Petroleum Engineering & Downstream Petroleum Marketing

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Course Content

Internet Links:

- **I)** **The United States Department of Energy, Energy Information Administration, Petroleum Data here: http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html**
- **II)** **The American Petroleum Institute (API): http://www.api.org/**
- **III)** **The Petroleum Marketers Association of American: https://www.energymarketersofamerica.org/**
- **IV)** **American Fuel and Petrochemical Manufacturers : https://www.afpm.org/**
- **V)** **Society of Petroleum Engineers: http://www.spe.org**
- **VI)** **National Association of Convenience Stores: https://www.convenience.org/**
- **VII)** **British Petroleum Reports & Publications: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html**
- **VIII)** **Oil & Gas Journal https://www.ogj.com/**

Origins of Petroleum

PETROLEUM or Rock Oil (Petros (Greek) stone or rock &-Oleum (Latin) oil). Rock oil, mineral oil, or natural oil, a dark brown or greenish inflammable liquid, which, at certain points, exists in the upper strata of the earth, from whence it is pumped, or forced by pressure of the gas attending it. It consists of a complex mixture of various hydrocarbons, largely of the methane series, but may vary much in appearance, composition, and properties. It is refined by distillation, and the products include kerosene, benzene, gasoline, paraffin, etc.

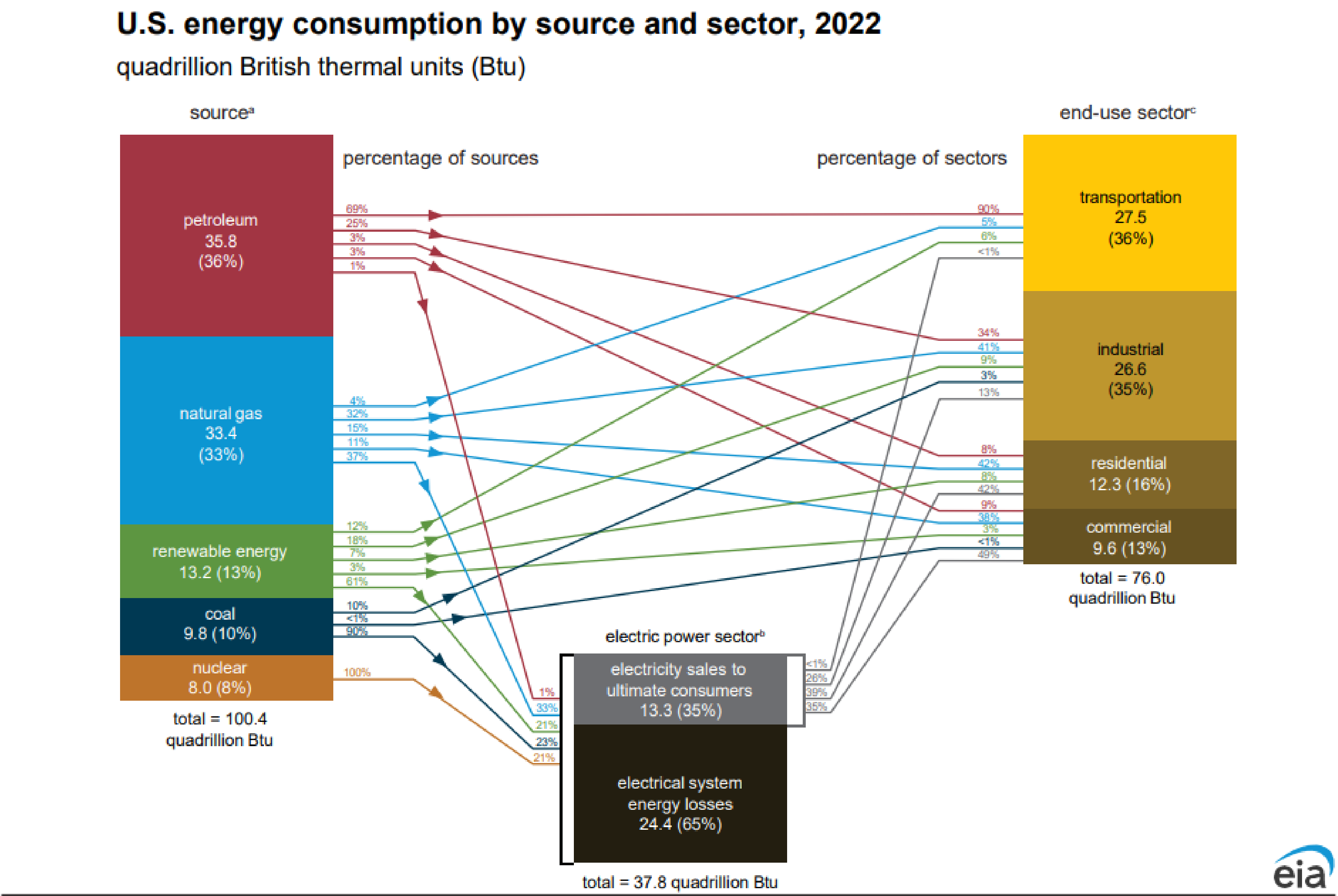
Almost all commercial oil is produced from rocks that were formed underwater or sedimentary rocks. Humans have used petroleum products for nearly 6,000 years. The Babylonians caulked their ships with asphalt, and the ancient Chinese lit their imperial palaces with natural gas. Egyptians also used asphalt, as a coating to help preserve mummies.

In 1859, Col. Edwin L. Drake drilled the first oil well (Titusville, Pennsylvania) that launched the modern petroleum industry. Col. Drake use a rotary drill and wooden pipe to a depth of 59.5 feet to reach sweet crude that needed little refining, which was practically Kerosene.

The United States gets 81% of its total energy from oil, coal, and natural gas, all of which are fossil fuels (2023). In 2022, liquid petroleum products contribute about 36% of the energy used in the United States. This is a larger share than any other energy source including natural gas with a 33% share; coal with about a 10% share, and the combination of nuclear, hydroelectric, geothermal, and other renewal sources comprising the remaining 21% share. In the United States, in all cases, U.S. petroleum consumption is projected to remain below the 2005 level, the highest recorded to date, through 2040. Although petroleum consumption will continue to increase worldwide, its share of total energy use has shrunk over the past several decades as a result of conservation efforts, fuel efficiency improvements, and growing use of alternative sources of energy.

Transportation is the greatest single use of petroleum, accounting for an estimated 69% of all U.S. petroleum consumed in 2022. The industrial sector is the second largest petroleum consuming sector and accounts for about 25% of all petroleum consumption in the U.S. Residential/Commercial and the electric utility sectors account for 9% of petroleum consumption.

Petroleum's share of total U.S. energy consumption peaked in the 1970s. In 1977, total petroleum consumption was about 48% (37 quads) of total U.S. energy consumption.



Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2023), Tables 1.3. 1.4c, and 2.1a-2.6.
Note: Sum of components may not equal total due to independent rounding. All source and end-use sector consumption data include other energy losses from energy use, transformation, and distribution not separately identified. See "Extended Chart Notes" on next page.

[a] Primary energy consumption. Each energy source is measured in different physical units and converted to common British thermal units (Btu). See EIA's *Monthly Energy Review* (MER), Appendix A. Generation from noncombustible renewable energy sources are converted to Btu using the "Fossil Fuel Equivalency Approach." See MER Appendix E.

[b] The electric power sector includes electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Energy consumed by these plants reflects the approximate heat rates for electricity in MER Appendix A. The total includes the heat content of are electricity net imports, not shown separately. Electrical system energy losses are calculated as primary energy consumed by the electric power sector minus the heat content of electricity sales to ultimate consumers. See Note 1, "Electrical System Energy Losses," at the end of MER Section 2.

[c] End-use sector consumption of primary energy and electricity sales to ultimate consumers, excluding electrical system energy losses. Industrial and commercial sectors consumption includes primary energy consumption by CHP and electricity-only plants contained within the sector.

What made Petroleum? Two Leading Theories:

Micropaleontology-the study of microscopic fossils: **Petroleum is the remains of organic material that was deposited, usually in marine environments, millions of years ago. One seep, in Michigan's Upper Peninsula, comes from billion-year-old rocks, although most commercial petroleum was generated from rocks that are between 65 million and 213 million years old. Most scientists agree that oil comes from creatures the size of a pinhead. These one-celled creatures, known as diatoms, (Plankton/Algae) are not really plants, but share one very important characteristic with them-they take light from the sun and convert it into energy.**

Petroleum was not generated from dinosaurs. Basically, as these marine diatoms died, their bodies formed organic-rich intervals between the sedimentary rock's layers, which were heated with burial in sedimentary basins.

The hydrocarbon chemicals within the diatoms were thermally cracked to yield liquid and gaseous petroleum hydrocarbons.

Abiogenic or Inorganic petroleum origin: **The hypothesis of inorganic petroleum origin holds that petroleum is formed by non-biological processes deep in the earth's crust. One prediction of most inorganic theories is that other planets of the solar system have large petroleum oceans, either from hydrocarbons present at the formation of the solar system, or from subsequent chemical reactions with pure carbon. The modern scientific consensus on abiogenic origin petroleum is that while there is evidence for it, most modern geologists do not support this for many petroleum deposits within the Earth. Theorists of abiogenic petroleum tend to see hydrocarbons as not just abundant but super-abundant, with no possibility of constrained supply. Petroleum generated by abiogenic processes could occur anywhere, so exploration need not be limited to sedimentary basins, or to depths of only a few miles.**

The hypothesis is founded primarily upon;

Large petroleum oceans exist on planets and moons, where no animal or plant life was known to exist. Large methane gas clouds are in the solar system. Hydrocarbons existing on meteors and comets.

The presence of oil within non-sedimentary rocks upon the Earth. Researchers have produced petroleum hydrocarbons using only wetted marble and solid iron oxide, at high pressures and temperatures.

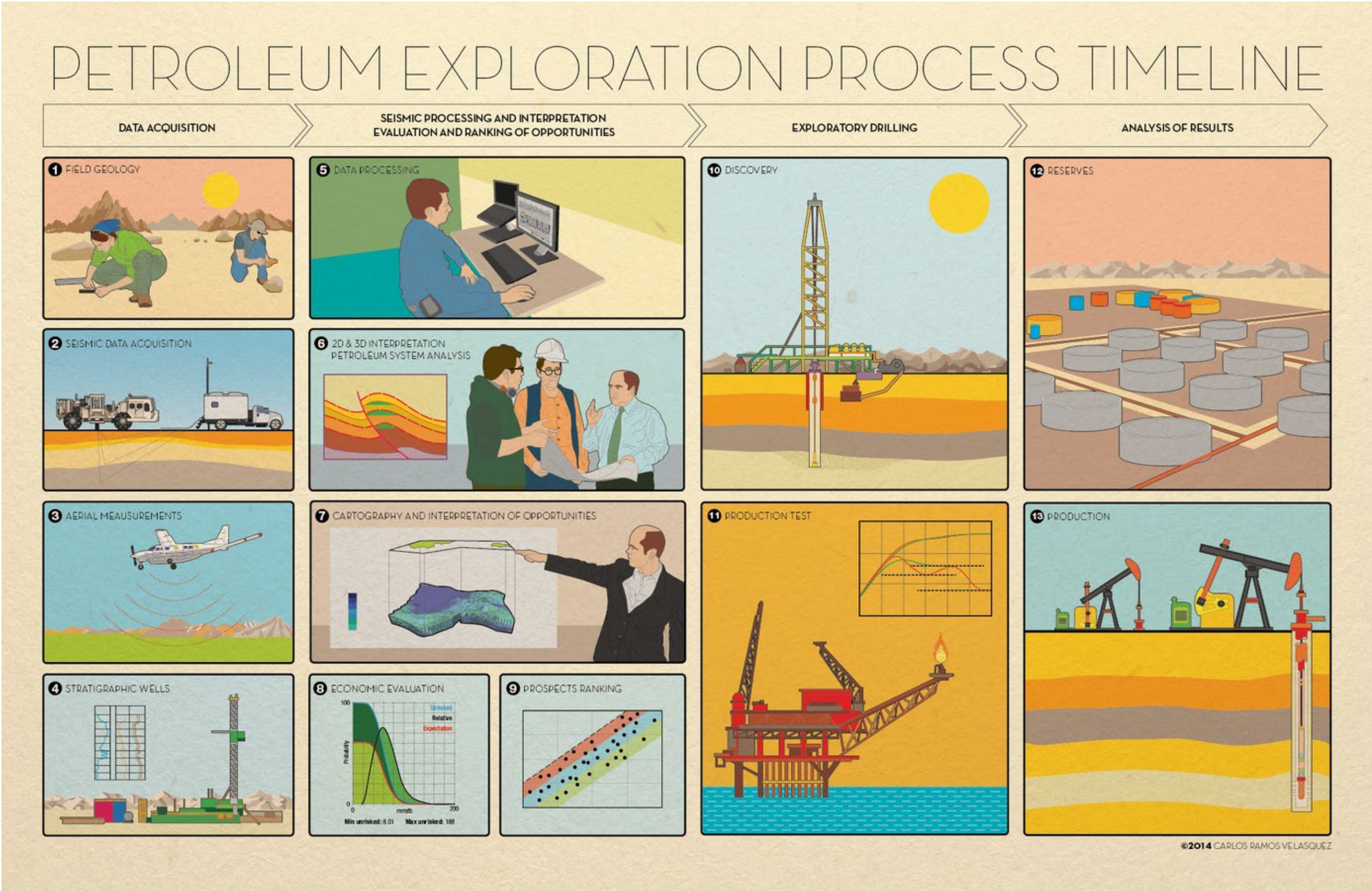
Hydrocarbon-rich areas tend to be hydrocarbon-rich at various different levels. Deep hydrocarbon seeps have been discovered. Oil fields are being refilled from deep sources; oil and natural gas are being produced from granite basement rock. It does not take millions of years to produce Hydro-Carbons, i.e., human skeletons found embedded in coal veins.

Another theory, deep biogenic petroleum theory (Deep biotic oil is considered to be formed as a byproduct of the life cycle of deep microbes) proposes, mostly after the work of Thomas Gold, that the ''deep hot biosphere'' may be the source of some petroleum alteration and for the observation of biomarkers in produced petroleum.

Where is Most Petroleum Found?

In order for a substantial gas or oil deposit, 3 geologic conditions must be met.
1st, somewhere in the subsurface there must be a source rock that will generate the Hydrocarbon.
Second, in that same general area, there must be a reservoir rock to hold the Hydrocarbon.
Third, there must be a trap in the underground reservoir rock to hold the Hydrocarbon.
Most petroleum is found in sedimentary-rock basins. In these basins the sedimentary rocks are 10,000 to 50,000 feet thick. There are about 700 sedimentary-rock basins worldwide. About half of these have been at least partially explored and drilled.

Petroleum Exploration



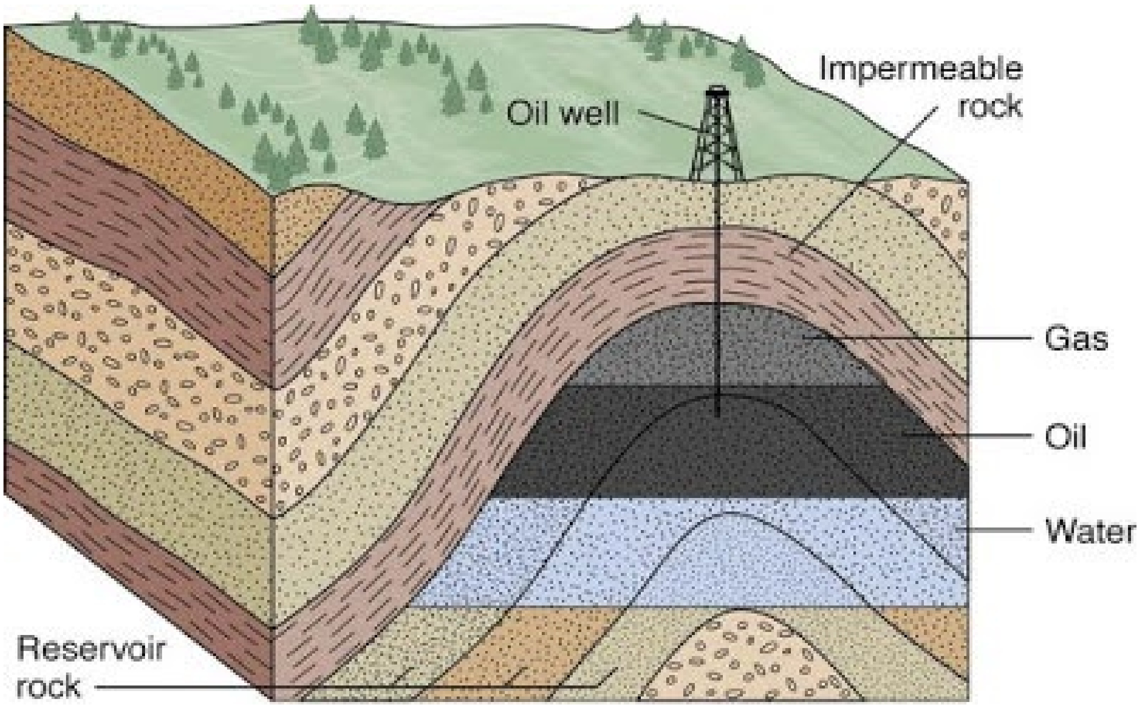
The goal is to find a convergence of the geologic elements necessary to form an oil or gas field. These elements include a source rock to generate hydrocarbons, a porous reservoir rock to hold them and a structural trap to prevent fluids and gas from leaking away. Traps tend to exist in predictable places - for example, along faults and folds caused by movement of the Earth's crust or near subsurface salt domes.

Finding these subterranean features requires a careful blend of science and art. For example, structural geology involves gathering and interpreting information from above ground to deduce what lies underground. Geologists obtain this information by examining exposed rocks or, when difficult terrain limits access, by examining images from satellites and radar. Subtle changes within the Earth's magnetic and gravitational fields also may signal the presence of petroleum traps. To measure these changes, geophysicists use sensitive instruments called gravity meters or trail a magnetometer from a plane in an aerial survey.

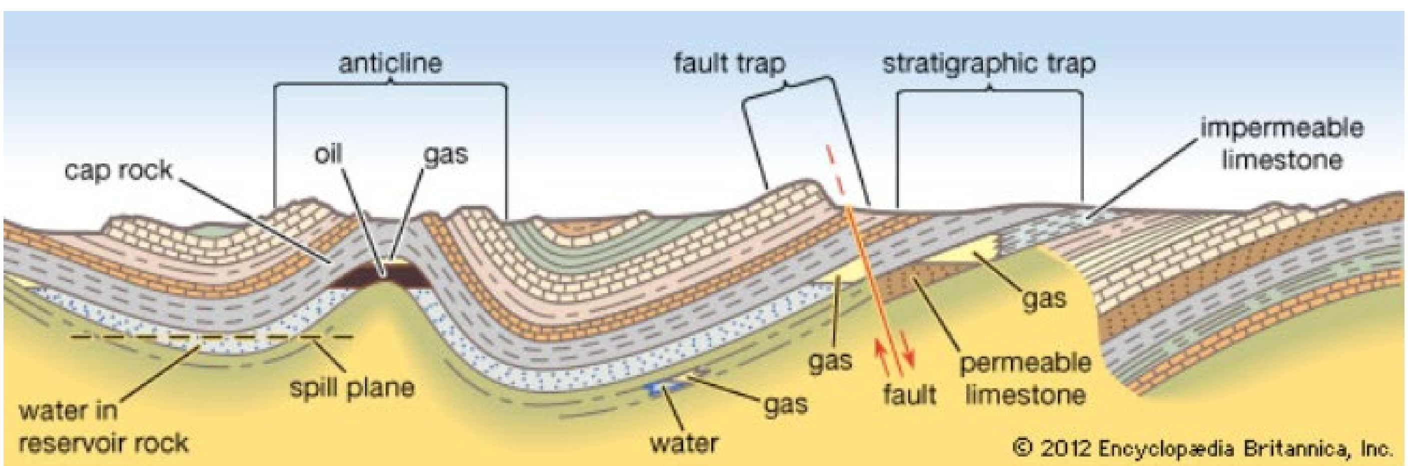
Seismic surveying involves sending sound waves underground and measuring how long it takes subsurface rocks to reflect them back to the surface. These waves are made by pounding the earth with a truck-mounted vibrator or by exploding small charges on land or compressed air guns at sea. As the waves are reflected back, they're collected by listening devices called geophones and processed by computers. Earth scientists use the data to create three-dimensional models of underground rocks.

Although sight and sound are the senses most frequently used in prospecting, smell also can come into play. A sniffer is a sort of high-tech "nose" that can detect traces of gaseous hydrocarbons escaping from subsurface accumulations. Geologic and geophysical clues are enticing, but drilling- both on land and offshore - is the only way to confirm an oil or gas field's existence. Once a well is drilled, downhole logging instruments yield data on the types of rock and fluid present.

Petroleum Drilling and Petroleum Geology

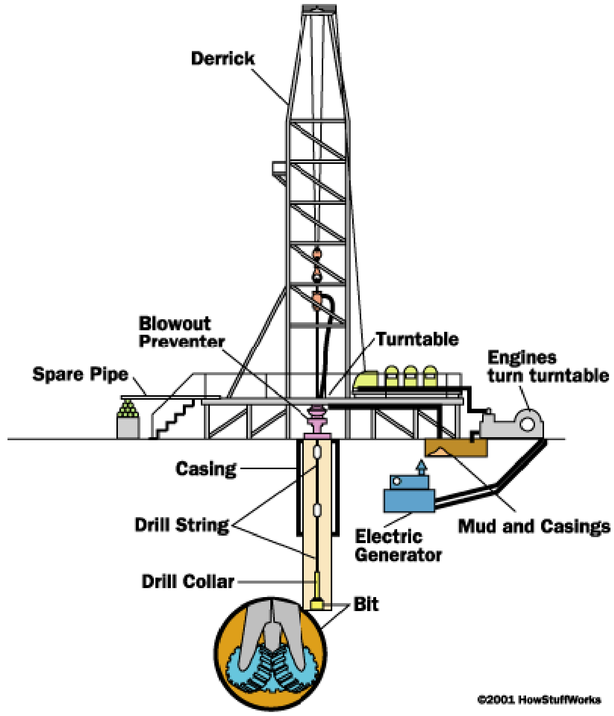


A reservoir rock is a place where hydrocarbon migrates and is held underground. Reservoir rocks are sandstone, limestone, chalk, dolomite, etc. Reservoir size and shape depends on depositional environment.
Major effects on reservoir properties are as follows;
Porosity = % of pore space in a reservoir rock; Permeability = ability of rock to allow reservoir fluid to flow through
Net to gross ration – ratio between effective reservoirs to entire reservoir interval.
Seal is an impermeable rock, which prevents hydrocarbon from passing through. Therefore, further migration of oil and gas is stopped. Typically, they are fine grain sediments such as shale and evaporite (salt). Additionally, deformed shale in a fault zone can be a seal.
Traps are impermeable structures where hydrocarbon accumulates underneath. Two types of traps are as follows; Structural Traps such as anticline, fault, and salt dome trap. Stratigraphic Traps occur where the reservoir itself is cut off up dip and no other structural control is needed. Examples of stratigraphy traps are pinch out traps, reef traps and lens traps.



Principal types of petroleum traps.

DRILLING METHODS-TERMS



In the petroleum industry, the average U.S. wildcat well (an exploratory well drilled a mile or more from existing production) has a one in ten chance of striking hydrocarbons. A rank wildcat well, drilled in an unproven, frontier area, stands a one in forty chance. Thus, although today's prospectors have better tools than their ancient counterparts, good luck still is a factor in the search for petroleum.

Appraisal wells are those drilled to assess the characteristics of a proven petroleum reserve such as flow rate.
Development or production wells are drilled to produce oil or gas in fields of proven economic and recoverable oil or gas reserves.
Relief wells are drilled to stop the flow from a reservoir when a production well has experienced a blowout.
An injection well is drilled to enable petroleum engineers to inject steam, carbon dioxide and other substances into an oil producing unit to maintain reservoir pressure or to lower the viscosity of the oil, allowing it to flow into a nearby well.

The process of drilling an oil and natural gas production well involves several important steps:
Boring - a drill bit and pipe are used to create a hole vertically into the ground. Sometimes, drilling operations cannot be completed directly above an oil or gas reservoir, for example, when reserves are situated under residential areas. Fortunately, a process called directional drilling can be done to bore a well at an angle. This process is done by boring a vertical well and then angling it towards the reservoir.

Circulation - drilling mud is circulated into the hole and back to the surface for various functions including the removal of rock cuttings from the hole and the maintenance of working temperatures and pressures.

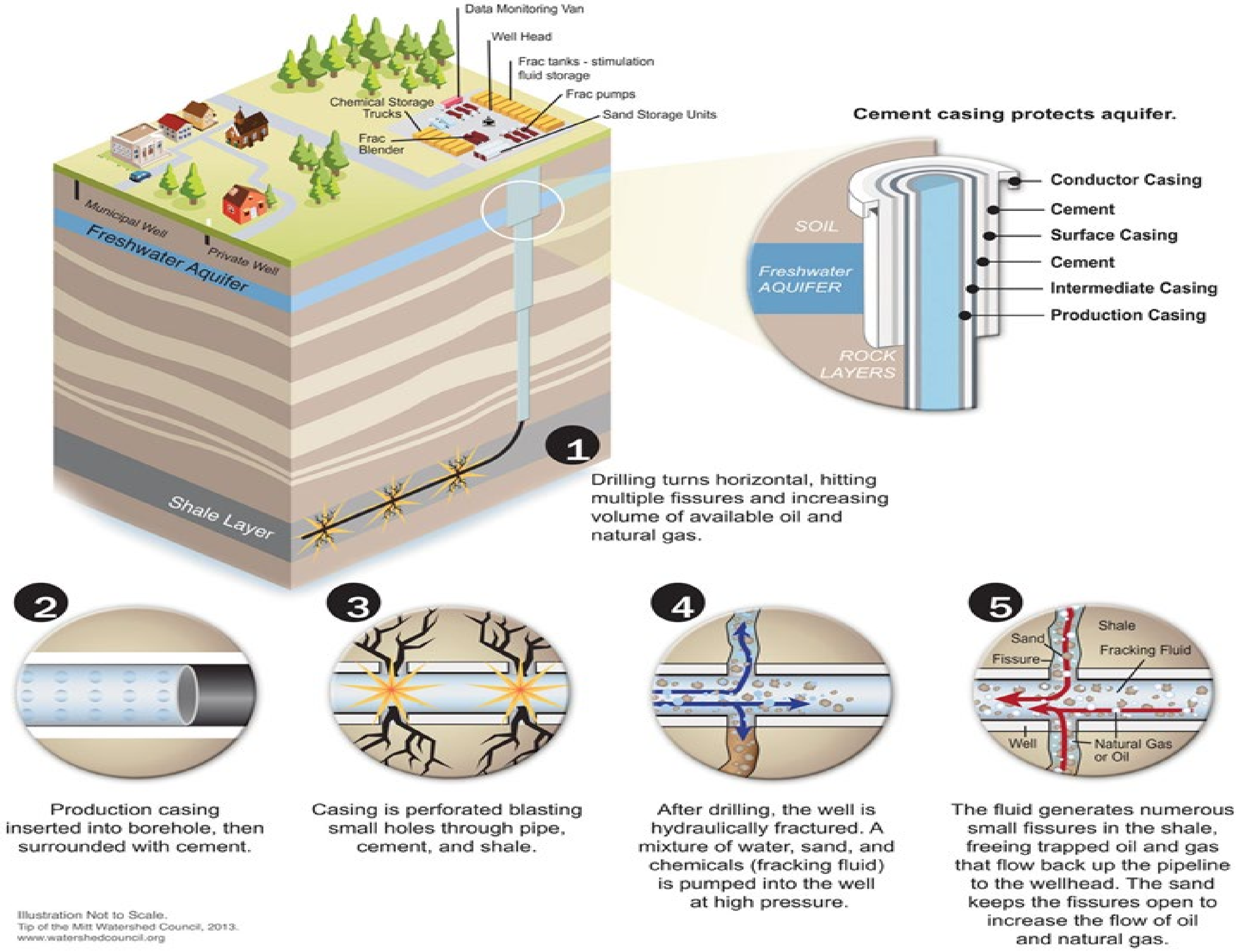
Casing - once the hole is at the desired depth, the well requires a cement casing to prevent collapse.

Completion - after a well has been cased, it needs to be ready for production. Small holes called perforations are made in the portion of the casing which passed through the production zone, to provide a path for the oil or gas to flow.

Production - this is the phase of the well's life where it produces oil and/or gas.

Abandonment - when a well has reached the end of its useful life (this is usually determined by economics), it is plugged and abandoned to protect the surrounding environment.

HYDRAULIC FRACTURING



Hydraulic fracturing is used to increase the rate at which fluids, such as petroleum, water, or natural gas can be recovered from subterranean natural reservoirs. Thus, creating conductive fractures in the rock is instrumental in extraction from naturally impermeable shale reservoirs.

The most common and controversial technique is hydraulic fracturing, or fracking, in which chemical-laced water is injected to break up subterranean rock formations to extract oil and natural gas. A host of exotic so-called Enhanced Oil Recovery (EOR) technologies—from solar-powered steam injection to microorganisms—that could be used to extend the life of old oil fields and gain access to so-called unconventional petroleum reserves like oil sands.

New oil drilling technologies will increase the world's petroleum supplies in the coming years. Total U.S. crude oil production roughly tripled in the decade spanning from 2010 to 2020. Over the same time period, the amount of total U.S. oil consumption provided by imports fell substantially. However, the increase in primary energy between 2019 and 2021 was entirely driven by renewable energy sources.

Petroleum Production and Refining of Crude Oil and Petrol-Chemicals.

The chemical composition of all petroleum is principally hydrocarbons, typically composed of 15% Hydrogen and 84% Carbon.

Simple Petroleum Chemistry:

- **Methane, C-H4; Ethane, C2-H6; Propane, C3-H8.**
- **Propane =**
```
 H-H-H
H-C-C-C-H
 H-H-H
```
- **The benzene molecule is a closed ring of six carbon atoms, formula C6-H6**

Most crude oils contain only 10 to 40 percent of their hydrocarbon constituents in the gasoline range, so refineries use cracking processes, which convert high molecular weight hydrocarbons into smaller and more volatile compounds. Polymerization converts gases into liquid gasoline hydrocarbons. Alkylation processes transform molecules into larger ones with a high-octane number.

Combining cracking, polymerization, and alkylation can result in a gasoline yield representing 70 percent of the starting crude oil. Modern refinery operations can be shifted to produce almost any fuel type with specified performance criteria from a single crude.

As of January 1, 2023, there were 129 operable petroleum refineries in the United States compared to 149 operable refineries on January 1, 2007 (excluding Puerto Rico and the Virgin islands). In 2023, total US crude distillation capacity of 18.1 million barrels per calendar day.

The 2023 U.S. petroleum refining and distribution industry is a large and complex system:
129 refineries (owned by 55 companies) with aggregate crude oil processing capacity of 17.4 million barrels per day.

- **200,000 miles of crude oil and refined petroleum product pipelines**
- **93 Jones Act vessels (U.S. flag ships which move products between U.S. ports)**
- **103,312 rail tank cars (2021)**
- **1,450 petroleum product terminals (2021)**
- **100,000 tank trucks**
- **150,000 retail motor fuel outlets (2023)**

Gasoline is the largest volume petroleum product, accounting for nearly half of U.S. petroleum product production. Highway (or on road) diesel represents 30 percent of the average production at a domestic refinery.

The refining industry responds to changes in demand and economics by adjusting processes and blending procedures to vary the yield of finished products. There are many different petroleum products. Fuels, nonfuel products, and petrochemical feedstocks are petroleum product categories.

1. **Fuels**
   - **Gasoline**
     - **Motor gasoline**

Types: reformulated gasoline (RFG), gasohol, conventional gasoline
Grades: regular, middle, and premium octane

- **Aviation gasoline**
   - **Distillate Fuel Oil**
     - **Diesel: low and ultra-low sulfur highway and high sulfur off-highway (or nonroad)**

Off-highway examples: locomotives, ships, farm tractors, bulldozers, forklifts, underground mining equipment, backhoes, cranes

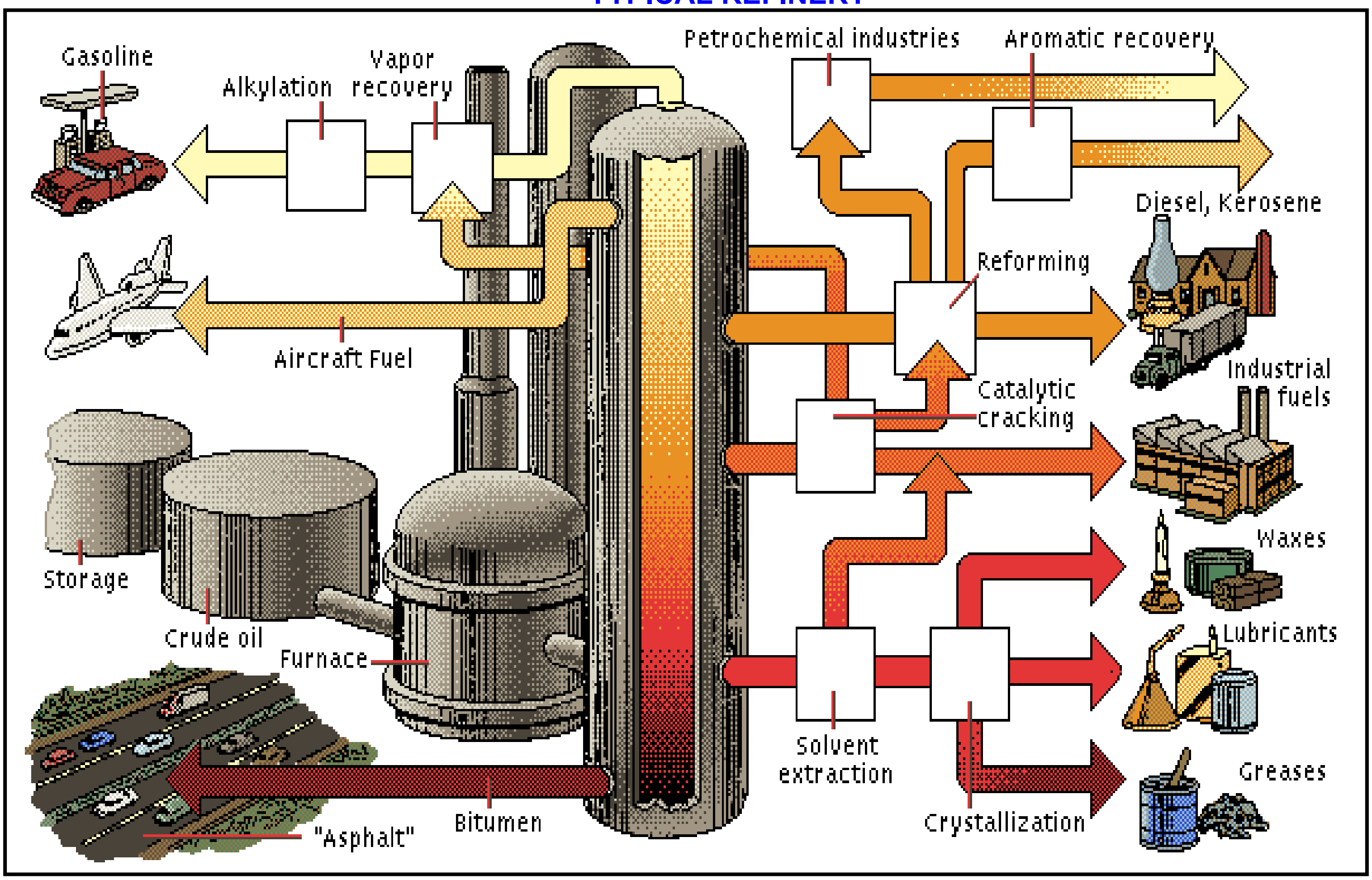
Home heating oil: space heating, electricity generation, crop drying, fuel for irrigation pumps on farms.

- **Jet Fuel**
  - **Kerosene-type: commercial and Military Grades JP-5 and JP-8**
  - **Naphtha-type: Military Grade JP-4**
- **Kerosene**
  - **Uses: space heating, cooking stoves, water heaters, lamp oil**
- **Residual Fuel Oil**

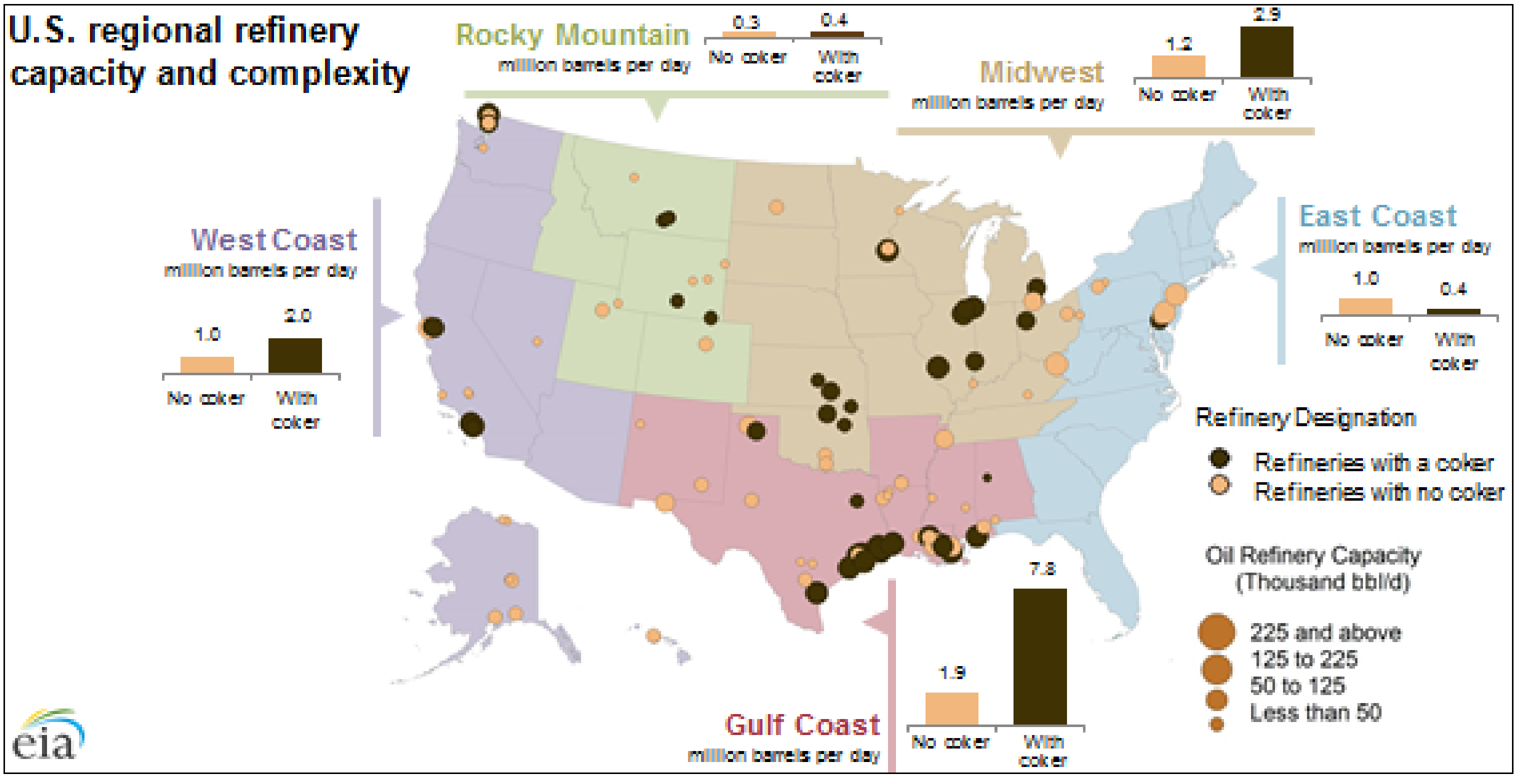
- **Use: fire boilers to provide steam for heating or electricity generation**
- **Liquefied Refinery Gases (LRG)**
  - **Ethane/ethylene, propane/propylene, normal butane/butylene, isobutane/isobutylene**
  - **Uses: space heating, cooking**
- **Still Gas or Refinery Gas**
  - **Use: a refinery fuel**

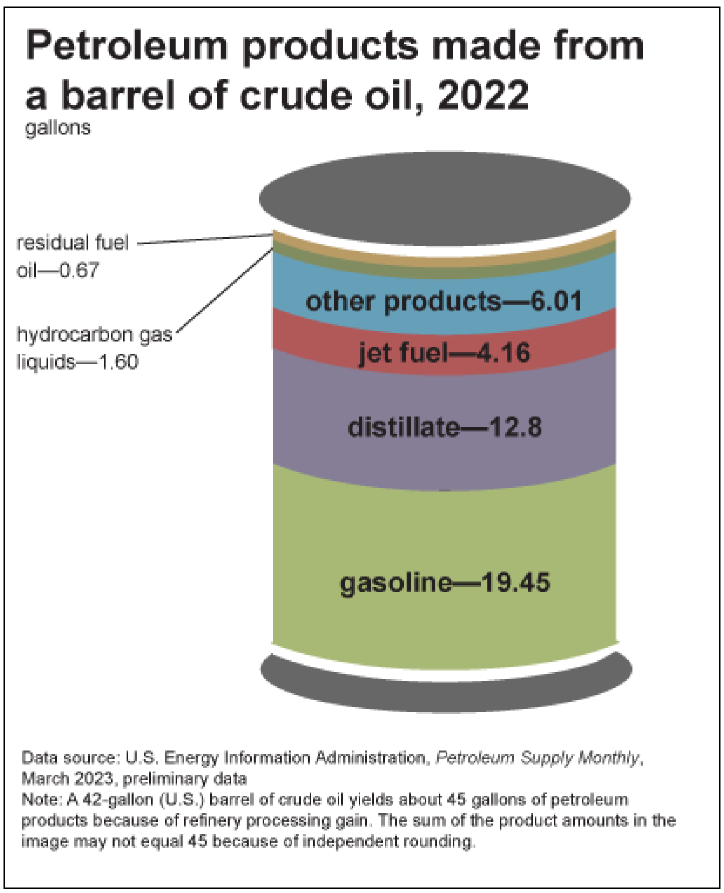
2. **Nonfuel Products**
   - **Asphalt**
   - **Lubricants**
     - **Uses: engine oil, gear oil, automatic transmission fluid**
   - **Petroleum Coke**
     - **Uses: carbon electrodes, electric switches**
   - **Road Oil**
     - **Uses: dust suppressor, surface treatment on roads, roofing, waterproofing**
   - **Solvents**
   - **Wax**
     - **Uses: chewing gum, candles, crayons, sealing wax, canning wax, polishes**
   - **Miscellaneous**
     - **Uses: cutting oil, petroleum jelly, fertilizers**
3. **Petrochemical Feedstocks**
   - **Examples: benzene, toluene, xylene, ethane, ethylene, propane, propylene, naphtha, gas oil**
   - **Uses: solvents, detergents, synthetic fibers, synthetic rubber, plastics, medicine, cosmetics**

TYPICAL REFINERY



UNITED STATES REFINERS AS OF 1-2015



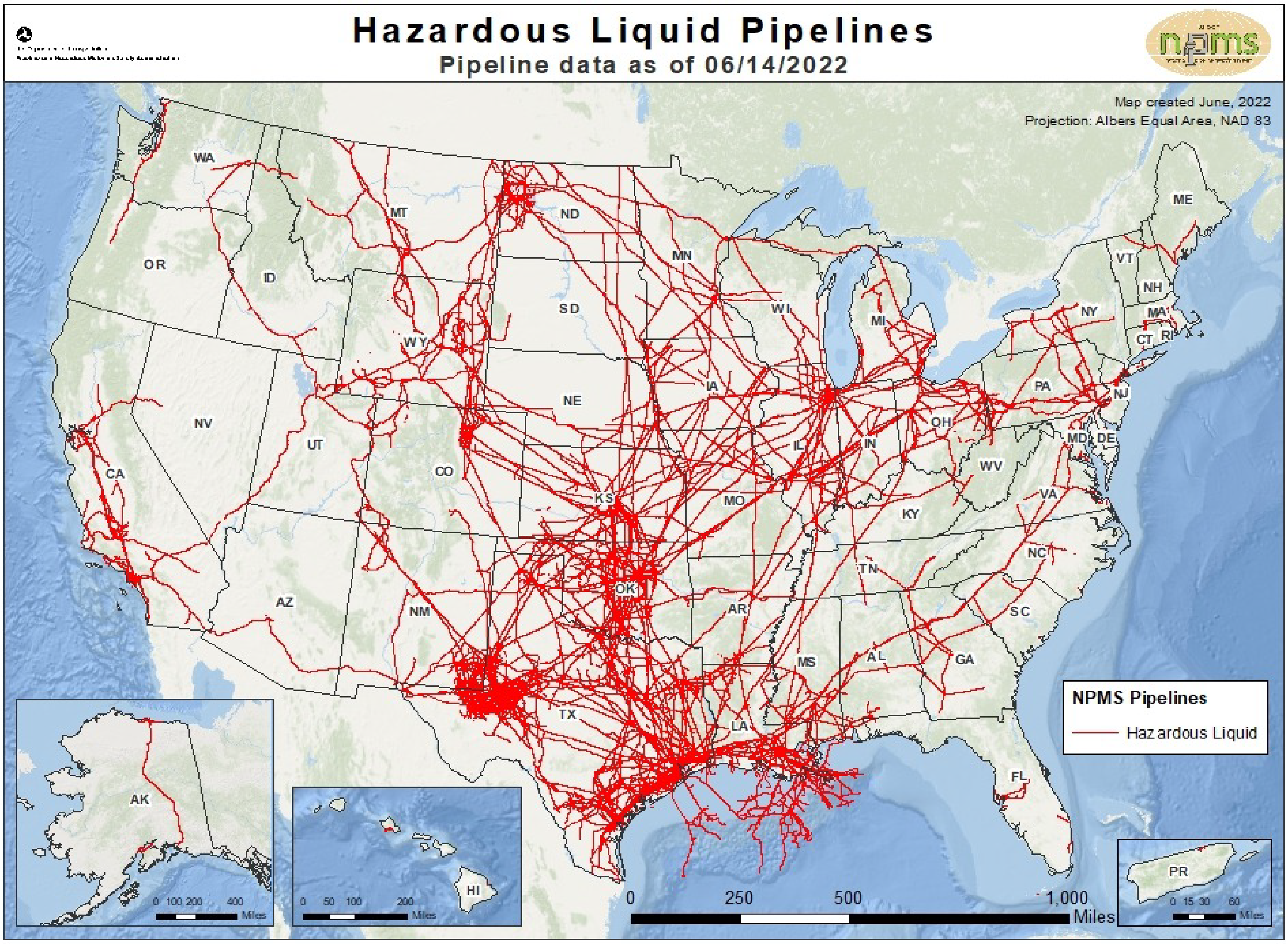


Petrochemicals are chemicals made from crude oil and natural gas.

These include purified fossil fuels, agricultural chemicals such as pesticides, herbicides and fertilizers, and other items such as plastics, asphalt, glues, resins, medications, and synthetic fibers (nylon).

The list of petrochemical-derived breakthroughs is endless: pens, sunglasses, trash bags, nylon rope, crayons, toothbrushes, deodorant, nail polish, tennis shoes, lipstick, CDs-DVDs, paint, carpet, soap, perfumes, balloons, photographic film, margarine, cassettes, telephones, polyester, antibiotics, hearing aids, bandages, artificial limbs, heart valves, contact lenses and condoms to name a very few.

UNITED STATES LIQUID PETROLEUM PIPELINES



<u>The Strategic Petroleum Reserve:</u>
In 1975, following the oil shortages and resulting economic problems created by the 1973-1974 oil embargo, Congress enacted the Energy Policy and Conservation Act which called for the Government to develop a Strategic Petroleum Reserve (SPR). The purpose of the SPR is to store crude oil which can be drawn upon to prevent shortages in domestic markets during a major interruption of crude oil supplies. SPR use is designated for emergency situations, such as when a disruption of imports, sabotage, or a natural disaster creates a severe national shortage that will threaten national safety and the national economy. Only the President has the authority to order that the SPR be used. In the event of a SPR distribution, the oil is sold to bidders in an open market.

In 1977, the Federal Government began purchasing crude oil and storing it in salt caverns. SPR facilities include six storage sites in Louisiana and Texas and a marine terminal at St. James, Louisiana (Current storage capacity - 727 million barrels maximum). Government-owned pipelines connect the storage sites to commercial crude oil pipelines and marine terminals through which the oil would be distributed. Most of the SPR crude oil has been purchased from foreign sources. As of September 2016, the SPR had 695.1 million barrels of crude oil in storage. The Maximum drawdown capability is 4.4 million barrels per day and the time for oil to enter U.S. market is 13 days from Presidential decision. For more information on SPR see web site:
https://www.energy.gov/ceser/strategic-petroleum-reserve

IS THE WELL RUNNING DRY?

Because the United States is the world's largest importer, it is easy to forget that it:

- **is the oldest major global oil producer and consumer;**
- **is formerly the Number 1 global oil producer;**
- **is currently the Number 1 global oil producer;**
- **has produced more oil, cumulatively, than any other country (255 billion barrels from 1900 to 2022);**
- **has produced more oil, cumulatively, than the current reserves of any country.**

US DOE/EIA REPORTS U.S. is Net Petroleum Energy Exporter (2022)

On December 18, 2015, the U.S. enacted legislation authorizing the export of U.S. crude oil without a license. Exports to embargoed or sanctioned countries continue to require authorization.

With rising U.S. exports of gasoline, diesel and other oil-based fuels, the US became a net exporter of petroleum products in 2011, the first time in 62 years that it will export more fuel than it imports. According to the *U.S. Energy Information Administration (EIA)*, as a net exporter, the United States would still import oil, natural gas, and other energy sources, but it would send out more of these products produced at home than it takes in from foreign sources.

The net exporter designation is significant as it signals a shift in the decades-old consumption imbalance, where the U.S. took in "huge quantities" of crude oil from the Middle East and refined fuels from Canada, Europe, and Latin America. Analysts said the trend does not appear to be fleeting, as the import imbalance has steadily shrunk over the past few years.

"It looks like a trend that could stay in place for the rest of the decade," said sources at Platts, which tracks energy markets. The US DOE EIA speculates the shift could eventually influence U.S. energy policy, which has been closely linked to events in the Middle East. The growth in exports is part of a "transformation of the energy system," said sources at Citigroup, Inc. "It's the beginning signs of a process that will continue for the next decade and will point toward energy independence."

U.S. demand for fuel has dropped over the last 20 years, in part because of higher fuel efficiencies, alternative energy and energy efficient homes/buildings. As a result, in 2022, the United States consumed an average of about 20.01 million barrels of petroleum per day, or a total of about 7.3 billion barrels of petroleum..

Petroleum Energy developments (2022): From BP Statistical Review of World Energy 2022
Web link: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

World petroleum energy consumption – grew by 1% in 2021. Consumption of fossil fuels was broadly unchanged. Fossil fuels accounted for 82% of primary energy use last year, down from 83% in 2019 and 85% five years ago.

Oil is the most consumed primary energy fuel in the world. In 2022, 34.42 billion bbls. of oil were consumed. This represented an increase of some three percent in comparison to the previous year. Natural gas and nuclear energy were the primary energy sources to note a consumption decline that year.

WORLD RISING DEMAND FOR FOSSIL FUELS

Demand for fossil fuels – such as natural gas, oil, and coal – has remained high, as overall primary energy demand continues to increase. Excluding the effects of the coronavirus pandemic, the use of oil has consistently grown each year. Consumption of other non-renewable fuel types has been more varied, with natural gas briefly overtaking coal as the second-most consumed fuel in 2015. Global natural gas consumption has risen more or less consistently. Its properties as a less carbon-intensive fossil fuel than coal have led to an increase in its use in the power sector, overtaking coal use in major economies such as the United States.

In 1985 Proven World Oil Reserves-770 billion barrels.

- **In 2005 Proven World Oil Reserves-1.23 trillion barrels.**
- **In 2015 Proven World Oil Reserves-1.69 trillion barrels.**
- **In 2020 Proven World Oil Reserves-1.73 trillion barrels.**

- **World Oil Production in 2005 was 81.26 million barrels per day.**
- **World Oil Production in 2015 was 91.70 million barrels per day.**
- **World Oil Production in 2020 was 88.49 million barrels per day.**

- **World Oil Demand in 2005 was 83.32 million barrels per day.**
- **World Oil Demand in 2015 was 95.00 million barrels per day.**
- **World Oil Demand in 2020 was 88.69 million barrels per day.**

- **Currently (2023), World oil demand grows by 1.2-1.6% per year.**
- **Current World Oil Refinery Capacity is 101.91 million BPD (2021).**
- **Current World Oil Demand is 94.08 million BPD (2021) ≈ 45,733 gallons per second.**
- **Current World Oil Reserves (does includes oil/tar sands) is estimated at 1.73 trillion barrels. Reserves have grown 0.50 billion barrels since 2005.**
- **About 47 years' worth @ 100 million BPD demand**
- **2021 US Demand – 18.68 million BPD (21% of World)**
- **2021 US Production – 16.59 million BPD (18.7% of World)**
- **2021 US Reserves – 44.4 Billion Barrels (2.56% of World)**

Renewable energy led by wind and solar power, continued to grow strongly and now accounts for 13% of total. power generation. Renewable generation increased by almost 17% in 2021 and account for over half of the increase in global power generation over the past two years.

This data indicates that as of 2021, world oil demand, world oil production and world oil reserves are at beginning to stabilized and most likely to remain flat or suffer demand destruction in the forthcoming years.
For future consideration, enhanced methods of findings more crude oil fields/reserves and superior technologies (deep ocean drilling and production) are coming online every year. Proving that reserves will continue to be built in the short term.

THIS WEEK IN PETROLEUM REPORT RELEASE – May 25, 2011
U.S. oil import dependence is an issue as hotly debated as it is loosely defined. As discussed in a *This Week in Petroleum* article published in 2008, there is more than one way of measuring it. Different methods of calculation yield different results. But whichever way it is defined, U.S. dependence on imported oil has dramatically declined since peaking in 2005, continuing a trend that was beginning to emerge the last time This Week in Petroleum examined the issue. By the broadest measure, U.S. dependence on imported oil fell below the 50 percent mark last year for the first time since 1997. To put it succinctly, discrepancies in the way dependence is assessed arise because oil, for the most part, is imported as crude oil, but is consumed as refined products, of which crude oil is the main but not the only input - hence the need to clarify whether dependence is assessed at the output/consumption level or at the input level, and in the latter case what range of inputs is included as a basis for comparison.

Shifts in supply patterns, including increases in domestic biofuels production, NGL output and refinery gain, also played an important role in moderating import dependence. U.S. ethanol net inputs grew from 230,000 bbl/d in 2005 to 779,000 bbl/d in 2010, helping to displace traditional hydrocarbon fuels and so reducing petroleum

import needs. Strong gains in the deepwater Gulf of Mexico and the Bakken formation brought decades of contraction in domestic oil production to a sudden halt, and even led to a rebound. U.S. crude oil output increased by an estimated 334,000 bbl/d between 2005 and 2010, further eroding the need for imported crude oil.

Consideration of Oil Tar Sands:

Tar sands deposits are found in over seventy countries throughout the world, but three quarters of the world's reserves are in two regions, Venezuela and Alberta, Canada. Tar sands represent as much as 66% of the world's total reserves of oil, with at least 1.7 trillion barrels in the Canadian Athabasca Tar Sands and 1.8 trillion barrels in the Venezuelan Orinoco tar sands, compared to 1.75 trillion barrels Alberta sits atop the biggest petroleum deposit outside the Arabian peninsula - as many as 300 billion recoverable barrels and another trillion-plus barrels that could one day be within reach using new retrieval methods. By contrast, the entire Middle East holds an estimated 685 billion barrels that are recoverable. But there is a catch, Tar Sands is more like a mix of Silly Putty and coffee grounds - think of the tar patties that stick to the bottom of your sandals at the beach - and it is trapped beneath hundreds of feet of clay and rock.

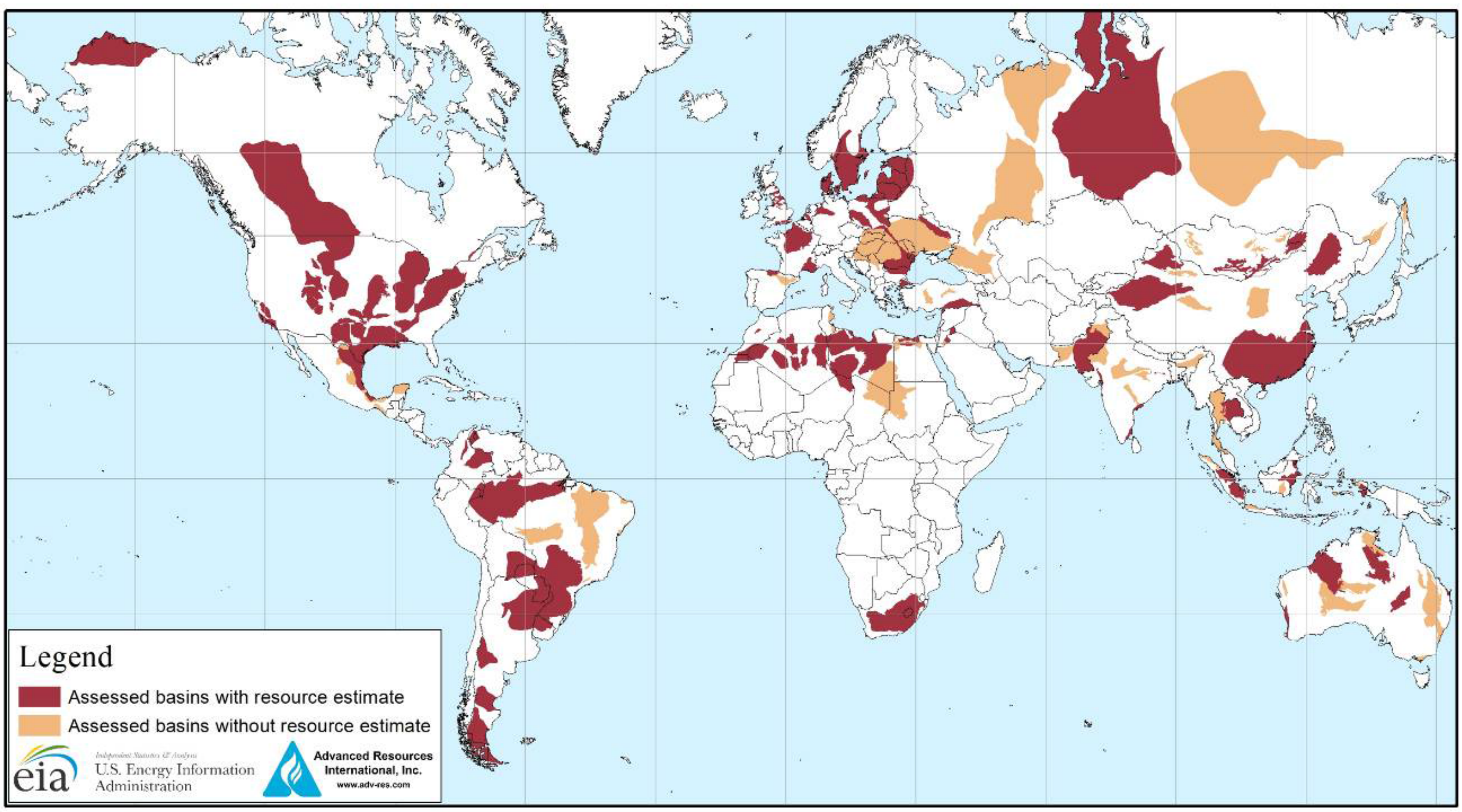
Consideration of Oil Shales: (Tight Oil)

Although the terms shale oil and tight oil are often used interchangeably in public discourse, shale formations are only a subset of all low permeability tight formations, which include sandstones and carbonates, as well as shales, as sources of tight oil production.

While oil shale is found in many places worldwide, by far the largest deposits in the world are found in the United States in the Green River Formation, which covers portions of Colorado, Utah, and Wyoming. Estimates of the oil resource in place within the Green River Formation range from 1.2 to 1.8 trillion barrels. Not all resources in place are recoverable; however, even a moderate estimate of 800 billion barrels of recoverable oil from oil shale in the Green River Formation is three times greater than the proven oil reserves of Saudi Arabia. The U.S. must overcome technical and economic problems for major production to be feasible.

Bakken Shale Formation and Bakken-Lodgepole: Total petroleum within using a geology-based assessment methodology, the U.S. Geological Survey estimated mean undiscovered volumes of 3.65 billion barrels of oil, 1.85 trillion cubic feet of associated/dissolved natural gas, and 148 million barrels of natural gas liquids in the Bakken Formation of the Williston Basin Province, Montana, and North Dakota.

Map of basins with assessed shale oil and shale gas formations, as of May 2013



Oil

World Oil Reserves by Country (2020)

Total proved reserves

	At end 2000 Thousand million barrels	At end 2010 Thousand million barrels	At end 2019 Thousand million barrels	At end 2020 Thousand million barrels	At end 2020 Thousand million tonnes	At end 2020 Share of total	At end 2020 R/P ratio
Canada	181.5	174.8	169.1	**168.1**	**27.1**	9.7%	89.4
Mexico	24.6	10.4	6.1	**6.1**	**0.9**	0.4%	8.7
US	30.4	35.0	68.8	**68.8**	**8.2**	4.0%	11.4
Total North America	236.5	220.3	243.9	**242.9**	**36.1**	14.0%	28.2
Argentina	3.0	2.5	2.5	**2.5**	**0.3**	0.1%	11.3
Brazil	8.5	14.2	12.7	**11.9**	**1.7**	0.7%	10.8
Colombia	2.0	1.9	2.0	**2.0**	**0.3**	0.1%	7.1
Ecuador	2.7	2.1	1.3	**1.3**	**0.2**	0.1%	7.4
Peru	0.9	1.2	0.8	**0.7**	**0.1**	♦	15.5
Trinidad & Tobago	0.9	0.8	0.2	**0.2**	**†**	♦	8.7
Venezuela	76.8	296.5	303.8	**303.8**	**48.0**	17.5%	*
Other S. & Cent. America	1.3	0.8	0.7	**0.8**	**0.1**	♦	10.9
Total S. & Cent. America	96.0	320.1	324.0	**323.4**	**50.8**	18.7%	151.3
Denmark	1.1	0.9	0.4	**0.4**	**0.1**	♦	16.2
Italy	0.6	0.6	0.6	**0.6**	**0.1**	♦	14.7
Norway	11.4	6.8	8.5	**7.9**	**1.0**	0.5%	10.8
Romania	1.2	0.6	0.6	**0.6**	**0.1**	♦	22.7
United Kingdom	4.7	2.8	2.5	**2.5**	**0.3**	0.1%	6.6
Other Europe	2.1	1.9	1.6	**1.6**	**0.2**	0.1%	14.9
Total Europe	21.0	13.6	14.2	**13.6**	**1.8**	0.8%	10.4
Azerbaijan	1.2	7.0	7.0	**7.0**	**1.0**	0.4%	26.7
Kazakhstan	5.4	30.0	30.0	**30.0**	**3.9**	1.7%	45.3
Russian Federation	112.1	105.8	107.8	**107.8**	**14.8**	6.2%	27.6
Turkmenistan	0.5	0.6	0.6	**0.6**	**0.1**	♦	7.6
Uzbekistan	0.6	0.6	0.6	**0.6**	**0.1**	♦	34.7
Other CIS	0.3	0.3	0.3	**0.3**	**†**	♦	17.3
Total CIS	120.1	144.2	146.2	**146.2**	**19.9**	8.4%	29.6
Iran	99.5	151.2	157.8	**157.8**	**21.7**	9.1%	139.8
Iraq	112.5	115.0	145.0	**145.0**	**19.6**	8.4%	96.3
Kuwait	96.5	101.5	101.5	**101.5**	**14.0**	5.9%	103.2
Oman	5.8	5.5	5.4	**5.4**	**0.7**	0.3%	15.4
Qatar	16.9	24.7	25.2	**25.2**	**2.6**	1.5%	38.1
Saudi Arabia	262.8	264.5	297.6	**297.5**	**40.9**	17.2%	73.6
Syria	2.3	2.5	2.5	**2.5**	**0.3**	0.1%	158.8
United Arab Emirates	97.8	97.8	97.8	**97.8**	**13.0**	5.6%	73.1
Yemen	2.4	3.0	3.0	**3.0**	**0.4**	0.2%	86.7
Other Middle East	0.2	0.3	0.2	**0.2**	**†**	♦	2.6
Total Middle East	696.7	765.9	836.0	**835.9**	**113.2**	48.3%	82.6
Algeria	11.3	12.2	12.2	**12.2**	**1.5**	0.7%	25.0
Angola	6.0	9.1	7.8	**7.8**	**1.1**	0.4%	16.1
Chad	0.9	1.5	1.5	**1.5**	**0.2**	0.1%	32.5
Republic of Congo	1.5	2.0	2.9	**2.9**	**0.4**	0.2%	25.7
Egypt	3.6	4.5	3.1	**3.1**	**0.4**	0.2%	14.0
Equatorial Guinea	0.8	1.7	1.1	**1.1**	**0.1**	0.1%	18.7
Gabon	2.4	2.0	2.0	**2.0**	**0.3**	0.1%	26.4
Libya	36.0	47.1	48.4	**48.4**	**6.3**	2.8%	339.2
Nigeria	29.0	37.2	36.9	**36.9**	**5.0**	2.1%	56.1
South Sudan	n/a	n/a	3.5	**3.5**	**0.5**	0.2%	56.4
Sudan	0.3	5.0	1.5	**1.5**	**0.2**	0.1%	47.9
Tunisia	0.4	0.4	0.4	**0.4**	**0.1**	♦	32.7
Other Africa	0.7	2.3	3.7	**3.8**	**0.5**	0.2%	33.2
Total Africa	92.9	124.9	125.0	**125.1**	**16.6**	7.2%	49.8
Australia	4.9	3.8	2.4	**2.4**	**0.3**	0.1%	13.9
Brunei	1.2	1.1	1.1	**1.1**	**0.1**	0.1%	27.3
China	15.2	23.3	26.0	**26.0**	**3.5**	1.5%	18.2
India	5.3	5.8	4.7	**4.5**	**0.6**	0.3%	16.1
Indonesia	5.1	4.2	2.5	**2.4**	**0.3**	0.1%	9.0
Malaysia	2.1	3.6	2.7	**2.7**	**0.4**	0.2%	12.5
Thailand	0.5	0.4	0.3	**0.3**	**†**	♦	1.7
Vietnam	2.0	4.4	4.4	**4.4**	**0.6**	0.3%	58.1
Other Asia Pacific	1.3	1.1	1.4	**1.3**	**0.2**	0.1%	17.4
Total Asia Pacific	37.7	47.8	45.3	**45.2**	**6.1**	2.6%	16.6
Total World	**1300.9**	**1636.9**	**1734.8**	**1732.4**	**244.4**	**100.0%**	**53.5**
of which: OECD	262.7	238.5	261.5	**260.0**	**38.3**	15.0%	25.2
Non-OECD	1038.2	1398.3	1473.3	**1472.4**	**206.1**	85.0%	66.9
OPEC	833.0	1137.7	1214.7	**1214.7**	**171.8**	70.1%	108.3
Non-OPEC	468.0	499.1	520.1	**517.7**	**72.6**	29.9%	24.5
European Union	3.9	3.2	2.4	**2.4**	**0.3**	0.1%	16.8
Canadian oil sands: Total	174.9	169.2	162.4	**161.4**	**26.2**	9.3%	
of which: Under active development	11.7	25.9	19.9	**18.9**	**3.1**	1.1%	
Venezuela: Orinoco Belt	–	220.0	261.8	**261.8**	**42.0**	15.1%	

Source of data – the estimates in this table have been compiled using a combination of primary official sources, third-party data from the OPEC Secretariat, World Oil, Oil & Gas Journal and Chinese reserves based on official data and information in the public domain.

†Less than 0.05.

♦Less than 0.05%.

n/a not available.

*More than 500 years.

Notes: Total proved reserves of oil – generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions. The data series for total proved oil reserves does not necessarily meet the definitions, guidelines and practices used for determining proved reserves at company level, for instance as published by the US Securities and Exchange Commission, nor does it necessarily represent bp's view of proved reserves by country.

Reserves-to-production (R/P) ratio – if the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate.

Canadian oil sands 'under active development' are an official estimate. Venezuelan Orinoco Belt reserves are based on the OPEC Secretariat and government announcements.

Reserves and R/P ratio for Canada includes Canadian oil sands. Reserves and R/P ratio for Venezuela includes the Orinoco Belt. Saudi Arabia's oil reserves include NGLs from 2017.

Reserves include gas condensate and natural gas liquids (NGLs) as well as crude oil.

Shares of total and R/P ratios are calculated using thousand million barrels figures.

World Oil Consumption by Country (2021)

Oil: Consumption in thousands of barrels per day*

Thousand barrels daily	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Growth rate per annum 2021	Growth rate per annum 2011-21	Share 2021
Canada	2400	2426	2422	2420	2443	2453	2424	2501	2491	2191	**2229**	1.7%	-0.7%	2.4%
Mexico	2065	2083	2034	1960	1939	1950	1883	1836	1698	1313	**1350**	2.9%	-4.2%	1.4%
US	17993	17581	17992	18111	18499	18593	18845	19417	19424	17183	**18684**	8.7%	0.4%	19.9%
Total North America	22458	22090	22448	22491	22881	22996	23153	23753	23613	20687	**22264**	7.6%	-0.1%	23.7%
Argentina	612	647	688	678	694	675	670	640	572	518	**598**	15.4%	-0.2%	0.6%
Brazil	2434	2519	2656	2729	2488	2370	2407	2293	2303	2134	**2252**	5.5%	-0.8%	2.4%
Chile	371	376	362	353	355	377	364	379	383	349	**365**	4.4%	-0.2%	0.4%
Colombia	259	279	277	292	312	320	313	322	340	277	**349**	26.0%	3.0%	0.4%
Ecuador	226	233	247	260	254	239	236	255	249	202	**247**	22.5%	0.9%	0.3%
Peru	211	211	222	221	235	250	260	267	278	210	**266**	26.3%	2.3%	0.3%
Trinidad & Tobago	42	40	45	41	45	47	44	41	32	28	**25**	-10.4%	-5.0%	♦
Venezuela	721	785	835	746	697	537	493	410	339	277	**289**	4.3%	-8.7%	0.3%
Central America	366	369	372	386	420	435	444	423	454	382	**433**	13.5%	1.7%	0.5%
Other Caribbean	637	617	591	581	604	624	611	622	617	511	**569**	11.3%	-1.1%	0.6%
Other South America	186	189	193	193	198	210	216	223	225	211	**229**	8.4%	2.1%	0.2%
Total S. & Cent. America	6066	6264	6491	6481	6302	6085	6057	5877	5791	5100	**5622**	10.2%	-0.8%	6.0%
Austria	244	244	252	242	241	249	252	255	265	229	**236**	2.8%	-0.4%	0.3%
Belgium	624	602	624	620	641	644	653	693	651	568	**638**	12.4%	0.2%	0.7%
Bulgaria	80	83	77	84	94	95	99	98	102	91	**96**	5.4%	1.8%	0.1%
Croatia	72	65	63	65	68	68	73	71	69	59	**65**	9.8%	-1.1%	0.1%
Cyprus	55	51	46	45	46	51	52	52	52	44	**45**	3.3%	-1.9%	♦
Czech Republic	191	189	181	192	184	172	205	207	209	181	**200**	10.6%	0.5%	0.2%
Denmark	165	153	152	153	155	153	152	154	154	127	**128**	1.1%	-2.5%	0.1%
Estonia	27	32	31	29	29	29	30	30	27	28	**29**	3.7%	0.6%	♦
Finland	202	194	208	197	196	206	200	200	199	178	**178**	-0.4%	-1.3%	0.2%
France	1666	1609	1596	1544	1544	1529	1540	1538	1528	1307	**1424**	9.0%	-1.6%	1.5%
Germany	2294	2276	2336	2273	2269	2307	2374	2255	2270	2049	**2045**	-0.2%	-1.1%	2.2%
Greece	350	305	282	281	294	293	298	294	304	246	**249**	1.5%	-3.3%	0.3%
Hungary	138	129	128	142	153	150	164	175	176	161	**171**	6.3%	2.2%	0.2%
Iceland	14	14	15	16	17	19	21	23	19	13	**13**	2.2%	-1.1%	♦
Ireland	147	138	138	137	143	149	149	155	153	130	**133**	2.0%	-1.0%	0.1%
Italy	1465	1367	1261	1196	1264	1255	1274	1300	1259	1039	**1156**	11.2%	-2.3%	1.2%
Latvia	33	33	33	34	35	36	37	34	38	33	**34**	2.0%	0.3%	♦
Lithuania	52	53	52	51	55	60	62	66	66	61	**64**	4.6%	2.1%	0.1%
Luxembourg	60	58	57	55	54	54	57	60	61	49	**51**	3.6%	-1.7%	0.1%
Netherlands	962	916	889	856	826	843	818	843	812	740	**742**	0.3%	-2.6%	0.8%
North Macedonia	20	19	19	19	20	22	21	21	22	20	**24**	16.0%	1.9%	♦
Norway	222	215	226	216	217	210	212	221	213	204	**199**	-2.3%	-1.1%	0.2%
Poland	574	552	520	521	542	594	646	663	679	640	**687**	7.4%	1.8%	0.7%
Portugal	249	225	235	241	238	241	240	239	247	202	**208**	3.2%	-1.8%	0.2%
Romania	186	186	170	184	186	195	206	212	221	205	**225**	9.5%	1.9%	0.2%
Slovakia	78	72	72	67	73	76	86	87	83	82	**86**	4.9%	1.1%	0.1%
Slovenia	54	53	50	49	49	52	53	55	52	44	**47**	6.8%	-1.5%	♦
Spain	1330	1237	1169	1165	1209	1252	1260	1286	1287	1056	**1169**	10.7%	-1.3%	1.2%
Sweden	295	292	291	285	279	289	286	273	292	255	**270**	5.9%	-0.9%	0.3%
Switzerland	234	238	249	224	226	214	219	212	216	179	**181**	0.9%	-2.5%	0.2%
Turkey	672	702	748	771	915	973	1022	989	999	913	**939**	2.9%	3.4%	1.0%
Ukraine	291	287	274	244	215	228	230	240	239	227	**237**	4.4%	-2.0%	0.3%
United Kingdom	1561	1508	1490	1491	1538	1587	1594	1569	1522	1172	**1236**	5.5%	-2.3%	1.3%
Other Europe	320	299	297	294	305	326	342	338	347	314	**322**	2.7%	0.1%	0.3%
Total Europe	14927	14396	14232	13980	14321	14622	14928	14903	14831	12846	**13527**	5.3%	-1.0%	14.4%
Azerbaijan	89	92	101	99	100	98	99	104	105	91	**95**	4.3%	0.7%	0.1%
Belarus	174	213	160	164	138	147	147	171	174	167	**159**	-4.3%	-0.9%	0.2%
Kazakhstan	270	288	297	304	289	304	313	338	345	302	**327**	8.3%	2.0%	0.3%
Russian Federation	3094	3140	3163	3300	3197	3275	3280	3310	3376	3210	**3407**	6.1%	1.0%	3.6%
Turkmenistan	125	129	137	143	145	143	144	145	146	140	**146**	4.5%	1.6%	0.2%
Uzbekistan	104	88	83	82	83	86	87	95	95	83	**90**	8.8%	-1.5%	0.1%
Other CIS	65	75	78	76	78	86	82	96	89	77	**84**	8.6%	2.5%	0.1%
Total CIS	3920	4025	4020	4168	4029	4140	4152	4259	4331	4069	**4307**	5.9%	0.9%	4.6%
Iran	1715	1762	1879	1765	1580	1579	1656	1728	1784	1673	**1690**	1.0%	-0.1%	1.8%
Iraq	564	619	688	650	630	687	720	847	720	629	**722**	14.8%	2.5%	0.8%
Israel	233	274	212	199	211	216	226	229	231	200	**209**	4.6%	-1.1%	0.2%
Kuwait	467	467	477	488	475	449	470	481	471	441	**450**	1.9%	-0.4%	0.5%
Oman	146	157	178	185	184	187	224	232	224	190	**209**	9.8%	3.6%	0.2%
Qatar	244	260	303	312	356	369	335	347	369	296	**311**	5.1%	2.5%	0.3%
Saudi Arabia	3285	3451	3444	3779	3901	3962	3870	3762	3691	3552	**3595**	1.2%	0.9%	3.8%
United Arab Emirates	723	766	847	858	927	1021	1006	1004	972	855	**952**	11.4%	2.8%	1.0%
Other Middle East	735	696	653	652	566	535	570	552	541	482	**502**	4.1%	-3.7%	0.5%
Total Middle East	8112	8451	8681	8889	8829	9005	9078	9182	9004	8318	**8640**	3.9%	0.6%	9.2%
Algeria	349	370	387	401	425	412	408	416	431	385	**403**	4.7%	1.4%	0.4%
Egypt	740	750	759	791	810	836	801	721	686	598	**648**	8.3%	-1.3%	0.7%
Morocco	275	277	282	272	268	275	291	287	293	258	**286**	10.8%	0.4%	0.3%
South Africa	532	542	552	544	601	576	576	575	569	465	**502**	7.9%	-0.6%	0.5%
Eastern Africa	447	466	492	513	559	569	604	626	626	549	**588**	7.1%	2.8%	0.6%
Middle Africa	230	251	284	298	290	267	252	251	262	239	**257**	7.6%	1.1%	0.3%
Western Africa	543	573	594	555	563	623	679	787	801	790	**856**	8.4%	4.7%	0.9%
Other Northern Africa	263	332	347	358	318	295	303	308	318	269	**326**	21.0%	2.1%	0.3%
Other Southern Africa	49	51	54	56	57	56	57	58	59	54	**56**	3.4%	1.3%	0.1%
Total Africa	3428	3612	3752	3788	3891	3910	3970	4030	4046	3608	**3922**	8.7%	1.4%	4.2%
Australia	980	1001	1031	1025	1015	1016	1063	1076	1064	916	**943**	3.0%	-0.4%	1.0%
Bangladesh	104	110	108	120	127	138	156	178	171	156	**179**	14.6%	5.6%	0.2%
China	9630	10061	10563	11018	11890	12297	13003	13642	14321	14408	**15442**	7.2%	4.8%	16.4%
China Hong Kong SAR	360	344	352	335	367	380	428	434	408	285	**255**	-10.5%	-3.4%	0.3%
India	3475	3674	3717	3832	4147	4544	4724	4974	5150	4701	**4878**	3.8%	3.5%	5.2%
Indonesia	1530	1612	1572	1572	1505	1454	1565	1616	1578	1398	**1471**	5.2%	-0.4%	1.6%
Japan	4410	4676	4499	4283	4116	3983	3949	3815	3692	3269	**3341**	2.2%	-2.7%	3.6%
Malaysia	696	757	802	803	753	839	797	804	868	749	**763**	1.8%	0.9%	0.8%
New Zealand	152	150	152	155	161	165	175	174	178	147	**144**	-1.9%	-0.6%	0.2%
Pakistan	414	402	442	458	505	566	589	498	446	437	**503**	15.1%	2.0%	0.5%
Philippines	292	301	316	336	384	413	445	450	459	378	**412**	9.1%	3.5%	0.4%
Singapore	1208	1202	1217	1259	1329	1372	1405	1432	1403	1343	**1330**	-1.0%	1.0%	1.4%
South Korea	2388	2466	2476	2473	2586	2811	2804	2800	2789	2630	**2813**	6.9%	1.6%	3.0%
Sri Lanka	102	109	94	106	111	134	130	126	135	123	**119**	-3.3%	1.5%	0.1%
Taiwan	961	950	987	1017	1041	1047	1032	1039	986	946	**989**	4.5%	0.3%	1.1%
Thailand	1140	1201	1216	1227	1265	1294	1336	1362	1374	1214	**1214**	♦	0.6%	1.3%
Vietnam	358	362	375	397	482	524	552	581	599	493	**464**	-5.8%	2.6%	0.5%
Other Asia Pacific	322	333	352	378	424	432	434	486	510	524	**546**	4.2%	5.4%	0.6%
Total Asia Pacific	28522	29709	30273	30795	32211	33410	34586	35486	36131	34117	**35806**	4.9%	2.3%	38.1%
Total World	**87433**	**88547**	**89897**	**90592**	**92464**	**94169**	**95924**	**97490**	**97747**	**88746**	**94088**	**6.0%**	**0.7%**	**100.0%**
of which: OECD	45155	44716	44746	44317	45026	45522	45952	46420	46070	40360	**42941**	6.4%	-0.5%	45.6%
Non-OECD	42278	43831	45151	46275	47439	48647	49972	51070	51677	48386	**51147**	5.7%	1.9%	54.4%
European Union	11637	11157	10955	10749	10913	11090	11319	11345	11307	9853	**10421**	5.8%	-1.1%	11.1%

*Inland demand plus international aviation and marine bunkers and refinery fuel and loss. Consumption of biogasoline (such as ethanol), biodiesel and derivatives of coal and natural gas are excluded. Derivatives of coal and natural gas are included.

♦Less than 0.05%.

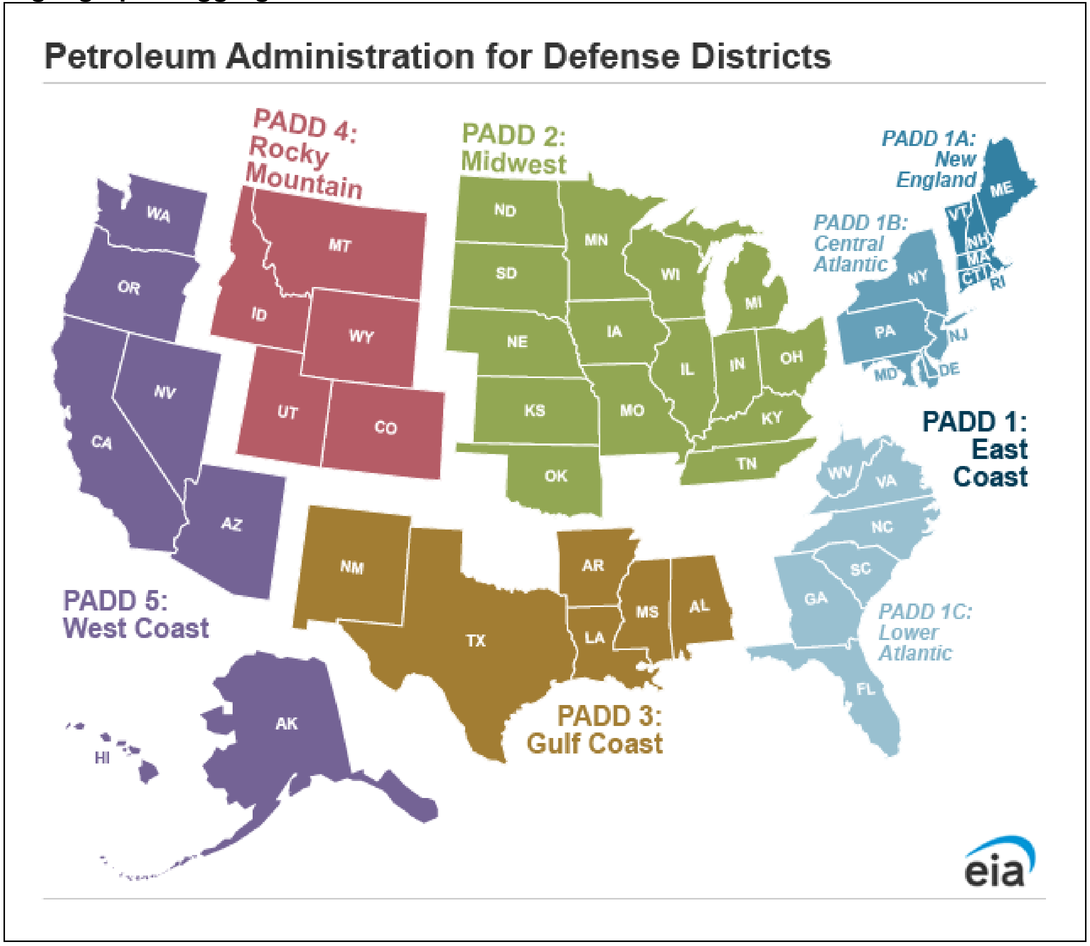
Notes: Differences between these world consumption figures and world production statistics are accounted for by stock changes, consumption of non-petroleum additives and substitute fuels, and unavoidable disparities in the definition, measurement or conversion of oil supply and demand data.

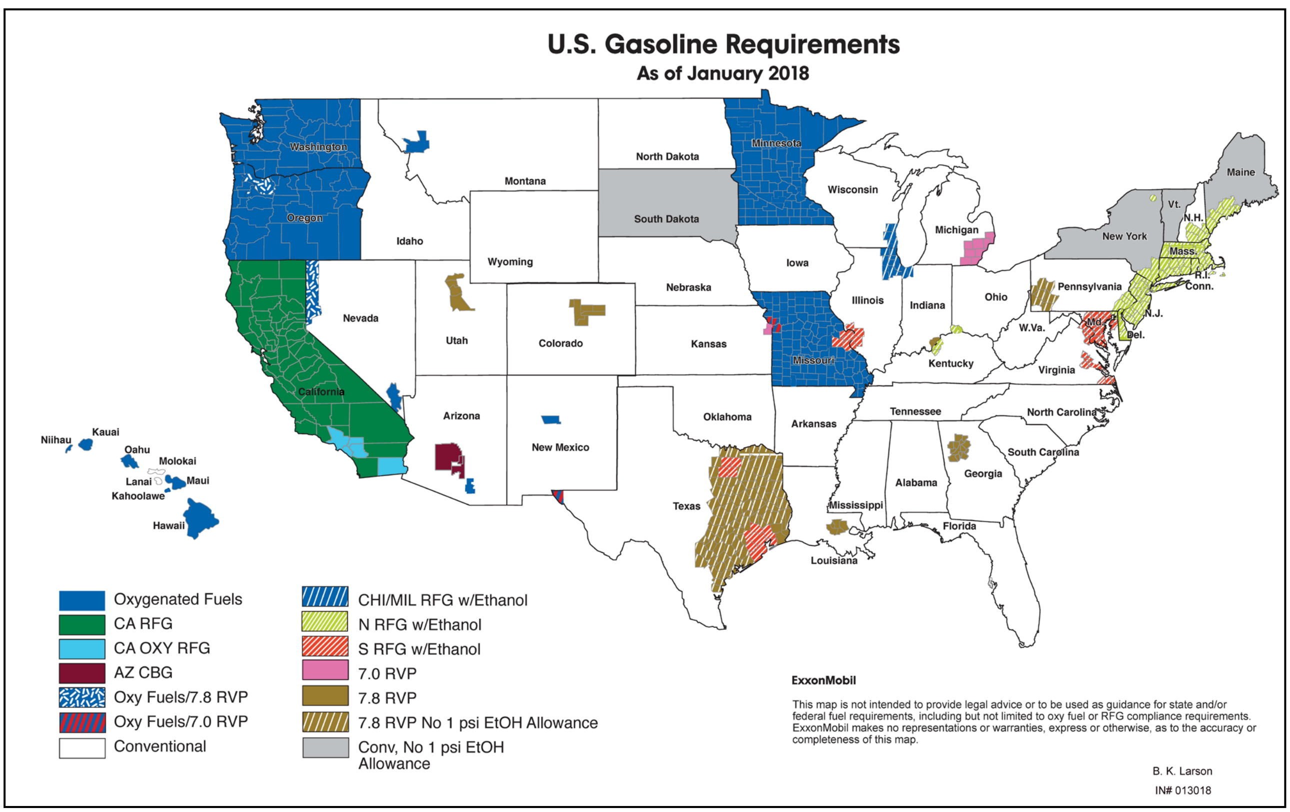
Annual changes and shares of total are calculated using thousand barrels daily figures.

Growth rates are adjusted for leap years.

PADD's were delineated during World War II to facilitate oil allocation.

A geographic aggregation of the 50 States and the District of Columbia into five Districts, with PADD I highest.





There are approximately 58 different petroleum products that use the same pipeline system, or Fungible Fuels. (see map above)

Northern RFG w/ethanol, Chicago Northern RFG w/Ethanol, Northern RFG w/MTBE, Southern RFG w/ethanol, Southern RFG, with MTBE or w/o oxygenate, Southern RFG w/o oxygenate, California CBG w/ethanol, California CBG w/ MTBE or w/o oxygenate, California CBG w/o oxygenate, 9.0 Fed CG w/ethanol, 9.0 Fed CG w/MTBE or w/o oxygenate, 9.0 RVP w/o oxygenate, Ethanol requirement in Minnesota, 7.8 RVP w/ethanol, 7.8 RVP w/MTBE or w/o oxygenate, 7.8 RVP w/o oxygenate, 7.2 RVP, 7.0 RVP 7.0 RVP, w/Sulfur control, Ultra Low Sulfur Diesel (ULSD), Low Sulfur Diesel (LSD), NRLM (Non-road, locomotive & marine) diesel fuel, Heating Oils, Kerosene, Jet Kerosene's, Aviation Gasoline's, & Military specification fuels.

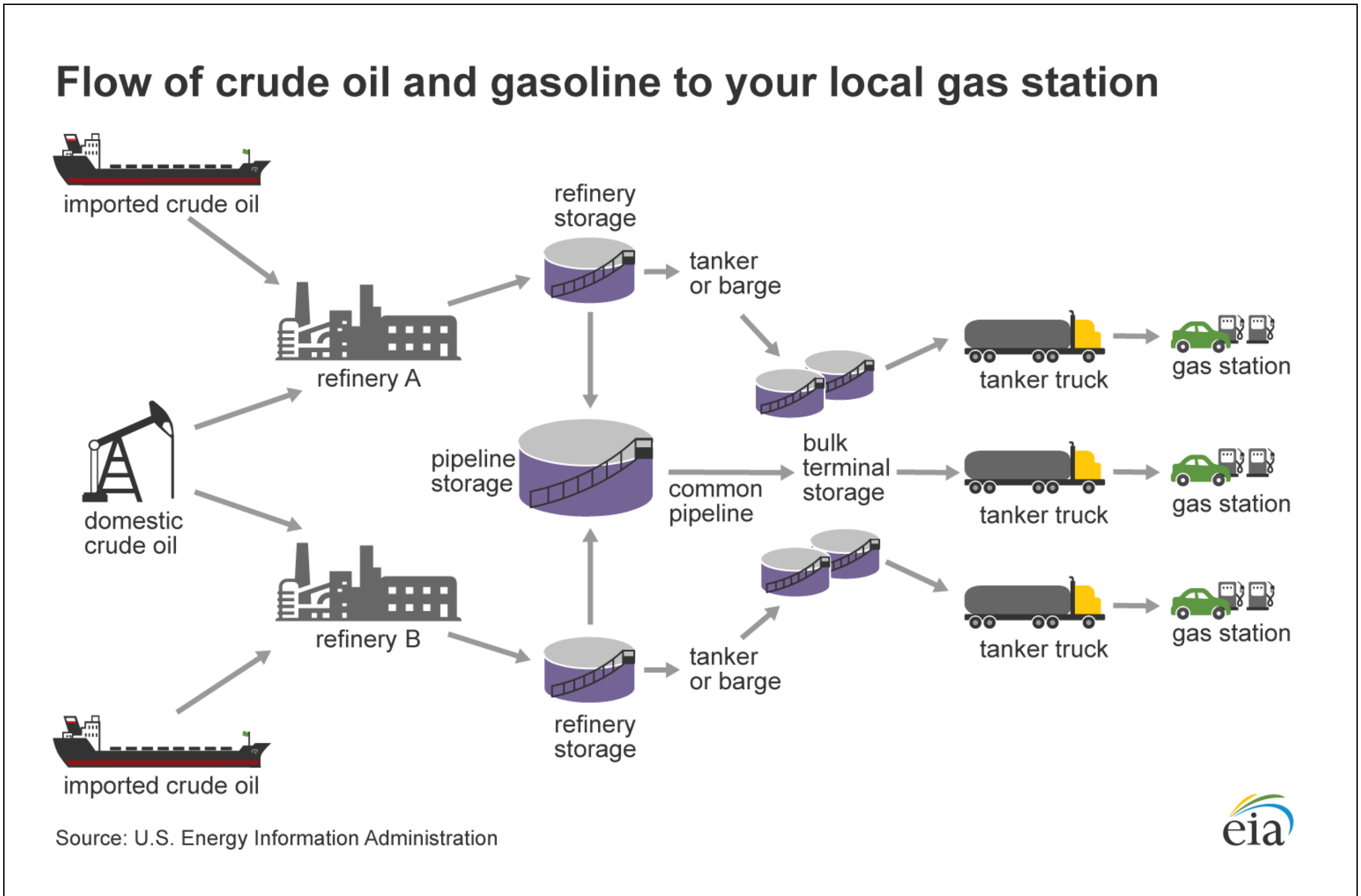
Boutique fuels are specialized blends produced for a specific state or area of the country to meet state and local air quality requirements. Boutique fuels deliver substantial air quality and public health benefits at minimal costs - ranging from three-tenths of a cent to three cents per gallon. However, these unique fuels may present serious challenges to the fuel distribution system and, especially in times of disruption, may have the potential to result in local supply shortages. Boutique fuels are used primarily in urban areas to address specific air quality problems, most particularly ozone. The control of certain fuel properties, such as fuel volatility, helps reduce exhaust and evaporative emissions from motor vehicles that cause or contribute to air pollution. Boutique fuels typically account for between 10 to 15 percent of the nation's summertime gasoline supply.

The boutique fuel provision in the EPAct makes an effort to reduce the number of different fuels required around the country and thus increase the fungibility of fuels. Most fuels travel through common carrier pipelines based upon general specifications, most of which are dictated seasonally and by regulation. Terminals have limited storage tanks. The proliferation of different fuels creates a serious challenge to production, distribution, and storage, especially during times of disruption such as refinery shutdowns or weather-related damage. The list and the EPAct limitations placed upon EPA's ability to approve future fuels in SIPs are intended by Congress to limit further expansion of boutique fuels.

The 2005 federal energy bill includes a provision to reduce the proliferation of boutique fuels (see section 1541 Also section 1541(c)(6) requires a report by August 2006 of a joint EPA/DOE study on boutique fuels, including effects on air quality, fuel availability and fungibility.

Roughly 15 states have adopted their own clean fuel programs for part or all of the state. Most of these states require gasoline with lower volatility than federal standards, and most are effective for only part of the year. These state fuel programs make up nine distinct kinds of fuels. The federal programs (Reformulated Gasoline (RFG) and low Reid Vapor Pressure (RVP)) make up six distinct kinds of fuel. The combination of federal fuel programs and states' abilities to adopt state fuel controls is intended to reflect a balance that allows areas sufficient flexibility to accomplish air quality needs. For more information on US EPA Boutique Fuels go to:
https://www.epa.gov/gasoline-standards

Petroleum from the Refinery to the Public



Downstream Petroleum Marketing Engineering Concerns:

As a petroleum engineer, I am appreciative of the reliance and dedication of other engineers in helping Downstream Petroleum Marketers meet their obligations towards the public good. The varied concerns of the marketers reflect upon the attitude of the professional engineering community that ensures that petroleum products are handled in a safe and environmentally friendly manner. Petroleum Marketers provide fuel to the motoring public, governmental, industrial, and commercial establishments. Marketers also provide heating fuels, hydraulic oils, lubrication oils and other chemicals in bulk to various end users. Approximately 90% of all US convenience stores and service stations are privately owned.

Professional Engineers are called upon by the Petroleum Marketing industry to provide numerous environmental and technical proposals/projects. Many State Professional Engineering Boards require a PE seal on all petroleum system designs/plans before installation. There are exceptions to this rule such as size limitations and tanks of any size storing Class III B combustible liquids or tanks storing heating oil for consumptive use on the premises where stored. Most city/county building code departments require a permit before tank installation and a permit for tank removal. This requirement typically is enforced by State Building codes. Typical tank installation must meet National Fire Protections Association (NFPA) Pamphlet No. 30 and 30A or the International Fire Code. State

Building Codes and various recommend practices such as the American Petroleum Institute (API) and Petroleum Equipment Institute (PEI) are use as legal requirements at all levels in the petroleum industry.

In the environmental arena, Petroleum Marketers are impacted by Clean Air and Clean Water regulations. Engineers provide valuable service to petroleum marketers by helping achieve compliance with State and Federal regulations.

EPA's Toxic Chemical Release Inventory (TRI) Reporting is a recent addition to our environmental to do list. TRI regulations state that certain Bulk Petroleum Storage Plants with Standard Industrial Classification (SIC) Code 5171 do an inventory of Toxic Chemical Releases into the environment. This requires air emission data and in some cases air modeling to maintain the TRI report due by July 1, of each year.

EPA's National Pollution Discharge Elimination System (NPDES) requires certain facilities with SIC Code 5171 (NAICS #422710) or others that discharge pollutants to the waters of the US, to be permitted. This allows these facilities to discharge stormwater from their property. This also requires the facility to analytically monitor and grab samples of stormwater run-off at a minimum of once per year. General Stormwater Permits may require PE certification. Only Wastewater Permits may also PE certification.

EPA's Spill Prevention Control & Countermeasure (SPCC) Plan is required for aboveground petroleum storage tanks more than 1,320 gallons and aggregate aboveground storage capacity of 1,320 gallons. Spill Plans are also required for underground petroleum storage capacity more than 42,000 gallons aggregate. A PE must review and certify the plan for compliance with the regulation. The PE is required to visit the site and determine if the facility meets the secondary containment requirements of the regulation. Contingency planning along with worst case spill scenarios must be developed to predict the impact of the spill to nearest navigable waters. There are a few exclusions to this rule.

Propane Fire Safety Analysis Plans may be required in accordance with NFPA-58. The plans may be required where the installation of new propane (LPG) storage facilities surpassing 4,000 gallons aggregate capacity in heavily populated or congested areas. The Fire Safety Analysis must be done in accordance with NFPA 58, and some state agencies require a PE. The PE must make determinations concerning fire protection of containers from a single fire and therefore if a serious hazard exist. The plan makes use of local fire fighting capabilities and what impacts would be on the community if the tank BLEVEs (explodes). Use of special fire protection is essential if a serious hazard exists.

In the event of a release from an underground petroleum storage tank, groundwater and/or soil remediation plans or corrective action plans are required when groundwater/soil quality has been degraded. The goal of corrective action shall be restoration to the level of the standard or as close thereto as is economically and technologically feasible. Responsible parties (RP) are required to immediately notify the proper State Agency of the release and the levels; take immediate action to eliminate the source or sources of contamination; perform a site assessment and; implement an approved corrective action plan. RP must also submit a copy of the report to the Health Director of the county or counties in which the contamination occurs. A corrective action plan must be implemented using the best available technology for restoring groundwater/soil to the level of the standards unless the State Agency approves an alternative cleanup plan. The rules give RPs three options other than cleanup to the standards. The RP may request the State Agency to approve a plan without requiring cleanup to the standards. The RP may request State Agency to approve a cleanup plan based on "natural remediation." Finally, the RP may request that the Director approve termination of a corrective action before the standards are achieved. The contamination cannot have migrated or will not migrate offsite, or permission is given by the owners of property where the contamination has migrated, or the area is served by a public water supply. For all three options, the State Agency may require a monitoring plan to be implemented that is sufficient to determine the effectiveness of the alternative.

The above does not include other items that the petroleum marketer requires of the PE. The PE that helps the petroleum marketer meet their obligations can feel proud that they have done their part in helping this country address its energy needs.

Course Conclusion:

Hopefully, this course has provided a basic primer on exploration, production refining, storage, transportation, and marketing of petroleum products. Updated February, 2024