IHS **Energy**

Special Report

Comparing GHG Intensity of the Oil Sands and the Average US Crude Oil

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About this report

Purpose. Oil sands crudes are often singled out for having higher greenhouse gas (GHG) emissions than the average crude consumed in the United States. Often 2005 is used as a reference year baseline. However, since 2005, the mix of crude oil refined in the United States has changed because of the surge in domestic US production and continued growth in the Canadian oil sands. How has this changed the GHG intensity of the average crude oil consumed in the United States? How do the Canadian oil sands compare?

Context. This report is part of a series of reports from the IHS Canadian Oil Sands Energy Dialogue. The dialogue convenes stakeholders to participate in an objective analysis of the benefits, costs, and impacts of various choices associated with Canadian oil sands development. Participants include representatives from governments, regulators, oil and gas industry, academics, pipeline operators, refiners, and nongovernmental organizations. This report and past Oil Sands Dialogue reports can be downloaded at www.ihs.com/oilsandsdialogue.

Methodology. IHS conducted our own extensive research and analysis on this topic, both independently and in consultation with stakeholders. This report was informed by multistakeholder input from a focus group meeting held in Washington, DC, on 22 October 2013 and participant feedback on a draft version of the report. IHS has full editorial control over this report and is solely responsible for the report's content (see the end of the report for a list of participants and the IHS team).

Structure. This report has four parts and an appendix:

- Part 1: Introduction
- Part 2: US average crude oil baseline method and common pitfalls
- Part 3: Results
- Part 4: Conclusion
- Appendix: Detailed method, source data, and calculations (a separate document)

Comparing the GHG Intensity of the Oil Sands and the Average US Crude Oil

Key insights

Oil sands are often singled out for having higher GHG emissions than the average crude oil consumed (refined) in the United States. The most commonly referenced year for such comparisons is 2005. However, the mix of crude oil consumed in the United States has changed dramatically since 2005. Have these changes—especially the increase in imports of Canadian oil sands and the growth in US domestic light, sweet crude oil production—changed the GHG intensity of crude oil consumed in the United States? And how does crude oil from the Canadian oil sands compare to the US average today?

- Despite significant changes in the mix of crude oil supplied to US refineries between 2005 and 2012, the average GHG intensity was unchanged. Growth in supply and consumption of relatively lower-carbon crudes offset increased use of relatively higher-carbon crudes.

- Forty-five percent of the crude oils consumed in the United States are within the same GHG intensity range as those from the Canadian oil sands. Comparing the oil sands against the average crude oil baseline estimated by IHS for 2012, refined products from oil sands has life-cycle GHG emissions that are between 1% and 19% higher than the average crude oil consumed in the United States. This places oil sands within the same GHG intensity range as 45% of crude oil supplied to US refineries in 2012. Two-thirds of the crudes in this range came from Latin America, Africa, the Middle East, and some US domestic production.

- GHG emissions figures for the average crude oil consumed in the United States should be treated as an estimate. The IHS estimate of the GHG emissions for the average crude in 2005 was almost 4% higher than an often-cited estimate from a US Department of Energy study. The difference gives an indication of the margin of error in estimating the GHG emissions for the average US crude oil. There are insufficient data on the life-cycle GHG emissions for many crude oils to obtain a precise value for the average crude oil consumed in the United States.

- The average GHG intensity for crude oil consumed in the United States can be a useful reference point to compare crude oils. However, it can also lead to confusion. For instance, it is misleading to use the baseline as a reference point when estimating the incremental GHG emissions associated with greater US consumption of one type of crude oil. For example, an increase in the import and consumption of oil sands will most likely replace a similar crude oil, not the average crude oil. The most likely substitute for Canadian oil sands in the United States is Venezuelan crude oil, which has a GHG intensity within the same range as the Canadian oil sands.

—May 2014

Comparing the GHG Intensity of the Oil Sands and the Average US Crude Oil

Part 1: Introduction

How much GHG is generated from the consumption of various types of crude oil? This question matters because policies are being rolled out based on various assumptions that could have significant economic consequences for different crudes, notwithstanding the validity of those assumptions.

The most direct policy example is Low Carbon Fuel Standards (LCFS), which use the life-cycle GHG emissions of crude oils as a basis for regulating the carbon intensity of transportation fuels. In the European Union and California, LCFS initiatives are in various stages of advancement. The GHG intensity of crude oil is also factoring into other decisions. For example, it has been a main topic in the debate about approving new crude oil pipelines between Canada and the United States. This was most evident in President Barack Obama's 25 June 2013 climate address when he pledged not to approve the Keystone XL pipeline if the project would "significantly exacerbate the problem of carbon pollution."

Thus, it is very important to understand GHG intensity. However, assessing the GHG intensity of any crude oil is a complex exercise. Data availability and quality are a challenge, as are differing methods of calculation. Understanding the average GHG intensity for crude oil consumed in entire country is even more challenging. Despite the uncertainty, individual crude oils are often compared to the average crude oil consumed (or refined) in the United States.[1] The most commonly cited GHG intensity estimate comes from a 2008 study by US Department of Energy's National Energy Technical Laboratory (DOE/NETL). DOE/NETL estimated the life-cycle GHG emissions for the average US crude oil consumed in 2005.[2]

However since 2005 (the year the average GHG intensity was quantified), the source of crude oil supplied to US refineries has changed dramatically. For our study we compared the estimates from 2005 to those of 2012. Major changes between these years include

- **Growth of oil sands and other Canadian heavy imports.** Between 2005 and 2012, US imports of oil sands (diluted bitumen [dilbit] and synthetic crude oil [SCO]) and other Canadian heavy supply increased by 900,000 barrels per day (bd), or 75%—from 1.2 million barrels per day (mbd) to nearly 2.1 mbd. In 2012, about 1.5 mbd was sourced from the oil sands, accounting for about 14% of US imports.[3]

- **The rise of US tight oil.** Nonexistent in 2005, tight oil production, led by production from the Bakken in North Dakota and the Eagle Ford in Texas, reached 1.8 mbd in 2012. Tight oil accounted for almost 30% of US domestic supply in 2012.[4] Tight oil continues to grow, and in 2013 total US tight oil production reached 2.7 mbd.

- **Decline in Mexican imports.** Between 2005 and 2012, US oil imports from Mexico declined almost 600,000 bd, or 38%.

1. Throughout this report, *consumed* and *refined* are used interchangeably.

2. DOE/NETL, "Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels," November 2008. Although DOE/NETL issued a subsequent report in 2009, we used the 2008 study because it reported oil production emissions on a per-barrel-of-crude basis.

3. The estimate of volume of US imports of oil sands is based on data from the Canadian National Energy Board (NEB) and the US Energy Information Administration (EIA). We have added 250,000 barrels per day (bd) to the reported values from the NEB to account for some oil sands blends that the agency categorizes as heavy conventional crudes.

4. Total US domestic production of 6.4 mbd; source US Energy Information Administration.

- **Reduction in light, sweet crude imports from Nigeria and other African suppliers.** As a result of growing domestic tight oil supply, imports of light, sweet crude oil from offshore suppliers dropped. From 2005 to 2012, Nigerian imports dropped more than 800,000 bd, or 64%. Other African suppliers declined by a similar percentage. It total, between 2005 and 2012, US imports of all light, sweet crude oil (not just African) fell 64%, from 3.8 mbd to 1.9 mbd.

- **Lower Alaska North Slope crude oil production.** By 2012, production was 40% lower than in 2005—a drop of more than 300,000 bd.

- **Declines in imports of Venezuela heavy crude oil, along with resources from other Latin American suppliers.** In 2012, combined US imports were 400,000 bd lower than in 2005.

Have these changes altered the GHG intensity of the average crude oil consumed in the United States? This report aims to answer that question. But to summarize, the conclusion is "no."

Since 2009, IHS has published a series of public reports quantifying the life-cycle GHG emissions of oil sands compared with other crude oils. Based on this body of prior research and some new research detailed in this report, we have estimated the GHG intensity of the average crude oil refined in the United States in 2005 and 2012. Our most recent GHG study, the IHS Special Report *Oil Sands, Greenhouse Gases, and US Oil Supply: Getting the Numbers Right—2012 Update*, November 2012 is referred to as IHS (2012) in this report. The original report can be downloaded at www.ihs.com\oilsandsdialogue.

This report comprises five parts, including this introduction and an appendix:

- Part 1: Introduction

- Part 2: US average crude oil baseline method and common pitfalls

- Part 3: Results

- Part 4: Conclusion

- Appendix: Detailed methodology, source data, and calculations (contained in a separate document that can be downloaded at www.ihs.com\oilsandsdialogue)

Throughout this report, we make reference to commonly understood principles of life-cycle analysis for petroleum-based transportation fuels. The "Life-cycle GHG emissions from crude oil: Basic terms" box

Life-cycle GHG emissions from crude oil: Basic terms

Life-cycle analysis of GHG emissions from crude oil. Life-cycle analysis estimates the amount of GHG emissions associated with the entire life of a product. For petroleum fuels, this includes crude oil production, transport, refining, refined product transport, and ultimately combusting the fuel in a vehicle (see Figure 1). The entire life cycle is referred to as "well-to-wheels." Emissions that include everything up to but not including combustion are described as "well-to-tank." When GHG emissions are viewed on a well-to-wheels basis, emissions released during the combustion of fuel (such as gasoline or diesel) make up 70% to 80% of total emissions. *These combustion emissions are the same for all crudes. Whether the fuel is derived from oil sands or conventional oil, the combustion emissions are equal.*

Life-cycle GHG emissions from crude oil: Basic terms (continued)

Wide boundary for measuring GHG emissions from crude oil. Throughout this report, we use a wide boundary for measuring the life-cycle GHG emissions from crude oil. Wide boundary results include emissions that occur at production facilities and refineries (often referred to as the tight boundary) plus GHG emissions that result from fuels used in the production and refining of crude oil (such as emissions from producing and processing natural gas used for production or emissions from off-site electricity production). Emissions from land use were not included in our results, since they are difficult to measure, studies are limited, and estimation methods are evolving.*

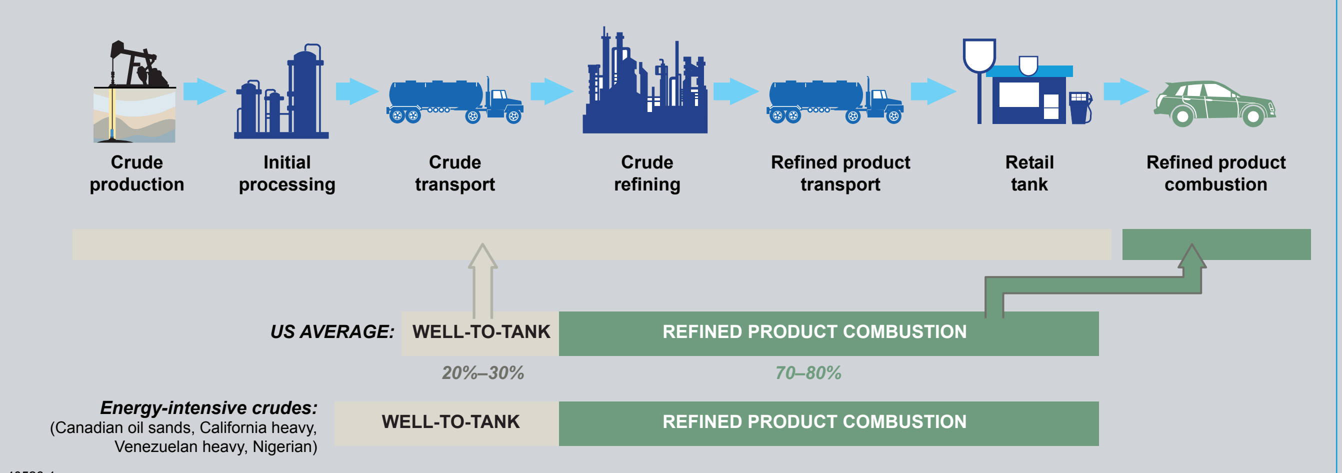
Areas of uncertainty in measuring GHG emissions from crude oil. Measuring the life-cycle emissions for crude oil is a complex process, and there can be significant variability in the estimates for a single crude oil. In our previous study, IHS (2012), we found that when multiple studies were compared, estimates of production emissions varied by an average of 30%. Depending on the crude oil, this level of error equates to between 5% and 15% variance in the well-to-wheels life-cycle GHG emissions estimate; in some cases the error is greater than the GHG reductions that LCFS policies require.

There are numerous sources of uncertainty in measuring emissions of crude oil. Three key challenges are

- **Data quality and availability.** This is the most significant factor contributing to the uncertainty in measuring crude oil GHG emissions. Accurate data are often difficult to obtain. Frequently, oil and gas data are considered proprietary. For example, flaring and venting, which can represent a large source of production emissions, must often be estimated from satellite imagery because of a lack of data. However, for Canadian crudes, venting and flaring data are measured, audited, and available.

FIGURE 1

Lifecycle GHG emissions for petroleum fuels



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Source: IHS Energy

*For more information on land use emissions, see the IHS Energy Special Report *Oil Sands Greenhouse Gases, and US Oil Supply: Getting the Numbers Right—2012 Update*, November 2012, page 12. This can be downloaded at www.ihs.com\oilsandsdialogue.

Life-cycle GHG emissions from crude oil: Basic terms (continued)

- **Allocation of emissions to coproducts.** For crude oil, life-cycle analysis requires attributing emissions to multiple products produced by a refinery, such as the gasoline or diesel. Studies of well-to-wheels emissions vary greatly in how they allocate emissions to refined products. For instance, some studies allocate all GHG emissions to gasoline stream (with the reasoning that all other products are simply by-products of gasoline production). Other studies allocate the emissions across all products by volume. And yet others divide GHG emissions based on the energy content of the products or the energy consumed in making the products. For this reason (among others), it is not valid to directly compare absolute GHG emissions estimates among studies.

- **Differing study purposes and methods.** The purpose of a study can drive the range of GHG emissions estimates observed. Some studies aim to present a detailed analysis of a specific operation and crude type, and require a high level of data precision. Other studies—often those oriented toward policy—aim to represent the average GHG emissions for the industry or a country as a whole and consequently rely on less precise data.

For more information on areas of uncertainty in measuring GHG emissions from crude oil please refer to the IHS (2012) report.

provides a brief overview of these terms. It also highlights some of the uncertainty in measuring GHG emissions from crude oil.

Part 2: Average crude oil baseline method and common pitfalls

In estimating the GHG emissions for the average crude oil consumed in the United States, IHS used a different method from the one used in the DOE/NETL study. This section explains our method and compares it to the DOE/NETL approach. We also identify some common pitfalls in using an average crude oil GHG intensity baseline when comparing the GHG emissions from different crude sources.

DOE/NETL used a top-down approach

A top-down approach weights the average life-cycle emissions at a country level by the volume of crude oil consumed from each country to arrive at an average GHG intensity. DOE/NETL used this approach to estimate the average GHG emissions for crude oil consumed in the United States in 2005. For example, it estimated the life-cycle GHG emissions intensity for the average crude imported from Mexico, Venezuela, and others; these values were weighted by the amount of crude oil imported from each nation to produce an average intensity estimate. Canada was one exception, since it estimated one average value for Canadian conventional sources and another for the Canadian oil sands. The DOE/NETL study concluded that emissions from oil sands were 17% higher than that from the average crude consumed in the United States in 2005. This is higher than the IHS estimate that represents the most current oil sands data and operations. Using a consistent baseline to DOE/NETL (which differs from the baseline used in the rest of this report), we estimate the average oil sands refined in the United States are now 12% higher than the emissions from average crude in 2005 (using the IHS baseline it would be 9%) (see Table 1 at the end of this report). Although the DOE/NETL value is frequently used to characterize the GHG emissions from oil sands, it is dated, relied on limited data sources, and is outside of the range of IHS and other studies.

DOE/NETL Canadian oil sands assumptions

The DOE/NETL study is dated and no longer represents current oil sands operations—which have lower emissions compared with 2005 (the DOE/NETL GHG emissions for oil sands extraction and upgrading are about 1.5 times higher than the IHS and other study results of current operations). Also, the DOE/NETL estimate does not account for how bitumen products are actually shipped to the US market for refining—as a blend of bitumen and lighter diluents.

Mining and upgrading SCO. About half of today's oil sands production is from mining integrated with an upgrader. DOE/NETL 2009 assumes a 2005 mining and upgrading emission value of 134 kilograms of carbon dioxide equivalent (kgCO_2e) per barrel of SCO, or about 120 kgCO_2e per barrel of refined products.[5] The source for this value is not clear. The DOE/NETL values are higher than those of any studies used in the IHS (2012) (which looks at the range of results across eight sources for mining and upgrading published since 2010). The range of results for the sources IHS studied was 87.5 to 103 kgCO_2e per barrel of refined products, and the average value was 92 kgCO_2e per barrel of refined products (see IHS (2012) Appendix A1-9 for data).

Thermal extraction emissions. Thermal extraction methods inject steam into oil sands in situ (or in-place) through a well to heat up the bitumen and allow it to flow to the surface. Two thermal processes are in wide use in the oil sands today: steam-assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS). On average, SAGD has lower GHG emissions per barrel produced than CSS. In 2012, about 65% of the oil produced from oil sands thermal extraction was from the SAGD method, and SAGD production is growing. To estimate GHG emissions for producing diluted bitumen, or dilbit, with thermal extraction, the DOE/NETL study draws on a 2005 value for producing bitumen using the relatively high-emission CSS method (a process used for 35% of current production) and assumes 134 kgCO2e per barrel.[6]

With thermal production, there is no source for the estimate used in the DOE/NETL 2009 paper. However, in a previous paper published in 2008, DOE/NETL does provide a source for this value (a 2006 estimate for CSS from Imperial Oil's Cold Lake operation to produce a barrel of bitumen). In addition, the estimate assumes the production of a barrel of bitumen only, a product that cannot be transported by pipeline. The IHS (2012) analysis (analyzing eight sources published since 2010) found that thermal extraction of dilbit produced between 43 and 109 kgCO_2e per barrel of refined products, and the average value (assuming 65% dilbit from SAGD and the remainder from CCS) was 80 kgCO_2e per barrel of refined products (see IHS (2012) detailed Appendix A1-9 for data).

IHS used a hybrid bottom-up approach

A bottom-up approach gathers life-cycle GHG emissions intensity data on each individual field or marketable crude (such as Mexican Maya or Nigerian Bonny Light) and weighs them by the volume of each crude consumed to arrive at an average US crude value. We estimate that in 2012, the United States consumed over 150 unique crude types.

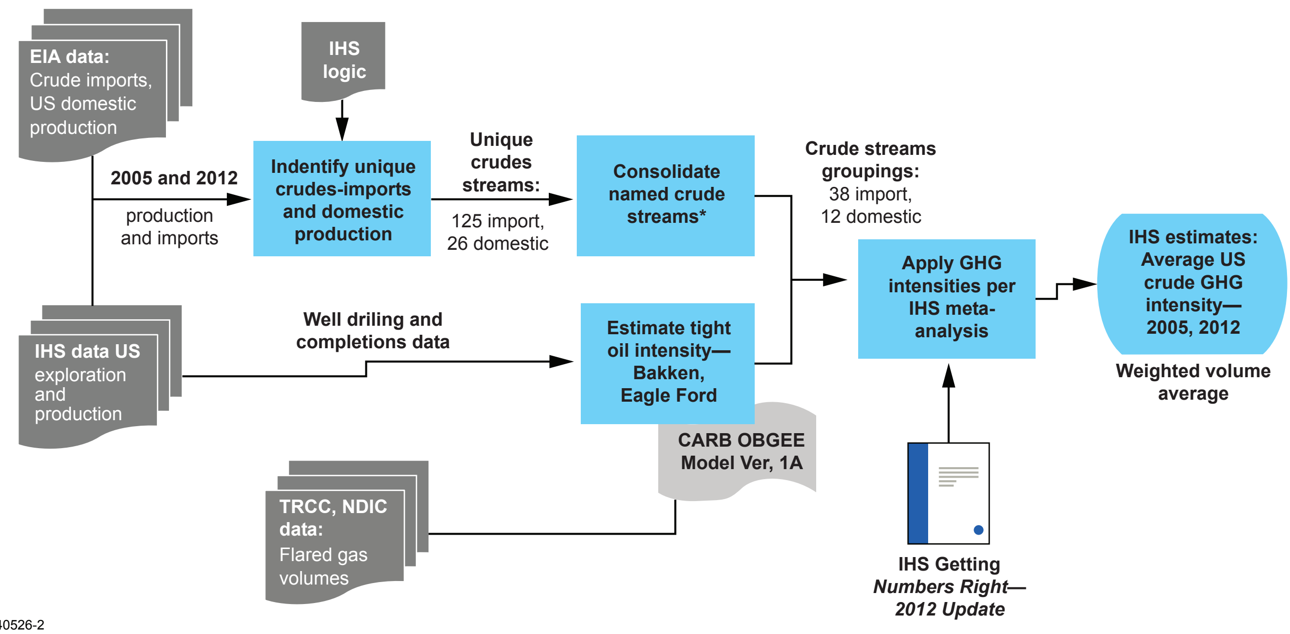
The main challenge of using a bottom-up approach is in estimating GHG intensity values for 150 unique crudes. Limited data on international oil production practices make estimating GHG emission, intensities for such a large group of crude oils impractical (see the box "Life-cycle GHG Emissions from crude oil: Basic terms" for more background). Consequently, IHS used a hybrid bottom-up method (see Figure 2).

5. SCO is produced from bitumen via refinery conversion units that turn very heavy hydrocarbons into lighter, more valuable fractions from which gasoline and diesel are manufactured. These units are called upgraders. SCO resembles light sweet crude oil with API gravity typically greater than 30 degrees.

6. Dilbit is bitumen mixed with a diluent. The diluent is typically a natural gas liquid such as condensate. Dilbit is generally a mix of about 72% bitumen and the remainder condensate. This is done to make the mixed product "lighter," and the lower viscosity enables the dilbit to be transported by pipeline. Some refineries will need modifications to process large amounts of dilbit feedstock because it produces more heavy and more very light oil products compared with most crude oils.

FIGURE 2

IHS hybrid bottom-up method for estimating the average GHG emissions for the average US crude oil



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*Consolidation considered production practices and crude quality

Source: IHS, US EIA, TRRC, NDIC, CARB

We applied the following steps to calculate the GHG intensity of the average US crude oil:

- **Identify each crude oil consumed.** Based on US government import and production data and using the IHS estimate of the specific crude oil based on country of origin, density, and sulfur information, we estimated the volume of US crude consumed by individual crude streams (e.g., Nigerian Bonny Light or Iraq Kirkuk). This resulted in 151 unique crude oils (125 imports and 26 domestic).

- **Consolidate the named crudes streams.** Estimating precise GHG intensities for 151 crude streams is not practical or even possible. We combined the streams into groupings with similar production practices and qualities. This resulted in 51 consolidated crude oil streams (38 imports and 12 domestic).

- **Estimate the GHG intensities for each crude oil.** In IHS (2012), we published a number of GHG emissions estimates for crude oil. However, our previous report did not include values for all 51 consolidated crude streams. Since then, we generated new life-cycle GHG intensity estimates for US domestic tight oil production (Eagle Ford and Bakken production). We also generated new estimates for 15 other crude oils based on estimates from the California Air Resources Board (CARB). For more information on new GHG emissions estimates and sources, please refer to the Appendix (download at www.ihs.com\oilsandsdialogue.)

- **Calculate the life-cycle GHG emissions for the average US crude oil.** Once GHG intensities were available, we calculated the average GHG intensity by weighting the volume of each crude stream (in 2005 and 2012) by its carbon intensity. Even with our expanded list of crude oil GHG emissions intensities, some of the 51 consolidated crude streams were still unknown (the unknown crudes oils accounted for about 15% of the total volume). As a result, we applied an average GHG intensity to account for the crude oils with missing values.

Comparing the country-level approach used by DOE/NETL, our view is that our hybrid bottom-up method provides more precision. Since we group crude oils based on quality and production practices, our approach is more indicative of GHG intensity than country of origin. However, both methods have inherent uncertainty and deliver estimates rather than precise values.

Assume static GHG intensity of individual crude oils between 2005 and 2012

In calculating the 2005 and the 2012 baselines, we used the same GHG intensity value for each crude oil. This simplification was required owing to a lack of data, which makes it impractical to quantify the GHG emissions in both 2005 and 2012 for all 51 consolidated crude oil streams. However, the GHG intensity of crude oils can change over the longer term. For example, using emissions data from Environment Canada and historical production data, the average GHG intensity of oil sands production decreased more than 26% between 1990 and 2011.[7] However, in general, over a shorter time period—such as seven years—the change is less pronounced. Consequently, we do not expect the static GHG intensity assumption between 2005 and 2012 to be a major factor in our results.[8]

Common pitfalls in using the average crude oil baseline

The DOE/NETL 2005 baseline is frequently used in comparisons of crude oil GHG intensities. Common baselines can be useful, since they provide a reference point for comparisons. However, at times the DOE/NETL baseline has been used inappropriately—for instance as a reference point to estimate the incremental GHG emissions associated with greater US imports of crude derived from Canadian oil sands. There are two primary faults with using the average crude baseline in this way:

- **Oil sands will not replace the average crude consumed in the United States.** The vast majority of future oil sands production growth will be heavy crude oil that targets US Gulf Coast refineries that are configured to processing heavy crude oils. Growing volumes of Canadian heavy crude are likely to displace other heavy crude oils imported from Venezuela and Mexico. Based on our earlier analysis reported in IHS Energy Insight *Keystone XL Pipeline: No Material Impact on US GHG Emissions* (download at www.ihs.com\oilsandsdialogue), crude from Venezuela is in the same GHG intensity range as oil sands. Further, if Canadian oil sands supply to the US Gulf Coast is limited, Venezuela is the most likely alternative source of supply.

- **The DOE/NETL baseline estimates the carbon intensity at a fixed point in time, 2005, but since that time the US crude slate has changed considerably.** Often the baseline is used to compare the GHG emissions of particular crude oil today or even long into the future (over more than 20 years or more into the future over the useful life of an infrastructure investment such as a pipeline). However, for this purpose, the baseline should be used with caution, since the future GHG intensity of both the US average crude oil and the crude being compared is uncertain.

Part 3: Results

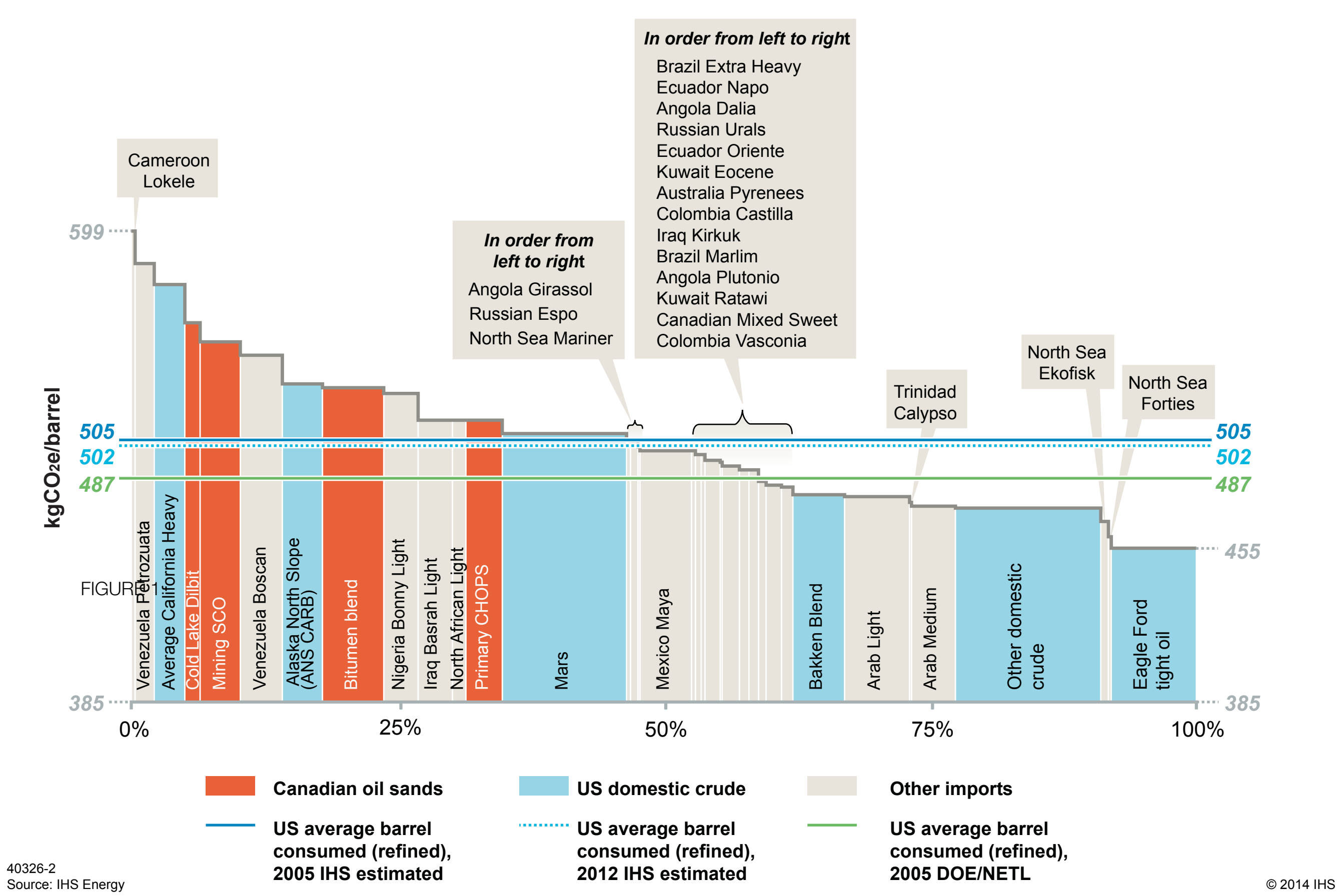
This section presents the results and key conclusions from our average US crude oil baseline analysis. The volume and intensity of US crude slate is shown in Figure 3.

7. Environment Canada, National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=A07ADAA2-E349-481A-860F-9E2064F34822–accessed 27 February 2014. For more information on the drivers of GHG emissions reductions and future outlooks, see *IHS Special Report "Oil Sands Technology: Past, Present, and Future"*, January 2011 (download at www.ihs.com\oilsandsdialogue).

8. IHS analysis is based on a meta-analysis of a range of studies that have occurred over a number of years. We did not anticipate material differences, plus or minus, between these various study dates and 2005 and 2012 years. For more information see IHS (2012) study.

FIGURE 3

Well-to-wheels GHG emissions: Oil sands compared to other crude oils
(Wide boundary—kgCO_2e per barrel of refined product)



Results: The 2005 and 2012 US baseline

The well-to-wheels life-cycle GHG emissions for the average US crude oil for the DOE/NETL 2005 and IHS 2005 and 2012 estimates are shown in Table 2. Table 3 includes other points of comparison, such as the average oil sands refined in the United States in 2012. See Table 3 on the last page of this report for a complete summary of the GHG emissions for each individual crude. A full profile of the volume and intensity of crude oil consumed in the United States—the US crude slate, including how the average compares is shown in Figure 3. IHS calculated the GHG intensity of the average oil sands refined in the United States by estimating the mix of oil sands products pipelined to and refined in the United States in 2012—a mix of bitumen, blended bitumen, and SCO (for more detailed information on the assumptions to calculate the average oil sands refined, refer to part 5 of the Appendix to this report).

TABLE 2

Well-to-wheels life-cycle GHG emissions of the average crude oil refined in the United States in 2005 and 2012
(kgCO_2e per barrel of refined product)

Average US barrel refined in the United States	Well-to-wheels life-cycle GHG emissions	Comments
2005 IHS	505	
2012 IHS	502	Less than 0.6% drop in GHG intensity of average US crude (2005–12), from IHS baseline
		IHS average US crude oil baseline for 2005 is 3.7% higher than DOE/NETL
2005 DOE/NETL	487	

*Well-to-wheels emissions include emissions from upstream fuel used in crude production, upgrading, and refining.

Source: DOE/NETL, "Development of Baseline Data and Analysis of Lifecycle Greenhouse Gas Emissions of Petroleum-Based Fuels," November 2008

GHG intensity of US tight oil production

Tight oil comes from rocks of low permeability and porosity that have hydrocarbons trapped within them. Oil is produced by drilling horizontal wells into the rock formations and fracturing them through hydraulic stimulation. This process opens pathways in the rocks that allow trapped hydrocarbons to be recovered.

To date, the most prolific regions in North America for tight oil production have been the Bakken in North Dakota and the Eagle Ford in Southwest Texas. In 2012, these regions were responsible for over 60% of US tight oil production.

Gas flaring is of particular importance when estimating the GHG emissions from crude oil. Flaring occurs when infrastructure needed to gather, process, and transport gas associated with oil production is not yet developed. This is an issue in the Bakken region since the building of new pipeline networks has not kept up with development. In addition, the remote nature of the production areas, harsh weather conditions, and difficulties in obtaining pipeline rights-of-way confound the issue. We used an estimate of 33-37% of the produced gas in the Bakken being flared. In contrast, flaring of associated gas from Eagle Ford production is a fraction of that value.

Based on the level of flaring, tight oil is often presumed to be a higher-carbon crude oil source. However, our analysis found that both Eagle Ford and Bakken crude oils have lower life-cycle GHG emissions than the average US crude oil refined—between 5% and 9% lower on a well-to-wheels basis (see Table 3).

The GHG intensity of producing the Eagle Ford crude oil is lower than that for any other crude oil estimate within our study. In addition to low extraction emissions, the Eagle Ford crude oil takes less energy (and consequently less GHG emissions) to refine into fuels.

TABLE 3

Well-to-wheels GHG emissions of US tight oil production
(kg CO_2e per barrel of refined product)

Crude name	Production-only GHG emission	Well-to-wheels life-cycle GHG emissions	Well-to-wheels percent difference from "average US barrel refined in the United States" in 2012
Bakken Blend	43	479	Minus 5%
Eagle Ford	18	455	Minus 9%
Average US crude oil consumed in 2012 (IHS estimate)	44	502	

*Well-to-wheels emissions include emissions from upstream fuel used in crude production, upgrading, and refining.

Source: DOE/NETL, "Development of Baseline Data and Analysis of Lifecycle Greenhouse Gas Emissions of Petroleum-Based Fuels," November 2008

Because of flaring, the GHG emissions for producing Bakken crude are more than two times higher than for the Eagle Ford and in the same GHG emissions range as producing Canadian oil sands mining dilbit. However, on a life-cycle basis, the Bakken crude is still below the average crude oil because it takes less energy to refine into fuels.

For more information on the inputs and assumptions in estimating the life-cycle GHG emissions from tight oil, download the Appendix of this report at www.ihs.com\oilsandsdialogue.

The GHG emissions rate for the average crude oil consumed in the United States should be treated as an estimate. Using the IHS method, the 2005 average was almost 4% higher than the DOE/NETL estimate. The difference highlights the level of uncertainty in estimating the GHG emissions for the average US crude oil. There are a large number of crude oil sources, and it is difficult to get precise GHG intensity data. Further, since calculating an average compounds the uncertainty associated with each individual crude oil, the average has a greater margin of error.

The GHG emissions rate for the average crude oil consumed in the United States was unchanged between 2005 and 2012. Despite the dramatic change in the geographic origin of US crude supply since 2005, GHG intensity remained essentially the same because crudes oils were substituted for other supply sources that were, on average, similar in GHG intensity. Higher-carbon crudes from North Africa were replaced with less GHG-intense domestic tight oil. At the same time the GHG impact of consuming more tight oil, along with declining consumption of higher carbon Latin American and Alaskan supplies, helped offset GHG impacts from increased imports of Canadian oil sands.

Canadian oil sands are in the same GHG intensity range as 45% of US oil supply. Using the IHS estimate of the US average crude oil baseline for 2012 estimated in this report, crude oils transported and consumed in the United States from oil sands had life-cycle GHG emissions that ranged from 1% higher than the average crude (for mining dilbit) to 19% higher (for SAGD SCO). In 2012, 45% of US oil supply was within the same GHG intensity range as oil sands. Two-thirds of the crude oil in this range come from sources other than the Canadian oil sands, such as from Latin America, Africa, the Middle East, and parts of the United States.

Part 4: Conclusions

The purpose of this report is to inform the dialogue surrounding the GHG emissions from US crude oil supply and Canadian oil sands. “Getting the numbers right” is especially important, considering how the GHG intensity of crude oil is factoring into policy decisions and may have direct economic implications for different crude sources.

The origin of US oil supply since 2005 has changed significantly. However, the GHG intensity of the average crude oil consumed in the United States did not materially change.

Common GHG intensity baselines—such as the average crude consumed in the United States—provide a useful reference point for comparisons. However, they should be used with caution. They are theoretical values to enable comparisons, not absolute numbers. There are simply too many crude oils consumed in the United States to accurately track and quantify emissions for each. The almost 4% difference between the IHS and DOE/NETL results indicates the possible margin of error in estimating the GHG emissions for the average crude oil.

Considering the uncertainty in measuring GHG emissions, it is important to avoid common pitfalls in using average baselines. The average crude should not be used as a reference point to estimate the incremental GHG emissions associated with greater US imports of crude derived from the Canadian oil sands. This approach is flawed since the oil sands will not replace the average crude oil; rather, they will replace other heavy crude oils.

Finally, despite commonly held views that oil sands are the highest-carbon crude oil, 45% of US oil supply falls within the same GHG intensity range as oil sands. Two-thirds of these crudes are coming from sources other than the Canadian oil sands, such as from Latin America, Africa, the Middle East, and some US domestic production.

Report participants and reviewers

IHS hosted a focus group meeting in Washington, DC, on 22 October 2013 to provide an opportunity for oil sands stakeholders to come together and discuss perspectives on the key issues related to quantifying GHG emissions from oil sands and other crude oils. Additionally, a number of participants reviewed a draft version of this report. Participation in the focus group or review of the draft report does not reflect endorsement of the content of this report. IHS is exclusively responsible for the content of this report.

Alberta Department of Energy

Alberta Innovates—Energy and Environment Solutions

American Petroleum Institute

BP Canada

Canadian Association of Petroleum Producers

Canadian Natural Resources Limited

Canadian Oil Sands Limited

Cenovus Energy Inc.

Center for Strategic and International Studies (CSIS)

ConocoPhilips Company

Enbridge Inc.

Nexen Energy ULC

Imperial Oil Ltd.

In Situ Oil Sands Alliance (IOSA)

Lawrence National Centre for Policy and Management, Ivey Business School, Western University

Natural Resources Canada

RAND Corporation

Shell Canada

Statoil Canada Ltd.

Suncor Energy Inc.

Total E&P Canada Ltd.

TransCanada Corporation

Woodrow Wilson International Center For Scholars (Wilson Institute)

IHS energy team

Jackie Forrest, former Senior Director, IHS Energy. Her recent contributions to oil sands research include reports on the life-cycle emissions from crude oil, the impacts of low-carbon fuel standards, effects of US policy on oil sands, and future markets for Canadian oil sands. Ms. Forrest is a professional engineer and holds a degree from the University of Calgary and an MBA from Queens University. Ms. Forrest is now a Vice-President at ARC Financial Corp.

Cheryl Dereniwski, Managing Director, IHS Energy, leads the Upstream Consulting practice in Canada. With 20 years of oil and gas industry experience, she has diverse business advisory and technical expertise, working in areas related to strategic planning, exploration and development, production operations, and corporate services across upstream, midstream, and downstream segments. She has worked with a wide range of clients, helping them to assess the impact of industry and market trends on future growth strategies, optimize capital investment decisions, improve organizational alignment to business function, streamline business processes, and identify and evaluate acquisition targets. More recently she has also been involved in assessing life-cycle emissions from crude oil. Before joining IHS, Ms. Dereniwski worked at Deloitte Consulting, Advantage Energy Services, and Imperial Oil. She is a professional engineer and holds a Bachelor of Science (honors) from Queens University.

Kevin Birn, Director, IHS Energy Insight, heads up the IHS Oil Sands Energy Dialogue. Recent contributions to oil sands research include analysis of the marine transport of oil sands crude, upgrading economics, and the future markets for oil sands. Prior to joining IHS, Mr. Birn worked for the Government of Canada as the senior oil sands economist at Natural Resources Canada, helping to inform early Canadian oil sands policy. He has contributed to numerous government and international collaborative research efforts, including the 2011 National Petroleum Council report *Prudent Development of Natural Gas & Oil Resources* for the US Secretary of Energy. Mr. Birn holds undergraduate and graduate degrees from the University of Alberta.

TABLE 1

Well-to-wheels GHG emissions for oil sands and conventional crude oils—Wide boundary results
($kgCO_2e$ per barrel of refined product)

		Tight boundary						Wide boundary					
Crude name	Source of production emissions	Crude production (includes venting and flaring, dilbit production, mine face, and tailings)	Upgrading	Crude transport	Crude refining	Refined product transport	Refined product combustion	Crude production: Upstream fuel	Upgrading: Upstream fuel	Crude refining: Upstream fuel	Well-to-tank (wide boundary)	Well-to-wheels (wide boundary)	Well-to-wheels percent difference from "average US barrel refined in the United States" IHS 2012
Cameroon Lokele	CARB (2012)	136	0	9	53	2	385	0	0	14	214	599	19%
Canadian oil sands: SAGD SCO	IHS (2012)	65	51	8	46	2	385	23	3	15	213	598	19%
Canadian oil sands: CSS bitumen	IHS (2012)	89		12	62	2	385	23		19	206	591	18%
Venezuela Petro zuata	IHS (2012)	22	103	4	52	2	385	0	3	14	200	585	16%
US: Average California Heavy	IHS (2012)—average	102	0	4	55	2	385	12	0	16	190	575	15%
Canadian oil sands: SAGD bitumen	IHS (2012)	65	0	12	62	2	385	23	0	19	183	568	13%
Canadian oil sands: CCS dilbit	IHS (2012)—CCS dilbit	74	0	10	54	2	385	17	0	17	173	558	11%
Canadian oil sands: Average produced (2012)	IHS (2014)	49	25	10	54	2	385	14	1	16	172	557	11%
Canadian oil sands: Mining SCO	IHS (2012)	28	51	8	46	2	385	10	3	15	163	548	9%
Average oil sands refined in the United States (2012)	IHS (2014)	50	15	9	53	2	385	12	1	16	160	545	9%
Venezuela Boscan	CARB (2012)	66	0	4	62	2	385	6	0	18	158	543	8%
Canadian oil sands: SAGD dilbit	IHS (2012)	57		10	54	2	385	17	0	17	156	541	8%
US: Alaska North Slope (ANS CARB)	CARB (2012)	83	0	4	41	2	385	0	0	14	145	530	6%
Canadian Bitumen Blend	IHS (2012)—average	42	13	10	51	2	385	8	1	16	143	528	5%
Nigeria Bonny Light	IHS (2012)	77	0	9	39	2	385	0	0	14	141	526	5%
Canadian oil sands: Mining bitumen (PFT)	IHS (2012)	29		12	62	2	385	10		19	134	519	3%
Iraq Basrah Light	IHS (2012)	60	0	9	43	2	385	0	0	14	128	513	2%
Canadian oil sands: Primary CHOPS	IHS (2012)	38	0	10	60	2	385	0	0	18	128	513	2%
US: Mars	IHS (2012)	60	0	4	42	2	385	0	0	14	122	507	1%
Venezuela–Bachaquero	IHS (2012)	35		4	64	2	385			18	122	507	1%
Canadian oil sands: Mining dilbit (PFT)	IHS (2012)	31		10	54	2	385	7	0	17	121	506	1%
Angola Girassol	IHS (2012)	51	0	9	44	2	385	0	0	14	120	505	1%
Average US barrel refined in the United States (2005 IHS est.)		49	3	6	45	2	385	1	0	14	120	505	1%
Russian ESPO	CARB (2012)	55	0	9	40	2	385	0	0	14	119	504	0%

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		Tight boundary											Wide boundary
Crude name	Source of production emissions	Crude production (includes venting and flaring, dilbit production, mine face, and tailings)	Upgrading	Crude transport	Crude refining	Refined product transport	Refined product combustion	Crude production: Upstream fuel	Upgrading: Upstream fuel	Crude refining: Upstream fuel	Well-to-tank (wide boundary)	Well-to-wheels (wide boundary)	Well-to-wheels percent difference from "average US barrel refined in the United States" IHS 2012
Average US barrel refined in the United States (2012 IHS est.)		44	4	6	45	2	385	1	0	14	117	502	
North Sea Mariner	IHS (2012)	23	0	9	64	2	385	0	0	18	116	501	0%
Mexico Maya	IHS (2012)	42	0	4	52	2	385	0	0	14	114	499	-1%
Ecuador Napo	CARB (2012)	38	0	4	55	2	385	0	0	14	113	498	-1%
Angola Dalia	CARB (2012)	37	0	9	51	2	385	0	0	14	112	497	-1%
Russian Urals	IHS (2012)	47	0	9	40	2	385	0	0	14	111	496	-1%
Ecuador Oriente	IHS (2012)	46	0	4	45	2	385	0	0	14	110	495	-1%
Kuwait Eocene	IHS (2012)	25	0	9	56	2	385	0	0	18	109	494	-2%
Australia Pyrenees	CARB (2012)	30	0	9	54	2	385	0	0	14	108	493	-2%
Colombia Castilla	CARB (2012)	29	0	4	55	2	385	0	0	18	108	493	-2%
Iraq Kirkuk	IHS (2012)	45	0	9	37	2	385	0	0	14	106	491	-2%
Brazil Marlim	CARB (2012)	32	0	4	54	2	385	0	0	14	106	491	-2%
Angola Plutonio	CARB (2012)	41	0	9	39	2	385	0	0	14	105	490	-2%
Average US barrel refined in the United States (2005 DOE/NETL)		36		6	43	2	385	0	0	14	102	487	-3%
Kuwait Ratawi	CARB (2012)	25	0	9	50	2	385	0	0	14	100	485	-3%
Canadian Mixed Sweet	CARB (2012)	36	0	10	37	2	385	0	0	14	99	484	-4%
Colombia Vasconia	CARB (2012)	30	0	4	48	2	385	0	0	14	98	483	-4%
Bakken Blend	IHS 2014	43	0	4	31	2	385	0	0	14	94	479	-5%
Arab Light	IHS (2012)	28	0	9	40	2	385	0	0	14	93	478	-5%
Trinidad Calypso	CARB (2012)	36	0	4	35	2	385	0	0	14	91	476	-5%
Arab Medium	IHS (2012)	22	0	9	42	2	385	0	0	14	89	474	-6%
US: Average crude oil (DOE/NETL)	IHS (2012)	25	0	4	43	2	385	0	0	14	88	473	-6%
North Sea Ekofisk	IHS (2012)	22	0	9	35	2	385	0	0	14	82	467	-7%
North Sea Forties	IHS 2014	19	0	9	31	2	385	0	0	14	75	460	-8%
Eagle Ford Tight Oil	IHS 2014	18	0	4	33	2	385	0	0	14	70	455	-9%

Notes: Tight boundary includes direct emissions from the oil production site and facilities.
Wide boundary adds emission for upstream fuels—natural gas and electricity produced off site.
Refining data sourced directly from Jacobs (2012).
"Average oil sands refined in the United States (2011)" assumes 7% SAGD SCO, 22% mining SCO, 20% CSS dilbit, 28.5% SAGD dilbit, 16% primary (CHOPS), 4% SAGD bitumen, and 3% CSS bitumen.
"Average oil sands produced (2011)" assumes 50% mining SCO, 5% SAGD SCO, 15% SAGD bitumen, 17% CSS bitumen, and 13% primary (CHOPS).
All dilbit blends are assumed 28% diluents and the remainder bitumen.
All oil sands cases marked "dilbit" assume that the dilbit is consumed in the refinery with no recycle of diluents.
All oil sands cases marked "bitumen" assume that diliuent is recycled back to Alberta, and only the bitumen part of the barrel is processed at the refinery.
For crude production using steam (California heavy crudes and oil sands in situ) impacts from cogeneration of electricity were not included in results.

Source: IHS Energy meta-analysis sourcing data from IHS Energy (2009), Environment Canada (2010), DOE/NETL (2008), Jacobs (2012), Jacobs (2009), Charpentier (2011), GHGenius (2011), GREET (2012), CARB-OPGEE (2012), Yeh(2010), past oil sands EIA's, and Alberta Environment