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A Perspective of the Oil and Gas Industry

Oil was always used for commercial purposes like lighting and heating for a long time. In 1859, the first commercial oil well was drilled for the purpose of finding oil and using it for industrial purposes

What does crude oil contain?

- Crude oil is a naturally occurring fossil fuel – meaning it comes from the remains of dead organisms like algae
- Crude oil is made up of a mixture of hydrocarbons – hydrogen and carbon atoms, methane, ethane, propane, and butane exist as gases, while pentane exists as liquids
- An oil well predominantly produces crude oil, which is mixed a bit with natural gas, mainly methane
- A gas well produces natural gas predominantly with very little crude
- Crude oil is often referred to as petroleum. This is because petroleum includes both the unrefined crude oil as well as refined petroleum products.

The oil and gas industry has the following stages of oil extraction:

Upstream – Exploration and Production
Midstream – Transportation
Downstream – Refining and Marketing

The Power of Artificial Intelligence for the Next-Generation Oil and Gas Industry: Envisaging AI-Inspired Intelligent Energy Systems and Environments, First Edition. Pethuru Raj Chelliah, Venkatraman Jayasankar, Mats Agerstam, B. Sundaravadivazhagan, and Robin Cyriac.

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1.1 Exploration and Production

Oil and gas exploration encompasses the processes and methods involved in locating potential sites for oil and gas drilling and extraction. Early oil and gas explorers relied upon surface signs like natural oil seeps, but developments in science and technology have made oil and gas exploration more efficient.

In the past, surface features such as tar seeps or marks provided initial clues to the location of shallow hydrocarbon deposits. Today, accurate geological surveys are conducted using various means for exploration. Rock or sand surveys are done to see if there can be any possible deposits under the surface. Seismic surveys are also conducted by geologists to find oil deposits under the surface. If a site seems to have oil, an exploratory well is drilled and if there are deposits worth of value, then full-fledged development wells are drilled to extract the oil

Once the prospective reserve is found, companies will start drilling using mobile offshore drilling units (MODU). Once the drilling units find oil, the company will replace it with a more permanent oil production rig to capture oil.

Exploration is of high risk and expensive. The cost of a basic exploration, such as one that involves deep seismic studies, can cost $5–$20 million per exploration site, and in some cases, much more. However, when an exploration site is successful and oil and gas extraction is productive, exploration costs are recovered and are significantly less in comparison to other production costs.

Proven reserves measure the extent to which a company thinks it can produce economically recoverable oil and gas in place, as of a certain point in time, using existing technology.

Once a company identifies where oil or gas is located, plans begin for drilling, and the drilling methods vary depending on the type of oil or gas and the geology of the location.

To drill a well, it is necessary to simultaneously carry out the following drilling process.

- Crush the rocks under the earth to small pieces so that liquid can flow and the drill can travel down to get to the oil or hydrocarbons
- Remove the rock debris and continue drilling
- To make sure the holes do not cave in, preventing the drilling
- Prevent the fluids contained in the drilled formations from entering the well.

This can be achieved by using rotary drilling rigs, which are the ones operating today in the field of hydrocarbon exploration and production. The drills have a conveyor belt which continuously removes the debris that the drill digs out. These modern drills operate with great efficiency, but they can also cause damages to the areas around the drill site if they are not operated according to the conditions. The specialized equipment and complex technology make drilling of oil wells extremely expensive and of high risk.

1.1.1 Onshore

In onshore drilling facilities, the wells are grouped together in a field, ranging from half an acre per well for heavy crude oil to 80 acres per well for natural gas. The group of wells are connected by steel tubes, which send the oil and gas to a production and processing facility where the oil and gas are treated through a chemical and heating process. Onshore production companies can turn on and off rigs more easily than offshore rigs to respond to market conditions due to the need that offshore rigs need to be visited by engineers to inspect and close.

1.1.2 Offshore

Offshore drilling uses a single platform that is either fixed (bottom supported) or mobile (floating secured with anchors). Offshore drilling is more expensive than onshore drilling, and fixed rigs are more expensive than mobile rigs. Most production facilities are located on coastal shores near offshore rigs to reduce expenses and safety issues.

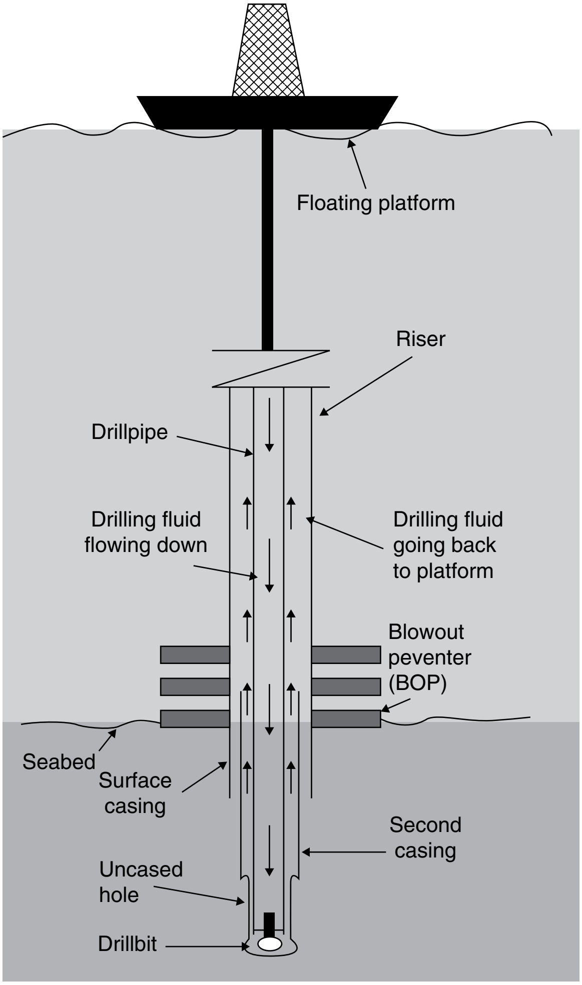
1.1.3 Hydraulic Fracturing

Fracking, or hydraulic fracturing, is a technique where a high-pressure liquid is injected to form cracks or fractures on the rocks to extract oil or gas. The use of fracking has led to recovering gas, and the oil extracted by this method is called shale oil.

Once a prospective reserve is found, companies will drill highly regulated exploration wells with Mobile Offshore Drilling Units (MODUs).

The MODU's job is to drill down into the ocean floor and find oil and natural gas reserves.

Once a well is found, the company switches to a more viable model of production. All the legal entities are created, and in many cases the drill that was used for initial explorations will be used for the production as well. The part of the well that allows the drill bit to drill without interruptions, like a pipe or casing, is called riser. A drilling riser may terminate at the sea floor or may extend slightly into the earth to prevent water infiltration.



Source: EnggCyclopedia.com.

1.2 Midstream Transportation

The midstream sector involves the transportation (by pipeline, rail, barge, oil tanker, or truck), storage, and wholesale marketing of crude or refined petroleum products. Pipelines and other transport systems can be used to transport crude oil from production sites to refineries and deliver the various refined products to downstream distributors. Natural gas pipeline networks aggregate gas from natural gas purification plants and deliver it to downstream customers, such as local utilities.

Midstream activity starts after oil and gas is extracted. Once the gas is extracted from the wells, it must be refined. Midstream activity consists of the different process steps to transport and refine the oil.

Modes of transportation include the following:

Oil tankers: A tank vessel as one that is constructed or adapted to carry oil or hazardous material in bulk as cargo or cargo residue – as defined by the US Coast Guard. There are various types of tankers like oil, parcel tanker, combination, and barges. Many oil companies work on upstream, downstream, midstream and hence considered integrated. In many countries, midstream business does not exist as a separate business and is combined with upstream business.

LNG tankers: High-pressure possibility of explosions make it difficult to transport natural gas. For this reason, natural gas is liquefied at extremely low temperatures and transported as LNG via liquefied natural gas (LNG) tankers. LNG tankers are specially designed with double hulls to allow extra ballast water because LNG is lighter than gasoline.

Pipelines: Pipelines can do the work of transporting oil and gas to gathering systems (wellhead to processing facilities), transmission lines (supply areas to markets), or distribution pipelines (most commonly to transport natural gas to medium or small consumer units). Pipelines play a very critical role in the transportation process because most of the oil moves through pipelines for at least part of the route. After the crude oil is separated from natural gas, pipelines transport the oil to another carrier or directly to a refinery. The only challenge is laying of pipelines to get the oil transported.

Strategic planning involves determining the shortest and most economical routes where pipelines are built, the number of pumping stations and natural gas compression stations along the line, and terminal storage facilities so that oil from almost any field can be shipped to any refinery on demand.

Railroad/tank trucks: Historically, before the introduction of pipelines, railroads were used to transport petroleum. Today, railroads compete with pipelines. The existing railroad infrastructure creates a more flexible, alternative route when pipelines are at capacity. For instance, many a times, a railroad exists; however, laying a pipeline becomes a huge challenge. The railroad would have been laid before the actual development or roadblocks came up due to growth in the area, and it would now become a challenge to create new pipelines. Also, there are many chances of pipelines breaking or getting damaged. Reaching a damaged pipeline maybe a difficult task for engineers, and it is time-consuming. However, transporting oil by railroads has its own set of challenges.

Storage of oil and natural gas helps smooth out supply and demand discrepancies. Companies store more when the prices are lower than they would like and withdraw when prices are high. The oil storage is also done by different countries and is known as strategic oil reserves. Strategic oil reserves usually help a country when there are issues in oil supply due to natural calamities, man-made issues, etc. The cheapest storage method is underground tanks, such as depleted reservoirs. This method is primarily used for natural gas. Aboveground tanks are used for crude and refined oil, finished oil products, and natural gas. At retail locations, like gas stations, tanks are stored underground for safety reasons.

1.3 Downstream – Refining and Marketing

Downstream covers refining and marketing, or in some organizations it is trading and supply. The goal of refining is straightforward, to take crude oil, which is virtually unusable in its natural state, and transform it into petroleum products used for a variety of purposes and then sell it. Downstream depends on upstream for a steady supply of crude oil to help refine the oil and supply downstream.

One of the key processes involved in refining depending on the product needed is hydrotreating.

1.3.1 Hydrotreating

Hydrotreating or hydrodesulfurization refers to a set of operations that remove sulfur and other impurities. During hydrotreating, crude oil is made to react with hydrogen in the presence of a catalyst at relatively high temperatures and moderate pressure.

Hydrotreating helps petroleum refineries transform crude oil into useful fuels and products while satisfying government safety requirements. One of the most common issues is nickel catalyst poisoning by sulfur, which is present in the crude form extracted from catalytic beds.

Marketing is the wholesale and retail distribution of refined petroleum products to business, industry, government, and public consumers. Marketing is also known as trading and supply in some organizations.

Gasoline service stations handle the bulk of public consumer sales, and oil companies sell their petroleum products directly to factories, power plants, and transportation-related industries. Natural gas sales are almost evenly divided between industrial consumers, electrical providers, and residential and commercial heating.

In simpler terms, upstream operations include oil and gas production, midstream includes storage and transportation, and downstream includes distribution and retail outlets.

1.4 Meaning of Different Terms of Products Produced by the Oil and Gas Industry

1.4.1 Natural Gas

Natural gas is a fossil fuel. Natural gas contains many different compounds. The components of natural gas include methane, natural gas liquids (NGLs, which are also hydrocarbon gas liquids), and nonhydrocarbon gases, such as carbon dioxide and water vapor. We use natural gas as a fuel and to produce materials and chemicals. Natural gas is the cleanest burning hydrocarbon. A natural gas-powered station takes lesser time to start and stop compared to a coal-powered station. The main natural gases are methane, ethane, butane, and propane.

It is used for many things, especially in the home. Some common examples are as follows:

- Home heating through furnaces
- Warming water in water heaters
- Cooking food on barbecues and gas-burning stoves
- Operating gas fired fireplaces

1.4.2 Extraction

Natural gas, being an unconventional gas, must be extracted from deeper areas below the surface of the Earth. It consists of fracking or fracturing the rocks, passing water in high pressure to simulate the gas to flow via the pipes to the surface.

1.4.3 Advantages and Disadvantages

Natural gas has a high energy density and can be used flexibly for multiple applications, which make it a popular fuel. People advocating using natural gas often point to it as the cleanest burning fossil fuel. Even as a cleanest burning fossil fuel, natural gas is still composed of hydrocarbons, and burning it releases CO_2 and other pollutants (NOx being a problem specifically). Natural gas use is often an improvement over that of coal; however, its combustion still contributes to air pollution and climate change.

With advances in fracking techniques, natural gas reserves are expected to last a long time.

Natural gas power plants generate electricity by burning natural gas as their fuel. There are many types of natural gas power plants which all generate electricity but serve different purposes. All natural gas plants use a gas turbine; natural gas is added, along with a stream of air, which combusts and expands through this turbine, causing a generator to spin a magnet, producing electricity.

Natural gas power plants are cheap and quick to build. They also have very high thermodynamic efficiencies compared to other power plants. Burning of natural gas produces fewer pollutants like NO_x, SO_x, and particulate matter than coal and oil.

Despite the improved air quality, natural gas plants significantly contribute to climate change, and that contribution is increasing. Natural gas power plants produce considerable carbon dioxide, although less than coal plants do. On the other hand, the process of getting natural gas from where it is mined to the power plants leads to considerable release of methane (natural gas leaks into the atmosphere). If natural gas plants are used to produce electricity, their emissions will continue to warm the planet in dangerous ways.

1.4.4 Types

The use of natural gas accounts for around 23% of the world's electricity generation.

This is second only to coal, and the fraction that is natural gas is expected to grow in coming years. This means that the contribution of natural gas to climate change will continue to increase.

1.4.5 Types of Natural Gas Deposits

Natural gas can be contained in a variety of different types of deposits that must be accessed if the natural gas is to be used. According to the Canadian Association of Petroleum Producers (CAPP), Canada has a natural gas reserve of between 700 and 1300 trillion cubic feet. While a little over 15% of that natural gas has been recovered, the rest is contained in four types of deposits: conventional and unconventional deposits: shale gas deposit, tight gas deposit, and coal bed methane.

Natural gas has been extracted from conventional natural gas deposits for a long time; the unconventional resources are resources that are being extracted using substantially new techniques.

1.4.6 Conventional Natural Gas Deposits

Conventional resources are gas contained within relatively porous rock, and they are the most easily mined. While hydraulic fracturing has allowed for more expansive access to these deposits, they can be mined without its use.

1.4.7 Coal Bed Methane

Coal bed methane is natural gas consisting mostly of methane, which is trapped inside coal deposits under the surface. This is extracted while the coal is being mined, as the diminishing pressure in the coal seam allows the gas to flow out of the seam and into a wellbore, where it is extracted.

1.4.8 Shale Gas

Shale gas is natural gas found inside a fine-grained sedimentary rock called shale. Shale is porous (there are lots of tiny spaces inside it), but it is non-permeable, which means the gas cannot flow through it. Shale gas requires the use of hydraulic fracturing for extraction.

1.4.9 Tight Gas

Tight gas is like shale gas, in that it is trapped inside a porous, non-permeable reservoir rock. The only differentiation between the two is that the term tight gas includes natural gas trapped inside reservoir rocks that are not shale.

1.4.10 Environmental Impacts of Natural Gas

1.4.10.1 Global Warming Emissions

Natural gas is a fossil fuel at the end of the day, which means there will be environmental impacts starting from drilling for gas, emissions during combustion, etc., though the global warming emissions from its combustion are much lower than those from coal or oil.

Natural gas emits 50–60% less greenhouse gases when combusted in a new, natural gas power plant compared with emissions from a typical new coal plant. Considering only tailpipe emissions, natural gas also emits 15–20% less heat-trapping gases than gasoline when burned in today's typical vehicles.

Drilling and extraction of natural gas from wells and its transportation in pipelines results in the leakage of methane, the primary component of natural gas, which is many times more stronger than CO_2 at trapping heat, which results in environmental hazards.

The emissions created by natural gas usually depend on the assumed leakage of methane, which is eventually a major reason for trapping the heat. One study found that methane losses must be kept below 3.2% for natural gas power plants to have lower life cycle emissions than new coal plants over short time frames of 20 years or lesser. This means implementation of more tighter controls and better systems to make sure the losses are monitored and reduced as per need. Similarly, vehicles burning natural gases must also keep methane losses much below 1% and 1.6% compared with those burning diesel fuel and gasoline, respectively. Technologies are available to reduce much of the leaking methane, but deploying such technology would require new policies and investments.

1.4.10.2 Air Pollution

Combustion of natural gas produces negligible amounts of sulfur, mercury, and other particulate matter. Burning natural gas does produce nitrogen oxides (NOx), which are precursors to smog, but at lower levels than gasoline and diesel used for motor vehicles. DOE analyses indicate that every 10,000 U.S. homes powered with natural gas instead of coal avoids annual emissions of 1900 tons of NO_x, 3900 tons of SO_2, and 5,200 tons of particulate matter. Reductions in these emissions translate into public health benefits.

However, despite these benefits, unconventional gas development can affect local and regional air quality. Some areas where drilling occurs have experienced increases in concentrations of hazardous air pollutants. Exposure to elevated levels of these air pollutants can lead to adverse health outcomes, including respiratory problems, cardiovascular diseases, and cancer. Another study found that residents living less than half a mile from gas well sites were at greater risk of health effects from air pollution from natural gas development than those living farther from the well sites.

1.4.10.3 Land Use and Wildlife

The construction and land required for oil and gas drilling can alter land use and harm local ecosystems by causing erosion and fragmenting wildlife habitats and migration patterns. When oil and gas operators clear a site to build a well pad, pipelines, and access roads, the construction process can cause erosion of dirt, minerals, and other harmful pollutants into nearby streams.

1.4.10.4 Water Use and Pollution

Unconventional oil and gas development can produce health risks by contaminating water and making people around fall sick. The hazardous chemicals which were once deep under the surface are drilled, and some of them get mixed with the water, causing serious contamination of water resources. There are many instances where clean water gets completely contaminated by chemicals as a result of deep drilling for oil and gas. Radioactive chemicals and methane can pose major health risks when leaked into the water supplies by carelessness or leaks or both.

The large volumes of water used in unconventional oil and gas development also raise water availability concerns in some communities.

1.4.10.5 Groundwater

There have been multiple documented instances of ground water getting contaminated with fracking or other fluids that are used to explore shale oil. One of the key challenges when ground water gets contaminated is that there are little options to clean up the mess that is created, and there must be a massive people/livestock relocation due to safety concerns. One major cause of gas contamination is improperly constructed or failing wells that allow gas to leak from the well into groundwater.

Another potential avenue for groundwater contamination is natural or man-made fractures in the subsurface, which could allow stray gas to move directly between an oil and gas formation and groundwater supplies.

In addition to gases, groundwater can become contaminated with hydraulic fracturing fluid. In several cases, groundwater was contaminated from surface leaks and spills of fracturing fluid.

1.4.10.6 Surface Water

Unconventional oil and gas development also poses contamination risks to surface waters through spills and leaks of chemical additives, spills and leaks of diesel or other fluids from equipment on-site, and leaks of wastewater from facilities for storage, treatment, and disposal. Unlike groundwater contamination risks, surface water contamination risks are mostly related to land management and to on- and off-site chemical and wastewater management.

There has been more than 1000 chemical additives identified that are used for hydraulic fracturing, including acids (notably hydrochloric acid), bactericides, scale removers, and friction-reducing agents. Large quantities – tens of thousands of gallons for each well – of the chemical additives are trucked to and stored on a well pad. If not managed properly, the chemicals could leak or spill out of faulty storage containers or during transport.

Drilling debris, diesel, and other material/fluids that are used when drilling can also spill at the surface, creating temporary or permanent damage. Improper management of flowback or produced wastewater can cause leaks and spills. There is also risk to surface water contamination from improper disposal. This could lead to areas around the drill site getting impacted: earthquakes around the drill site, water issues, and agriculture getting impacted and many more.

1.4.10.7 Water Use

The growth of hydraulic fracturing and its use of huge volumes of water per well may strain local ground and surface water supplies, particularly in water-scarce areas. The amount of water used for hydraulically fracturing a well can vary because of differences in formation geology, well construction, and the type of hydraulic fracturing process used The EPA estimates that 70–140 billion gallons of water were used in 2011 for fracturing an estimated 35,000 wells. This water is not sea water or ground water, which can get years to be replenished. Unlike other energy-related water withdrawals, which are commonly returned to rivers and lakes, most of the water used for unconventional oil and gas development is not recoverable. Depending on the type of well along with its depth and location, a single well with horizontal drilling can require 3–12 million gallons of water when it is first fractured – dozens of times more than what is used in conventional vertical wells. Similar vast volumes of water are needed each time a well undergoes a "work over," or additional fracturing later in its life to maintain well pressure and gas production.

1.4.11 The Future of Natural Gas

Replacing coal with natural gas in the electricity sector is not an effective long-term climate strategy.

Low natural gas prices and recent increases in the cost of generating electricity from coal have resulted in a significant shift from coal to natural gas over the past few years. With sufficient regulatory oversight, burning natural gas instead of coal could help reduce air pollution, providing immediate public health and environmental benefits. And because natural gas generators can be ramped up and down quickly, they could support the integration of wind and solar energy, provide increased flexibility to the electricity system, and continue to be used to meet peak demand.

Natural gas can also play an important role in meeting peak electricity demand and fueling cogeneration plants that generate both heat and power – which are up to twice as efficient as plants that only generate electricity using highly efficient technologies that provide both heat and power in the commercial and industrial sectors. The greenhouse emissions produced by natural gas are half the amount of emissions produced by coal when it is burnt.

However, natural gas is by no means a silver bullet solution for the environmental problems caused by our energy use. There is broad agreement among climate scientists that carbon reductions of at least 80% by 2050 will be needed to avert the worst effects of climate change. Simply switching to natural gas from coal and oil will not ultimately bring about the necessary reductions as natural gas pollutes the atmosphere and emits greenhouse gases when burnt, and in addition, the development of our newly discovered shale gas resource will disturb areas previously untouched by oil and gas exploration and raise serious water management, contamination, and other disturbances for the habitat.

Also, using natural gas as the primary source of electricity will motivate companies to find more sources, which means more contamination and polluting of the surroundings. The better option would be going in for a good mix of generating electricity by getting energy from renewable resources along with other sources. This mix coupled with renewables can provide an important hedge against future natural gas price increase.

Thus, while natural gas has a role to play in our future electric mix, a natural gas-centered energy pathway would also carry significant economic, environmental, and public health risks. Instead, a diversified electricity system – with amplified roles for renewable energy and energy efficiency and a modest role for natural gas – would both limit the threat of climate change and mitigate the risks of an overdependence on natural gas.

1.4.11.1 Liquefied Natural Gas (LNG)

Decades ago, the fossil fuel industry figured out how to transport gas by ships, in its quest to open markets beyond the domestic pipeline network. Its trick – liquefying natural gas – was a boon for energy companies. However, there were issues in that too. Liquefying huge volumes of natural gas to transport them to other places (that cannot be connected by pipelines) is no less carbon-intensive. The energy/electricity needed to chill, ship, and regasify the natural gas makes it far more carbon-intensive and increases the potential for leakage of dangerous methane. In addition, once there is a way to store huge volumes of gas through massive long-term infrastructure projects, it would mean more hazards to the environment, and this could make it impossible to limit global warming to 1.5°C.

What Was the Issue and Why Was Liquefaction Invented? The fossil fuel known as "natural gas" or "fracked gas" – the stuff frackers are after – exists in a gaseous state at room temperature. Natural gas is part of unconventional gas since it mostly needs to be drilled from deep under the surface from shale rock. The conventional oil is drilled from far lesser deeper rock like limestone or sandstone.

This presents a problem for transport. Since gases are made up of substantial empty space with just a few molecules bouncing around, it would take a massive container to ship a useful amount of gas by road or rail. That leaves pipelines as the primary means to transport gas at room temperature. This huge amount of new gas needs to be transported, and that needs to be done quickly without the need for laying of pipelines.

Enter liquefied natural gas (LNG). By cooling natural gas to −259°F – a very energy-intensive undertaking—processors can transform it into a denser liquid. (For context, the coldest temperature ever recorded outdoors on Earth is −135.8°F.) This liquid is then loaded into specialized oceangoing containers, which look like gigantic domes rising from the ship's deck.

Shippers have a trick to keep the LNG cold and in a liquid state during its long maritime journey. The product is loaded onto the ship at its condensation point of −259°F. As the storage container absorbs heat from the outside air, that energy goes toward converting small amounts of the LNG back into its gaseous form. The regasified molecules are directed out of the storage container and into the ship's engines, where they power the ship. Most of the LNG, however, remains in its liquid state until it reaches its destination, where it is regasified and transported through existing pipelines to consumers.

What Is Liquefied Natural Gas Used For? Once LNG is regasified at room temperature, it is used the same way as any natural gas – it is burned to generate electricity, heat, and cooking fuel in homes and businesses, as well as processed for plastics or other petrochemical products. LNG can also be used as a vehicle fuel without being returned to its gaseous form. But, since holding the liquid at −259°F is difficult, LNG's transport use is limited

Power plants also use LNG as a backup fuel. By cooling gas, utilities are able to store LNG on-site in cryogenic tanks. When demand peaks, or supply drops due to limited pipeline availability, the utility returns the LNG to its gaseous state and burns it to generate electricity.

What Are the Differences Between Raw, Compressed, and Liquefied Natural Gas? Raw natural gas is the name for unprocessed natural gas that has just been pumped from the ground. Because raw natural gas is unprocessed, it contains several components (like water, nitrogen, sand particles, rocks, and carbon dioxide) that must be removed.

Once the natural gas has been separated into its useful parts, there are two ways to make it dense enough to transport: compressing it or liquefying it.

Compressed natural gas (CNG) is gas that has been physically stuffed into a chamber, which is then gradually shrunk. CNG has 100 times as much energy as the same volume of uncompressed gas and can be stored at room temperature.

Liquefied natural gas, as mentioned, is chilled and liquefied gas held at very cold temperatures. Although LNG comes with storage and transport challenges, it is much more energy-dense than CNG – and about 600 times more energy-dense than ordinary gas.

LNG is an especially problematic form of natural gas for the climate. Chilling gas to incredibly cold temperatures uses much energy. Holding it at that temperature also uses energy. Transporting it by ship, rail, and truck uses energy. So, liquefying natural gas causes additional emissions and energy use to even get the natural gas to its usable state. Warming it back up also uses a lot of energy. When you add all of that up, LNG is responsible for almost twice as much greenhouse gas as ordinary natural gas, including from gas leaks, flaring, or intentional venting (for example, when operators release gas into the atmosphere to allow for maintenance on a pipe) during production and transport.

1.4.11.2 Compressed Natural Gas (CNG)

CNG comprises

- Mostly methane gas which, like gasoline, produces engine power when mixed with air and fed into your engine's combustion chamber.
- When CNG reaches the combustion chamber, it mixes with air, is ignited by a spark, and the energy from the explosion moves the vehicle.

- CNG is compressed so that enough fuel can be stored in your vehicle to extend the driving range, much like the gasoline tank in vehicle.
- Although vehicles can use natural gas as either a liquid or a gas, most vehicles use the gaseous form compressed to 3000 psi. CNG is produced by compressing natural gas to less than 1% of its volume at standard atmospheric pressure.

Due to the high production cost of CNG, it must be stored in cryogenic tanks, and hence CNG use in commercial applications has been limited.

Hydrocarbon resources are resources that contain both hydrogen and carbon. Hydrocarbon resources are often known as fossil fuels (natural gas, oil, and coal) since hydrocarbons are the primary constituents in these.

1.4.12 CNG vs. Liquid Fuels

- CNG is one of the most viable alternatives to traditional liquid fuels for vehicles.
- CNG is called as clean fuel because it is free from lead and sulfur and reduces harmful emissions. It is also lighter than air; hence, if there are leaks, it rises up, disperses into the atmosphere, and mixes easily and evenly
- CNG is approximately one-fifth the price of gasoline, resulting in substantial savings in fuel costs.
- CNG reduces maintenance costs since it contains no additives and burns cleanly, leaving no by-products of combustion to contaminate your spark plugs and engine oil.
- The combustion chamber parts function at peak output for longer periods before requiring service. The engine oil also remains clean, which minimizes engine wear and requires less frequent changes.
- CNG is more environment-friendly, and CNG engines are much quieter due to the higher octane rating of CNG over gasoline.
- CNG produces less exhaust emissions, and as a result, harmful emissions such as carbon monoxide (CO), carbon dioxide (CO_2), and nitrous oxide (N_2O) are generally reduced by as much as 95% when compared to gasoline-powered vehicles.
- CNG is the safe bet as its components are designed and made to international standards and are monitored to ensure safe operation.
- CNG fuel systems are also sealed, which prevents any spill or evaporation losses.

The extraction and processing cost of CNG makes it a very expensive proposition to use as fuel.

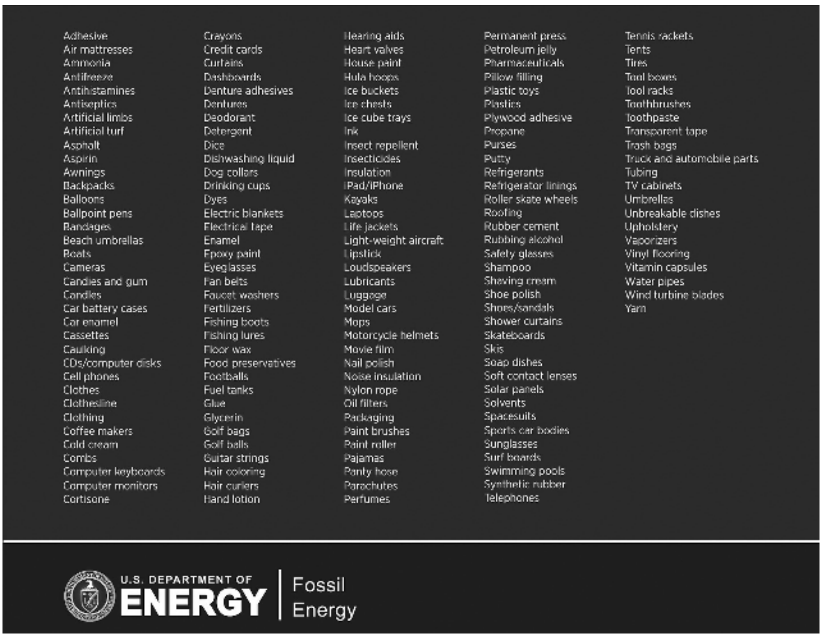
1.4.13 Unconventional Oil and Gas

Unconventional resources are generally oil or natural gas resources that do not appear in traditional formations and must use specialized extraction or production techniques to obtain. Fracking or hydraulic fracturing is increasing the viability of the extraction of these resources.

Examples of unconventional deposits are shale oil, oil sands (refer to a mixture of sand, water, clay, and bitumen), shale gas, tight gas (type of natural gas), and coal bed methane (natural gas stored in coal beds).

The reservoirs described earlier are called conventional sources of oil and gas. As demand increases, prices increase, and new conventional resources become economically viable. At the same time, production of oil and gas from unconventional sources becomes more attractive. These unconventional sources include very heavy crudes, oil sands, oil shale, gas, and synthetic crude from coal, coal bed methane, methane hydrates, and biofuels.

Products produced by the oil and gas industry are as follows:



1.5 Oil and Gas Pricing

Oil and gas pricing is determined very carefully as the oil price has political ramifications. Oil prices are based on barrels of oil as the unit. A barrel of oil is equivalent to 42 US gallons or 159 l.

Price benchmarks are used in the oil and gas industry to give buyers a way to value the commodity based on quality and locations. The main benchmarks used in this industry are as follows:

- **Brent blend** is the most common, internationally used oil benchmark. It is based in London, traded on the InterContinental Exchange (ICE), and consists of light, sweet crude oil from offshore drilling in the North Sea.

- **West Texas intermediate (WTI)** is used for light and sweet oil in the United States, specifically crude oil that comes from land-locked wells in Oklahoma.
- **Dubai/Oman** is used for heavier oil, with a higher sulfur content from the Persian Gulf to the Asian market.
- **Henry Hub** is the benchmark for North American natural gas and global liquefied natural gas (LNG), based off of the Henry Hub natural gas pipeline in Louisiana

1.6 A Note on Renewable Energy Sources

What is renewable energy?
Renewable energy, as the term indicates, is the energy that can be renewed naturally. It is energy from sources that can be naturally replenished

The major types of renewable energy sources are as follows:

- Biomass
- Hydropower
- Geothermal
- Wind
- Solar

1.6.1 Biomass

Biomass is obtained from plants and animals. Biomass contains stored chemical energy from the Sun. Biomass can be burned directly for heat or converted to renewable liquid and gaseous fuels through various processes.

Biomass sources for energy include the following:

- **Wood and wood processing wastes**: firewood, wood pellets, and wood chips, lumber and furniture mill sawdust and waste, and black liquor from pulp and paper mills
- **Agricultural crops and waste materials**: corn, soybeans, sugar cane, switchgrass, woody plants and algae, and crop and food processing residues, mostly to produce biofuels
- **Biogenic materials in municipal solid waste**: paper, cotton, and wool products and food, yard, and wood wastes
- Animal manure and human sewage for producing biogas/renewable natural gas.

1.6.2 Hydropower

Hydropower is generated by fast-moving water in a large river or rapidly descending water from a high point and converts the force of that water into electricity by spinning of a generator's turbine blades. Hydropower is used in almost all countries where there is forceful waterflow.

1.6.3 Geothermal

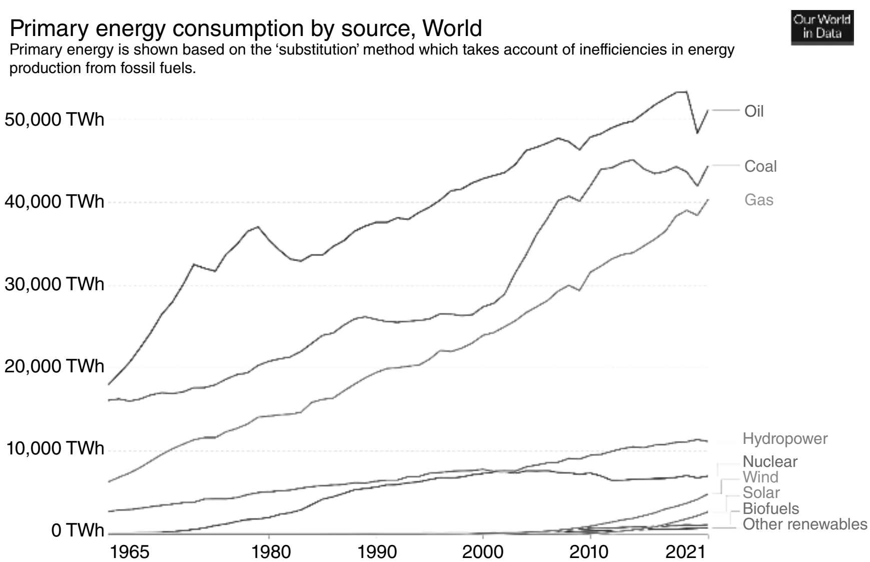
The Earth's core is about as hot as the Sun's surface, due to the slow decay of radioactive particles in rocks at the center of the planet. The water that has seeped into the Earth's crust heats up and comes out as steam. This steam is captured and used for powering a turbine, which in turn will run a generator.

1.6.4 Wind

Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones. Offshore wind power offers tremendous potential.

Wind energy is obtained by harnessing the kinetic energy of moving air by using large wind turbines located on land (onshore) or in sea or freshwater (offshore). Large windmills are installed in the areas where huge winds are expected, and the blades when turned run a turbine, which in turn produces power.

Though average wind speeds vary considerably by location, the world's technical potential for wind energy exceeds global electricity production, and ample potential exists in most regions of the world to enable significant wind energy deployment.



1.6.5 A Note About Hydrogen

Hydrogen, looked up as an energy hydrogen, is a clean fuel that, when consumed in a fuel cell, produces only water. Hydrogen can be produced from a variety of domestic resources, such as natural gas, nuclear power, biomass, and renewable power like solar and wind. These qualities make it an attractive fuel option for transportation and electricity generation applications. It can be used in cars, in houses, for portable power, and in many more applications.

1.6.6 How is Hydrogen Produced

There are four main sources that can help in extracting or producing hydrogen: natural gas, oil, coal, and electrolysis. The predominant composition of oil is hydrocarbon, which is a mix of hydrogen and carbon, and extracting hydrogen is one possible way of producing hydrogen.

1.6.7 Production of Hydrogen

Today, hydrogen fuel can be produced through several methods. The most common methods today are natural gas reforming (a thermal process) and electrolysis. Other methods include solar-driven and biological processes.

Synthesis Gas: Natural gas is reacted with high-temperature steam, which creates a mixture of carbon monoxide, hydrogen, and carbon dioxide. The carbon monoxide is reacted with water to produce more hydrogen.

1.6.8 Electrolysis

An electric current splits water into hydrogen and oxygen. If the electricity required to split the water comes from renewable resources, then the hydrogen is considered a fully renewable resource.

1.6.9 Biological Processes

Biological processes use microbes such as bacteria and microalgae and can produce hydrogen through biological reactions. In microbial biomass conversion, the microbes break down organic matter like biomass or wastewater to produce hydrogen.

1.6.10 Converting Hydrogen to Hydrogen-Based Fuels

Hydrogen has low energy density, which makes it more challenging to store and transport than fossil fuels. However, it can be converted into hydrogen-based fuels such as synthetic methane, synthetic liquid fuels, and ammonia, which can make use of the existing infrastructure for their transport, storage, and distribution. This can reduce the costs of reaching end users. Some of the synthetic hydrocarbons produced from hydrogen can be direct substitutes for their fossil equivalents.

1.7 Environmental Impact

As of 2020, most hydrogen is produced from fossil fuels, resulting in carbon dioxide emissions. This is often referred to as **gray hydrogen** when emissions are released to the atmosphere, and **blue hydrogen** when emissions are captured through carbon capture and storage (CCS). Blue hydrogen has been estimated to have a greenhouse gas footprint 20% greater than that of burning gas or coal for heat and 60% greater when compared to burning diesel for heat.

Hydrogen produced using the newer, non-polluting technology like methane pyrolysis is often referred to as **turquoise hydrogen**. High-quality hydrogen is produced directly from natural gas by splitting methane (from in natural gas) into hydrogen and carbon.

Hydrogen produced from renewable energy sources is often referred to as **green hydrogen**. There are two ways of producing hydrogen from renewable energy sources. One is to use power to gas, in which electric power is used to produce hydrogen from electrolysis of water, and the other is to use landfill gas to produce hydrogen in a steam reformer. Hydrogen fuel, when produced by renewable sources of energy like wind or solar power, is a renewable fuel.

Turquoise hydrogen has been touted as a game changer.

One major factor here is that the methane pyrolysis process does not result in any CO_2 emissions, so there is no need to invest in carbon capture facilities and no need to worry about where to store it.

Especially while electrolyzer capacity worldwide is building up, methane pyrolysis could provide another effective route toward generating carbon-free hydrogen, helping build the hydrogen value chain.

1.8 Uses of Hydrogen

So why is there so much buzz about the benefits of hydrogen as an energy transition fuel?

One of its key advantages is that it is the perfect complement to renewables. Wind, solar, and other renewables remain vital for the global energy transition, and they can be complemented by on-demand power generation when the output from renewable sources cannot meet all the electricity demands. Part of the reason is hydrogen's potential to help decarbonize sectors like hard-to-abate industries, mobility, and power generation.

1.8.1 Challenges in Using Hydrogen as a Fuel

1.8.1.1 Old Product, Old Problems

This is not the first time hydrogen has been hailed as the fuel of the future. It powered the first internal combustion engine in 1806. In 1970, the term hydrogen economy was coined after a report by a US academic Lawrence Jones started hydrogen hype in the country, which eventually died down in the 1980s.

Today, hydrogen produced from fossil fuels, without capturing the carbon, is used mainly in the chemicals and refining industries. It is responsible to 830 million tons of CO_2 emissions per year, equivalent to the annual emissions of the UK and Indonesia combined.

While green hydrogen will avoid this pollution, many old problems remain, most notably how to store it safely. While less toxic and more readily dispersed than natural gas, hydrogen has a wide range of flammable concentrations in air and lower ignition energy than petrol or natural gas, which means it can ignite more easily.

Currently, hydrogen storage requires extremely high pressure and is therefore too expensive and inefficient for widespread use in vehicles.

With technologies advancing and other forms of fuel becoming easier to produce, maintain, and renew, it is only a matter of time before the world finds a replacement for fossil fuels as a renewable way to produce energy

Most of the air pollution occurs due to incomplete burning of fossil fuels. Coal and oil are burnt for generating electricity, fuel for transportation, etc. Inhaling air induced with pollutants due to the burning of natural gas and fossil fuel reduces the heart's ability to pump enough oxygen, hence causing one to suffer from various respiratory and heart illnesses. One of the solutions that is being explored is to use nuclear-fired power plants instead of coal-fired power plants.

Nuclear power is the use of nuclear reactions to produce electricity. Nuclear power can be obtained from nuclear fission, nuclear decay, and nuclear fusion reactions.

However, disposal of nuclear waste, health hazard in case of accident within the power plants, and many more challenges are faced by commissioning a nuclear power plant. While a nuclear power plant may not be ideal, it is one of the least polluting in the current scenario.

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