IHS ENERGY

Where Will Transportation Drive Global Oil (and Oil Sands) Demand?

December 2016

ihs.com

STRATEGIC REPORT

Kevin Birn
Senior Director

Tiffany Groode
Senior Director

Hossein Safaei
Associate Director

Contents

Part 1: Introduction 6

Part 2: Importance of on-road transportation in global oil demand 6
On-road transportation is the primary driver of crude oil demand 8
Transportation is a large source of GHG emissions 8

Part 3: Liquid hydrocarbon transportation fuel demand is not likely to peak overnight 9
Global oil demand growth 9
Personal vehicles: Tomorrow's market is not like the past 9
Commercial fleets: Few alternatives to diesel power 13
The future of oil demand might be more uncertain than we think 15

Part 4: Canadian oil sands are likely to remain a key source of global oil supply 15
A lot of effort is needed just to hold global oil supply flat 16
A multitude of new sources of supply is needed 16
Competition for capital is fierce and oil sands contribution is not secure 17

Part 5: Concluding remarks 18

Report participants and reviewers 19

The IHS team 20

Where Will Transportation Drive Global Oil (and Oil Sands) Demand?

Key implications

Global oil demand has increased 19 million barrels per day since 2000—a gain of 25%. Accounting for more than half of global liquids demand, growth in transportation fuels, particularly for passenger vehicles such as car and trucks, is a key element of this trend. But will growth continue? Rising fuel economy standards, the prospect of greater electric vehicle sales, and potential shifts in consumer behavior will shape the course of future oil demand and the market for key sources of oil supply like the Canadian oil sands.

- **Many mainstream global energy forecasts expect oil demand to continue to grow over the next two decades.** However, some forecasts see the potential for oil demand to peak within the next 10–20 years. Uncertainty about future oil demand is growing due in part to the potential for dramatic changes in the transportation sector.

- **Transitions typically take time, and the long life of the existing on-road fleet means that the impact of new vehicles on global oil demand will likely be gradual.** In 2016, 96% of new vehicle sales featured combustion engines. IHS estimates average vehicle life globally to be about 15 years. This is critical as it means the impact of new vehicle technologies takes time to materially affect the vehicle fleet and overall fuel demand.

- **Indeed, the future of the car—and the sources of energy that propel it—is not predetermined.** There are downside risks that could see oil demand peak or reach new heights. A different mix of policy, changes in consumer behavior, new technologies, and economic growth could lead to different outcomes. Moreover, the effects of new mobility business models, such as ride-hailing, and emerging technologies, such as autonomous vehicles, are not yet fully understood.

- **Even with slower or even flat world oil demand, significant investments in upstream production are needed to maintain supply levels.** The world needs to find and replace about 45 million barrels per day of crude oil by 2040 (or about half of what the world consumed in 2016): 37 million barrels per day will be needed to offset production from declining fields while 8 million barrels per day will be needed to meet demand growth.

- **The Canadian oil sands are likely to remain an important part of meeting global oil demand.** Unlike most other sources of oil supply globally, production from oil sands facilities does not decline in the short term. This means new investments in oil sands production have a more pronounced effect on supply growth. Oil sands production has the potential to reach 3.9 MMb/d in 2030—a 1.5 MMb/d increase from 2016.

—December 2016

Page intentionally blank

Where Will Transportation Drive Global Oil (and Oil Sands) Demand?

Kevin Birn, Senior Director
Tiffany Groode, Senior Director
Hossein Safaei, Associate Director

About this report

Purpose. Since 2009, IHS has provided public research on issues surrounding the development of the Canadian oil sands. However, oil supply is balanced by demand, and the largest source of demand is transport. This report explores future demand for transportation fuels—a critical part of overall global oil demand—and the implications for the Canadian oil sands.

Context. This report has been done in collaboration with IHS Automotive Scenarios and is part of the IHS Oil Sands 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. Stakeholders include representatives from governments, regulators, oil companies, shipping companies, and nongovernmental organizations. This report and past Oil Sands Dialogue reports can be downloaded at www.ihs.com/oilsandsdialogue.

Methodology. IHS conducted its own extensive research and analysis on this topic, both independently and in consultation with stakeholders. This report was informed by multi-stakeholder input from a focus group meeting held in Toronto, Ontario, on 18 November 2015, as well as participant feedback on a draft version of the report. IHS 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 team).

Structure. This report has five sections.

- Introduction
- Importance of on-road transportation in global oil demand
- Liquid hydrocarbon transportation fuel demand is not likely to peak overnight
- Canadian oil sands are likely to remain a key source of global oil supply
- Concluding remarks

Part 1: Introduction

Since Edwin Drake drilled the first commercial oil well in 1859, global oil demand has not looked back. Oil—an easily transported, energy-rich commodity—has been found in great abundance and has made its way into nearly every aspect of modern society. In 2016, IHS estimates the world will have consumed about 96 million barrels per day of liquid hydrocarbons, over 1.2 MMb/d more than the year prior and 11 MMb/d more than a decade earlier.

Oil is pervasive. It is used in numerous applications, including medications, cleaning products, computers, mobile phones, and clothing. But, for good reason, it is most commonly associated with transportation fuels—enabling trade and personal mobility, whether by road, rail, air, or water. By far, oil's largest use is for on-road transportation, refined into gasoline and diesel to fuel cars, trucks, and buses. In 2016 on-road transportation accounted for more than half of global oil demand.

Bending the curve of global oil demand growth may be on the horizon. In fact, it has happened before. From 1979 to 1984 global oil demand fell by 6 million barrels per day—a 10% reduction. But since the early 1980s, oil demand has almost always increased each year, underpinned by gasoline and diesel consumption. However, there is increasing uncertainty about the outlook for global oil demand. On one side, new technologies as well as concerns over air pollution, climate change, and urban congestion are contributing to policies that could erode crude oil's dominance in the transportation sector and negatively impact global oil demand. On the other side, the impact of new mobility options, such as car- and ride-sharing already being utilized by millions around the world, is uncertain. Some factors have the potential to be more disruptive, and change could occur faster and in more unpredictable ways than anticipated.

This report will explore the demand for liquid hydrocarbon-based transportation fuels and the relationship with global demand for crude oil. What are the key factors shaping the future of automotive demand for liquid hydrocarbons? How will this influence global crude oil demand? And what does this mean for key sources of global supply, such as the Canadian oil sands? This report has five sections:

- Introduction
- Importance of on-road transportation in global oil demand
- Liquid hydrocarbon transportation fuel demand is not likely to peak overnight
- Canadian oil sands are likely to remain a key source of global oil supply
- Concluding remarks

In the last section of this report we refer to different types of oil sands production methodologies. Additional background information is included in the primer (see the box "Primer on oil sands production.")

Part 2: Importance of on-road transportation in global oil demand

Around the world petroleum is produced and manufactured into numerous products that find their way into almost every aspect of our lives, from consumer products such as clothing, plastics, detergents, and mobile phones to more commonly thought-of uses such as road asphalt and gasoline (see Figure 1). Petroleum products enable the global economy to function.

Hydrocarbons come in a variety of different forms, differentiated by chemical composition and density. This affects their energy content, handling, and use. The broadest definition is petroleum, which generally encompasses all hydrocarbons historically associated with oil extraction and production. We have provided the general definitions of the subgrouping of petroleum used in this report (see Table 1). This report is focused on transportation fuels that are primarily derived from crude oil and condensate (an ultra-light crude oil). Unless otherwise stated in this report, crude oil includes condensate.

Primer on oil sands production

The Canadian oil sands

The oil sands are grains of sand covered with water, bitumen, and clay. The “oil” in the oil sands is bitumen, an extra-heavy crude oil with high viscosity. Oil sands are unique in that they are extracted via mining and in-situ processes.

Mining. About 20% of currently recoverable oil sands reserves are close enough to the surface to be mined. In a surface mining process similar to coal mining, the overburden (vegetation, soil, clay, and gravel) is removed and stockpiled for later use in reclamation. The layer of oil sands ore is excavated using massive shovels that scoop the material, which is then transported by truck to a processing facility. About 45% of today’s production is from mining.

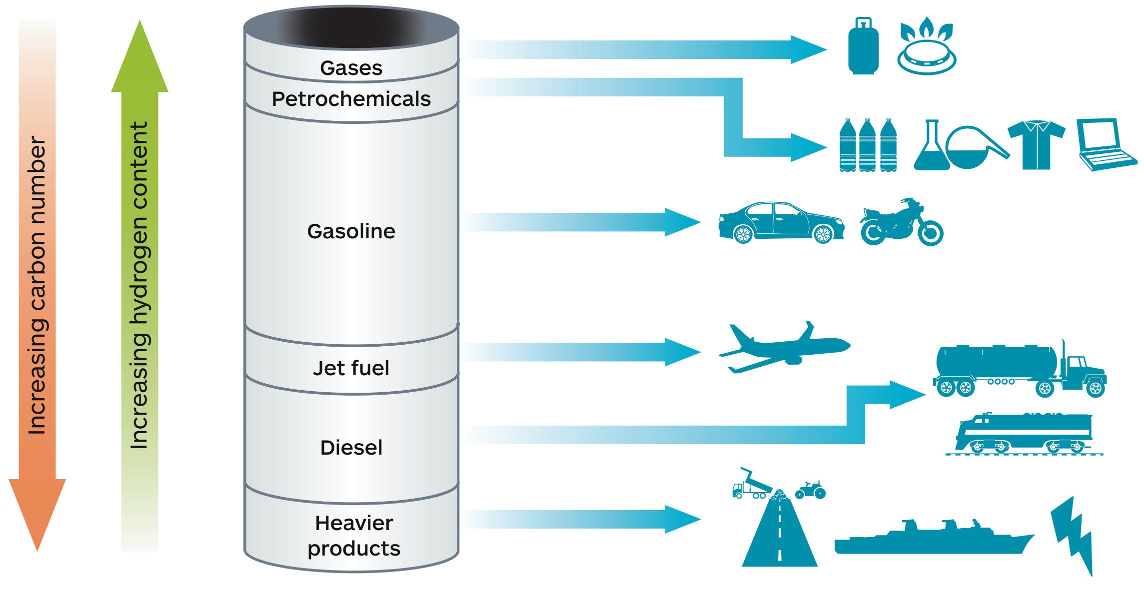
In-situ thermal processes. About 80% of the recoverable oil sands deposits are too deep to be mined and are recovered by drilling. Thermal methods inject steam into the reservoir to warm and lower the viscosity of the bitumen and allow it to flow to the surface. Similar methods are used in oil fields around the world to recover oil. Thermal processes make up 46% of current oil sands production, and two commercial processes are used today:

- **Steam assisted gravity drainage (SAGD) is the fastest-growing method; it is projected to grow from 36% of production in 2016 to 50% of oil sands production by 2030.**
- **Cyclic steam stimulation (CSS), also known as “huff-and-puff,” was the first process used to commercially recover oil sands in situ.** CSS currently makes up about 10% of production and is projected to account for less than 7% of total production in 2030.

Primary production. The remaining oil sands production is referred to as primary production. Less viscous, it is extracted without steam using conventional oil production methods. Primary production currently makes up nearly 6% and is projected to be less than 5% by 2030.

Figure 1

Value chain of a barrel of oil



Source: IHS Energy

Table 1

Petroleum definitions

State	Category	Description	Primary Use
Liquids	Crude oil	Semi-solid to very mobile at room temperature (API < 50 degrees)	Transportation fuel
	Condensate	Ultra-light crude oil (API > 50 degrees)	Transportation fuel
	Natural gas liquids	Intermediate range of products between natural gas and crude oil. Some are generally liquid—butane, isobutane, natural gasoline/pentane plus—while others are typically gaseous, such as ethane and propane.	Petrochemical feedstock and transportation fuel
Natural gas		Methane	Heating and power generation

Note: Although not shown, liquids include biofuels, or hydrocarbons produced from plant matter that are not petroleum as well as gas-to-liquids or methane manufactured into a liquid fuel.

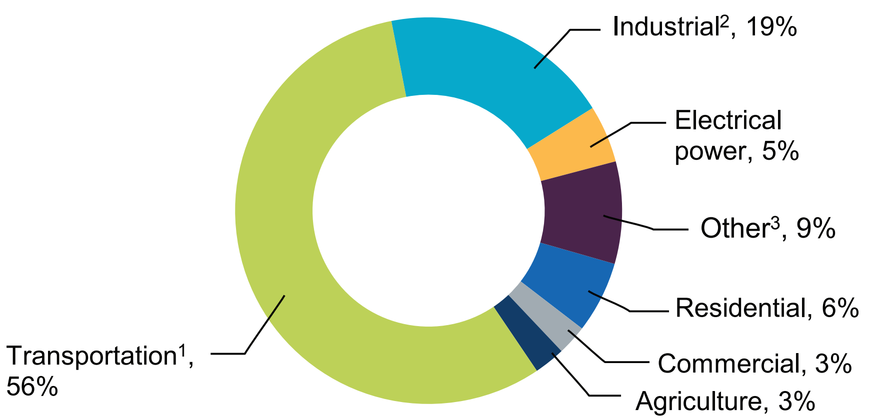
Source: IHS

On-road transportation is the primary driver of crude oil demand

Transportation fuels, such as gasoline, diesel, and jet fuel, are the largest source of global liquid hydrocarbon demand (see Figure 2). Most transportation fuels are derived from crude oil. Although the majority of a barrel of oil typically ends up as transportation fuel, not all of it does and the corresponding demand for crude oil is greater. In 2016 it is estimated the world will consume about 54 MMb/d of liquid transportation fuels (consisting principally of jet, gasoline, diesel, and marine fuel oil). On-road transportation, such as cars and trucks, accounted for nearly four-fifths of this demand, with planes, marine vessels, and trains making up the remainder of oil used in transportation. In 2016, total crude oil demand and total liquids demand were around 79 MMb/d and 96 MMb/d, respectively.

Figure 2

Liquids consumption by sector (total 96 MMb/d in 2016)



Notes: (1) Includes biofuels. (2) Includes feedstocks. (3) Includes energy sector uses, distribution losses, and statistical differences. Negative numbers may indicate use of synthetic fuels.
Source: IHS Energy

Transportation is a large source of GHG emissions

The combustion of liquid hydrocarbon fuels to power transportation is a major source of greenhouse gas (GHG) emissions. For example, in 2014, the latest year data are available, transportation accounted for more than one-fourth of US GHG emissions—second only to power generation.[1] On-road transportation was responsible for most of these emissions.[2]

Greenhouse gases are emitted over the entire life of transportation fuel: from extraction, to the manufacturing of refined products in refineries, to transportation and distribution to consumers, and, ultimately, to combustion in cars and trucks. The vast majority, 70–80% of emissions over the life of the transportation fuel—from oil production to vehicle tailpipes—occur at the final use: combustion.

1. For more details on US and Canada emissions, see the IHS Special Report *The State of Canada and United States Climate Policy,* August 2016, at www.ihs.com/oilsandsdialogue.

2. See the pdf *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2013,* US Environmental Protection Agency, 2015, accessed 13 September 2016.

Part 3: Liquid hydrocarbon transportation fuel demand is not likely to peak overnight

Since commercial oil production began, oil demand has generally risen. One notable exception was in the early 1980s, when demand fell 10% as a result of the repercussions of the high prices of the 1970s. This also led to a permanent deceleration in the pace of oil demand growth. But since the early 1980s oil demand has risen almost every year. Indeed, in 2015, lower oil prices contributed to an acceleration of global oil demand growth. Over the longer term, growth may eventually decline as the world transitions away from fossil fuels. But transitions of this scale typically do not occur overnight.

Global oil demand growth

As we look into the future, changes in transportation, particularly changes in the on-road sector, will be critical to the future of liquid fuel demand. While many acknowledge these changes are occurring, there is a difference of opinion on the possible pace of change. As a result, oil demand forecasts are varied. For example, notable energy forecasters such as the US Energy Information Administration (EIA) and the International Energy Agency (IEA) expect oil demand will continue to grow in their base cases, albeit at a slowing pace out to 2040.[3] In both the IEA and EIA outlooks, global oil demand increases about 20 MMb/d to exceed 120 MMb/d by 2040. However, more bearish outlooks for global oil demand exist. Both the IEA and Statoil conceive of worlds where oil demand peaks before 2040 and 2030, respectively.[4] Our own energy scenarios consider drastically different futures, some where demand continues to grow to 2040 and others where oil demand peaks. These widely different outlooks are a reflection of the uncertainty facing on-road transportation and global oil demand.

IHS divides the global on-road fleet into two broad categories: personal and commercial. They have different characteristics and needs, with large implications for transportation fuel demand and penetration of alternatives such as electric- or natural gas-powered vehicles. For this report we define these two groups as follows:

- **Personal vehicles** or light-duty vehicles (LDV) are the largest market for liquid hydrocarbon fuels, with gasoline being the dominant fuel option. These vehicles are generally owned by individuals and have low utilization rates and a long life (typically between 11 years and 20 years).

- **Commercial vehicles**, also known as medium-duty vehicles (MDVs) and heavy-duty vehicles (HDVs), are typically owned by municipalities and businesses. In contrast to LDVs, these vehicles have high utilization rates with a much shorter effective life (three to five years).[5] Diesel serves as the main fuel option for these vehicles, such as trucks and buses.

This section will discuss the factors shaping the fuel demand for these vehicle fleets separately and how they inform the future of global oil demand.

Personal vehicles: Tomorrow's market is not like the past

There are a number of factors that influence automotive demand for refined products and, in turn, refiners' demand for crude oil. This includes vehicle fuel efficiency, how much people drive, and technology, such as powertrain efficiency (see Figure 3). Looking forward, we are also seeing emerging drivers of change such as car-sharing and ride-hailing. These new mobility options could greatly influence personal miles traveled and fuel demand, but their effects are currently not fully understood. In recent years, there has been intense focus on electric vehicles, but it is more likely the change in an

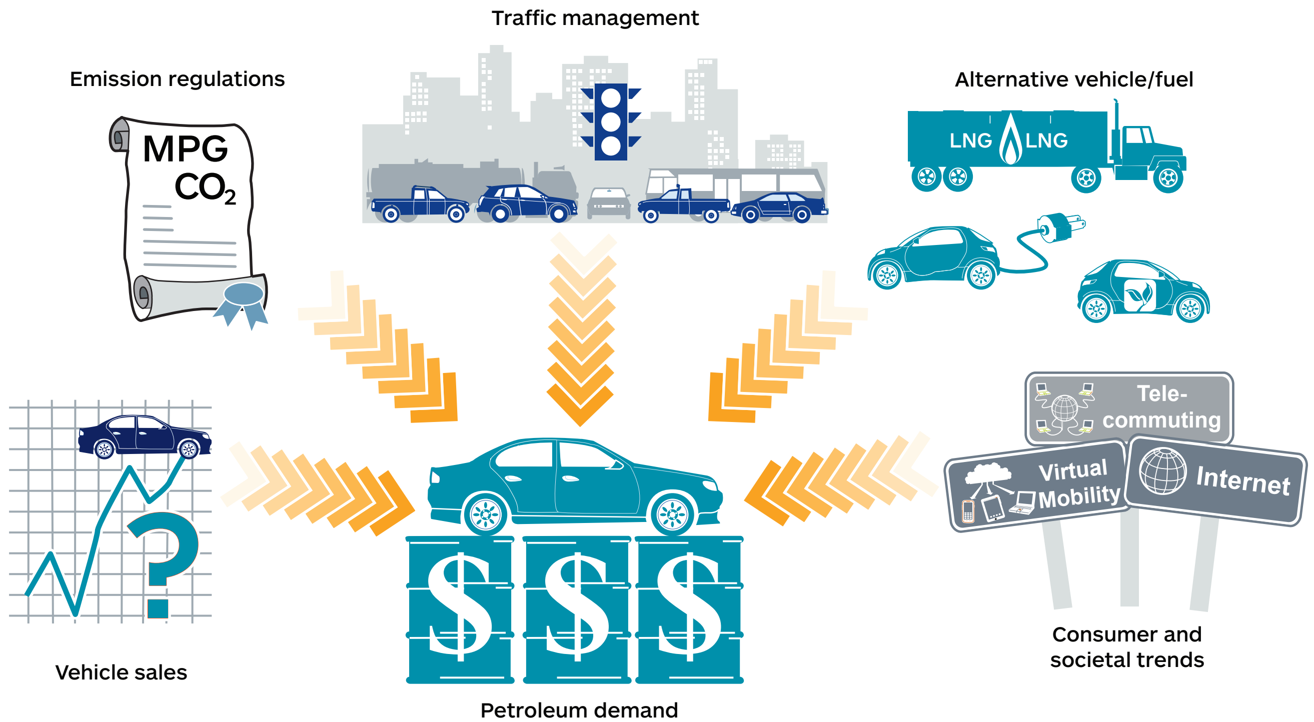
3. See the US EIA report *International Energy Outlook 2016* and the IEA report *World Energy Outlook 2016*.

4. See the Statoil report *Energy Perspectives reports – 2011-2016*.

5. Average vehicle life of a commercial vehicle is more nuanced than light-duty vehicles. The average life of a commercial vehicle depends on the size and application but generally ranges from about 12 years to 21 years. However, the commercial fleet turnover rate is higher. Despite these vehicles staying in the fleet longer than a typical car, their use drastically declines after three to five years for the majority of the fleet. For example, long-haul trucks will go from averaging more than 90,000 miles per year to fewer than 20,000 miles per year.

Figure 3

Automotive fuel demand drivers that impact future demand



Source: IHS Energy

© 2016 IHS: 1694003

array of variables, from economic activity, to government policy, to shifting consumer preferences, that will collectively influence worldwide oil consumption. This section explores some of these factors.

Automotive sales to grow, but legacy fleet will delay impact of new technologies

Vehicle ownership and the size of the on-road passenger vehicle fleet (cars and light trucks) influence on-road fuel demand. Although there are a number of potential constraints to vehicle sales, such as vehicle cost, congestion, sales, and end-use restriction policies, IHS expects automotive sales to increase. We believe more—not less—personal mobility will be needed in the future, although it may be lower than earlier estimates may have anticipated.

Historically, forecasting vehicle sales was relatively straightforward: vehicle ownership was strongly correlated with GDP and personal income. In the past, a general rule was that a billion dollars of GDP growth equated to about 1,200 new vehicle sales. Historically, there were also fewer powertrain and fuel options, leaving consumers to choose primarily among different vehicle sizes, styles, and colors. However, additional factors are making forecasting vehicle sales, powertrain, and other personal transportation trends more difficult.

One of the key changes is the effect urbanization is having in developing countries. These cities, being developed upward, have very high levels of population density. This and growing affluence, brought on by economic growth, have led to record vehicle sales. The resulting high density of vehicles in urban areas, coupled with lagging infrastructure, is often leading to crippling congestion in the major cities of the developing world as well as poor air quality.

The severity of these city-level issues is influencing municipal decisions in both the public and private sectors. On the public-sector side, there is an increasing number of policies focused on limiting urban vehicle sales. For example, as of 2016 there are seven cities in China that have some form of city-level vehicle sales restrictions or additional vehicle purchase levy. These policies aim to limit vehicle ownership in response to congestion and air-quality concerns. On the private side, new personal mobility options such as car-sharing and ride-hailing have emerged. Car-sharing and ride-hailing provide people with greater transportation options and convenience while dramatically lowering the cost in comparison to outright ownership. All of these factors affect how consumers view mobility and will impact long-term vehicle sales and use (which we will talk about later in the report).

The effects of advancing policies and shifting consumer preferences on vehicle sales and use are not fully understood. For example, car-sharing could result in higher vehicle turnover and greater sales, which could in turn accelerate penetration of new technologies. Conversely, other changes such as restrictive ownership rules could negatively affect sales and fleet turnover, slowing the effect of new technologies.

On balance, IHS expects that automotive sales will continue to grow, carried upward by developing countries, but at a lower rate than may have been previously anticipated. Automotive sales could expand from about 90 million vehicles in 2016 to nearly 128 million vehicles by 2040. This could lead to an expansion of personal vehicles on roads from 1.2 billion vehicles to 1.8 billion vehicles over the next 25 years. At the same time, changes to vehicle sales and the powertrains sold take time to impact fuel demand. The pace of this change is often attributed to the inertia of the vehicle fleet. IHS estimates average vehicle life globally to be about 15 years (12 years in the United States). This is critical as it means the impact on fuel demand from new vehicle technologies takes time to materially affect the vehicle fleet and overall fuel demand.

Even with a potentially 50% increase in the number of vehicles on the road globally, a number of compounding factors are currently expected to act as a drag on oil demand growth. These include increased vehicle efficiency, people driving less, and the proliferation of alternative powertrains and fuels.

If people drive less

The amount people drive, measured as total vehicle miles traveled (VMT), is—by far—the most influential factor affecting automotive fuel demand, especially in the short term. For instance, in 2008 during the Great Recession, North American gasoline consumption—a mature market for transportation fuels—declined 3%.[6] Globally, even with continued growth from China, gasoline consumption growth still receded from 1.3% in 2007 to 0.4% in 2008. But was the drop because of weaker vehicle sales, people scrapping their cars, or their cars becoming suddenly more efficient? While vehicle sales did decline 8% between 2007 and 2009 and some people may have gotten rid of their vehicles to cut costs, these were not the primary reasons for the rapid decline in demand. The main reason was that people simply drove less. People who were unemployed stopped driving to work. Households on a budget reduced driving for shopping, entertainment, and holidays. This shift in people's everyday behavior had a quick and pronounced impact on global oil demand, which was 2% lower in 2009 compared with 2007 (5% lower in North America).

Conversely, increases to VMT can cause demand to respond quickly. For example, in response to lower US gasoline prices in 2015 demand increased 2.7%, even though economic growth remained sluggish. Compared with 2014, the average person in 2015 drove almost 4% more, leading to higher gasoline demand.

Although VMT is critical to forecasting vehicle fuel demand, it is also the most difficult to forecast.[7] Factors such as fuel prices, GDP, public transportation, new mobility options, lifestyle, congestion, and availability of parking all influence vehicle use.

IHS believes driving habits around the world are changing. Developed countries, such as the United States, Japan, and in Europe, are characterized as mature automotive markets. A mature market is a place where everyone who wants a car—by and large—has one, and vehicle use is unlikely to change dramatically in the long run.

It was long thought that developing countries would progress along a similar vehicle ownership and use pattern as developed countries. This was expected to drive automotive sales and global oil demand to new heights. However, this seems increasingly unlikely. One of the key differences is the aforementioned effect of urban congestion in developing countries. Crippling congestion, poor air quality, and increasing cost of vehicle ownership in city centers can discourage car ownership and use. In response to these challenges, local- or city-level policies have emerged in cities around the

6. North America includes Canada, Mexico, and the United States.

7. Outside of the United States there are limited data—both historically and forecast—for VMT.

world. Policies such as tolls, congestion charges, city access restrictions, increasing parking costs, and even restrictive sales have proliferated.

In terms of vehicle use, Beijing, China; Sao Paulo, Brazil; and Tehran, Iran, are examples of cities that have vehicle-use restriction policies. These policies limit the use of a personal vehicle in the city center depending on the day of week. Congestion charging, as seen in London, United Kingdom, can also impact the value proposition of driving to work compared with taking public transportation. For example, it now costs about US$15.00 (£11.50) during the day to drive a car into London's city center.[8] These policies make not only owning personal vehicles less attractive (as discussed earlier) but also driving. This could encourage lower sales and utilization rates than may have been earlier anticipated.

The internet and smartphones may also lead to changes in how people consume mobility. It is not just about vehicle ownership or people's relationships with cars. Instead, online businesses enable people to connect over the internet (e.g., teleworking) and shop online. Transportation is also seeing new mobility options such as car-sharing, like Zipcar, and new taxi-style or ride-hailing companies, like Uber and Lyft. For example, in 2014 Uber stated it was transporting 1 million people each day—this is equivalent to moving a city the size of Austin or San Jose in the United States each day.[9] There is also increasing interest about how autonomous vehicles may further alter consumer mobility choices.[10] All of these factors will affect how people consume mobility and influence future automotive use and ownership. A person driving less is generally anticipated to be negative for oil demand. However, a shift in how mobility is consumed is not entirely understood. Autonomous vehicles and ride-hailing could significantly increase oil demand—or push it to lower levels.

New vehicles are more fuel-efficient

What is well understood is the influence of fuel-economy standards on conventional automobiles. The distance vehicles travel on a gallon of gasoline, often called miles per gallon (MPG), is another important factor affecting transportation fuel demand. The average fuel economy of the automotive fleet is a function of the average efficiency of all the different vehicles and their powertrains on the road. This changes as vehicles enter and exit the market.

Concerns over energy security, air quality, and climate change have led legislators to develop and expand fuel-economy standards to reduce fuel consumption and emissions. Globally, 80% of new passenger vehicle sales are under some type of fuel-economy regulation. These regulations push automakers to advance conventional gasoline and diesel engine technology and to develop advanced powertrains (e.g., conventional hybrids) and alternatively fueled vehicles such as electric- and hydrogen-fueled cars. Although fuel-economy standards lead to improvement in the fuel consumption of new vehicles, the impact on overall vehicle fleet fuel economy tends to be gradual because of the time it takes the fleet to turn over.

Alternative powertrains: Growing, but it's still early days

Internal combustion engines have been in production for more than 100 years. Today, the combustion engine still makes up nearly 96% of passenger vehicle sales and nearly 98% of on-road vehicles.[11] While alternative powertrains and fuel options—such as electric vehicles, hydrogen fuel cells, and natural gas—continue to try to penetrate this market, they have yet to topple liquid hydrocarbon transportation fuels' hold over personal mobility. But that may be changing.

Helped along by government policy, alterative vehicles, specifically electric vehicles, have started to gain traction in the market. Policies intended to bolster energy security, address climate change, and improve urban air quality are working to increase the adoption of electric vehicles around the world.[12]

8. London's congestion toll varies based on payment method and time of payment. For more information see https://tfl.gov.uk/modes/driving/congestion-charge.

9. See the Uber Newsroom posting "Our Commitment to Safety," accessed 13 December 2016.

10. Autonomous vehicles could transform personal mobility, potentially reducing cost and increasing access, but also shifting consumer preferences and automotive utilization.

11. These values include gasoline, diesel, and flexible-fuel vehicles that can run on alternative fuels to gasoline or diesel. These values would be greater if conventional mild and full hybrid were included.

12. Two notable examples include the *US Department of Transportation Corporate Average Fuel Economy (CAFE) Standards* and the *US EPA tailpipe emission standards.* There are also numerous examples of tax credits and rebates in the United States, parts of the European Union, Canada, Singapore, and others.

This has encouraged large investments in battery technology by both the public and private sectors.[13] Investments are starting to pay off with the cost of vehicle-based lithium batteries declining almost 30% from 2012 to 2015. In 2010, there were only two primary electric vehicles available on the market—the Chevy Volt and the Nissan Leaf—by 2020, IHS expects to see more than 130 models in showrooms.

This does not mean that it is smooth sailing for electric vehicles. A historical challenge associated with the success of electric cars was batteries. Even though there has been a significant reduction in battery cost, electric vehicles made up less than 1% of new vehicle sales in 2016. But there are signs of consumer interest. For example, as of mid-year 2016, 375,000 people paid a US$1,000 deposit to Tesla to buy a car that does not yet exist.[14]

It is unclear how further reductions in battery costs might be applied and how these may impact sales. Car manufacturers have the options of passing along cost savings to the consumer in the form of less-expensive cars, delivering greater range for a similar price point, or even keeping the savings for better margins or redeployment into research and development. Likely some combination of all three will result. Also, consumers' concerns with other issues such as charging time, uncertain resale value, reliability, and safety of electric cars have been hurdles for adoption.

Meanwhile, the internal combustion engine is also not standing still. Combustion technology is constantly improving, making it difficult for alternative technologies to compete. Simultaneously, refueling time and existing refueling infrastructure provide a barrier to new market entrants. While recharging electric cars at home or at a public station still cannot compete with the under-five minutes it takes a conventional vehicle to refill, the cost of charging infrastructure is far less of an obstacle than some other options such as natural gas or hydro. For example, the high cost of compressed natural gas (CNG) and liquefied natural gas (LNG) refueling stations is the primary reason natural gas has struggled to take off as a vehicle fuel. It is estimated that the cost to add an additional gasoline or diesel refueling terminal (pump and tank) to an existing station is less than half the cost to add a similar LNG terminal, which can range more than US$1 million in the United States.[15]

IHS expects sales of electric vehicles to grow but their adoption to be gradual and dependent on favorable policy until at least into the early 2020s, maybe even beyond. In 2016, sales of full electric vehicles (which include pure battery electric vehicles [BEV] and plug-in hybrid electric vehicles [PHEV]) are expected to reach 0.9% globally. While IHS expects both BEV and PHEV sales to increase over time, their influence on the fleet and fuel demand will take time. With the average life of an on-road vehicle globally around 15 years, the impact of new technologies, such as electric vehicles or higher-fuel-economy gasoline vehicles, will take more than a decade to materially affect vehicle fleet and fuel demand. For example, even if one-fourth of all new vehicle sales in the United States in 2016 were electric and maintained that level going forward, by 2030 electric vehicles would make up just 17% of the on-road vehicle fleet. Alone, the impact of increased electric vehicle sales on global gasoline demand will likely be relatively minimal.

Commercial fleets: Few alternatives to diesel power

Commercial vehicles are used primarily for business applications. As a market, commercial vehicles account for 30% of on-road transportation fuel demand.[16] The majority of commercial vehicle sales and fuel demand are associated with on-road freight transportation by long-haul tractor-trailers.

While gasoline engines dominate the passenger vehicle market, diesel engines dominate commercial vehicles, specifically long-haul tractor-trailers.[17] In 2016, the commercial fleet accounted for about 3% of on-road gasoline and 70% of on-road diesel demand. Diesel engines provide better fuel economy, more power (higher torque at lower speeds), and

13. See the pdf *Guide to Federal Funding, Financing, and Technical Assistance for Plug-in Electric Vehicles and Charging Stations,* US Department of Energy, 2016.

14. See http://www.teslamodel3fan.com/pre-order, accessed 1 November 2016.

15. IHS estimates the cost for an LNG refueling station—just the infrastructure and not including convenience store or land—could run between US$1.2 million and US$2.4 million depending on a range of factors in the United States. See the IHS Energy Special Report *LNG in Transportation: Challenging oil's grip,* 2015.

16. Not including biofuels.

17. Although diesel is more energy-dense than gasoline—capable of producing more energy for equal volumes of fuel—combustion of diesel also emits more air pollutants than gasoline. European fiscal and regulatory policy has historically focused more on efficiency while North America has focused on air quality, which has contributed to greater gasoline use in North America and greater diesel use in Europe.

greater reliability compared with gasoline engines. These are all important for the economical transportation of cargo over long distances.

Decisions are business-oriented

Commercial vehicle fleet operators make decisions very differently from the personal vehicle market. While both care about costs, personal vehicle consumers often place more value on less-tangible factors such as aesthetics that include vehicle accessories, design, brand, and lifestyle. When a fleet operator is buying a vehicle, its main focus is the vehicle's performance, reliability, and cost—the economics. Commercial vehicles are characterized by high utilization (and thus high fuel cost and turnover rate), extended use (long-distance travel), high reliability requirements, and often high horsepower.

The demand for commercial vehicles is even more sensitive to economic activity than the demand for personal vehicles. When the economy is doing well, more goods are transported and activity increases. In turn, these result in more vehicle sales, more miles traveled, faster fleet turnover, and greater fuel demand. Commercial operators are also very sensitive to fuel prices. In the United States, up to 20% of a trucker's costs can be related to fuel.[18] So as retail diesel prices increase, the cost of trucking increases, making other modes of transport, such as rail, possibly more competitive.[19] Higher diesel prices can also improve the relative attractiveness of alternative fuels such as natural gas.

Diesel's primary competitor, natural gas, remains behind

Attractive attributes of diesel engines such as efficiency, reliability, and power challenge the penetration of alternative powertrains and fuels. Today, batteries lack the energy density, range, and life to maintain high utilization rates desired by most commercial actors. More energy-dense forms of natural gas, such as CNG and LNG, are penetrating into return-to-base fleets. These vehicles are used for repetitive tasks on fixed routes—such as garbage trucks, city buses, and delivery vans—which require fewer refueling stations.

Fuel switching from diesel to natural gas is based on the time it takes to pay back the greater upfront capital investment required for natural gas engines and refueling infrastructure from the savings obtained by being able to use lower-cost natural gas as fuel. The main drivers for payback are the average VMT each year, the fuel economy, and the fuel-price differential.

In the short term, higher upfront CNG and LNG vehicle purchase costs and limited refueling infrastructure are the primary barriers to natural gas adoption within commercial fleets, particularly long-haul commercial tractor-trailers or "trucking." Additionally, current narrow diesel to natural gas price differentials, fewer CNG or LNG vehicle product offerings, limited vehicle maintenance and business infrastructure knowledge, and longer refueling times are also expected to hinder—but not cease—the adoption of natural gas into long-haul trucking. IHS expects oil prices to increase gradually, which may lead to a greater diesel-gasoline price differential to natural gas, which should contribute to greater CNG and LNG adoption (depending again on other market and policy conditions).

However, should adoption accelerate, the impact on liquid hydrocarbon demand may appear more rapidly for some segments of the commercial fleet than in the passenger vehicle market. For example, in the United States, long-haul trucking typically operates between 75,000 miles per year and 175,000 miles per year (120,000 kilometers and 280,000 kilometers) for three to five years. This faster turnover makes the impact and potential payback of new technologies and fuel choices appear more quickly on the commercial vehicle side than the passenger vehicle market.

Efficiency and natural gas are expected to slow diesel demand growth

Over the longer term, IHS expects global economic growth to average about 3% per year in our base case scenario until 2030 and push commercial vehicle energy demand and commercial vehicle diesel demand higher. However, diesel demand will not grow unabated as increased fuel economy and natural gas penetrate into the commercial fleets.

18. See the American Trucking Associations' "Reports, Trends, and Statistics," accessed 29 August 2016.

19. For the case of rail, diesel is the dominant fuel source as well; however, it is a smaller share of the transportation cost. For example, CSX claims to be able to move a ton of freight nearly 500 miles on a gallon of diesel fuel. See https://www.csx.com/index.cfm/about-us/the-csx-advantage/fuel-efficiency.

IHS expects business owners will continue to demand more-efficient vehicles and government policy to expand into commercial fleets through initiatives like the US medium- and heavy-duty vehicle GHG and fuel efficiency standard finalized in 2016.[20] Even through the lower oil-price environment, adoption of natural gas will continue, driven by a belief that oil prices will eventually rebound and that environmental regulation will only get stricter and more costly in the future. In North America, particularly, the less-volatile or more-predictable nature of natural gas prices will also aid in adoption. Commercial fleet owners face few options that can match the power, efficiency, and reliability of the diesel engine, but greater fuel economy and lower and less-volatile natural gas pricing will likely lead to a gradual erosion of diesel demand growth.

The future of oil demand might be more uncertain than we think

As we look at the on-road transportation landscape we see considerable attention being paid to one or two downside risks such as electric vehicles and fuel efficiency. There are other risks, however, ones that may not be fully understood and others that risk being overlooked, including new sources of demand.

Though IHS currently believes the present trajectory is for decelerating global oil demand growth, upside risks also exist. For example, should our expectation regarding the proliferation of legislation restricting vehicle sales and use fall short or expand slower than expected, should India or Africa grow faster than currently anticipated as a result of the large increase in their working-age populations, or should developing countries see a greater shift from more-efficient motorcycles toward less-efficient automobiles than currently expected, crude oil demand could be pulled higher.

As we look into the future, there are a number of uncertainties that could accelerate or decelerate future oil demand. New transportation options such as car-sharing, ride-hailing, and autonomous cars will change how consumers view and value personal mobility. How these new mobility modes and autonomous vehicles ultimately affect demand is still uncertain—and currently poorly understood. They may increase or decrease local fuel demand depending on the fuel they use, how they are utilized, and the policies in place. Today, this is probably the greatest uncertainty facing both the automotive and energy industries.

While new mobility options and alternative vehicles may influence the vehicle market faster than anticipated, large shifts typically take time. The inertia of the legacy vehicle fleet and the recent record-high global vehicle sales will continue to be among the largest barriers to the erosion of liquid hydrocarbon-based transportation fuels. However, this does preclude a more rapid shift in transportation fuel demand. Changes to how consumers use mobility and policies that affect vehicle use can still have a large and relatively rapid impact on fuel demand. Electric vehicles are still relatively young, and it is still early in an adoption curve that could accelerate. This is among the greatest risks to the future demand for liquid hydrocarbon transportation fuels.

The future can be surprising in ways that are difficult to anticipate. IHS maintains alternative scenarios, each equally credible in their own ways. Although not expressly discussed in the report, a brief discussion on alternative scenarios and how the world may evolve differently in each follows (see the box “IHS scenarios”).

Part 4: Canadian oil sands are likely to remain a key source of global oil supply

Since oil sands production began in 1967, it has taken an increasing role in helping to meet global oil demand. Since 2005, Canadian oil sands have added more than 1.4 MMb/d of production, topping 2.4 MMb/d in 2016. The long-term development of Canadian oil sands, like other sources of supply, is inextricably linked to global demand for crude oil and in turn for transportation fuels.

If future global demand falls short of expectations—such as if disruptive technologies take hold and the transition away from liquid hydrocarbon fuels is quicker than anticipated—what could this mean for oil sands development?

20. See *EPA and DOT Finalize Greenhouse Gas and Fuel Efficiency Standards for Heavy-Duty Trucks,* accessed 13 December 2016.

IHS scenarios

When developments occur that surprise us, it is often because our assumptions about the present, not to mention the future, have turned out wrong. No course of action will lead to the gift of perfect clairvoyance about the future. Scenarios force us to question the present in order to understand the different ways the future could unfold.

Rivalry, autonomy, and vertigo are the three scenarios that make up our current generation of global scenarios. Defining characteristics of each scenario are below.

- **Rivalry.** Rivalry sees a period of the most intense competition in history among energy sources for market share amid evolutionary social and technology change. Energy rivalry is driven by four factors: price differentials, environmental concerns, technology improvements, and energy security. Gas loosens oil's grip on transportation demand, and renewables are increasingly competitive with gas, coal, and nuclear in power generation. Global crude oil liquid demand continues its long-term trend of decelerating growth.

- **Autonomy.** A transition to an energy mix away from fossil fuels occurs at a much faster pace than expected. Market, technology, and social forces decentralize the global energy system. Generational change and urbanization pressures alter energy demand dynamics—demand for coal and oil falls. Congestion and air-quality issues push more aggressive transportation policies, leading to greater engine efficiency and penetration of alternate powertrains.

- **Vertigo.** The world economy is like weather on a mountaintop—sunny and pleasant one moment, then engulfed in fog and rocked by hurricane-force winds the next. Economic instability undermines confidence and exacerbates risk aversion. Volatile economic growth creates mismatches between demand and supply. Conservative capital investment spending slows the move to a less-carbon-intensive economy. Transportation emissions-related policies slow in favor of more economic-focused initiatives. Increased risk aversion and less-aggressive transportation policy nearly stall the adoption of alternative powertrains.

Each IHS scenario is equally credible with changes in economics, market dynamics, and consumer choices driving an alternative future.

A lot of effort is needed just to hold global oil supply flat

Although the global oil market is currently well-supplied, maintaining existing levels of supply over the longer term will take considerable effort. There is an ongoing treadmill of the need to find new sources of oil supply to meet growing demand while at the same time make up for production declines as existing fields are exhausted. We estimate in our base case that between 2016 and 2040 global crude oil demand may increase 8 MMb/d while production from existing fields will fall by about 37 MMb/d. This means that about 45 MMb/d of new supply will be required. This is close to half of what the world consumed last year, about 96 MMb/d.

Even in the event disruptive technologies such as the adoption of electric cars accelerate more than anticipated or global oil demand growth falls short of expectations, considerable upstream investment will still be required just to maintain current levels of global oil consumption.

A multitude of new sources of supply is needed

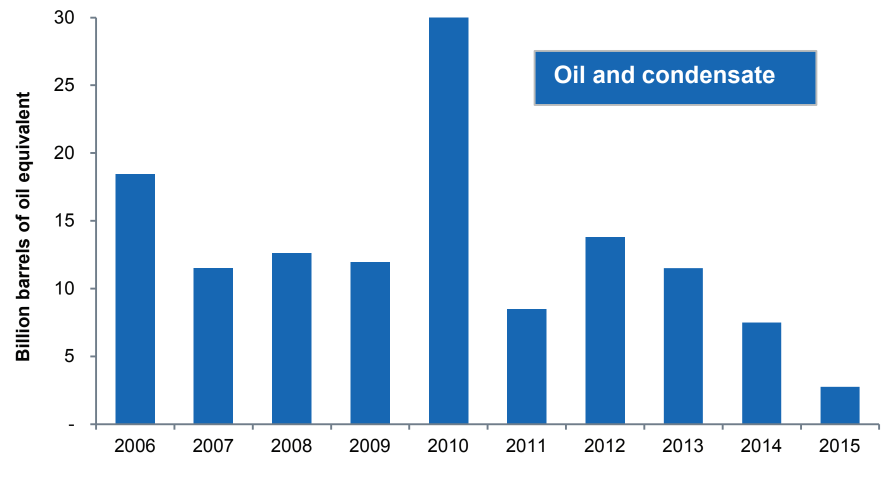
For supply to meet the demand for crude oil in the long term, prices will likely have to rise from 2016 levels to encourage sufficient investment in new oil production.

In recent years discoveries of new conventional oil fields have slowed. Since the deepwater offshore Brazil discoveries in 2010, discoveries of new oil have trended down (see Figure 4). Lower prices have reduced investments in upstream production, including exploration. This has added to pessimism about the prospects of major new discoveries in the immediate future and may place a greater reliance on existing reserves to meet demand.

A multitude of sources of supply from around the world at various costs will be required to meet demand over the longer term. Although late in 2016 OPEC has re-entered the supply management game, its overall output is still greater than it was in 2014 and expected to remain so for some time. OPEC membership constraints have also posed a historical challenge that could result in greater contribution to supply in the future. US tight oil producers have seen costs deflate and are poised to resume supply growth in the future. Although price recovery is anticipated to be gradual, increased output from the Middle East and the United States will not be able to supply all future needs and IHS expects an array of new supply from around the world will be required. This may include production from Russia, Brazil, and the Canadian oil sands.

Figure 4

Conventional discoveries of conventional oil by year (2005 to 2016)



Notes: Data exclude onshore Canada, US lower-48 onshore, and US shallow water.
Source: IHS Energy

© 2016 IHS

Competition for capital is fierce and oil sands contribution is not secure

A common perception is that oil sands projects are among the highest-cost sources of oil in the world. However, within any oil-producing region costs vary—sometimes wildly—and the oil sands are no exception. In 2015 IHS published a report detailing oil sands cost structures.[21] Investments in new oil sands mines were found to be among the higher cost globally. However, in-situ projects were lower, breaking even between $50/barrel and $60/barrel WTI. These values overlap the cost structures of two-thirds of the supply additions IHS anticipates to see over the next decade and a half (see Figure 5).[22] Yet this does not make them more competitive.

The factors behind oil sands growth and its role in the world are changing. IHS expects oil sands growth will continue but at a more modest pace than the years preceding the 2014/15 oil-price crash. In a lower-price environment, future investment in oil sands production will focus on the most economic projects—expansions of existing in-situ facilities. Breaking even at the bottom end of the in-situ cost range—currently just beneath $50/barrel WTI—IHS expects that the majority of future activity (2016–30) will come from the expansion of existing facilities. Expansions benefit from being better understood, quicker to first oil, and cheaper to construct.

A lack of production declines in the oil sands will help support growth. Unlike other oil-producing fields globally, oil sands facilities are more akin to manufacturing facilities. Once operating they are built to last 30–40 years with a fixed output. The absence of production declines means that each investment in new oil production results in growth.

Yet, oil sands face additional hurdles that their competitors may not face, such as increasing climate policy in Alberta and Canada or a constrained pipeline system. Both these factors may pose additional costs and uncertainties that their global peers may not face.[23]

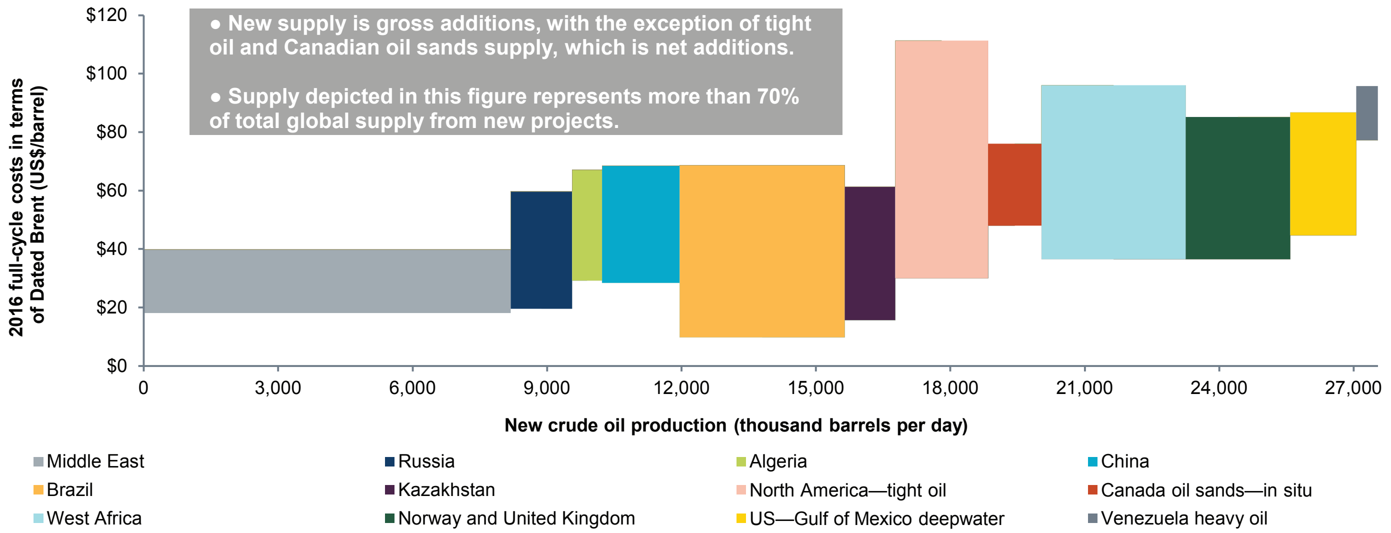
21. For more information on the IHS Oil Sands Dialogue Special Report *Oil Sands Cost and Competitiveness*, December 2015, see www.ihs.com/oilsandsdialogue.

22. A word of caution when reviewing Figure 5. While efforts have been made to capture the most likely representative cost range, costs are not fixed in time and range subject to market conditions and external variables such as exchange rates.

23. For more information on Alberta and Canadian climate policy, see the IHS Oil Sands Dialogue Special Report *The State of Canada and US Climate Policy*, August 2016, www.ihs.com/oilsandsdialogue.

Figure 5

Indicative cost curve of global crude oil supply from new projects in select areas to 2030



Notes: This cost of oil is expressed by the Dated Brent price necessary for projects to break even, assuming a 10% internal rate of return. The low- and high-cost projects are chosen from among the more than 600 that IHS has modeled for our cost of oil analysis. For North American tight oil, the cost estimates are for subplays. For each region, the supply additions are gross additions in 2016–30 from new projects, which are calculated by summing the maximum annual production of sanctioned projects, of unsanctioned projects, and of yet-to-find categories for the areas. Exceptions are North American tight oil, the tight oil components of other producing areas, and Canadian oil sands, all of which are net additions from 2015, using the maximum annual value. The global supply shown represents more than 70% of all global supply from new projects, as calculated by the method explained above. Global supply from new projects in all producing areas is not shown, in part so as not to reduce clarity of the figure. The break-even cost estimate for in-situ Canadian oil sands is based on a steam-assisted gravity drainage project. The Middle East includes Saudi Arabia, Kuwait, the United Arab Emirates, Iraq, Iran, Oman, Qatar, and Bahrain. West Africa includes Nigeria and Angola. Break-even costs for groups of countries are weighted by volume.

Source: IHS

In the IHS base case we anticipate that oil sands production will increase, reaching 3.9 MMb/d in 2030. Should this level of growth come to pass, Canada would rank among the top three-to-four sources of global supply growth over this period.

Part 5: Concluding remarks

The outlook for global oil demand is inextricably linked to transportation fuel demand. Since gasoline won the market battle as the main fuel for cars more than a century ago, crude oil has held a near-monopoly on the transportation fuel market. However, a convergence of disruptive forces could alter demand growth and possibly even lead to its eventual decline. But it is unlikely to occur overnight. A combination of new technology, government policy, new mobility business models, and shifting consumer preferences is set to affect oil's place in transport. The entrenched incumbent fleet, powered by gasoline and diesel, will delay the impact of changes. As a result, global oil demand is expected to continue to increase into the 2030s, although potentially at a decelerated pace.

Although the world is very well-supplied at the moment, a multitude of new sources of supply will be required to meet crude oil demand over the longer term. The Canadian oil sands are positioned to remain one of the key sources of supply growth in the world, but their position is not assured, having to compete for investment and markets with other global sources of oil supply.

Report participants and reviewers

IHS hosted a focus group meeting in Toronto, Ontario, on 18 November 2015 to provide an opportunity for stakeholders to come together and discuss the future of transportation fuels. A number of participants also 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

Aramco Services Company: Aramco Research Center – Detroit

Canadian Association of Petroleum Producers

Cenovus Energy

Crow's Nest Consulting, LLC

Canada's Ecofiscal Commission

Global Automakers of Canada

Imperial

Natural Resources Canada

Pollution Probe

Suncor Energy

The Bowman Centre for Technology Commercialization

TransCanada Pipelines LP

University of Calgary

The IHS team

Kevin Birn, Senior Director, IHS Energy, is part of the IHS North American Crude Oil Markets team and leads the IHS Oil Sands Dialogue. His expertise includes energy and climate policy, project economics, transportation logistics, and oil market fundamentals. His recent research includes analysis of the greenhouse gas intensity of oil sands, economic benefits of oil sands development, upgrading economics, oil sands competitiveness, and implications of advancing climate policy. To date, Birn has authored or co-authored 30 reports associated with development of the Canadian oil sands. Prior to joining IHS, Birn worked for the Government of Canada as the senior oil sands economist at Natural Resources Canada. 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. Birn holds undergraduate and graduate degrees in business and economics from the University of Alberta.

Tiffany Groode, Senior Director, IHS Energy, leads the IHS Automotive Scenarios, including the vehicle and fuels modeling and long-term forecasting. She focuses on the forecasting and impact of future alternative vehicle and fuels technology on the automotive and energy sectors. Groode collaborates between IHS Automotive and Energy experts to integrate, analyze, and forecast how light-duty vehicle sales, powertrain technology, policy, and consumer choice will evolve and impact fuel demand globally over the next 25 years. This includes working with IHS natural gas analysts to develop our LNG forecast in medium- and heavy-duty trucking. Groode also leads research on the well-to-wheels CO_2 impact of vehicle fuel emissions. Groode has a PhD and MS in Mechanical Engineering from Massachusetts Institute of Technology and a BS from UCLA.

Hossein Safaei, Associate Director, IHS Energy, is a part of the North American Crude Oil Markets team and the Oil Sands Dialogue team. Hossein joined IHS in January 2015 upon completion of his PhD on the techno-economics and public policy of renewable power and energy storage in the United States. He was also a graduate fellow with the Harvard University Center for the Environment. Safaei is a recipient of the Alexander Graham Bell PhD scholarship from the Natural Sciences and Engineering Research Council of Canada, the Future Leaders Award from Natural Resources Canada, and the Graduate Citizenship Award from the Government of Alberta. Safaei holds a Bachelor of Science degree from Sharif University of Technology, a Master of Science degree from the University of Alberta, and a PhD from Harvard University, all in mechanical engineering.