Summary of Chapter 2: Hydraulic Fracturing, Oil and Gas Production, and the U.S. Energy Sector

What is Hydraulic Fracturing?

General Fracking Concepts:
- General concepts of fluid injection under pressure to fracture geologic formation structure
- Concept of fluid pressure being generated by equipment at surface and transferred to subsurface
- Fluid carries a proppant material, whose function is to “prop open” the fractures and keep them open after pressure is released; can be sand or other materials
- Oil and gas can then flow through fractures into well and then to surface
- Process used since late 1940s mainly for vertical wells
- Has evolved to be used for unconventional hydrocarbon reservoirs and may now be vertical, deviated or horizontal in orientation. May be used in previously untapped geologic settings, altering and expanding the geologic settings and altering and expanding the geographic range of oil and gas production activities.
- Wells may be newly drilled or older at the time of fracturing
- Reviews history and notes fracturing now economical enough to become standard practice in oil and gas industry and is characterized by the use of long horizontal wells and higher volumes of complex mixtures of water, proppants and chemical additives for injection as compared to earlier practices.
- Wells are often deep and long; shale gas well are commonly 5,000 to 13,000 feet deep with long horizontal sections of 2,000 to 5,000 feet long (Reviewer note: reminder; one mile is 5,280 feet).

Comparing older standard, historic methods of drilling with newer hydraulic fracking method:
- Conventional wells drill down to hydrocarbons that formed in deeper geologic formations and that migrated up until they accumulated underneath an impermeable layer. (Figure 2-1. Schematic cross-section of general types of oil and gas resources and the orientations of production wells used in hydraulic fracturing). In this case, several methods have traditionally been used for extraction. If the reservoir of oil or gas can be easily reached by drilling and the oil and gas is under sufficient pressure of its own, a drilled well allows hydrocarbons to flow to the surface.
- In other conventional cases, the process may inject water and or carbon dioxide under pressure into the reservoir through one or more nearby wells to help move and enhance production of the oil or gas. In both of these previous cases, producers are removing hydrocarbons that have already accumulated in a relatively accessible form.
- There are several ways to enhance production compared to above. One is to called “enhanced recovery techniques” and involved injecting fluids to influence either reservoir pressure, fluid viscosity or both. Another method to enhance production is hydraulic fracturing and is designed to increase the surface area of the reservoir rock by creating fractures that are propped open, allowing the hydrocarbon to flow from the rock through the fractures to the well and then up to the surface.
- Horizontal drilling and directional drilling have made it possible to economically extract oil and gas from “unconventional” geologic formations such as relatively low permeability shales in which oil and gas form (but cannot migrate and collect in pools).
- Text Box 2-2. “Conventional versus Unconventional” clarifies these possibly confusing terms
- So with modern horizontal drilling techniques, producers can drill a single well that follows the contours of a relatively thin, horizontal shale formation (Figure 2.1). Such drilling allows fracturing to
be conducted in a long horizontal section of the well that accesses an extensive portion of the oil or gas bearing formation.

Unconventional geologic formations where hydraulic fracturing is valuable:

- **Shales**: organic-rich black shales. Oil and gas forms in these on geologic timescales. Have low permeability and the oil/gas is contained in the pore space in the shales. Some shales produce mainly gas and other oil; often there is coproduction of both with one being dominant.

- **Tight Formations**: These are sedimentary formations of sandstone, siltstone and carbonate, etc. type rock and have relatively low permeability. There is a continuum in permeability between tight formations which require hydraulic fracturing to be produced economically and sandstone (and other) formations that do not. A technical usage is that in the literature, “tight gas” is generally distinguished from “shale gas,” while oil resources from shale and tight formation are frequently lumped together under the label “shale oil” or “tight oil.”

- **Coalbeds**: Hydraulic fracturing can be used to extract methane (the primary component of natural gas) from coal seams. Here the methane is adsorbed to the coal surface, not the pore space. Pumping the water out of the coalbed after fracturing causes the coal to be “depressurized” allowing the methane to be released from the coal.

- **The way that fracturing is accomplished varies due to general location and geologic conditions, whether the well is existing or newly drilled, the proximity of the well to infrastructure and raw materials, operator preferences and other factors.**

- **Technological advances have allowed deeper drilling and longer horizontal wells and to conduct fracturing through longer portions of the well. Also multiple wells may be place on a single well pad. It is predicted that as operators gain experience with both evolving and new technologies, practices will continue to change.**

- **Figure 2-2. Shale gas and oil plays in the lower 48 states** (an oil and gas “play” is an area in which hydrocarbon accumulations or prospects of a given type occur. For example, the shale gas plays in North America include the **Barnett**, **Eagle Ford**, **Fayetteville**, **Haynesville**, **Marcellus**, and **Woodford**, among many others.

**Hydraulic Fracturing and the life of a Well**

- Fracking technically is a term referring to the short-term process of cracking and fracturing rock to access the gas; a typical treatment being two to ten days during which fluids are injected into the well to cause fracturing. It is the period of most activity at a well site during its existence.

- **Other supporting and ancillary activities at a well site include (1) initial site development, (2) production and (closure) and all of these together range from years to decades, depending on rate of depletion of the hydrocarbon, cost of production and price of the hydrocarbon. Rate of depletion in the reservoir is somewhat uncertain in these unconventional formations because of the lack of enough history on which to base predictions.**

- **Well preparation, operations and closure vary from company to company, from play to play, from jurisdiction to jurisdiction and from well to well. (A “play”, is a group of oil fields or prospects in the same region that are controlled by the same set of geological circumstances.)**
The various activities involved in well development and operations can be conducted by the well owner and/or operator, owner/operator representatives, service companies or other third parties contactors working for the well owner.

Figure 2-5. Generalized timeline and summary of activities that take place during the operational phases of an oil or gas well site operation in which hydraulic fracturing is used.

Site Assessment and Development, Well Drilling and Construction:

- Identify geologically suitable well site by integrating data from geophysical/seismic surveys, rock core samples which may involve drilling exploratory wells or test holes.
- Study logistical factors including topography, proximity to facilities (roads, pipelines, water resources), well spacing considerations, well setback requirements, potential for site erosion, location relative to environmentally sensitive areas, and proximity to populated areas.
- Obtain mineral rights lease, negotiate with landowners and apply for drilling permits from appropriate state and local authorities. Gather leases and permissions for other activities such as performing seismic survey and drilling exploratory holes. This initial site assessment phase may take several months.
- Access roads may need to be built to accommodate truck traffic. Level and grade site to manage drainage and to allow equipment to be hauled to and placed on site.
- Excavate and grade impoundments or storage pits near well pad. If needed, install steel tanks to hold fluids instead of, or in addition to, pits. Pits may hold water for drilling fluids, materials generated during drilling such as used drilling mud and drill cuttings or the flowback and produced waters after fracturing. Depending on local regulations and perhaps federal regulations on federal and Indian Country; pits may need to be lined to prevent fluid seepage into the shallow subsurface or pits may be prohibited altogether. Piping may need to be laid for some or all of these: the delivery of water, for the removal of flowback and produced water or for the transport of oil and gas once production begins.
- Drill rigs and associated equipment (drill rig platform, drilling mud system components, generators, chemical storage tanks, blowout preventer, fuel storage tanks cement pumps, drill pipe and casing) are moved on and off the pad at the different stages of well drilling and completion.
- Well pads can range in size from less than an acre to several acres depending of the scope of the operations.

Well Drilling and Construction:

- Involves the drilling of a wellbore (main hole) and cementing of a series of casing strings (see below). In certain settings, some portions of the well can be completed as open holes. Chapter 6 has details on this.
- Drilling begins by lowering and rotating the drill string which consists of the drill bit, drill pipe and drill collars (heavy pieces of pipe that add weight to the bit). With rotation the bit advances and new sections of pipe are added. A drilling fluid is circulated during drilling. This fluid may be water-based or oil based and is pumped down to the drill bit, where it cools and lubricated the bit, counterbalances downhole pressures and lifts the drill cuttings to the surface.
- All wells are initially drilled vertically but finished well orientations include vertical, deviated (some angle off vertical) and horizontal; whatever provides the best access to the targeted zones within a formation. Deviated wells may even be “S” shaped or continuously slanted. Horizontal well lengths may reach 5000 feet or more.
The process proceeds with repeated steps of the drill string being lowered, rotated, drilled to a certain depth, pulled out and then casing pipe is lowered into the hole, set and cemented. Casing is a steel pipe lowered into the wellbore as described and extends from the bottom of the hole to the surface; cement is poured between the outside of the casing and the borehole. This unit is called a casing string. Depending on the conditions encountered (e.g., zones of differing formation pressure gradients), three or four casing strings may be required to reach the target depth; each new casing string with smaller diameter pipe will be placed inside an existing one and cemented. That is, successively smaller diameters of casing are used as the hole is drilled deeper.

This structure functions to stabilize and support the wellbore, isolate and protect the hydrocarbons being produced and any water bearing zones through which the well passes; it also prevents fluid movement along the well between the outside of the casing and wellbore. The well can be cemented continuously from the surface down to the production zone of the well. Partially cemented wells are also possible with, for example cement from the surface to some distance below the deepest fresh water-bearing formation and perhaps cement across other deeper formations. See chapter 6 and Appendix D for more details on casing and cement.

When this drilling, casing and cementing are finished, the well can be completed in the production zone in several ways. The casing may be cemented all the way through the production zone and perforated prior to hydraulic fracturing in the desired locations. Alternately, operators may use an open hole completion, in which the casing is set just into the production zone and cemented. The remainder of the wellbore within the production zone is left open without cement.

Once all these aspects of well construction are completed, the operator can remove the drilling rig, install the wellhead and prepare the well for stimulation by hydraulic fracturing and production. The wellhead is the component at the surface of an oil or gas well that provides the structural and pressure-containing the interface for the drilling and production equipment; its primary purpose is to provide the suspension point and pressure seals for the casing strings that run from the bottom of the hole sections to the surface pressure control equipment.

Hydraulic Fracturing:

[Reviewer note: the term “hydraulic fracturing” technically refers to the short, intense, repetitive process at the drill site when rock is fractured by injecting fracking fluids – this is often confused with the general popular term “fracking.” This is important to note when talking about human health risks associated with “fracking” because confusion can arise in the popular media as to whether one is talking about this short, intense period of fracturing rock with pressure of water, chemicals and proppant or the overall large scale mining process of site preparation, drilling bore-holes, cementing drill strings, hydraulic fracturing, fluid recovery-management-disposal, site and well closure and oil and gas production.

Machinery and equipment are usually brought to the site mounted on trucks and remain that way during this process. Tanks, totes and other storage containers of various sizes holding water and chemicals are also transported and installed on site. Figure 2-8. Site with all equipment on site in preparation for injection for hydraulic fracturing.

Fluids are mixed using specialized feeding and mixing equipment; this is usually performed on a truck-mounted blender and is electronically monitored and controlled by the operator in a separate van (see chapter 5).

A wellhead assembly is temporarily installed on the wellhead to allow high pressures and volumes of water, chemicals and proppant-laden fluid to be injected into the well. Pressures required for fracturing
can vary widely depending on depth, formation pressure and rock type. Reported pressures range from 4,000 psi to 12,000 psi. Pressure gauges measure this pressure and can be installed at the surface or “downhole.” Figure 2-9. Two wellheads side-by-side being prepared for hydraulic fracturing at a well site in Pennsylvania.

- The entire well is not fractured all at the same time but in shorter lengths. And these sections are fractured in stages, each stage having different fluids injected. The function of the different chemicals/additives is to (1) remove excess drilling fluids or cement (often with acid), (2) initiate fractures (pad fluid without proppant), (3) carry the proppant and (4) flush the wellbore to ensure that all proppant-laden fluids reach the fractures. Each phase requires moving up to millions of gallons of fluids around the site through various hoses and lines, blending the fluids and injecting them at high pressures down the well.

- The number of stages for each well section being fractured can vary with several sources stating between 10 and 20 as typical but one source documenting between 1 and 59 stages per well with others sources reporting values within this range. For more details on hydraulic fracturing stages see Chapter 5, Section 5.2.

- [Reviewer note: this chapter strangely does not give any detail on perforation of the well casing during hydraulic fracturing using “perforation guns.”] These are a string of shaped charges which are exploded and function to perforate the casing allowing the high pressure fluid out into the formation. The perforating gun is lowered into position in the horizontal portion of the well and an electrical current is used to set off small explosive charges in the gun, which creates holes through the well casing and out a short, controlled distance into the formation. A typical perforating gun can carry many dozens of charges. Text box 5-1 in Chapter 5 does discusses perforation and perforation guns]

- Fracturing is planned and designed to achieve optimum drainage of hydrocarbons from the formation and engineers must carry out the fracturing using knowledge of the specific characteristics of the project rock formation and monitoring of the process occurs during and after the process using pressure and tracer data. See chapter 6 and appendix D for more details.

Fracturing Fluids:

- These fluids have a variety of purposes and require chemical additives and specifics depend on factors such as the geologic setting, reservoir geochemistry, production type, proppant size, etc. Water-based fluids are the most common but other fluid types can be (1) foams or emulsions made with nitrogen, carbon dioxide or hydrocarbons or (2) acid based fluids and (3) other types.

- The most common water-based fluids are called slickwater formulations which are typically used in very low permeability reservoirs and gelled fracturing fluids which are used in reservoirs with higher permeability. See section 5.3 for more details. Slickwater is mainly water with a very low portion of additives like polymers that reduce friction loss; Gelled fluids are water based with added gels to increase viscosity.

- Chemical usage in the industry is continually changing as studied, experienced and refined. These changes in fluid formulations is driven by economics, technological developments and concerns about environmental and health impacts.

- Water is the largest component of typical fracking fluid. The sources for this water are ground water, surface water, treated wastewater and reused flowback or produced water from other wells. Water is usually brought to the production site via trucks or piping or it may be locally sourced such as pumped from a local river or water well tapping local ground water. The source depends on availability, cost
quality of water and the logistics of delivering it to the site. See chapter 4 for more detail. Figure 2-10. Water tanks lined up for hydraulic fracturing at a well site in central Arkansas.

- **Proppants**, by volume, are second to water in the fluid. Silicate minerals, usually quartz sand, and the most common types of proppants. They are increasingly being coated with resins that help prevent creation and flowback of particles or fragments of particles. Ceramic materials, such as those based on heated bauxite or kaolin are also used as proppants due to their high strength and resistance to crushing and deformation.

- **Additives** are a relatively small percentage of the fluids system, generally less than 2% [whether by weight or volume is not stated]. EPA analyzed additive data using the FracFocus database 1.0 and estimated 2011 and 2012 additives totaled 0.43% of the total amount of fluid injected. This small percentage can total tens of thousands of gallons of chemical additives. See chapter five for more details.

- The FracFocus registry was developed by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. Oil and gas well operators can use the FracFocus registry to disclose information about hydraulic fracturing well locations, and water and chemical use during hydraulic fracturing operations. Submission of information to FracFocus was initially voluntary (starting in January 2011), but now about half of the 20 states represented in FracFocus have enacted reporting requirements for well operators that either mandate reporting to FracFocus or allow it as one reporting option. FracFocus data are discussed in more detail in Chapter 4 (regarding water volumes) and Chapter 5 (regarding chemical use). For more information see [www.fracfocus.org](http://www.fracfocus.org) and [U.S. EPA (2015a)](https://www.epa.gov/).  

(Reviewer note: FracFocus has critics. A Harvard Report is one, [see summary of Harvard Report here](http://example.com) the Energy Advisory Board-FracFocus 2.0 report is another and a general media article.)

**Fluid Recovery, Management and Disposal:**

- When hydraulic fracturing fluid injection and fracturing has been completed the injection pressure is reduced and the direction of fluid flow reverses. This causes some of the injected fluid into the well and to the surface; naturally occurring fluids in the formation usually also will flow upwards. These are referred to as flowback and produced water respectively. Chapter 7 has details and discussion regarding the composition and quantities of these fluids. The proportion of flowback water is highest initially but with time the proportion of produced water predominates.

- This flowback water as well as any other liquid waste from the well pad (e.g., rainwater) is typically stored on-site in impoundments. Figure 2-11. Impoundment on the site of a hydraulic fracturing operation in central Arkansas. This wastewater can be moved offsite via truck or pipelines. Nationally, most of this wastewater is managed through disposal into deep Class II injection wells regulated under the UIC (Underground Injection Control) program within the Safe Drinking Water Act; see chapter 8 for detail. Other management strategies include treatment followed by discharge to surface water bodies or reuse for subsequent operations either with or without treatment. Factors effecting management of these waters is driven by factors of cost, availability of facilities for treatment, reuse or disposal and regulations. This waste water management is another aspect of the hydraulic fracturing process that is changing significantly. See chapter 8 for details.

**Oil and Gas Production:**
After fracturing equipment is removed, partial site reclamation may take place if drilling of additional wells or laterals is not planned. Operators may dewater, fill in and regrade pits that are no longer needed. Parts of the pad may be reseeded and the well pad may be reduced in size (e.g., from 3 to 5 acres). Wells may be shut-in immediately after completion if there is no infrastructure to receive the product or if prices are unfavorable. Before bringing a well into production the operator typically runs a production test to determine the maximum flow rate the well can sustain and to optimize equipment settings and these test may be repeated throughout the life of the well. During production, monitoring (e.g., mechanical integrity testing, corrosion monitoring), including any compliance with state monitoring requirements, may be conducted to enable operators to be sure that the well is operating as intended.

Gas produced in wells flows through a flowline to a separator that separates the gas from water or any liquid hydrocarbons. Finished gas is sent to a compressor station where it is compressed to pipeline pressure and sent to a pipeline for sale. Production at oil wells proceeds similarly but oil/water/gas separation occurs on the well pad; no compressor is needed and the oil can be hauled by truck or train or piped from the well pad.

During the life of the well it may be necessary to perform workovers to maintain or repair portions or components of the well and replace old equipment. This involves ceasing production and removing the wellhead and may include cleaning out sand, etc., from the well, repairing casing, replacing worn well components such as tubing or packers or installing or replacing lift equipment to pump hydrocarbons to the surface. Wells may be recompleted after the initial construction with re-fracturing if production has decreased. Recompletion also may include additional perforation in the well at different intervals to produce from a different formation than originally done, length the wellbore or drilling new laterals from an existing wellbore.

As of 2012 a report suggested that the rate of re-fracturing in gas wells was about 1.6%. An EPA analysis in the same year indicated a re-fracture rate of 1% for gas wells and another EPA inventory study of 2015 this figure was 0.3% to 1% per year in the period 1990 to 2013.

Production Rates and Duration:

Life of a well depends on some obvious variables: the amount of hydrocarbons in the play, the reservoir pressure, production rate and the economics of well operations. In conventional oil and gas wells, it can be as short as three or four years in deep-water, high-permeability formations and as long as 40 to 60 years in onshore tight gas reservoirs. In hydraulically fractured wells in unconventional reservoirs, production is often characterized by a rapid drop followed by a slower decline compared to conventional wells. Most modern, high volume fractured wells are less than a decade old. Hence there is limited data to determine the full extent of the production decline and final production amounts.

Site and Well Closure:

Once a well reaches the end of its useful production, it is plugged and the well site closed. Failure to plug the wellbore properly can cause fluids from higher pressure zones to migrate through the wellbore to the surface or to other zones such as fresh water aquifers. State regulations are usually governed by state regulations which indicate the locations and materials for plugs. Cement plugs are typically used.
• Some surface structures can be left in place and the local topography and land cover are restored to predevelopment conditions to the extent possible, per state regulations. The wellhead and any surface equipment are removed. Impoundments are dewatered, filled in and graded. The well casing is typically cut off below the surface and a steel plate or cap is emplaced to seal the top of the casing and wellbore. Some states require notification of the landowner or a government agency of the location of the well.

**How Widespread is Hydraulic Fracturing?**

• Hydraulic fracturing activity in the United States and worldwide is substantial. One industry cumulative estimate stated that by 2010, close to 2.5 million fracture treatments had been performed globally. In 2002 an interstate commission stated that close to 1 million wells had been hydraulically fractured in the United States since the 1940s. A 2015 U.S. Geological Survey publication analyzed 1 million fracked wells and 1.8 million fracturing treatment records from the U.S. from 1947 to 2010.

• Although some form of hydraulic fracturing has been used for more than 60 years, the technological advancements that combined hydraulic fracturing and directional drilling in the early 2000s resulted in the new era of modern hydraulic fracturing, which uses higher volumes of fracturing fluids than were typically used in prior decades.

• Modern hydraulic fracturing is typically associated with horizontal wells producing from unconventional shale reservoirs, but hydraulic fracturing continues to be done in vertical wells in conventional reservoirs also. This ongoing mix of traditional and modern hydraulic fracturing activities makes estimates of the total number of hydraulic fracturing wells challenging.

• Some traditional oil- and gas-producing parts of the country, such as Texas, have seen an expansion of historically strong production activity as a result of the deployment of horizontal drilling and modern hydraulic fracturing. Pennsylvania, a century ago one of the leading oil- and gas-producing states, has seen a resurgence in oil and gas activity. Other states currently experiencing a steep increase in production activity, such as North Dakota, Arkansas, and Montana, have historically produced less oil and gas and are therefore undergoing new development.

• Figure 2-12. Aerial photograph of a well pad and service road in Springville Township, Pennsylvania
• Figure 2-13. Aerial photograph of hydraulic fracturing activities near Williston, North Dakota
• Figure 2-14. Landsat photo showing hydraulic fracturing well sites near Frierson, Louisiana
• Figure 2-15. Landsat photo showing hydraulic fracturing well sites near Frierson, Louisiana
• Figure 2-16. Location of horizontal wells that began producing oil or natural gas in 2000, 2005, and 2012

**Number of Wells Fractured per year**

• There is no complete database or registry of wells that are hydraulically fractured in the United States. Another source of uncertainty is the rate at which relatively new hydraulic fracturing wells are re-fractured or the rate at which operators use older, existing wells for hydraulic fracturing.

• Since the early 2000s, the percentage of all fractured wells that are either horizontal or deviated has steadily grown. Our estimates are based on data detailed below from several public and private sector organizations that track drilling and various aspects of hydraulic fracturing activity.
The number of wells reported to the FracFocus registry provides a low estimate of the number of hydraulically fractured wells. As of early April 2015, the FracFocus registry reported receiving information on a cumulative total of approximately 95,000 fracturing jobs, or roughly 22,400 per year over the 51-month period from January 2011 through March 2015 (GWPC, 2015). In a more detailed review of FracFocus data from 2011 and 2012, the EPA found there were approximately 14,000 and 22,500 fracturing jobs reported to the FracFocus website in those years, respectively, across 20 states. These 2011 and 2012 numbers are likely underestimates of wells hydraulically fractured annually, in part because FracFocus reporting was voluntary for most states for at least a portion of 2011 to 2012 (though the increase from 2011 to 2012 in part reflects more states requiring reporting to the registry).

Hydraulic fracturing practices may alternately (or in addition to FracFocus) be tracked by states. Compared to state records of hydraulic fracturing from North Dakota, Pennsylvania, and West Virginia in 2011 and 2012, we found that the count of wells based on records submitted to FracFocus was an underestimate of the number of fracturing jobs in those states by an average of approximately 30% (see Text Box 4-1).

EPA estimates that from roughly 2011 to 2014 approximately 25,000 to 30,000 new oil and gas wells were fracked each year. Additional, pre-existing wells (more than one year old that may or may not have been fracked in the past) were also likely fractured each year.

Future trends in the number of wells hydraulically fractured per year will be affected by the cost of well operation and the price of oil and gas. Scenarios of increasing, flat, and decreasing hydraulic fracturing activity all appear to be possible.

An additional estimate of the number of hydraulically fractured wells can be obtained from DrillingInfo, a commercial database compiling data from individual state oil and gas agencies (DrillingInfo, 2014a). The data indicate an increase in the number of new hydraulically fractured wells drilled each year, from approximately 12,800 in 2000 to slightly more than 21,600 in 2005, to nearly 23,000 in 2012. The number of new horizontal wells (which are likely all hydraulically fractured) show a significant increase, from 344 (about 1% of all new production wells) in 2000, to 1,810 in 2005, to 14,560 (nearly 41% of all new production wells) in 2012 (see Figure 2-16).

There is conflicting data between the EPA Greenhouse Gas Reporting Program and an EPA survey of an estimated 23,200 oil and gas production wells that were hydraulically fractured by nine oil and gas service companies in 2009 and 2010. Differences in data definitions, and assumptions used to estimate the percentage of pre-existing wells hydraulically fractured in a year could account for the different results.

In summary, determination of the national scope of hydraulic fracturing activities in the United States is complicated by a lack of a centralized source of information and the fact that well and drilling databases each track different information. There is also uncertainty about whether information sources are representative of the nation, whether they include data for all production types, whether they represent only modern (high volume) hydraulic fracturing, and whether they include activities in both conventional and unconventional reservoirs. Taking these limitations into account, however, it is reasonable to assume that between approximately 25,000 and 30,000 new wells (and, likely, additional pre-existing wells) were hydraulically fractured each year in the United States from about 2011 to 2014.

Hydraulic Fracturing Rates:
Estimates of hydraulic fracturing rates, or the proportion of all oil and gas production wells that are associated with hydraulic fracturing, also indicate widespread use of the practice. Based on one assessment fracturing rates have increased over time. From 2005 to 2013, rate of fracking increased from 57% to 64% of all new production wells (oil wells, gas wells, and wells producing both oil and gas).

In 2009, industry consultants stated that hydraulic fracturing was used on nearly 79% of all wells and more than 95% of “unconventional” wells. A 2010 article in an industry publication noted “some believe that approximately 60% of all wells drilled today are fractured”. Of 11 important oil and gas producing states that responded to an IOGCC survey (Arkansas, Colorado, Louisiana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, and West Virginia), ten estimated that 78% to 99% of oil and gas wells in their states were hydraulically fractured in 2012; Louisiana was the one exception, reporting a fracturing rate of 3.9% in 2012. Although estimates of fracturing rates are variable, largely ranging from near 60% to over 90% (as described above), they are often higher for gas wells than they are for oil wells. A 2010 to 2011 industry survey of 20 companies involved in natural gas production found that 94% of the wells that they operated were fractured; among those, roughly half were vertical and half were horizontal.

Trends and Outlook for the Future

Fossil fuels are the largest source of all energy generated in the United States. They currently comprise approximately 80% of the energy produced. However, the mix of fossil fuels has shifted in recent years. Coal, the leading fossil fuel produced by the U.S. since the 1980s, has experienced a significant decrease in production. In 2007, coal accounted for approximately 33% of U.S. energy production, and by 2013 it decreased to approximately 24%. On the other hand, natural gas production has risen to unprecedented levels, and oil production has resurged to levels not seen since the 1980s (see Figure 2-17). Oil went from accounting for 15% of U.S. energy production to 19% between 2007 and 2013, and natural gas (both dry and liquid) went from 31% to 35%.

Natural Gas (Including Coalbed Methane):

Natural gas production in the United States peaked in the early 1970s, reached those levels again in the mid-1990s, and between the mid- to late-2000s has increased to even higher levels (see Figure 2-17). The recent increase in total gas production has been driven almost entirely by shale gas (see Figure 2-18).

As natural gas prices fell between 2008 and 2012, drilling of new natural gas wells declined markedly (see Figure 2-19). Nevertheless, natural gas production is expected to increase over the coming decades (see Figure 2-18). U.S. Energy Information Administration (EIA) predicts that shale gas production will more than double between 2011 and 2040 and that the portion of total natural gas production represented by shale gas will increase from one-third to one-half. The EIA projects steady growth in the development of tight gas as well (about a 25% increase in production over the 30-year period) and delayed growth in the development of coalbed methane resources, for which production is not expected to increase again until sufficiently high natural gas prices are realized around 2035. Overall, the EIA projects that the share of U.S. natural gas production from shales, tight formations, and coalbeds will increase from 65% in 2011 to nearly 80% in 2040.

Shale gas production varies by play (see Figure 2-20a). Until 2010, the Texas Barnett Shale was the play with the most production. Although production from the Barnett Shale is still significant, production has increased sharply in other plays. By 2012, production from the Haynesville play (on the
Louisiana/Texas border) surpassed that in the Barnett play, and by 2013 the Marcellus Shale (in the Appalachian Basin underlying Pennsylvania, West Virginia, and other states) was the play with the most production. Because technically recoverable resources are an order of magnitude higher in the Marcellus than in any other U.S. shale gas play, it is likely that the Marcellus Shale will be very active in shale gas production for the foreseeable future.

- In the 1970s, most tight gas production in the United States was in the San Juan Basin centered in New Mexico. As modern hydraulic fracturing came into common usage in the mid-2000s, the lead in tight gas production shifted to Texas (especially East Texas) and the Rocky Mountain states.
- Figure 2-20(a). Production of U.S. shale gas plays, 2000-2014, in billion cubic feet per day; (b) Production from U.S. tight oil plays, 2000-2014.

Oil:

- The U.S. Energy Information Administration data indicate that as drilling activity for natural gas declined between 2008 and 2012, drilling for oil increased by a similar order of magnitude (see Figure 2-19). Figure 2-21 shows past and projected future trends in U.S. oil production and importation. The current surge in tight oil production is expected to continue until the latter part of the current decade and then taper, while conventional oil production is projected to remain fairly level. However, downward trends in the price of oil since mid-2014 are not reflected in these projections.

Conclusion

Since about 2005, the combination of hydraulic fracturing and horizontal drilling pioneered in the Barnett Shale have become widespread in the oil and gas industry. Hydraulic fracturing is now a standard industry practice and has significantly contributed to a surge in U.S. production of both oil and gas. Modern hydraulic fracturing has resulted in additional types of geological formations being tapped, and sometimes these formations are located in regions of the country new to intensive oil and gas exploration and production. In other areas, the improved techniques have made possible a resurgence of production.

An estimated 25,000 to 30,000 new wells drilled in the United States were hydraulically fractured as a production-enhancing technique in each year from 2011 to 2014. Additional pre-existing wells were also fractured. Since the early 2000s, the percentage of all hydraulically fractured wells that are either horizontal or deviated has steadily grown. Reserves of oil and gas that are now accessible with modern hydraulic fracturing are considerable, and if technical improvements outpace depletion of oil and gas resources, the quantity of resources that are deemed economically and technically recoverable may continue to grow. Given current trends, it appears likely that hydraulic fracturing will continue to play an important role in the oil and gas industry, and the United States’ energy portfolio, in the decades ahead.