

# HONR 229L: Climate Change: Science, Economics, and Governance

## Discussion #22: Fracking and Project Organization

Ross Salawitch [rjs@atmos.umd.edu](mailto:rjs@atmos.umd.edu)

Class Web Site: <http://www.atmos.umd.edu/~rjs/class/honr229L>

ELMS Page: <https://myelms.umd.edu/courses/1269254>



<https://www.npr.org/2015/08/31/434599379/how-are-u-n-climate-talks-like-a-middle-school-cliques-rule>

**14 November 2019**

## 'Venice Is On Its Knees': Mayor Blames Worst Flood Tide In 50 Years On Climate Change

November 13, 2019 · 10:15 AM ET



Venice Mayor Luigi Brugnaro trudges through high water in St. Mark's Square on Wednesday, the result of an exceptionally high tide in the scenic Italian ci

*Manuel Silvestri/Reuters*

<https://www.npr.org/2019/11/13/778812333/venice-is-on-its-knees-mayor-blames-worst-tides-in-50-years-on-climate-change>



# Climate In the News

EUROPE

## 'Venice Is On Its Knees': Mayor Blames Worst Flood Tide In 50 Years On Climate Change

November 13, 2019 · 10:15 AM ET



The crypt of St Mark's Basilica was flooded Wednesday. The high tide that has deluged Venice, Italy, created the second-worst case of flooding since the city started keeping official records.

*Luca Silvestri/Reuters*

<https://www.npr.org/2019/11/13/778812333/venice-is-on-its-knees-mayor-blames-worst-tides-in-50-years-on-climate-change>

## 'Venice Is On Its Knees': Mayor Blames Worst Flood Tide In 50 Years On Climate Change

November 13, 2019 · 10:15 AM ET



Water flows inside a shop in Venice during an exceptionally high tide. "A long and dramatic night for Venice," the city said on its Facebook page.

*Simone Padovani/Awakening/Getty Images*

<https://www.npr.org/2019/11/13/778812333/venice-is-on-its-knees-mayor-blames-worst-tides-in-50-years-on-climate-change>

# Greta Thunberg to hitch a ride to Europe with Australian YouTube influencers

**Swedish climate activist will join Riley Whitlum, Elayna Carausu and their baby, who have been sailing the world for five years**



▲ Swedish teen environmental activist Greta Thunberg posing on La Vagabonde with Riley Whitlum, Nikki Henderson, Elayna Carausu and baby Lennon. Photograph: @gretathunberg/Reuters

**Greta Thunberg** will hitch a ride with two Australian sailing YouTubers on her low-emissions voyage from America to the UN climate change conference in Madrid.

The 16-year-old Swedish climate activist had initially been stranded in the United States after the location of the conference was abruptly changed from Chile to Spain at the last minute.

“It turns out I’ve travelled half around the world, the wrong way,” she said at the time.

<https://www.theguardian.com/environment/2019/nov/13/greta-thunberg-to-hitch-a-ride-to-europe-with-australian-youtube-influencers>

# Class Logistics

- Paper due on Thursday, 14 Nov
  - Will except papers without penalty until Sunday, 17 Nov at 11:59 pm
- Papers received after Sunday, 17 Nov at 11:59 pm will incur the following late penalty:
  - Half a letter grade until Tues, 19 Nov at 11:59 pm
  - Full letter grade until Thurs, 21 Nov at 11:59 pm
  - No grade (i.e., “0” into ELMS) if not received by Fri, 22 Nov at 5 pm

- Please email paper to me as a Word file

Writing tips:

One thought per paragraph

Begin paragraphs with simple declarative sentences

Strive to not use “This” or “It” as nouns

Try to not repeat the same word twice in close succession,  
either in a single sentence or nearby sentences, because this  
becomes a distraction to the discerning reader

Be kind to your reader: economy of words is the mark of a great writer

# Hydraulic Fracturing

- Pumping of chemical brine to loosen deposits of natural gas from shale
- Extraction of CH<sub>4</sub> from shale gas became commercially viable in 2002/2003 when two mature technologies were combined: horizontal drilling and hydraulic fracturing
- High-pressure fluid is injected into bore of the well at a pressure that fractures the rock

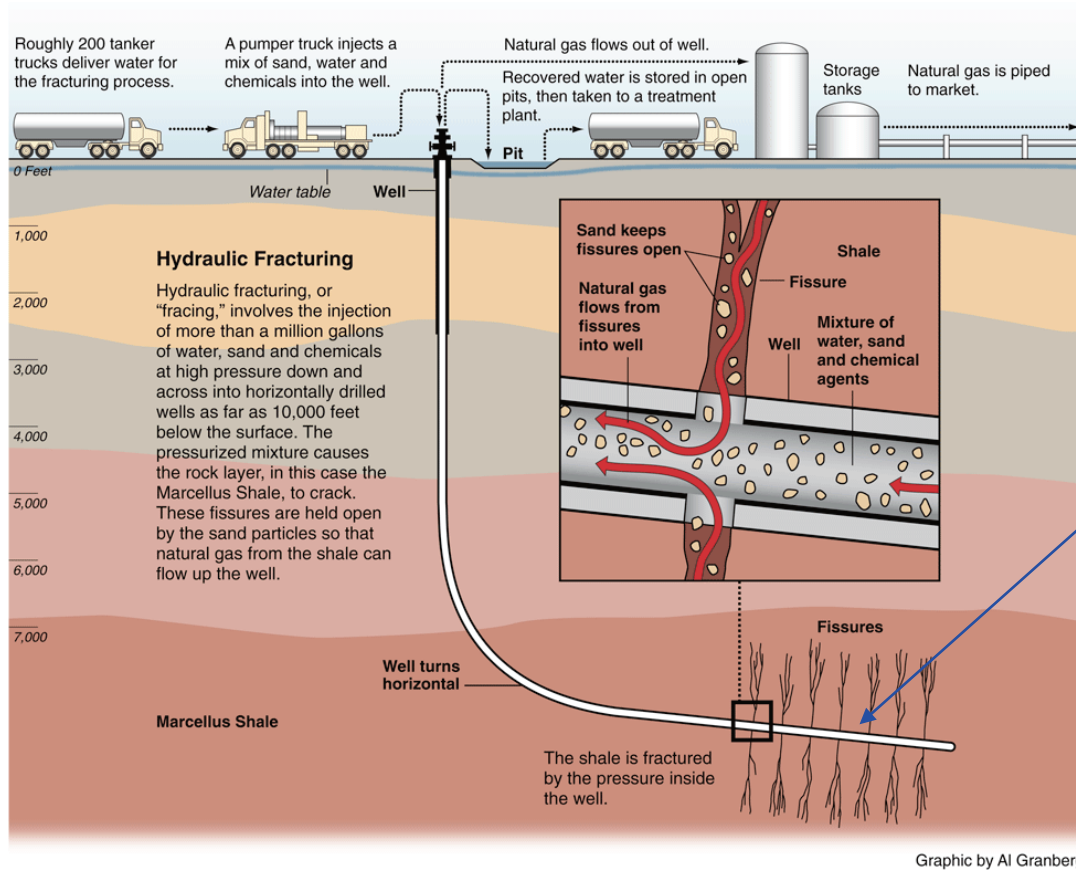


Image: [https://assets.propublica.org/legacy/images/articles/natural\\_gas/marcellus\\_hydraulic\\_graphic\\_090514.gif](https://assets.propublica.org/legacy/images/articles/natural_gas/marcellus_hydraulic_graphic_090514.gif)

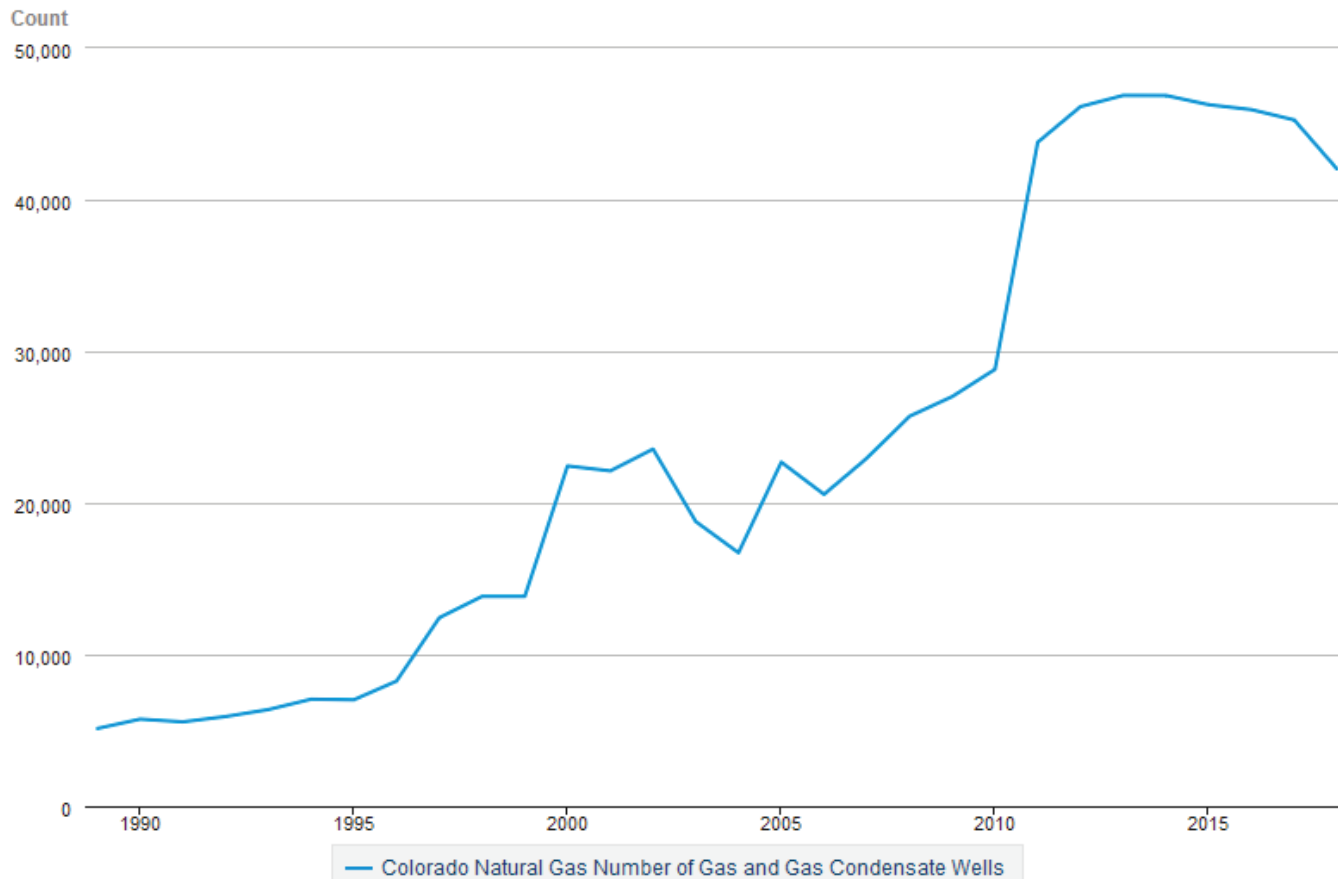


A hydraulic fracturing natural gas drilling rig on the Eastern Colorado plains.  
In 2017, there were more than 45,00 natural gas wells in the state of Colorado.

Weinhold, *Envir. Health Perspective*, 2012: <http://ehp.niehs.nih.gov/120-a272/>  
[http://www.eia.gov/dnav/ng/ng\\_prod\\_wells\\_s1\\_a.htm](http://www.eia.gov/dnav/ng/ng_prod_wells_s1_a.htm)



## Colorado Natural Gas Number of Gas and Gas Condensate Wells



Source: U.S. Energy Information Administration

A hydraulic fracturing natural gas drilling rig on the Eastern Colorado plains.  
In 2018, there were more than 42,00 natural gas wells in the state of Colorado.

Weinhold, *Envir. Health Perspective*, 2012: <http://ehp.niehs.nih.gov/120-a272/>  
[http://www.eia.gov/dnav/ng/ng\\_prod\\_wells\\_s1\\_a.htm](http://www.eia.gov/dnav/ng/ng_prod_wells_s1_a.htm)

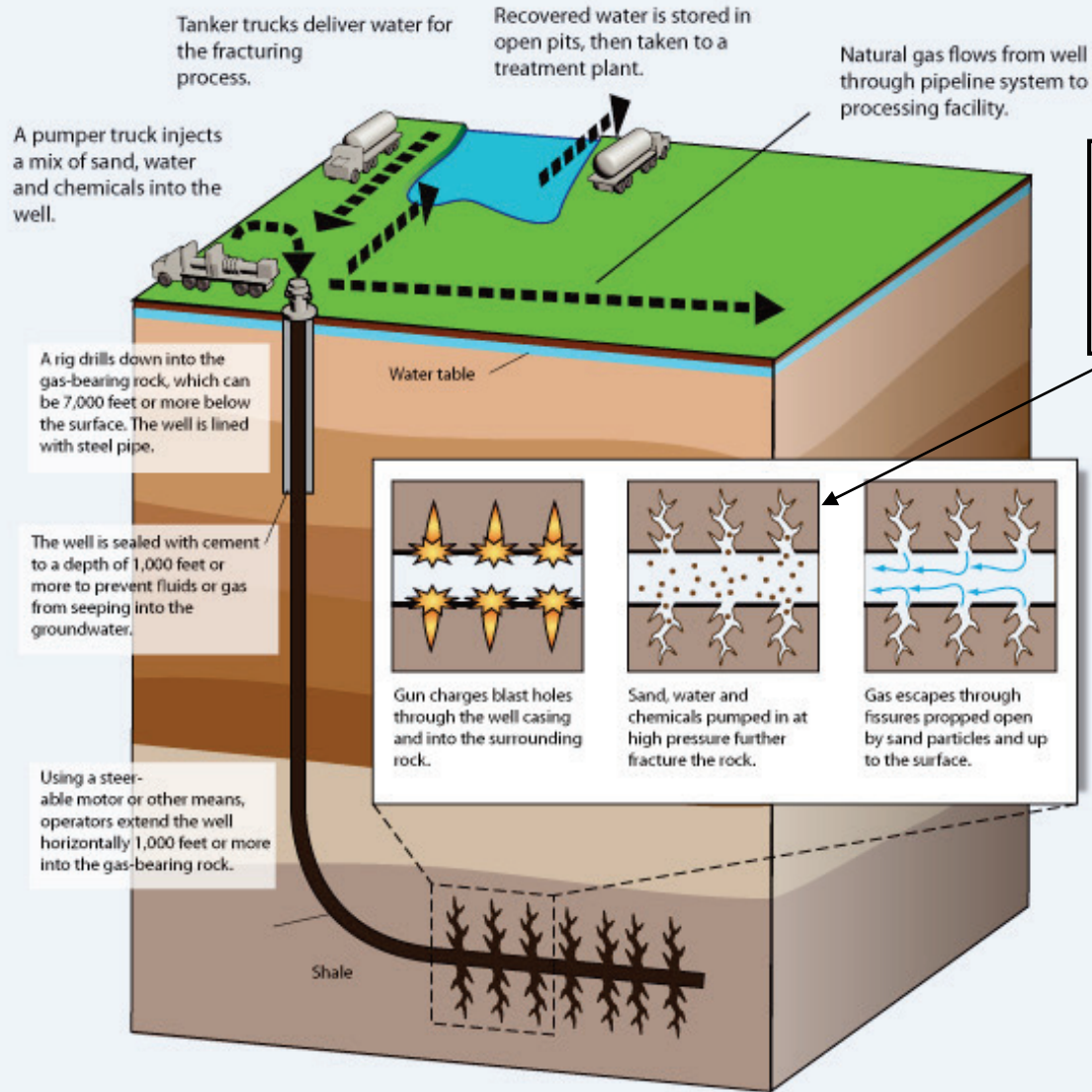


**Storage tank of fracking well, Longmont, Colorado**

<http://www.timescall.com/portlet/article/html/imageDisplay.jsp?contentItemRelationshipId=4995872>

# Tapping the Gas

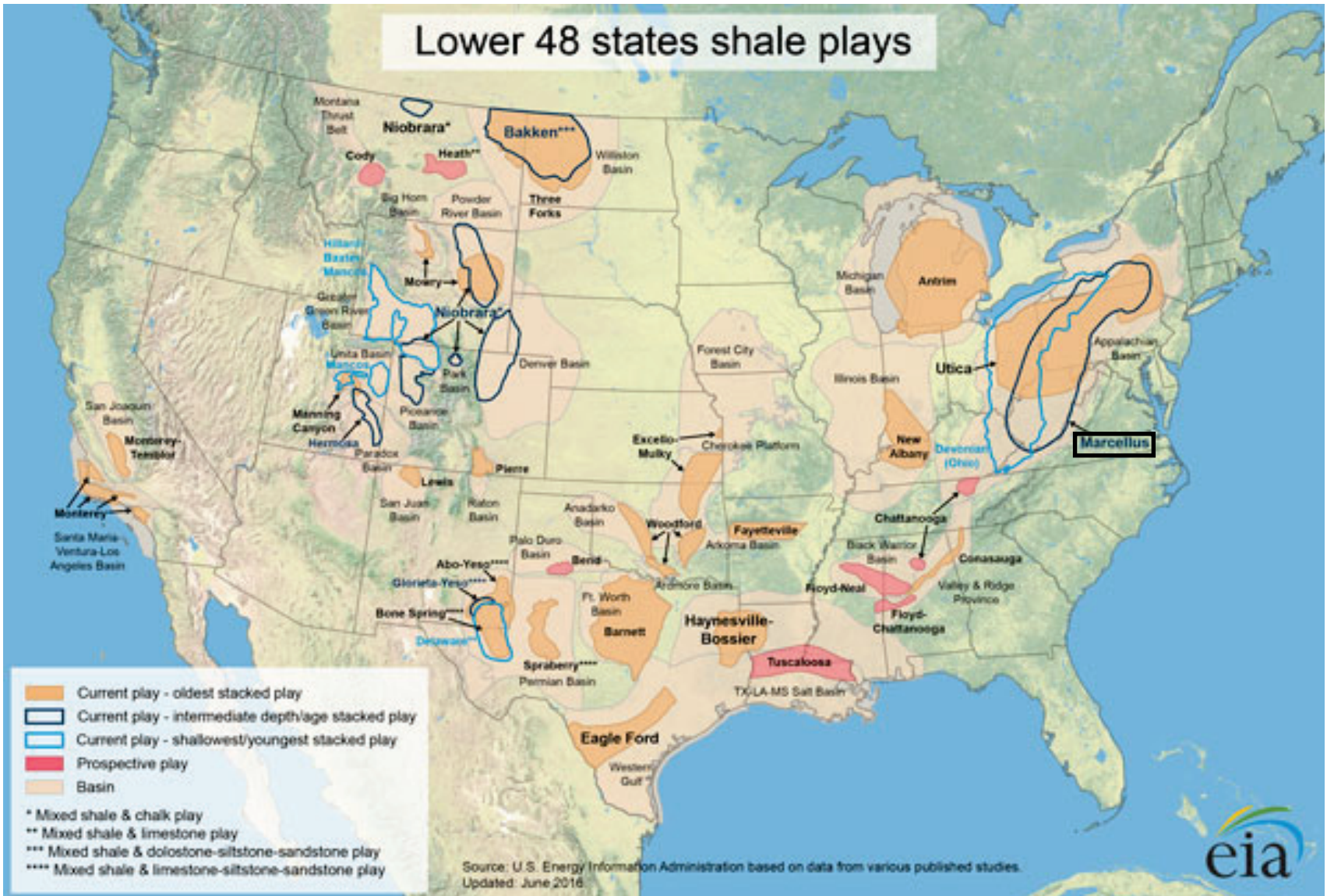
Horizontal drilling and hydraulic fracturing have made it feasible to extract huge amounts of natural gas trapped in shale formations. Here's how they work.



Sources: Chesapeake Energy; Al Granberg; WSJ research

Image: <http://online.wsj.com/article/SB10001424052702303491304575187880596301668.html>

# Lower 48 states shale plays

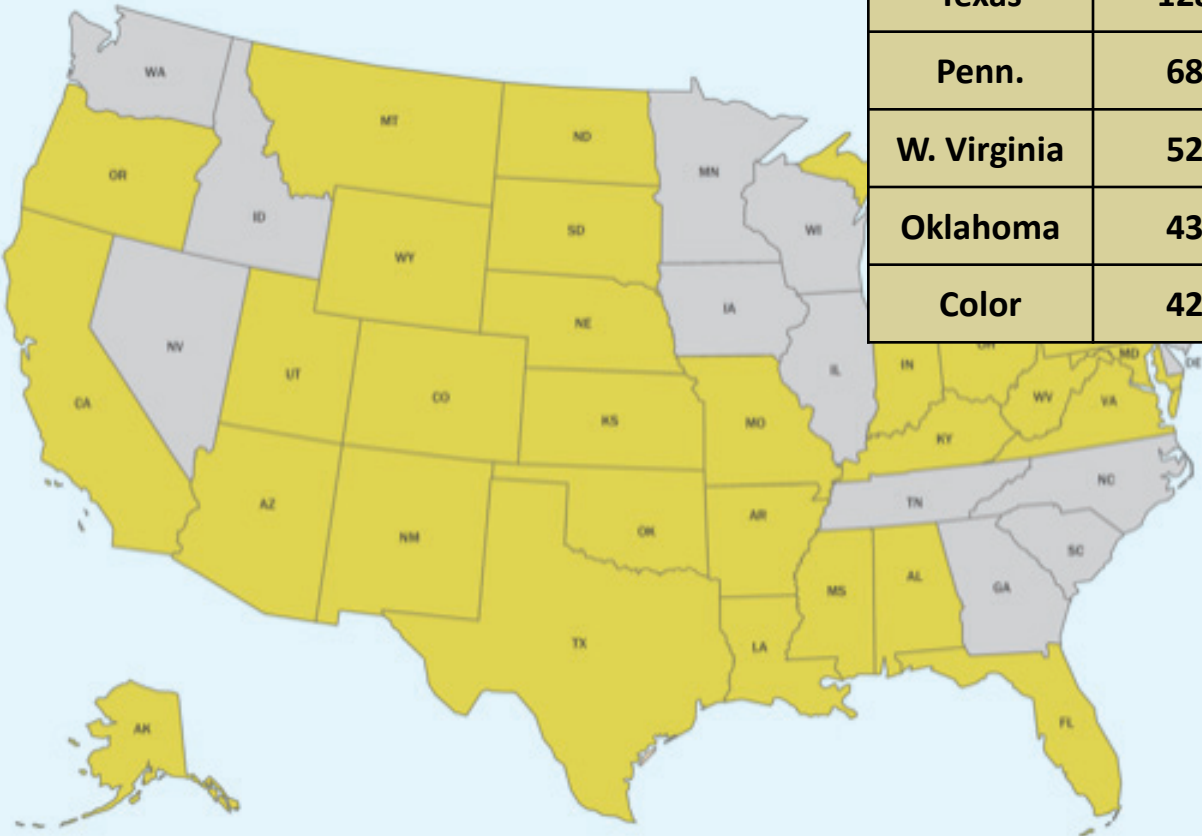


[https://www.eia.gov/energyexplained/index.cfm?page=natural\\_gas\\_where](https://www.eia.gov/energyexplained/index.cfm?page=natural_gas_where)



# States with Active Natural Gas Production

as of 2009 (most states)



**States with Active Natural Gas Production**

For most states these figures reflect the number of wells as of 2009. At the time this census was published, three states had not yet reported 2009 data. The number reported for Kentucky is for 2008, the number for Pennsylvania is for 2004, and the number for Tennessee is for 2006.

2018	No. of Wells
Texas	128,020
Penn.	68,421
W. Virginia	52,348
Oklahoma	43,083
Color	42,033

States	No. of Wells
Texas	121,534
Oklahoma	52,287
West Virginia	42,645
New Mexico	39,497
Colorado	38,278
Pennsylvania	35,928
Wyoming	32,617
Ohio	28,181
Kansas	26,025
Louisiana	18,519
Kentucky	13,330
Michigan	10,462
Virginia	7,078
New York	6,995
Utah	6,860
Arkansas	6,859
Montana	6,760
Alabama	6,157
California	4,142
Mississippi	1,734
Alaska	1,046
Indiana	620
North Dakota	509
Nebraska	354
South Dakota	137
Oregon	23
Arizona	6
Maryland	4
Florida	4
Missouri	2

Source: U.S. Energy Information Administration<sup>72</sup>

# Capital Gazette

## Governor Hogan signs fracking ban



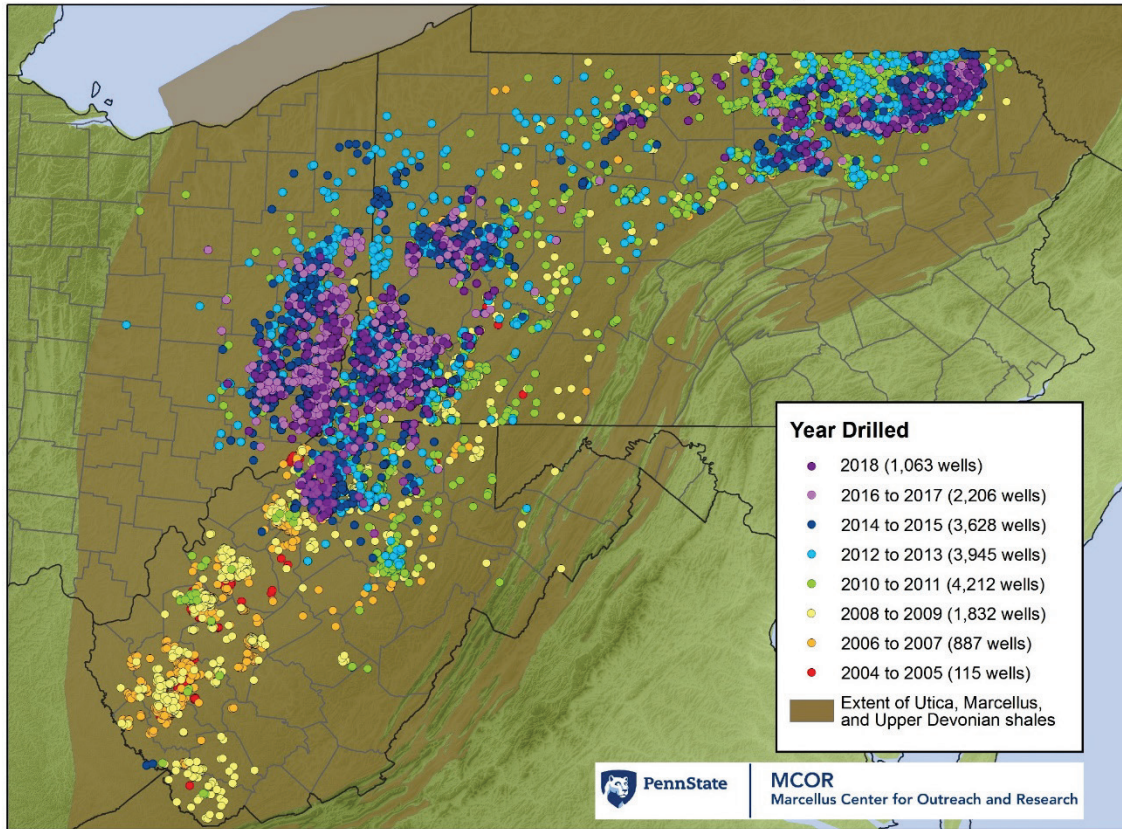
Larry Hogan, Governor of Maryland, along with, on the left, President of Senate Mike Miller, and on the right, Speaker of the House of Delegate Michael Busch, sign the fracking ban during a bill signing ceremony. (Pamela Wood, Baltimore Sun video)

<https://www.capitalgazette.com/multimedia/videos/92970771-132.html>

See also [https://www.washingtonpost.com/local/md-politics/maryland-senate-gives-final-approval-to-fracking-ban/2017/03/27/362649d8-1349-11e7-833c-503e1f6394c9\\_story.html](https://www.washingtonpost.com/local/md-politics/maryland-senate-gives-final-approval-to-fracking-ban/2017/03/27/362649d8-1349-11e7-833c-503e1f6394c9_story.html)

# Pa Active Natural Gas Production

## Unconventional Wells Drilled by Year



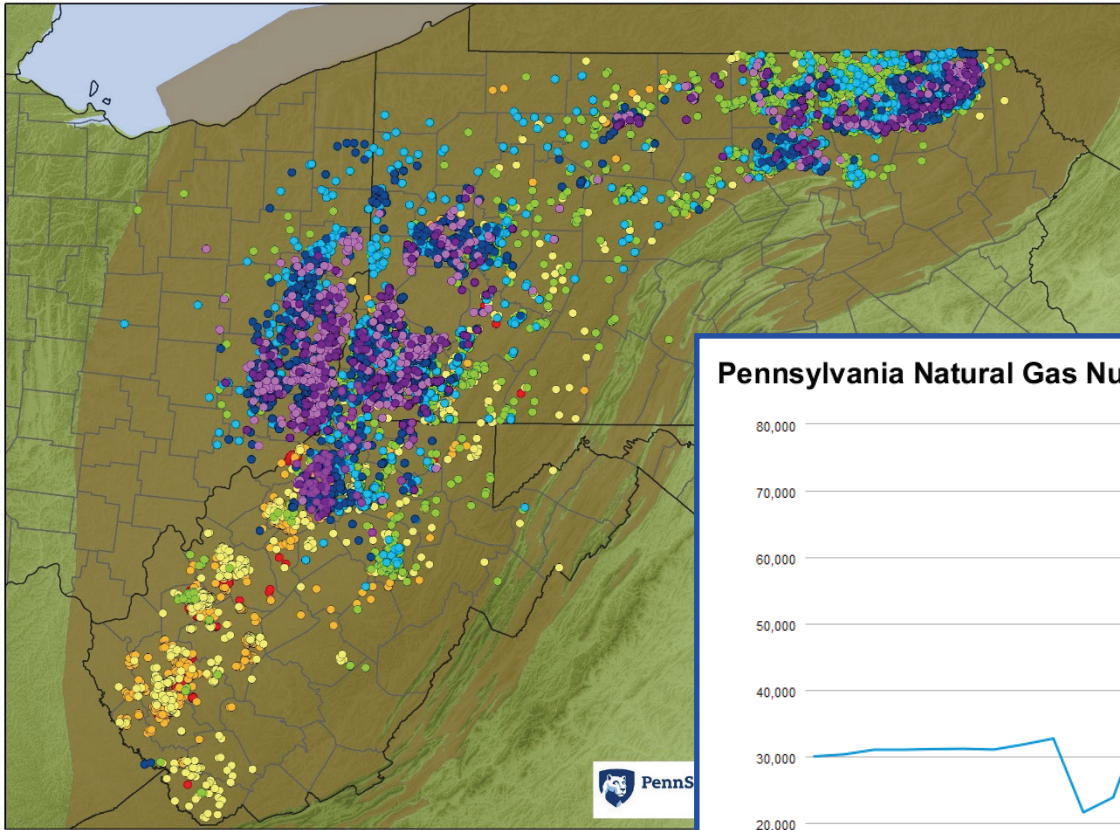
Map: <http://www.marcellus.psu.edu/images/Spud%20Map%20All%2011.19.13.jpg>

Chart: [http://www.eia.gov/dnav/ng/hist/na1170\\_spa\\_8a.htm](http://www.eia.gov/dnav/ng/hist/na1170_spa_8a.htm)

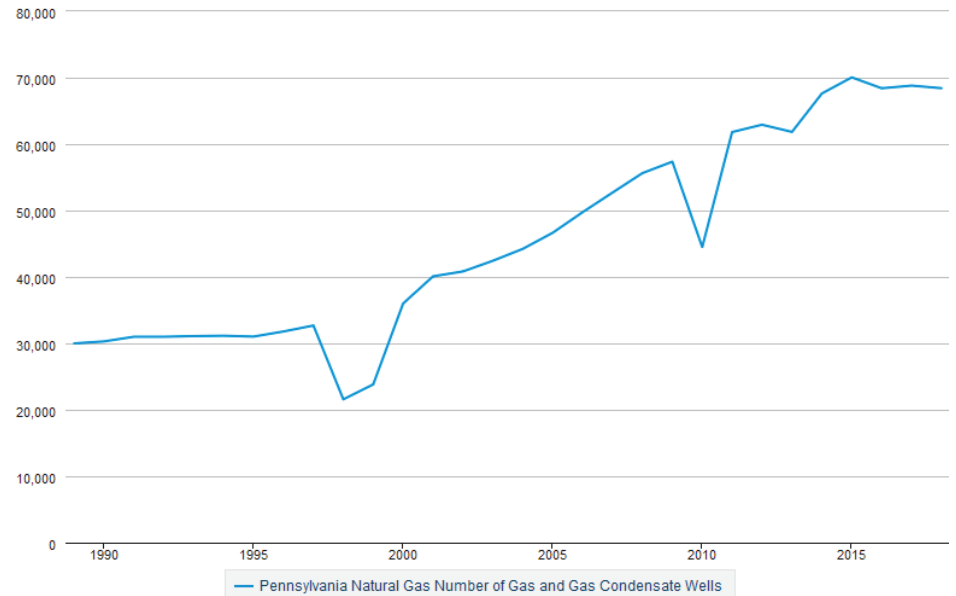


# Pa Active Natural Gas Production

## Unconventional Wells Drilled by Year



Pennsylvania Natural Gas Number of Gas and Gas Condensate Wells



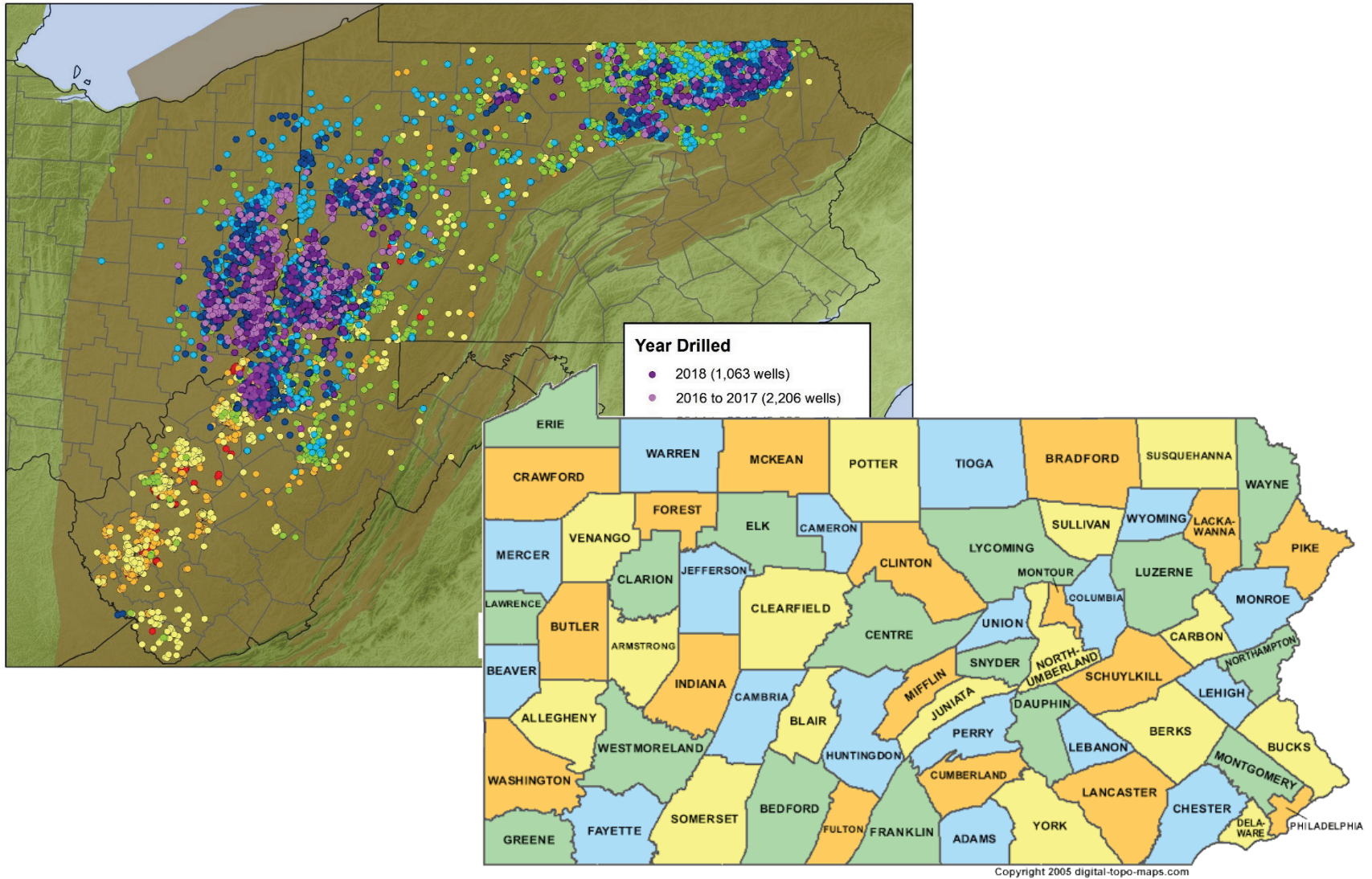
Source: U.S. Energy Information Administration

Map: <http://www.marcellus.psu.edu/images/Spud%20Map%20All%2011.19.13.jpg>

Chart: [http://www.eia.gov/dnav/ng/hist/na1170\\_spa\\_8a.htm](http://www.eia.gov/dnav/ng/hist/na1170_spa_8a.htm)

# Pa Active Natural Gas Production

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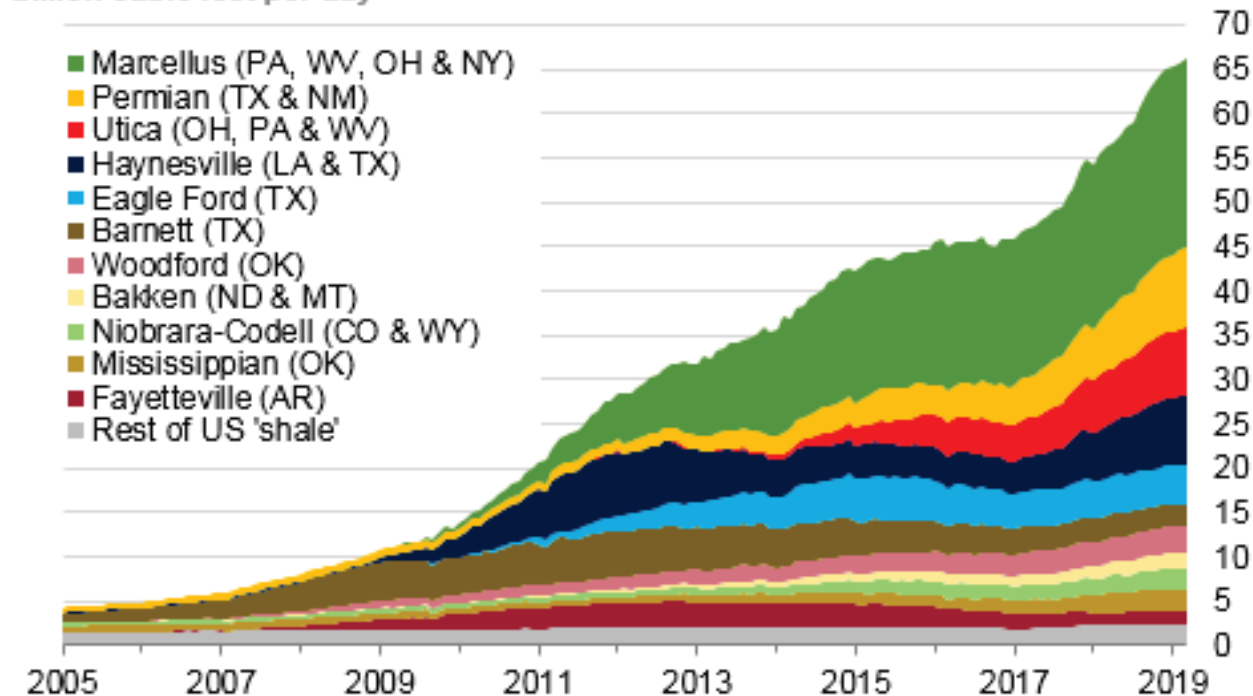
Map: <http://www.marcellus.psu.edu/images/Spud%20Map%20All%2011.19.13.jpg>

Chart: [http://www.eia.gov/dnav/ng/hist/na1170\\_spa\\_8a.htm](http://www.eia.gov/dnav/ng/hist/na1170_spa_8a.htm)

# Monthly US natural gas production

## Monthly dry shale gas production

billion cubic feet per day



Marcellus accounts for  
~ 30% of U.S. shale gas  
production

Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through March 2019 and represent EIA's official tight gas estimates, but are not survey data. State abbreviations indicate primary state(s).



[https://www.eia.gov/energyexplained/index.php?page=natural\\_gas\\_where](https://www.eia.gov/energyexplained/index.php?page=natural_gas_where)

# Shale Gas Production & Public Policy

- U.S. imports very little CH<sub>4</sub> (some imports from Canada)
- Price of CH<sub>4</sub> has fallen by a factor of 2 since 2008
- Concerns about shale gas production fall into four categories:
  - **Earthquakes**
  - **Contamination of ground water**
  - **Air quality (surface O<sub>3</sub> precursors)**
  - **Climate (fugitive release of CH<sub>4</sub>)**
- Former U.S. Dept of Energy Secretary David Chu (served 21 Jan 2009 to 22 April 2013) commissioned two reports from the Shale Gas Subcommittee of the Secretary of Energy Advisory Board (SEAB) to “identify measures that can be taken to reduce the environmental impact and to help assure the safety of shale gas production”
- First report (11 Aug 2011) identified 20 action items (see table, next slide)
- Second report (18 Nov 2011) outlined recommendations for implementation of action items
- EPA issued new standards for the oil and natural gas industry on 14 Jan 2015
- Notably absent is extended discussion of earthquake issue

<https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry>

# Concern #1: Earthquakes

## 2012 Seismological Society of America meeting

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### ARE SEISMICITY RATE CHANGES IN THE MIDCONTINENT NATURAL OR MANMADE?

ELLSWORTH, W. L., US Geological Survey, Menlo Park, CA; HICKMAN, S. H., US Geological Survey, Menlo Park, CA; LLEONS, A. L., US Geological Survey, Menlo Park, CA; MCGARR, A., US Geological Survey, Menlo Park, CA; MICHAEL, A. J., US Geological Survey, Menlo Park, CA; RUBINSTEIN, J. L., US Geological Survey, Menlo Park, CA

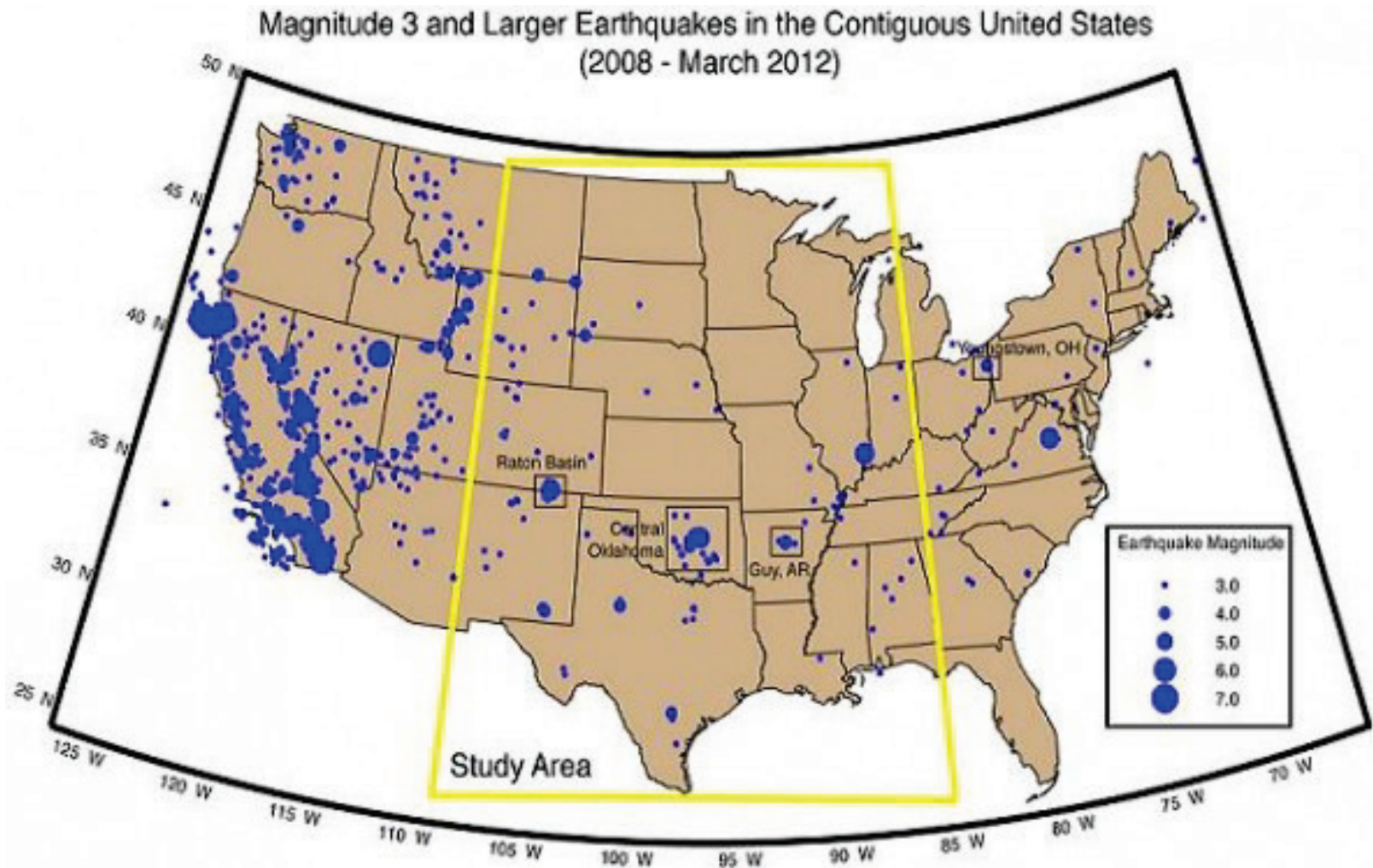
A remarkable increase in the rate of M 3 and greater earthquakes is currently in progress in the US midcontinent. The average number of  $M \geq 3$  earthquakes/year increased starting in 2001, culminating in a six-fold increase over 20th century levels in 2011. Is this increase natural or manmade? To address this question, we take a regional approach to explore changes in the rate of earthquake occurrence in the midcontinent (defined here as  $85^\circ$  to  $108^\circ$  West,  $25^\circ$  to  $50^\circ$  North) using the USGS Preliminary Determination of Epicenters and National Seismic Hazard Map catalogs. These catalogs appear to be complete for  $M \geq 3$  since 1970. From 1970 through 2000, the rate of  $M \geq 3$  events averaged  $21 \pm 7.6$ /year in the entire region. This rate increased to  $29 \pm 3.5$  from 2001 through 2008. In 2009, 2010 and 2011, 50, 87 and 134 events occurred, respectively. The modest increase that began in 2001 is due to increased seismicity in the coal bed methane field of the Raton Basin along the Colorado-New Mexico border west of Trinidad, CO. The acceleration in activity that began in 2009 appears to involve a combination of source regions of oil and gas production, including the Guy, Arkansas region, and in central and southern Oklahoma. Horton, et al. (2012) provided strong evidence linking the Guy, AR activity to deep waste water injection wells. In Oklahoma, the rate of  $M \geq 3$  events abruptly increased in 2009 from 1.2/year in the previous half-century to over 25/year. This rate increase is exclusive of the November 2011 M 5.6 earthquake and its aftershocks. A naturally-occurring rate change of this magnitude is unprecedented outside of volcanic settings or in the absence of a main shock, of which there were neither in this region. While the seismicity rate changes described here are almost certainly manmade, it remains to be determined how they are related to either changes in extraction methodologies or the rate of oil and gas production.

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*Wednesday, April 18th / 3:45 PM Oral / Pacific Salon 4 & 5*

# Concern #1: Earthquakes

Ellsworth's study area:



<http://www.esa.org/esablog/ecology-in-the-news/increase-in-magnitude-3-earthquakes-likely-caused-by-oil-and-gas-production-but-not-fracking>

# Concern #1: Earthquakes

## Ellsworth's study suggests:

- Deep waste water injection wells are the culprit, especially if in the vicinity of a fault
- Increased fluid pressure in pores of the rock can reduce the slippage strain between rock layers
- Speed of pumping is important (slow better than fast)

## USGS testimony:

- On 19 June 2012, Dr. William Leath of the U.S. Geological Survey testified before the U.S. Senate Committee on Energy and Natural Resources, stating:

The injection and production practices employed in these technologies have, to varying degrees, the potential to introduce earthquake hazards

Since the beginning of 2011 the central and eastern portions of the United States have experienced a number of moderately strong earthquakes in areas of historically low earthquake hazard. These include M4.7 in central Arkansas on Feb27, 2011; M5.3 near Trinidad, Colorado on Aug 23, 2011; M5.8 in central Virginia also on Aug 23, 2011; ... M5.6 in central Oklahoma on Nov 6, 2011 ... and M4.8 in east Texas on May 17, 2012. Of these only the central Virginia earthquake is unequivocally a natural tectonic earthquake.

In all other cases, there is scientific evidence to at least raise the possibility that the earthquakes were induced by wastewater disposal or other oil- and gas-related activities.

USGS scientists documented a seven-fold increase since 2008 in the seismicity of the central U.S., an increase largely associated with areas of wastewater disposal from oil, gas & coalbed methane production

First three bullets:

<http://www.esa.org/esablog/ecology-in-the-news/increase-in-magnitude-3-earthquakes-likely-caused-by-oil-and-gas-production-but-not-fracking>

USGS testimony:

[http://www.usgs.gov/congressional/hearings/docs/leith\\_19june2012.DOCX](http://www.usgs.gov/congressional/hearings/docs/leith_19june2012.DOCX)

# Concern #1: Earthquakes

28 Jan 2015 Washington Post

The Washington Post

Economy

Search

## Oklahoma worries over swarm of earthquakes and connection to oil industry

GUTHRIE, Okla. – The earthquakes come nearly every day now, cracking drywall, popping floor tiles and rattling kitchen cabinets. On Monday, three quakes hit this historic land-rush town in 24 hours, booming and rumbling like the end of the world.

“After a while, you can’t even tell what’s a pre-shock or an after-shock. The ground just keeps moving,” said Jason Murphey, 37, a Web developer who represents Guthrie in the state legislature. “People are so frustrated and scared. They want to know the state is doing something.”

What to do about the [plague of earthquakes](#) is, however, very much an open question in Oklahoma. Last year, 567 quakes of at least 3.0 magnitude rocked a swath of counties from the state capital to the Kansas line, alarming a populace long accustomed to fewer than two quakes a year.

Scientists [implicated](#) the oil and gas industry – in particular, the deep wastewater disposal wells that have been linked to a dramatic increase in seismic activity across the central United States. But in a state founded on oil wealth, officials have been reluctant to crack down on an industry that accounts for a third of the economy and one in five jobs.



# Concern #1: Earthquakes

28 Jan 2015 Washington Post

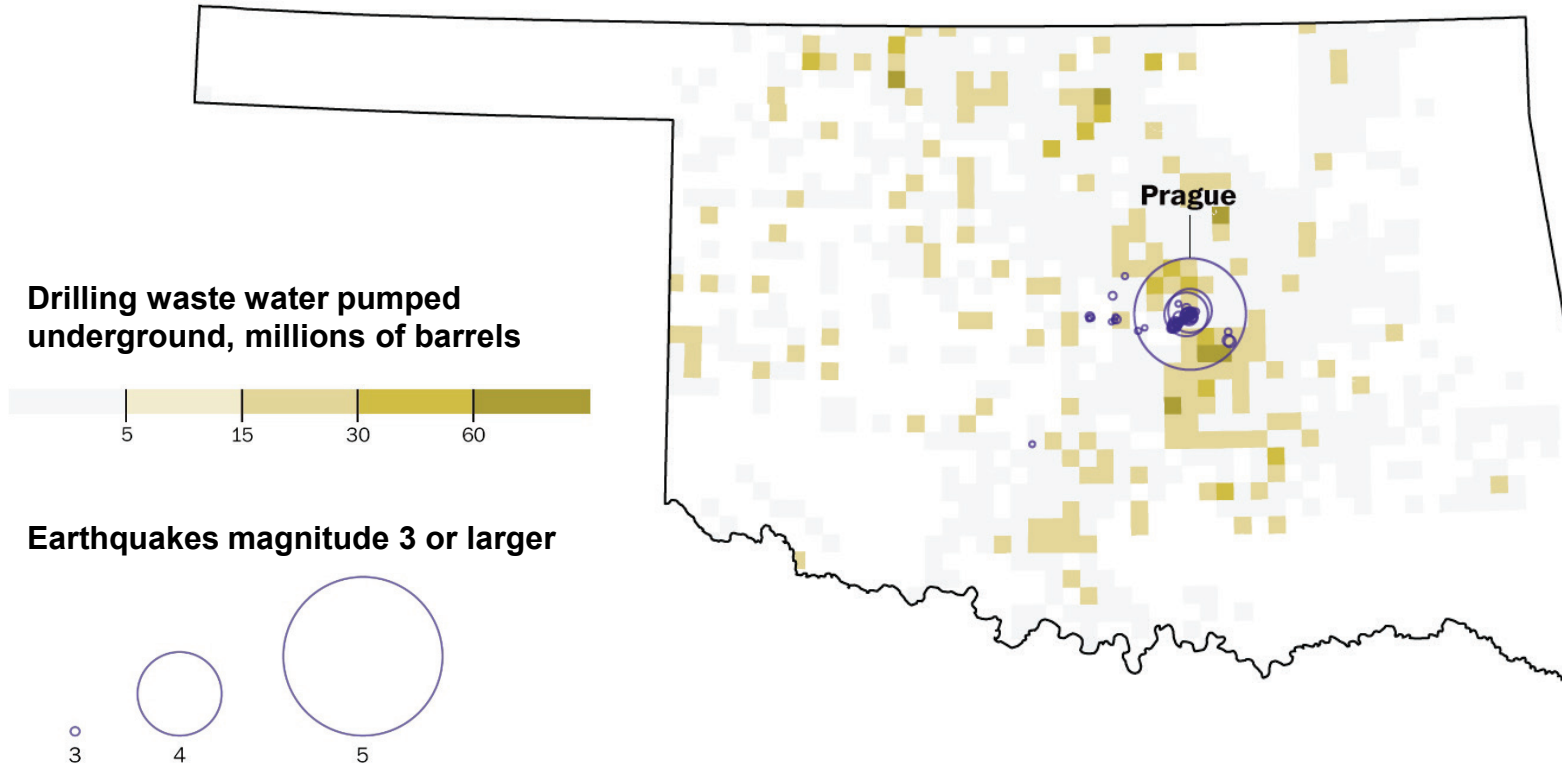
The Washington Post

Economy

Search

## Oklahoma worries over swarm of earthquakes and connection to oil industry

2011



<http://www.washingtonpost.com/graphics/national/oklahoma-earthquakes/>

# Concern #1: Earthquakes

28 Jan 2015 Washington Post

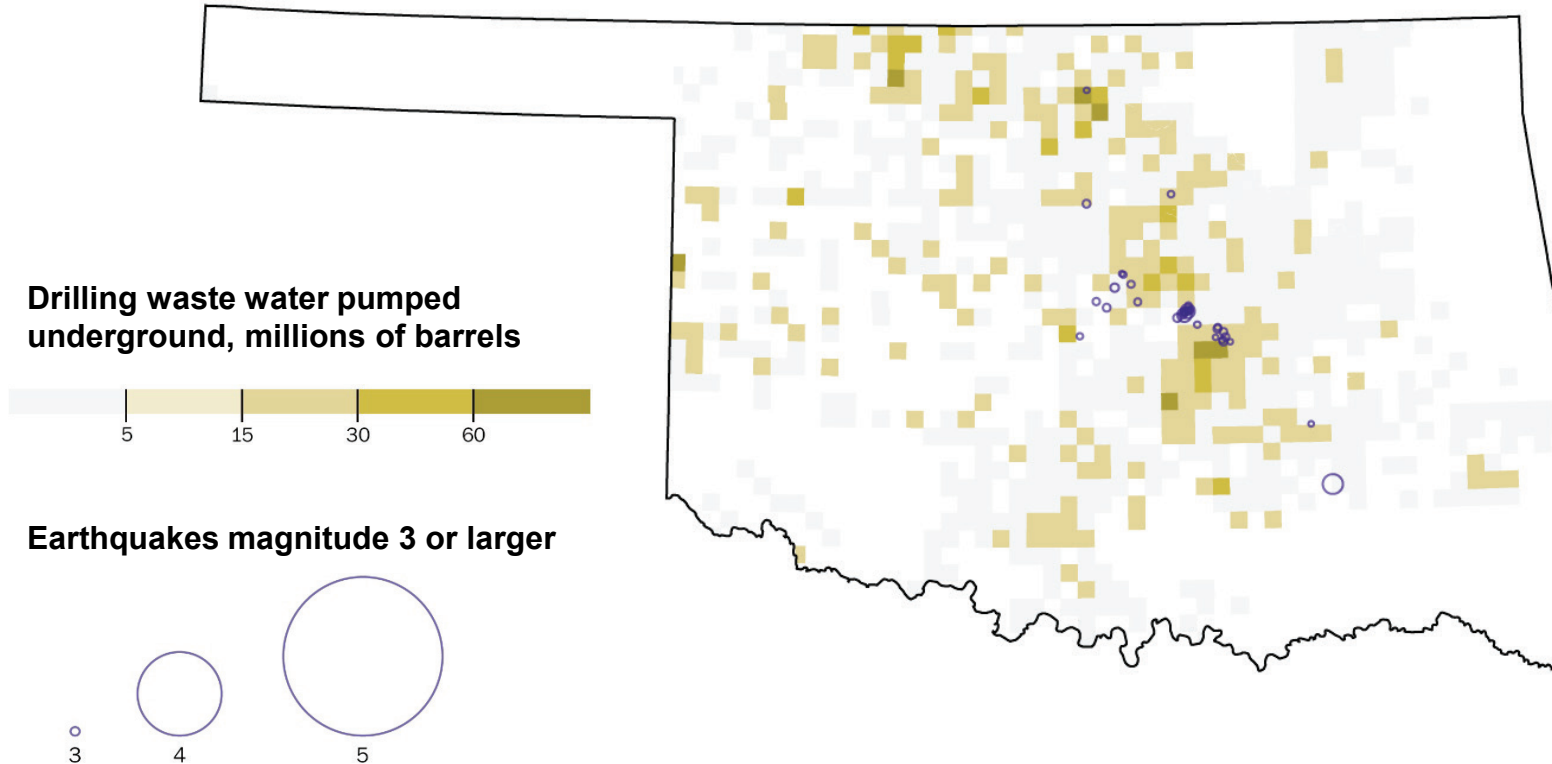
The Washington Post

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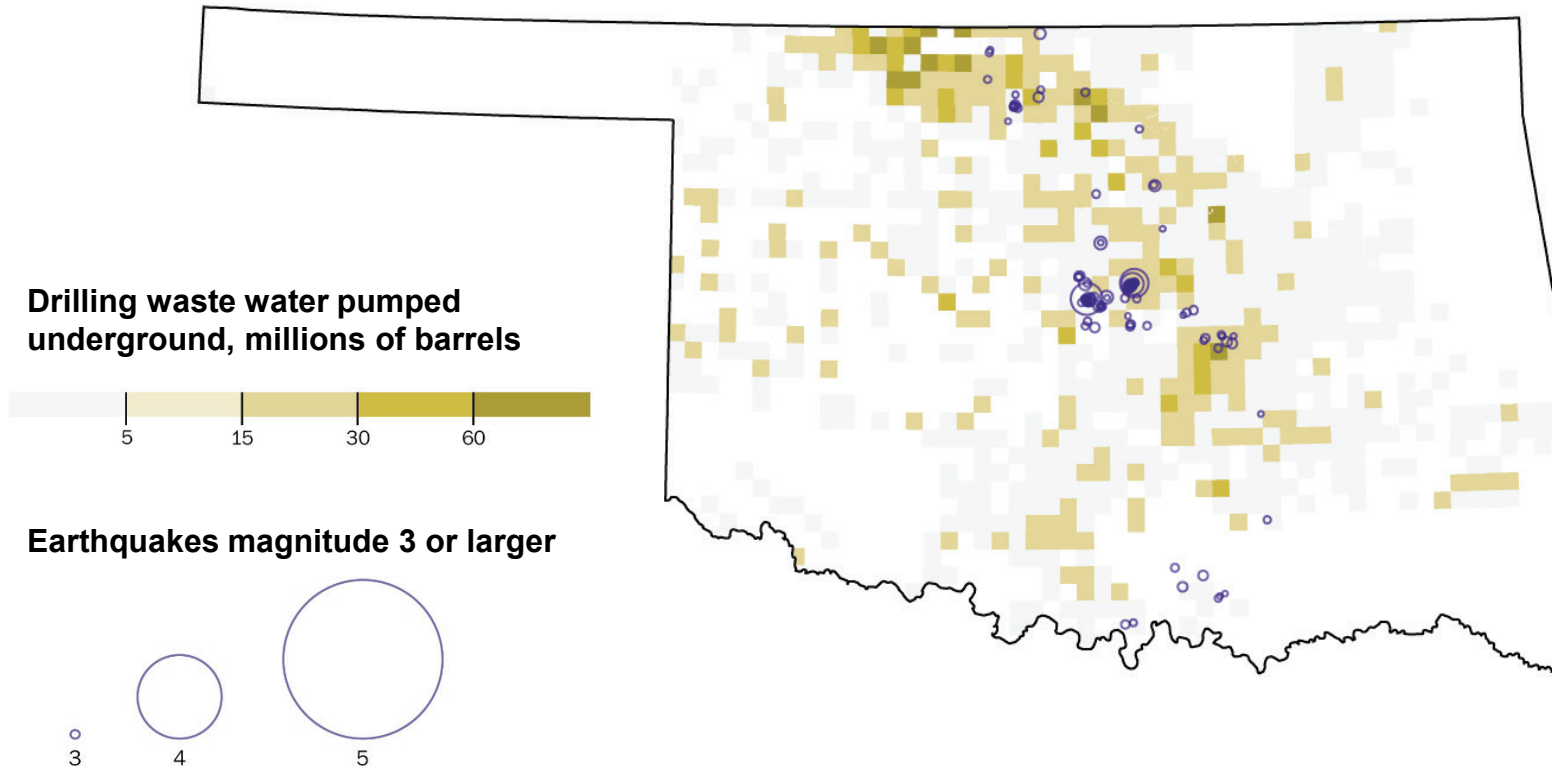
The Washington Post

Economy

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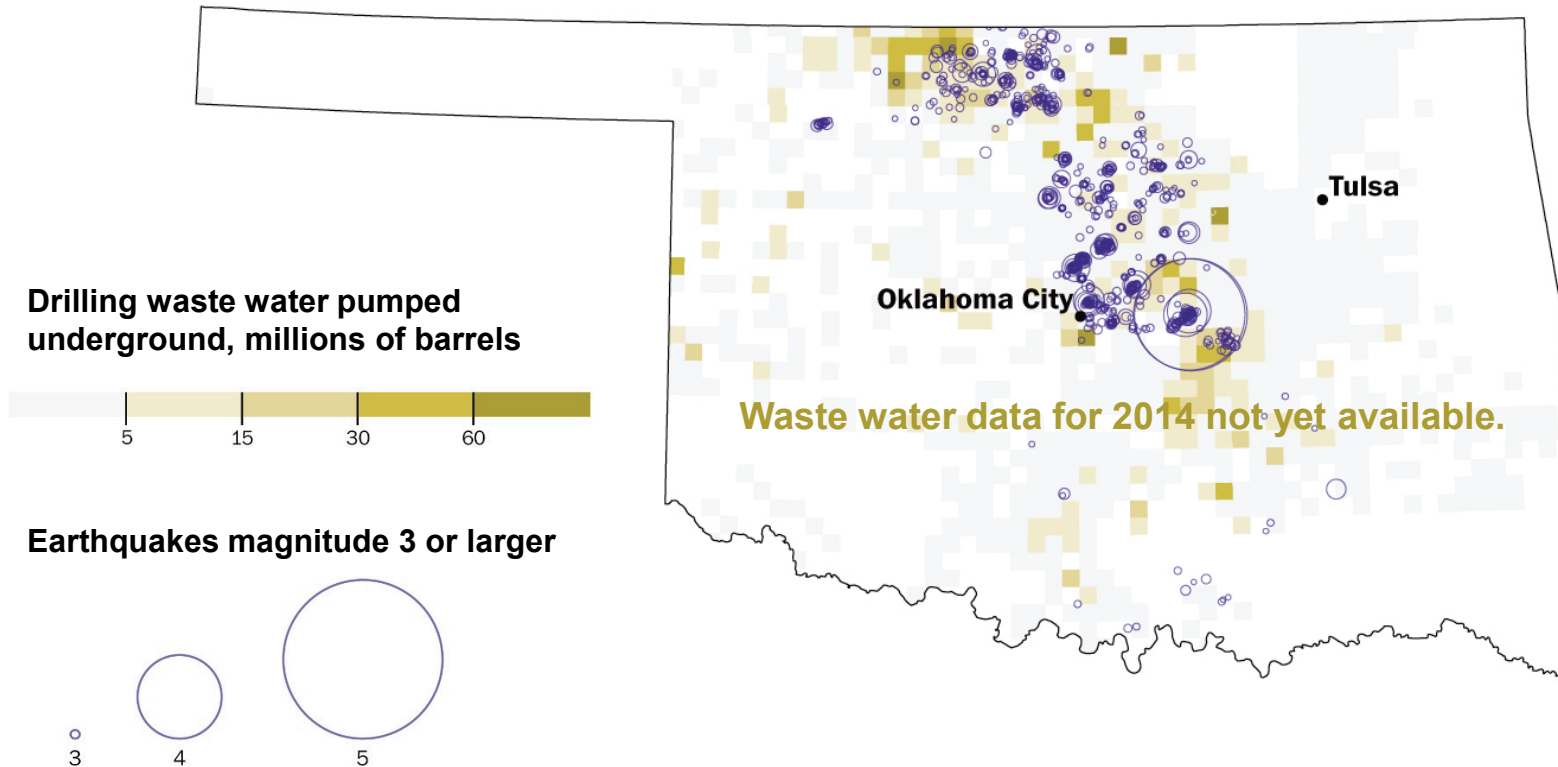
The Washington Post

Economy

Search

## Oklahoma worries over swarm of earthquakes and connection to oil industry

2014



<http://www.washingtonpost.com/graphics/national/oklahoma-earthquakes/>

# Concern #1: Earthquakes

7 Nov 2016 USA Today

The image is a screenshot of a news article on the USA Today website. At the top left is the USA Today logo. To the right is a search bar. Below the logo is a navigation menu with categories: NEWS, SPORTS, LIFE, MONEY, TECH, TRAVEL, OPINION, 80° (weather), CROSSWORDS, WASHINGTON, VIDEO, STOCKS, APPS, and MORE. The main headline is "Oklahoma earthquake reignites concerns that fracking wells may be the cause". Below the headline is the author "Rick Jervis, USA TODAY" and the date "5:34 p.m. ET Nov. 7, 2016". On the left side of the article is a vertical sidebar with social media sharing icons for Facebook (1253), Twitter, LinkedIn (10), Email, and Print. The article text begins with "A 5.0 magnitude earthquake that rattled north-central Oklahoma Sunday was only the sixth of that strength in state history and has reawakened concerns that oil and gas activity could be causing the tremors." It continues with "The temblor, which occurred around 7:44 p.m. Sunday about a mile west of Cushing, Okla., sheared bricks off buildings, caused structural damage to homes and forced local schools to close Monday. Around 40 residents were evacuated from a retirement home and sheltered at a local gymnasium." The final sentence is "It was only the sixth 5.0 magnitude or higher to strike Oklahoma since 1882, said George Choy, a geophysicist with the U.S. Geological Survey in Boulder, Colo. Three of those larger quakes occurred this year. The strongest ever recorded in Oklahoma". An inset photo shows a person walking past a building with significant brick damage.

**USA TODAY**

Search

NEWS SPORTS LIFE MONEY TECH TRAVEL OPINION 80° CROSSWORDS WASHINGTON VIDEO STOCKS APPS MORE

## Oklahoma earthquake reignites concerns that fracking wells may be the cause

Rick Jervis, USA TODAY 5:34 p.m. ET Nov. 7, 2016

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**in** 10  
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(Photo: Jim Beckel, AP)

**f** 1253 CONNECT **t** TWEET **in** 10 LINKEDIN **🗨️** COMMENT **✉** EMAIL **📄** MORE

A 5.0 magnitude earthquake that rattled north-central Oklahoma Sunday was only the sixth of that strength in state history and has reawakened concerns that oil and gas activity could be causing the tremors.

The temblor, which occurred around 7:44 p.m. Sunday about a mile west of Cushing, Okla., sheared bricks off buildings, caused structural damage to homes and forced local schools to close Monday. Around 40 residents were evacuated from a retirement home and sheltered at a local gymnasium.

It was only the sixth 5.0 magnitude or higher to strike Oklahoma since 1882, said George Choy, a geophysicist with the U.S. Geological Survey in Boulder, Colo. Three of those larger quakes occurred this year. The strongest ever recorded in Oklahoma

# Concern #1: Earthquakes

7 Nov 2016 USA Today

**USA TODAY** Search

NEWS SPORTS LIFE MONEY TECH TRAVEL OPINION 80° CROSSWORDS WASHINGTON VIDEO STOCKS APPS MORE

## Oklahoma earthquake reignites concerns that fracking wells may be the cause

Rick Jervis, USA TODAY 5:34



(Photo: Jim Bechel, AP)

Sunday about a mile west of C... structural damage to homes an... residents were evacuated from... gymnasium.

It was only the sixth 5.0 magnit... George Choy, a geophysicist w... of those larger quakes occurred



# Concern #1: Earthquakes

7 Nov 2016 USA Today

**USA TODAY** Search

NEWS SPORTS LIFE MONEY TECH TRAVEL OPINION 80° CROSSWORDS WASHINGTON VIDEO STOCKS APPS MORE

## Oklahoma earthquake reignites concerns that fracking wells may be the cause

Rick Jervis, USA TODAY 5:30

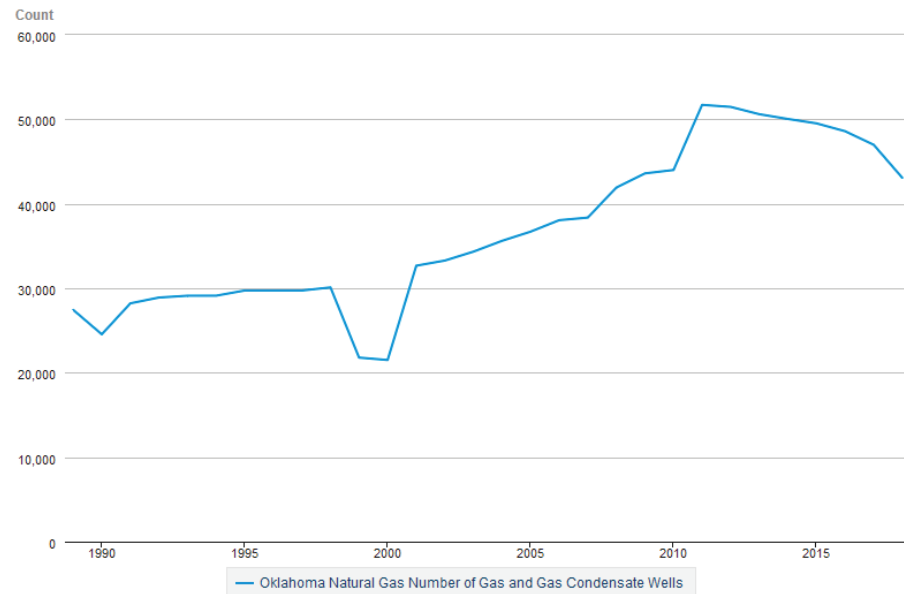


(Photo: Jim Beckel, AP)

Sunday about a mile west of C structural damage to homes and residents were evacuated from gymnasium.

It was only the sixth 5.0 magnitude earthquake in Oklahoma since 1992. George Choy, a geophysicist with the U.S. Geological Survey, said that of those larger quakes occurred

### Oklahoma Natural Gas Number of Gas and Gas Condensate Wells

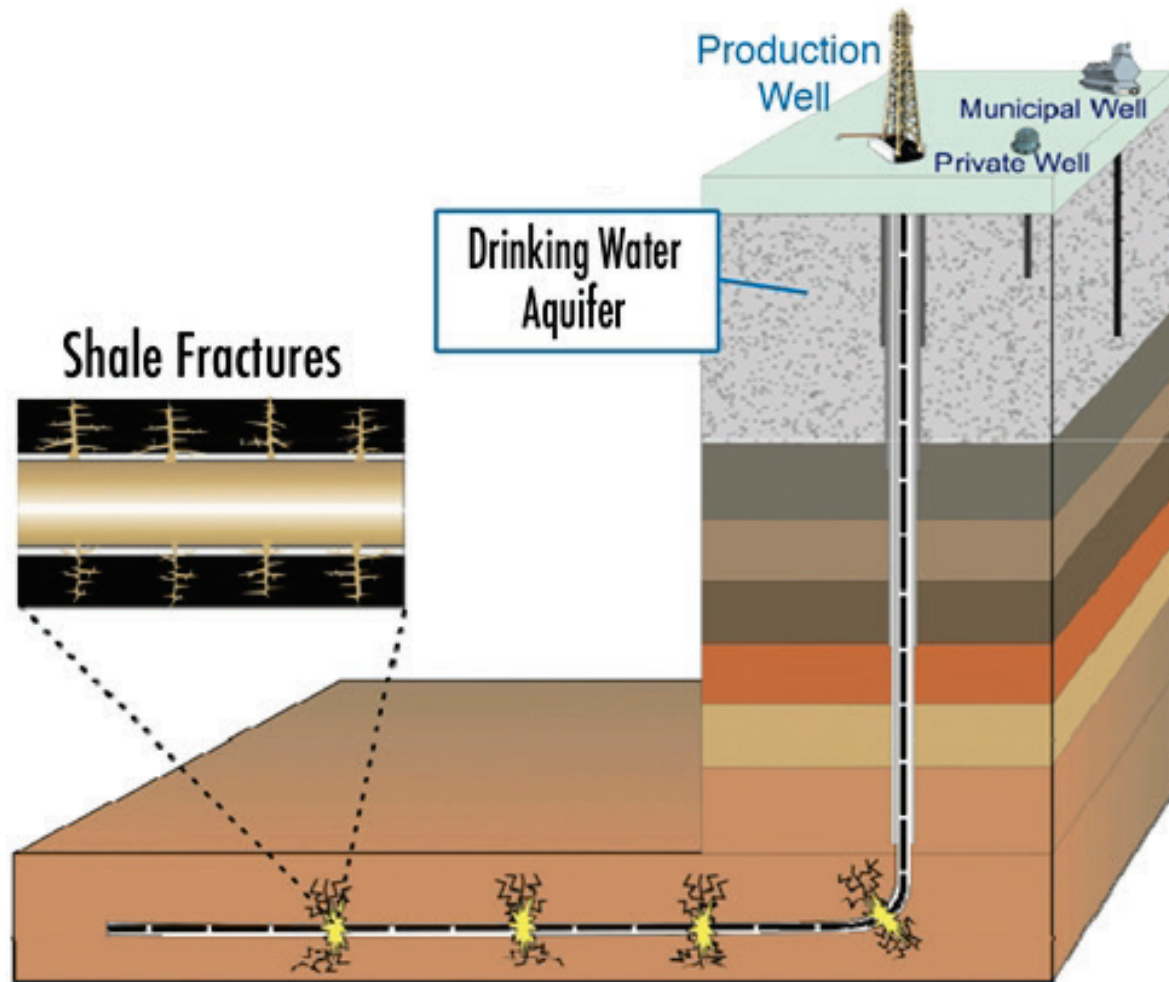


Source: U.S. Energy Information Administration

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[http://www.eia.gov/dnav/ng/hist/na1170\\_spa\\_8a.htm](http://www.eia.gov/dnav/ng/hist/na1170_spa_8a.htm)

## Concern #2: Water Quality



Source: EPA

<http://savethewater.org/wp-content/uploads/2013/02/Stock-Save-the-water-New-Study-Predicts-Fracking-Fluids-Will-Seep-Into-Aquifers-Within-Years.jpg>



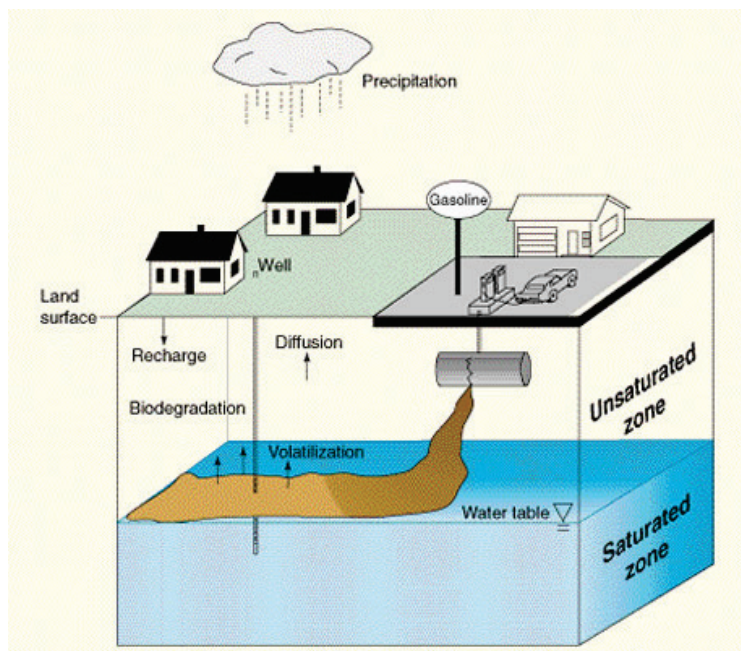
## Concern #2: Water Quality

Spread of contaminants in ground water determined by

**Dispersion** – differential flow of water through small openings (pores) in soil

**Diffusion** – random molecular (Brownian) motion of molecules in water

**Sorption** – some chemicals may be *absorbed by soil* while others are *adsorbed* (adhere to surfaces)



**Highly diffusive chemicals (such as MTBE) can spread quickly even though ground water is relatively motionless.**

MTBE: Methyl tert-butyl ether;  $(\text{CH}_3)_3\text{COCH}_3$

<https://www.cancer.org/cancer/cancer-causes/mtbe.html>

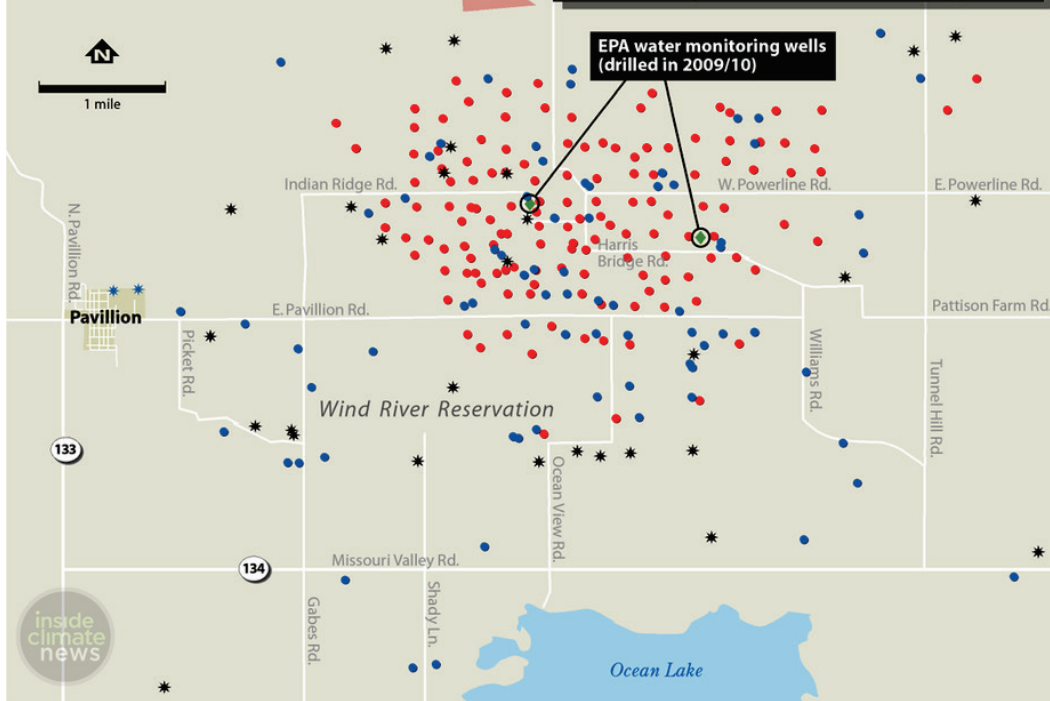
[http://toxics.usgs.gov/topics/gwcontam\\_transport.html](http://toxics.usgs.gov/topics/gwcontam_transport.html)

# Concern #2: Water Quality

## PAVILLION, WYOMING Hotbed of Fracking Activity

Wells crowd the landscape in Pavillion, Wyo. where oil and gas operations began in the 1950s. Between the first well fracked in 1964 and the last well fracked in 2007, an estimated 11 million gallons of fracking fluid was injected into the ground. A new study, based partly on EPA data, finds that chemicals from hydraulic fracturing and other oil and gas operations have contaminated the groundwater.

- Domestic water well
- Oil/gas production well
- \* Plugged & abandoned production well



SOURCE: Environmental Science & Technology, March 18, 2016

PAUL HORN / InsideClimate News

Wyoming:

25000 wells

Study area:

11 million gallons of various fluids including hydrochloric acid and methanol, many of which are neurotoxins and carcinogens, pumped into the ground

Companies frequently fracked at much shallower depths than previously thought, sometimes very close to wells

High levels of diesel-related organic compounds & acids were found...  
"it seems implausible this is due to natural conditions," DiGiulio said. "When you look at the compounds, it's a virtual fingerprint of chemicals used in the field."

<https://insideclimatenews.org/news/29032016/fracking-study-pavillion-wyoming-drinking-water-contamination-epa>



## Fluid composition: Concern #2: Water Quality

April 2011: [www.fracfocus.org](http://www.fracfocus.org) created as central disclosure registry for industry use

As of January 2016, 28 states require the disclosure of some, but not all, chemicals used during fracking & 23 use Frac Focus

Searchable database & Google map interface allow user to obtain info for individual wells

### **Harvard Law School study highlights flaws in this system:**

- 1) Timing of Disclosures: Site does not notify States if company submits late**
- 2) Substance of Disclosure: Site does not provide state specific forms, no minimum reporting standards**
- 3) Nondisclosures: Companies not required to disclose chemicals if they are considered a “trade secret”**  
**~20% of all chemicals not reported.**

[http://www.eenews.net/assets/2013/04/23/document\\_ew\\_01.pdf](http://www.eenews.net/assets/2013/04/23/document_ew_01.pdf)

See also <http://www.factcheck.org/2017/04/facts-fracking-chemical-disclosure>

# Fluid composition: Concern #2: Water Quality



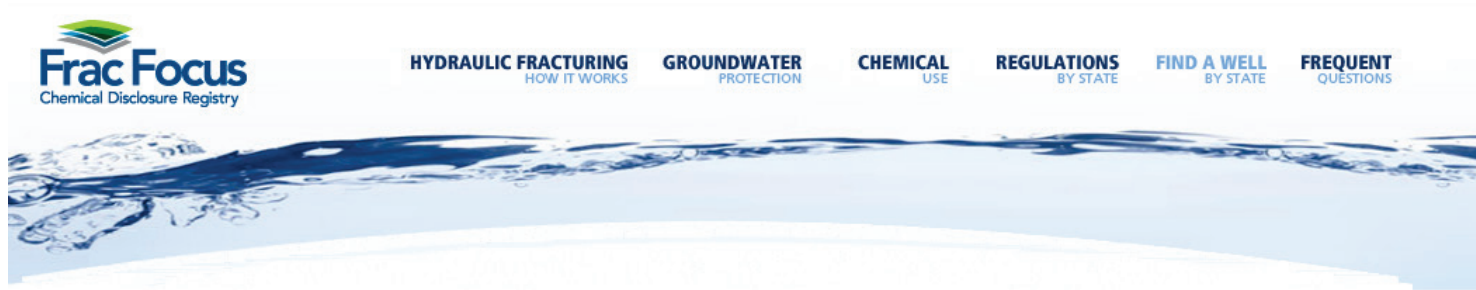
## Find a Well

Map Search

Search Options Show/Hide

STATE: Pennsylvania	COUNTY: Washington	WELLS IN COUNTY: Bird Run 10H	OPERATOR: Choose One
JOB/SUBMITTED DATE: Job Start Date	Please Wait..		DATE: [Calendar Icon]
FEDERAL WELL: <input type="checkbox"/>	[Progress Bar]		RANGE END DATE: [Calendar Icon]
INDIAN WELL: <input type="checkbox"/>	[Progress Bar]		
CAS Number: [Input Field]	[Progress Bar]		
INGREDIENT LIST [Progress Bar]			
Clear Ingredient			
SEARCH		RESET	

# Fluid composition: Concern #2: Water Quality



## Find a Well

Map Search

Narrow Results:

- Chemical Tracer -- Proprietary
- Chemical 2 Ingredient 11 -- Proprietary
- Chemical Entity Nitrogen -- 7727-37-9
- Chemical Tracer -- Proprietary
- Chemplex -- Proprietary
- CHEMPLEX-Polymer\_00019 -- Trade Secret
- Choline Chloride -- 67-48-1
- Chloine Dioxide -- 10049-04-4
- Chloine Bicarbonate -- 78-73-9
- Chlorid Acid, Sodium Salt -- 7775-09-9
- Chloride -- \*3rd Party Additive
- Chloride -- 16887-00-6
- Chloride Dioxide -- 10049-04-4
- Chloride Glutaraldehyde -- 111-30-8
- Chloridne dioxide -- 10049-04-4
- Chlorin Dioxide -- 10049-04-4
- Chlorine Chloride -- 67-48-1
- CHLORINE CHLORIDE -- Proprietary
- Chlorine compound -- Confidential
- Chlorine compound -- Proprietary
- Chlorine Dioxide -- 10049-04-04
- Chlorine Dioxide -- 7631-90-5

Press and hold "ctrl" to select more than one ingredient.

### Options

Show/Hide

N COUNTY:

Jun 10H

OPERATOR:

Choose One

DATE:



RANGE END DATE:



# Fluid composition: Concern #2: Water Quality



## Find a Well

Narrow Results:

Options

N COUNTY:

DATE:

Narrow Results:

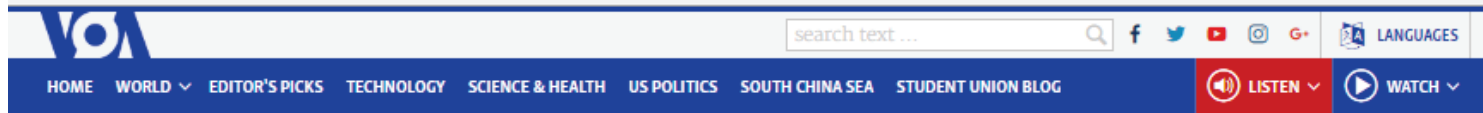
Chemical 1 -- Proprietary  
Chemical 2 Ingredient 11 -- Proprietary  
Chemical Entity Nitrogen -- 7727-37-9  
Chemical Tracer -- Proprietary  
Chemplex -- Proprietary  
CHEMPLEX-Polymer\_00019 -- Trade Secret  
Choline Chloride -- 67-48-1  
Chloine Dioxide -- 10049-04-4  
Chloine Bicarbonate -- 78-73-9  
Chlorid Acid, Sodium Salt -- 7775-09-9  
Chloride -- \*3rd Party Additive  
Chloride -- 16887-00-6  
Chloride Dioxide -- 10049-04-4  
Chloride Glutaraldehyde -- 111-30-8  
Chloridne dioxide -- 10049-04-4  
Chlorin Dioxide -- 10049-04-4  
Chlorine Chloride -- 67-48-1  
CHLORINE CHLORIDE -- Proprietary  
Chlorine compound -- Confidential  
Chlorine compound -- Proprietary  
Chlorine Dioxide -- 10049-04-04  
Chlorine Dioxide -- 7631-90-5

Press and hold "ctrl" to select more than one ingredient.

Acryimide Polymer -- Proprietary  
Acylamide polymer -- proprietary  
Acrylic amide (impurity) -- Proprietary  
Additive 1 -- Proprietary  
Additive 2 -- Proprietary  
Additive 3 -- Proprietary  
AG-2 Blend -- Proprietary  
AI-3 -- Proprietary  
Aiphatic Hydrocarbon -- Proprietary  
Akylene oxide block polymer -- proprietary  
Akylene Oxide Block Polymer -- Proprietary  
Akylene oxide block polymer -- proprietary  
Akybenzene sulfonate -- Proprietary  
Akybenzene sulfonate #2 -- Proprietary  
AKYLBENZENE SULFONATE, COMPD. WITH 2-PROP  
Alcohol -- Proprietary  
ALCOHOL ETHOXYLATE -- Proprietary  
Alcohol Ethoxylates -- Proprietary  
Alchol Alkoxy Sulfate -- Proprietary  
Alchol Ethoxylates -- Proprietary  
Alcohol -- Proprietary  
Alcohol (Alkoxy) -- Proprietary

Press and hold "ctrl" to select more than one ingredient.

# Fluid composition: Concern #2: Water Quality



## ECONOMY

March 15, 2017 9:55 PM

Associated Press

# Trump Administration Halts Obama-Era Rule on Fracking on Public Land

WASHINGTON — The Trump administration is rolling back an Obama administration rule requiring companies that drill for oil and natural gas on federal lands to disclose chemicals used in hydraulic fracturing, better known as fracking.

The administration said in court papers Wednesday that it is withdrawing from a lawsuit challenging the Obama-era rule and will begin a new rule-making process later this year.

The Interior Department issued the rule in March 2015, the first major federal regulation of fracking, the controversial drilling technique that has sparked an ongoing boom in natural gas production but raised widespread concerns about possible groundwater contamination and even earthquakes.

The rule has been on hold since last year after a judge in Wyoming ruled that federal regulators lack congressional authority to set rules for fracking.

### FracFocus.org started in 2011

The rule relies on an online database used by at least 16 states to track the chemicals used in fracking operations. The website, FracFocus.org, was formed by industry and intergovernmental groups in 2011 and allows users to gather well-specific data on tens of thousands of drilling sites across the country.

Companies would have had to disclose the chemicals they use within 30 days of the fracking operation.

Fracking involves pumping huge volumes of water, sand and chemicals underground to split open rocks to allow oil and gas to flow.

<http://www.voanews.com/a/trump-administration-halts-obama-era-rule-on-racking-on-public-land/3768474.html>



# The Show Must Go On

The New York Times



By Eric Lipton and Hiroko Tabuchi

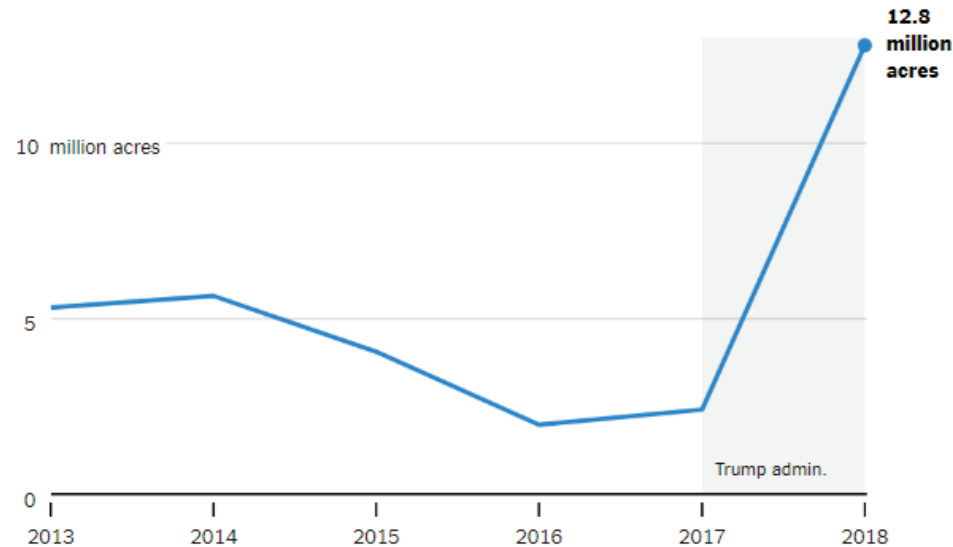
Oct. 27, 2018

## Driven by Trump Policy Changes, Fracking Booms on Public Lands

The administration is auctioning off millions of acres of drilling rights and rolling back regulations, raising environmental concerns in states like Wyoming.

### Federal Land For Sale

The amount of federal land offered at oil and gas lease sales has greatly increased under the Trump administration.



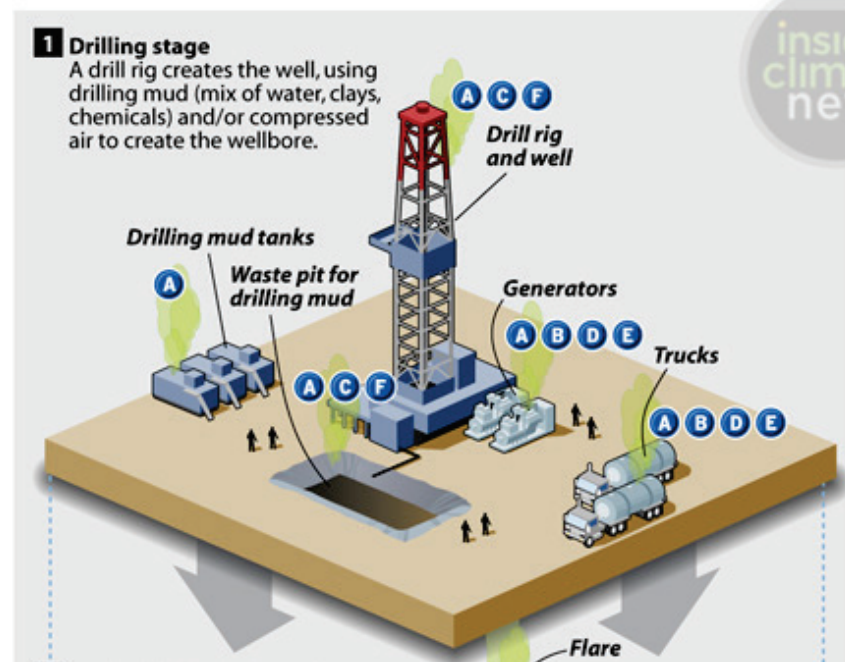
<https://www.nytimes.com/2018/10/27/climate/trump-fracking-drilling-oil-gas.html>

# Concern #3: Air Quality

- Fracking releases a lovely mixture of air pollutants

## Air Emissions from Oil and Gas Development in the Eagle Ford

There are more than 7,000 oil and gas wells in the Eagle Ford Shale, and Texas regulators have approved another 5,500. Most of them, like the one shown here, are oil wells that also produce condensate and natural gas. Developing these resources releases various air pollutants, some of which are shown in this simplified diagram.



### Emission Sources

The pollutants come from a number of sources, including the diesel- or natural gas-fueled equipment, the oil and gas itself, and leaks from storage devices. The emissions' actual and relative amounts vary widely based on operator practices and local geology. The emissions occur regularly in some cases, but are intermittent in others.

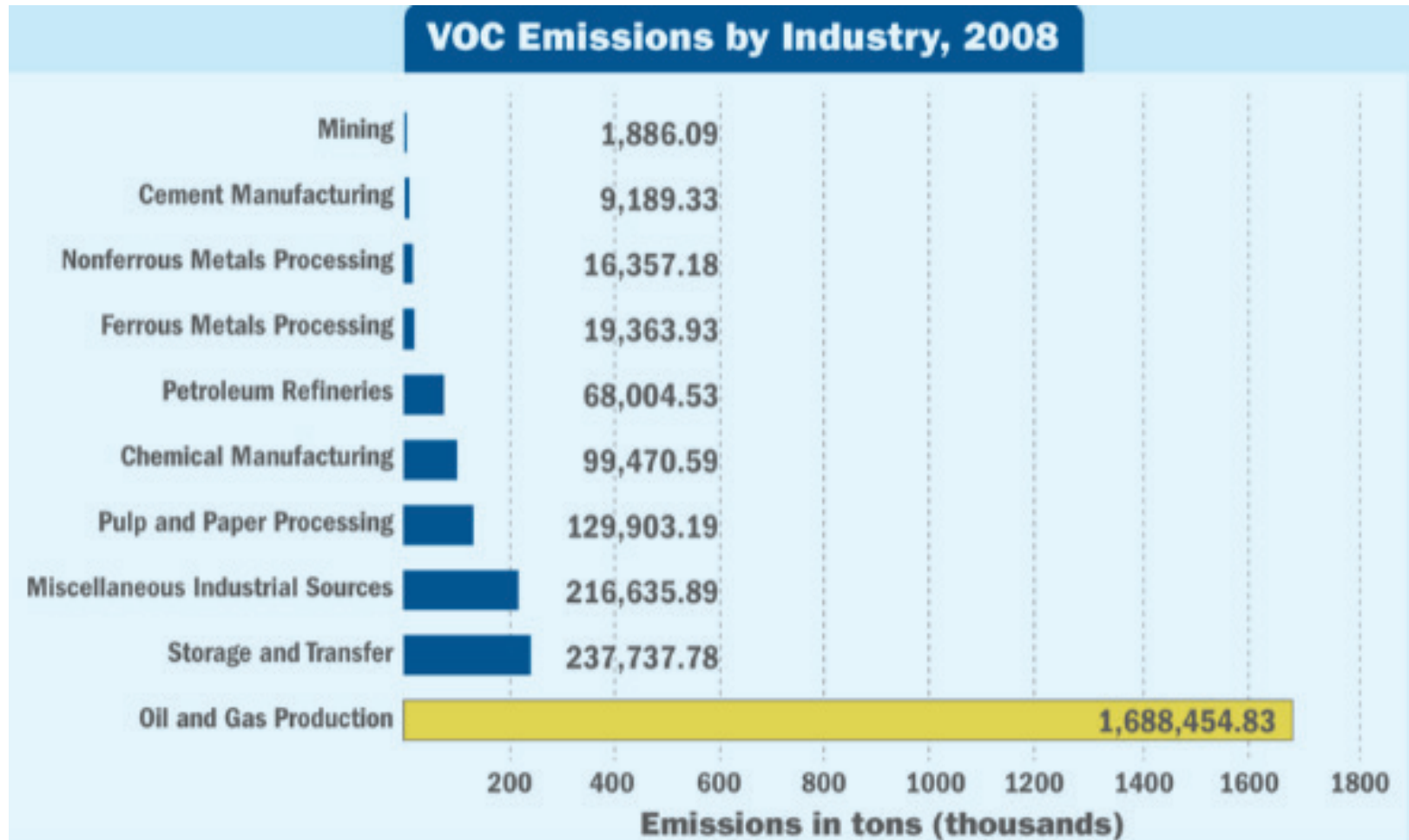
CHEMICAL	WHAT IT IS	WHAT IT DOES
<b>A</b> VOCs	Volatile organic compounds including benzene, formaldehyde	There are dozens of VOCs that make people sick. Some can cause cancer. VOCs react with NO <sub>x</sub> to form ozone, a respiratory irritant and greenhouse gas.
<b>B</b> PM	Particulate matter	Affects the heart and lungs.
<b>C</b> CH <sub>4</sub>	Methane	Main component of natural gas. Much more powerful than CO <sub>2</sub> as a greenhouse gas.
<b>D</b> CO <sub>2</sub>	Carbon dioxide	Major greenhouse gas.
<b>E</b> NO <sub>x</sub>	Nitrogen oxides	Reacts with VOCs to create ozone.
<b>F</b> H <sub>2</sub> S	Hydrogen sulfide	Toxic gas found in some gas fields. Causes illness and death at certain concentrations.

**Fugitive emissions:** pipelines, valves, pneumatic devices etc. leak methane, VOCs, H<sub>2</sub>S and CO<sub>2</sub> throughout the entire process.

<https://insideclimatenews.org/infographics?topic=All&project=&keywords=&page=16>

## Concern #3: Air Quality

- Fracking is a major contributor to anthropogenic VOCs



<https://ehp.niehs.nih.gov/120-a272/>

## Concern #3: Air Quality

- Fracking is a major contributor to anthropogenic VOCs

VOC Emissions by Sector, 2008	
Sector	Emissions (in tons)
Vegetation and Soil	31,743,795.67
Solvent Utilization	3,299,117.52
On-Road Vehicles	3,055,361.80
Wildfires	2,847,133.50
Off-Road Vehicles	2,492,752.86
Prescribed Fires	1,696,594.50
<b>Oil and Gas Production</b>	<b>1,688,454.83</b>
Gas Stations	643,277.44
Residential Fuel Combustion	367,023.10
Storage and Transport	237,737.78
Miscellaneous Nonindustrial Sources	226,996.24
Miscellaneous Industrial Sources	216,635.89
Waste Disposal	179,769.43
Pulp and Paper Processing	129,903.19
Chemical Manufacturing	99,470.59
Bulk Gasoline Terminals	92,808.65
Agriculture/Livestock Waste	92,448.42
Industrial Fuel Combustion	80,142.47
Petroleum Refineries	68,004.53
Agricultural Field Burning	53,269.51
Locomotives	44,198.42
Electric Utility Fuel Combustion	43,246.70
Ferrous and Nonferrous Metals Processing	35,721.12
Aircraft	35,445.09
Commercial Marine Vessels	20,645.64
Commercial/Institutional Fuel Combustion	13,454.01
Commercial Cooking	13,366.75
Cement Manufacturing	9,189.33
Mining	1,886.09
Construction Dust	16.63

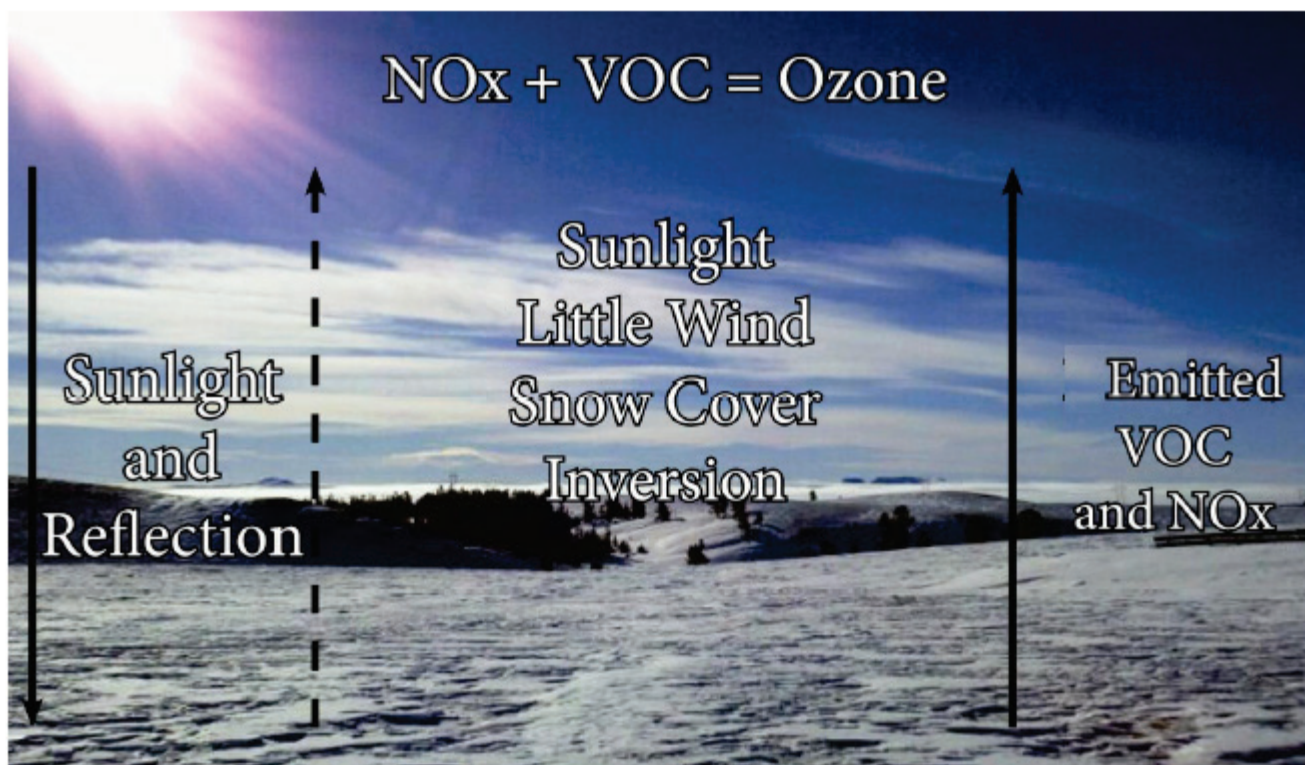
Source: U.S. Environmental Protection Agency<sup>8</sup>

<https://ehp.niehs.nih.gov/120-a272/>

# Concern #3: Air Quality (Case Study: Wyoming)



## Ozone: Wintertime Phenomenon



<http://deq.state.wy.us/out/downloads/UGRBTaskForce02212012WDEQAQD.pdf>

# Concern #3: Air Quality (Case Study: Wyoming)

## Dramatic ozone spikes puzzle regulators, locals in Wyoming gas field

Heather Richards Mar 22, 2019



An Ensign drilling rig contracted by Jonah Energy at a drilling site is shown in 2014 in the Jonah Field near Pinedale. Ozone levels this year in the Upper Green River Basin have puzzled regulators.

Alan Rogers, Star-Tribune

[https://trib.com/business/energy/dramatic-ozone-spikes-puzzle-regulators-locals-in-wyoming-gas-field/article\\_82837053-a70d-5591-b4a4-e83c24e8565b.html](https://trib.com/business/energy/dramatic-ozone-spikes-puzzle-regulators-locals-in-wyoming-gas-field/article_82837053-a70d-5591-b4a4-e83c24e8565b.html)

# Concern #3: Air Quality (Case Study: Wyoming)

## Dramatic ozone spikes puzzle regulators, locals in Wyoming gas field

Heather Richards Mar 22, 2019

Joel Bousman wasn't sure if ozone would be a problem Friday, despite a warning from the state. The snow covered the sage brush and the wind was less than 10 miles per hour — both bad signs. On the other hand, it had been overcast most of the day at the Sublette County commissioner's ranch near Boulder — a small community about 12 miles southeast of Pinedale, within view of the Wind River Mountains.

You need the right mix of factors to create ground-level ozone: sunlight, snow cover, little to no wind and, of course, emissions from the oil and gas industry — which arrived in force more than a decade ago in the Jonah and Pinedale gas field.

And this year the factors have been right more often than usual.

Friday was the 12th ozone action day of the season — a warning system from the Wyoming Department of Environmental Quality that forces industry to pull back when conditions for ozone are expected. It's a record number for recent years, and another action day was forecast for Saturday.

But there's something more troubling in the case of the Boulder area: ground-level ozone is regularly forming despite precautions. Breathing it in can cause a variety of health problems, from chest pain to reduced lung function.

For reasons still unclear to state regulators, in one corner of the Upper Green, the rules and regulations that reversed an air quality crisis more than a decade ago haven't been enough. "We don't have all the answers, yet," said Keith Guille, spokesman for the state Department of Environmental Quality. "It's definitely not being ignored. We understand that the public is concerned, as we are."

[https://trib.com/business/energy/dramatic-ozone-spikes-puzzle-regulators-locals-in-wyoming-gas-field/article\\_82837053-a70d-5591-b4a4-e83c24e8565b.html](https://trib.com/business/energy/dramatic-ozone-spikes-puzzle-regulators-locals-in-wyoming-gas-field/article_82837053-a70d-5591-b4a4-e83c24e8565b.html)

# Concern #3: Air Quality (Colorado)

NEWS > ENVIRONMENT

## Colorado lets oil and gas companies pollute for 90 days without federally required permits that limit emissions

State health officials say they'll review whether exemption for fossil fuels industry violates Clean Air Act

By **BRUCE FINLEY** | bfinley@denverpost.com | The Denver Post

April 7, 2019 at 6:00 am



Michael Ciaglo, Special to the Denver Post

Stephanie Nilsen, left, and her partner Janis Butterfield walk down the road next to their small ranch — and in front of Extraction Oil and Gas' Trott pad — on Thursday, March 28, 2019, in Berthoud. Butterfield and Nilsen live about 1,000 feet south of the oil and gas site, which they say emitted harmful pollution last year. The site is one of nearly 200 in Colorado that was allowed to pollute without a federally required permit limiting emissions for its first 90 days.

Colorado public health officials have let oil and gas companies begin drilling and fracking for fossil fuels at nearly 200 industrial sites across the state without first obtaining federally required permits that limit how much toxic pollution they can spew into the air.

Air pollution control officials at the Colorado Department of Public Health and Environment allow the industry to emit hundreds of tons of volatile organic chemicals, cancer-causing benzene and other pollutants using an exemption tucked into the state's voluminous rules for the industry — rules that former Gov. John Hickenlooper, state leaders and industry officials long have hailed as the toughest in the nation.

They rely on this 27-year-old state exemption to give oil and gas companies 90 days to pollute, then assess what they need from Colorado regulators before applying for the air permits that set limits on emissions from industrial sites.

"It is a loophole that allows pollution at some of the times when the pollution is the most extreme," said U.S. Rep. Diana DeGette, D-Denver, who chairs a congressional panel that oversees the Environmental Protection Agency.

<https://www.denverpost.com/2019/04/07/colorado-oil-gas-air-pollution>



# Concern #4: Climate

Combustion of 1 gram of CH<sub>4</sub> results of 50.1 kJ of energy  
Combustion of 1 gram of C results in 32.8 kJ of energy

Alas, coal is not pure carbon in the real world. Rather, notational formula for coal is C<sub>135</sub>H<sub>96</sub>O<sub>9</sub>NS (page 162 of Chemistry in Context): i.e., coal has a carbon content of 85% by mass.

Therefore, we'd state:

natural gas is actually  $1.33 \times 50.1 / (32.8/0.85) = 1.73$ ; i.e., 73% more efficient than coal.

**Break even point, for leakage of CH<sub>4</sub>**

**First, would like GWP on a per molecule basis, rather than a per mass basis**

GHG	IPCC (2013) per mass	IPCC (2013) per molecule
<i>100 Year Time Horizon</i>		
CH <sub>4</sub>	28	10.2
<i>20 Year Time Horizon</i>		
CH <sub>4</sub>	84	30.5

**Next, must balance energy gain from combustion of CH<sub>4</sub> relative to coal versus climate penalty.**

**If CH<sub>4</sub> is inadvertently released, then for the per molecule GWP on 100-year time horizon, break even point is:**

$$\text{CO}_2 + \text{Leak Fraction} \times 10.2 = 1.73 \times \text{CO}_2$$

$$\text{Leak Fraction} = 0.072$$

⇒ leakage of 7.2 % of CH<sub>4</sub> causes

**climate penalty to balance climate benefit**

# Concern #4: Climate

Combustion of 1 gram of CH<sub>4</sub> results of 50.1 kJ of energy  
Combustion of 1 gram of C results in 32.8 kJ of energy

Alas, coal is not pure carbon in the real world. Rather, notational formula for coal is C<sub>135</sub>H<sub>96</sub>O<sub>9</sub>NS (page 162 of Chemistry in Context): i.e., coal has a carbon content of 85% by mass.

Therefore, we'd state:

**natural gas is actually  $1.33 \times 50.1 / (32.8/0.85) = 1.73$ ; i.e., 73% more efficient than coal.**

**Break even point, for leakage of CH<sub>4</sub>**

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GHG	IPCC (2013) per mass	IPCC (2013) per molecule
<i>100 Year Time Horizon</i>		
CH <sub>4</sub>	28	10.2
<i>20 Year Time Horizon</i>		
CH <sub>4</sub>	84	30.5

**Next, must balance energy gain from combustion of CH<sub>4</sub> relative to coal versus climate penalty.**

**If CH<sub>4</sub> is inadvertently released, then for the per molecule GWP on **20-year time horizon**, break even point is:**

$$\text{CO}_2 + \text{Leak Fraction} \times 30.5 = 1.73 \times \text{CO}_2$$

$$\text{Leak Fraction} = \mathbf{0.024}$$

**⇒ leakage of **2.4 %** of CH<sub>4</sub> causes**

**climate penalty to balance climate benefit**

# Concern #4: Climate

Break Even Points: **7.2%** (100-yr time horizon) and **2.4%** (20-yr time horizon)

Leakage (%)	Region	Method	Citation
4.2 – 8.4	Bakken Shale, North Dakota	Aircraft Sampling	Peischel et al. (2016)
1.0 – 2.1	Haynesville Shale, Louisiana and Texas	Aircraft Sampling	Peischel et al. (2015)
1.0 – 2.8	Fayetteville Shale, Arkansas		
0.18 – 0.41	Marcellus Shale, Pennsylvania		
9.1 ± 6.2	Eagle Ford, Texas	Satellite Sampling	Schneising et al. (2014)
10.1 ± 7.3	Bakken Shale, North Dakota		
0.42	190 production sites including Gulf Coast, Rocky Mountain, and Appalachia	In situ within facility grounds	Allen et al. (2013)
6.2 – 11.7	Unitah County, Utah	Aircraft sampling	Karion et al. (2013)
2.3 – 7.7	Julesburg Basin, Denver, Colorado	Tall tower and ground level mobile sampling	Pétron et al. (2012)

**Table 4.4** Estimates of % of CH<sub>4</sub> leakage relative to production in the US, selected studies

*Paris Climate Agreement, Beacon of Hope*

# HONR 229L: Climate Change: Science, Economics, and Governance

Bonus material: two short videos, one photo

<https://www.youtube.com/watch?v=p0Aw3JEtQoU>

<https://www.youtube.com/watch?v=RZwjrrViBsQ&list=WL&index=20&t=41s>

# HONR 229L: Climate Change: Science, Economics, and Governance



**Greta Thunberg** ✓  
@GretaThunberg

Rapa Nui, South Pacific.  
(Easter Island)

#ClimateStrike #FridaysForFuture



**Benjamin Alvarez** @BenjAlvarez1 · Sep 27

Today: #ClimateStrike on #RapaNui island 📷 (pictures via Bruno Lacoconi)

[Show this thread](#)



<https://twitter.com/gretathunberg/status/1177646731183493122?lang=en>

# HONR 229L: Climate Change: Science, Economics, and Governance

## Project Organization

Ross Salawitch

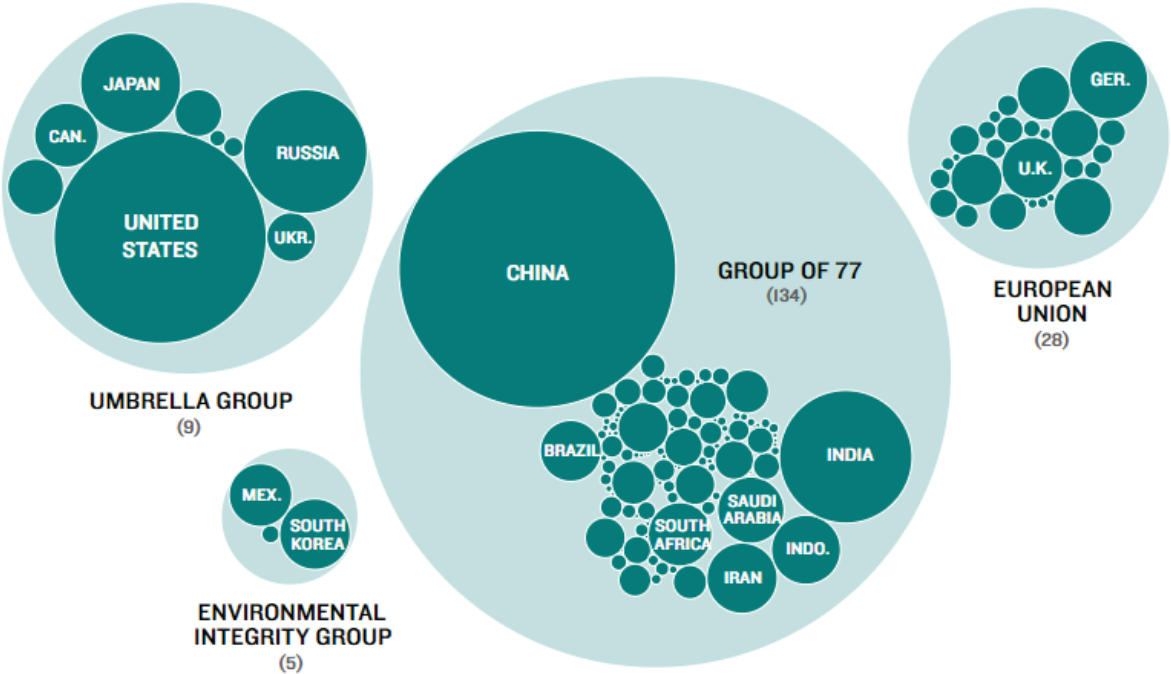
**14 November 2019**

# HONR 229L: Climate Change: Science, Economics, and Governance

## Project Organization

### Major Alliances In U.N. Climate Negotiations

Countries participating in the United Nations climate talks have allied in expected — and some unexpected — ways. Below, the major alliances, with countries sized by CO<sub>2</sub> emissions in 2011. Countries may also belong to other smaller negotiating groups (such as the Alliance of Small Island States and the Organization of Petroleum Exporting Countries).



<https://www.npr.org/2015/08/31/434599379/how-are-u-n-climate-talks-like-a-middle-school-cliques-rule>

# HONR 229L: Climate Change: Science, Economics, and Governance

## Energy Plan Organization

**President:** Organizes group and must sign three documents, but only after Senate approval:

- 1) International agreement for exchange of technology and finance
- 2) Region's energy plan (written by Energy Minister)
- 3) Region's economic development plan (written by Senate)

**3 person Senate:** Votes on international agreement, energy plan, & authors economic plan:

**Each** needs unanimous approval of the Senate, except the President can override a 2 to 1 vote and grant his or her "approval" ... only once!

3 pieces of legislation: President get's one override

**Energy Minister:** **One to two page document** outlining how the Paris NDCs will be implemented within the region (i.e., specific mix of renewables, etc)

Economic Development Plan: **One to two page document** overview of how the transition to renewables will impact the economy, including jobs, to be written by the Senate

**Negotiator:** Communicates with other groups and formulates international agreement

**One to two page document** detailing how 3 regions will cooperate to achieve their respective energy plans: could be cap & trade, carbon tax with funds flowing internationally, technology transfer, etc



# HONR 229L: Climate Change: Science, Economics, and Governance

## **Energy Plan Implementation**

### **China**

President

3 Member Senate

Economic Minister

Energy Minister

Negotiator

## Energy Plan Implementation

### China

President

3 Member Senate

Economic Minister

Energy Minister

Negotiator



**Channel the energy & vision of President Xi**

**Nov 2014:**

Presidents Obama & Xi announce:

U.S. will reduce GHG emissions to 27% below 2005 level by 2025  
China will peak CO<sub>2</sub> emissions by 2030 with best effort to peak early



# HONR 229L: Climate Change: Science, Economics, and Governance

## **Energy Plan Implementation**

### **Developing World**

President

3 Member Senate

Economic Minister

Energy Minister

Negotiator

# HONR 229L: Climate Change: Science, Economics, and Governance

## Energy Plan Implementation

### Developing World

President

3 Member Senate

Economic Minister

Energy Minister

Negotiator



**Channel the courage & wisdom of Dr. Sunita Narain**

<https://www.youtube.com/watch?v=IEqBduQIx-Q>



**and the words of Energy Minister of Tanzania, Sospeter Muhongo  
pages 158 – 159, *Paris Climate Agreement: Beacon of Hope***

# HONR 229L: Climate Change: Science, Economics, and Governance

## **Energy Plan Implementation**

### **United States & Europe**

President

3 Member Senate

Economic Minister

Energy Minister

Negotiator

# HONR 229L: Climate Change: Science, Economics, and Governance

## Energy Plan Implementation

### United States & Europe

President

3 Member Senate

Economic Minister

Energy Minister

Negotiator



### Channel the voice of America's Pledge

**During COP23 in Bonn, America's Pledge presented the official report on US climate action, analysing how US states, cities, businesses, citizens, and universities can support the Paris Agreement even without federal action.**

<http://www.climateaction.org/news/we-are-still-in-coalition-launched-the-americas-pledge-report-during-cop23>

# HONR 229L: Climate Change: Science, Economics, and Governance

## Energy Plan Implementation

**Select your team preference, using a 10 point system:**

**Your name:**

**China:**

**Developing World (India & Africa):**

**Developed World (US & Europe):**

**Meet to elect a President and then decide on 1.5° C or 2.0° C goal**

**China: Here**

**Developing World (India & Africa): ATL 3425**

**Developed World (US & Europe): ATL 3400**

# **Energy Plan Implementation**

**Select your team preference, using a 10 point system:**

**Your name:**

**China:**

**Developing World (India & Africa):**

**Developed World (US & Europe):**