Hydraulic Fracturing

Unlocking America's Natural Gas Resources

America's Oil and Natural Gas Industry

July 2014

For the latest report, please visit www.api.org/hydraulicfracturing

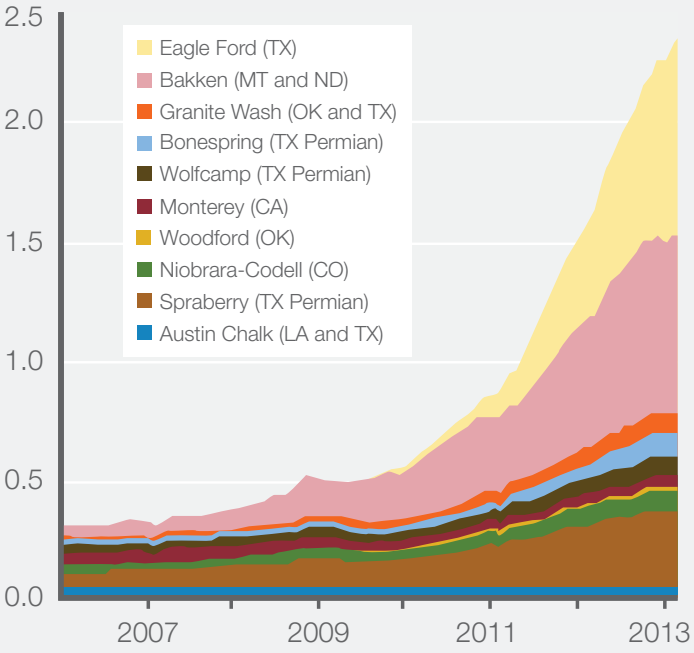
Table of Contents

What is Fracking?

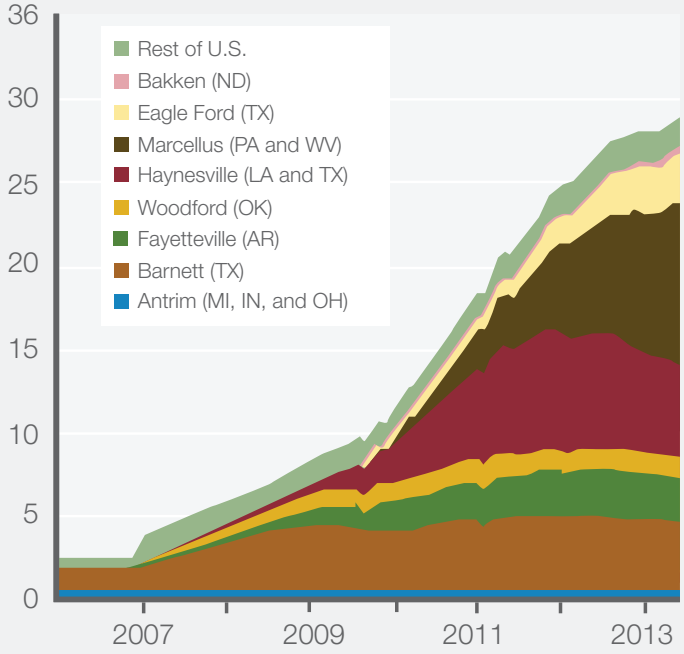
Hydraulic fracturing and horizontal drilling are safely unlocking vast U.S. reserves of oil and natural gas found in shale and other tight-rock formations. Developing energy from shale is an advanced process that uses the latest drilling technologies and equipment. As for what fracking means to the United States – the answers, are security, economic growth and jobs, jobs, jobs.

This change is driven by production from unconventional reserves using fracking and horizontal drilling.

Shale And Tight Oil Production
million barrels per day



Dry Shale Gas Production
billion cubic feet per day



Hydraulic fracturing and horizontal drilling are safely unlocking vast U.S. reserves of oil and natural gas found in shale and other tight-rock formations. Developing energy from shale is an advanced process that uses the latest drilling technologies and equipment. As for what fracking means to the United States – the answers are security, economic growth and jobs, jobs, jobs.

The U.S. Energy Information Administration (EIA) details how surging domestic oil production is narrowing net petroleum imports – from 60 percent of what the United States used in 2004 to 38 percent in 2013. This change is driven by production from unconventional reserves using fracking and horizontal drilling.

The story of natural gas produced using hydraulic fracturing is equally dramatic. The U.S. energy outlook has changed from one of having to import natural gas to having ample supply to both meet domestic needs and export gas to friendly nations around the world. A little more than a decade ago natural gas production from shale accounted for 2 percent of total U.S. output. Today that figure is 37 percent, and an IHS study projects that natural gas developed through the use of hydraulic fracturing will rise to more than 75 percent of the domestic supply by 2035.

Shale Plays in the Lower 48 States

Unlocking shale gas now guarantees the U.S. more than a 100-year supply of clean-burning natural gas.

Source: Energy Information Administration based on data from various published studies. Updated: May 28, 2009.

Hydraulic fracturing has been used in the oil and natural gas industry since the 1940s, producing more than 600 trillion cubic feet of natural gas and 7 billion barrels of oil. Used with modern horizontal drilling technology, fracking has unlocked vast U.S. shale reserves, launching a renaissance in oil and natural gas production, creating tens of thousands of jobs and generating economic growth. Without these advanced technologies, we would lose 45 percent of domestic natural gas production and 17 percent of our oil production within five years.

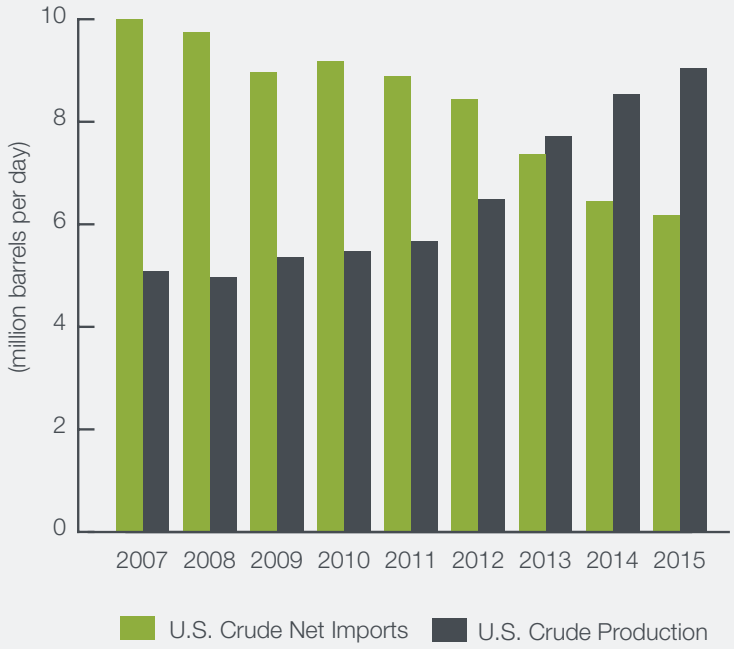
> *"America has abundant natural resources and recent innovations combined with horizontal drilling in shale formations has unlocked vast new supplies of natural gas, allowing the nation to get to the energy it needs today, and transforming our energy future."*
>
> —**Daniel Yergin,**
> *IHS vice chairman*

The U.S. Energy Information Agency (EIA) reports that over 750 trillion cubic feet of technically recoverable shale gas and 24 billion barrels of technically recoverable shale oil resources currently exist in discovered shale plays. Responsibly developing these resources creates jobs and fuels our economy. And the key to unlocking these resources is through the process of hydraulic fracturing, also known as fracking.

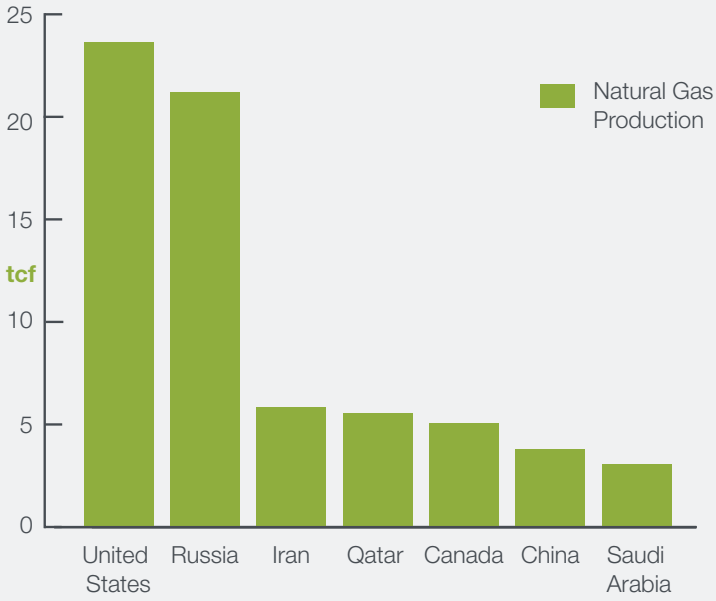
Securing Our Energy

Petroleum and Other Liquids Supply and Disposition, Reference Case.

EIA – Annual Energy Outlooks 2010–2013



EIA – International Energy Outlook 2013

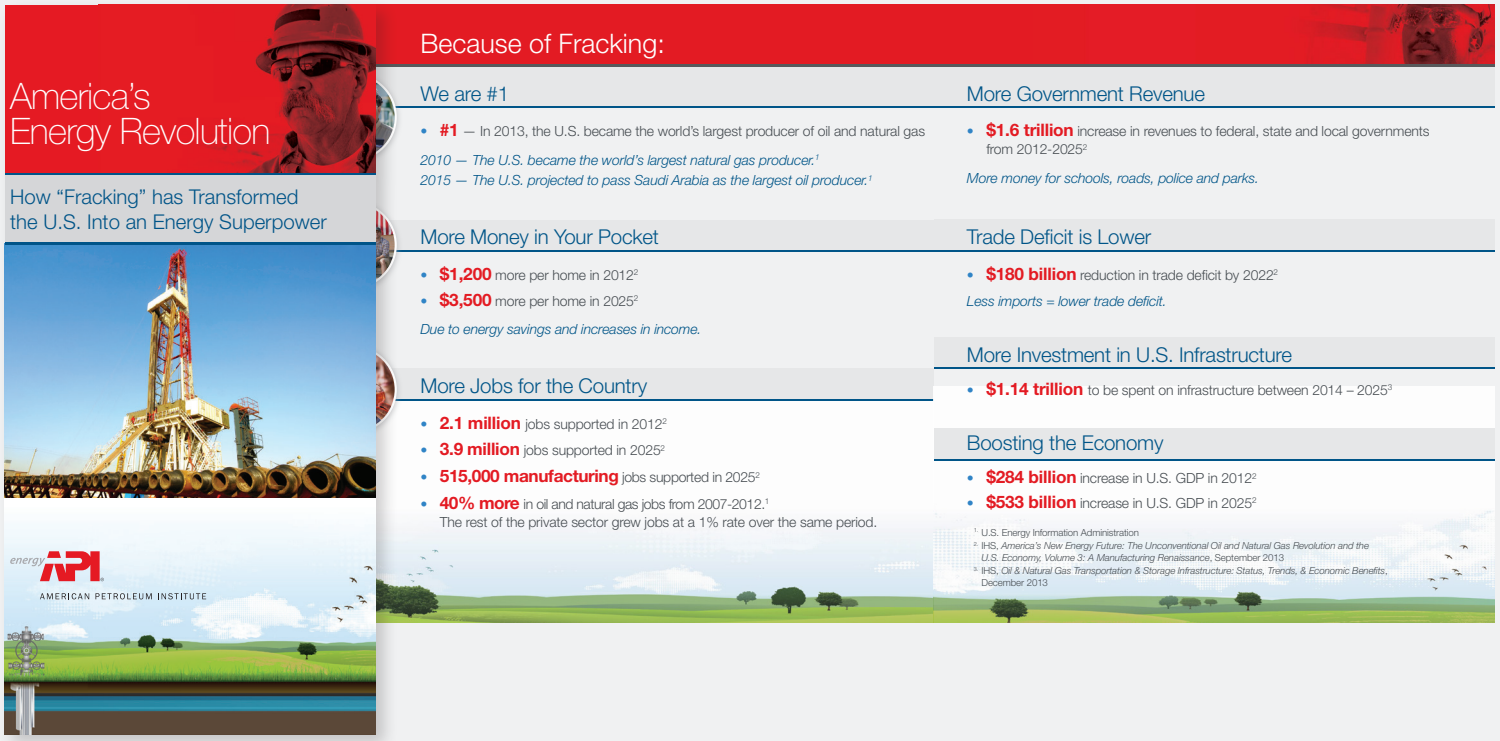


In his 2012 State of the Union address, President Obama described a 100-year supply of natural gas. Meanwhile, energy analyst predict the U.S. will remain the world's biggest oil producer this year after overtaking Saudi Arabia and Russia. We can thank hydraulic fracturing for both. Fracking has unlocked vast reserves of shale and other tight-rock formations to produce an American energy renaissance that has seen a dramatic lowering of oil imports while shifting America from needing to import natural gas to potentially rank as one of the world's leading natural gas exporters.

> "Every barrel of oil or cubic foot of natural gas that we produce at home instead of importing from abroad means … More jobs … Faster growth … A lower trade deficit."
>
> —**Jason Furman,** *Chairman of the Council of Economic Advisers and* **Gene Sperling,** *Director of the National Economic Council*

and a more energy-secure America.

Jobs and the Economy



The economic lift from fracking is being felt strongly in the U.S. manufacturing sector and will continue, according to IHS. It estimates that between now and 2025, one out of every eight U.S. jobs supported by unconventional oil and natural gas development will be in manufacturing. Labor income – a measure that includes earnings and employer-provided benefits – from unconventional oil and natural gas is projected to surpass $278 billion by 2025 (from $149 billion in 2012). Job creation in the energy-related chemicals sector is projected to increase from about 53,000 last year to 149,000 in 2015 and almost 319,000 in 2025. Hydraulic fracturing means individual opportunity for prosperity and overall economic growth.

What is hydraulic fracturing? It's energy and opportunity – for better lives and a stronger, more energy-secure country. It is largely responsible for changing America's energy narrative from one of limited options to one of nearly limitless plenty. David Garman, former energy undersecretary (2001-2005) at a natural gas forum hosted by the Bipartisan Policy Center said:

> "We are in the midst of a great policy reset. Our energy policy heretofore had been based on scarcity is now confronting a tremendous abundance. The shale gas boom … is a cause for a tremendous celebration."
>
> —Bipartisan Policy Center

With the right policies, strong industry standards and effective state oversight the celebration can continue as we safely and responsibly build on the ongoing shale energy revolution.

What they are Saying

Former Interior Secretary Ken Salazar

"(Hydraulic fracturing) is creating an energy revolution in the United States. I would say to everybody that hydraulic fracturing is safe."

Former Energy Undersecretary David Garman

"We are in the midst of a great policy reset. Our energy policy heretofore had been based on scarcity is now confronting tremendous abundance. The shale gas boom … is cause for a tremendous celebration."

Bryan Burrough, New York Times

"One could argue that, except for the Internet, the most important technological advance of the last two decades has been hydraulic fracturing, widely known as fracking. Practically overnight, it seems, this drilling technique has produced so much oil and gas beneath American soil that we are at the brink of something once thought unattainable: true energy independence."

Dan Tormey, Hydrologist, Geochemist, Civil Engineer

"The oil and gas development that's been facilitated by these new technologies – hydraulic fracturing, horizontal drilling, the ability to precisely locate within the (geologic) formation where you're drawing from – has brought undeniable benefits to the United States."

Interior Secretary Sally Jewell

"The Bakken boom is a perfect example of how new and improved technology is allowing industry to tap previously inaccessible or unknown energy resources to create jobs, decrease our dependence on foreign oil and grow our economy. … Working hand in hand with industry, we have an opportunity to use innovative technologies to capture natural gas to power more homes with cleaner American-made energy, while reducing methane emissions and cutting carbon pollution."

U.S. Energy Information Administration

"Recent U.S. production growth has centered largely in a few key regions and has been driven by advances in the application of horizontal drilling and hydraulic fracturing technologies."

California Department of Conservation Director Mark Nechodom

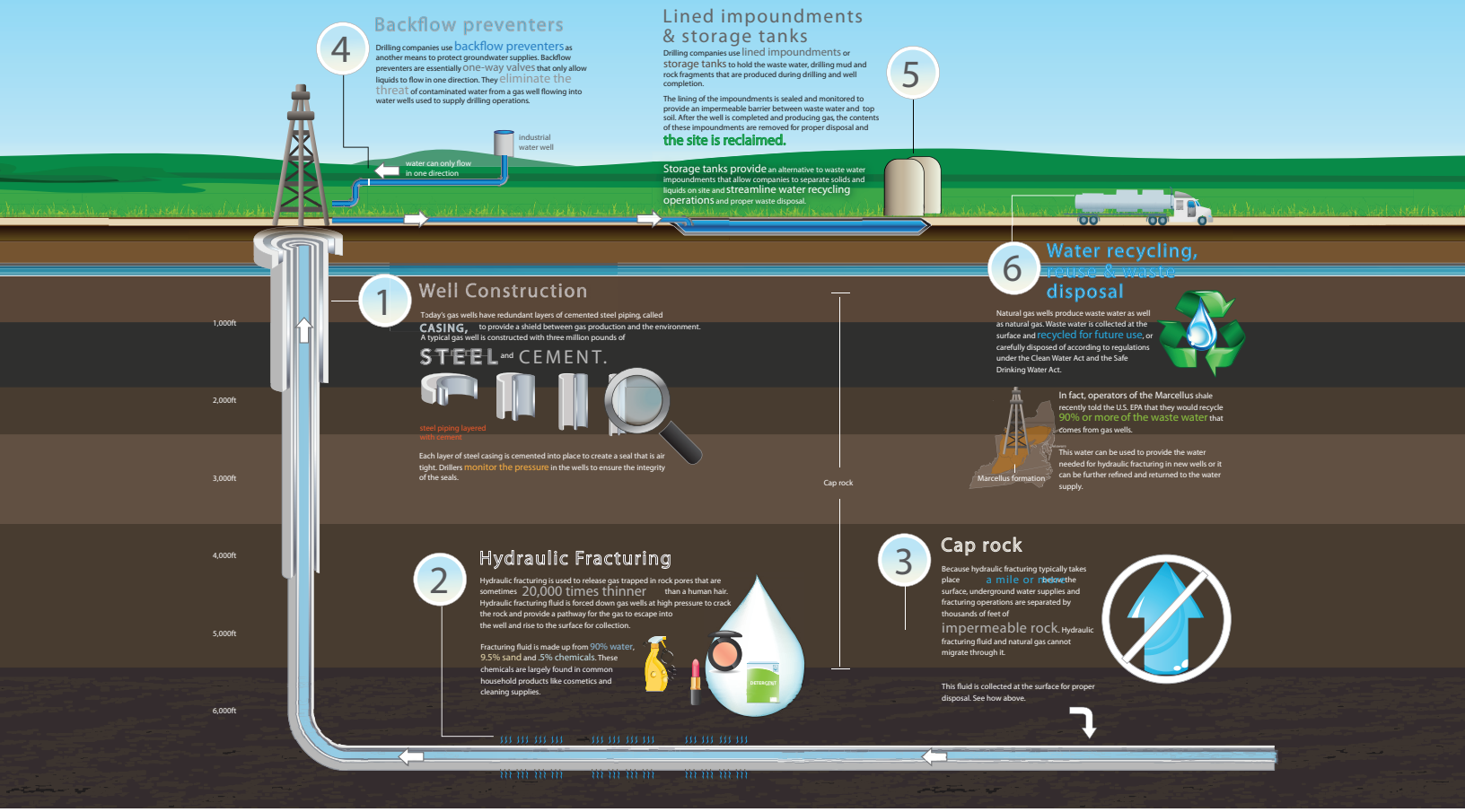
"In California it has been used for 60 years, and actively used for 40 years, and in California there has been not one record of reported damage directly to the use of hydraulic fracturing. But despite that, given the great nationwide wave of concern, we at the Department of Conservation are treating this as an opportunity to again embrace public demand for knowledge and transparency, and this is an opportunity for people to learn where their oil comes from, just the same way we want to teach people where their milk and water come from."

Process, Safety, and the Environment

The members of the American Petroleum Institute are dedicated to continuous efforts to improve the compatibility of our operations with the environment while economically developing energy resources and supplying high quality products and services to consumers. We recognize our responsibility to work with the public, the government, and others to develop and to use natural resources in an environmentally sound manner while protecting the health and safety of our employees and the public.

Drilling

There are zero confirmed cases of groundwater contamination connected to the fracturing operation in one million wells hydraulically fractured over the last 60 years.



Developing energy from shale (and other tight-rock formations) using hydraulic fracturing/horizontal drilling takes four to eight weeks – from preparing the site for development to production itself – after which the well can be in production for 20 to 40 years. A well can be a mile or more deep and thousands of feet below groundwater zones before gradually turning horizontal from vertical. The horizontal portion then can stretch more than 6,000 feet. A single well site (or pad) can accommodate a number of wells.

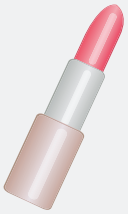
Steel pipe known as surface casing is cemented into place at the uppermost portion of a well to protect the groundwater. As the well is drilled deeper, additional casing is installed to isolate the formation(s) from which oil or natural gas is to be produced, further protecting groundwater from the producing formations in the well. There have been no confirmed cases of groundwater contamination from hydraulic fracturing itself in 1 million wells fracked over the past 60 years. Numerous protective measures are in place at well sites, including liners under well pads, rubber composite mats under rigs, storage tanks with secondary containment measures, and barriers to control any potential runoff.

Stimulation

The fracturing mixture consists primarily of fresh water mixed with some sand and a small proportion of common chemicals.


Table salt

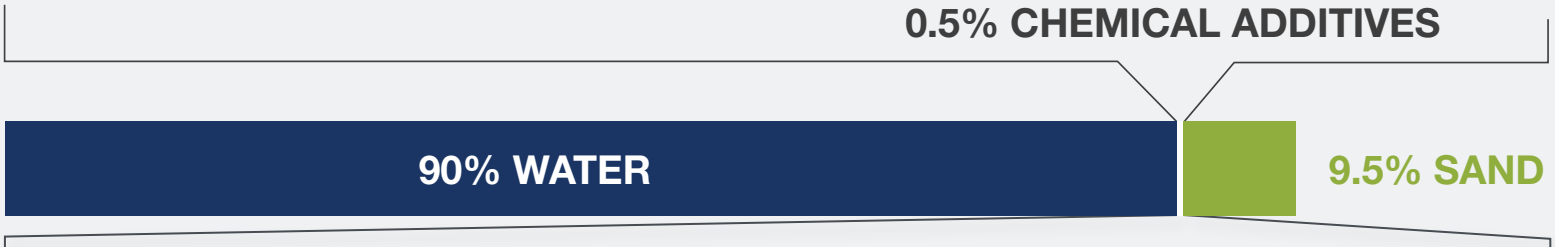

Laundry detergent


Thickener in cosmetics

Washing soda, detergent, soap


Food additive


Deodorant



Compound	Purpose	Common Application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Sodium Chloride	Allows a delayed breakdown of the gel polymer chains	Table salt
Polyacrylamide	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergent, hand soap, cosmetics
Sodium/Potassium Carbonate	Maintains effectiveness of other components, such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant, sterilization of medical and dental equipment
Guar Gum	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
Citric Acid	Prevents precipitation of metal oxides	Additive in food and beverages
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, hair coloring

Source: DOE, GWPC: Modern Gas Shale Development in the United States: A Primer (2009).

After the wells on a pad are drilled, cased and cemented, a device perforates the horizontal part of the production pipe to make small holes in the casing, exposing the wellbore to the shale. Then a mixture of water (90 percent), sand (9.5 percent) and chemicals (0.5 percent) is pumped into the well under high pressure to create micro-fractures in the shale and free natural gas or oil. Sand keeps the fractures open after the pressure is released. The chemicals are chiefly agents to reduce friction and prevent corrosion.

State Regulation

Effective hydraulic fracturing regulation can only be achieved at the state level as state regulations can be tailored to geological and local needs. Key state regulations include: Review and approval of permits; well design, location and spacing; drilling operations; water management and disposal; air emissions; wildlife impacts; surface disturbance; worker health and safety; and Inspection and enforcement of day-to-day oil and gas operations.

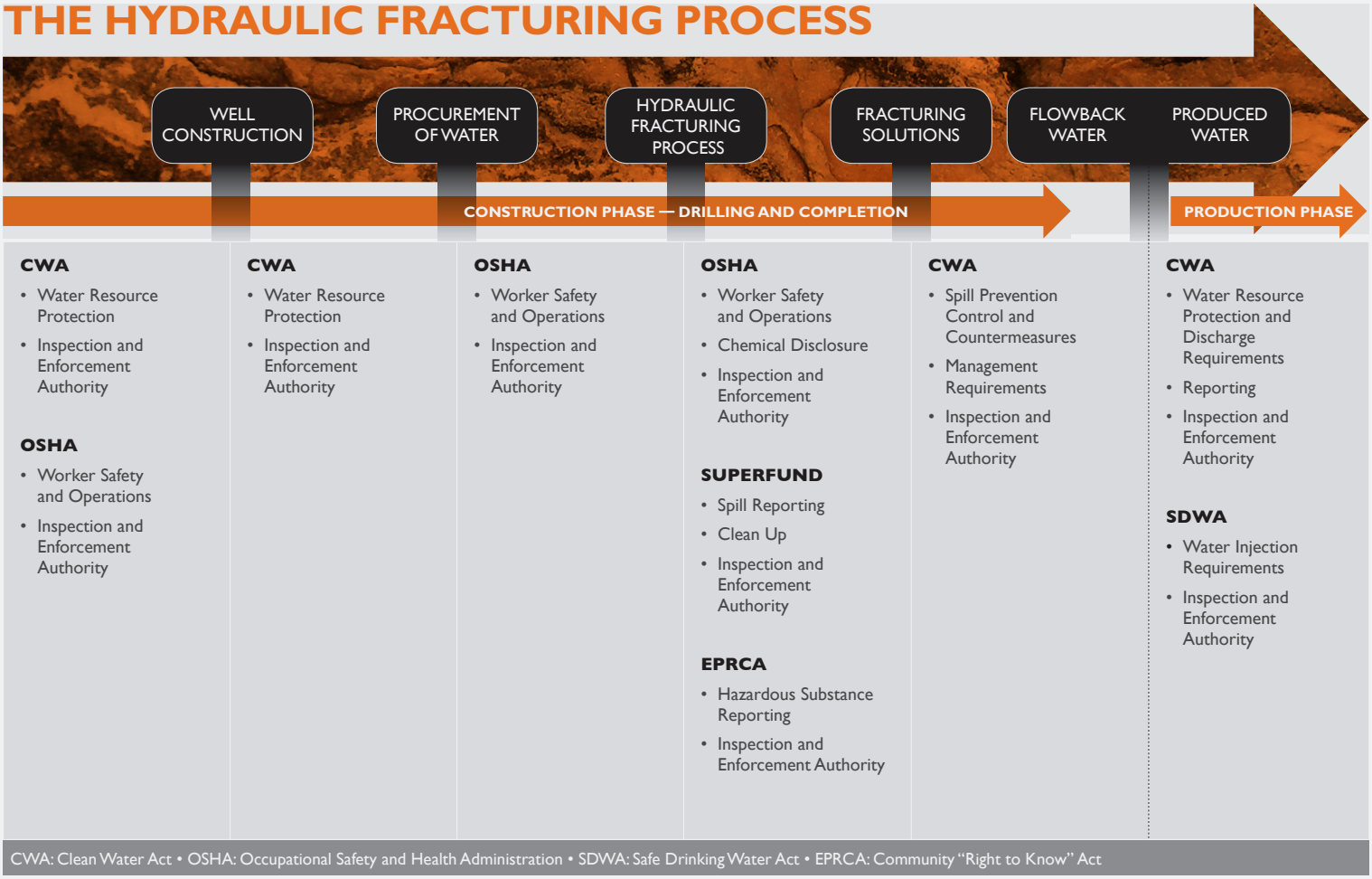
For example, the following are just some of the permits required in Pennsylvania:

1	Well drilling permit (w/ well location plat, casing and cementing plan, PNDI for threatened or endangered species, landowner/water well owner notifications, coal owner or operator notification and gas storage field owner notification)
2	Water management plan for Marcellus Shale wells
3	Proposed alternate method of casing, plugging, venting or equipping a well
4	Bond for Oil and Gas Well(s) (individual or blanket, various bond types allowed)
5	Waiver of distance requirements from spring, stream, body of water, or wetland (to put the well closer than 200 feet)
6	Variance from distance restriction from existing building or water supply (to put the well closer than 100 feet)
7	Proposed alternate method or material for casing, plugging, venting or equipping a well
8	Approval for alternative waste management practices
9	Approval of a pit for control, handling or storage of production fluids
10	Use of alternate pit liner
11	NPDES GP-1 for discharges from stripper oil wells
12	Water Quality Management Permit for treatment facilities
13	Alternative pit liners
14	Inactive status
15	Roadspreading plan approval
16	Transfer of well permit or registration
17	Orphan well classification
18	Off-site solids disposal
19	Residual waste transfer stations and processing facilities
20	Transportation of residual waste
21	Road use permit – construction of access to state roadway
22	Road use bond (PennDOT or municipality)
23	Surface use permit (if in the Allegheny National Forest)
24	PASPGP-3 or PASPGP-4 for pipelines crossing streams (if < 1 acre)
25	Water Obstruction – Encroachment – US Army Corps of Engineers Section 404 Joint Permit
26	Dam permit for a centralized impoundment dam for Marcellus Shale gas wells
27	GP-11 for non-road engine air emissions
28	GP-05 for natural gas compression facilities emissions
29	Earth disturbance permit (if > 5 acres)
30	Erosion and sedimentation control permit (if > 25 acres)
31	NPDES storm water for construction activities
32	Water allocation (SRBC, DRBC or DEP for Ohio River basin)
33	GP-3 for bank rehabilitation, bank protection, and gravel bar removal
34	GP-4 for intake and outfall structures
35	GP-5 for utility line stream crossings
36	GP-7 for minor road crossings
37	GP-8 for temporary road crossings
38	GP-11 Maintenance, Testing, Repair, Rehabilitation or Replacement of Water Obstructions and Encroachments

ENERGYINDEPTH

The Energy You Need. The Facts You Demand.

FEDERAL STATUTES REGULATE EVERY STEP OF THE HYDRAULIC FRACTURING PROCESS



Source http://energyindepth.org/wp-content/uploads/2009/03/Federal-Hydraulic-Fracturing-Process.pdf

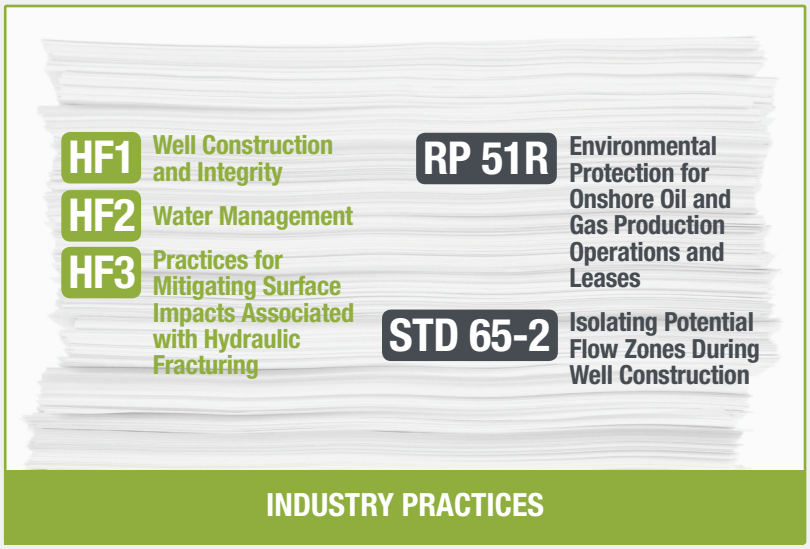
Federal regulations provide a broad regulatory foundation for energy development in the United States, including hydraulic fracturing. Key federal regulations governing shale development include: Clean Water Act; Clean Air Act; Safe Drinking Water Act; National Environmental Policy Act; Resource Conservation and Recovery Act; Emergency Planning and Community Right to Know Act; Endangered Species Act and the Occupational Safety and Health Act.

Industry Standards

Existing regulations covering well design requirements and hydraulic fracturing operations are specifically formulated to protect groundwater.

Working through API's standards program, accredited by the American National Standards Institute (ANSI) - accredited standards program, the industry has adopted standards and practices for continuous improvement, hundreds of which are referenced in state regulations thousands of times.

Several federal agencies, including the Environmental Protection Agency, the Bureau of Land Management, and the Occupational Safety and Health Administration, also cite API standards.



Source: http://www.api.org/policy-and-issues/policy-items/hf/shale-answers

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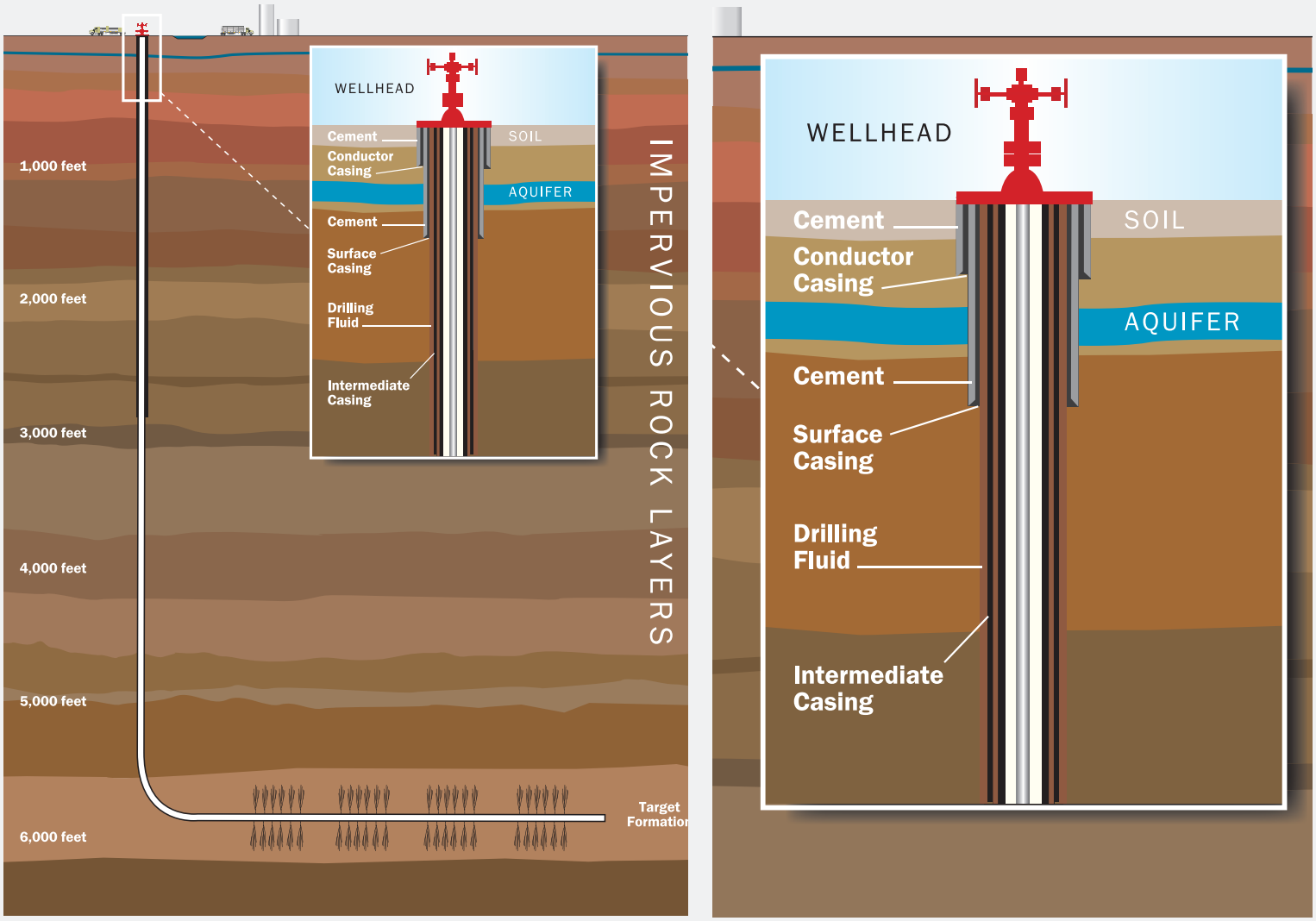
Water Protection

Proper well construction provides groundwater protection.

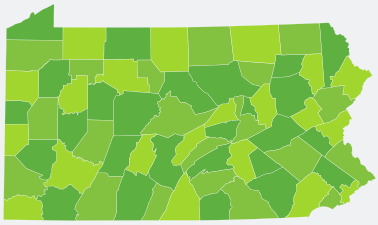


Source: http://www.api.org/~/media/Files/Policy/Exploration/HYDRAULIC_FRACT_ILLUSTRATION_121609.pdf

The key to protecting groundwater is proper well construction, and industry has developed detailed standards for this based on field experience and significant advances in drilling and construction techniques. A typical natural gas well uses 3 million pounds of steel and cement. Each layer of steel casing is cemented in place to create an air-tight seal.

Alternating layers of cement and steel casings are designed to ensure well integrity as is passes through groundwater levels thousands of feet down to the energy-holding layers of rock.

Water Usage



PENNSYLVANIA
Annual Water Usage Example

1.42 BILLION GALLONS per day
PUBLIC WATER SUPPLY

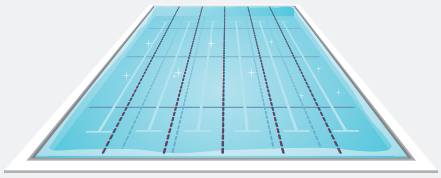
6.43 BILLION GALLONS per day
THERMOELECTRIC POWER

61.8 MILLION GALLONS per day
LIVESTOCK

24.3 MILLION GALLONS per day
IRRIGATION

SITE LEVEL

The amount of water used durin hydraulic fracturing for one well is typically the equivalent of the volume of three to six Olympic sized swimming pools



Each American Golf Course Uses More Than **4 MILLION GALLONS** of Water Per Summer Month

Sources: U.S. Geological Survey Circular 1344. 52p. and Marcellus Shale Development Water Use: June 1, 2008 - May 21, 2010; Energy In Depth, October 8, 2012; Aboutnaturalgas.com

Industry is mindful of the amount of water needed for hydraulic fracturing, which is why a number of companies are working on new technologies that reduce needed volumes as well as ways to fracture wells without water. Some perspective is helpful. In Pennsylvania, for example, all shale energy development across the state uses 1.9 million gallons per day, which is small relative to the water needed for livestock (61.8 million gallons/day) and irrigation (24.3 million gallons/day). It's also less than the 4 million gallons of water the average U.S. golf course uses per summer month.

Water Treatment Technologies

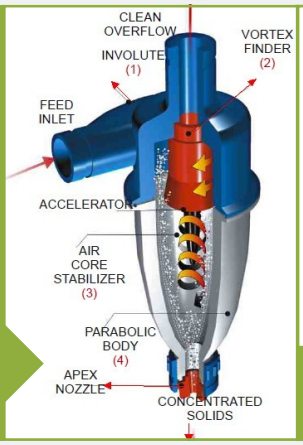
1.Chemicals

2.Ozone Oxidation

5. Deionization

3. Nano-filtration

4. Hydrocyclones



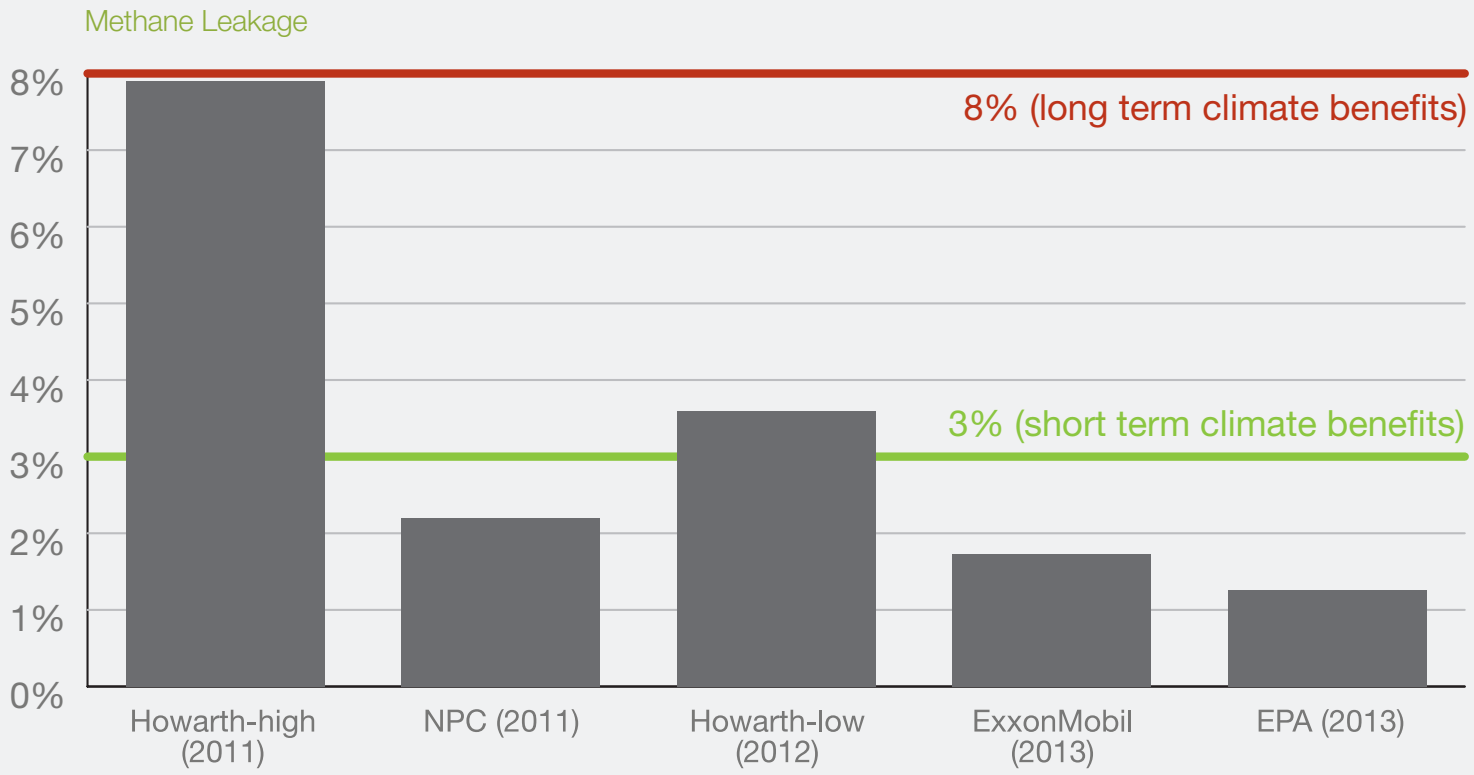
6. UV

MVR Evaporator, RO, EC…and many more

Sources: http://www.apachecorp.com/index.aspx

The development of advanced hydraulic fracturing and horizontal drilling has been accompanied by safe and responsible water management strategies employing innovative technologies to allow reuse of fluids produced during the fracturing phase of well development. According to the Penn State Marcellus Center for Outreach and Research, during the first half of 2013 in the Marcellus shale play, 90 percent of the more than 14 million barrels of produced fluids from fracturing was reused. That represents a significant savings in the amount of new water needed for hydraulic fracturing elsewhere. It illustrates industry's focus on environmental issues and efforts to reduce energy development's impacts on resources and communities.

Air Emissions



Source: IEA, U.S. EPA, ExxonMobil and WRI. All leakage rates, except ExxonMobil's are based on estimates and empirical; Exxon's leakage rates include actual measured data from some production and gathering operations in the Marcellus; EPA estimates are computed based on gross production reported from the EIA.Aboutnaturalgas.com

Thanks to increased use of natural gas, U.S. energy-related emissions of CO2 are at their lowest point in two decades. At the same time, industry is developing and implementing new technologies to reduce methane released during production. By January 2015, for example, all new natural gas wells are required to include green completions measures to reduce emissions. Additional new requirements also will impact tanks, pneumatic devices, leak detection and leak control. EPA's current inventory estimates show the methane leakage rate for natural gas systems well under 2 percent. This is less than the 3 percent cited as necessary for immediate climate benefits for the use of natural gas in power plants and well under the 8 percent estimate cited for delivering long-term benefits as compared to coal. Industry measures are working, with recent research showing that methane emissions from natural gas production are 10 percent lower than the most recent EPA estimates.

Hydraulic Fracturing and Seismic Activity

The Facts About Hydraulic Fracturing and Seismic Activity.

Hydraulic fracturing is accomplished by pumping a mixture of more than 99.5 percent water and sand into dense rock formations deep below the earth's surface. Multiple fracture sections or "stages" are carefully targeted for controlled stimulation. This process forms a network of narrow (a few millimeters wide) and limited extent (a few hundred feet long) fractures in the rock.

Hydraulic fracturing is accompanied by microseismic vibrations that can be recorded with sensitive listening devices and analysed with established scientific methods. Microseismic mapping is used to understand and optimise field development, well completions, and stage treatments. This monitoring produces extensive data, thus microseismic activity associated with hydraulic fracturing is well understood.

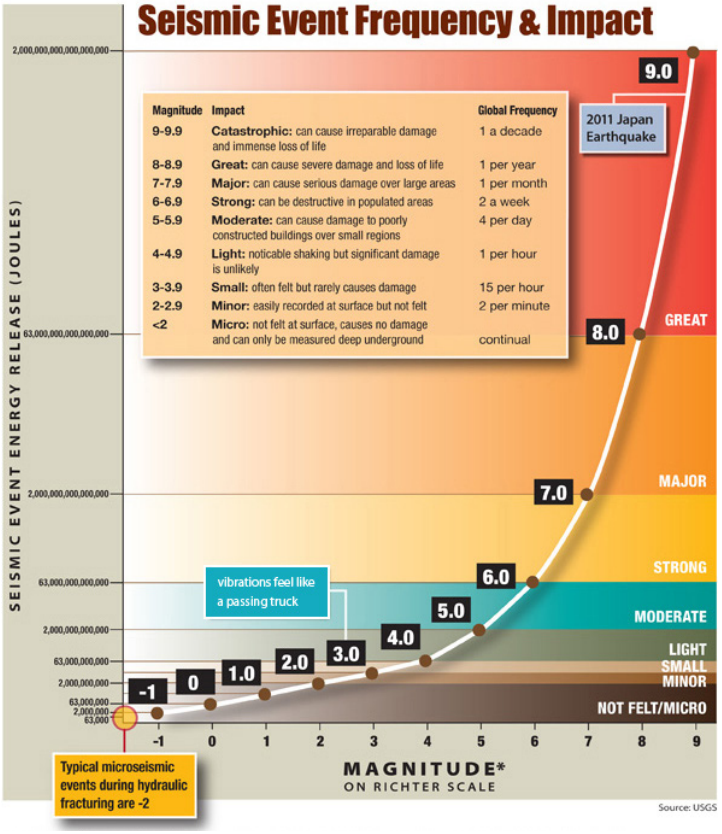
*USGS estimates that there are approximately **1.3 million** naturally-occurring earthquakes between 2 and 2.9 every year and an additional **130,000** between 3 and 3.9.*

A review of published research shows no cases of injuries or damage as a result of the very low level of seismicity related to this well-completion technique, which has been used in more than one million applications.

During hydraulic fracturing, the microseismic events are generally less than magnitude minus two (-2) or minus three (-3) on the Richter scale. A study of hydraulic fracturing-related seismic activity in England found that the combination of geological factors necessary to create a higher-than-normal seismic event was "extremely rare" and such events would be limited "to around magnitude 3 on the Richter scale as a "worst-case scenario."

For reference, a magnitude three earthquake is described by the United States Geological Survey (USGS) as causing "vibrations similar to the passing of a truck."

An Oklahoma Geological Survey study on seismicity near hydraulic fracturing activities concluded that it was "impossible to say with a high degree of certainty whether or not these earthquakes were triggered by natural means or by the nearby hydraulic-fracturing operation."



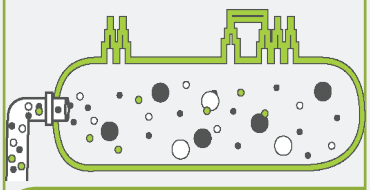
The study did note, however, the events under examination were "small earthquakes with only one local resident having reported feeling them. The earthquakes range in magnitude from 1.0 to 2.8."

As shown by the research, this well-understood phenomenon represents minimal risk to humans, animals, structures or the environment. Nonetheless, the industry has made safety a top priority and invests heavily in modeling and mapping the earth's subsurface to constantly improve its understanding of fault lines and other geological structures.

Hydraulic fracturing is a safe, proven technology that has been monitored, researched, and studied for decades. Microseismic analysis has been used extensively for monitoring fracture behaviour and is well-documented in the geoscience literature. The continued development of monitoring and modeling capabilities to improve the process will provide ongoing assurance of the safety and effectiveness of this critical well-completion procedure.

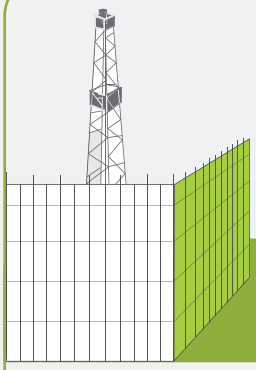
Sources: http://www.api.org/~/media/Files/Policy/Hydraulic_Fracturing/HF-and-Seismic-Activity-Report-v2.pdf

Innovations Promote Safe & Environmentally Friendly



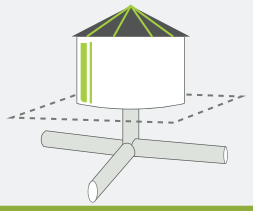
"PITLESS" DRILLING

Use of aboveground tanks for managing well fluids so that there is limited danger of well fluids getting into groundwater



SOUND CONTROL

Sound control and surface management allows for safe drilling in close proximity to people



WATER SYSTEMS

Centralized water management systems that remove trucks from roads

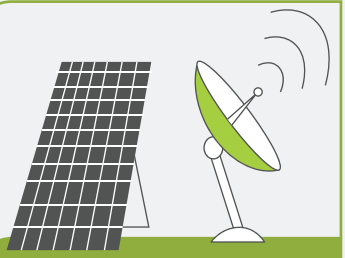
DRILLING SYSTEMS

1) Closed loop drilling systems; all drilling fluid stored in steel tanks

2) Whole site liners

"GREEN" FLUIDS

"Green" frac fluids
(Example: Environmentally benign components)



SOLAR PANELS

Photovoltaic solar telemetry to transmit well date from remote locations to central office (reduces use of diesel fuels)

America's shale energy revolution is built on innovation that produced advanced hydraulic fracturing and horizontal drilling technologies and techniques. And that innovation continues, working on ways to make fracking even safer for the surrounding environment. Safe and responsible drilling means site management – from multi-layer surface liners that protect the entire drilling area to closed-loop systems to maintain control of drilling fluids. Safe operating practices and water management are just two areas for which API has developed standards to protect the environment. The shale energy surge also is spurring innovation: waterless hydraulic fracturing fluid, methods to decontaminate and recycle water used in fracking and more.

Resources

1 IHS Global: http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx?ocid=anef-21350:consulting:print:0001

2 IHS Unconventionals: http://www.api.org/~/media/Files/Policy/American-Energy/Americas_New_Energy_Future_Mfg_Renaissance_Main_Report_4Sept13.pdf

3 FracFocus: http://fracfocus.org/

4 STRONGER: http://www.strongerinc.org/

5 Shale Answers: http://www.api.org/~/media/Files/Policy/Hydraulic_Fracturing/Shale-Answers-Brochure.pdf

6 Methane Management Answers:
https://remote.api.org/~/media/Files/Oil-and-Natural-Gas/Natural_Gas/,DanaInfo=www.api.org+MethaneBrochure.pdf

7 UT Methane Study: http://www.pnas.org/content/early/2013/09/10/1304880110.full.pdf+html

8 CardnoENTRIX Study: http://www.inglewoodoilfield.com/res/docs/102012study/Hydraulic%20Fracturing%20Study%20Inglewood%20Field10102012.pdf

9 API Groundwater Protection PDF:
http://www.api.org/policy-and-issues/policy-items/exploration/hydraulic-fracturing-well-construction

10 Hydraulic Fracturing and Seismic Activity:

[1] Cardno ENTRIX – Hydraulic Fracturing Study PXP Inglewood Oil Field: http://www.eenews.net/assets/2012/10/11/document_ew_01.pdf.

[2] "The Geo-mechanical Study of Bowland Shale Seismicity":
http://www.cuadrillaresources.com/news/cuadrilla-news/article/press-release-geomechanical-study/.

[3] USGS Earthquake web site, 2012: http://earthquake.usgs.gov/learn/topics/mag_vs_int.php.

[4] Examination of Possibly Induced Seismicity from Hydraulic Fracturing in the Eola Field, Garvin County, Oklahoma:
http://www.eenews.net/assets/2011/11/02/document_pm_01.pdf.

[5] USGS Earthquake: http://earthquake.usgs.gov/earthquakes/eqarchives/year/eqstats.php.

11 EIA Shale Gas projection: http://www.eia.gov/energy_in_brief/images/charts/nat_gas_production_1990-2040-(large).jpg

12 EIA 2013 Annual Energy Outlook Early Release 2014: http://www.eia.gov/forecasts/aeo/er/

13 Apache Corporation, Safe and Responsible Water Management: http://www.apachecorp.com/index.aspx

For more information, please visit
www.energytomorrow.org
www.api.org

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