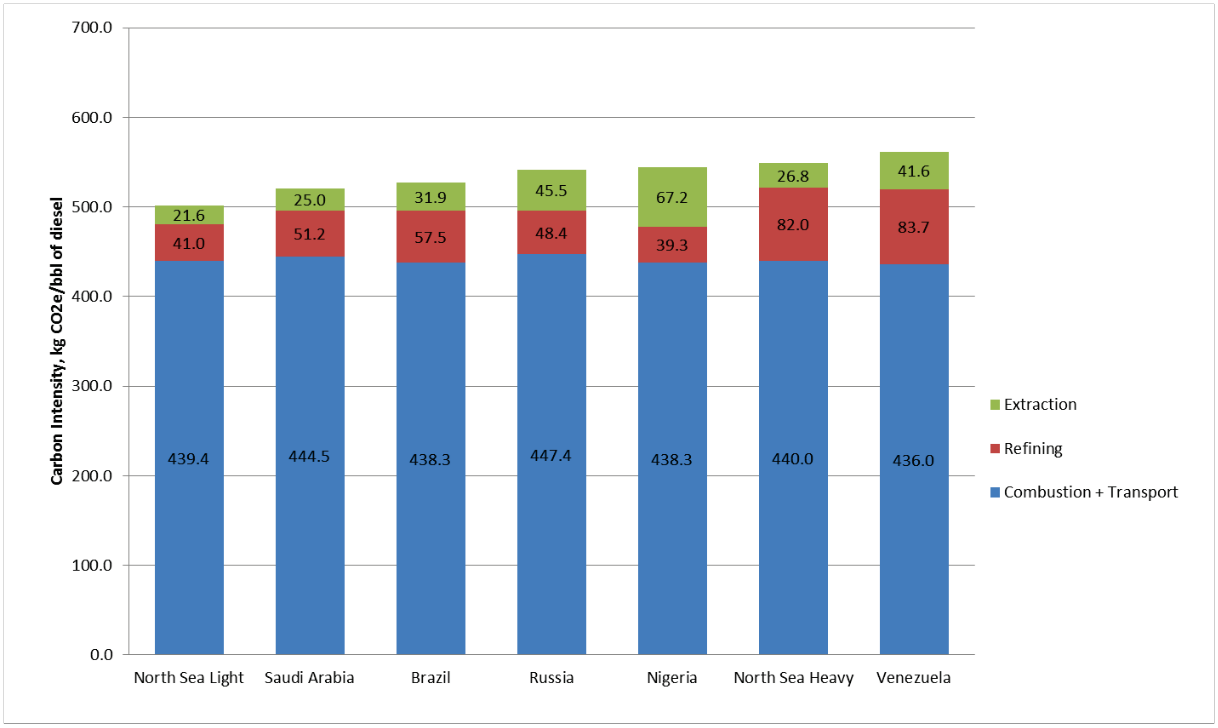
The studies and models included in this assessment (see Appendix U, Lifecycle Greenhouse Gas Emissions, Table 3-1, for the full list and references for the studies) were selected by the Department in conjunction with USEPA, U.S. Department of Energy, and the CEQ on the following basis:

- The studies evaluate oil sands crudes in comparison to selected reference crude oils;
- The studies focus on GHG impacts throughout the crude oil lifecycle;
- The studies were published within the last 10 years, and most were published within the last 5 years; and
- The studies represent the perspectives of various stakeholders, including industry, governmental organizations, and non-governmental organizations.

In particular, four studies from the list of those selected by the agencies were subsequently used to develop the GHG emission estimates for WCSB oil sands crudes and reference crudes. Jacobs Consultancy (2009),[21] TIAX (2009), and National Energy Technology Laboratory (NETL 2008, 2009)[22] provided sufficient independent information to develop internally-consistent averages for the mix of oil-sands crudes likely to be transported by the proposed Project.

There are numerous crude oil sources in the global energy markets, and these crude oils have differing GHG intensities based upon their properties (such as API gravity), the method of extraction, and the refinery process utilized. Figure 4.14.3-3 illustrates a range of crude oil GHG intensities.

[20] Often referred to as *cracking.*
[21] In 2012, Jacobs Consultancy released another crude oil LCA study, however, because Jacobs Consultancy (2012) focuses on European markets, this analysis continued to use Jacobs Consultancy (2009). For more detailed information on the various studies, see Appendix U, Lifecycle Greenhouse Gas Emissions.
[22] NETL (2009) is an update of the (2008) study that provided more information. The two NETL reports are considered together as one study in our analysis.



Source: Jacobs Consultancy 2012

Notes: This figure is reproduced to illustrate the range of GHG intensities for different crudes based on origin, properties, and refining processes. Jacobs Consultancy 2012 evaluated WTW emissions for crude oils sent to European markets. The results shown are for refineries in the U.S. Gulf Coast, but include transportation and delivery to Europe.

Figure 4.14.3-3 Illustration of GHG Intensities for Different Crude Oils

Four reference crudes were selected to reflect a range of crude oil sources and GHG intensities currently being distributed and refined in the United States, as follows:

- The average U.S. barrel consumed in 2005, providing a baseline for fuels produced from the average crude consumed in the United States;
- Venezuela Bachaquero and Mexico Maya, which are representative of heavy crudes currently refined in the Gulf Coast area.[23] These crudes, and/or other similar heavy crudes produced in Latin America, are the crudes that would likely be displaced in the United States market by WCSB crude. As shown in Figure 4.14.3-3, Venezuela Bachaquero (shown as *Venezuelan* in the figure) lies at the upper end of the WTW GHG emission estimates; and
- Saudi Light (i.e., Middle Eastern Sour), which is assumed to be the balancing grade for world crude oil supplies in the short to medium term. Although Saudi Light is not a direct competitor to heavy crude oils in complex refineries, assuming it is the balancing grade for

[23] The results in TIAX 2009 and NETL 2008, 2009 reflect refining at PADD 3 Gulf coast refineries; Jacobs 2009 results reflect refining at PADD 2 Midwest refineries. See Section 1.4, Market Analysis, for a description of refinery regions and PADD locations.

world oil supplies means it is the crude that would likely ultimately be left in the ground. This assumption is based on the view that generally in the global market, only the Organization of the Petroleum Exporting Countries has spare production capacity that can be increased or decreased to balance the global crude market. As shown in Figure 4.14.3-3, Middle Eastern Sour (shown as *Saudi Arabia* in the figure) lies at the lower end of the WTW GHG emissions estimates.

The time period over which GHG estimates of WCSB oil sands and reference crudes are valid is a critical design factor. Most studies focused on recent conditions or years for which data were available. Since the lifecycle emissions of both WCSB oil sands crudes and reference crudes will change over the design lifetime of the proposed Project, comparisons based on current data will not account for future changes that could alter the differential between oil sands and reference crudes. How the differential will change in the future is not known, but determining if currently available studies have evaluated the impact is important, and this issue has been further considered with respect to several factors that could play a role in influencing GHG emission estimates in the near or long term.

An extensive assessment of the age of secondary data was conducted for four studies that were used to develop WTW GHG emission estimates for WCSB oil sands crudes in Section 6.0 of Appendix U, Lifecycle Greenhouse Gas Emissions (Jacobs Consultancy 2009, NETL 2008, NETL 2009, and TIAX 2009). The assessment showed that the studies sought to use the latest data available but, where data were limited, resorted to older studies for certain parameters. The older sources of secondary data are primarily for modeling reference crudes, with studies generally using more recent data for modeling WCSB oil sands crudes. According to the U.S. EIA, U.S. crude oil production is the highest it has been since 1992, at an average of 7 million bpd in November and December of 2012 (EIA 2013a). While there are many factors contributing to supply growth, a large factor is the emergence of light tight oil.[24] The U.S. crude oil share of total refinery crude slate has grown significantly over the last 7 years primarily as the result of increased tight oil production and decreased imports. While information on the lifecycle GHG emission implications of tight oil is limited, analysis of available studies (CARB OPGEE 2013 and MathPro 2013) indicates the emissions from production may increase while emissions from refining may decrease.

Crude Types and Extraction

The analysis also sought to understand how different crude types and extraction technologies associated with the oil sands crudes may affect GHG emissions. Two main methods of extracting bitumen are currently used in the WCSB oil sands:

- Shallower oil sands deposits (less than 75 meters below the surface) are typically removed using conventional mining methods, and the bitumen is separated from the rock and fine tailings.

[24] *Tight oil* refers to oil found in low-permeability and low-porosity reservoirs, typically shale. Bakken crude is considered tight oil. The technology of extracting crude oil from tight rock formations has only recently been exploited, but produces and supplies large quantities of crude oil into the domestic market. Shale oil extraction is a completely different process than oil sands development.

- Deeper oil sands deposits (more than 75 meters below the surface) are recovered using *in situ* methods. Most *in situ* recovery methods currently in operation involve injecting steam into an oil sands reservoir to heat the bitumen, and thus decreasing the bitumen's viscosity, enabling it to flow out of the reservoir sand matrix to collection wells. Steam is either injected using cyclic steam stimulation (CSS), where the same well cycles between periods of steam injection and bitumen production, or by steam-assisted gravity drainage (SAGD), where a pair of horizontal wells is drilled; the top well is used for steam injection and the bottom well for bitumen production.

GHG emissions vary by the type of extraction process used to produce bitumen. Due to the high energy demands for steam production, steam injection *in situ* methods are generally more GHG-intensive than mining operations. The studies reviewed indicate that *in situ* methods of extraction emit between 3 and 9 percent more GHGs than mining (on a WTW basis) (see Table 4-5 of Appendix U, Lifecycle Greenhouse Gas Emissions, for more details).

Once extracted, raw bitumen has a viscosity that is too high to be transported via pipeline. It is either blended with diluents[25] to lower its viscosity (the resulting blended bitumen is referred to as *diluted bitumen or dilbit*) and enable better flow through a pipeline, or is sent to an upgrader where the bitumen is partially refined—to remove the heavier hydrocarbon fractions (also known as *residuum*)—into synthetic crude oil (SCO),[26] which is a lower-viscosity crude oil with a resulting lower sulfur content. Bitumen that is blended with SCO produces synbit.

Other Factors

Other factors that affect GHG emissions intensity and were considered in the study in the process of estimating the differential between oil sands crude and the reference crudes included:

- Overall steam-oil ratios (SORs)[27] in CSS and SAGD processes (lower SORs are less energy intensive);
- Type of upgrading processes;
- Use of electricity cogeneration and export in facilities being studied;
- Accounting for the effects of upgrading in estimates of emissions related to refining;
- Accounting for the effects of diluting bitumen throughout the full lifecycle;
- Inclusion or exclusion of considerations for energy required to recover crudes from conventional oil reservoirs in reference crudes;
- Transportation distances; and
- Inclusion or exclusion of co-products within the LCA boundaries – such as petroleum coke (see Section 4.14.3.3).

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[25] Diluting raw bitumen with lighter hydrocarbons
[26] Upgrading to produce SCO lowers the viscosity of bitumen by removing the heaviest fraction of the oil (known as residuum).
[27] The SOR measures the volume of steam used to produce one unit volume of oil, and is a metric used to quantify the efficiency of oil recovery processes.

Sections 4.2, 4.3, and 4.4 of Appendix U, Lifecycle Greenhouse Gas Emissions, provide detailed discussions of these factors.

4.14.3.3 Petroleum Coke

Petroleum coke is a co-product produced by thermal decomposition (breaking down by heat) of residuum into lighter hydrocarbons, which occurs either during bitumen upgrading to create SCO prior to transportation or when transported dilbit or reference crudes are refined (see Figure 4.14.3-2). Petroleum coke is approximately 95 percent carbon by weight, and is a co-product that has very low demand in the U.S. marketplace and is therefore shipped to overseas markets, primarily China, for use as a fuel source. Petroleum coke is an important consideration in assessing lifecycle GHG emissions. It must be ensured that petroleum coke produced at the upgrader during production of SCO from oil sands bitumen is treated consistently in lifecycle analyses with petroleum coke produced at the refinery for transported dilbit and reference crudes. The LCA studies reviewed for this analysis applied different assumptions and approaches to include or exclude petroleum coke and other co-products from the LCA boundaries. These assumptions are discussed in Section 4.2.3.1 of Appendix U, Lifecycle Greenhouse Gas Emissions.

The actual net GHG emissions from petroleum coke, however, depend on the final end use of the petroleum coke (i.e., whether it is stockpiled or combusted). The fate of petroleum coke is influenced by market effects and access to markets, and varies depending on whether petroleum coke is produced at WCSB oil sands upgrading facilities in Alberta, Canada, or at U.S. Gulf Coast refineries. Section 5 of Appendix U, Lifecycle Greenhouse Gas Emissions, contains a detailed discussion of petroleum coke and market effects, and concludes that the lifecycle GHG emissions from the production and combustion of petroleum coke from oil sands should fundamentally be similar to heavy reference crudes due to the following:

- A barrel of raw bitumen will produce roughly the same amount of petroleum coke as a barrel of heavy crude, such as Venezuelan Bachaquero or Mexican Maya, which are commonly refined in the Gulf Coast;[28]
- Approximately half the upgrader petroleum coke manufactured in Alberta is stockpiled and not combusted, and therefore not emitting GHGs. This is due primarily to the lack of cost-effective routes to get the petroleum coke to market;
- Even if the share of petroleum coke stockpiled at upgraders in Canada declines, lifecycle GHG emissions from oil sands will nonetheless continue to be similar to the heavy reference crudes because oil sands contain approximately the same amount of petroleum coke as the heavy reference crudes;

[28] WCSB oil sands crude contain a similar fraction of vacuum residuum—the fraction of crude oil that is commonly used to produce petroleum coke, among other products—as other heavy crudes, such as Mexican Mayan and Venezuelan Bachaquero; see the discussion in Appendix U, Lifecycle Greenhouse Gas Emissions, for more information.

- Petroleum coke manufactured from heavy crude oils (both heavy crudes and oil sands) at U.S. Gulf Coast area refineries is combusted and GHG emissions from transportation to the China market need to be considered;
- The likely transportation of displaced reference crudes to alternative markets (e.g. Mexican Maya transported 10,000 miles to China rather than 700 miles to the Gulf Coast); and
- SCO has lower refining emissions because all the residuum processing was done at the upgrader.

The oil sands lifecycle petroleum coke-associated GHG emissions would likely be higher than the U.S. average barrel, especially with rapidly expanding shale oil production in North America, where the shale oils typically have a lighter composition and therefore do not result in as much petroleum coke production. Section 4.14.3.6, Near- and Long-Term Trends that Could Affect WTW GHG Emissions, provides further assessment of the petroleum coke GHG emissions specific to the proposed Project.

4.14.3.4 Land Use Change

Land use change emissions refer to land-related lifecycle GHGs emitted as a result of human activities, such as development, deforestation, and other physical impacts to the land. These can include immediate GHG releases from land disturbance as well as long-term changes to GHG sequestration patterns from changes in ecosystems. The land use changes resulting from WCSB oil sands development include the development of infrastructure, deforestation, and disturbance of peat-forming marshland to facilitate petroleum extraction. The use of mining techniques results in greater acreage of land use change than *in situ* and conventional crude extraction processes.

Carbon is sequestered and stored in several land-based stocks, including above- and below-ground biomass (i.e., biomass carbon stocks), and soil organic carbon (i.e., soil carbon stocks). Extraction of both conventional crudes and bitumen and the subsequent reclamation of extraction sites affect the levels of carbon in these stocks through several key carbon flows. These include immediate carbon release from land clearance and soil disturbance, foregone carbon sequestration, and carbon uptake during land reclamation. Foregone sequestration refers to the carbon which would have been sequestered had a land-based carbon sink where carbon is stored, such as in a peatland, not been cleared for development.

Section 4.2.3.3 of Appendix U, Lifecycle Greenhouse Gas Emissions, provides estimates of carbon stocks, carbon sequestration rates, and land reclamation rates for Canadian boreal forests and peatlands based on available studies. These studies conclude that oil sands developments will result in net releases of carbon from land-based stocks, and one study (Yeh et al. 2010) found that the net contribution of land use change to lifecycle emissions from WCSB oil sands development is relatively small, with the land use GHG emissions amounting to less than 0.4 to 2.5 percent of WTW lifecycle GHG emissions from oil sands production (considering both surface mining and *in-situ* production) over a 150-year modeling period. Section 4.14.3.5, Incremental GHG Emissions, provides further assessment of the land use GHG emissions specific to the proposed Project.

4.14.3.5 Incremental GHG Emissions

GHG Emissions Comparisons between Crudes

An analysis was undertaken to calculate GHG emissions associated with both WCSB oil sands crudes[29] and the reference crudes (that will be displaced). To ensure a consistent and like-for-like comparison of GHG emissions between WCSB oil sands crudes and the reference crudes, the WTW GHG emissions estimates were converted from barrels of crude to a weighted-average kilograms carbon dioxide equivalent ($kgCO_2e$) per barrel of gasoline and distillates (i.e., the total sum of gasoline, diesel, and jet fuel products) based on the yield of gasoline and distillates per barrel of crude for each respective study. The calculations also acknowledged the different methods used in GHG-intensity estimates between the studies reviewed. The ranges of WTW GHG emissions estimates from the studies for the relevant reference crudes are provided in Table 4.14-3 for each of the WTW lifecycle stages.

Table 4.14-3 Ranges of WTW GHG Emissions per Barrel for Weighted-Average Crudes by Lifecycle Stage

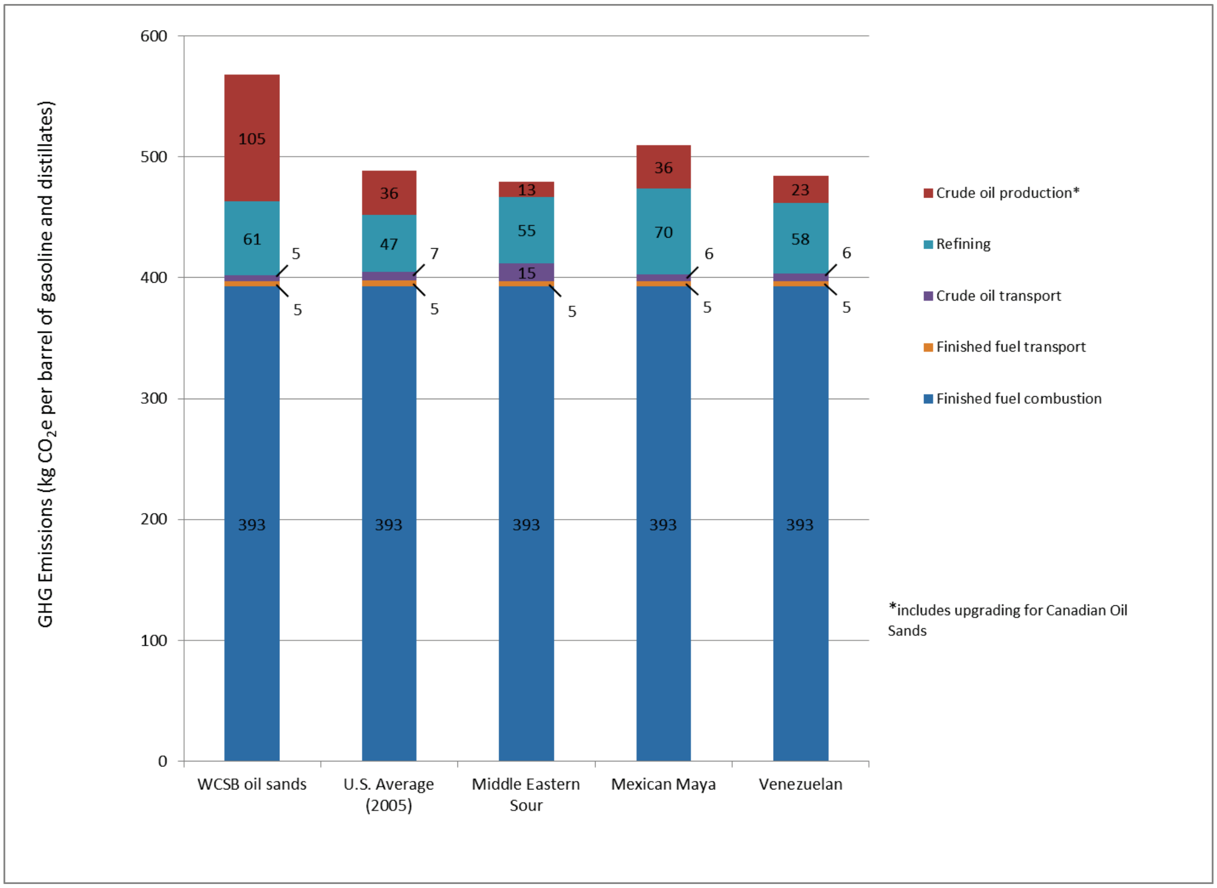
Crude Type	GHG Emissions $kgCO_2e$ per Barrel of Gasoline and Distillates[a]					
	Crude Oil Extraction/ Production[b]	Crude Oil Transport	Refining	Finished Fuel Transport	Fuel Combustion[c]	WTW Total
WCSB Oil Sands	74 - 105	1 - 9	59 - 71	2 - 5	387 - 393	533 - 568
U.S Average (2005)	36	7	47	5	393	488
Middle Eastern Sour	1 – 43	5 - 15	55 – 69	2 - 5	390 - 396	456 - 526
Mexican Maya	17 – 68	1 - 6	63 – 74	2 - 5	390 - 398	470 - 549
Venezuelan	23 - 55	1 - 7	58 - 86	2 - 5	390 - 405	485 - 553

[a] The yield of gasoline and distillates (i.e., premium fuel products) is calculated as the total volume of gasoline, diesel, and kerosene or kerosene-based jet fuel, divided by total refinery output.
[b] Includes upgrading for WCSB oil sands crudes.
Notes: GHG = greenhouse gas; IE = emissions from lifecycle stage included in other lifecycle stage; $kgCO_2e$ = kilograms carbon dioxide equivalent; SCO = synthetic crude oil; WCSB = Western Canadian Sedimentary Basin; WTW = well-to-wheels
Because these values represent a range drawn from the results of various studies, it is not possible to add them together to get to the total results. Instead, the results from one study need to be consistently summed with results from that study to produce the final result. For results by study, see Table 6-3 (for WCSB Oil Sands Crudes) and Table 6-12 (for Reference Crudes) in Appendix U, Lifecycle Greenhouse Gas Emissions.
[c] The fuel combustion lifecycle stage results in a range because each of the respective studies has a different relative yield of gasoline and distillates.

When comparing weighted average WTW GHG emissions estimates for WCSB oil sands crudes to those of reference crudes replaced by WCSB oil sands crudes transported by the proposed Project, the higher WTW emissions for WCSB oil sands crudes are largely driven by higher mining/extraction emissions. It also illustrates that the majority of WTW GHG emissions occur in the end use combustion phase, and that these emissions are consistent across all crudes. For illustration purposes, Figure 4.14.3-4 demonstrates this effect by comparing weighted average

[29] It is assumed that the composition of WCSB oil sands crude that would be transported by the proposed Project would be 80 percent dilbit and 20 percent SCO.

WCSB oil sands crudes to WTW emissions from relevant references crudes across the WTW lifecycle stages (using the specific data set from NETL 2009).



Sources: NETL 2009

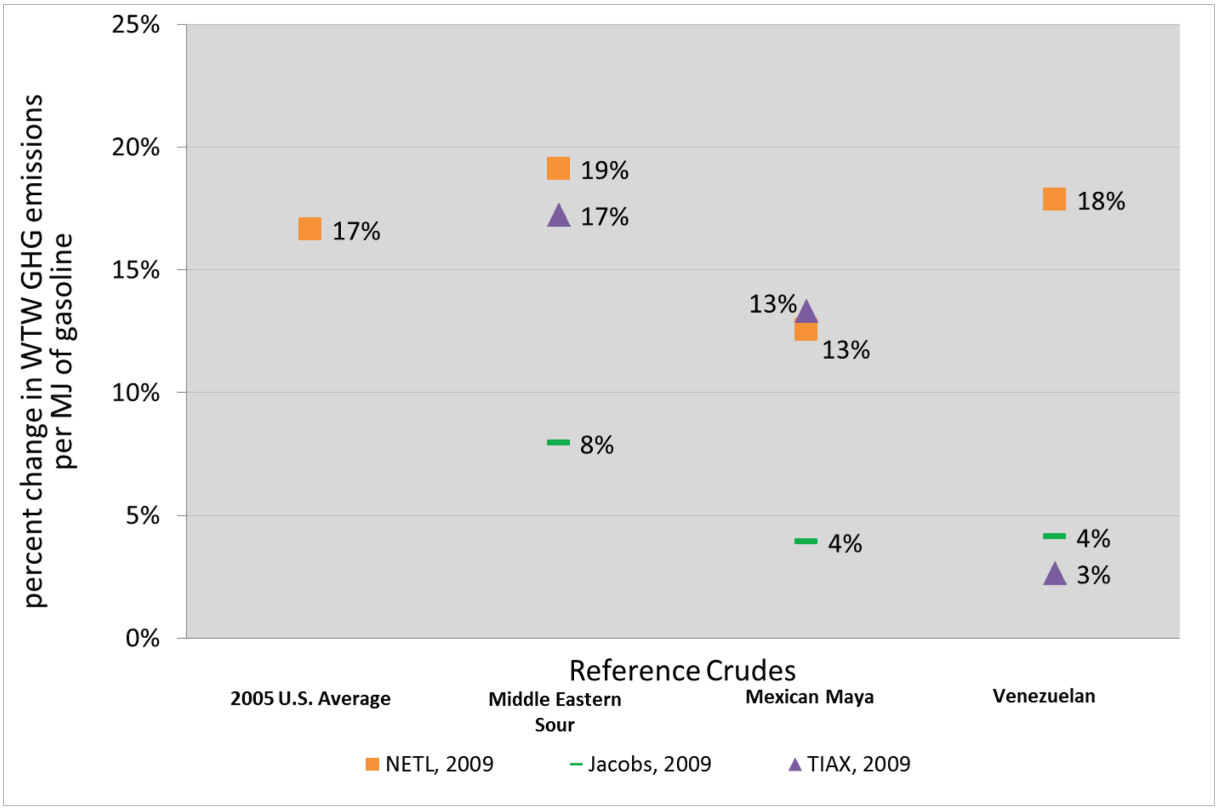
Notes: In this chart, all emissions are per barrel of gasoline and distillates. Venezuela Conventional is used as the NETL reference crude for Venezuela Bachaquero in this analysis. This is a medium crude, not a heavy crude; thus, the NETL values are compared against a lighter Venezuelan reference crude than other studies.
GHG = greenhouse gas, WCSB = Western Canadian Sedimentary Basin, WTW = well-to-wheels

Figure 4.14.3-4 WTW Weighted-Average GHG Emissions from the Mix of WCSB Oil Sands Crudes Compared to Reference Crudes in NETL (2009)

This trend is further demonstrated in Figure 4.14.3-5, which indicates the GHG intensity of crudes likely to be transported in the proposed Project relative to each of the four reference crudes on a gasoline basis. The weighted average mix of oil sands crudes is 2 to 13 percent[30]

[30] The results from NETL show that the GHG intensity of the weighted average mix of oil sands crudes is 18 percent higher than the Venezuelan crude. Venezuelan Conventional is used as the NETL reference crude for Venezuela Bachaquero in this analysis; this is a medium crude, not a heavy crude; thus, the NETL values are compared against a lighter Venezuelan reference crude than other studies in Figure 4.14.3-5.

higher in WTW GHG emissions compared to heavy reference crudes, and 8 to 19 percent higher compared to the lighter reference crudes.



Sources: NETL 2009, Jacobs 2009, TIAX 2009

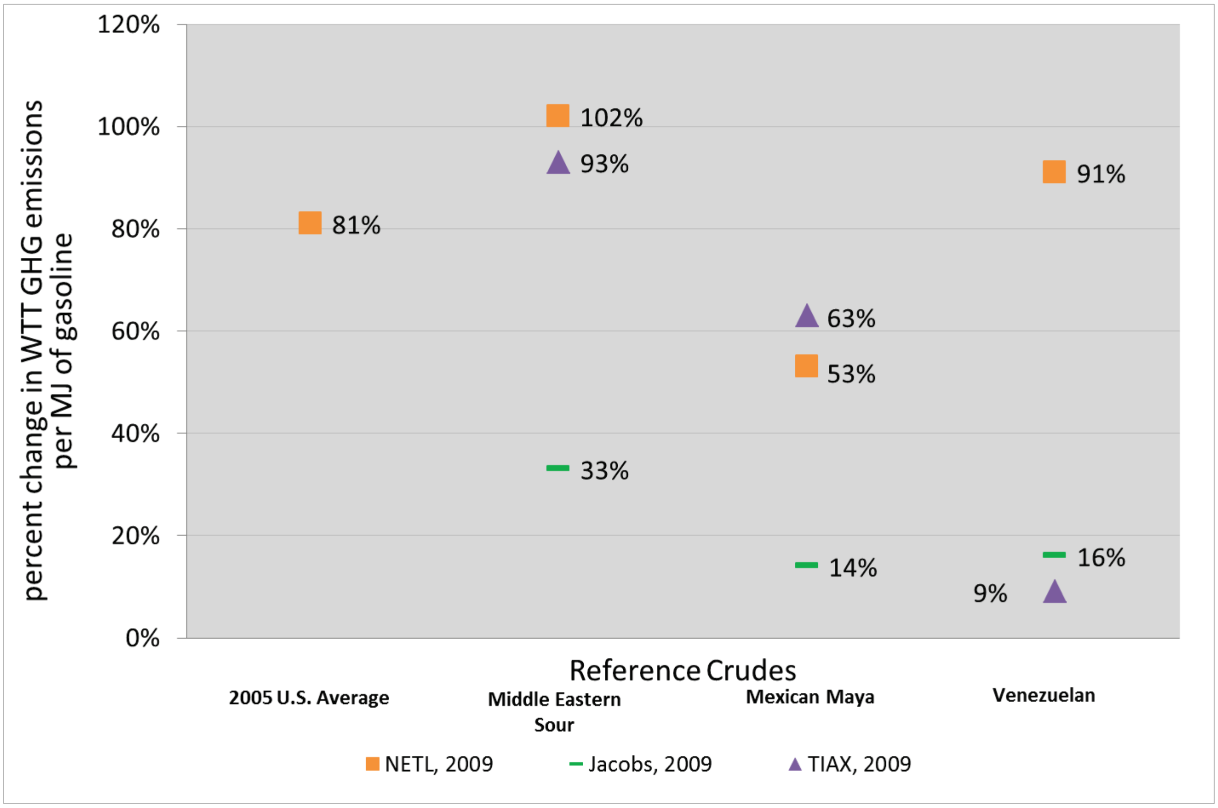
Notes: All emissions are per megajoule (MJ) of reformulated gasoline with the exception of NETL 2009, which is per megajoule of conventional gasoline. Venezuela Conventional is used as the NETL reference crude for Venezuela Bachaquero in this analysis; this is a medium crude, not a heavy crude; thus, the NETL values are compared against a lighter Venezuelan reference crude than other studies.

Figure 4.14.3-5 Percent Change in Near-Term WTW Weighted-Average GHG Emissions from the Mix of Oil Sands Crudes that may be Transported in the Proposed Project Relative to Reference Crudes

Well-to-Tank (WTT) Considerations

As introduced earlier, WTT analyses include the emissions associated with the processes up to, but not including, combustion of the refined products. Since final product combustion generally makes up approximately 70 to 80 percent of the WTW emissions and is the same regardless of the crude source, comparing crudes on a WTT basis accentuates their relative differences by only considering GHG emissions up to the refinery gate and excluding finished fuel combustion.

Compared to the WTW results in Figure 4.14.3-5 (showing that weighted average mix of oil sands crudes are 3 to 13 percent[31] higher in WTW GHG emissions compared to heavy reference crudes, and 8 to 19 percent higher compared to the lighter reference crudes), Figure 4.14.3-6 illustrates the same trends from the WTT perspective. The resulting percentage increases are much larger because they are calculated using the same numerator as in the WTW calculations, but with a much smaller denominator.



Sources: Data from NETL 2009, Jacobs Consultancy 2009, TIAX 2009

Notes: In this chart, all emissions are per MJ of reformulated gasoline with the exception of NETL 2009, which is per MJ of conventional gasoline. Venezuela Conventional is used as the NETL reference crude for Venezuela Bachaquero in this analysis. This is a medium crude, not a heavy crude; thus, the NETL values are compared against a lighter Venezuelan reference crude than other studies. The percent differentials refer to results for scenarios from the various studies and are calculated using the oil sands results relative to the corresponding study's reference crudes.

Figure 4.14.3-6 Comparison of the Percent Differential for Various WTT GHGs from Gasoline Produced from WCSB Oil Sands Relative to Reference Crudes

[31] Venezuela Conventional is used as the NETL reference crude for Venezuela Bachaquero in this analysis; this is a medium crude, not a heavy crude; thus, the NETL values are compared against a lighter Venezuelan reference crude than other studies. The 18 percent shown in Figure 4.14.3-5 for NETL is a medium Venezuelan crude.

Treatment of Petroleum Coke in WTW GHG Emission Estimates

The combustion of co-products is a significant issue for GHG emissions along the lifecycle of both WCSB oil sands and other crudes. The issue of petroleum coke has been summarized in Section 4.14.3.3, Petroleum Coke, and this section shows the contribution of petroleum coke to WTW GHG emissions estimates for WCSB oil sands crudes and other reference crudes.

Table 4.14-4 shows the range of GHG emissions from production and combustion of petroleum coke and other co-products. For WCSB oil sands crudes, the table also shows GHG emissions accounting for stockpiling at Canadian upgraders, assuming that an 80/20 ratio of dilbit to SCO is transported by the proposed Project, that none of the bitumen produced from dilbit is stockpiled, and that 54 percent of the bitumen produced from SCO is stockpiled at Canadian upgraders (Energy Resources Conservation Board [ERCB] 2013). Table 4.14-4 also calculates the GHG gains achieved (referred to as substitution credit) associated with the petroleum coke that is used to offset coal-fired electricity generation.[32] Coal accounted for nearly half the increase in global energy use over the past decade, and China was responsible for nearly half of global coal use in 2009 (IEA 2011). Against this demand, the influx of new coke into the market and the impact it might have on the coal and electricity markets is relatively small. If all the produced coke from the proposed Project were shipped to China, this would only replace 0.16 percent of the coal currently consumed there.

The results from Table 4.14-4 are used below to include the net GHG contribution of co-products—particularly from the production and combustion of petroleum coke—in the WTW GHG emissions for WCSB oil sands and other reference crudes.

[32] The combustion of petroleum coke offsets GHG emissions from coal-fired electricity production, and this offset has been assumed to be on a one-to-one basis per unit of energy (from Jacobs Consultancy 2009). The comparison is made on an energy basis—as opposed to a mass basis—because energy is the final desired output when petroleum coke or coal are used as fuels. Further detail is provided in Section 6.2 of Appendix U, Lifecycle Greenhouse Gas Emissions.

Table 4.14-4 Range of GHG Emissions from the Production and Combustion of Petroleum Coke and Other Co-Products for WCSB Oil Sands Crudes and Other Reference Crudes

Crude	GHG Emissions from Production and Combustion of Petroleum Coke and Other Co-Products (kgCO2-equivalent per barrel of gasoline and distillates)	Substitution Credit for Combustion of Petroleum Cokec (kgCO2-equivalent per barrel of gasoline and distillates)	Net GHG Emissions from Production, Combustion of Petroleum Coke and Other Co-Products and Coal Substitution (kgCO2-equivalent per barrel of gasoline and distillates)
WCSB oil sands	110 - 156 / 98 - 152[a]	0 - 132 / 0 - 118[a]	0 - 13 / 0 - 11[a]
U.S. Average (2005)[b]	131	Not calculated	Not calculated
Middle Eastern Sour	36 - 124	0 - 61	0 – 6
Mexican Maya	99 - 132	0 - 100	0 – 9
Venezuelan	105 - 126	0 - 103	0 - 10

[a] The second value for WCSB oil sands crudes represents petroleum coke emissions from WCSB oil sands emissions, accounting for stockpiling at Canadian upgraders. Stockpiling of petroleum coke at Canadian upgraders assumes an 80/20 ratio of dilbit to SCO, in the proposed Project, that none of the petroleum coke produced from dilbit is stockpiled, and that 54 percent of the petroleum produced from SCO is stockpiled at Canadian upgraders (ERCB 2013).
[b] The 2005 U.S. average crude is based on NETL (2008, 2009), which includes the production and combustion of co-products other than petroleum coke (i.e., residual fuel oil, light and heavy ends). The study did not calculate a substitution credit for these values, so it has not been included for the WCSB oil sands and reference crude results that are based on NETL—including the 2005 U.S. average.
[c] The substitution credit represents petroleum coke production that goes into fuels markets, which results in more coke consumed and displaces the consumption of some coal.
Notes: Please refer to Section 6.3 and Table 6-11 in Appendix U, Lifecycle Greenhouse Gas Emissions, for full details of these calculations and for results by study.
Because these values represent a range drawn from the results of various studies, it is not possible to add them together to get to the net emission results. Instead, the results from one study need to be consistently summed with results from that study to produce the final result.

Land Use Emissions

The GHG emissions from land clearing for WCSB oil sands projects were not included in the NETL, Jacobs, or TIAX studies. The study by Yeh et al. (2010), published after these reports were released, estimated land use GHG intensity for oil sands developments and included GHG emissions from losses in soil carbon, biomass, forgone CO_2 sequestration in peatland, and CH_4 emissions from tailings ponds. The Yeh et al. (2010) estimates range from 3.9 to 10.24 gCO_2e/MJ refinery feedstock for surface mining extraction and 0 to 0.23 gCO_2e/MJ refinery feedstock for *in situ* extraction. Those estimates were used in one LCA study to calculate the magnitude of land use change emissions relative to incremental GHG emissions from WCSB oil sands crudes transported through the proposed Project (Jacobs Consultancy 2012). Jacobs Consultancy 2012, using data from Yeh et al. 2010, provided land use emissions estimates for oil sands mining and *in situ* extraction. Table 4.14-5 below summarizes how each land use change source contributes to the total land use change emissions for each extraction method.

Table 4.14-5 Share of Total GHG Emissions from Land Use Change by Land Use Change Source

Land Use Change Source	Oil Sands Mining	Oil Sands In Situ
Soil CO_2	25%	86%
Biomass CO_2	1%	0%
Foregone Sequestration of CO_2	1%	14%
Tailing Pond CH_4	55%	0%
Jacobs Estimate of CH_4 from Mine Face	18%	NA

Source: Jacobs Consultancy 2012 (Table 5-8) on a bitumen basis, based on Yeh et al. 2010 (Table 3)

Note: NA = not applicable

Jacobs Consultancy 2012 calculated values for Yeh et al.'s central estimate only. This Final Supplemental EIS took the high and low estimates from Yeh et al. (2010), and scaled by an equivalent yield of SCO from bitumen to calculate the full range. These values were converted using the energy content of bitumen and the yield of gasoline and distillates per barrel of bitumen from Jacobs to calculate low, central, and high estimates of net land use GHGs for surface mining and *in situ* WCSB oil sands crudes (see Section 6.1.1 of Appendix U, Lifecycle Greenhouse Gas Emissions). Finally, weighted average low, central, and high estimates of annual land use change GHG emissions were calculated based on the assumed composition of WCSB oil sands crude that the proposed Project would transport (i.e., 80 percent *in situ* dilbit, 18.6 percent surface mining SCO, and 1.4 percent *in situ* SCO). The median weighted average annual land-use change emissions for WCSB oil sands crudes were estimated to be approximately 4.9 $kgCO_2e$/barrel of gasoline and distillates, with a range of 0.8 to 10.8 $kgCO_2e$ per barrel of gasoline and distillates (see Table 4.14-6).

Table 4.14-6 Range in Net Land Use GHG Intensity of Surface Mining and *In Situ* Extraction Methods, and the Weighted Average Mix of WCSB Oil Sands Crudes

Extraction method	Land use intensity (calculated) ($kgCO_2e$/bbl gasoline and distillates)		
	Central	Low	High
Surface Mining	24.3	4.3	52.5
In situ	0.4	0.0	1.3
Weighted Average[a]	4.9	0.8	10.8

[a] Calculated based on assumed composition of WCSB oil sands crude that will be transported by the proposed Project.
Notes: Please refer to Section 6.1.1 and Tables 6-4, 6-5, and 6-6 in Appendix U, Lifecycle Greenhouse Gas Emissions, for further detail on these calculations and for results by study.
The results from Table 4.14-6 are used below to separately show the contribution of land use change emissions to lifecycle GHGs for oil sands crudes (see Table 4.14-8).

Estimates of Incremental GHG Emissions

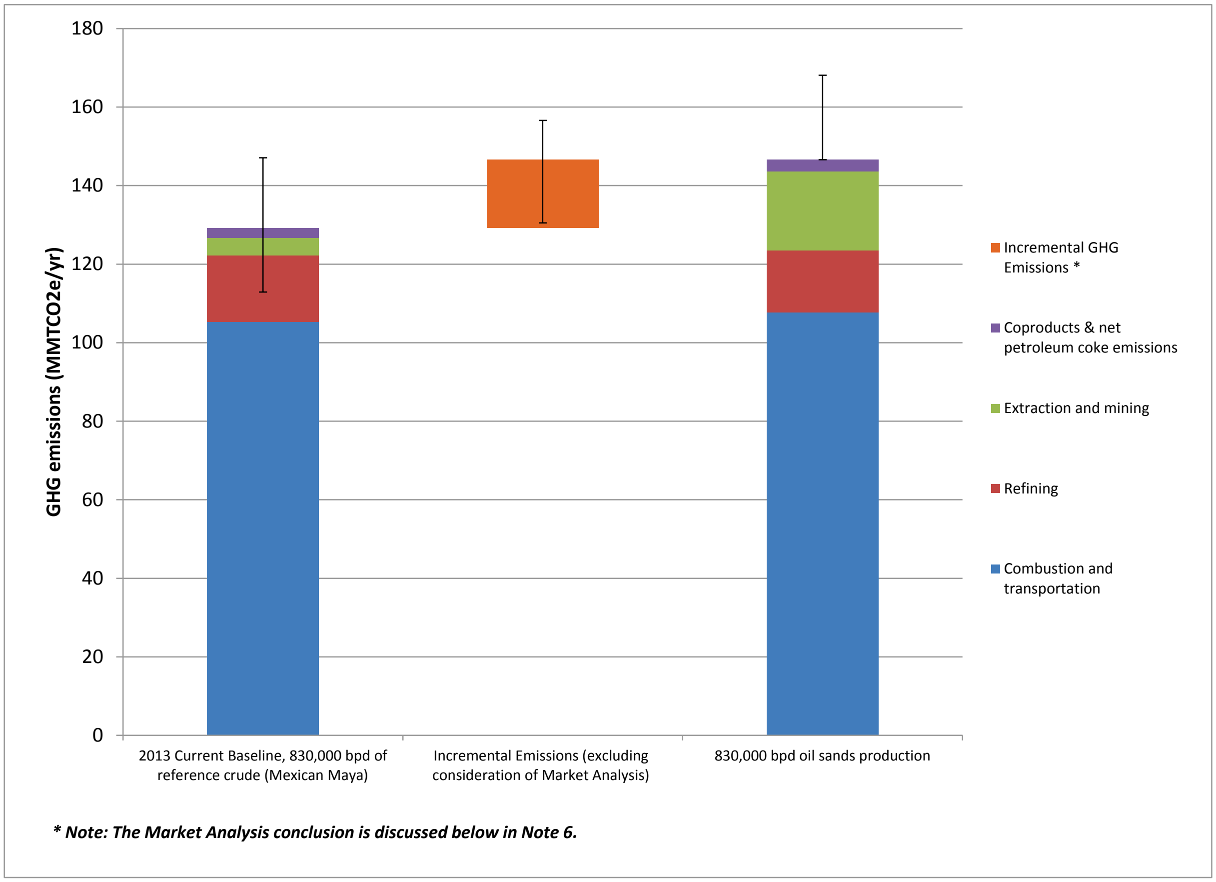
This section draws together the different contributing factors for GHG emissions in order to calculate the GHG emissions associated with crude oil that would be transported by the proposed Project.

The total lifecycle emissions associated with production, refining, and combustion of 830,000 bpd of oil sands crude oil is approximately 147 to 168 $MMTCO_2e$ per year.[33] The annual lifecycle GHG emissions from 830,000 bpd of the four reference crudes examined in this section are estimated to be 124 to 159 $MMTCO_2e$. The range of incremental GHG emissions for crude oil that would be transported by the proposed Project is estimated to be 1.3 to 27.4 $MMTCO_2e$ annually.[34, 35] Figure 4.14.3-7 presents these emissions and the associated incremental emissions.

[33] This emissions estimate, 147 to 168 $MMTCO_{2e}$, could be considered an increase in total global CO_2 emissions if one assumed the full 830,000 bpd of additional supply was equivalent to 830,000 bpd of additional demand/consumption. A working document from the Stockholm Environmental Institute estimated GHG emissions associated with different assumptions about whether additional oil sands crude would make it to market, and the potential impact increased oil supplies could have on increased oil consumption by lowering crude oil prices. It estimated that an additional 830,000 bpd of additional global crude oil supply could result in a total increase in global oil demand/consumption of approximately 500,000 bpd in 2020. According to the estimates in the working paper, such an increase in global demand/consumption could produce approximately 93 $MMTCO_{2e}$ emissions per year (Lazarus and Erickson 2013).

[34] Because the estimates of lifecycle emissions from oil sands (i.e., 147 to 168 $MMTCO_2e$) and the four reference crudes (i.e., 124 to 159 $MMTCO_2e$) both represent ranges across various studies, it is not possible to subtract the high and low bounds from each to arrive at the net emissions result. Instead, the results for oil sands crudes from one study need to be consistently compared against the results for the other reference crudes from the same study to produce the final net emissions result (i.e., 1.3 to 27.4 $MMTCO_2e$).

[35] These estimates include GHG emissions from co-product combustion and any offsets for displacement of coal from petroleum coke co-products, as calculated in Table 4.14-4.



Notes:
1) The columns plotted are illustrative to show the order of magnitude of GHG emissions for the different lifecycle stages (TIAX 2009 data was used as a mid-range data set; for the 2013 Current Baseline, Mexican Maya was used at the Reference Crude).
2) The range bars represent the range of GHG emissions estimated across the three studies (NETL 2009, Jacobs 2009, TIAX 2009) and each of the reference crudes.
3) The results are based on the preceding results presented in Section 4.14.3.5, Incremental GHG Emissions, which are from Appendix U, Lifecycle Greenhouse Gas Emissions, and based on NETL 2009, Jacobs 2009, TIAX 2009.
4) 2013 Current Baseline: This represents today's position of the WTW GHG emissions currently being emitted based on 830,000 bpd of each of the selected reference crudes (the column is for TIAX Mexican Maya as per note 1, and the range bar is for all reference crudes).
5) 830,000 bpd Oil Sands Production: This assumes the proposed Project is built and a maximum of 830,000 bpd of WCSB crude oil that otherwise would not have been produced is transported to the Gulf Coast refineries.
6) Incremental Emissions: This represents the difference between the 2013 Current Baseline and the 830,000 bpd Oil Sands Production, and excludes consideration of the Market Analysis. The orange bar represents incremental emissions. The bar itself is for a single crude (Mexican Maya) from the TIAX study. The range bar is representative of all studies and reflects the 1.3 to 27.4 $MMTCO_2e$ annual incremental emissions presented in the Final Supplemental EIS. These Incremental Emissions represent the potential increase in emissions attributable to the proposed Project if one assumed that approval or denial of the proposed Project would directly result in a change in production of 830,000 bpd of oil sands crudes in Canada. However, as set forth in Section 1.4, Market Analysis, such a change is not likely to occur. Section 1.4 notes as stated in the conclusion of the Draft Supplemental EIS that approval or denial of any one crude oil transport project, including the proposed Project, remains unlikely to significantly impact the rate of extraction in the oil sands, or the continued demand for heavy crude oil at refineries in the United States (based on expected oil prices, oil-sands supply costs, transport costs, and supply-demand scenarios).

Figure 4.14.3-7 WTW GHG Emissions from Weighted Average WCSB Oil Sands Crudes, and Incremental WTW GHG Emissions from Displacing Reference Crudes

The estimated range of potential emissions is large because there are many variables, including the reference crude that is displaced, which reference crude is used for the comparison, and which study is used for the comparison. Below is more summary information explaining the range:

- The upper end of this range, the 27.4 MMTCO_2e estimate, is based on comparing the average emissions for 830,000 bpd of oil sands crude (the total capacity of the proposed Project), assuming the displaced reference crude is a light, low-GHG crude oil, such as Middle-Eastern Sour, and looking at emissions estimates from the NETL study.
  - Based on these same assumptions, and looking at the Jacobs Study, the estimate would be approximately 9.0 MMTCO_2e.
  - Based on these same assumptions, and looking at the TIAX Study, the estimate would be approximately 22.2 MMTCO_2e.
- The lower end of the range, down to the 1.3 MMTCO_2e estimate, is based on assuming the displaced reference crude is a heavy crude such as Mexican Maya or Venezuelan heavy, and looking at the results from the Jacobs study.
  - Based on these same assumptions, and looking at the TIAX Study, the estimate would be approximately 5.9 MMTCO_2e for Venezuelan heavy to 17.4 MMTCO_2e for Mexican Maya.
  - Based on the assumption that the displaced reference crude is Mexican Maya, and looking at the NETL Study, the estimate would be approximately 18.4 MMTCO_2e.[36]

The above estimates represent the total incremental emissions associated with production and consumption of 830,000 bpd of oil sands crude compared to the reference crudes. These estimates represent the potential increase in emissions attributable to the proposed Project if one assumed that approval or denial of the proposed Project would directly result in a change in production of 830,000 bpd of oil sands crudes in Canada. However, as set forth in Section 1.4, Market Analysis, such a change is not likely to occur. Section 1.4 notes that as stated in the conclusion of the Draft Supplemental EIS, approval or denial of any one crude oil transport project, including the proposed Project, is unlikely to significantly impact the rate of extraction in the oil sands, or the continued demand for heavy crude oil at refineries in the United States

[36] Venezuelan Conventional is used as the NETL reference crude for Venezuelan Bachaquero in this analysis. This is a medium crude, not a heavy crude. Therefore, the NETL comparison uses a lighter Venezuelan reference crude than the Jacobs and TIAX studies.

(based on expected oil prices, oil-sands supply costs, transport costs, and supply-demand scenarios).[37]

The incremental GHG emissions associated with production and consumption of 830,000 bpd of oil sands crude oil compared to the reference crudes is estimated to be 1.3 to 27.4 $MMTCO_2e$ annually.[38] This is equivalent to annual GHG emissions from combusting fuels in approximately 270,833 to 5,708,333 passenger vehicles, the CO_2 emissions from combusting fuels used to provide the energy consumed by approximately 64,935 to 1,368,631 homes for 1 year, or the annual CO_2 emissions of 0.37 to 7.8 coal fired power plants.

The increments presented here are based on lifecycle emission estimates for current or near-term conditions in the world oil market. Over time, however, the GHG emission estimates for fuels derived from both oil sands crude oils and the reference crude oils are likely to change. For instance, it would likely become more energy-intensive to produce reference crudes over time as fields mature and secondary and tertiary recovery techniques, such as CO_2 or water flooding, are required to maintain production levels. Many of the reference crude oil reservoirs are 1 to 2 miles (or more) underground or under the ocean floor, and exploration efforts for new deep oil reservoirs would continue as known reservoirs deplete. GHG emissions from mining and *in situ* SAGD oil sands crude production have decreased over the last decade (IHS CERA 2012).[39] Although it is unclear how the GHG intensity of reference crudes relative to oil sands crudes will change over time, if these trends continue (i.e., the GHG intensity for future reference crudes continued upward and the GHG intensity of future oil sands production continued downward), then the differential in WTW GHG emissions of oil sands crudes would decrease relative to reference crudes. See Section 4.1.4 of Appendix U, Lifecycle Greenhouse Gas Emissions, for a discussion of factors that could influence the GHG emissions intensity of both WCSB oil sands and other reference crudes in the future.

The full summary of results for all studies and reference crudes is shown in Table 4.14-7.

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[37] The Draft Supplemental EIS estimated how oil sands production would be affected by long-term constraints on pipeline capacity (if such constraints resulted in higher transportation costs) if long-term WTI-equivalent oil prices were less than $100. The Draft Supplemental EIS also estimated a change in GHG emissions associated with such changes in production. The additional data and analysis included in this Final Supplemental EIS provide greater insights into supply costs and the range of prices in which pipeline constraints would be most likely to impact production. If WTI-equivalent prices fell to around approximately $65 to $75 per barrel, if there were long-term constraints on any new pipeline capacity, and if such constraints resulted in higher transportation costs, then there could be a substantial impact on oil sands production levels. This is discussed further in Section 1.4.5.4, Implications for Production.

[38] The Draft Supplemental EIS indicated that this range to be 3.3 to 20.8 $MMTCO_2e$ per year, but noted that the NETL (2008, 2009) study did not account for production and combustion of co-products, and that the calculated incremental GHG emissions could increase by 30 percent if these were accounted. The upper end of the range in the Final Supplemental EIS reflects the inclusion of co-products in the calculated results based on the NETL study.

[39] The estimate of oil sands GHG intensity used in this Final Supplemental EIS is based on an approximate 80 percent mix of *in situ* production. This estimated mix of *in situ* production is based on the pipeline design specifications, which assume up to an approximate 80 percent mix of diluted bitumen that is derived primarily from *in situ* projects.

Table 4.14-7 Incremental WTW GHG Emissions from Weighted-Average WCSB Oil Sands Crudes Relative to Reference Crudes

Crude Contribution	2013 Current Baseline, 830,000 bpd of Reference Crude(s)[a]	830,000 bpd Oil Sands Production[b]	Incremental Emissions (Excluding Consideration of Market Analysis)[c]
WCSB oil sands	Not currently transported	147-168	--
U.S. Average (2005)	145	--	23.5
Middle Eastern Sour	124-151	--	9.0-27.4
Mexican Maya	129-158	--	2.2-18.4
Venezuelan [d]	141-159	--	1.3-25.7
Summary Range	124-159	147-168	1.3-27.4

Notes: Because these values represent a range drawn from the results of various studies, it is not possible to add them together to get to the net emission results. Instead, the results from one study need to be consistently summed with results from that study to produce the final result.

[a] Based on a combination of the WTW GHG emissions for the reference crudes provided in Table 4.14-3 and the net petroleum coke GHG emissions in Table 4.14-4 for 830,000 bpd.

[b] Based on a combination of the WTW GHG emissions for the WCSB crude oil provided in Table 4.14-3 and the net petroleum coke GHG emissions in Table 4.14-4 (assuming all petroleum coke is combusted) for 830,000 bpd.

[c] Incremental Emissions: This represents the difference between the 2013 Current Baseline and the 830,000 bpd Oil Sands Production, and excludes consideration of the Market Analysis. These Incremental Emissions represent the potential increase in emissions attributable to the proposed Project if one assumed that approval or denial of the proposed Project would directly result in a change in production of 830,000 bpd of oil sands crudes in Canada. However, as set forth in Section 1.4, Market Analysis, such a change is not likely to occur.

[d] Venezuelan Conventional is used as the NETL reference crude for Venezuelan Bachaquero in this analysis. This is a medium crude, not a heavy crude, thus, the NETL values are compared against a lighter Venezuelan reference crude than other studies.

If these incremental emissions are summed for the entirety of the proposed Project timeframe (construction plus 50 operational years), the total accumulated range of incremental WTW GHG emissions attributable to the proposed Project and associated with the crude oil that could be transported by the proposed Project would be as summarized in Table 4.14-8. This estimate does not account for factors that could change the relative GHG intensity of WCSB oil sands crudes compared to other reference crudes, which are discussed in Section 4.14.3.6, Near- and Longer-Term Trends that Could Affect WTW GHG Emissions.

Table 4.14-8 Accumulated Incremental WTW GHG Emissions over Proposed Project Lifetime

Crude	Construction GHG Emissions[a]	Land Use Change Emissions[b]	50-Year Incremental GHG Emissions[c]	Accumulated Incremental GHG Emissions[d]
	MMTCO$_2$e			
Incremental GHG Emissions for Construction and Operation of the Proposed Project plus Incremental Emissions Associated with Production and Consumption of 830,000 bpd of Oil Sands Crude[d]	0.24	70	65 - 1,370	135 - 1,430

Notes: GHG = greenhouse gas, MMTCO$_2$e = million metric tons carbon dioxide equivalent, WTW = well-to-wheels

[a] Results are from Table 4.14-1.

[b] Results are from Table 4.14-6, where the results were converted to annual GHG emissions by multiplying by the maximum throughput of the proposed Project (830,000 bpd), assuming operation over the full 365 days in a year. The throughput of the proposed Project was normalized to a basis of gasoline and distillates using the yields in each study. The result was multiplied by 50 years.

[c] Results from Table 4.14-7 multiplied by 50 years. Does not account for changes in pipeline throughput over time or changes in the GHG intensity of WCSB oil sands crudes relative to other reference crudes in the future. Operational GHG emissions are assumed to be covered in the incremental emissions as part of the lifecycle assessment.

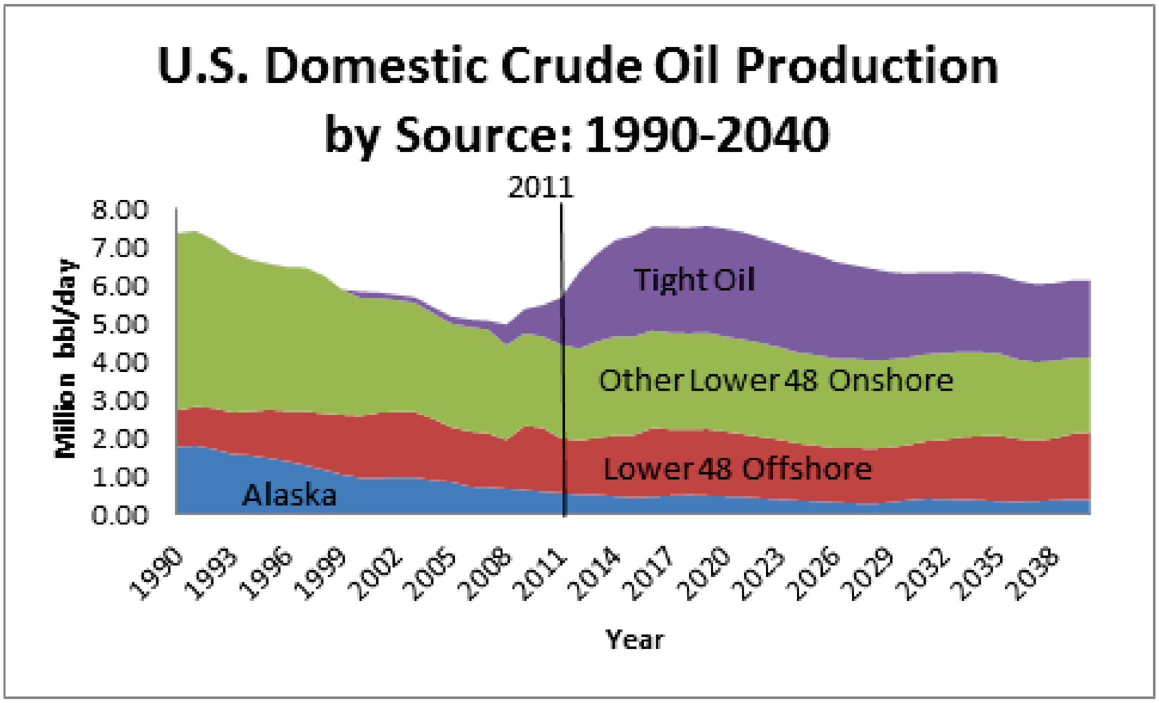
[d] Calculated by summing the Construction GHG Emissions, Land Use Change Emissions and 50-Year Incremental GHG Emissions.

4.14.3.6 Near- and Longer-Term Trends that Could Affect WTW GHG Emissions

The increments presented here are based on lifecycle emission estimates for current or near-term conditions in the world oil market. Over time, however, the GHG emission estimates for fuels derived from both oil sands crude oils and the reference crude oils are likely to change. Since the lifecycle emissions of both WCSB oil sands crudes and reference crudes will change over the design lifetime of the proposed Project, comparisons based on current data will not account for future changes that could alter the differential between oil sands and reference crudes. How the differential will change in the future is not known, but determining if currently-available studies have established the impact is important. This section discusses key factors that could play a role in influencing GHG emission estimates in the near- or long-term.

Emergence of Tight Oil Production, Decrease in U.S. Imports, and Change in Average U.S. Crude Slate Mix

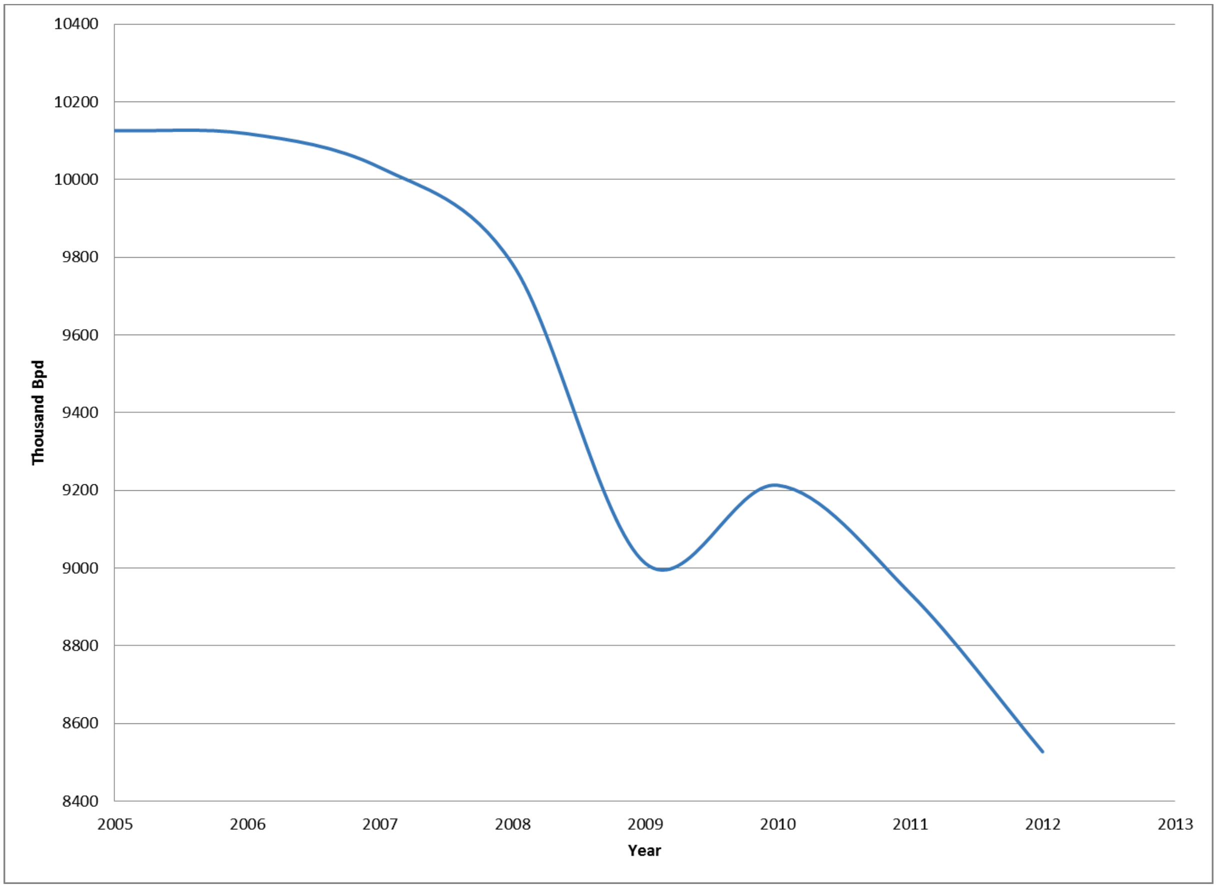
U.S. crude oil production is the highest it has been since 1992, at an average of 7 million bpd in November and December of 2012 (EIA 2013b). While many factors contribute to supply growth, a large factor is the emergence of tight oil. Domestic tight oil production has increased from 0.19 million bpd in 2005 to 1.22 million bpd in 2011 (EIA 2013c). Figure 4.14.3-8 below illustrates these trends.



Source: EIA 2013c

Figure 4.14.3-8 U.S. Domestic Crude Production by Source from 1990 to 2040

In addition to the emergence of tight oil, a decrease in crude oil imports is changing the U.S. crude oil slate mix. Crude oil imports have fallen nearly 16 percent from 2005 to 2012, as shown in Figure 4.14.3-9 (EIA 2013d).



Source: EIA 2013d

Figure 4.14.3-9 U.S. Crude Oil Imports from 2002 to 2012

The U.S. crude oil share of total refinery crude slate has grown significantly over the last 7 years, primarily as the result of increased tight oil production and decreased imports. The crude volumes from countries supplying the U.S. have decreased significantly (as shown in Table 4-3 of Appendix U, Lifecycle Greenhouse Gas Emissions). IHS CERA, however, found in preliminary results from a recent assessment that the GHG intensity of the U.S. average crude baseline has *not changed materially* between 2005 and 2012 despite significant changes to the crude mix (IHS CERA 2013).[40, 41] Applying GHG intensities developed by NETL (2009) to the 2012 crude mix in Table 4-3 of Appendix U, Lifecycle Greenhouse Gas Emissions, the reduction

[40] IHS CERA (2013) estimated that the differential between the WTW GHGs for oil sands crudes and their derived 2012 U.S. average crude mix is 9 percent higher, which is 3 percent lower than the IHS CERA 2012 report of a 12 percent differential with the NETL 2005 U.S. average crude mix. IHS CERA attributes the difference to the uncertainty in calculating carbon intensities. IHS CERA (2013) also used a different methodology from NETL to estimate the average crude mix and the GHG emissions for each crude stream.
[41] Brandt (2012) found that the most important factor affecting the comparability of studies is whether study results are industry average oil-sands fuel pathways, or modeled emissions from specific oil sands projects. This methodological difference overshadows the other sources of between-model variability.

in WTW GHG intensity is estimated to be on the order of 1 percent for gasoline produced from the average crude mix in the United States between 2005 and 2012. These estimates indicate that the overall change in the GHG intensity of the U.S. average crude is minor, as increases in higher-GHG intensity crudes have been offset by greater volumes of lower-GHG intensity crudes.

Impact on Crude Oil Extraction and Refining GHG Emissions

The GHG emissions associated with the raw material acquisition and refining stages of the NETL 2009 LCA study are likely to change due to increased tight oil production, decreased crude oil imports, and a shifting crude slate mix. Little information is available on tight oil production lifecycle effects in the recent U.S. crude oil market; however, analysis of the available studies indicates the emissions from production may increase while emissions from refining may decrease (CARB OPGEE 2013 and MathPro 2013), as discussed in Section 4.1.4 of Appendix U, Lifecycle Greenhouse Gas Emissions.

Other Factors That May Influence the Longer-Term GHG Emissions of WCSB Oil Sands and Reference Crudes

Many factors will likely affect the lifecycle GHG emissions of both WCSB oil sands and reference crudes over time. First, GHG emissions from extraction will increase in the future for most reference crudes as it will take more energy to extract crude from increasingly depleted oil fields and to explore for further resources. In comparison, many WCSB oil sands are near the surface. This means that, for surface-mined bitumen, energy requirements are likely to stay relatively constant. At the same time, *in situ* extraction, which is generally more energy- and GHG-intensive than mining, will represent a larger share of the overall oil sands production in the future, increasing from about 45 percent of 2009 oil sands production to an estimated 58 percent by 2022 (ERCB 2013). In particular, the share of SAGD *in situ* extraction methods is projected to rise from roughly 20 percent in 2011 to 45 percent of oil sands production in 2030 (IHS CERA 2012).[42] As with reference crudes, reservoir quality is expected to decline over time and could lead to increased energy needs for extracting bitumen using *in situ* methods (IHS CERA 2012), though this *depletion effect* has not been observed yet and may be relatively minor (Brandt et al. 2013). While these factors could increase oil sands lifecycle emissions, some analysts also predict that technical innovations will likely continue to reduce the GHG-intensity of *in situ* SAGD operations. For example, decreased steam use and new hybrid steam-solvent techniques could reduce WTT GHG emissions by as much as 5 to 20 percent for *in situ* production (IHS CERA 2012). IHS CERA 2012 also describes a new mining method that will eliminate the upgrading step and reduce WTW GHG emissions by 6 percent. Jacobs Consultancy (2012) investigated several technologies and process improvements that are reducing the carbon intensity of WCSB oil sands crude production. These efficiencies could reduce the WTW carbon intensity of refined products from oil sands crudes by 7 to 5 percent for *in situ* and mining extraction methods, respectively (Jacobs Consultancy 2012).

[42] Although the balance of mining and *in situ* extraction will change in the future, there are incentives for producers to keep GHG intensity as low as possible. For example, Alberta's climate policy requires that oil sands producers and other large industrial GHG emitters reduce their emissions intensity by 12 percent from an established baseline.

Over the longer term, CCS technologies could reduce the GHG footprint of WCSB oil sands crudes. The feasibility and timeframe for widespread adoption and commercialization of CCS remains highly uncertain (Alberta Carbon Capture and Storage Development Council 2009).

Alternatively, traditional oil wells will likely require more energy intensive techniques to continue extracting oil. For example, all conventional crudes such as Saudi Arab Light and most of U.S. production prior to the shale oil boom are in various stages of declining production, requiring enhanced production techniques with larger energy intensities per barrel of oil produced. This is because traditional oil extraction techniques can only extract between 45 and 55 percent of the oil in the reservoir. To extract more oil, enhanced oil recovery techniques (formerly called *Tertiary Recovery Techniques*) must be used (Tzimas et al. 2005). These techniques are not only more expensive, but are usually more energy intensive, especially in terms of increased electricity consumption (NETL 2009), and potentially more harmful to the environment (USEPA 2013c). Also, these enhanced oil recovery techniques can only currently extract an additional 5 to 15 percent of the oil in the reservoir, which means that additional techniques will need to be developed to continue extracting oil from these reservoirs (Tzimas et al. 2005).

The gap in WTT GHG emissions between WCSB oil sands and reference crudes may narrow as reference crude production becomes more energy intensive, and if the energy intensity of oil sands *in situ* production becomes more efficient. On the other hand, there is considerable uncertainty regarding the extent to which petroleum coke combustion could increase and the rate of adoption of CCS and development of CO_2 pipeline infrastructure.

4.14.4 Cumulative Greenhouse Gas Emissions and Climate Change Impacts

This section provides a summary of the GHG emissions of the proposed Project described in the previous sections, along with information on other GHG emission levels to provide additional context for the proposed Project's GHGs and potential impacts.

4.14.4.1 GHG Emissions

Tables 4.14-7 and 4.14-8 present the annual and lifetime[43] GHG emissions respectively attributable to the proposed Project. These total direct and indirect emissions associated with the proposed Project, as well as those of alternative actions, contribute to cumulative global GHG emissions together with those of other past, present, and reasonably foreseeable future actions. GHG emissions differ from other impact categories discussed in this Final Supplemental EIS in that all GHG emissions of the same magnitude contribute to global climate change equally regardless of the source or geographic location where they are emitted. Therefore, a consideration of the alternative actions and other past, present, and reasonably foreseeable future actions that contribute to cumulative global GHG emissions would include any global action that emits any quantity of GHGs.

[43] The estimate of incremental lifetime GHG emissions does not account for changes in pipeline throughput over time. The GHG intensities of WCSB oil sands crudes and reference crudes are based on current analyses reflecting recent extraction, processing, refining operations and conditions. This estimate does not account for changes that could occur in the GHG intensity of WCSB oil sands crudes relative to reference crudes, as discussed in Section 4.14.3.6, Near- and Long-Term Trends that Could Affect WTW GHG Emissions.

4.14.4.2 Emissions and Impacts in Context

The total lifecycle emissions associated with production, refining, and combustion of 830,000 bpd of oil sands crude oil transported through the proposed Project are approximately 147 to 168 $MMTCO_2e$; however, the equivalent annual lifecycle GHG emissions from 830,000 bpd of the four reference crudes (representing crude oils currently refined in Gulf Coast area refineries) are estimated to be 124 to 159 $MMTCO_2e$. The range of incremental GHG emissions (i.e., the amount by which the emissions would be greater than the reference crudes) for crude oil that would be transported by the proposed Project is estimated to be 1.3 to 27.4 $MMTCO_2e$ annually. This is equivalent to annual GHG emissions from combusting fuels in approximately 270,833 to 5,708,333 passenger vehicles, the CO_2 emissions from combusting fuels used to provide the energy consumed by approximately 64,935 to 1,368,631 homes for 1 year, or the annual CO_2 emissions of 0.37 to 7.8 coal fired power plants.

These estimates represent the potential increase in emissions attributable to the proposed Project if one assumed that approval or denial of the proposed Project would directly result in a change in production of 830,000 bpd of oil sands crudes in Canada. However, as set forth in Section 1.4, Market Analysis, such a change is not likely to occur.[44]

Contributions to the buildup of GHGs in the atmosphere vary greatly from country to country and depend heavily on the level of industrial and economic activity, population, standard of living, character of a country's buildings and transportation system, available energy options, and climate. Emissions from the United States account for approximately 16 percent of total global CO_2 emissions, and Canada's account for approximately 1.7 percent (WRI 2013).

Transportation CO_2 emissions comprise roughly 12 percent of total global GHG emissions. Emissions from transportation are primarily due to the combustion of petroleum-based fuels to power vehicles. Global transportation CO_2 emissions have increased by 39 percent from 1990 to 2009 (WRI 2013).

The emissions associated with extraction of the oil sands would occur in Canada and are subject to Canadian federal, provincial, and local regulations; this Final Supplemental EIS is presenting information from Canadian government reports on Canada's emissions trends. According to Environment Canada, Canada's total GHG emissions in 2011 were 702 $MMTCO_2e$ (Environment Canada 2013). To meet its commitment to the Copenhagen Accord (made at the 15th session of the Conference of Parties to the United Nations Framework Convention on Climate Change) to reduce emissions in the range of 17 percent below 2005 levels, Canada needs to achieve a target emission level in 2020 of 607 $MMTCO_2e$. The Government of Canada currently projects that Canadian emissions in 2020 will be 734 $MMTCO_2e$ (Environment Canada 2013).

In 2011, the oil and gas sector accounted for 163 $MMTCO_2e$ (23 percent of Canada's emissions). Environment Canada projects this to grow to 200 $MMTCO_2e$ by 2020 (27 percent of the projected Canadian emissions). The increase in the oil and gas sector is attributable to the

[44] Section 1.4, Market Analysis, notes that as stated in the conclusion of the Draft Supplemental EIS, approval or denial of any one crude oil transport project, including the proposed Project, is unlikely to significantly impact the rate of extraction in the oil sands, or the continued demand for heavy crude oil at refineries in the United States (based on expected oil prices, oil-sands supply costs, transport costs, and supply-demand scenarios).

projected growth in oil sands production, which outpaces decreases in the production of conventional oil and in the downstream sectors. Total emissions associated with oil sands production (including upgrading bitumen to synthetic crude oil) was 55 $MMTCO_2e$ in 2010 (8 percent of Canadian emissions). This is projected to grow to 101 $MMTCO_2e$ in 2020 (14 percent of Canadian emissions).[45]

The total capacity of the proposed Project could transport up to 830,000 bpd of crude oil. If the full capacity of the proposed Project transported only oil sands bitumen delivered to market as diluted bitumen, it could transport approximately 575,000 to 625,000 bpd of bitumen[46], or approximately one third of the projected production increase in the Environment Canada report. Approximately 100,000 bpd of the proposed Project's capacity is reserved for production in Montana and North Dakota, which would reduce the bitumen capacity of the proposed Project to approximately 500,000 to 525,000 bpd.

The weighted-average range of GHG emissions from oil sands extraction and upgrading across NETL, Jacobs Consultancy, and TIAX is 74 to 105 $kgCO_2e$ per barrel of gasoline and distillates. The annual GHG emissions from the extraction of this 830,000 bpd of oil sands crude would be between 20 to 27 $MMTCO_2e$, equivalent to 20 to 27 percent of total emissions from Canadian oil sand production in 2020.[47]

4.14.5 Climate Change Impacts on the Proposed Project

This section presents the setting and context of climate change, as well as, an analysis of the potential impacts of climate change on the construction and operation of the proposed Project.

4.14.5.1 Setting and Context

Historical Climate Trends

Changes to the global climate have been observed over the past century. Between 1895 and 2009, the annual average global temperature has increased, and the states in which the proposed Project would be constructed and operated are, on average, warmer than they have been in the past. The northern states (i.e., Montana and North Dakota) have experienced relatively greater

[45] The Environment Canada report projects production and emissions trends only out to 2020. The Environment Canada report calculates these emissions based on growth in bitumen production from 1.7 million bpd in 2010 to 3.3 million bpd in 2020. Further context for the climate change impacts of oil sands production is estimated in an article by Swart and Weaver (2012), which estimated the temperature change impacts from the GHG emissions resulting from combustion of the entire Alberta oil sands. The authors estimate the economically viable proven reserves of the Alberta oil sands of 170 billion barrels of oil-in-place equals 22 billion metric tons of carbon. The authors estimate that, if all proven reserves were combusted, they would emit 80,667 $MMTCO_2$ and would result in a warming potential of 0.03°C. The estimates in Swart and Weaver (2012) are based on the emissions from oil sands crude combustion alone and do not include indirect emissions from natural gas, diesel, and electricity use during bitumen extraction, upgrading, and refining and do not account for GHGs other than CO_2. Including indirect emissions and non-CO_2 GHGs would increase the temperature change potential from the combustion of all known WCSB oil sands.

[46] This is based on an estimated diluent ratio of 25 percent to 30 percent.

[47] The estimates from NETL, Jacobs, and TIAX are based on LCAs of the inputs and activities at oil sands extraction, but not all of these emissions would occur at Canadian oil sands production facilities: these lifecycle estimates include a broader range of emissions than those strictly from oil sands production.

warming compared to southern states (BOR 2011a); in addition, more of that warming has been observed in the winter. In North Dakota, the average temperature in the winter increased by 5˚F between 1895 and 2009, while in Nebraska there was only a 1.8°F increase over the same period. The historical changes in temperature are presented for each of the proposed Project states in Table 4.14-9. These historical climate trends are expected to continue and to intensify according to GHG emissions levels (both man-made and natural) and the associated climate change projections (IPCC 2007 and 2012).

Table 4.14-9 Historical Changes in Temperature by State (1895-2009)

State	Annual Average Increase (°F)	Summer Average Increase (°F)	Winter Average Increase (°F)
Montana[a]	1.6	1.0	1.7
North Dakota[b]	2.9	1.8	5.0
South Dakota[b]	2.2	1.6	3.9
Nebraska[b]	1.2	0.7	1.8
Kansas[b]	1.1	0.6	2.0

[a] Source: Michelle Breckner, personal communication, October 12, 2012
[b] Source: High Plains Regional Climate Center (HPRCC) 2012

Projected Climate Change Effects

Climate changes can produce a range of effects, such as direct effects that include increases/decreases in temperature and precipitation on a seasonal basis, as well as indirect effects including increases in freeze-thaw cycles along with increased occurrences of flooding/drought and wind erosion of soil. It can also lead to broader effects such as changes to the natural environment (e.g., vegetation changes).

As part of preparation of this Final Supplemental EIS, an analysis was performed to evaluate the potential impacts of climate change on the proposed Project construction and operations. The analysis identified available, credible information on the projected climate change effects and the time horizons of these changes to identify potential impacts. The climate projections examined as part of this analysis were *downscaled* from general circulation models for North America. Downscaling disaggregates and refines climate modeling results from a global to a regional scale of relevant interest, or to a finer scale. Since this analysis relied on the downscaled model results reported by existing studies, less information was available on the possible extreme conditions and, by extension, the *worst-case* scenarios. There is, however, general consensus among the downscaled general circulation models[48] about average future climate change effects and that severe storm events will increase in frequency and duration (USGCRP 2013).

A number of sources were reviewed and cited as part of this analysis. IPCC reviews existing studies, multiple global climate models, and multiple regional climate models and generates non-numerical confidence levels for heat waves and extreme weather events for North America (IPCC 2012). The High Resolution Interpolation of Climate Scenarios for the Conterminous

[48] The term *downscaled general circulation models* is generally applied to models and studies where future climate predictions are downscaled from the global to regional level.

United States and Alaska Derived from General Circulation Model Simulations study (Joyce et al. 2011) downscaled four global climate models and averaged the model results for eight climate regions in the United States. Of the sources reviewed, it was determined that this study provides the most complete set of data available for application to the proposed Project across all the climate regions. However, due to the averaging of all the models, it likely underestimates the possible climate extremes. Where possible, other studies such as those from the U.S. Global Change Research Program (USGCRP 2009 and 2013) and BOR (2011a and 2011b) were referenced to obtain further detail on the possible extremes. Cumulatively, these studies covered the proposed Project areas with respect to projected climate effects.

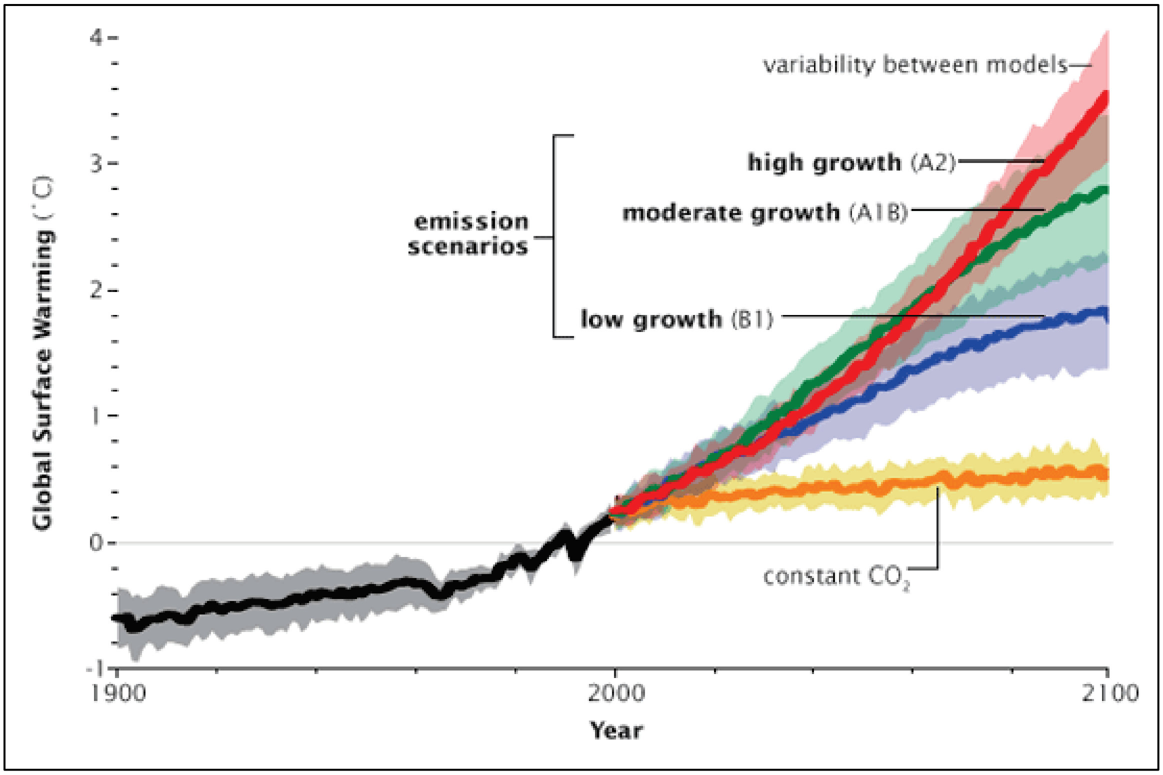
Climate change projections have been included for a range of future carbon emissions scenarios. The IPCC developed several future scenarios for GHG emissions; these were dependent on population and economic growth, as well as technology for fuel use and fuel production (IPCC 2007). These scenarios are used to project the degree and severity of climate change effects.

The emissions scenarios examined for this Final Supplemental EIS included a high (A2) scenario, a medium (A1B) scenario, and a low (B1) scenario.[49] These emissions scenarios are presented in Figure 4.14.5-1.

This analysis has taken a precautionary approach by using the worst-case projections (A2 scenario) to ensure potential impacts and outcomes are not underestimated. The climate change effects examined as part of this study can be broadly grouped into two categories: temperature and precipitation.

The proposed pipeline route would cross through Montana, South Dakota, and Nebraska, with ancillary facilities (e.g., access roads, pump stations, and construction camps) in North Dakota and Kansas. These areas correspond to the Dry Temperate and Prairie climate regions referenced in Joyce et al. 2011. These region designations are specific to this section on climate change impacts, and do not correspond with region designations discussed in other sections of this Final Supplemental EIS.

[49] The three selected scenarios are described in the 2007 IPCC report as follows: The A2 scenario is a heterogeneous world with rapid population growth and slow economic development and technological innovation rates. The A1B scenario assumes rapid economic growth and a world population that peaks around 2050. Technological innovation and adoption of energy-efficient technologies is balanced and does not rely on any one energy source. The B1 scenario assumes very rapid economic growth, a world population that peaks around 2050, and a very fast innovation and adoption of energy-efficient technologies. The economy makes rapid changes toward services and information.

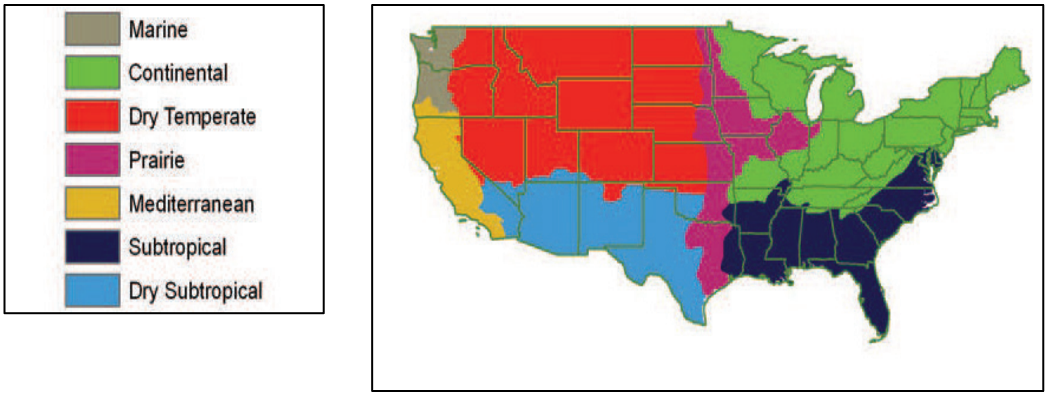


Source: IPCC 2007

Figure 4.14.5-1 Emissions Scenarios

The proposed pipeline route would primarily be in the Dry Temperate climate region and cross into the Prairie climate region toward the southern end of the route. Due to the linear nature of the proposed Project, the pipeline would cross a number of diverse climates as the route threads north to south from the mountain ranges of the continental divide toward Steele City, Nebraska. When climate change is overlaid atop these diverse regions, there are localized changes to temperature and precipitation.

In general, A2 scenario modeling results for each of these two climate regions show the same overall trends in temperature and precipitation, with some variation in the magnitude of the change. Therefore, for each category of climate effect, general changes for the United States are summarized below prior to a review of the projections for each climate region. A map further detailing the locations of the climate regions relative to the states is presented in Figure 4.14.5-2.



Source: Joyce et al. 2011

Figure 4.14.5-2 Climate Regions of the United States

The climate projection data for the two climate regions (from Joyce et al. 2011) are presented in Appendix V, Literature Review. Further summaries and analysis of these data are presented by climate effect category in the following sections. Given that the proposed Project has a nominal operating life of 50 years, from 2015 to 2065, the most relevant of the data are in the 2010 to 2039 and 2040 to 2069 timeframes. However, projected data from 2070 to 2099 are also included because, historically, pipelines have been known to remain in service longer than 50 years.

Temperature

By 2040 to 2069, the national average annual temperature is predicted to increase above the baseline of 1980 to 2009[50] by between 2.8°F and 6.6°F, depending on the model and the emissions scenario evaluated (USGCRP 2009). These changes would modify the seasonal patterns such that spring arrives earlier and summer lasts longer and is generally hotter, both in terms of its average and peak temperatures. Winters have already experienced and are expected to continue to experience the greatest degree of change from historical norms, and these changes would result in the winter season becoming shorter and warmer than in the recent past (USGCRP 2009).

[50] A lengthy period of climate data is used as a baseline because, for long-term climate modeling, a single baseline year is typically not used. A time period of historical data is used for long-term climate modeling since these will show the historical trend line as a starting point.

For western and central North America, multiple general circulation models predict, with high confidence in the opinion of IPCC, that heat waves and warm spells will likely be more frequent, more intense, and longer in duration (IPCC 2012). Increased temperature over a shortened time span would be expected to have a number of implications, including an increase in the likelihood of soil contraction, a shorter cool season, a shorter duration of frost periods, and more freeze-thaw cycles. The predicted average incremental temperature increases in the two climate regions for the three scenarios referenced above are presented in Table 4.14-10. Predicted temperatures for the two regions are discussed below.

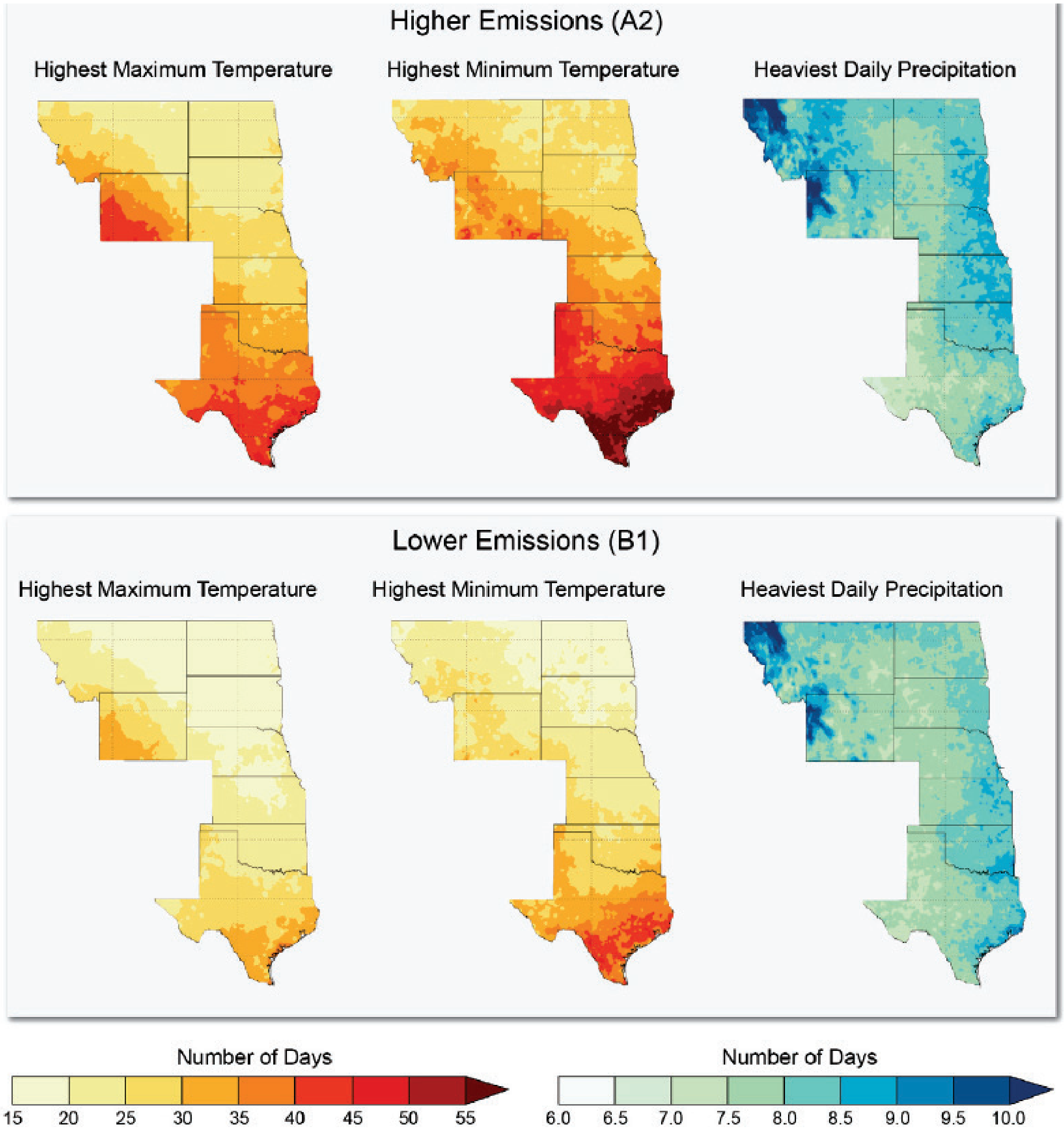
Table 4.14-10 Projected Changes in Average Mean Daily Maximum Temperatures (2010-2099)

		Climate Regions					
Temperature Changes		**Dry Temperate**			**Prairie**		
		High Emissions A2	**Medium Emissions A1B**	**Low Emissions B1**	**High Emissions A2**	**Medium Emissions A1B**	**Low Emissions B1**
Annual Mean Daily Max Temp Δ[a] from 1980-2009 (°F)	Baseline	59.2	59.2	59.1	65.8	66.0	66.0
	2010-2039	1.8	2.4	2.0	2.1	2.4	1.8
	2040-2069	4.6	4.6	3.3	4.6	4.6	3.1
	2070-2099	7.7	6.4	4.4	7.8	6.4	4.1
Winter Mean Daily Max Temp Δ from 1980-2009 (°F)	Baseline	36.3	36.3	36.2	41.2	41.1	41.1
	2010-2039	1.3	1.8	1.3	1.5	2.1	1.2
	2040-2069	3.8	3.9	3.0	4.0	4.4	3.1
	2070-2099	6.3	5.4	4.1	6.9	6.3	4.2
Summer Mean Daily Max Temp Δ from 1980-2009 (°F)	Baseline	82.4	82.4	82.5	87.7	88.2	88.3
	2010-2039	2.6	3.0	2.3	2.7	2.7	2.1
	2040-2069	5.5	5.5	3.5	5.2	4.7	2.7
	2070-2099	8.8	7.4	4.5	8.6	6.5	3.9

Source: Joyce et al. 2011

[a] **Δ** = change

Just as the current trends presented in Table 4.14-10 demonstrate, the temperature increases are occurring at different rates depending on existing climatic trends. The predicted average incremental temperature and precipitation increases for the Great Plains for 2041 to 2070 are presented in Figure 4.14.5-3 (USGCRP 2013).



Source: USGCRP 2013

Figure 4.14.5-3 Temperature and Precipitation Change for the Great Plains

Dry Temperate Climate Region

Under the A2 scenario, by 2040 to 2069, the annual maximum mean daily summer temperature is projected to increase by as much as 5.5°F in the Dry Temperate climate region (Joyce et al. 2011). This would result in a new daily mean summer maximum temperature of 88°F, which would also mean that the temperature extremes for the region would be expected to be greater than historical extremes. The Dry Temperate climate region is expected to have more frequent, longer, and more extreme (intense) events, including days with extreme cold and frosts (HPRCC 2012).

Prairie Climate Region

For the Prairie climate region, the A2 scenario predicts an annual maximum mean daily summer temperature increase of as much as 5.2°F for the region by 2040–2069. The inter-annual temperature variability[51] is projected to increase by 15 to 40 percent under the A2 scenario (Joyce et al. 2011), suggesting that although temperature is expected to rise, it could vary widely between seasons.

Precipitation

Annual precipitation is expected to increase across most of the climate regions from the 1980 to 2009 baseline depending on the emissions scenario. More of the precipitation is predicted to be associated with severe storm events (USGCRP 2009), which are projected to increase in frequency over future time periods. The model projections also indicate a greater inter-annual variability, suggesting that there might be more variability between seasons (e.g., periods of drought interspersed by heavy precipitation events).

Increased rainfall in a shortened time span increases the likelihood of flooding, soil submersion, heavy snow, runoff, sinkholes, riverbed scour, washouts, landslides, and (in mountain regions) avalanches (USGCRP 2009). The predicted precipitation changes in the two climate regions for the three scenarios referenced above are presented in Table 4.14-11. Predicted precipitation for the two regions is discussed below.

Table 4.14-11 Projected Changes in Precipitation by Climate Region (2010-2099)

		Climate Regions					
Precipitation		**Dry Temperate**			**Prairie**		
		High Emissions A2	**Medium Emissions A1B**	**Low Emissions B1**	**High Emissions A2**	**Medium Emissions A1B**	**Low Emissions B1**
Annual Precipitation Δ in inches from 1980-2009	Baseline	16.7	16.7	16.7	35.1	34.7	34.7
	2010-2039	0.5	0.2	0.3	0.2	0.2	0.0
	2040-2069	0.5	0.9	1.0	0.6	0.8	1.8
	2070-2099	0.9	0.9	0.9	0.6	1.7	1.3

Source: Joyce et al. 2011

[51] Inter-annual temperature variability is the relative change in temperature that occurs between years.

Dry Temperate Climate Region

Precipitation increases are expected between 2010 and 2099. Under the A2 scenario, the increase in average annual precipitation for the Dry Temperate climate region by 2040 to 2069 is projected to be 0.5 inch. For parts of the Dry Temperate climate region in the Missouri River Basin, by 2050, the projected increases in temperature will offset increases in precipitation in that evapotranspiration is predicted to result in a net loss in the water balance. The net loss in the water balance would be further compounded by less snowpack accumulation and more precipitation falling as rain earlier in the season. Though there is less certainty around this prediction, this phenomenon could result in more acute runoff events. An increase in the intensity of precipitation events is also predicted with each successive decade (BOR 2011b).

Prairie Climate Region

Precipitation increases are also expected between 2010 and 2099. Under the A2 emissions scenario, the increase in average annual precipitation for the Dry Temperate climate region by 2040 to 2069 is projected to be 0.6 inch. The studies examined did not include an evaluation of the net impact upon the water balance in this portion of the Missouri River Basin; however, because of the geologic formation of the Red River in a low lying basin, climate change is expected to further exacerbate flooding (USGCRP 2013).

4.14.5.2 Impacts on the Proposed Project

The climate modeling results described above show that there are relatively small differences between projected temperature changes across the two climate regions. For precipitation, the relative differences are greater, mainly due to the differences in the baseline precipitation rates for the two climate regions.

The sections below present the potential impacts of climate change on construction and operation of the proposed Project. The analysis primarily focuses on the direct impacts to the pipeline; however, there are also potential impacts to the infrastructure supporting the pipeline and human communities.

Construction

The construction of the proposed pipeline is planned to occur in 2015; if construction occurs on that schedule, climate conditions during the 1- to 2-year construction period would not be expected to differ much from current conditions, even under worst-case modeling scenarios. Keystone has confirmed that the measures identified in the Construction, Mitigation, and Reclamation Plan (CRMP) (see Appendix G) are sufficient to deal with any potential predicted effects as described above. These measures address the effects of extreme weather conditions, including high precipitation effects such as an extremely wet ROW, high stream flows, and increased scour potential, and drought effects such as increased dust and vegetation stress.

Operation

From a temperature perspective, projections suggest warmer winter temperatures, a shorter cool season, a shorter duration of the time period that frost occurs, and more freeze-thaw cycles per year, which could lead to an increased number of episodes of soil contraction and expansion. In summer, warmer summer temperatures, increased number of hot days, increased number of consecutive hot days, and longer summers are predicted, which could lead to impacts associated with heat stress and wildfire risks. Keystone has confirmed that the proposed Project is designed in accordance with USDOT regulations and the PHMSA Special Conditions (see Appendix B, Potential Releases and Pipeline Safety), and that these design standards are sufficient to accommodate an increased number of hot days or consecutive hot days. Keystone has also stated that because the proposed pipeline would be buried to at least 4 feet of cover to the top of the pipe, it would be below most surface temperature impacts, including wild fires and frequent freezing and thawing.

With respect to precipitation, the potential for increased winter and spring precipitation with increase in frequency of heavy precipitation events could result in increased runoff and stream flow; increased potential for flooding, erosion, washouts, and hydraulic scour in streambeds; as well as increased periods of soil saturation and increased risk of subsidence. The potential for increased severity, frequency, and duration of droughts could lead to an increase in episodes of soil contraction and movement. Keystone has stated that the design of the proposed Project in accordance with USDOT regulations and the PHMSA Special Conditions (see Appendix B, Potential Releases and Pipeline Safety) is sufficient to accommodate the effects of increased precipitation and increased drought. In addition, Keystone has stated that the design of pipeline crossings of all waterbodies is required (through these design standards in conjunction with the state permit conditions) to accommodate lateral stream migration and scour. In addition, areas where subsidence is known to be present would be designed accordingly. Finally, the magnitude and intensity of severe storm events can exacerbate existing trends found in precipitation, including the likelihood of flooding, soil submersion, heavy snow, runoff, sinkholes, riverbed scour, washouts, landslides, and (in mountain regions) avalanches (USGCRP 2009).

4.14.6 Climate Change Impacts on the Affected Environment and Associated Impacts

The affected environment and the identified environmental consequences described in Chapter 3, Affected Environment, and Chapter 4, Environmental Consequences, also need to be considered in the context of a potential change in climate as detailed in Section 4.14.5, Climate Change Impacts on the Proposed Project. Because climate change impacts are only likely to be experienced in the long term, this discussion focuses on climate change impacts during operation of the proposed Project.

Broad climate change effects will occur to varying levels to natural resources and the environment along the proposed Project corridor. However, these changes will occur irrespective of the presence of the proposed Project. This section therefore seeks to focus on the impacts that have been presented in this Final Supplemental EIS that are attributable to the proposed Project, and further consider whether the projected climate changes could further exacerbate or influence the identified impacts.

4.14.6.1 Soils

Potential impacts to soil resources associated with future climate change and construction and operation of the proposed Project and connected actions could include additional soil erosion and loss of topsoil from projected increases in temperature and annual precipitation. Soil erosion may result in loss of valuable topsoil from its original location through wind and/or water erosion.

A small portion of the proposed Project route would cross drought-prone soils. Drought-prone soils would be relatively more prone to wind erosion.

To address concerns related to potential soil erosion, Keystone has developed specific construction, reclamation, and post-construction procedures detailed in the Project CMRP (see Appendix G). The CMRP document itemizes construction, erosion control, and revegetation procedures to avoid and reduce soil erosion. Additional procedures are also described in Sandy Prairie Construction/Reclamation Unit Plan (see Appendix R, Construction/Reclamation Plans and Documentation). In addition, the proposed Project ROW would be monitored to ensure that reclamation and revegetation efforts are successful. Any proposed Project areas where reclamation and revegetation efforts are initially unsuccessful would be re-evaluated.

4.14.6.2 Water Resources

Surface Waters

The key potential surface water impacts associated with the proposed Project identified in Sections 3.3 and 4.3, Water Resources, relate to the pipeline construction as the pipeline crosses rivers, streams, and surface impoundments. Bank failure or improper restoration can lead to erosion points, which in turn can have impacts on habitat and fisheries. Following construction, the proposed Project plan stipulates that the proposed Project ROW, staging areas, and temporary access locations would be reclaimed and/or restored to as near pre-construction conditions as possible. The proposed Project design addresses near-term weather extremes and climate adjustment by specifying construction methods and mitigations for stream bed scour and lateral bank/channel migration. With these committed measures, and considering the short duration of the construction period and subsequent restoration period (up to 2 years post-construction), the projected climate changes are not anticipated to exacerbate the potential impacts already identified.

Climate change has the potential to exacerbate changes to hydraulic and hydrologic systems, particular in severe storm events. Channel migration zones and historic flood plains may be altered through the life of the proposed Project. Keystone stipulates that the proposed Project's design accommodates potential changes to surface water hydrology and the associated hydraulics attributable to future weather extremes and climate change. Keystone would employ industry-accepted engineering practices for the design of the proposed Project, including adequate setbacks from erodible bluff and bank locations. This would help protect against future channel changes due to weather extremes or climate adjustment, although additional analysis on extreme flood events would enable the design to be fully assessed.

Groundwater Resources

Groundwater systems will be susceptible to potential spills and releases from the proposed Project as described in Section 4.3, Water Resources. During extended drought conditions, recharge to the aquifers would be less and the need for municipalities and landowners to pump would be greater; therefore, this greater dependence on pumping would have the effect of lowering the water table. Increasing pumping could increase the distance that a spill or release will need to travel to impact ground water. However, during an extended drought, groundwater availability would be reduced, making the resource more valuable.

4.14.6.3 Wetlands

The key impacts associated with wetlands due to the proposed Project relate to disturbance of the wetlands due to construction activities and potential operational-related impacts such as spills (as presented in Sections 3.4 and 4.4, Wetlands). Keystone has committed to return wetlands to a pre-construction level whenever possible. Wetlands that recover rapidly from construction and operational-related impacts (such as spills) would likely be the least affected by minimal changes in weather and climate. However, some wetlands with narrower environmental tolerances, or those that take longer to restore and stabilize, would be potentially susceptible to additional impacts from projected climate changes. Wetlands within the proposed Project area may be particularly susceptible to climate-related changes if they are still in a state of transition or recovery from proposed Project-related impacts 10 to 20 years following construction. For example, wetland communities that require long-term timeframes for restoration, such as scrub-shrub and forested wetlands, could be more susceptible to negative impacts resulting from climate change. Other proposed Project area wetlands that may be more susceptible to climate related impacts include: riparian wetlands that may be affected by larger flood events in adjacent rivers and streams and depressional or pothole wetlands that rely primarily on precipitation, not groundwater, for hydrology (e.g., Prairie Pothole and Rainwater Basin wetlands). Where projected climate changes are creating or exacerbating drought conditions due to decreased precipitation, wetlands recovering from construction or operational-related impacts may be more susceptible to loss.

4.14.6.4 Terrestrial Vegetation

Impacts due to the proposed Project (see Section 4.5, Terrestrial Vegetation) would relate to the land disturbance required for the pipeline ROW and from construction-related impacts. Keystone is committed to post-construction restoration (as detailed in the CMRP, see Appendix G), and therefore long-term impacts to terrestrial vegetation communities are anticipated to be minimal. With the commitment to these mitigation measures, and considering the short duration of the construction period as well as the relatively short restoration periods in most areas required to reach pre-construction conditions, the projected climate changes are not anticipated to exacerbate the impacts to terrestrial vegetation already identified.

The primary impacts (approximately 59 percent) to terrestrial vegetation from the proposed Project would be to grassland/pasture communities. The proposed Project crosses an estimated 9,071 acres and 523 miles of Grassland/pasture. Research of the potential effects of increased atmospheric CO_2 and the anticipated changing weather patterns on these habitats suggests that inter annual variability makes predictions of the affects very difficult. The U.S. Department of Agriculture (2013) Forest Service Climate Change Resource Center states, “on a large scale grassland-suitable habitat in the U.S. is expected to increase, but projections vary by grassland type. Climate suitable for Great Plains grasslands is expected to remain relatively stable with some expansion to the north in Canada and retraction on the eastern and southern boundaries.”

There are unique biological, chemical, and physical relationships/interactions that make predicting the long-term effects difficult. Specifically with changing weather patterns, the resulting changes in species composition and overall changes in grassland distribution will likely vary by region and by year, and will particularly depend on the frequency of droughts, floods, and fires. These natural processes are important for sustaining the ecological integrity of such sensitive community types; however, fluctuations in frequency could substantially alter the species composition and diversity.

4.14.6.5 Fisheries

Potential long-term and permanent impacts from construction and operation of the proposed Project include increased water temperature; transfer of non-native or invasive plants, animals, or pathogens; increased sedimentation; bank and floodplain alteration; and loss of shading, nutrients, and cover.

Proposed Project-related impacts to water temperature are anticipated to be limited and generally minor overall; however, an increase in water temperature due to climate change could add to this impact. Increased sedimentation resulting from the proposed Project could be amplified by climate change impacts that result in increased erosion or flood magnitude, frequency, and duration. Similarly, potential impacts of the proposed Project that result in the loss of shading, nutrients, and cover, or any other bank or floodplain alterations are also subject to climate change impacts, particularly those that affect the hydrologic regime, sediment supplies, and riparian vegetation. The proposed Project has the potential to transfer non-native or invasive plants, animals, or pathogens into waterbodies along the proposed route, though it is uncertain whether climate-related impacts would make conditions more or less favorable regarding spread and/or persistence. However, it could be presumed that most native fish species will be adversely impacted by climate change, thus leaving them more vulnerable to problems associated with non-native and invasive species.

4.14.6.6 Wildlife and Threatened & Endangered Species

As presented in Sections 4.6, Wildlife, potential wildlife impacts associated with the proposed Project include:

- Habitat loss, alteration, and fragmentation;
- Direct mortality during construction and operation (e.g., vehicle collisions, power line/power pole collisions, etc.);
- Indirect mortality because of stress or avoidance of feeding due to exposure to construction and operations noise, low-level helicopter or airplane monitoring overflights, and from increased human activity;
- Reduced breeding success from exposure to construction and operations noise as well as from increased human activity;
- Reduced survival or reproduction due to less availability of edible plants, reduced cover, and increased exotic and invasive plants; and
- Increased predation (i.e., nest parasitism, creation of corridors used by predators, and poaching).

In some of these instances, the impacts are associated with disturbance during the construction activities, and are therefore short-term in their duration. The projected changes in climate are not expected to exacerbate these short-term and temporary impacts. Some of the impacts identified would be of a longer duration and associated with permanent changes such as the removal of permanent vegetation from the ROW, might increase the number of predators to some species.

For these longer term impacts, climate change may add to the stress some species may be experiencing. As explained below, the American burying beetle (*Nicrophorus americanus*) (see Section 4.8, Threatened and Endangered Species and Species of Conservation Concern) is one such species that would be impacted by the proposed Project and climate change.

A 5-year review was completed for the American burying beetle, which identified the potential effects of global climate change on American burying beetle habitat and disease (U.S. Fish and Wildlife Service 2008a). The effects of more frequent extreme weather events on the American burying beetle populations have not been assessed. Nevertheless, some predictions, although anecdotal, can be made about how weather events may affect the species, such as the projected gradual drying trend predicted in the summer months in South Dakota and Nebraska through 2050. The American burying beetle is subject to desiccation; thus, a drying trend may result in the contraction of the species' range over the next 50 years (i.e., the life of the proposed Project) (see the 2013 USFWS Biological Opinion in Appendix H, 2012 Biological Assessment, 2013 USFWS Biological Opinion, and Associated Documents). An elevation in winter temperatures could result in the species not going completely dormant and using extra fat reserves, potentially precluding the species from being able to overwinter. This could also result in a range contraction for the species (see the 2013 USFWS Biological Opinion in Appendix H, 2012 Biological Assessment, 2013 USFWS Biological Opinion, and Associated Documents).

4.14.6.7 Land Use

Section 4.9, Land Use, Recreation, and Visual Resources, describes the impacts of the proposed Project on land use and land ownership, recreation and special interest areas, and visual resources. As described in Section 4.9, the vast majority of land impacted by operation of the proposed Project would be privately owned land that is used either for agriculture or rangeland. Overall impacts on land use and ownership would be small and limited to restrictions on some kinds of land development activities (i.e., construction of structures) in the permanent ROW. Operation of the proposed Project would not likely affect recreational resources. Permanent impacts to visual resources would be limited to the presence of new pump stations as well as some changes in vegetation patterns along the proposed pipeline route. Impacts attributable to connected actions would be similar, although visual impacts would be higher in the case of transmission lines.

To the degree that the proposed Project is designed in a way to accommodate anticipated climate change (as discussed in Sections 4.14.5, Climate Change Impacts on the Proposed Project, and 4.14.6, Climate Change Impacts on the affected Environment and Associated Impacts), climate change would not be expected to exacerbate the Land Use, Recreation, and Visual Resources impacts described above.

4.14.6.8 Socioeconomics

Higher average annual temperatures, increased precipitation, and greater inter-annual variability could affect agriculture, which employs approximately 18,000 people in the counties that make up the economic corridor, as defined in Section 3.10, Socioeconomics. Changes in agriculture could result in a greater or lesser need for employment depending on the nature of the changes and whether; for example, climate change would make the proposed Project area more suited to different types of crops or livestock practices, requiring different levels of employment. Change in agricultural employment, in turn, could affect population and the demand for housing. Climate change would not be expected to affect other, non-agricultural employment.

Climate change could increase the cost of some public services, such as road repair and transportation infrastructure maintenance, as a result of increased wear and tear and damages caused by more extreme weather events. Such events could also require increased or enlarged police and emergency services coverage. Such increased costs could result in reduced property values if property taxes needed to increase substantially to make up for the increased costs of providing public services.

The projected annual temperature increases and longer and hotter summer periods could exacerbate poor air quality conditions such as those caused by ozone. Decreased air quality could have a disproportionate effect on environmental justice populations in such areas, especially those areas that are or contain Health Professional Shortage Areas and Medically Underserved Areas.

4.14.6.9 Cultural Resources

As presented in Section 4.11, Cultural Resources, the principal impacts of the proposed Project on cultural resources first relate to physical disturbance to artifacts and cultural sites, and second to historic and culturally significant landscapes. In both cases, the projected climate changes are not expected to exacerbate or change the nature of these impacts.

4.14.6.10 Air Quality and Noise

Air quality is strongly dependent on weather and is therefore sensitive to climate change. The two air pollutants of most concern are surface ozone and particulate matter. Ozone is produced in the troposphere by photochemical oxidation of carbon monoxide, CH_4, and non-methane volatile organic compounds by the hydroxyl radical in the presence of reactive nitrogen oxides. Ozone pollution is mostly a summer problem because of the photochemical nature of the source (i.e., it increases with temperature increase). Particulate matter (PM) includes sulphate, nitrate, organic carbon, elemental carbon, soil dust, and sea salt. The first four components are mostly present as fine particles less than 2.5 millimeters in diameter, and these are of most concern for human health. Sulfate, nitrate, and organic carbon are produced within the atmosphere by oxidation of sulfur dioxide, nitrogen oxides, and non-methane volatile organic compounds. Carbon particles are also emitted directly by combustion. Seasonal variation of PM is complex and location dependent; precipitation is its main atmospheric sink (Jacob and Winner 2009).

As indicated earlier in this section, some of the projected climate changes by 2040 to 2069 include:

- Increase in national average annual temperature above the baseline of 1980 to 2009 by between 2.8°F and 6.6°F;
- Modification of seasonal patterns such that spring arrives earlier and summer lasts longer and is generally hotter, both in terms of its average and peak temperatures; and
- Increase in annual precipitation.

The projected annual temperature increases and longer and hotter summer periods could increase summertime surface ozone. Recent climate studies find that climate change alone would increase summertime surface ozone and temperature in polluted regions by 1 to 10 parts per billion over the coming decades, with the largest effects in urban areas and during pollution episodes (Jacob and Winner 2009). This implies that stronger emission controls would be needed in the future to meet a given air quality standard. The effect of climate change on PM is more complicated and uncertain than for ozone. Precipitation frequency and mixing depth are important driving factors, but projections for these variables are often unreliable. Wild fires fueled by climate change could become an increasingly important PM source; however, future increases in annual precipitation could reduce PM concentrations (fugitive dust) in some regions. Recent climate studies find that climate change would affect PM concentrations in polluted environments by +0.1-1 microgram per cubic meters over the coming decades (Jacob and Winner 2009).

4.14.6.11 Potential Releases

Overall, the anticipated effects of climate change on potential dilbit releases would be no different from the effects on potential releases from any other crude oil because the characteristics of dilbit are similar to those of heavy crude oil. Therefore, the effect of climate change on release frequency of the proposed pipeline has been considered, along with severity of a spill from the pipeline.

Temperature, changes in seasonal patterns, increased short-term precipitation, and increased periods of drought would not directly affect the operation of the proposed Pipeline. This is because of the insulating and protective nature of soil surrounding a buried pipeline from aboveground climatic changes. The pipeline could potentially be affected by secondary effects brought on by climatic change such as increased flooding and drought, which could create ground instability conditions (i.e., natural damage) and endanger a buried pipeline to increased stress on its structure. Statistically, leak frequency due to natural damage is very low compared to other causes of leaks (Section 4.13, Potential Releases) and is unlikely to exceed the frequency caused by corrosion, the most likely cause for a loss of pipeline integrity.

Climate change could have an effect on the severity of a spill. Shorter winters and higher winter temperatures reduce the timeframe when the cold weather could make oil more difficult to flow and thereby decrease the distance of oil spreading. Extended drought conditions allow oil to be more readily absorbed by soil, reducing overland spreading and vertical migration to groundwater. Additionally, deeper groundwater conditions that occur during drought also increase the distance for oil to travel to reach that groundwater. Therefore, the potential to affect groundwater could be reduced, and the severity of an impact could be reduced. Periods of increased precipitation and flooding could have the most effect on a spill severity. Increased precipitation increases soil moisture content, reducing the ability of oil to seep into the ground and increasing the distance that oil could spread overland. Increased high water in streams and rivers would result in greater flow velocities, meaning a release to these features could travel longer distances before response teams could contain the oil. Additionally, response measures are more difficult to implement during high water conditions, also resulting in longer distances that oil could migrate.

Although the changes in climate could have an effect on pipeline integrity and the severity of a spill, modern construction design and mitigation, including the PHMSA Special Conditions applied to the proposed Project, are expected to result in a substantial reduction in incident[52] frequency (Section 4.13, Potential Releases). As a result, these preventative measures and standards developed by organizations such as the American Petroleum Institute, National Association of Corrosion Engineers, American Society of Mechanical Engineers, as well as PHMSA have the capacity to address changes in climate for at least the design life of the proposed Project.

4.14.7 References

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