Hydraulic Fracturing ~ Fracking Fracing
What is Natural Gas?

• Natural gas is a gas mixture consisting primarily of methane. The exact composition varies by source.

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition (%)</th>
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</thead>
<tbody>
<tr>
<td>Methane</td>
<td>87.0 - 97.0%</td>
</tr>
<tr>
<td>iso-Butane</td>
<td>0.01 - 0.3%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.2 - 5.5%</td>
</tr>
<tr>
<td>Ethane</td>
<td>1.5 - 7.0%</td>
</tr>
<tr>
<td>normal-Butane</td>
<td>0.01 - 0.3%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.1 - 1.0%</td>
</tr>
<tr>
<td>Propane</td>
<td>0.1 - 1.5%</td>
</tr>
<tr>
<td>iso-Pentane</td>
<td>trace - 0.04%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.01 - 0.1%</td>
</tr>
<tr>
<td>Hexanes</td>
<td>trace - 0.06%</td>
</tr>
<tr>
<td>normal-Pentane</td>
<td>trace - 0.04%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>trace - 0.02%</td>
</tr>
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</table>

• “Dry gas”:
  • Almost 100% methane, used for home heating, power generation, vehicle fuel etc.
  • Usually referred to as gas
  • Colorless and odorless
    • Mercaptan, a substance with a strong smell is added to dry gas (and propane) to make it easier to detect in case of a leak

• LNG (liquified natural gases); NLG (natural gas liquids); “wet gas”
  • Separated from natural gas and sold on their own
  • Ethane, Propane, Butane, etc.
Why Frack?
Conventional vs. Unconventional Resources

**Conventional Resources:**
Connected pore spaces
Pools of oil or natural gas will flow or can be pumped to the surface

**Unconventional Resources:**
Fine-grained rocks, such as shales, sandstone or limestone are low permeability (also called “tight”)
Fracking enhances the permeability of these rocks to a point where oil and gas can economically be extracted
History of Fracking

“exploding torpedo” patented by A. Roberts in 1865-1866. by Lt. Col. Edward A. Roberts

“Hydrafrac” process patented in 1949, with Halliburton holding an exclusive license. A typical early fracture took 750 gallons of fluid (water, gelled crude oil, or gelled kerosene) and 400 pounds of sand.

1980s and 1990s, Mitchell Energy experimented with alternative methods of hydraulically fracturing the Barnett Shale. By 2000, the company had developed a hydraulic fracturing technique that produced commercial volumes of shale gas.
Horizontal Drilling

Traditional Vertical Well Spacing: 32 Separate Padsites Needed For 32 Wells.

Idealized Horizontal Well Spacing: 1 Padsite Yields Up To 32 Wells.
**HOW FRACKING WORKS**

**STAGE 1**

It takes around a month to drill down to the gas-rich shale beds that lie between one and two and a half kilometres beneath the surface.

Freshwater aquifers, which typically lie no deeper than 100 metres underground, are protected from possible pollution from the wellbore by triple-layered steel casings.

The well is turned and drilled horizontally into the shale layer for up to three kilometres.

**STAGE 2**

A mixture of water, sand and chemicals is pumped into the well to a pressure of around 1,500 lbs per square inch. This forces the rock apart, releasing the gases stored within its pores.

An average well will use up 20,000 cubic metres of water, around 500 tankers’ worth.

**STAGE 3**

The liquid is pumped out of the well and the remaining sand keeps the fractures open, allowing gas to seep out of the broken shale layer to be piped to the surface.

A well can remain productive for 20 to 40 years, pumping out thousands of cubic metres of gas every day.

**GRAPHIC: PETE GUEST**

**SOURCES: GRAPHIC NEWS, ENVIRONMENT AGENCY**
Hydraulic Fracturing

Hydraulic fracturing, or "fracking," involves the injection of more than a million gallons of water, sand and chemicals at high pressure down and across into horizontally drilled wells as far as 10,000 feet below the surface. The pressurized mixture causes the rock layer, in this case the Marcellus Shale, to crack. These fissures are held open by the sand particles so that natural gas from the shale can flow up the well.

The shale is fractured by the pressure inside the well.
Shale gas and tight oil plays make up half of US natural gas production. By 2018, the US became a net exporter of natural gas for the first time since the 1950s.
U.S. dry shale gas production

Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through July 2016 and represent EIA’s official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).
Gas Resources in Virginia, 2016

Marcellus

- Largest shale play in the US
- July 2016: 38% of US shale gas production.
- USGS says Marcellus in Virginia is thermally overmature so does not have economic quantities of gas or oil

Nov 18, 2014
US Forest Service released new land use plan for GWNF:
- Land available for oil and gas leases down to 177,000 acres from 995,000.
- Private companies own the mineral rights for 167,000.
- Remaining 10,000 available for oil and gas drilling.
8,062 producing wells in Virginia
All located in Buchanan, Dickenson, Lee, Russell, Scott, Tazewell and Wise counties
6,000 Coalbed Methane Wells
Unconventional

- The underground coal is fractured, just like shale, to increase the amount of methane that flows to the well.

- Foam Fracking: Nitrogen gas rather than water is used to fracture because water would block gas flow.

- In Virginia, as little as 35,000 gallons of water may be required to fracture a coalbed methane well compared to up to 6,000,000 gallons for gas in the Marcellus shale.

- A 100% nitrogen frack (“dry” frack) is being developed.

2,100 wells have been fracked from shale, sandstone and limestone formations since the 1950s
Previous explorations of Richmond and Taylorsville Basins (between 1917-1992) found no "reservoirs of gas or oil large enough to be economically developed."

2011 USGS Assessment estimated:

<table>
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<tr>
<th></th>
<th>Natural Gas</th>
<th>Liquid Natural Gas (ethane, butane, etc.)</th>
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<tbody>
<tr>
<td>Taylorsville</td>
<td>1 Tcf</td>
<td>37 m barrels</td>
</tr>
<tr>
<td>Richmond</td>
<td>0.2 Tcf</td>
<td>11 m barrels</td>
</tr>
</tbody>
</table>
Shore Exploration & Production Corp.

- Opened a field office in Caroline
- Paid over $1.26 million for 84,000 acres of land in leases
  - Caroline (40,000 acres)
  - Essex (13,000 acres)
  - King and Queen (6,000 acres)
  - King George (10,000 acres)
  - Westmoreland (14,000 acres)
- 7 year leases at $15 per acre
- Productive wells could yield $400,000 per year to landowner
- Shore has the right to sell the leases to a partner who would determine the drilling methods to be used.
Fracking Laws and Regulations-Federal

<table>
<thead>
<tr>
<th>Act</th>
<th>Purpose</th>
<th>Fracking Exemption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Air Act of 1963</td>
<td>Control air pollution at the federal level.</td>
<td>Treats each individual well as a source of pollutants and does not require well operators to consider the aggregate impact of many wells in a specific area.</td>
</tr>
<tr>
<td>Clean Water Act of 1972</td>
<td>Ensure that surface waters meet minimum pollution standards.</td>
<td>Fracking fluids are exempt from classification as pollutants even though more common pollutants such as storm run-off are included.</td>
</tr>
<tr>
<td>Safe Water Drinking Act of 1974</td>
<td>Protect the quality of the country's groundwater and drinking water supply.</td>
<td>Amended in 2005 to exclude injection wells.</td>
</tr>
<tr>
<td>The Energy Policy Act of 2005</td>
<td>Regulates many aspects of federal energy policy.</td>
<td>Only regulates fracking when diesel fuels are used in the fracking fluids.</td>
</tr>
</tbody>
</table>

June 2016- A federal judge ruled that 2015 federal regulations to ensure that wells are properly constructed to:

- protect water supplies
- make certain that flowback fluids are managed in an environmentally responsible way
- provide public disclosure of the chemicals used in hydraulic fracturing


June 2016- EPA banned unconventional oil and gas extraction wastewater from municipal sewage plants, citing the inability of these plants to handle toxic and radioactive pollutants. This rule does not address underground injection of wastewater since such activity is not subject to the Clean Water Act but rather the Safe Drinking Water Act.
Massachusetts and Vermont (states without shale resources), and New York have banned fracking. Maryland has a moratorium in place until October 2017. North Carolina, Oklahoma, and Texas have passed restrictions on local communities’ ability to limit fracking. The Delaware River Basin Commission (Delaware, New Jersey, New York, Pennsylvania) has had a de facto moratorium on gas drilling in the Delaware River Basin since 2009, but this is being challenged in federal court.
Fracking Laws and Regulations - Virginia

All oil and gas operators must comply with:

The Virginia Gas and Oil Act of 1990
Virginia Gas and Oil Regulation
Virginia Gas and Oil Board Regulations
State Water Control Law
Virginia Pollution Discharge Elimination System Regulations
Additional requirements for the Tidewater Region
Virginia Department of Mines Minerals and Energy (DMME) is the regulatory authority for statewide gas and oil permitting and operations.

Division of Gas and Oil regulates the effects of gas and oil operations both on and below the surface.

Virginia Department of Environmental Quality (DEQ) administers state and federal laws and regulations for air quality, water quality, water supply and land protection.

In August 2014, DMME and DEQ signed a Memorandum of Agreement outlining special requirements for wells drilled in the Tidewater region.

Note: Previously, the 2014 Legislative Session killed SB48, “Eastern Virginia Groundwater Management Area; prohibition on oil and gas drilling” which allowed for the drilling for oil and gas only if certain DEQ standards for the protection of groundwater and surface water are met.

In 2016, DMME asked STRONGER (State Review of Oil and Natural Gas Environmental Regulations) to do a review of Virginia’s regulations (an initial review was done in 2004). STRONGER also held public hearings. They anticipate publishing the Virginia Follow-Up Review in December 2016.
New DMME regulations submitted to executive branch August 2016; no timeline for approval.

(i) amend permit application requirements to include disclosure of all ingredients anticipated to be used in hydraulic fracturing operations, certification that the proposed operation complies with local land use ordinances, inclusion of a groundwater sampling and monitoring plan, and submission of an emergency response plan;

(ii) require a pre-application meeting jointly conducted by the DMME and the Department of Environmental Quality before an operator drills for gas or oil in Tidewater Virginia;

(iii) require well operators to use FracFocus, the national hydraulic fracturing chemical registry website, to disclose the chemicals used in hydraulic fracturing operations;

(iv) establish a groundwater sampling, analysis, and monitoring program before and after well construction;

(v) add language related to the use of centralizers in the water protection string of the casing;

(vi) strengthen casing and pressure testing requirements for well casings used in conventional and coalbed methane gas wells; and

(vii) provide protection for trade secrets from public dissemination while allowing this information to be made available to first responders and local officials in the event of an emergency.
What regulatory authority do Virginia localities have?

2013: Virginia Attorney General Ken Cuccinelli:
Local governing bodies could place reasonable restrictions but “cannot ban altogether” the exploration for or drilling of oil and natural gas.

2014: King George County Attorney Eric Gregory:
Virginia localities may regulate oil and gas drilling activities via their zoning and land use authority under state law, so long as such regulation does not encroach upon those areas regulated by state (DMME and DEQ) and federal law and regulatory agencies.”
He cited VA Code § 15.2-2280:
Any locality may...regulate, restrict, permit, prohibit and determine...
1. The use of land...for...industrial..uses;...
4. The excavation of mining of soil or other natural resources

2015: Virginia Attorney General Mark Herring:
Counties have the authority to prohibit fracking through duly enacted land use or zoning ordinances.
On August 16, 2016, the King George Board of Supervisors voted to amend their zoning ordinance and Comprehensive Plan, prohibiting drilling within 750 feet from resource protected areas, such as rivers and creeks, as well as roads, buildings and schools, making only 9 percent of the county potentially eligible for drilling.
Fracking has received a lot of bad press. League looks at all sides of an issue and then takes a position through informed understanding.
The Issues

Drinking water wars
ISSUE: Fracking may threaten human health by contaminating drinking water supplies.

Earthquakes: Seismic worries
ISSUE: Fracking wells, drilled thousands of feet down, may change geology in a potentially negative way, leading to earthquakes.

Greenhouse gas leaks, methane and fugitive emissions
ISSUE: The extraction process results in some greenhouse gas emissions leakage.

Infrastructure, resources, and communities
ISSUE: Fracking operations are sometimes taking place near and around populated areas, with consequences for the local built and natural environments.

Air quality, health, and the energy menu
ISSUE: The new supply of natural gas reachable by fracking is now changing the overall picture for U.S. electricity generation, with consequences for air quality.
Drinking Water Wars

Fracking Fluids

Traditional fracking fluids are composed of mostly water with added proppants and chemicals. Proppants are small granular particles such as sand or glass beads. They are used to keep the cracks open.

Flowback is fracking fluid that returns to the earth's surface along with the oil or natural gas that is extracted.

Produced water is the salty water or brine that has been under the earth for millions of years and is released when extracting oil or natural gas. It contains many substances trapped in the rock, including naturally occurring radioactive material (NORM), such as radium.

Wastewater includes both produced water and flowback. This contaminated water is stored in injection wells. It has also been sent to municipal sewage plants (a practice banned by the EPA in June 2016) or used as a deicer in road spray.
Fracking Fluid Chemicals

Chemicals are added to fracking fluids to control viscosity, and prevent build-up of particulates, fouling, and corrosion of pipes.

Each well requires a unique blend of these components that depend upon the type of rock, the material being extracted, and the flow-back viscosity desired, but a typical ratio would be ~90% water: ~9.5% proppant: ~0.5% chemicals.

In 2005-2009, 650 out of 2500 fracking products contained known or possible human carcinogens regulated under the Safe Drinking Water Act, or listed as hazardous air pollutants.

Fracfocus.org
Website where fracking operators are required by some states to post their ingredients (though not their quantities). DMME has recommended that VA require posting on this website.
Contamination of Drinking Water

EPA, June 4, 2015: “From our [draft] assessment, we conclude there are above and below ground mechanisms by which hydraulic fracturing activities have the potential to impact drinking water resources. These mechanisms include

- water withdrawals in times of, or in areas with, low water availability;
- spills of hydraulic fracturing fluids and produced water;
- fracturing directly into underground drinking water resources;
- below ground migration of liquids and gases; and inadequate treatment and discharge of wastewater.

We did not find evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources.

August 2016: EPA’s Scientific Advisory Board noted that while the EPA’s analysis on a national level was appropriate, it failed to recognize that many stresses to surface or groundwater resources… are often localized…These local-level impacts, when they occur, have the potential to be severe.”
No clear evidence that contamination of drinking water wells more than 1 km away is a result of fracking.

There remains a concern that, over time, fracking materials from deep wells or faulty casings may find its way into aquifers and wells by travelling through underground channels.
Surface water contamination

Accidents or spills from wastewater storage pits are minimal and transient

- Contaminants in produced water have low mobility, solubility, and volatility
- Do not, in general, spread far from the spill site
- Allow for feasible cleanup with minimal long-range effects
- Contaminants include salts, hydrocarbons (oil and grease), inorganic and organic additives, and NORM
- Chemicals used in each well are unique--each spill must be treated for its specific contaminants.
Waste disposal

Minimization and recycling/reuse
- Increasingly popular as the costs of obtaining input water and treating wastewater increases
- However, at some point the now highly concentrated waste must be treated.

Wastewater treatment plants
- EPA banned use of municipal treatment plants
- Increasingly being done in centralized treatment plants dedicated to handling brines and industrial waste.

Beneficial uses:
- Brines are applied to road surfaces for deicing or dust control.
- Decreased use because the efficacy is inferior to that of commercial products and contaminants left behind are detrimental to the environment.

Injection wells:
- Difficult to treat industrial waste has been disposed of in this manner for many years; method preferred in the industry.
- Two types of injection wells:
  - Class I: highly regulated and the EPA has deemed them safe for the disposal of waste materials
  - Class II: less tightly regulated. All fracking waste is currently being injected into Class II wells.
Earthquakes: Seismic worries

Earthquakes are not directly associated with the process of fracking.

Earthquakes appear to be caused by rapid injection of waste fluids inducing a high pressure that destabilizes fragile existing fault lines.

This pressure differential can be exaggerated if large volume water withdrawals occur nearby.

Should fracking be allowed in a seismic zone?
Greenhouse gas leaks, methane and fugitive emissions

Methane
- a key constituent of natural gas
- second most prevalent greenhouse gas emitted by humans in the US
- one-third of methane emissions are from the oil and gas industry

May 12, 2016 – EPA issued three rules to curb emissions of:
- methane
- smog-forming volatile organic compounds (VOCs)
- toxic air pollutants such as benzene

Only applies to new, reconstructed and modified oil and gas sources

EPA has now begun the process of regulating emissions from existing sources.
**Infrastructure, resources, and communities**

**Transportation Infrastructure**

For each well, trucks must haul in gravel, pipes, water, water and chemicals, then haul out liquid fuels and waste — anywhere from 600 to 1,000 one-way trips for the fracking phase alone.

Damage to local transportation infrastructure:

- Heavier vehicles cause exponentially greater roadway damage: a 30,000-pound single-axle does about 7,500 times more damage than a 3,000-pound single axle

- In PA, estimated road reconstruction costs per well range from $13,000 - $23,000.

- In 2011, the estimates of fracking-related PA road costs paid by state transportation authorities, and thus taxpayers, range up to $39 million.
Other traffic-related issues that need to be considered include:

- Congestion
- Noise
- Air pollution
- Accidents: injury and damage to property, or accidental spillage of materials or chemicals.

“An Associated Press analysis of traffic deaths…in six drilling states shows that in some places, fatalities have more than quadrupled since 2004 — a period when most American roads have become much safer…The industry acknowledges the problem, and traffic agencies and oil companies say they are taking steps to improve safety.”

Potential approaches:

- Additional fee or tax on top of current per-well impact fees
- Limiting truck size and weight
- Encouraging the use of pipelines rather than trucks
Local Benefits

Revenue from property, sales and severance taxes

Jobs creation:
- Goods and services suppliers-- healthcare, amusement, food, merchandise
- Construction
- Oil and gas extraction
- Environmental hydro-geologists
- Ecologists
- Drill site managers
- Pipeline engineers
- Metal fabrication
- Truck transport
- Financial, administrative, HR, IT, legal
- Real estate
- Sales managers

Local Costs

Local government costs:
- Increased demand for public services
- Police, emergency and medical personnel, and other government workers
- Road repair associated with truck traffic
- Sewer and water services associated with industry-driven population growth
- Raising compensation to compete with high-paying jobs in the oil and gas sector

Other costs:
- Negative effect on other businesses, property values, current land uses
- Land remediation
- Water pollution treatment
- Noise
- Traffic
- Night-time lighting
- Demand on water supplies
Most of the toxic chemicals that may be used in hydraulic fracturing are exempt from resources otherwise available to communities:

EPCRA (Emergency Planning and Community Right to Know Act) helps communities plan for chemical emergencies; requires industry to report on storage, use and releases of hazardous substances

TRI (Toxic Release Inventory) a resource for learning about toxic chemical releases and pollution prevention activities reported by industrial and federal facilities. TRI data support informed decision-making by communities, government agencies, companies, and others

CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act of 1980) a.k.a. Superfund: cleanup of sites contaminated with hazardous substances and pollutants
Taxes, fees and revenue

Fracking booms can increase local government revenue through property and sales taxes.

Mineral leasing revenues and severance taxes—go to state and federal governments.
Mineral leasing revenue: income generated by those who lease their property.
Severance taxes: intended to compensate citizens for the loss of resources extracted ("severed")

As of June 2013, Virginia employed the following city and county license taxes on severed resources:
- 1.5% gross severance tax on oil
- 1% on gross severance tax on coal or gas
- Counties and cities can levy an additional maximum 1% gross tax on gas
- Cities and counties may adopt a maximum 1% gross tax on every person engaged in the business of severing coal or gas.

The revenue collected from an additional gas tax is deposited in the general fund of the respective county or city. Revenue from an additional county or city coal or gas tax is deposited into the Coal and Gas Road Improvement Fund. Areas that comprise the Virginia Coalfield Economic Development Authority have 75 percent of their tax deposited into the Coal and Gas Road Improvement Fund. The remaining 25 percent is deposited into the Virginia Coalfield Economic Development Fund.

In fiscal year (FY) 2014, Virginia collected almost $2.2 million in severance taxes, which accounted for 0.01 percent of the state's tax revenue.
Air Quality

Emissions are associated with four shale gas-related activities:

1. Diesel and road dust emissions from trucks
2. Emissions from well drilling and hydraulic fracturing
3. Emissions from the production of natural gas
4. Combustion emissions from natural gas powered compressor stations
   More than half of emissions damages come from compressor stations, which may serve dozens of individual wells

Regulatory agencies and the shale gas industry, in developing regulations and best practices, should account for air emissions from ongoing, long-term activities and not just emissions associated with development.
Health

“…fracking is an important global public health issue. Given that no sound epidemiologic study has been done to assess the extent of exposure-related adverse health effects among populations living in areas where natural gas extraction is going on, it is imperative that research be conducted to quantify the potential risks to the environment and to human health not just in the short-term, but over a longer time period since many diseases (i.e., cancers) appear years after exposure. It should not be concluded that an absence of data implies that no harm is being done.”

From the National Institute of Environmental Health Sciences (NIEHS):

Does hydraulic fracturing pose health risks to the people living near drilling sites?

The short answer is we don’t know.

Few studies to date have provided conclusive evidence about how unconventional natural gas development affects nearby communities.

It may be possible for chemicals to travel into a drinking water source. Drilling sites can potentially affect local air quality in several ways.

Most of what is known comes from studies of workers at these sites. Currently, three hydraulic fracturing-specific health risks have been identified:

- Silica sand inhalation can cause lung diseases
- Exposure to chemical spills
- Exposure to high levels of volatile hydrocarbons during flowback operations, which have resulted in the death of at least 4 workers since 2010.

NIEHS is funding research on pregnancy risks, asthma, stress, cardiovascular health, inflammation, and more.
The Energy Menu

How does the availability of inexpensive natural gas affect the development of alternate energy sources?

Wind power
Solar power
Geothermal energy
Biomass for electricity
Hydroelectric power
Hydrokinetic energy
For Your Consideration…

Most proposed gas drilling projects are located in rural areas where a ready supply of fresh water is essential to agriculture, tourism, sport fishing, hunting and manufacturing. Drilling accidents, which can and do happen, can have a profound impact on these industries, and the boom-bust cycle of energy extraction can irreparably change the way of life in rural communities.

Local governments should monitor: population growth & worker residency patterns; employment, personal income, and local business effects; cost of living and housing; service, infrastructure, capacity, and revenue; quality of life and other local concerns. “Monitoring can help local governments better understand the socioeconomic impacts caused by energy development, and support requests to industry and state government for assistance to implement appropriate mitigation. Effective monitoring also is an essential part of adaptively managing drilling activity to minimize negative impacts while maximizing benefits.”

In the short run, there will be profit for property owners, but the natural gas will eventually run out and the value of the property, the ability to insure it, and to mortgage it, may all be negatively impacted.
How can we ensure that the benefits of fracking outweigh the costs for Virginia?

What regulations will financially protect communities that are potential sites for fracking?

How will being a Dillon Rule state affect Virginia communities' response to fracking?

Will Virginia see increased prosperity from fracked natural gas?

Will Virginia see an increase or a decrease in income inequality from fracking?

Will natural gas help or hinder us in responding to the costs of climate change?