Fueling a Clean Transportation Future

Chapter 2: Gasoline and Oil

Union of Concerned Scientists

For as long as most Americans can remember, gasoline has been the only fuel they buy to fill up the cars they drive. However, hidden from view behind the pump, the sources of gasoline have been changing dramatically.

Gasoline is produced from crude oil, and over the last two decades the sources of this crude have gotten increasingly diverse, including materials that are as dissimilar as nail polish remover and window putty. These changes have brought rising global warming emissions, but not from car tailpipes. Indeed, tailpipe emissions per mile are falling as cars get more efficient. Rather, it is the extraction and refining of oil that are getting dirtier over time.

The easiest-to-extract sources of oil are dwindling, and the oil industry has increasingly shifted its focus to resources that require more energy-intensive extraction or refining methods, resources that were previously too expensive and risky to be developed. These more challenging oils also result in higher emissions when used to produce gasoline (Gordon 2012). The most obvious way for the United States to reduce the problems caused by oil use is to steadily reduce oil consumption through improved efficiency and by shifting to cleaner fuels. But these strategies will take time to fully implement. In the meantime, the vast scale of ongoing oil use means that increases in emissions from extracting and refining oil can substantially undermine climate progress.

Fortunately, there are important mitigation measures that can reduce avoidable emissions, and choices about whether the dirtiest resources should be tapped. Clear disclosure and tracking of emissions from the entire oil supply chain are needed to show oil producers and investors which sources carry more or less climate risk, and policies are needed to prevent oil from getting any more polluting than it already is.

This chapter examines how gasoline is used, how it is produced, and how the oil used to make gasoline is changing.


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Heat-trapping emissions from producing transportation fuels such as gasoline are on the rise, particularly emissions released during extracting and refining processes that occur out of sight, before we even get in the car.

Three important sources of oil are examined in more detail: oil from old depleted wells, "tight" oil accessed by hydraulic fracturing (fracking), and extra-heavy crudes like tar sands. Finally, we consider some promising routes by which the rising emissions of oil extraction and gasoline refining can be mitigated. Given that gasoline will be used as a transportation fuel for decades to come, opportunities to reduce emissions from oil production must be identified quickly and implemented widely.

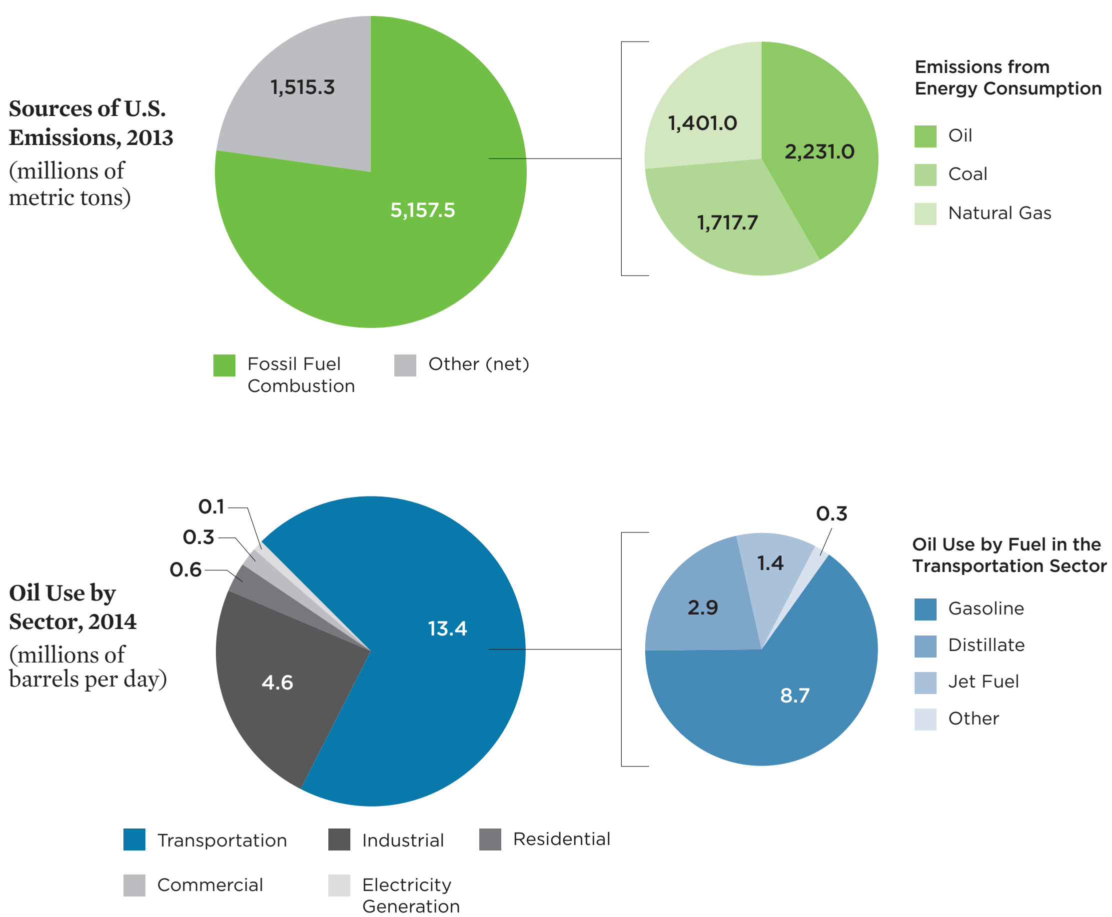
BOX 3.

Oil and Gasoline Are Not the Only Things Causing Climate Change, but They Are Among the Biggest

Fossil fuel combustion accounts for the vast majority of U.S. global warming pollution (EPA 2015a), and of the three primary sources of fossil fuel associated carbon emissions, oil is the largest (EIA 2015b). Most of the oil is used in the transportation sector, and gasoline constitutes the majority of transportation fuel. Emissions from U.S. gasoline use alone amount to about 1 billion tons of CO_2.

As these statistics make plain, transportation in general, oil in particular, and especially gasoline are among the most significant sources of global warming pollution. Cutting global warming emissions enough to stabilize CO_2 concentrations and avoid the most damaging impacts of climate change will require deep reductions in emissions across the whole economy (IPCC 2014). And emissions reductions from the transportation sector must start with dramatic cuts in oil use over the next few decades.

FIGURE 2. Reducing Emissions from Gasoline Is Key to Mitigating Global Warming



Fossil fuel combustion is the largest source of the heat-trapping emissions that cause global warming. Of the three major fossil fuels, oil accounts for the largest share of CO_2 emissions. The majority of oil is used for transportation, and within that category, the largest share of oil is used in the production of gasoline. Reducing gasoline and oil use is crucial to reducing global warming emissions.

SOURCE: EPA 2015A; EIA 2015B.

Use of Gasoline and Oil Today, and Related Emissions

Coal rather than oil launched the industrial revolution; in 1900 oil was a minor source of energy and had an insignificant role in the transportation sector. Oil's importance grew through the 1920s, and in the years shortly after World War II, as coal-fired trains were replaced by diesel locomotives, oil began 50 years of almost total dominance of the transportation sector (see Figure 3, p. 5). Oil supplied 95 percent of transportation energy from 1958 to 2008, and fell below this level only in 2009 as biofuels grew to become a small but increasingly significant part of the transportation fuel pool (see Chapter 3).

After World War II, as coal-fired trains were replaced by diesel locomotives, oil began 50 years of almost total dominance of the transportation sector.

Gasoline use rose steadily for three decades in the post–World War II years, until oil price shocks associated with the oil embargo in the 1970s led to the introduction of fuel economy standards in the mid-1970s (see Figure 4, p. 6). The rising fuel efficiency of new cars combined with another oil price spike at the end of the 1970s led to a significant drop in the nation's gasoline consumption. In the 1980s, oil prices fell and fuel economy standards stagnated, and gasoline use resumed its upward trajectory. In the late 2000s, after 20 years of relatively low oil prices, prices rose sharply, and booming global demand and another round of political turmoil in the Middle East led to oil price spikes. Higher oil prices refocused consumers and policy makers on fuel economy, and in 2007 new standards were passed by Congress and signed into law, although not fully implemented until 2012. As a result, the cars, minivans, and light trucks sold today have higher efficiency

TIMELINE 1. Changes in the Oil Industry

1900 1925 1950 1975 2000

1901
Oil is discovered at the Spindletop oil field in Texas; oil accounts for just 2 percent of U.S. energy use, and almost four times as much capital is invested in manufacturing locomotives and railroad equipment as motor vehicles in the United States (EIA 2012; Census Bureau 1975).

1945-1960
In the post–World War II boom years, oil rapidly becomes the dominant transportation fuel. Oil accounts for 80 percent of transportation energy in 1950 and 95 percent in 1958 as the automobile age comes into full swing, the interstate highway system is built, and railroads shift from coal-fired steam locomotives to diesel power.

1973
The first Arab oil embargo causes oil prices to triple and highlights the political and economic vulnerabilities that the nation's heavy oil use imposed.

1975
In response to the embargo, the first fuel economy standards for cars are implemented, improving the efficiency of cars from 13 mpg in 1975 to 23 mpg 1985.

1990
The Exxon Valdez spill releases more than one-quarter million barrels of crude oil into Prince William Sound, off the coast of Alaska, making it the largest U.S. maritime oil spill to that point in time.

2009
The Securities and Exchange Commission expands legal definitions of oil to include tar sands and other unconventional sources including oil and gas extracted from coal and shales (SEC 2009). This expands what oil companies can count among their "proven reserves."

2010
The BP Deepwater Horizon offshore drilling rig explodes and sinks, killing 11 people and releasing about five million barrels of oil into the Gulf of Mexico.

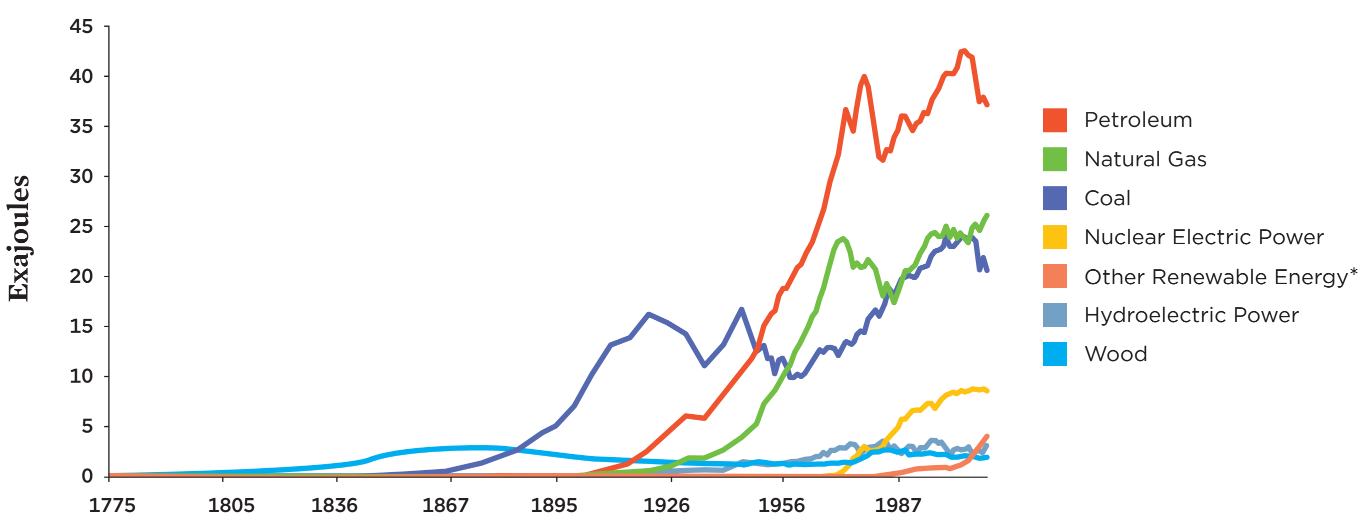
than in the past, ranging from less than 20 mpg to as high as 50 mpg. The average efficiency of new passenger cars and trucks sold in 2014 was 28 mpg for cars and 20 mpg for trucks, with a sales-weighted average overall of just over 24 mpg (EPA 2014a; DOE 2015), which is 20 percent higher than in 2006. Efficiency improvements are expected to continue as standards get more stringent over time, pushing toward an average real-world fuel economy of 37 mpg by 2025 (UCS 2015a, UCS 2011a). Already, millions of gasoline-powered hybrid electric vehicles (HEVs) on the road today get up to 50 mpg.

Automobile drivers' habits have played an important role in the nation's gasoline consumption over time. One key reason that gasoline consumption fell after 2007 was the reduction in the number of miles Americans drove their cars. The average number of miles travelled in a vehicle annually—vehicle miles traveled (VMT)—fell on a per-capita basis by more than 6 percent in 2014 compared to its peak in 2005 (see Figure 4, p. 6). This was due in part to Americans' increased use of telecommuting, bicycling, public transit, and other alternatives to driving (Dutzik and Baxandall 2013). Following the dramatic fall in oil prices in 2014, per-capita VMT increased somewhat, but it is still well below its previous peak, and changing demographics and attitudes toward transportation choices may be leading to more lasting decreases. A shift toward more dense urban development together with new transportation services like ride-sharing, car-sharing, and regional bike-sharing services are changing the way people access transportation, moving away from the near-universal car ownership that has prevailed since World War II.

[Millions of gasoline-powered HEVs on the road today get up to 50 mpg.]

Recent progress in fuel efficiency and reduced VMT demonstrates that a cleaner transportation system is a realistic goal, but continued action in all of these areas is needed to maintain this progress over the long term. Complacency in the 1980s undermined early progress cutting oil in the 1970s, and low oil prices lulled policy makers into allowing vehicle efficiency standards and other oil-saving policies to stagnate. Avoiding the same mistake now is critical. To chart a path toward steady progress, the Union of Concerned Scientists (UCS) developed a practical plan to cut projected oil use in half by 2035 (see Box 4, p. 7). Even as progress on reducing oil use proceeds, however, it remains important to clean up all of the fuels the nation's drivers use, including clean fuels like

FIGURE 3. U.S. Primary Energy Consumption Estimates by Source, 1775–2011

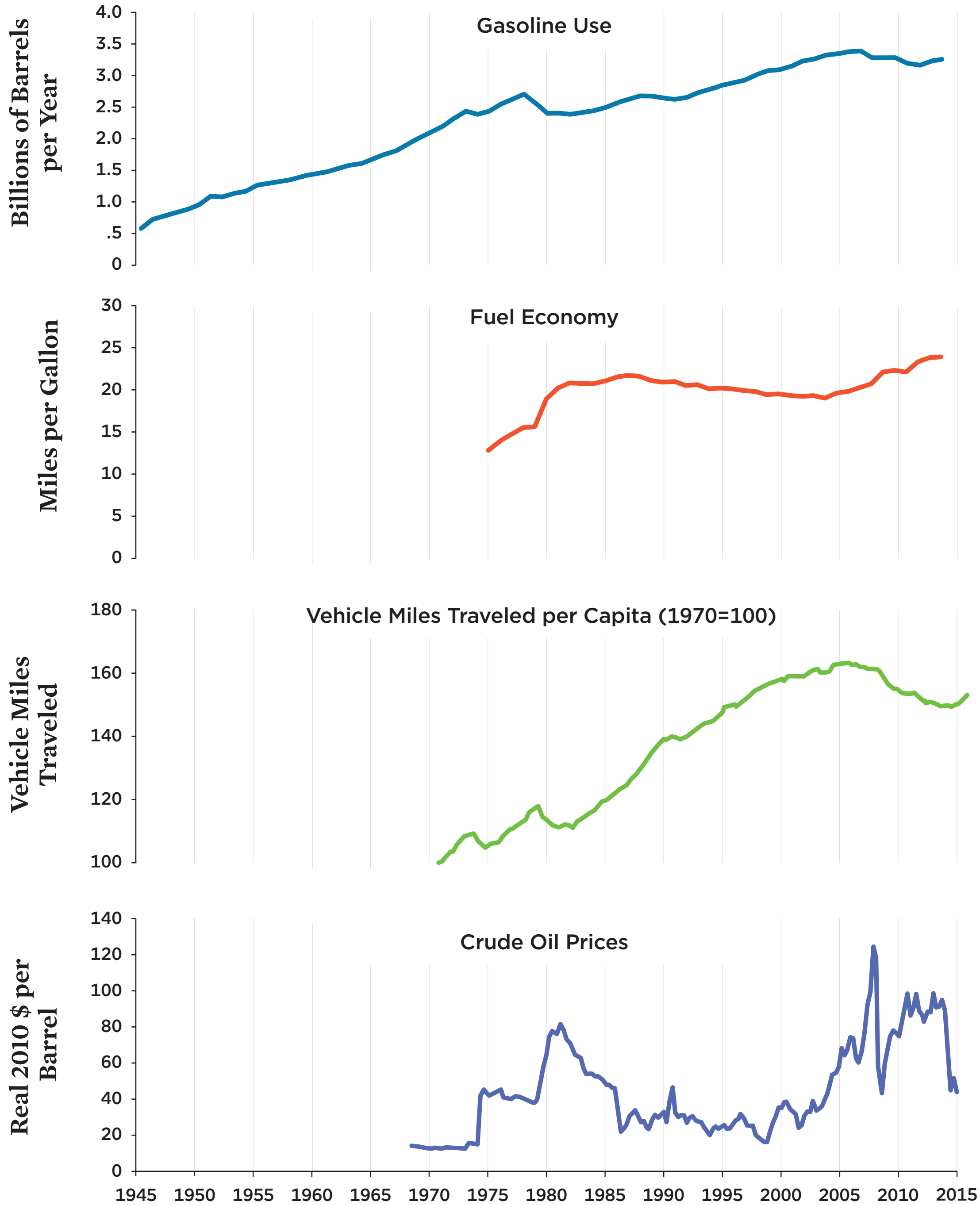


Since the 1940s, petroleum has been the largest source of energy in the United States.

* Geothermal, solar/photovoltaic, wind, waste, and biofuels.

SOURCE: EIA 2012.

FIGURE 4. Historical U.S. Gasoline Use and Key Factors that Influence It



Changes in gasoline use depend upon fuel economy, vehicle miles traveled, and crude oil prices.

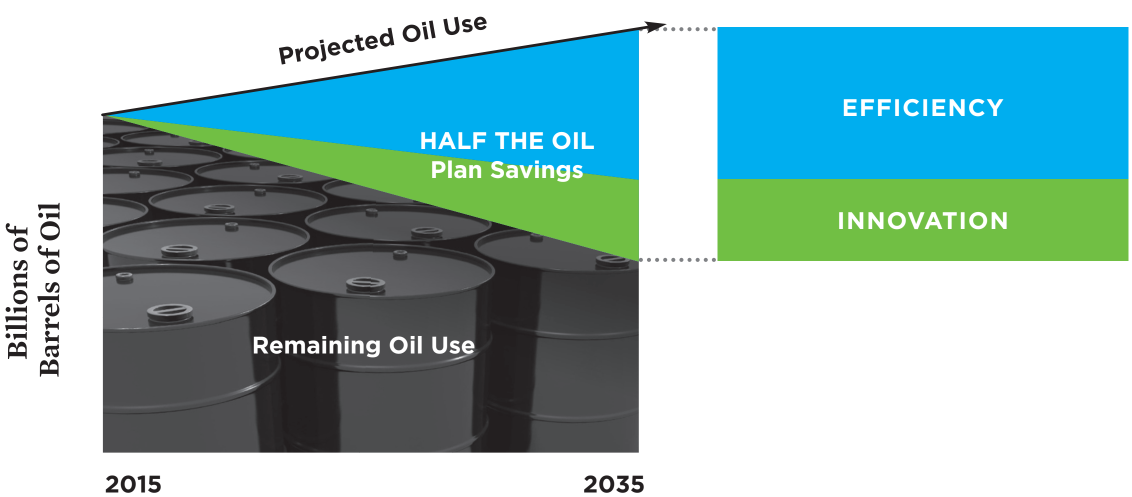
SOURCE: EIA 2015B; EPA 2014A; BLS 2015; DOT 2015; EIA 2015D.

BOX 4.

Half the Oil

The most straightforward way to reduce the pollution and other problems caused by oil is to use less of it. UCS has developed a plan to cut projected oil use in the United States in half by 2035 by aggressively improving the efficiency of all uses of oil—not just for cars using gasoline, but trucks, trains, planes, and ships, as well as industrial uses—and expanding the use of innovative technologies including EVs and advanced biofuels (UCS 2012a). Important early progress demonstrates that these strategies are realistic and can lead to the desired results, but further progress on more efficient vehicles, cleaner fuels and other innovative oil-saving solutions is required to deliver on their full potential.

Yet, even as oil use falls, it remains a major source of pollution. Under the UCS Half the Oil plan, although oil use would fall to 11 million barrels per day by 2035, cumulative oil use between 2015 and 2035 would still be approximately 100 billion barrels (EIA 2015a, UCS 2012a). If we made less progress on oil-saving strategies, we would see even higher oil use during that period.



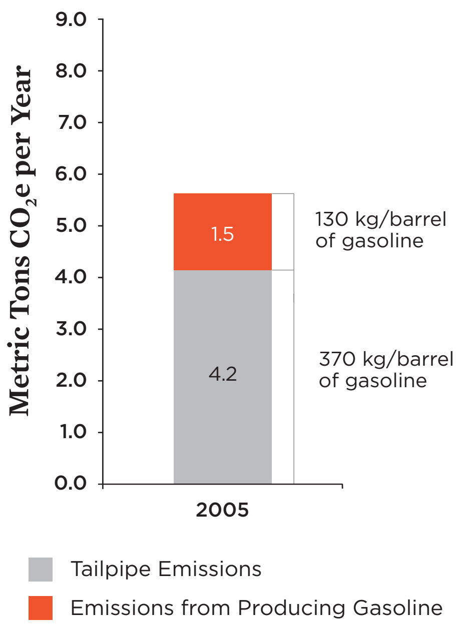
advanced biofuels (see Chapter 3) and electricity (see Chapter 4), and also the oil that will continue to be used for decades to come.

> ***The shift toward more polluting sources of oil and more extreme extraction and refining methods is increasing emissions.***

Production of Gasoline, and Related Emissions

The most obvious source of global warming emissions from gasoline are the CO_2 emissions from a car's tailpipe during the operation of a gasoline-powered vehicle. But the combustion emissions from gasoline are by no means the whole story. Emissions from oil extraction and refining oil into gasoline are also major sources of global warming pollution. A typical new car getting 25 mpg that is driven 12,000 miles per year has emissions of 4.2 metric tons of CO_2e global warming pollution (hereafter simply tons CO_2e). The emissions produced through extracting and refining the oil add on average 1.5 tons of CO_2e, an additional 35 percent (CARB 2015a). Moreover, the 1.5 ton figure is an average that includes a very wide range of types of oil, some of which produce far more global warming emissions than the average. As we discuss below, detailed annual tracking of the production emissions per gallon of U.S. gasoline is not available. However, the shift toward more polluting sources of oil and more extreme extraction

FIGURE 5. Emissions from Oil Production



While using vehicles is the most obvious source of emissions from gasoline, producing the gasoline involves substantial emissions from extracting and refining oil. The magnitude of these emissions depends on which sources of oil are used, and how these sources are extracted and refined.

Note: The global warming emissions of gasoline represents the metric tons of CO_2e associated with the production and consumption of fuel required to power a typical car (getting 25 mpg) for a year (driving 12,000 miles).

SOURCE: CARB 2015A.

and refining methods is increasing emissions. This means that even as the tailpipe pollution from driving a car is falling, the pollution associated with producing a gallon of gasoline is rising.

EASY OIL IS RUNNING OUT

Conventional, easy-to-access oil is running out. But the result is not gasoline shortages. Rather, the oil industry has shifted its focus to unconventional fossil resources and extraction methods. The prototypical "gusher" that marked the discovery of the Spindletop oil field in Texas in 1901 is no longer an accurate representation of where oil comes from or what oil production looks like. As oil fields age and their output declines, oil companies are turning to oil resources once thought to be too risky or too expensive to exploit, establishing and rapidly scaling up production of unconventional sources of oil that are costly, physically difficult, and energy-intensive to extract and refine compared to "easy" oil. So long as continued demand for oil exists, oil companies will find technical means to develop these increasingly challenging and risky fossil fuel resources (Gordon et al. 2015).

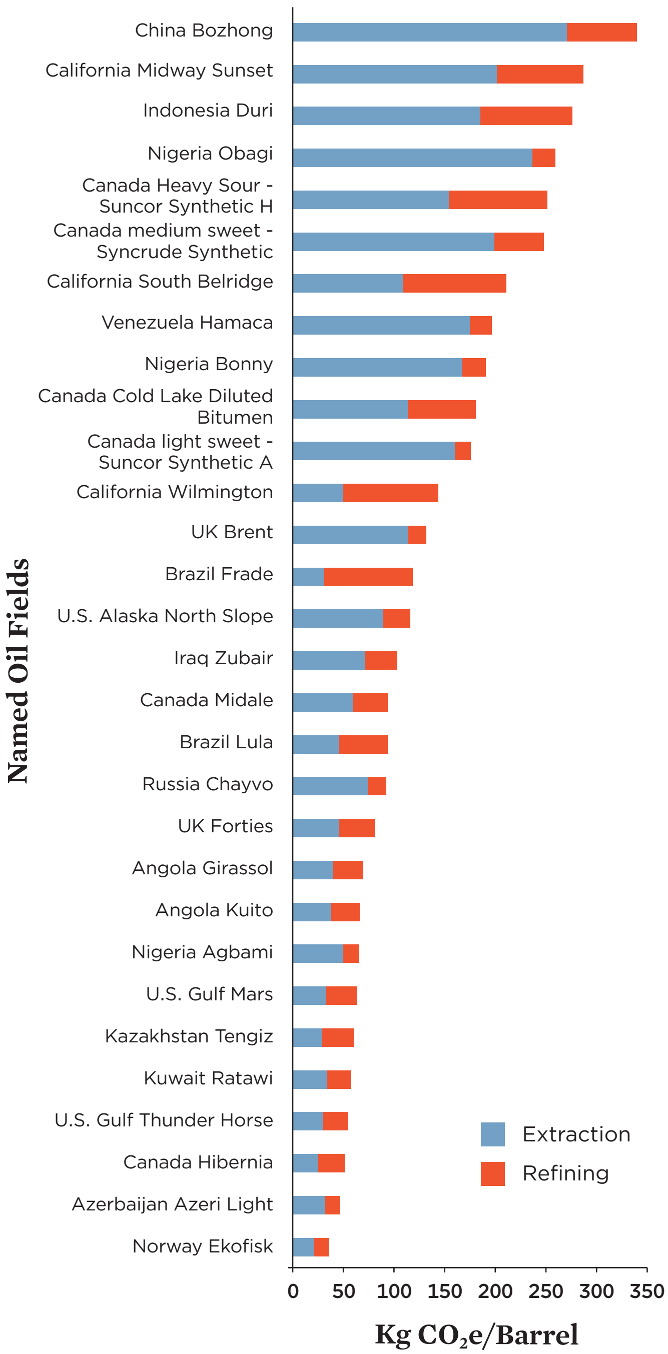
The common image of oil as a dark liquid with the viscosity of cooking oil captures just the center of a wide range of hydrocarbons that are now used to make gasoline and other transportation fuels. At one end of the spectrum is ultra-light oil, a thin liquid with the viscosity of nail polish remover. At the other end of the spectrum are bitumen and kerogen, long-chain hydrocarbons with the viscosity of caulk or putty (Gordon 2012). Just off the spectrum on the light end are methane and other components of natural gas, which are often found together with lighter oils. At the very heavy end is coal, which shares features and uses with some of the heaviest sources of oil. Different types of oil are made into different products, with very different impacts on the climate.

With different types of oil come different techniques to extract and refine them. From fracking tight oil in North Dakota to surface mining tar sands in Canada, new extraction techniques and the different types of oil that they produce mean that the total emissions of driving a car are changing, although not in ways that drivers can see or control. These changes are occurring before the gasoline gets to the gas station and are a function of the choices, actions, and inactions of oil companies and their supply chains.

[***New extraction techniques and the different types of oil that they produce mean that the total emissions of driving a car are changing, although not in ways that drivers can see or control.***]

Researchers at the Carnegie Endowment, Stanford University, and the University of Calgary recently released the Oil Climate Index, a set of three linked open-source models for oil extraction, refining, and use that illustrate the increasing complexity of the oils used to produce transportation fuels and other petroleum products. Their initial work looked at 30 representative sources of crude oil from around the world, finding that the global warming emissions from extracting

FIGURE 6. Emissions from Extracting and Refining Oil Can Vary



According to the Oil Climate Index, emissions from extracting and refining emissions can vary dramatically, depending on the sources of oil and the extraction and refining practices and methods.

SOURCE: GORDON ET AL. 2015.

one barrel of oil ranged from 22 to 270 kg CO_2e, and emissions from refining ranged from less than 15 to more than 100 kg CO_2e (Gordon et al. 2015).[1]

The Oil Climate Index takes an in-depth look at many of the key factors that differentiate the world's varied oil resources. In this report we highlight just three that illustrate some of the key issues at play in the changing world of oil production:

- **Depleted oil wells** that require a great deal of water and steam to extract oil
- **Tight oil** production using hydraulic fracturing and associated gas flaring
- **Tar sands oil** and the associated emissions from mining and processing

DEPLETED OIL WELLS

As oil wells age—some of the wells in Texas and California are more than 100 years old—the pressure drops and the flow of oil slows. The remaining oil is typically heavier and does not flow easily out of the ground, requiring more aggressive recovery techniques, and it is also more energy-intensive to refine. Heavy oils are more resistant to flow due to their higher viscosity. When a new well is drilled, there may be sufficient pressure for the oil to flow without pumping, but this initial pressure-driven flow is generally sufficient to extract only 10 percent or so of the available oil. Once the pressure falls, pumping is driven by an electric motor, which requires energy and generates additional emissions.

PUMPING LOSSES

Once the easily accessible oil runs out, oil producers often pump water into the ground (see Figure 7, p. 10), which allows more oil to be recovered. Anywhere from 20 to 40 percent of the total recoverable oil in a field can be extracted by injecting water into the oil field at an injection well. However, in the case of water-flooded oil wells, much of the injected water comes out together with the oil. Thus, over time, more and more water must be pumped into the ground and back out again to get less and less oil, with some older wells using 30 barrels of water for each barrel of oil extracted. As the ratio of water to oil increases, so too do the emissions per barrel. According to the the Oil Production Greenhouse Gas Estimator (an open-source oil emissions calculator), lifting an additional 10 barrels of water per barrel of oil increases production emissions from oil extraction by 15 kg CO_2e per barrel (El-Houjeiri et al. 2015). With average oil extraction emissions of about 70 kg CO_2e per barrel, an additional 15 kg is a meaningful increase (CARB 2014).

1 *Although non-transportation uses are beyond the scope of this report, the Oil Climate Index considered how the whole barrel of oil is used—not just the gasoline derived from it, but also other transportation fuels such as diesel, jet, and marine fuels, as well as other petroleum products used outside of transportation (Gordon et al. 2015).*

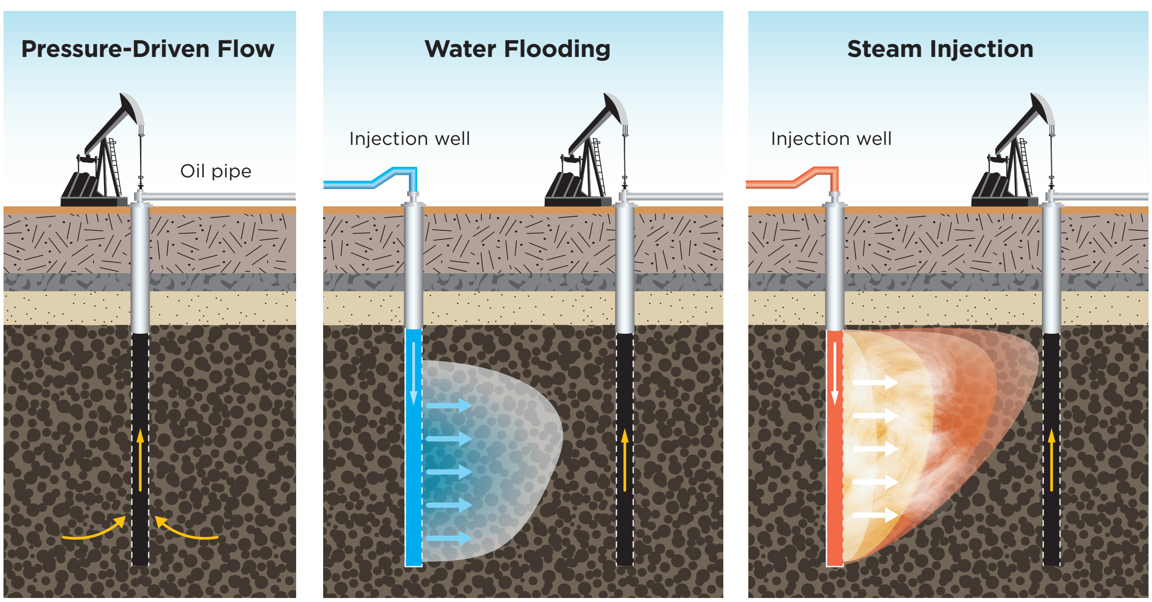
Lost Hills Oil Field in California has been producing oil for over 100 years. As wells age, more energy is required to extract the remaining oil from the ground, and more emissions are released in the process.

STEAM INJECTION

Water is not the only thing pumped into oil wells. Over time, flooding wells with water becomes ineffective, and other techniques are required to continue production. These techniques, which increase pressure and change the physical properties of the oil, are referred to as enhanced oil recovery. They consist of injecting either steam, other gases (including methane or CO_2), or chemicals into oil wells to make the oil flow more easily, enabling the recovery of more oil than would be possible by simply pumping or flooding the wells. In general, up to 60 percent of the total recoverable oil in an oil field can be extracted using these techniques.

In the United States, steam injection (also called thermal-enhanced oil recovery) accounts for 20 percent of the volume of oil produced each year. In California in particular, steam injection is the most prevalent form of oil extraction for older wells and in fields with heavy oil. In addition to the energy required to run the pumps, energy is required to make steam. Different types of oil and different wells require different amounts of steam, and sometimes steam can be efficiently procured from a power plant that generates both steam and grid electricity. Typical quantities of water used in steam-flooded wells in California are between three and six barrels of water (converted to steam) used to extract one barrel of oil. Each barrel of water converted to steam increases emissions by about 25 kg CO_2e per barrel (El-Houjeiri et al. 2015; Brandt

FIGURE 7. Extracting Oil from Depleted Wells



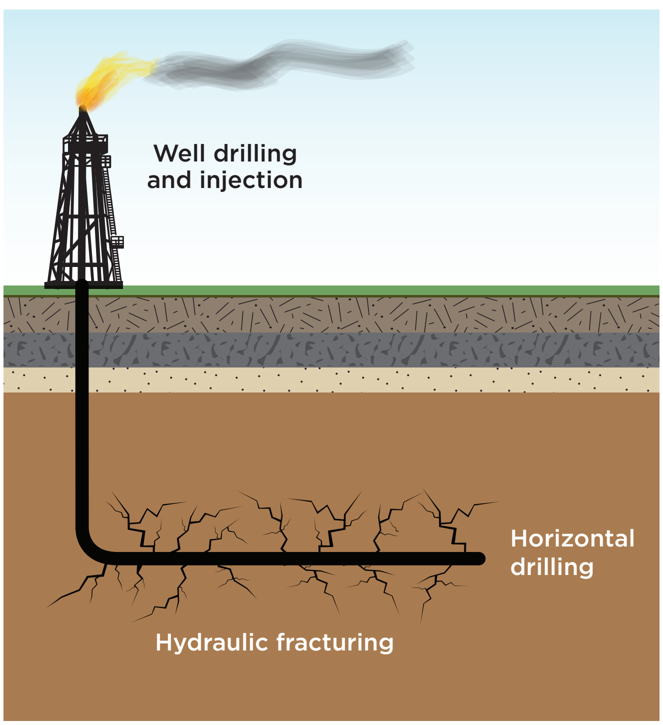
When a new oil well is drilled, oil can easily be extracted using the internal pressure of the well. Over time however, this easy oil will stop flowing, and enhanced recovery methods are needed. Water injected into the oil field makes further extraction possible, and when these secondary techniques are no longer effective, injecting steam, other gases, or chemicals can facilitate further oil recovery. These methods require more and more energy to extract less and less oil, raising the emissions of each barrel produced.

and Unnasch 2010), compared to 75 kg CO_2e per barrel associated with extracting an average barrel of oil (CARB 2014).

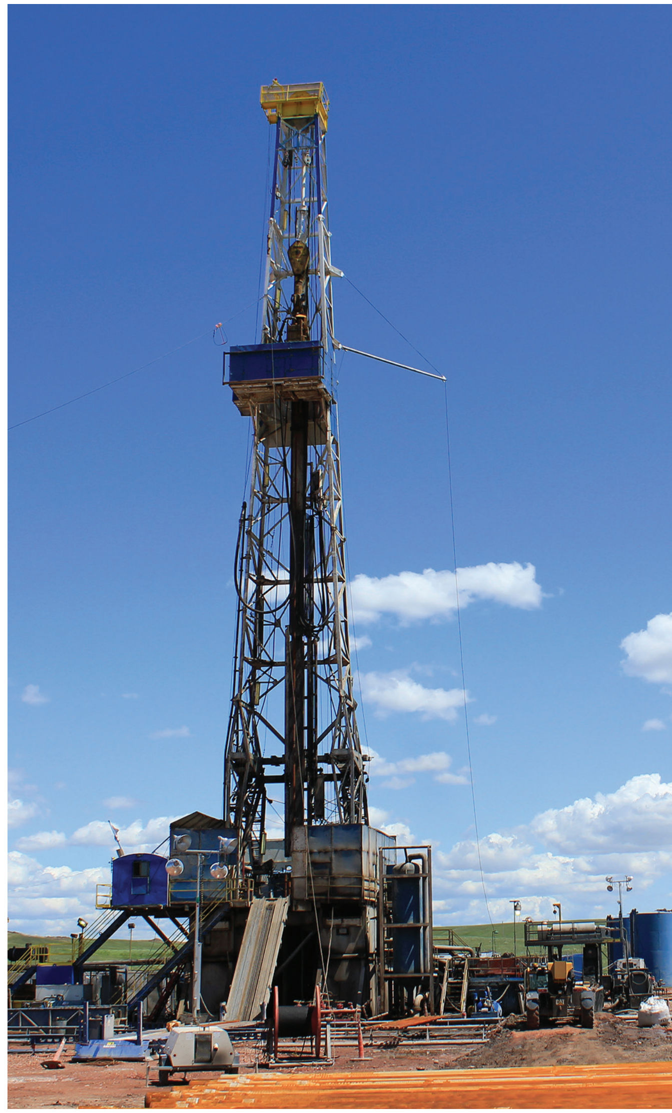
TIGHT OIL

Tight oil is found in shale deposits, especially in the Bakken field in North Dakota and the Eagle Ford field in Texas. (Because tight oil is found in shale deposits, it is often called "shale oil," which can cause confusion with oil shale, an entirely different resource. In this report the term "tight oil" is used to avoid this confusion.) Tight oil is extracted using horizontal drilling and hydraulic fracturing (fracking), techniques that were not as widely used before 2010, but became much more common when oil prices rose. Tight oil accounts for a growing share of U.S. oil production and is produced at a scale that is significantly changing the global oil marketplace

FIGURE 8. Extracting Tight Oil Using Hydraulic Fracturing



As gas prices and oil demand rise, producers have turned to extracting tight oil using horizontal drilling and hydraulic fracturing. A relatively new process, this involves using pressure to create cracks in porous rocks, and injecting water, sand, and chemicals to keep those cracks open and allow oil to flow. This process uses substantial energy and water, creates local air and water pollution, and is often associated with extensive production of gases as well as crude oil. Most of the gas is sold, but in some cases the gas is flared at the well, a wasteful and polluting practice that can be avoided by building the infrastructure needed to bring the gas to market or reinjecting it into the well.



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Extracting tight oil, like in the North Dakota operation pictured here, requires an energy-intensive hydraulic fracturing process.

(Hamilton 2014). Fracking uses pressure to create cracks in porous rocks and injects chemicals and sand to keep the cracks open, allowing oil and natural gas from the pores to flow out. The extraction process creates local air and water pollution, a great deal of road traffic, high water use, and other problems that make it a problematic source of oil (Goldman et al. 2013; Gordon 2012).

The tight oil developed in the United States to date tends to be a relatively light crude. These light tight oil deposits also come with many intermediate-molecular-weight hydrocarbons called natural gas liquids, which—instead of being processed into gasoline or diesel—are typically used in the chemical industry or for other purposes. An important feature of tight oil from North Dakota and Texas is that both oil and natural gas are present in the same formations and are produced from the same wells. The relative fraction of oil to gas differs from region to region and dictates the design, management, and utility of the resources extracted in these regions. For example, the Marcellus shale in the northeastern United States produces primarily gas, while the Bakken and Eagle Ford are exploited largely to access liquid oil, although a great deal of gas comes up with the oil.

Gassy oils like those produced in the Bakken field in North Dakota require different techniques, infrastructure, and equipment to manage. Methane, the main component of natural gas, is a potent greenhouse gas, with 34 times the global warming potential of CO_2 over a 100-year time frame and 86 times the global warming potential over a 20-year time frame (Myhre et al. 2013). Releases of methane and other gases from oil wells—or venting—can dramatically increase the emissions associated with oil production. Therefore, it is very important that methane not be released into the atmosphere, which can be accomplished by reinjecting it into the well, where it can maintain pressure and assist in the oil recovery process, or transporting it by pipeline to be sold for use in electricity generation or for other purposes. However, since 2007, oil producers rushing to bring oil to market have increasingly resorted to burning the natural gas—flaring it and releasing it into the atmosphere—rather than building the necessary infrastructure to prevent its release into the atmosphere and bring it to market (see Box 5).

Releases of methane and other gases from oil wells—or venting—can dramatically increase the emissions associated with oil production. It is very important that methane not be released into the atmosphere.

The surge in tight oil production since 2010 has outpaced the development of infrastructure required to transport the oil to market. Train shipments moving oil to U.S. refineries have grown from less than 10,000 train cars in 2008 to more than 435,000 in 2013, and with them an increased frequency of derailments. Because of the higher volatility of some tight oil compared to conventional crude, derailments of these fuels also have more often caused fires (Frittelli et al. 2014).

BOX 5.

Flaring

The routine combustion of useable natural gas from oil wells might seem counterintuitive: why would an oil producer burn something that it could sell for a profit? The rapid expansion of tight oil extraction occurred more rapidly than the build-out of infrastructure necessary to gather, process, and transport the associated gas to market. Producers prioritized getting liquid fuels to market quickly and used their capital to drill new wells rather than first putting in place the necessary pipelines and other gas infrastructure. Instead, the natural gas was vented to the atmosphere or burned at the well site. These flares are visible by satellite, and analysis of the satellite data has been used to calculate the extent of flaring from countries around the world (Elvidge et al. 2009).

In the North Dakota oil fields, the rapid expansion of wells has not been accompanied by a similar expansion in producers' capacity to recover the natural gas; therefore, flaring and venting have substantially increased. On average, less than 5 percent of natural gas produced in North Dakota

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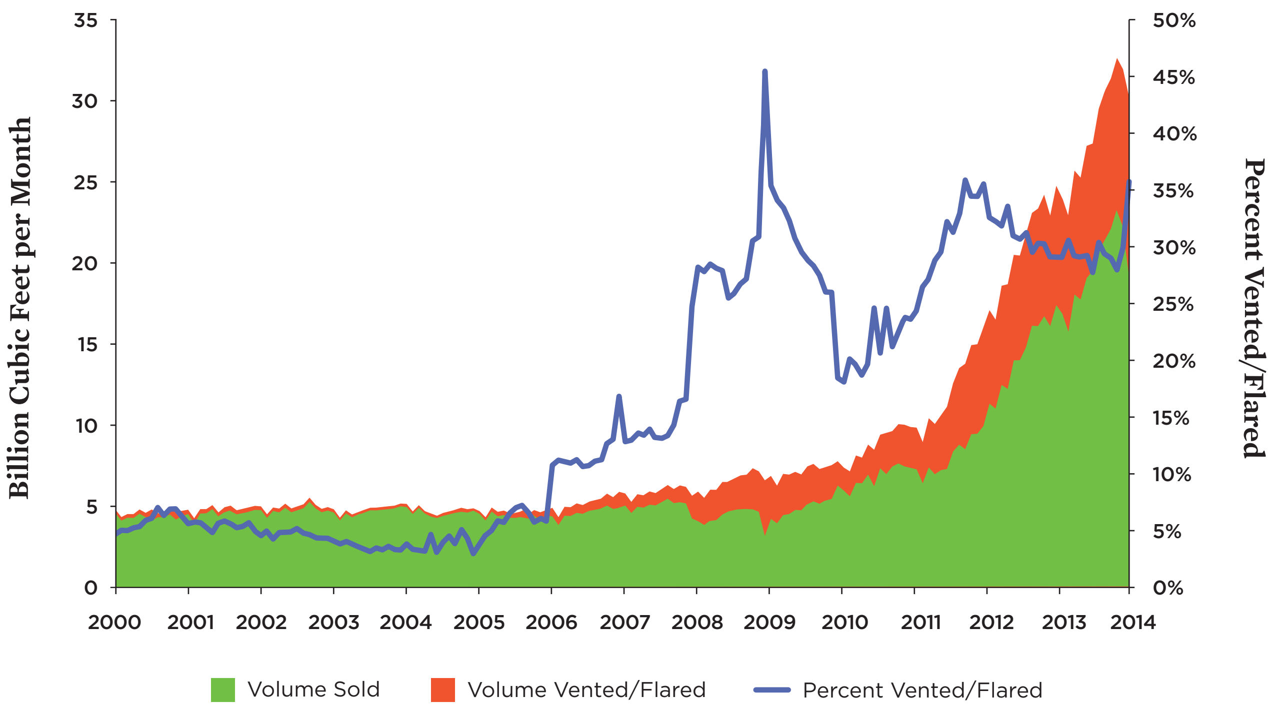
When tight oil is extracted, natural gas rises along with the liquid oil. Because the oil is often the more profitable product, fossil fuel companies prioritize extracting the oil over capturing the natural gas, choosing instead to flare the natural gas in order to reach the oil. Flaring is a very emissions-heavy practice and is currently surging in North Dakota.

was flared between 2000 and 2005, but after 2005 venting and flaring grew quickly as tight oil production accelerated. Between 2011 and 2013, more than 30 percent of natural gas was vented and flared, and given the rapidly rising overall natural gas production, the result was a very large increase in global warming emissions of CO_2, methane, and other pollutants without producing any useful product or service.

Flaring is surging in North Dakota, but it need not be. Tight oil production has also been growing at the Eagle Ford formation in Texas, but in Texas less than 1 percent of extracted natural gas has been vented or flared, owing to the more extensive network of pipelines to collect and market natural gas. Oil fields in Norway also flare and vent very little natural gas. Norway effectively banned the routine use of flaring in 1972; oil production projects there must either reinject natural gas or put in place the infrastructure to sell the gas prior to commencing production. Norway's major oil industry therefore has very low upstream emissions: Norway's Ekofisk field was found to have the lowest upstream emissions of 30 major global oils evaluated as part of the Carnegie Endowment Oil Climate Index. By contrast, the two oils with the highest extraction emissions in the index, China Bozhong and Nigeria Obagi, are gassy oils produced with extensive venting and flaring, increasing their emissions substantially.

Inadequate information on tight oils prevented the inclusion of any U.S. tight oil sources like Bakken and Eagle Ford fields in the Oil Climate Index (Gordon et al. 2015). But more recent analysis from the Stanford research team working with Argonne National Laboratory and other groups is increasing our knowledge of the emissions from this increasingly important source of oil and highlights the role played by flaring in the total emissions of these oils (Brandt et al. 2015; Ghandi et al. 2015).

FIGURE 9. North Dakota Monthly Natural Gas Production



Venting or flaring natural gas is an avoidable source of global warming pollution that occurs when oil producers extract oil without putting in the required infrastructure to manage the natural gas, and instead release it into the atmosphere (venting) or burn it on site (flaring). As oil production increased in North Dakota so too did venting and flaring, which averaged less than 5% between 2000 and 2005 and has increased to more than 30% from 2011 to 2013. Because the quantity of gas has increased as well, the total quantity of venting and flaring in 2011 to 2013 is more than 25 times higher on an absolute basis than it was between 2000 and 2005.

SOURCE: EIA 2015C.

TAR SANDS AND EXTRA-HEAVY CRUDE

Tar sands, also referred to as oil sands, are composed of approximately 10 to 18 percent bitumen in a matrix of soil including sand, clay, and quartz, as well as water (Gordon 2012). Creating gasoline and diesel from tar sands is a very different process from the use of conventional oil, as bitumen is an extra-heavy crude that is semi-solid at room temperature. These tar sands do not look like oil. Indeed, prior to a 2010 ruling by the Securities and Exchange Commission, tar sands resources were not included as proven reserves in U.S. oil companies' financial reporting (SEC 2009).

Tar sands are extracted by either surface mining or in situ recovery. Surface mining is used for tar sands that are within 75 meters of the ground surface, while in situ recovery is used for deeper reservoirs (Charpentier, Bergerson, and MacLean 2009). The vast majority of the world's reserves of tar sands are located in Alberta, Canada. Approximately 20 percent of the Canadian reserves of tar sands are within 75 meters of the surface and can therefore be surface mined; the remaining 80 percent of Canadian reserves would have to be mined in situ, which can significantly increase extraction emissions (CAPP 2015a).

SURFACE MINING

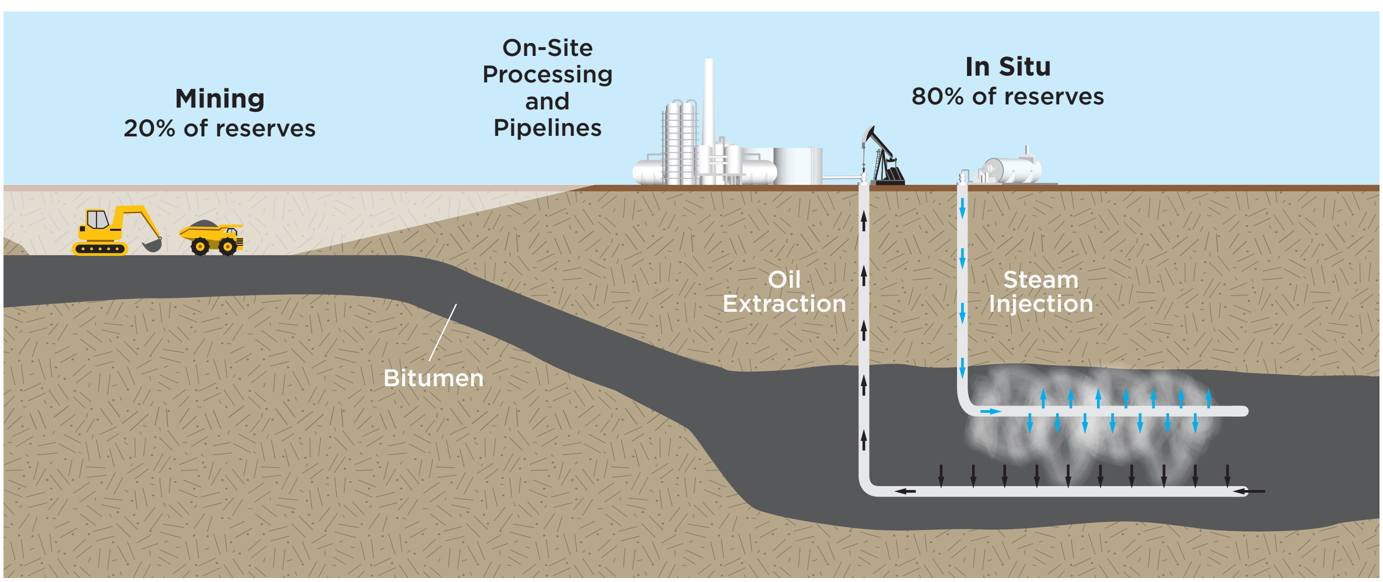
Tar sands reserves accessible to surface mining cover approximately 1,800 square miles of Alberta, an area larger than Rhode Island (CAPP 2015a). The surface mining, also known as open-pit mining, of tar sands involves removing all of the ground above the tar sands and exposing its entire surface area for mining. The tar sands are then physically gathered by enormous trucks in much the same way that coal is extracted during open-pit mining.

Once the tar sands are mined, the bitumen is separated from the soil matrix using water and heat in an energy-intensive process that generates carbon emissions and leaves behind highly polluted water. Once separated, the bitumen is still too viscous to flow through pipelines; therefore, prior to transportation it must be either upgraded or diluted. Upgrading is another energy-intensive process, converting bitumen into synthetic crude that more closely resembles conventional crude oil. Alternatively, bitumen can be diluted with lighter hydrocarbons to enable it to flow through pipelines to refineries, where it is further processed.

IN SITU RECOVERY

In instances when tar sands reserves are deeper than 75 meters, in situ recovery techniques are employed. In situ mining requires steam (or solvents) to lower the viscosity of bitumen enough to be pumped out of the reservoir for further processing. This oil-recovery approach requires injections of massive amounts of steam, which requires heat generated from natural gas as well as a great deal of water, all of which lead to emissions even higher than for surface-mined tar sands oil (Cai et al. 2015).

FIGURE 10. Extracting Oil from Tar Sands



Tar sands are a mixture of clay, sand, and bitumen—an extra-heavy crude that is solid at room temperature. They are collected either by surface mining, in which soil covering the tar sands deposits is removed and the bitumen is trucked to upgraders for further processing, or in situ mining, in which massive amounts of steam are injected into the ground to make the tar sands flow. The emissions from both methods of collecting tar sands are very high, and the process to convert tar sands into gasoline and other products is very energy-intensive.

BOX 6.

Tar Sands Mining Destroys Forests and Contaminates Water

Surface mining destroys the boreal forest ecosystem found above Alberta's tar sands and releases the associated soil carbon. Projected land area disturbed between 2012 and 2030 is estimated to be 500 km^2 for surface mining and 2,400 km^2 for in situ mining, with combined emissions from land use of more than 100 million tons CO_2e (Yeh et al. 2015). Water used to process the tar sands is also a major concern, as it becomes heavily polluted and is held in very large artificial reservoirs (tailings ponds) that cover a total area of 176 km^2 (67 square miles) (CAPP 2015b). Pollutants from these tailing ponds are finding their way into plants, fish, and birds, posing risks to wildlife and people who consume the fish from the region (Schindler 2014).

UPGRADING AND REFINING

Refining tar sands oil is a more energy intensive and polluting process than refining conventional crude oils. Tar sands oil is composed of extremely heavy hydrocarbons and is also often high in contaminants such as sulfur, which must be removed either as part of the process of making synthetic crude or later at the oil refinery in the process of making finished fuels such as gasoline. Emissions associated with extracting and refining a barrel of tar sands oil are also higher, ranging from 180 to 250 kg CO_2e per barrel of oil (Gordon et al. 2015).

The Future of Oil and Gasoline

With smart policies, gasoline use in the United States should decline steadily over the next several decades, as vehicles become more efficient, the use of clean fuels like electricity and biofuels continues to expand, and transportation options that reduce travel by car are more widely adopted. However, even with steady progress, gasoline will remain a major part of the U.S. transportation fuel mix for decades to come. Other oil-based fuels like diesel and jet fuel will likely also remain significant parts of the fuel mix through 2050. As a consequence, the emissions associated with extracting oil and producing gasoline, diesel, and other transportation fuels will continue to be an important part of our country's total transportation emissions through 2035 and beyond.

Even with steady progress in cutting oil use, improving vehicle efficiency, and ramping up EVs and biofuels, the United States will still be using 11 million barrels per day—or 4 billion barrels per year—of oil in 2035 (see Figure 11, p. 16). Cumulative oil use in those two decades will be about 100 billion barrels, or more if oil reduction strategies are not implemented aggressively (EIA 2015a, UCS 2012a). If emissions associated with oil extraction and refining rise by just 1 kg of CO_2e per barrel each year (less than 1 percent) over this time frame, the cumulative additional emissions would be almost 1 billion metric tons of CO_2e, almost as much as tailpipe emissions from all gasoline-powered vehicles in the United States in 2014 (EIA 2015b).

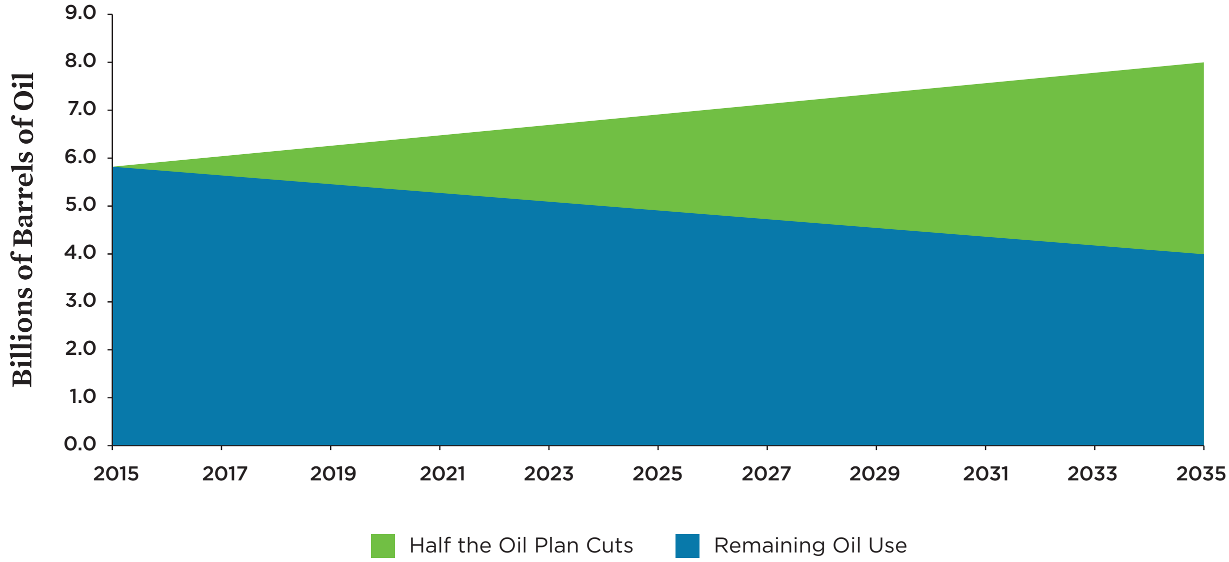
It is crucial that oil producers and refiners—even as they continue to produce gasoline and other fuels—clean up and reduce global warming emissions from their operations. There are ample opportunities for them to do so.

The emissions associated with extracting oil and producing gasoline, diesel, and other transportation fuels will continue to be an important part of our country's total transportation emissions through 2035 and beyond.

ELIMINATE ROUTINE FLARING

Flaring natural gas associated with oil production generates high levels of emissions. Fortunately, it is unnecessary and can be readily avoided. Flaring materially increases carbon emissions while reducing the energy production and economic activity associated with a given oil well. Oil production without flaring would create jobs, not just for oil extraction but for building and operating the required infrastructure for responsible energy production and distribution. The products would include the liquids as well as the natural gas. Where bringing gas to market is not practical or economic, gas can also be reinjected into the well and be used to maintain pressure required for continued oil extraction. The economic circumstances that make flaring an attractive option today are not an inevitable feature of the oil itself, but a result of the

FIGURE 11. The UCS Half the Oil Plan



The UCS Half the Oil plan outlines how the United States could reduce its projected oil use by 50 percent by 2035 through increasing vehicle efficiency and increasing the use of innovative clean fuels. However, even with these aggressive oil saving measures, 100 billion barrels of oil would still be used between 2015 and 2035, and emissions associated with producing oil would continue to be very significant, especially if oil production continues to get more polluting over time.

The economic circumstances that make flaring an attractive option today are not an inevitable feature of the oil itself, but a result of the flawed regulatory system that does not hold oil producers accountable for their carbon emissions.

flawed regulatory system that does not hold oil producers accountable for their carbon emissions.

Russia, Nigeria, Iran, and Iraq have been among the largest flaring countries, but increasing flaring from tight-oil production brought the United States higher in the ranking in recent years. The United Nations is coordinating a program aimed at phasing out the routine use of flaring by 2030, but meeting these goals requires action by oil-producing countries and the oil industry.

USE RENEWABLE SOURCES OF HEAT FOR STEAM GENERATION

Oil extraction from depleted wells often relies on steam generation that is most commonly produced by burning natural gas, adding substantially to the emissions associated with oil production. However, burning natural gas is by no means the only cost-effective way to generate steam. For example, concentrating solar energy is a highly effective means of generating steam that is already used extensively for electricity generation. For oil extraction located in areas with high solar-generating potential, including many oil fields in California and elsewhere around the world, this is an important opportunity for oil producers to reduce emissions.

Analysis by CARB found that using solar steam reduces emissions from oil production by 29 kg CO_2e per barrel of steam, and CARB is implementing a policy providing emissions reduction credits under its Low Carbon Fuel Standard for oil companies that adopt this innovative technology (CARB 2015b).

© GlassPoint Solar

Using solar energy to generate steam creates less emissions than creating steam by burning natural gas.

PRIORITIZE RESOURCES THAT CAN BE PRODUCED WITH MINIMAL UPSTREAM EMISSIONS

Oil industry emissions from steam generation and flaring can be readily and cost-effectively mitigated with existing technology, keeping emissions from oil extraction and refining from rising and perhaps even reducing them somewhat. But not all upstream emissions are easily managed. In particular, the tar sands and other extra-heavy crudes are among the most carbon-intensive oils currently being produced. Until practical mitigation measures are in place to reduce the emissions from extracting and refining these sources, their use should be reduced or eliminated.

Oil companies have highlighted the potential for technologies such as carbon capture and sequestration to mitigate the high upstream emissions of tar sands at some point in the future. However, this technology is not in widespread use today, and it is unclear whether it will be a realistic and cost-competitive carbon mitigation strategy on a large scale. As time continues to pass with mitigation remaining uncertain, investments in tar sands production, pipelines to transport it to market, and refinery investments to process it are locking in place one of the dirtiest sources of transportation fuel we have.

Decisions about which fossil resources to extract should take into consideration their full climate impact, especially because, once initial investments and infrastructure are put into place, the capital- and infrastructure-intensive projects may operate for many decades into the future. Policy makers and investors need accurate disclosure and comprehensive evaluations about the climate implications of these important decisions.

[*The tar sands and other extra-heavy crudes are among the most carbon-intensive oils currently being produced.*]

USE RENEWABLE INPUTS AND IMPROVE EFFICIENCY AT REFINERIES

In addition to oil producers' choices regarding oil extraction, oil refiners have significant opportunities to cut emissions associated with refining crude oil into gasoline and other products. These include investing in more energy-efficient equipment and integrating renewable resources into their operations. Renewable resources could include renewable electricity, bio-methane from wastewater treatment in place of natural gas, or replacing a portion of their fossil fuel crude with bio-crude produced from wastes or low-carbon sources. Refineries are complex and each is unique—the specific opportunities that make sense in each one will differ. But large refineries are major carbon emitters, and oil companies have the expertise and technology to reduce their emissions. This opportunity must not be lost.

Conclusions and Recommendations

Oil is changing and with it is the climate impact of driving a car. While the window sticker on a new car indicates the oil use and carbon emissions from the operation of the car, no such information is provided at the gas pump about emissions from the production of the gasoline. Easy oil is running out, and new sources of oil and different technologies used to extract and process it are increasing the carbon emissions of gasoline. However, some key mitigation measures are available to prevent oil from getting dirtier than it already is. To accomplish this requires reducing avoidable emissions and avoiding the dirtiest sources of oil.

MANAGING EMISSIONS FROM OIL PRODUCTION IS CRITICAL

Even with aggressive action to cut projected oil use in half by 2035 with efficiency and innovative transportation fuels such as electricity and biofuels, the United States is still on course to use 100 billion barrels of oil between 2015 and 2035 (EIA 2015a; UCS 2012a). Extracting and refining each barrel of oil has emissions of roughly 130 kg of CO_2e per barrel, and because of changes in oil production, these emissions could rise significantly as production shifts to more energy- and carbon-intensive oil sources and extraction techniques (Gordon et al. 2015).

Given the enormous scale of emissions from oil, even an increase of a 1 kg per barrel per year will lead to an increase of a billion metric tons of CO_2 between 2015 and 2035, and increases two or three times as large are certainly possible

BOX 7.

Major Carbon Emitters

The majority of fossil fuel CO_2 emissions released since the industrial revolution can be traced to just 90 entities, including the largest oil companies (Heede 2014).

These companies have known for decades that their products were major contributors to climate change, but rather than seek to reduce this harm, many of the companies instead have knowingly worked to deceive the public about the risks and realities of climate change (Mulvey and Shulman 2015).

Oil Companies with the Largest Cumulative Emissions

Entity	2010 Emissions $MtCO_2e$	Cumulative 1854–2010 $MtCO_2e$	Percent of Global $MtCO_2e$ 1751–2010
Chevron, USA	423	51,096	3.52%
ExxonMobil, USA	655	46,672	3.22%
Saudi Aramco, Saudi Arabia	1,550	46,033	3.17%
BP, UK	554	35,837	2.47%
Gazprom, Russian Federation	1,371	32,136	2.22%
Royal Dutch/Shell, Netherlands	478	30,751	2.12%
National Iranian Oil Company	867	29,084	2.01%
Pemex, Mexico	602	20,025	1.38%
ConocoPhillips, USA	359	16,866	1.16%
Petroleos de Venezuela	485	16,157	1.11%

A recent analysis traced the cumulative emissions of CO_2 and methane between 1751 and 2010 and found that more than 60 percent of the total fossil fuel associated emissions could be attributed to 90 private and state-owned entities. The top 10 listed above are led by the largest oil companies in the world.

Note: $MtCO_2e$ stands for million metric tons carbon dioxide equivalent.

unless the oil industry minimizes unnecessary emissions and avoids the dirtiest resources.

DISCLOSURE AND TRANSPARENCY ARE THE FIRST STEP

While some information on oil industry emissions is reported in a variety of contexts, the oil industry is not held to the same level of accountability for its carbon emissions as automakers, electric utilities, or the biofuels industry. Comprehensive disclosure and reporting are needed to clarify which emissions associated with oil extraction, refining, and use are avoidable and which fossil resources are most polluting. Researchers have developed estimates of emissions from a number of different sources including data collected by regulators in various jurisdictions, voluntary disclosure of carbon emissions by some of the major oil companies, and data and secondary observations such as satellite data on flaring. Given the importance of these emissions, more direct reporting requirements and tracking are necessary to inform investors, regulators, and policy makers.

[***Comprehensive disclosure is needed to clarify which emissions associated with oil extraction, refining, and use are avoidable and which fossil resources are most polluting.***]

OIL COMPANIES MUST BE HELD ACCOUNTABLE TO REDUCE EMISSIONS FROM THEIR OPERATIONS

Oil is not a singular product, and every oil well and oil refinery is the subject of many decisions that have significant consequences for global warming pollution. Choices about which sources of unconventional oil are developed and how they are extracted and processed can substantially affect the global warming emissions generated by the 100 billion barrels the United States will consume by 2035. As the largest producers of fossil fuels in the industrial age, oil companies have a major responsibility for climate change, and should reduce emissions and avoid the dirtiest sources of oil in order to reduce the global harm caused by their products.

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A NOTE ON THE FEBRUARY 2017 CORRECTED VERSION

The original release of this report made an incorrect inference based on preliminary research. The error became apparent upon subsequent publication of the final analysis, so we have removed the specific claim and the reference to the preliminary analysis. The revised report reflects the literature available at the beginning of 2016, when this report was originally published. Subsequent analysis will be reflected in future publications.

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Fueling a Clean Transportation Future

Smart Fuel Choices for a Warming World

Cutting oil use dramatically is essential to avoiding the worst impacts of climate change, but to achieve a clean transportation future, we must ensure that all of our fuels are as clean as possible.

Oil is the largest source of U.S. global warming pollution and for more than half a century has been the dominant source of transportation fuel. Hidden behind the pump is a global supply chain for oil that is changing in ways that have important consequences for the climate. As the easily accessed oils that characterized the oil booms of the last century are dwindling, the oil industry is looking increasingly to ever-riskier sources of oil and more polluting practices in production.

The surprising truth is that global warming emissions associated with extracting and refining a barrel of oil vary from less than 50 kilograms to 250 kilograms, depending on where the oil comes from and how it was extracted and refined. Some oil extraction techniques use large amounts of natural gas to generate energy to pump oil and water, and to generate steam. Natural gas that is extracted along with oil is sometimes simply burned in place (flared) because oil operators start extracting oil without providing the infrastructure necessary to bring the gas to market. Emissions are also much higher for unconventional fossil resources like Canadian tar sands, whose emissions can be higher by as much as 100 kilograms per barrel than more conventional crude oil.

Because we use so much oil, even relatively small changes in emissions per barrel have major climate impacts. Choices about which sources of unconventional oil are developed and how they are extracted and processed can substantially affect the global warming emissions generated by the 100 billion barrels the United States will consume by 2035. As the largest producers of fossil fuels in the industrial age, oil companies have a major responsibility for climate change, and should be held accountable to reduce emissions and avoid the dirtiest sources of oil in order to reduce the global harm caused by their products.

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