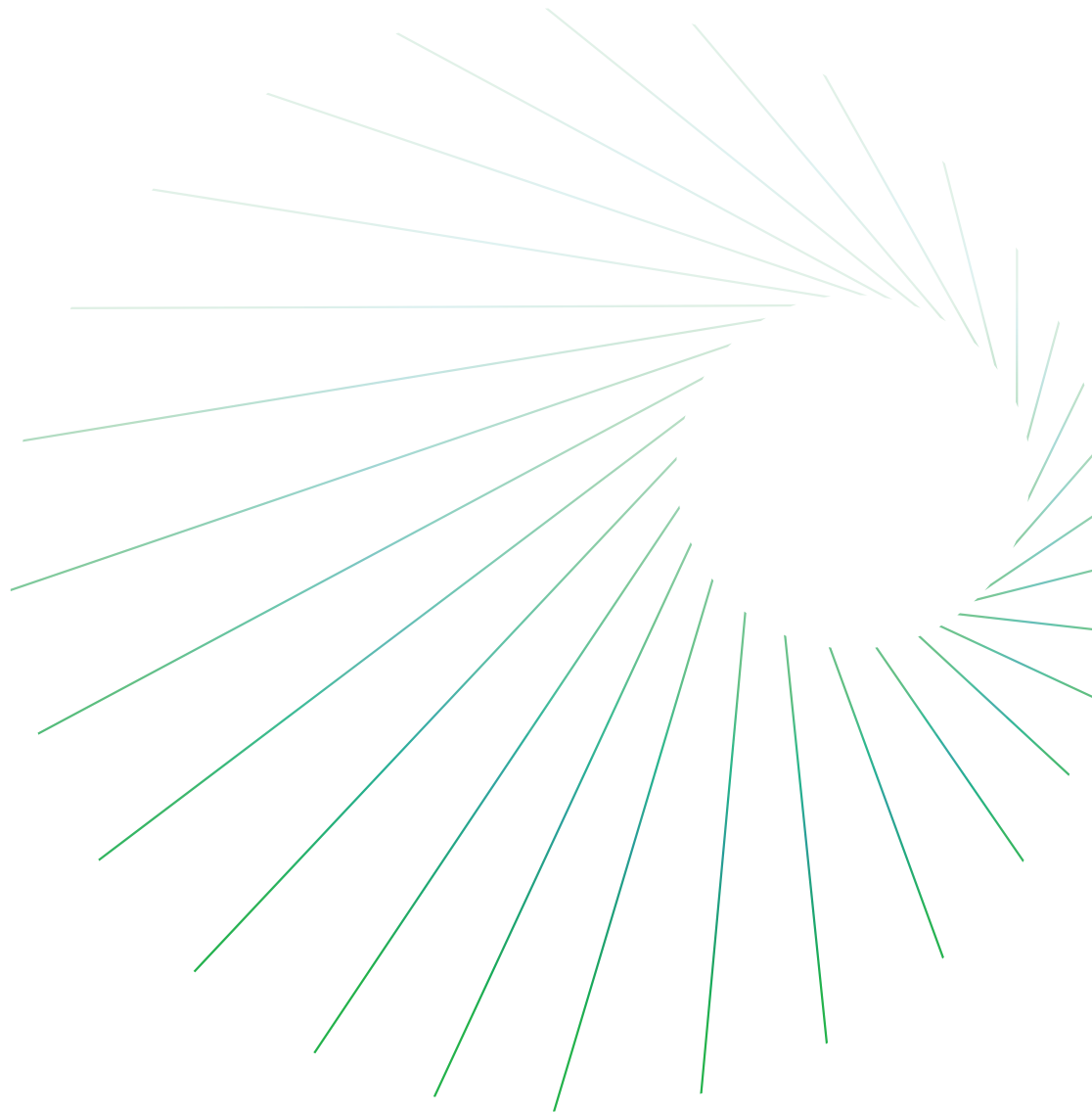


Looking north

A US perspective on Canadian heavy oil
November 2018



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*A special thanks to Steve Fekete, Executive Director, Consulting, for contributing to this report.

Contents

Introduction	5
The United States is the world's largest heavy oil market	6
The historical role of Canadian heavy oil in the United States	6
The history of US heavy oil demand	8
– Latin American JVs and supply agreements lead to a heavy oil expansion in the USGC	9
– Canadian supply fueled a heavy oil expansion in the Midwest	9
The global heavy oil market has tightened	10
The importance of Canadian heavy oil imports has risen	11
Report participants and reviewers	13
IHS Markit team	14

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About this report

Purpose. Since 2009, IHS Markit has provided research on issues surrounding the development of the Canadian oil sands. This is the second of two reports exploring the relationship between US heavy oil demand and Canadian heavy oil supply. The renaissance in the US hydrocarbon production has changed the world. However, US demand and import of heavier crude oils have persisted, with Canada taking on an increasing share and role in the US market. This report will explore the outlook for US heavy oil demand.

Context. This report is part of a series of reports from the IHS Markit Canadian Oil Sands Dialogue. The dialogue convenes stakeholders in the oil sands to participate in an objective analysis of the benefits, costs, and impacts of various choices associated with Canadian oil sands development. Stakeholders include representatives from governments, regulators, oil companies, refiners, and nongovernmental organizations.

This report and past Oil Sands Dialogue reports can be downloaded at www.ihsmarkit.com/oilsandsdialogue.

Methodology. IHS Markit conducted extensive research and analysis on this topic, both independently and in consultation with stakeholders. This report was informed by multistakeholder input from a workshop held in Washington, DC, on 7 November 2017, as well as participant feedback on a draft of the report. IHS Markit has full editorial control over this report and is solely responsible for its content (see the end of the report for a list of participants and the IHS Markit team).

Structure. This report has six sections.

1. Introduction
2. The United States is the world's largest heavy oil market
3. The historical role of Canadian heavy oil in the United States
4. The history of US heavy oil demand
5. The global heavy oil market has tightened
6. The importance of Canadian heavy oil imports has risen

Looking north

A US perspective on Canadian heavy oil

Key implications

The renaissance of US hydrocarbon production has changed the world. However, US demand and import of heavier crude oils have persisted. In 2018, US refiners will process nearly 17 MMb/d of crude oil. About half of this volume will be imported, and more than half of all imports are heavy oil. A key growing source of US oil imports has come from Canada. This report explores the US demand for and relationship with heavy oil and the role that Canadian heavy oil plays in the United States.

- **The United States is the world's largest market for heavy oil.** Over the past 40 years, the US refining complex has invested in expanding its ability to process heavy oil, first from Latin America and later from Canada. This fact has not only made the United States the world's largest market for heavy oil but has also given US refineries a competitive advantage. In 2018, the United States will demand more than 5 MMb/d of heavy oil.
- **As tight oil has risen, the global heavy oil supply may have tightened because key sources of heavy supply have declined.** Some factors contributing to a tightening heavy oil market may be short-lived, such as heavy oil cuts by OPEC, while others may be more protracted, such as the collapse of Venezuelan heavy oil output—heavy alone, down nearly 500,000 b/d since 2014.
- **Lacking alternative markets, growing heavy oil supply from Canada has taken on an increasing role in meeting US demand.** In 2018, the United States will import more than 3.6 MMb/d from Canada—more than any other nation, even the combined imports from all of OPEC. Most of these imports—four-fifths—will be heavy oil.
- **Canadian heavy crude oil fits an important supply gap for US refiners designed to process heavy oil.** At the same time that US production of light oil has grown, the relative importance of Canadian heavy oil to the United States has increased. The United States will soon become the largest crude oil producer in the world, but that growth is from light crude oil. In the absence of Canadian supply, heavy oil may otherwise be more scarce and expensive to US refiners.

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Looking north

A US perspective on Canadian heavy oil

Vijay Muralidharan, Director

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Introduction

The renaissance of US hydrocarbon production has changed the world, but the impact has not been borne evenly across the oil market. The revival and abundance of US supply has come from tight oil, a light, sweet crude oil. However, US refineries are designed to process a range of crude oils—from light to heavy. The impact has backed out almost all offshore imports of similar quality crude oil, but imports of heavier grades—medium to heavy—have persisted.

In 2018, IHS Markit estimates that US refineries will process nearly 17 MMb/d of crude oil. Of this volume, less than half will be light oil; a quarter medium; and the remaining third heavy. Over the past decade, from 2009 to 2018, imports of light, sweet crude oil fell 1.5 MMb/d while demand increased 1.5 MMb/d. Meanwhile, demand and imports of heavier and/or sourer crude oils increased by more than 200,000 b/d.

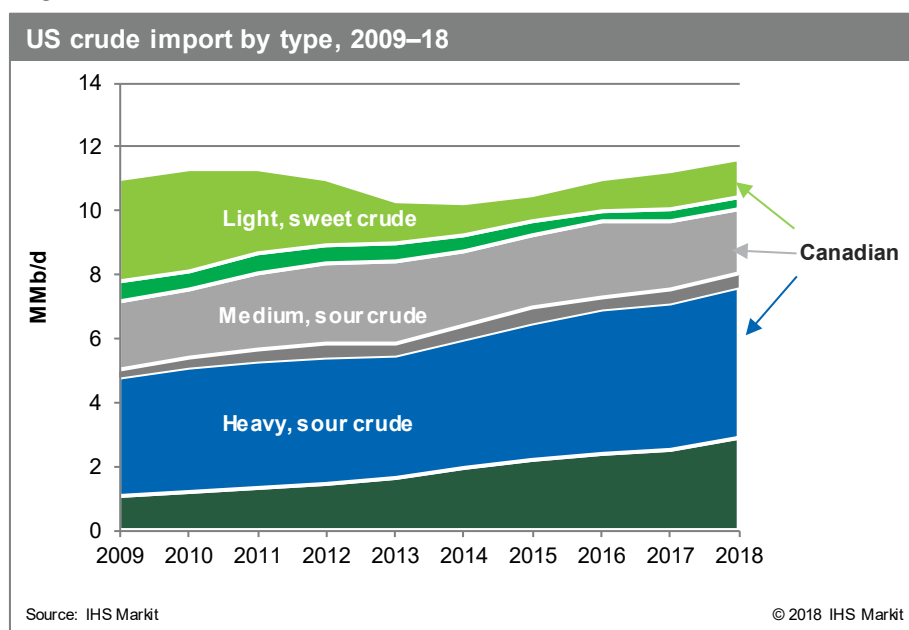
Lacking alternative markets and with growth dominated by heavy crude oil, Canada has taken on an increasing role in meeting US demand (see Figure 1). In fact, in 2015 imports from Canada overtook the combined imports of all of OPEC to the United States.¹

All indications are that US output will continue to rise. Having nearly saturated all US demand for light oil, increasing volumes are expected to move offshore. Indeed, US exports of crude oil doubled between 2016 and 2017 to about 1.1 MMb/d and have averaged about 1.8 MMb/d in 2018.² Meanwhile, the key sources of heavy oil have declined, and the relative importance of Canadian, both volumetrically and in meeting the need of specialized complex refineries in the United States, has increased.

This report is the second in a series looking at the interdependence and outlook for North American heavy supply and demand. The first report,

Looking south: A Canadian perspective on the US Gulf Coast heavy oil market, looked at the potential of the US

Figure 1



1. Source: Energy Information Administration (EIA), "U.S. Imports by Country of Origin," www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbbldpd_a.htm, retrieved 16 July 2018.

2. Source: EIA, "Exports," https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbbldpd_a.htm, retrieved 5 October 2018.

market from a Canadian export perspective.³ This report takes the opposite perspective: what do US refineries want, why heavy oil, and how much?

Throughout this report, numerous terms relating to crude quality, value, and processing are discussed. For simplicity, heavy, sour crude oil—the dominant form of Canadian output and exports to the United States—will be referred to as just heavy crude oil or heavy oil. More information on crude quality and refining is available in the box “Refining 101: Crude quality matters.”

The United States is the world’s largest heavy oil market

In 2018, IHS Markit estimates that the global refining system will process about 85 MMb/d of crude oil and condensate.⁴ As shown in Figure 2, nearly 10 MMb/d, or 12%, of this result is heavy crude oil.

Over the past decade, global heavy oil demand has increased. As shown in Figure 3, from 2009 to 2018 demand rose from 7.0 MMb/d to 9.6 MMb/d. During this period, growth in heavy oil demand in Asia doubled from 1 MMb/d to 2 MMb/d. This result was closely followed by North America, nearly all occurring in the United States, where heavy oil processing expanded by just over 1.0 MMb/d, to reach 5.3 MMb/d in 2018.

By a wide margin, the United States remains the largest market for heavy crude oil. As shown in Figure 3, more than half of all heavy oil globally was processed in North America in 2018, predominantly the United States.

The majority of the heavy oil processing is occurring on the USGC, followed by the Midwest and the West Coast. As shown in Figure 4, the USGC region has processed more than half of all US heavy oil demand in 2018, or 2.7 MMb/d. In 2018, the Midwest has processed 1.3 MMb/d, while the West Coast (California and Washington State specifically) has accounted for just under 700,000 b/d.

Processing in the remaining regions, the East Coast and Rockies, is smaller and geared more toward lighter oils. In 2018, the two regions processed just over 400,000 b/d of heavy oil.

The historical role of Canadian heavy oil in the United States

Canadian heavy oil imports have traditionally found a home in the Midwest, with offshore suppliers from Mexico, Venezuela, and the Middle East meeting the needs of the USGC. Today, the Midwest region may have hit its maximum capacity to consume more heavy oil from Canada (and elsewhere). Growing Canadian heavy supply has been making its way down to the USGC at the same time that key sources of Latin American heavy oil, namely Venezuelan and Mexican supply, have declined. In fact, IHS Markit estimates that current consumption of Canadian crude on the USGC may already be in excess of 800,000 b/d—far greater than headline EIA import data would indicate—owing to commingling, storage, and internal transfers within the United States.⁵

Meanwhile, to date, logistical issues have impaired the ability of meaningful volumes of Canadian supply to access the US West Coast and East Coast markets. Although some limited rail has made its way from Canada to the US East Coast, this market traditionally processes lighter crudes and lacks the complexity for heavier grades of oil. On the US West Coast, the majority of heavy demand has been met by domestic Californian or Alaskan output. However, as Californian and Alaskan production has slowly declined, offshore imports have

3. For more information, this report can be accessed here: www.ihsmarkit.com/oilsandsdialogue.

4. This estimate does not include biofuels/NGLs and other petroleum products.

5. The EIA tracks overland crude oil imports when they “break bulk,” meaning when the crude oil is unloaded or leaves the pipeline. IHS Markit believes that Canadian heavy oil imports may be “stopping off” at Cushing, which would result in a reported delivery into PADD 2 as opposed to PADD 3.

Refining 101: Crude quality matters

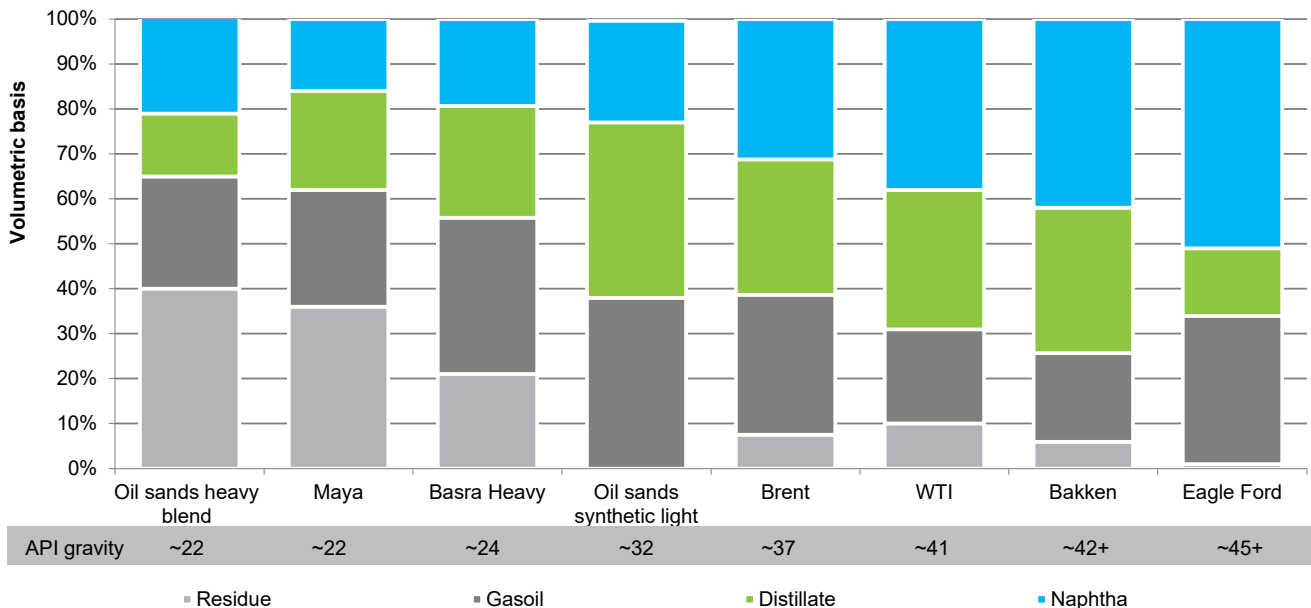
Crude oil is not homogeneous. It is commonly differentiated by density—light or heavy—and impurities, most notably sulfur—sweet or sour. API gravity is a common measure of density. IHS Markit defines heavy crudes as those with an API gravity of 24° or less, light crudes as those with an API gravity of 32° or greater, and everything in between as medium.

Notwithstanding the global value of crude oil, the relative value refiners place on different quality crude depends on how much effort it takes to convert it into higher-value refined products and the type of products that can be derived from it. Crude oil will differ by its composition and/or groupings of similar hydrocarbons (known as fractions). Lighter fractions, such as naphtha and distillate, boil at lower temperatures and are in a general sense more easily converted into higher-value refined products such as gasoline and jet fuel. Heavier fractions, such as residue and gasoil, boil at higher temperatures. Figure B1 illustrates the distribution of various fractions for a select set of crude oils, ordered from left to right and from heavy to light.

The heaviest fractions (i.e., residue, shown in light gray in Figure B1) require specialized processing units capable of reaching the temperature and pressure needed to break or convert these more complex hydrocarbons into lighter fractions, which can then be converted into gasoline and diesel. Heavier crude oils typically have a greater share of fraction of heavier molecules such as residue. Refiners that lack heavy crude oil processing capacity are unable to process the heaviest fractions and face selling a larger share of the barrel they purchased at a lower value. Heavy crude oil refineries—the types best suited to process such crudes—are generally known as complex refineries.

Figure B1

Assay of select crudes



Note: Crude assays will vary. Values are approximations and will vary by cut point and reservoir quality, which does vary across a play and over time. Estimates are assembled from various sources and adjusted based on feedback.

Source: Derived and adapted from IHS Markit, EIA, BP Global Energy Trading, and CrudeMonitor.ca

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crept up, which could provide future opportunities for Canadian heavy oil.

The history of US heavy oil demand

Refining is a complex and ever-changing business. Over time, refineries invest to better tailor their facilities to available feedstock and refined products in demand. Prior to the advent of US tight oil and the revival of US supply, domestic US production was in long-term decline. After peaking in the early 1970s, US crude oil production entered a 40-year decline.⁶ Moreover, the world thought it was running out

of lighter grades of crude oil. US refiners faced with the prospect of continued reductions in the availability of domestic supply looked increasingly offshore. Infrastructure was built to deliver increasing volumes inland from offshore. US imports of foreign crude oil increased, reaching a rough plateau between 2004 and 2007 at

Figure 2

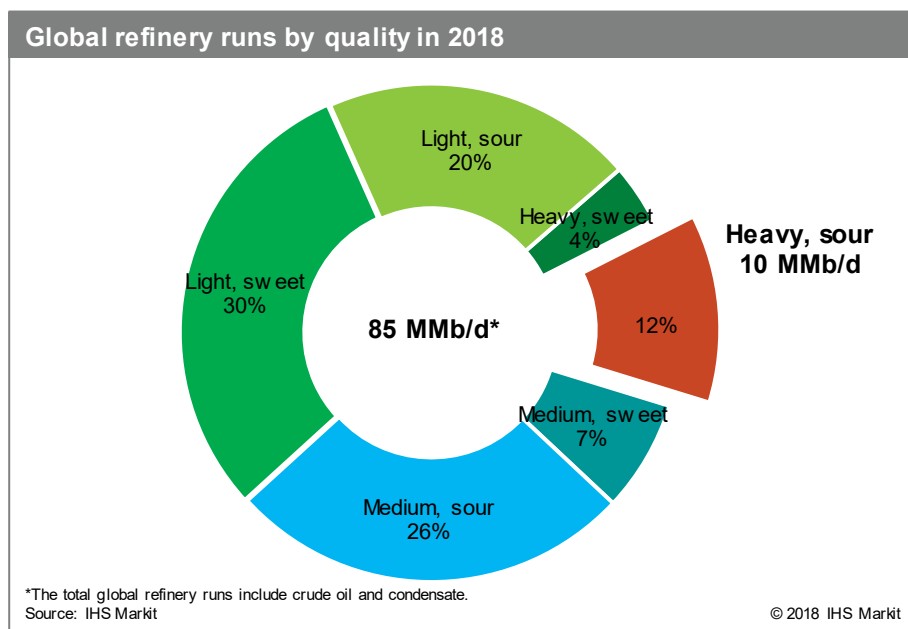
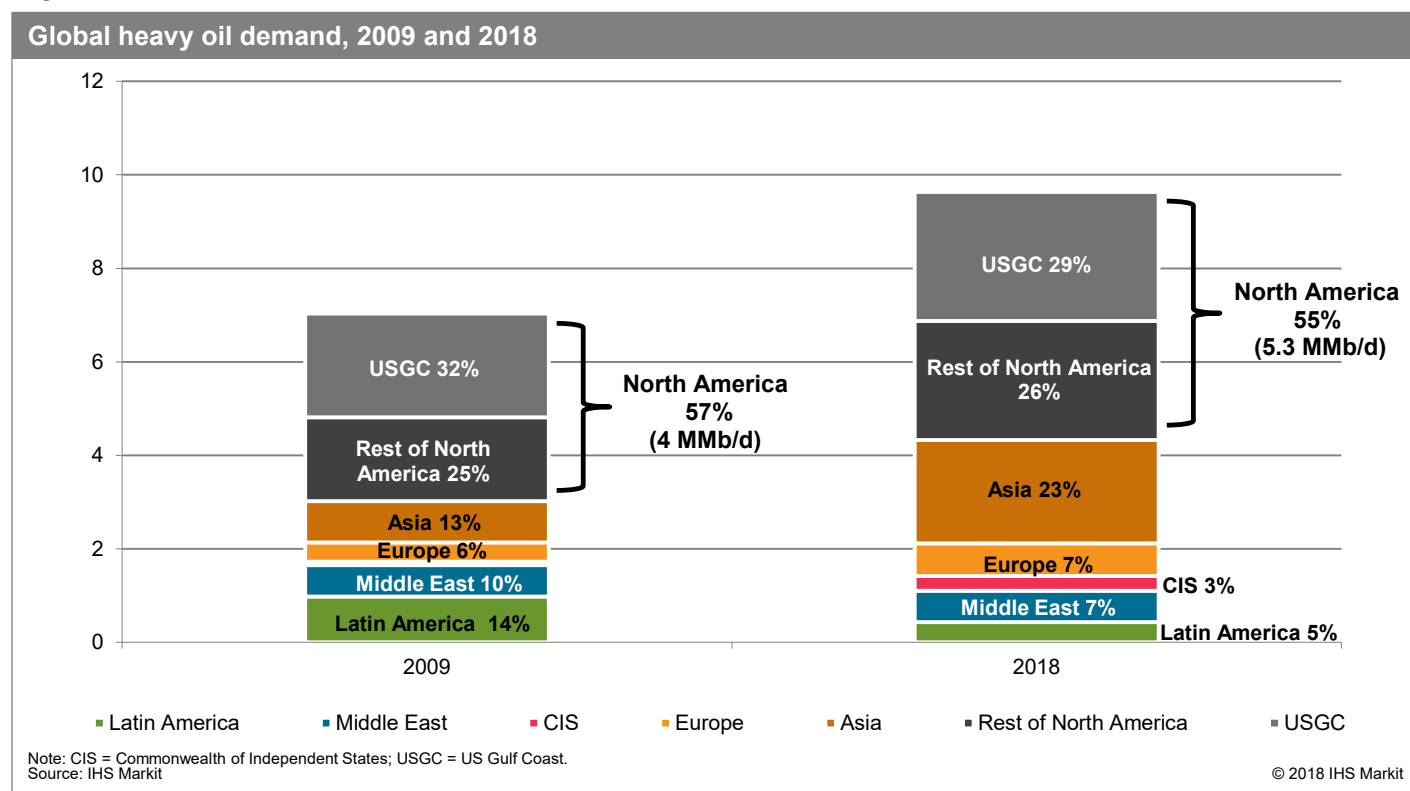


Figure 3

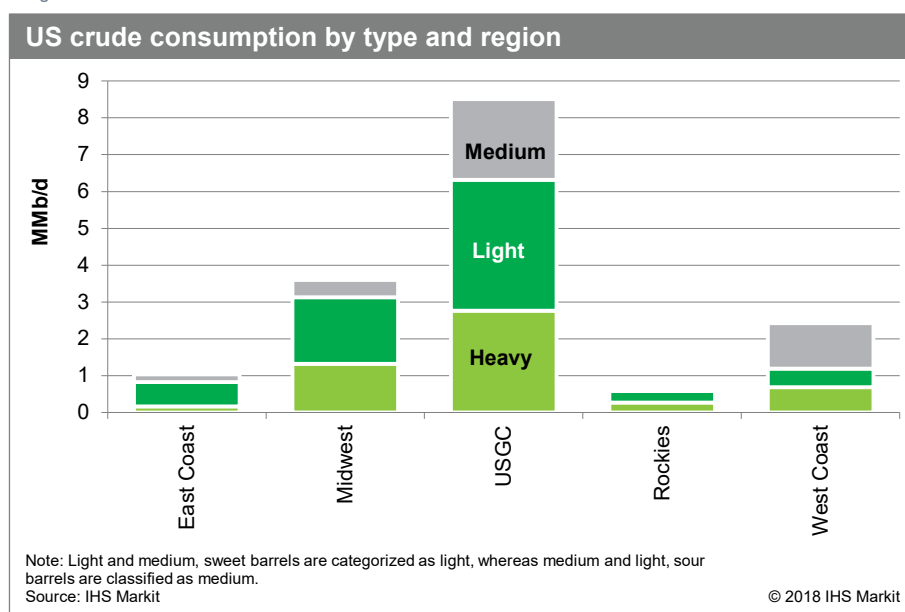


6. The estimate does not include NGLs, biofuels, and other petroleum products. Source: EIA, "Crude Oil Production," https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbldpd_a.htm, retrieved 5 September 2018.

more than 10 MMb/d.⁷ Deposits of heavy crude in Mexico, Venezuela, and Canada were viewed as a limited set of resources globally capable of meaningful production growth. Heavy oil supply expanded in these regions, first in Latin America and then later in Canada.

These conditions set the stage for an expansion of US heavy crude oil refining capacity. Over the past 30 years, heavy oil processing capacity expanded from about 1.5 MMb/d to 2.5 MMb/d (from 1990 to 2018).⁸ This expansion occurred during two distinctive periods, first on the USGC and then later in the US Midwest.

Figure 4



Latin American JVs and supply agreements lead to a heavy oil expansion in the USGC

The first period of heavy oil processing expansion occurred during the 1990s. Faced with declining domestic production, US refiners looked offshore for supply. Meanwhile, Latin American heavy oil production was on the rise, but was limited in the number of markets capable of economically processing the crude oil. Many refiners entered into JVs and/or supply arrangements that provided crude oil at prices that supported the refinery investment necessary to convert heavier crude oils into refined products. In exchange, the producers received security of demand for their output. Most of the expansion that occurred during this period happened on the USGC and to a lesser extent in the Midwest and on the West Coast. Gradually, these arrangements unwound, as the terms expired in the early 2000s and because of the rise of alternative sources of heavy oil from places such as Canada. Nevertheless, as seen in Figure 5, investments resulted in an expansion of heavy oil processing capacity from just over 1.5 MMb/d in the early 1990s to more than 2.1 MMb/d in the early 2000s. Correspondingly, US heavy oil processing (demand) climbed from 2.5 MMb/d to 3.9 MMb/d from 1990 to 2001 (approximate period of these contracts).⁹

Canadian supply fueled a heavy oil expansion in the Midwest

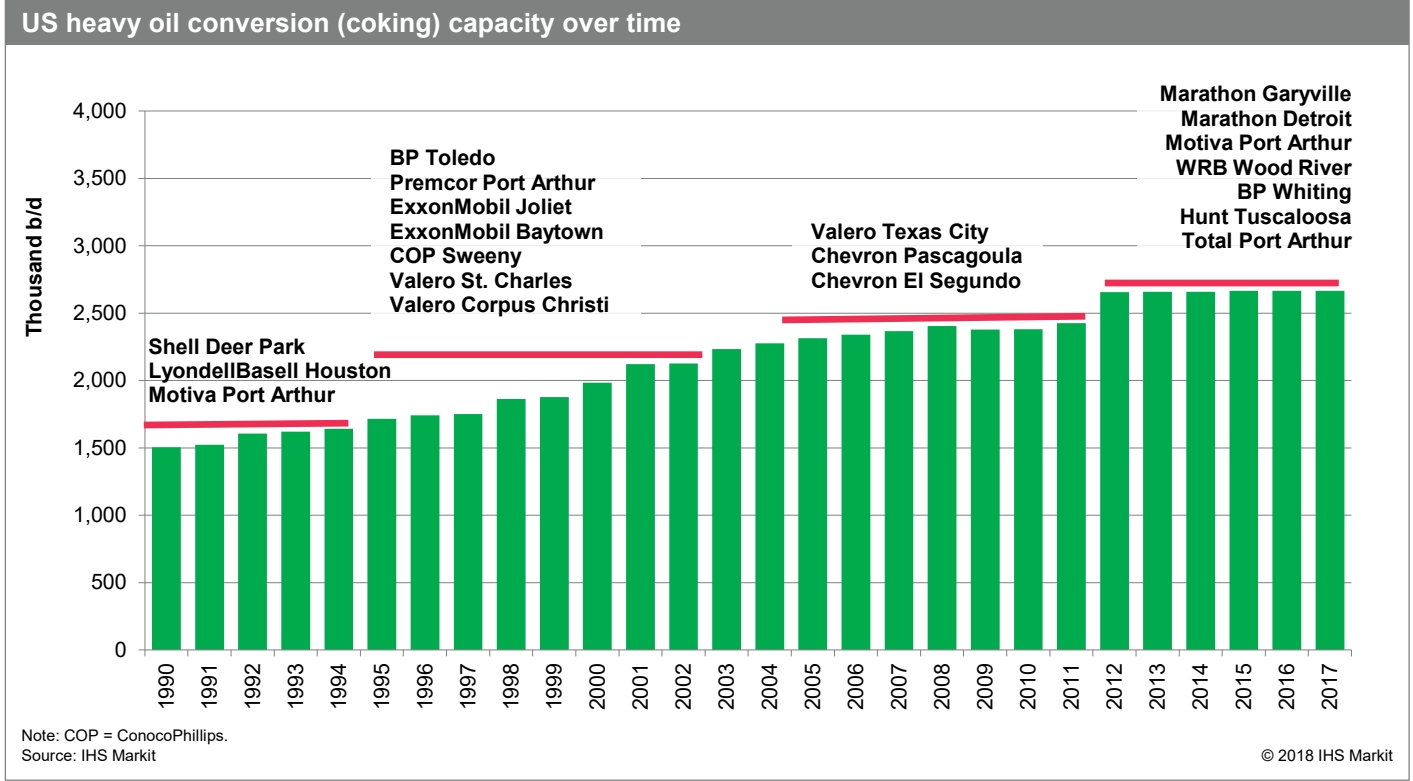
The second wave of expansion began to emerge in the mid-2000s and lasted just over a decade. The dawn of the millennium brought the development of the first commercial steam-assisted gravity drainage (SAGD) project in the Canadian oil sands. This development unlocked the majority of the resource potential in the oil sands. Unlike oil sands mining, which dominated at the time and marketed a light synthetic crude oil (SCO), SAGD plants predominantly marketed heavier bitumen blends. Investment increased in the Canadian oil sands, and production grew.

7. The estimate includes only crude oil, not NGLs, biofuels, and other petroleum products. Source: EIA, "U.S. Imports by Country of Origin," www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbldpd_a.htm, retrieved 16 July 2018.

8. The estimate is based on coking capacity. Generally, total heavy oil demand need not be the same as total heavy oil processing capacity (coking capacity), given that only the residual, which is a fraction of the heavy barrel, needs to be processed through cokers.

9. Heavy oil processing capacity typically relates to coking capacity. A coker is a specialized refinery processing unit capable of achieving the environment necessary to process the heaviest fractions in crude oil. Because crude oil varies in the share of these heavy fractions even within heavy crude oil, heavy oil processing can be greater than coking capacity. Moreover, there are other heavy oil processing technologies, but, by far, coking is the most common.

Figure 5



From 2001 to 2018, the Canadian oil sands supply expanded 2.2 MMb/d, and increasing volumes headed south. A wide price difference between light and heavy crude oil incentivized an expansion in the US Midwest to process greater volumes of lower-cost heavy, sour crude oil from Canada (and in Canada in upgrading bitumen into light SCO).¹⁰ To a lesser extent, some investments were also made in the USGC. The majority of the expansion occurred in the US Midwest and USGC.

Throughout this period, less complex, smaller refining operations have generally given way to larger, more complex operations. Complex refiners are benefiting from the ability to optimize over a greater range of feedstock (or crude quality) while expanding in size to capture greater economies of scale. Over the past decade, from 2009 to 2018, three-quarters of more than 1 MMb/d of refinery capacity that has been rationalized came from less complex crude distillation units.

The global heavy oil market has tightened

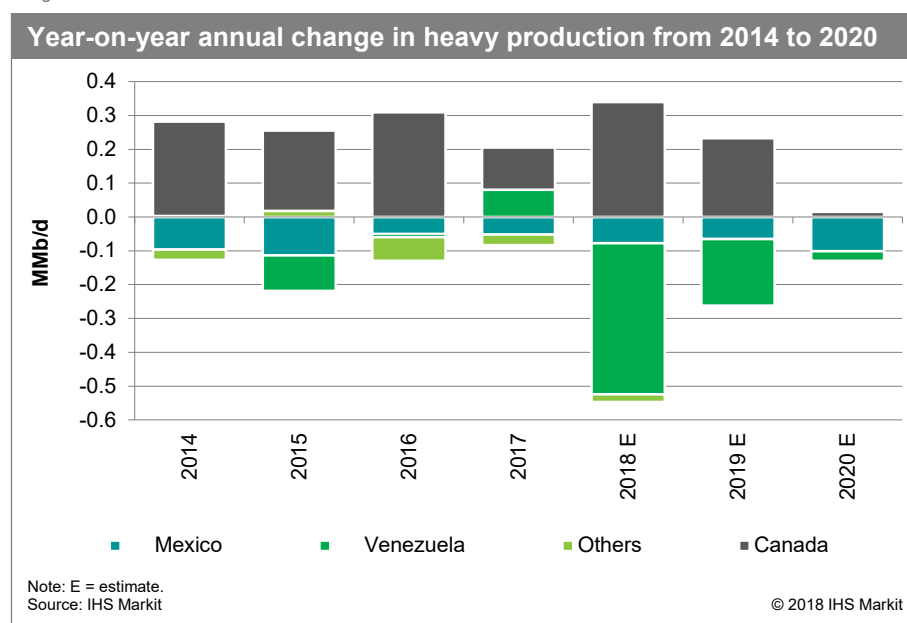
The conditions that gave rise to the expansion of US heavy oil demand over the past 40 years have changed. The world has found itself flush with light oil, while the relative availability of heavy oil has tightened. This result has reduced the price difference between light and heavy crude oil globally and thus the incentive in further investments in heavy oil processing capacity—particularly in North America.

10. SCO is a light crude oil produced from bitumen via specialized heavy oil refinery conversion units, known as upgraders, which turn very heavy hydrocarbons into lighter, more valuable fractions from which gasoline and diesel are manufactured. From 2001 to 2018, investments in oil sands upgrading increased overall SCO production by more than 600,000 b/d, to about 1 MMb/d, and a new heavy oil refinery was completed in 2017.

The rise of tight oil is well documented, while the tightening of the heavy crude oil market has come about from the accelerated declines of key sources of heavy crude oil, OPEC production restraint, and the ongoing expansion of heavy oil processing capacity elsewhere in the world. Below are some key contributing factors:

- Expanding Russian heavy oil capacity.** Changes to Russian fiscal policy have incentivized Russian refineries to process more of the heavier fractions that would otherwise be exported. This has reduced the availability of heavy bottom material, which traditionally would have been processed in Europe. Consequently, there has been increasing demand for heavy bottom fractions globally, which are typically found to a greater degree in heavier grades of oil. IHS Markit estimates that from 2013 to 2017, more than 300,000 b/d of heavy bottom processing capacity has been implemented in Russia, with additional investments under way or planned before 2020.¹¹
- Lower heavy oil supply due to OPEC cutbacks, decay of the Venezuelan oil sector, and falling Mexican output.** The 1.8 MMb/d of crude oil supply cuts that were agreed to by OPEC and numerous non-OPEC countries in 2017–18 have been borne to a greater degree by heavier crude oils. Although the cuts have been rolled back, Venezuela’s heavy oil production continues to fall owing to a lack of investment and decay. Also, Mexican heavy oil production has been in steady decline for more than a decade. Mexico has liberalized and opened its upstream oil sector to help arrest and reverse these declines. To date, there has been considerable interest by international investors in the Mexican upstream sector. However, any reversal will take time, and there is no guarantee that heavy oil will be the beneficiary with considerable interest in lighter plays. As shown in Figure 6, Latin American heavy oil output has declined about 900,000 b/d over the past four years (from 2014 to 2018, or since the oil price collapse began in 2014) and could decline by another 500,000 b/d by 2020. Venezuela alone has lost about 500,000 b/d of heavy oil since 2014. The only source of material heavy crude oil growth globally has come from Canada.

Figure 6



The importance of Canadian heavy oil imports has risen

The historical incentives that led to the expansion of heavy oil processing capacity in the United States have subsided in the past few years. The economics of investing in heavy oil conversion capacity are predicated on the anticipated savings in being able to convert heavier crude oils that typically trade at a discount to lighter grades into higher-value refined products. The rise of light, tight oil in great abundance and the contraction (temporary or otherwise) in the availability of heavy oil globally have reduced the price difference (and future

11. Heavy bottom processing capacity includes coking and hydrocracking. The value represents only the heaviest components of a barrel of crude oil.

expectation) between light and heavy crude oil. Over 2017, the price of Mexican Maya—a globally traded heavy oil—averaged about \$7/bbl lower than Light Louisiana Sweet—a globally traded light crude oil on the USGC—compared with a historical five-year average of \$9/bbl.¹² Moreover, anecdotally, there have been instances in 2018 where the price of Canadian heavy oil in Houston has traded at a premium to WTI, Cushing.

The presence of light, tight oil in great abundance will encourage US refiners—big and small—complex or not—to process more of it. Investments will be made to widen out the top end of refiners—to process crude oil with a larger share of light ends—such as are found in the Permian.

However, facilities that have invested in heavy oil processing capacity are not expected to go backward or “uncomplicate” themselves. These investments, which can be significant at well over US\$1 billion to integrate a heavy oil conversion unit known as a coker, give a refinery greater flexibility to optimize over a greater range of feedstock. This situation has historically given the USGC (and other heavy complex refiners) a competitive advantage that has allowed the region to expand output and increase market share in the United States and abroad. It will not wish to idle this capacity.

A key question that has emerged as a result of the accelerating uncertainty over the future output of Venezuela—one of the largest historical producers of heavy oil in the world—is the adequacy of heavy oil supply going forward, a situation that is clearly visible in Figure 6.

Through this period, the importance of Canadian heavy oil has arguably risen. Canada has become the largest producer of heavy crude oil in the world and over the past few years the only source of material heavy growth globally. To date, IHS Markit believes rising Canadian heavy supply—which increased 1.1 MMb/d from 2012 to 2017—has managed to offset most of the contraction in heavy oil supply globally. Additionally, Canada’s market share in the United States has expanded, offsetting and/or displacing offshore imports from Latin America and elsewhere. This result has shored up the US heavy oil market to date.

Looking to the future, there are valid questions about the future balance of the heavy oil market. Venezuelan output is increasingly unreliable and uncertain, and it may well get worse before a recovery can be mounted. In turn, any recovery depends on broader political and economic reforms in Venezuela, which will take time. IHS Markit expects Canadian heavy oil imports will be increasingly in demand in the United States, expanding from 2.5 MMb/d in 2017 to more than 3.0 MMb/d in 2020. However, the pace of Canadian heavy oil growth is also set to slow owing to the declining level of oil sands projects under active development. IHS Markit expects new oil sands projects will advance in the next few years. Yet with oil sands projects taking two years or more before production can be brought online, a slower period of growth at least to the early part of the next decade is almost assured. OPEC could help moderate the heavy oil market, but there are quality differences between Middle Eastern heavy oil and the much heavier grades found in the Americas. If this trend continues, it could set the stage for a protracted period of a tighter heavy oil market in the world and a greater importance for Canadian output to US refiners—at least in the medium term.

12. Differentials have widened closer to historical relationships for Mexican Maya in 2018. However, inland US crude congestion contributed to both distortions to US crude benchmarks and the formula used to set Mexican Maya.

Report participants and reviewers

IHS Markit hosted a focus group meeting in Washington, DC, on 7 November 2017 to provide an opportunity for stakeholders to come together and discuss the future of the US heavy oil market. Numerous participants also reviewed a draft 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 Markit is exclusively responsible for the content of this report.

Alberta Department of Energy

Alberta Innovates

Canadian Association of Petroleum Producers

Genovus Energy

Inter-American Dialogue

Natural Resources Canada

Suncor Energy

TransCanada Corporation

IHS Markit team

Kevin Birn, vice president, IHS Markit, is part of the IHS Markit North American Crude Oil Markets team and leads the IHS Markit Oil Sands Dialogue. Mr. Birn is responsible for a team of oil market analysts focused on western Canada. Mr. Birn has authored more than 50 reports related to the western Canadian oil market as well as the development of the Canadian oil sands. His expertise includes Canadian oil sands development, oil sands cost and competitiveness, crude oil markets, crude oil transportation logistics, greenhouse gas intensity of crude oil, and Canadian energy and climate policy. Mr. Birn 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. Prior to joining IHS Markit, Mr. Birn was a senior economist with the Government of Canada and a partner in a software firm. Mr. Birn holds undergraduate and graduate degrees from the University of Alberta.

Vijay Muralidharan, director, IHS Markit, is part of the IHS Markit North American Crude Oil Markets team and is an integral part of the IHS Markit Oil Sands Dialogue. Mr. Muralidharan has more than 12 years of experience in upstream, midstream, and downstream global oil and gas economic evaluation. His expertise includes crude oil market analysis, macroeconomics, risk analysis, oil asset evaluation, technology, crude oil logistics, and Canadian energy and climate policy. Prior to joining IHS Markit, Mr. Muralidharan held posts at ConocoPhillips, Statoil, EY, and Bank of Canada. As a senior economist at Statoil, he oversaw the global macroeconomic forecast and contributed to the global energy market group. He has authored many reports, both in the public and private sectors, and in 2006 won the John Vanderkamp Prize for best public policy paper from the University of Alberta, Department of Economics. Mr. Muralidharan holds undergraduate and graduate degrees from the University of Alberta.

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