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Life cycle energy and greenhouse gas emissions from transportation of Canadian oil sands to future markets

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HIGHLIGHTS

- A life cycle model is developed to compare transportation of oil sands products.
- The model is applied to several potential future oil sands markets.
- Energy inputs and GHG emissions are compared.
- Model inputs are explored using sensitivity analysis.
- Policy recommendations are provided.

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ABSTRACT

Oil sands transportation diversification is important for preventing discounted crude pricing. Current life cycle assessment (LCA) models that assess greenhouse gas (GHG) emissions from crude oil transportation are linearly-scale and fail to account for project specific details. This research sets out to develop a detailed LCA model to compare the energy inputs and GHG emissions of pipeline and rail transportation for oil sands products. The model is applied to several proposed oils sands transportation routes that may serve as future markets. Comparison between transportation projects suggest that energy inputs and GHG emissions show a high degree of variation. For both rail and pipeline transportation, the distance over which the product is transported has a large impact on total emissions. The regional electricity grid and pump efficiency have the largest impact on pipeline emissions, while train engine efficiency and bitumen blending ratios have the largest impact on rail transportation emissions. LCA-based GHG regulations should refine models to account for the range of product pathways and focus efforts on cost-effective emission reductions. As the climate-change impacts of new oil sands transportation projects are considered, GHG emission boundaries should be defined according to operation control.

1. Introduction

1.1. Background

Canadian oil has recently been termed “the cheapest oil in the world” (Blas, 2012). The North America benchmark oil price, West Texas Intermediate (WTI), has been trading at a premium to both Western Canada Select (WCS), the benchmark oil price in Alberta, and oil sands bitumen. The price differential for WTI compared to WCS and bitumen for 2013 is expected to be 28% and 44% respectively (Ollenberger and Dziuba, 2012). Maya, a benchmark for oil set in Mexico, is nearly identical in quality to Alberta's WCS (Alberta Energy, 2013), but in 2012 sold closer to the Brent world benchmark price, at a premium of 6%, 37%, and 69% over WTI, WCS, and oil sands bitumen respectively (Ollenberger and Dziuba, 2012). This price discount of oil sands products is expected to persist in the coming years (see Fig. 1).

Three factors are contributing to the price differential. First, Canadian oil sands production is growing at a rapid pace. The Canadian Association of Petroleum Producers (CAPP) is projecting that oil sands production will grow to 3.16 million bbl/d by 2020 from 1.61 million bbl/d in 2011. By 2030, it is expected that 5.02 million bbl/d will come from the oil sands, making up over 80% of total Canadian crude oil production (CAPP, 2012a). Western Canadian oil refinery capacity is expected to remain fairly constant at around 600,000 bbl/d out to 2020 (CAPP, 2012b). This growing production not consumed in Western Canada will need to find a pathway to market. Second, Canadian crude oil pipeline networks were originally designed to transport crude oil to the US Midwest (CERI, 2012). A surge in unconventional crude oil production, particularly from light tight oil in the Eagle Ford and Bakken formations, is raising the prospect of US energy independence

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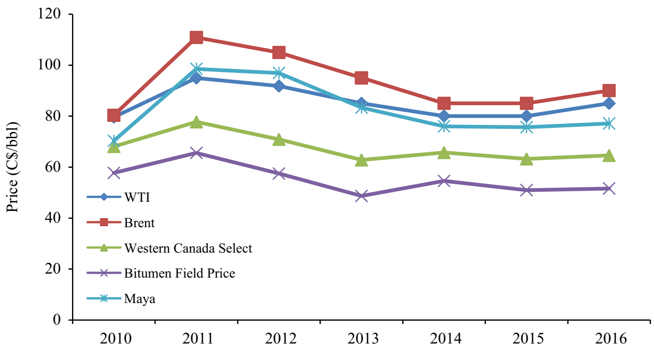

Fig. 1. Oil sands products (Bitumen and Western Canada Select) have been trading at a steep discount to other oil benchmarks. This price discount is expected to continue in the near- to mid-term given the rapid expansion of Canada's oil sands, increased production light, tight oil in the US Midwest, and limited export capacity. *Source*: BMO Capital Markets, 2012.

(EIA, 2013) while at the same time squeezing pipeline capacity for oil sands producers looking to move their product to the US (IEA, 2013). While oil sands crude has limited pipeline connections beyond the US Midwest (PADD II) market, oil from Mexico fetches a higher price given its direct access to the US Gulf coast (PADD III) and other international markets (Argus Media, 2012). Third, despite the need for additional pipeline capacity to export oil sands out of the region, regulatory approvals for new pipelines have been delayed by environmental groups and First Nations' that oppose the projects (Parliament of Canada, 2012).

The Canadian Energy Research Institute (CERI) estimates that failure to expand Canada's pipeline export capacity could constrain future oil production resulting in up to a $1.35 trillion loss in GDP and $225 billion in tax revenues from 2011 to 2035 (CERI, 2010). In March 2013, the Alberta government cited lower than expected oil revenue as the driver for a $6.2 billion dollar budget deficit (CBC, 2013). Alberta's energy minister, Ken Hughes, highlighted the need to connect Alberta to international markets: “It is a strategic imperative, it is in Alberta's interest, in Canada's interest, that we get access to tidewater, whether that's east, north or west, to diversify away from the single continental market and be part of the global market” (Van Loon, 2013). Several pipeline options are being considered to expand the oil sands transportation network and increase market access (IHS CERA, 2013a). Crude export by rail is also expected to play an increasingly important role in oils sands export (CERI, 2012). In early 2011, virtually no western Canadian crude was exported by rail. By the end of 2013, crude oil being transported out of Western Canada by rail will increase to 200,000 bbl/d (Peters & Co., 2013).

With various proposed rail and pipeline export routes for oil sands products being considered, it is important to understand the implications of crude transportation using a life cycle analysis (LCA) approach. This study seeks to quantify the comparative energy inputs and greenhouse gas (GHG) emissions of the proposed routes. This study is particularly timely given the numerous transportation projects being considered and the contentious debate over their environmental impacts. The results of this analysis are relevant to industry, policymakers, regulators, and environmental non-governmental organizations.

1.2. LCA models for oil sands

Only a small pool of research exists in the area of comparative transportation LCAs (Bergerson and Lave, 2005; Weber and Matthews, 2008; Wakeley et al., 2009; Pootakham and Kumar, 2010). Oil sands products have been studied more extensively from an LCA perspective, but the transportation component usually forms part of a broader Well-to-Wheels (WTW) or Well-to-Refinery (WTR) analysis. Charpentier et al. (2009) reviewed 13 LCA research papers exploring the GHG emission associated with oil sands operations. The review found that eight of 12 studies did not calculate emissions resulting from transportation or did so incompletely. While the emissions associated with transportation were reported to be small (ranging from 0.3% to 2.1% of total WTW GHG emissions) the variability was considerable, ranging from 1.0 to 5.5 gCO_2e/km. In order to address the reliance on low-quality, publically available data in oil sands LCA, Charpentier et al. (2011) developed the GHOST (GHG emissions of currently operating Oil Sands Technologies) model which augments publically available data with confidential operating data collected from the industry. Under the GHOST model, transportation emissions are attributed entirely to the electricity required to pump the product to the upgrader and/or the refinery, and were found to contribute 7–25% of the WTR emissions (Charpentier et al., 2011) and 4% of WTW emissions (Bergerson et al., 2012). The developers of the model identified the need for future studies to better quantify GHG emissions related to transportation for specific oil sands pathways.

Typically, LCA practitioners refer to five prominent models and studies that assess GHG intensity associated with oil sands production (Brandt, 2012): (1) GREET, the Greenhouse gases Regulated Emissions and Energy in Transportation model (Wang, 2012); (2) GHGenius, the model developed by O'Connor S&T2 Consultants (2011); (3) Jacobs, a study by Keesom et al. (2009); (4) TIAX, a study by Rosenfeld et al. (2009); and (5) NETL, studies by the National Energy Technology Laboratory (Gerdes and Skone, 2009; Skone and Gerdes, 2009). The Jacobs, TIAX, and NETL studies assume that oil sands products are transported along defined pathways from the production locations to a specified US refinery location through a mix that may include tanker, rail, truck, and/or pipeline transportation. The GREET and GHGenius models provide default transportation intensity values but only employ a single greenhouse gas intensity that is linearly scaled by the distance over which the crude oil is transported. The development of a new model to compare oil sands transportation options in greater detail and that takes into account the full life cycle impacts fills a current gap in the literature.

The purpose of this research is twofold. The first goal is to develop a detailed LCA model to compare the energy inputs and GHG emissions of pipeline and rail transportation for oil sands products. The second goal is to apply this model to compare life cycle energy and GHG emissions from transportation to potential seaport destinations that may serve as future oil sands markets. Transportation to seaport destinations is crucial to avoiding price discounts at crowded inland markets (IHS CERA, 2013a), and therefore makes up the endpoint in this transportation analysis. Downstream processes including refining and transportation of refined or unrefined products are well developed in other models and studies reviewed by Brandt (2012) and may be used to determine full WTW emission intensity profiles.

2. Methodology

2.1. Boundary and functional unit

A LCA transportation model was constructed for two unique processes: transportation of oil sands products by pipeline and by rail. The project boundary is defined to include energy inputs and GHG emissions from construction through to operation. The energy inputs are normalized and reported in a functional unit of GJ/bbl. The functional unit for GHG emissions is tCO_2e/bbl. Global warming potentials from the Second Assessment Report of the Intergovernmental Panel on Climate Change are used for consistency with GHG inventory reporting standards under the United Nations Framework Convention on Climate Change (Environment Canada, 2012a). A barrel (bbl) refers to unrefined, undiluted bitumen. Bitumen, as