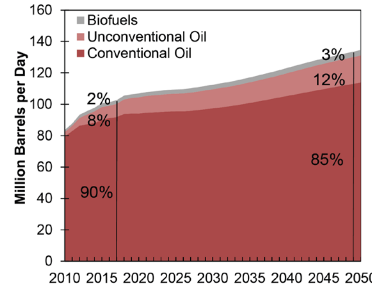
Unconventional Fossil Fuels

Patterns of Use

Globally, fossil fuels supply 81% of primary energy.[1] In 2018, 80% of U.S. primary energy consumption came from fossil fuels.[2] Conventional and unconventional fossil fuels differ in their geologic locations and accessibility; conventional fuels are often found in discrete, easily accessible reservoirs, while unconventional fuels may be found within pore spaces throughout a wide geologic formation, requiring advanced extraction technologies.[3] If unconventional oil resources (oil shale, oil sands, extra heavy oil, and natural bitumen) are taken into account, the global oil reserves quadruple current conventional reserves.[4] The price of crude oil increased 115% from 2000 to 2018 making unconventional fossil fuels more cost-competitive.[5] However, in 2017, the price of crude oil fell to $50.80 per barrel from its 2013 peak of $97.98.[5] The Energy Policy Act of 2005 includes provisions to promote U.S. oil sands, oil shale, and unconventional natural gas development.[6]

Global Projected Liquid Fuel Production[7]

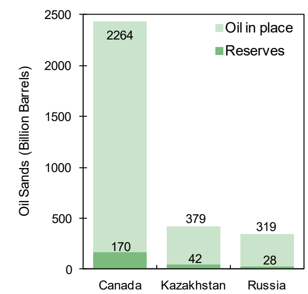


Major Unconventional Sources

Oil Sands

- Oil sands, i.e., "tar sands" or "natural bitumen," are a combination of sand (83%), bitumen (10%), water (4%), and clay (3%).[8] Bitumen is a semisolid, tar-like mixture of hydrocarbons.[9]
- Known oil sands deposits exist in 23 countries. Canada has 73% of global estimated oil sands, approximately 2.4 trillion barrels (bbls) of oil in place.[10] The U.S. has less than 2% of global oil sands resources; however, 48% of U.S. crude oil imports came from Canada in 2018, and 64% of Canadian production comes from oil sands.[10,11,12]
- Deposits less than 250 feet below the surface are mined and processed to separate the bitumen.[13] Bitumen must be upgraded to synthetic crude oil (SCO) before it's refined into petroleum products; non-upgraded bitumen must be diluted ("dilbit") or mixed with SCO ("synbit") before transport.[9] Deeper deposits employ *in situ* (underground) methods, including steam or solvent injection, or "firefloods"—oxygen injection with a portion of oil sands burned for heat.[9] Cyclic steam stimulation (CSS) and steam-assisted gravity drainage (SAGD) are the most common *in situ* methods used in Canada.[13]
- Two tons of oil sands produce one barrel of SCO.[9]

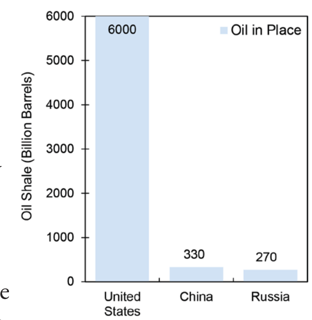
Oil Sands Resources, Top 3 Countries[10]



Oil Shale

- Oil shale is a sedimentary rock with deposits of organic compounds called kerogen, that has not undergone enough geologic pressure, heat, and time to become conventional oil. Oil shale contains enough oil to burn without additional processing, but it can be heated ("retorted") to generate petroleum-like liquids.[14]
- Oil shale deposits exist in 33 countries.[4] The U.S. has the largest oil shale resource in the world, approximately 6 trillion bbls of oil in place, with the Green River formation in the Western U.S. accounting for 83% of the U.S. total.[4,10] Roughly 353 billion bbls is considered to be "high grade" (>25 gallons of oil per ton of shale), representing a 50-year supply of oil for the U.S.[15] However, oil shale is far from commercial development.[7]
- Oil shale can be processed in two ways. In the first method, oil shale is mined and brought to the surface to be retorted to temperatures above 900° F.[16] The second method, *in situ* conversion process (ICP), involves placing electric heaters throughout the shale for up to three years until it reaches 650-700°F, at which point oil is released.[14]
- Oil retorted above-ground must be further processed before refining and disposing of the spent shale. Oil extracted through ICP can be sent directly to the refinery.[14]

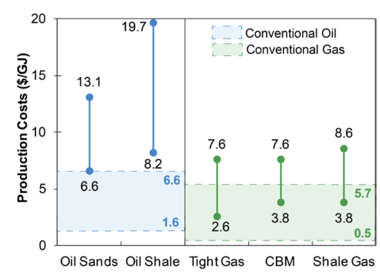
Oil Shale Resources, Top 3 Countries[4]



Unconventional Natural Gas

- Unconventional natural gas (UG) comes primarily from three sources: shale gas found in low-permeability shale formations; tight gas found in low-permeability sandstone and carbonate reservoirs; and coalbed methane (CBM) found in coal seams.[17]
- Although several countries have begun producing UG, many global resources have yet to be assessed. According to current estimates, China has the largest technically recoverable shale gas resource with 1,115 trillion cubic feet (Tcf), followed by Argentina (802 Tcf) and Algeria (707 Tcf).[18] Global tight gas resources are estimated at 2,684 Tcf, with the largest in Asia/Pacific and Latin America.[17] Resources of CBM are estimated at 1,660 Tcf, with more than 75% in Eastern Europe/Eurasia and Asia/Pacific.[17]
- U.S. resources that are recoverable with current technologies are estimated at 1280 Tcf from shale and tight gas and 109 Tcf from CBM.[19]
- UG, particularly shale and tight gas, is most commonly extracted through hydraulic fracturing, or "fracking." A mixture of fluid (usually water) and sand is pumped underground at extreme pressures to create cracks in the geologic formation, allowing gas to flow out. When the pressure is released, a portion of the fluid returns as "flowback," and the sand remains as a "proppant," keeping the fractures open.[17]
- UG accounted for 81% of total U.S. natural gas production in 2018 and is expected to account for 90% of production by 2050.[20]

Production Cost Ranges, Conventional and Unconventional Fossil Fuels[8]

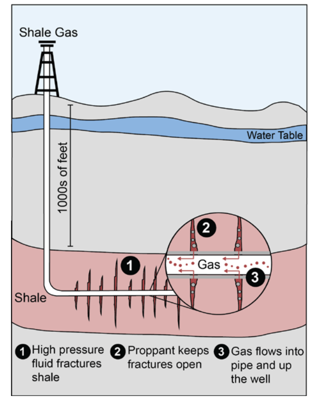


Life Cycle Impacts

Greenhouse Gases

- Fossil fuel combustion accounted for 76% of U.S. greenhouse gas (GHG) emissions in 2017.[21]
- Equivalent amounts of GHGs are released by conventional and unconventional fuels at the point of use. Some studies suggest the life cycle emissions for unconventional oil sources are similar to or slightly lower than conventional oil.[22] On average, however, life cycle emissions for unconventional oil are higher. Studies have found life cycle emissions for Canadian oil sands are 17% higher than average crude refined in the U.S., and oil shale emissions are 21% to 47% higher than conventional oil.[23,24]
- Studies of life cycle emissions for UG have resulted in estimates from 6% lower to 43% higher than conventional natural gas sources.[25,26]
- Overall, natural gas combustion generates fewer GHG emissions than other fossil fuels.[27] However, natural gas is primarily methane (CH_4), a potent greenhouse gas, and CH_4 leakage or "venting" can significantly decrease any emissions benefit of natural gas over other fossil fuels.[25]

Hydraulic Fracturing Horizontal Well[17]



Water

- Producing one barrel of oil from oil shale uses 2.6 to 4 barrels of water; one barrel of oil from oil sands uses 2.3 to 5.8 barrels of water.[28] In comparison, producing one barrel of crude oil from Saudi Arabia's Ghawar field requires 1.4 barrels of water.[29]
- A horizontal gas well can require 2 to 4 million gallons of water to drill and fracture.[30] One study found shale gas production consumes up to four times more water than producing conventional natural gas.[31]
- CBM production requires groundwater extraction; U.S. CBM basins produce 32 million to 15 billion gallons of water per year.[32]
- Wastewater, produced water, and flowback water from oil and gas extraction can contain excess salts, high levels of trace elements (e.g., barium and iron), and naturally-occurring radioactive materials (NORM).[33] Groundwater can be polluted through above- and below-ground activities, including construction, drilling, chemical spills, leaks, and discharge of wastewater.[34]

Land Impacts and Waste

- More than 70% of U.S. oil shale is on federal land, of which 678,700 acres has been designated for development.[35,36] A 20,000 bbl/day oil sands facility requires 2,950 acres of land and creates 52,000 tons/day of sand waste; a 25,000-30,000 bbl/day oil shale facility requires 300-1,200 acres and creates 17 to 23 million tons/year of waste per retort.[28]
- One gas well requires one to two hectares of land, in addition to road networks.[37] Drilling fluid, or "mud," is used to cool the drill bit, regulate pressure, and remove rock fragments.[17] One well may require hundreds of tons of mud and produce 110 to 550 tons of rock cuttings.[17]
- Small to moderate magnitude (<6) seismic activity has been linked to underground injection of wastewater produced in oil and gas operations, including a 5.3 and a 5.6 magnitude earthquake in 2011.[38,39] Hydraulic fracturing has been associated with microearthquakes (magnitude <2), but no association has been found with larger magnitude events.[40] However, there has been an increase in seismic activity in the past several years. There were an average of 99 M3+ earthquakes in central and eastern U.S. between 2009-2013 and 658 M3+ earthquakes were recorded across the country in 2014. There were, on average, 21 M3+ earthquakes per year between 1973 and 2008.[41]
- The human toxicity impact (HTI) of electricity produced from shale gas is estimated to be 1-2 orders of magnitude less than that from coal. Particulate matter is the dominant factor for both systems.[42]

Solutions and Sustainable Alternatives

- Chemicals used in hydraulic fracturing fluid are often considered proprietary.[37] Requiring companies to disclose these chemicals will lead to better understanding of the risk to public health from their use.[30] 18 U.S. states require disclosure and 9 others have proposed legislation.[43]
- Careful siting and monitoring of injection wells can reduce the potential for seismic events.[17]
- Water consumption in oil and gas extraction can be significantly reduced through efficiency improvements and the recycling of wastewater.
- Support policies that increase energy efficiency and renewable energy use. Although natural gas has been considered preferable to other fossil fuels because it is less expensive and burns more cleanly, it ultimately remains a nonrenewable, fossil-based resource.

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