Overview: Fossil Fuels
All fossil energy sources fall under one of three broad categories: (1) coal, (2) petroleum, or (3) natural gas. These fossil resources are so called because their energy content comes from prehistoric organic life. Over millions of years, this organic matter was buried under layer upon layer of rock and was eventually transformed due to temperature and pressure. The type of fossil fuel formed is a product of the organic matter present, how long it was buried, and the specific temperature and pressure conditions to which it was subjected.

Unconventional Fossil Fuels
Unconventional fossil resources are those forms of coal, petroleum, and natural gas that have historically been economically or technically infeasible to produce. Generally, this is due to the geologic location of the fuel source, host rock composition, and the methodology necessary to acquire and refine it. Unconventional fossil fuels include the following:

- Shale gas, tight gas, coalbed methane, and gas-to-liquids
- Oil Sands, shale oil, oil shale, and heavy oil
- Coal-to-liquids

With recent advances in technology and increasing demand for domestic fossil fuels, many unconventional resources have become economically viable. One of the best examples of this pattern is shale gas in the United States.

Unconventional Natural Gas

Types
Unconventional natural gas includes shale gas, tight gas, coalbed methane, and gas-to-liquids. As the name suggests, shale gas is natural gas that is trapped within a low-permeability rock called shale, “a fine-grained sedimentary rock that forms when silt and clay-size mineral particles are compacted... [shale] is easily broken into thin, parallel layers”. Tight gas describes pockets of natural gas located within low-permeability reservoir rock such as sandstone or carbonate. Coalbed methane is methane gas located within a coal reservoir. Finally, gas-to-liquids is a process by which natural gas is converted into liquid fuels such as gasoline, jet fuel, and diesel.

There are also a variety of designations that describe natural gas more generally. These are provided in the table below:

<table>
<thead>
<tr>
<th>Key Terms: Natural Gas</th>
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<tbody>
<tr>
<td>Dry</td>
</tr>
<tr>
<td>Wet</td>
</tr>
<tr>
<td>Sweet</td>
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</tbody>
</table>
Sour | Natural gas with a relatively high sulfur content
---|---
Clean | Natural gas with a relatively low CO\textsubscript{2} content
Dirty | Natural gas with a relatively high CO\textsubscript{2} content

Trends

*Figure 1. US dry natural gas production by source, 1990-2040. Source: US Energy Information Administration*

In the United States, unconventional natural gas production has increased dramatically from 2005 to present. As demonstrated by Figure 1, this increase in unconventional natural gas - a product of advances in development and production technologies - contributed in large part to overall dry production climbing from less than 20 trillion cubic feet in 2005 to well over 25 trillion cubic feet in 2016.

*Figure 2. US natural gas consumption, dry production, and net imports, 1950-2016. Source: US Energy Information Administration*

As a result of this increased production, domestic net imports of natural gas reached multi-decade lows in 2015, as shown in Figure 2. The explosive growth in unconventional natural gas production has also led to significant decreases in domestic natural gas prices since 2005, shown in Figure 3.

*Figure 3. Henry Hub Natural Gas Spot Price. Data source: US Energy Information Administration*

Geographic Distribution

In 2016, just five states accounted for more than 65% of total US dry natural gas production:

- Texas – 24%
- Pennsylvania – 20%
Oklahoma – 9%
Louisiana – 6%
Wyoming – 5%

Key terms: Geology

| Shale Gas Play | "A set of discovered, undiscovered or possible natural gas accumulations that exhibit similar geological characteristics. Shale plays are located within basins, which are large-scale geologic depressions, often hundreds of miles across, which also may contain other oil and natural gas resources." |

In the Eastern US, the main shale gas plays of the Marcellus and Utica formations are located through much of Appalachia. The Devonian play also partially overlaps both the Marcellus and the Utica, though it trends more westward.

In Texas, the Barnett shale formation is notable for being the first major unconventional shale gas play, which demonstrated that shale gas could be produced profitably. Texas is also home to several other significant shale gas plays including the Eagle Ford play, the Barnett-Woodford play, and – the Haynesville-Bossier play.

Many of the other plays run along the American South or up through the center-west of the country and can be seen in Figure 4.

![Figure 4. Shale plays in the continental US. Source: US Energy Information Administration](image)

Extraction

Advances in hydraulic fracturing techniques and horizontal drilling equipment have made unconventional natural gas resources economically viable.

Hydraulic fracturing – often simply called “fracking” – was invented in the 1950s and has been used in shale gas recovery since the 1980s. Fracking is a multistep process in which the low-permeability reservoir rocks associated with unconventional natural gas are perforated and filled with high-pressure fluid mixtures of water, proppants, and chemicals. The exact composition of fracturing fluid varies by well, operator, and location.

Horizontal drilling, first developed in the 1930s, involves drilling vertically down thousands of feet and then continuing horizontally
outward to tap previously inaccessible gas deposits – potentially for miles. Horizontally drilled wells can be multiple times more productive than a regular vertical well due to the greater geographic area they can cover. A single well pad can be drilled and “fracked” horizontally multiple times in different directions, which allows for greater coverage of an area with significantly less well pad construction.

The initial perforations occur along the horizontal track of the well and allow the high-pressure fluid mixture to efficiently fracture the rock. The proppant, usually sand, holds open the small gaps in the rock created by the high-pressure fluid. The chemicals used serve various functions as “friction reducers, biocides, oxygen scavengers, stabilizers, and acids, all of which are necessary to optimize shale gas production.” Finally, when the pressure at the top of the well is released, natural gas that was previously trapped in low permeability rock is able to escape through the fissures held open by the sand, while as much as 20% of the fluid mixture returns back to the surface as “flowback.” A diagram of a horizontal fracking operation is shown in Figure 5.

Figure 5. Graphic representation of a fracking operation. Source: National Energy Technology Laboratory

Wastewater

After the well is established, operators must then dispose of the flowback wastewater produced along with the natural gas. Flowback water is most commonly injected back underground via specialized Class II injection wells. Class II wells are specifically associated with fluids from oil and gas production. This practice is federally regulated via the Safe Drinking Water Act, more specifically through the Underground Injection Control (UIC) program. Injection wells require permitting such that the following attributes are considered:

1. The location of existing wells and other geographical features in the area
2. The well operator’s proposed operating date
3. The injection fluid’s characteristics
4. The injection zone’s geological characteristics
5. The proposed well’s construction details
6. The operator’s demonstration of mechanical integrity

Many operators in regions where deep well injection is not feasible (e.g., Pennsylvania due to its heavily fractured subsurface) transport their wastewater to treatment facilities authorized under the Clean Water Act's National Pollutant Discharge Elimination System. Then, the treated water is discharged, which requires obtaining a permit and the annual reporting of discharges and pollutant amounts.

Recently, many well operators have started recycling flowback for reuse in the fracking process. This practice has become increasingly common in states where discharge standards are more stringent. Wastewater that is recycled for reuse in fracking operations is not subject to federal regulation. Thus, some states have introduced laws to regulate the temporary storage of wastewater on-site, while others require well operators to disclose the chemical composition of their fracking fluid mixture.

Health and Environment

An estimated 90% of US oil and gas wells rely on hydraulic fracturing. Yet, despite its ubiquity, fracking remains a contentious issue with many concerned about the possible dangers that it presents to human health and the environment.

Although there have been a limited number of scientific studies, federal agencies such as the EPA, NIEHS, and Department of Energy have recognized several potential risks that could be associated with fracking. Potential fracking-related health and environmental risks can be divided into four primary categories:

1. Water
2. Air
3. Seismicity

4. Surface disturbance

### Key Terms: Natural Gas

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Stray Gas</td>
<td>Methane leaked from oil and gas operations</td>
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<tr>
<td>Flaring</td>
<td>The burning off of excess natural gas</td>
</tr>
<tr>
<td>Moratorium</td>
<td>A suspension of activity as mandated by law</td>
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### Water

- Large withdrawals of water – which are used as a primary component in the fracking fluid mixture – can stress surface water and/or ground water supplies and lead to shortages.
- Stray gas can contaminate subsurface drinking water due to improper well construction or cracked cement well casings over the lifetime of the well.
- Surface and underground sources of drinking water can be contaminated by spills.
  - This could include accidental releases of flowback during transport, or improper management of storage facilities such as on-site tanks and surface impoundments (pits or ponds).

### Air

- Flaring, heavy equipment operation, and the use of diesel trucks can all contribute to air pollution.
- Chemicals and sand can also become airborne and threaten air quality.

### Seismicity

- Fracking operations have been linked to small-scale earthquakes in various states due to wastewater injection lubricating geologic faults.
  - Most injection wells do not cause seismic activity as a combination of factors is required to induce felt earthquakes.
  - Contributing factors of induced seismicity are thought to include: wastewater volume and injection rates, the presence of large enough faults, the presence of large enough geologic stresses, and the presence of pathways from injection site to fault.

### Surface disturbance

- Noise pollution from increased heavy-vehicle traffic and drilling can affect wildlife and quality of life for residents.
- Clearing land for well construction operations can affect habitat connectivity, wildlife patterns, and stormwater run-off.
- Erosion can occur due to earth disturbing activities (clearing, grading, and excavating).

### RELEVANT EXPERTS

For more resources on hydraulic fracturing, how it works, and its potential environmental and health impacts, explore the following links:

- US Department of Energy | [Hydraulic Fracturing Technology](https://www.energy.gov/energyinformation/hydraulic-fracturing-technology)
- EIA | [Maps: Exploration, Resources, Reserves, and Production](https://www.eia.gov/energyexplained/maps-natural-gas/)
- NOAA | [Fracking](https://www.noaa.gov/fracking)
- EPA | [Unconventional Oil and Natural Gas Development](https://www.epa.gov/energy/unconventional-oil-and-natural-gas-development)