

Energy 101: Introduction to Oil

From the CSIS Energy & National Security Program

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Crude oil, a fossil fuel, is the most widely used energy source in the world, accounting for 31 percent of total primary energy demand in 2012. Crude oil itself has limited applications; it must first be refined before it can be used. Refining crude oil results in several products, including gasoline, diesel, bunker fuels, jet fuel, and asphalt, among other products. Because of its importance as an input in many industrial processes and its role as the world's primary transportation fuel, oil is extremely important to the global economy. The long-term relationship of oil prices to the economy—that is, the causal effect of a change in oil price on a change in GDP—is the subject of significant academic debate, but there is no doubt that oil influences and is influenced by economic growth, consumer spending, income, and inflation.

Crude oil is a generic term for a host of hydrocarbons of varying characteristics; there are hundreds of grades of crude oil sold around the world. Once produced, oil is classified and priced based on its quality. This classification is determined by density (which ranges from “heavy” to “light”) and sulfur content (which ranges from “sweet” to “sour”). Lighter, sweeter crudes are sold at a higher price relative to heavier, more sulfuric crudes because less processing is generally required to convert them into refined products. The quality of a crude oil varies significantly depending on the geologic conditions under which it is produced; crude from Nigeria may be [very different](#) from that produced in Canada. Since crude quality varies so greatly, benchmark crudes are used both as a quality reference for buyers and to set the value of other, non-benchmarked crudes. Examples of regional benchmarks are Brent, West Texas Intermediate, Urals, and Bonny Light.

Quick Facts about Oil

- Crude oil is measured in barrels. One barrel is 42 gallons.
- Crude oil quality is measured by density and sulfur content. Density, or gravity, is measured on the American Petroleum Institute (API) scale in degrees. The higher the degree, the lighter the oil. Sulfur is measured in percentages; the higher the percentage, the higher the sulfur content.
- In 2014, the world consumed about 92.4 million barrels of crude oil per day.
- The largest global consumers and importers of crude oil are the United States, China, and Japan.
- The largest producers of crude oil are the United States (11.75 MMbbl /d), Russia (10.93 MMbbl /d), and Saudi Arabia (9.53 MMbbl /d).
- The largest crude oil exporters are Saudi Arabia, Russia, and the UAE.
- In 2014, oil consumption was relatively flat in the OECD (demand growth of -1 percent in 2014). Most demand growth is in non-OECD countries (2.4 percent in 2014), primarily non-OECD Asia (2.5 percent)
- The largest crude oil reserves are in Venezuela, Saudi Arabia, Iran, Iraq, Kuwait, the UAE, and Russia.

The Oil Value Chain

The oil sector can be divided into upstream, midstream, and downstream segments. Upstream encompasses exploration and production; the midstream includes transporting oil from production

sites to refineries via pipelines, trains, tankers, and trucks; and the downstream is comprised of refining and marketing refined petroleum products. All segments of the value chain are capital intensive. Some companies specialize in just one component of the value chain, while others, called integrated companies, participate in all of them.

In the upstream sector, oil can be either unconventional or conventional depending on the method of extraction, although there is no consensus on what methods or processes are unconventional. Canadian oil sands, tight oil, and ultradeepwater offshore oil are examples of unconventional oil sources. Unconventional sources may become conventional over time, as the unconventional technologies become better understood and more widely adopted.

Oil production is a capital- and technology-intensive process, and can range in complexity, from relatively simple onshore projects to multibillion-dollar, multi-decade complex ultradeepwater projects. In addition, many exploration and production ventures are long-term investments; it can take a decade or more from initial prospects to bring a well to production. As a result, the industry plans and operates with long lead times and exposure to price risk.

In the downstream sector, refineries, industrial users, and others consume about 90 million barrels of crude oil every day. Refineries convert crude oil into a variety of useful products that are consumed by residential and commercial users, industrial users, and electric utilities. Petroleum products, like crude oil, are traded globally.

The United States has the largest refining capacity in the world (about 18 million barrels per day, or MMbbl/d), followed by China (about 13 MMbbl/d) and Russia (about 6 MMbbl/d). Refineries employ a variety of chemical and physical processes to convert crude oil into petroleum products. Refinery processing capability ranges from very simple, with minimal equipment and processing capabilities (called teapot

refineries) to extremely complex, requiring expensive and technical equipment. The extent of processing required depends on the quality of the crude oil as input (sweet vs. sour, light vs. heavy) and the product slate desired as output. Because light, sweet crudes require less processing, they are sold at higher prices than heavier, sourer crudes. In 2014, global refining capacity grew by 1.4 MMbbl/d, with significant expansion in China and Saudi Arabia. In Europe and Japan, conversely, refining capacity has declined.

Petroleum is also a key input in a variety of products, including [plastics](#) and fertilizer. Crayons, dishwashing liquids, eyeglasses, tires, garbage bags, and ammonia, for example, all contain petroleum. In the United States in 2010 (the most recent year for which data is available), about 2.7 percent of petroleum consumption was used in the plastic materials and resins industry.

Most petroleum is consumed in its product form, and primarily in the transportation sector. The transportation sector accounts for about half of the oil consumed globally and 72 percent in the United States in 2013. Beyond the transportation sector, oil-derived fuels are sometimes used for electric power generation (oil accounted for 6 percent of electricity generation globally in 2013, but only about 1 percent of [U.S. electricity generation](#) in 2013), as well as in the petrochemicals, buildings, and agriculture sectors.

Crude Oil Supply and Production

In 2012, approximately 100 countries produced crude oil, with the top five producing countries (Saudi Arabia, Russia, the United States, China, and Canada) contributing nearly half of global production. While governments generally own the right to the oil itself (with exceptions; for example, in the United States, subsurface mineral rights can be privately held), oil production is undertaken by oil production companies. Such companies can be either privately controlled—international oil companies (IOCs)—or government controlled—national oil companies (NOCs). ExxonMobil, BP, and Total are examples of IOCs,

while Saudi Aramco, Petrobras, and Statoil are examples of NOCs. NOCs control the majority of the world's [oil reserves \(78 percent in 2012\) and production \(58 percent\)](#). They vary in the level of government control over their operations and management and the extent to which they are driven by commercial versus political objectives.

Crude Oil Markets

Oil is a globally traded commodity—in fact, it is the world's most actively traded commodity. Between [61 percent](#) and [63 percent](#) of oil is traded, mostly by sea as well as by pipeline and its price is thus determined by global market factors, most prominently supply and demand. Both supply and demand, however, can be influenced by key factors external to the market such as government policies, weather, and geopolitical dynamics. For example, the majority of the world's oil reserves are located in regions that have experienced political instability or conflict that affected the production risk and thus supply of oil, tightening the market. On the demand side, the global economic recession in 2008 significantly lowered the demand for oil, thus lowering the price.

In addition to being bought and sold on the spot market (purchased for immediate delivery at the current price) oil is also traded on the futures market. Crude oil futures are contracts that establish that the buyer will take a delivery of predetermined size at a predetermined price from the seller in the future. As with other commodities, the oil futures market allows oil traders, marketers, buyers, and other market participants to hedge exposure to price risk and volatility.

It is a common misconception that one country or a group of countries like the Organization of Petroleum Exporting Countries (OPEC) control the global oil price. [No single country or company controls more than 12 percent of the global market](#); OPEC's share is about 40 percent of the market. While OPEC has significant market share, it has historically not been

able to effectively coordinate among its members to add or displace barrels from the market in response to price.

In recent years, oil has become an attractive asset for many investors. The impact this influx of traders with no interest in the physical barrels has had on the overall price level and price volatility in oil markets has been the subject of [much debate](#).

Oil and U.S. Security

In October 1973, the Organization of Arab Petroleum Exporting Countries imposed an oil embargo on many Western countries, contributing to (according to some analysts, triggering) a significant recession in the West. Since then, energy security in general, and crude oil security in particular, have moved higher on the national security agenda. Energy security is often discussed in terms of import dependence or independence. Within this framework, dependence on imported oil is often perceived as a point of energy vulnerability, and independence is a touted goal. As a result, energy security efforts have focused on reducing import dependence by cutting consumption and increasing domestic supplies.

In the wake of the 1973 embargo, the United States, in coordination with other Organization for Economic Coordination and Development (OECD) consumer economies, formed an organization known as the International Energy Agency (IEA) and passed legislation that attempted to curtail consumption through energy efficiency measures, stimulating domestic oil production, and creating internationally coordinated strategic stocks to ensure emergency supplies in the event of an oil supply disruption. In the United States, this took the form of the [Strategic Petroleum Reserve](#). Despite these policies, it is neither likely nor desirable that the United States will ever achieve true independence (defined as immunity from global market dynamics); the oil market is global, and while the United States is exposed to the volatility of

the global market, it also reaps many economic and security benefits from participation in such a market.

Further, energy security cannot be assured by security of physical supply alone. Diversity of supply sources, fungibility, price stability, affordability, reliability, and availability of infrastructure are also key components of energy security. Relying primarily on domestically produced and refined oil would impose a steep cost on consumers and foreign trade relationships.

Oil and Climate

Because of its role in the transportation sector, oil is a large source of greenhouse gas emissions both globally (22 percent) and in the United States ([28 percent](#)).

In recognition of the role that burning oil plays in contributing to climate change, environmentalists and others have become concerned about the global dependence on oil. At the same time, there are few substitutes for oil in the transportation sector. The [nonpetroleum share of fuels used for transportation](#) is 8.5 percent in the United States, most of which is biofuels. Biofuels, or fuel made from biomass (most commonly corn or sugar), are one potential alternative source of fuel in the transportation sector. The long-term commercial viability of biofuels in the transportation sector is not yet established. In addition, while biofuels are promoted as a renewable and environmentally friendly alternative to petroleum products, the overall environmental and social impact of biofuels has been questioned; there have been concerns about lifecycle emissions, the impact of increased biofuels (especially those derived from corn) use on global food prices, and deforestation and other land use issues driven by the expansion of land cultivation for biofuels.

Compressed or liquefied [natural gas vehicles](#) (CNG and LNG, respectively) are a growing share of fleet vehicles in the United States and [natural gas vehicle fuel consumption is growing](#); globally, natural gas vehicles are prominent in the transportation sectors of

some countries (such as Iran, Pakistan, and China). Nonetheless, they are still a very small share of the vehicle fleet overall for a variety of [reasons](#). Plug-in electric vehicles (PEVs) and hybrid electric vehicles [have seen less adoption to date](#). In the United States, PEVs accounted for 0.7 percent of new vehicle sales in 2014; [globally](#), electric vehicles represent 0.02 percent of all passenger cars. The [barriers](#) to widespread [adoption](#) of nonpetroleum vehicles [vary by vehicle type](#) but generally include cost, driving range, fueling infrastructure, and consumer preferences. Moreover, while alternatives are being developed for road transportation, fewer alternatives exist for aviation and marine oil-based fuels. Tighter air emissions standards are likely to be a more important driving force than market incentives in the short to medium term for fueling switching in both the aviation and marine sectors.

Future oil use in the transportation sector—and therefore one of the main sources of greenhouse gas emissions attributable to oil—will depend on the pace and scope of alternative vehicle adoption, [fuel economy improvements in gasoline and diesel vehicles](#) (often but not exclusively driven by fuel economy standards, such as Corporate Average Fuel Economy, or [CAFE](#), in the United States, and [other regulatory programs](#)), as well as broader factors such as population density, availability of alternatives such as mass transit, and consumer preferences.

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