Hydraulic Fracturing in the Marcellus Shale: Boon or bust?

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Overview:

Until a century ago, natural gas was considered a waste product in oil fields and flared or vented off. If you've ever travelled past the Sunoco refinery near the Philadelphia airport at night and seen the constant blue flame atop the distillation unit you know that this is still true in some places and times. But the energy landscape is changing and natural gas is enjoying elevated standing in the world energy portfolio.

World energy usage has never been higher. According to the World Bank, each person in the U.S. uses the equivalent of 7,075 kg of oil each year. That is significantly more than the 1,835 kg that each global citizen on average uses (World Development Indicators, The World Bank). Clearly our energy appetite is enormous and given the finite nature of oil and coal, concerns over greenhouse gas and other pollution, dependence on foreign regimes the U.S. is looking for a cleaner more domestic energy sources.

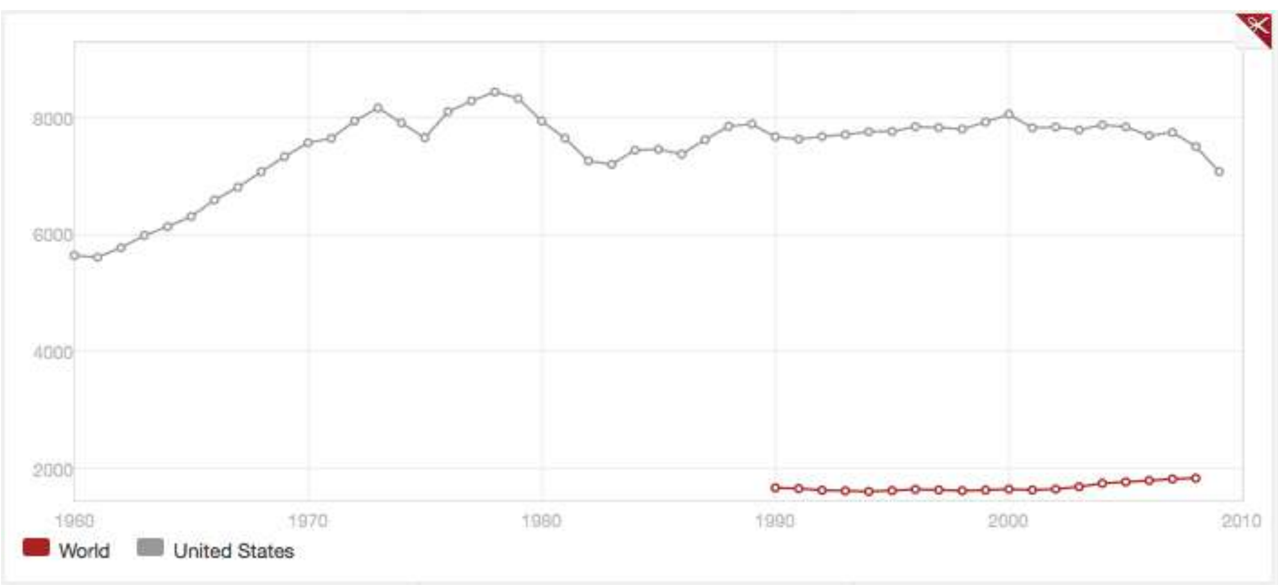


Fig 1. Comparison of world and U.S. energy usage. The average U.S. citizen utilizes far more energy than the global citizen.

Natural gas may be an appropriate and promising "bridge" energy source to transition the U.S. economy and infrastructure from dirty fossil fuels to renewable energy sources. It is already a significant fraction of our energy economy and can be expanded with new technologies.

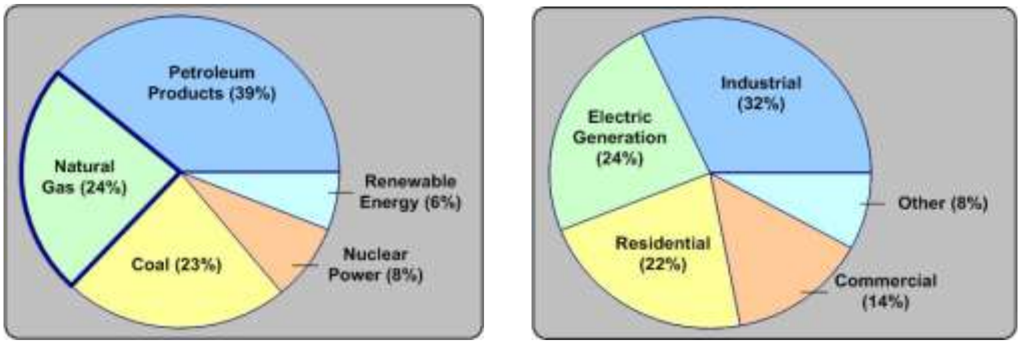


Fig 2. Natural gas comprises 24% of energy consumed in the U.S. in 2000 and is used for industrial and residential heating as well as in electric generation. http://www.naturalgas.org/overview/uses.asp

The majority of that natural gas is used for industrial purposes, electric generation (replacing the far dirtier coal) and residential (for home and water heating, and cooking). Other applications include natural gas vehicles like the Honda Civic NGV and fleet vehicles. Most of the natural gas used in the United States comes from conventional reservoirs above oil fields and coal deposits, but new technology has recently made the extraction of previously inaccessible shale deposits (like the Marcellus Shale in Pennsylvania) economically viable. The process used to liberate trapped natural gas from tiny crevices within shale formations deep underground is controversial. Residents of regions above shale gas deposits are struggling to understand and regulate the industry's environmental impact on freshwater resources while also taking advantage of economic opportunities.

This unit is designed as part of a non-renewable energy unit in an environmental science elective course following oil and coal. This unit is particularly appealing to students because of its relevance to their lives. The shale gas industry is in the news nearly every day and references to the fracking controversy have made their way into popular culture (such as the CSI episode "Fracked" that aired 11 November 2010). Students living in watersheds impacted by fracking will be particularly interested since this issue is local enough to impact them directly and sized large enough to matter but small enough to impact. In this unit students will explore the science, politics, and ethics surrounding the Marcellus Shale. By investigating different perspectives on exploiting our local natural gas resources students will review and reinforce existing understandings relating to geology, ecology, water quality and also engage in real decision-making requiring analysis of primary and secondary information sources and determination of priorities, examination of bias, and the process of compromise around trade offs.

This unit begins with an audit of students' own natural gas usage through their household's utility bill. The activity is intended to raise questions about what the natural gas is used for, where it comes from, how it compares to other energy sources etc. It's also a compelling application of math and graph analysis skills. Throughout the body of the unit, students will be able to compare methods, benefits and costs of various sources and extraction methods through a combination of lecture, research, and viewing the film *Gasland*. The unit ends with a discussion of bias in information sources and writing a newspaper article (for the school newspaper) with either a balanced perspective or in editorial form.

Rationale:

Benefits of natural gas

The United States consumes about 19 million barrels of oil a day, but only produces about 8 million barrels/day, importing the rest from Canada, Mexico, and a wide range of countries including members of OPEC ("A map of," 2007). Natural gas is often proposed as a cheaper and cleaner than oil and coal. Natural gas can be 30% cleaner burning than coal or oil because it has higher hydrogen to carbon ratio than larger hydrocarbons. For example, methane has a 4:1 hydrogen to carbon ratio whereas benzene (not even a very large hydrocarbon) has just a 1:1 ratio. The combustion reaction of smaller hydrocarbons yields more water and less carbon dioxide than burning larger carbon molecules. Natural gas deposits are also less contaminated with nitrogen, sulfur, and mercury than hydrocarbons in solid and liquid forms and do not produce particulates when burned.

Further, natural gas is abundant domestically (87% of the natural gas consumed in the U.S. in 2009 was produced here (eia, 2010).) A domestic energy source would be more economically viable and suffer fewer transport disruptions. These factors suggest to some that natural gas is a good candidate for weaning the U.S. economy away from oil dependence. According to T. Boone Pickens, a famous advocate of a natural gas economy, "We imported 11.5 million barrels of oil every day at a cost of $42.5 billion for the month. At that rate, we will be sending more than half a trillion dollars offshore just to pay for the oil we have to import" (Pickens, 2011).

Natural gas extraction and usage certainly is growing. A report from the International Energy Agency released on June 6, 2011 projects that natural gas will grow 4% by 2035, making up 25 percent of the global energy mix. Natural gas is enjoying a surge in popularity due to uncertainty about nuclear power following the recent Fukushima, Japan disaster. Other factors contributing to growing natural gas production is a boom in demand from China and the widespread development of unconventional natural gas sources (Krauss, 2011). Those unconventional resources (described in more detail later) were considered uneconomical until just a few years ago but could contain enough energy to supply the U.S. for 110 years assuming that the 2,552 Tcf available are used at a rate of 22.8 Tcf/year (eia, 2010).

<u>Geology of Shale Deposits</u>

The most recently-made available natural gas deposits are those contained within shale rock formations. Our nearest formation is the Marcellus Shale, which stretches along the Appalachian Mountains from West Virginia up to the western half of the state of New York. The Marcellus Shale was formed in the Middle Devonian period of geologic history, between 416-359 million years ago. What was going on during the Devonian? Well, that's when forests started spreading across terrestrial regions due to the success of seed-bearing plants. It's also when arthropods were dominant on land and fish began to come on land due to the evolution of lobe fins. Pennsylvania during the Devonian must have supported a lush biota resulting in our significant fossil fuel deposits.

It is that biotic lushness that allowed so much carbon to remain behind in the pores within shale for us to discover and use as fuel. Fossil fuel containing rock (carbon rich) only occurs in sedimentary rock- because of how that rock is formed. Sedimentary rock is really just a thin layer over the earth's crust that consists mostly of igneous and metamorphic rock. It is formed by the accumulation of sediments at the Earth's surface and within bodies of water. Common sedimentary rocks include sandstone, limestone, and shale. As sediment deposits over time, it traps partially decomposed organic material which forms shale oils and natural gas. As sediments form from weathering or glacial wear become deposited, minerals and organic particles settle and precipitate from solution to form rock. This sedimentation over time gives shale their characteristic horizontal layering.

While there are several large shale gas formations, also called "plays" in the U.S., the Marcellus Shale is notable because it contains so much natural gas (about 50 trillion cubic feet). Annual natural gas consumption in the U.S. is 21.7 trillion cubic feet, so the Marcellus Shale could support our entire nation alone for a little more than two years.

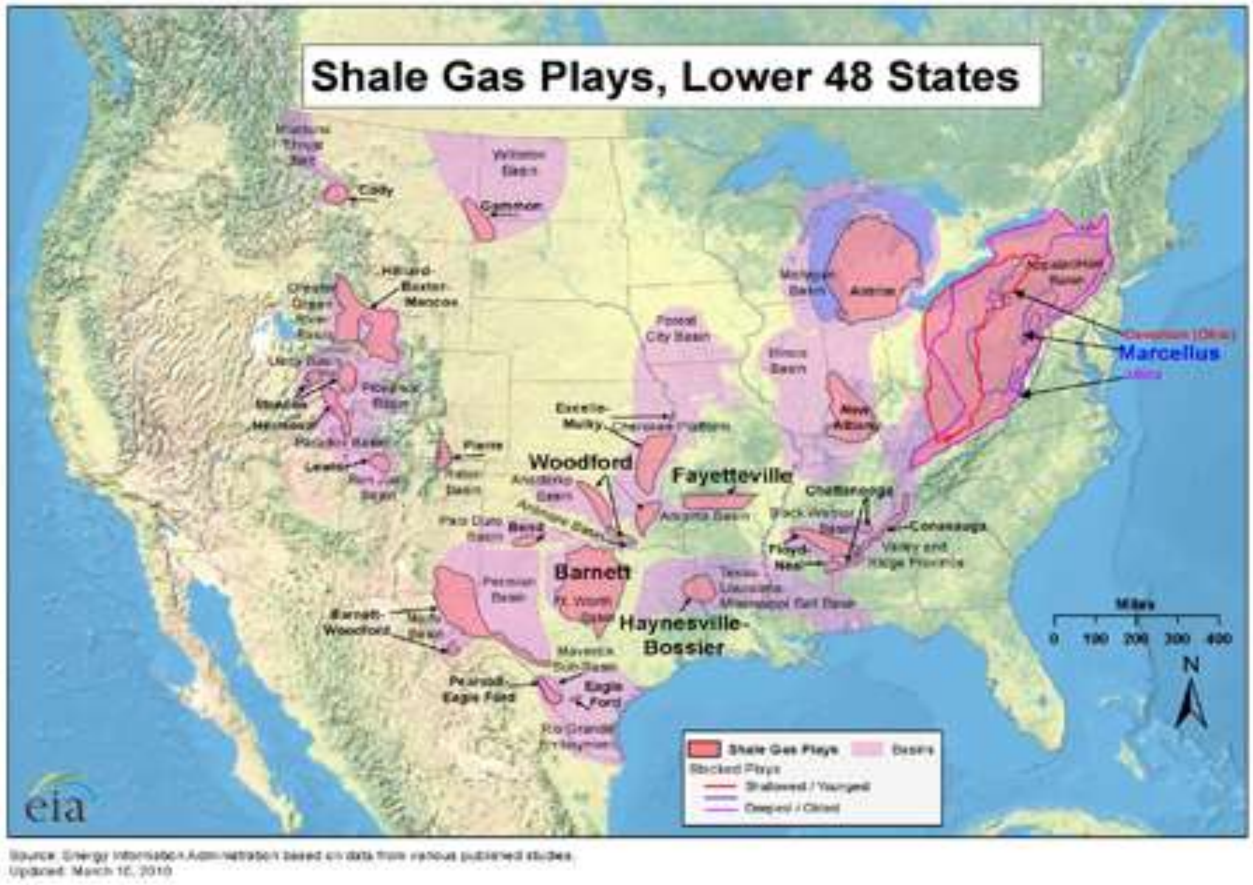


Fig 3. There are multiple shale gas plays in the United States. The Marcellus Shale is one of the most gas rich.

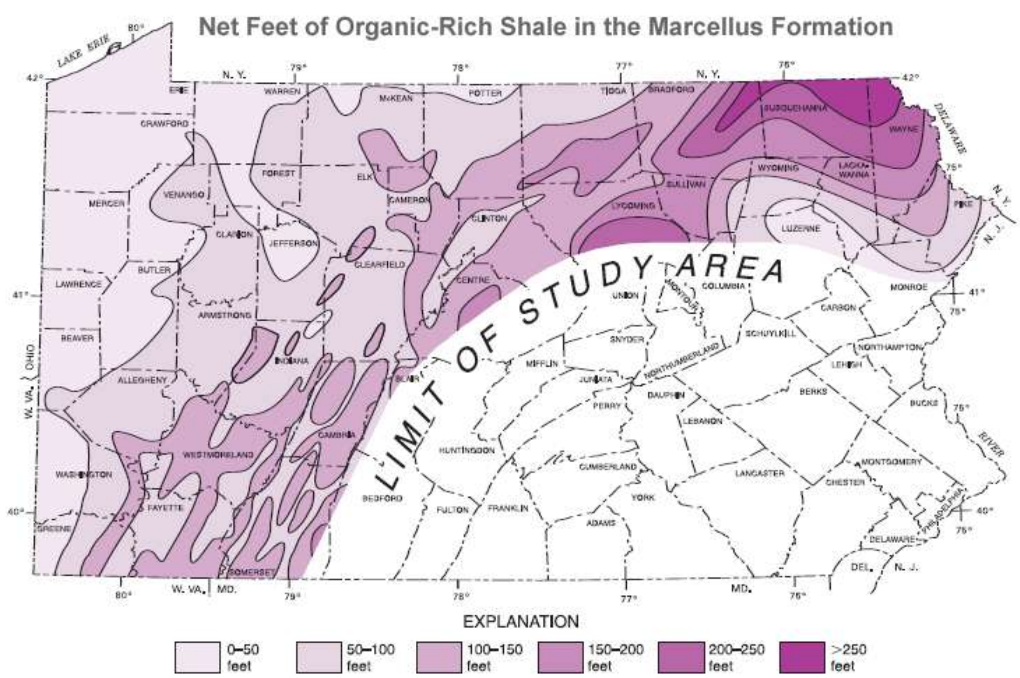


Fig 4. The Marcellus Shale extends from West Virginia to New York and includes a large swath of Pennsylvania. The largest natural gas deposits occur in the northeast part of the state. http://geology.com/articles/marcellus/marcellus-net-feet-organic-rich-shale.gif (originally from Piotrowski, R.G. and Harper, J.A., 1979)

Natural Gas Extraction

Natural gas in the U.S. is produced from two different main categories of fields: conventional and unconventional. Conventional fields are those associated with other fossil fuels (oil and coal). They contain obvious seals and traps, which contain the fuel within a concentrated area making the gas easily recoverable. Nonconventional fields have more diffuse boundaries with poor seals and traps, have inconsistent pressures and are diffused through a matrix like sand or rock and have low permeability (the gas is not released easily from the pores/rock surface) leading to a lower recovery rate. Despite these geologic limitations, extraction of natural gas from unconventional deposits is increasing rapidly. In the United States shale gas production increased from less than 2 percent to 6 percent of all domestic natural-gas production in the decade between 1996-2006 (Bateman, 2010).

The process for extracting natural gas from deep shale deposits is called hydraulic fracturing or fracking. It was developed in 1949 by oil-field-services provider Halliburton to increase production of conventional oil and gas wells when a well starts to run dry (Bateman, 2010). Its use in unconventional types of drilling, from coal-bed methane to shale gas, is relatively new. Fracking entails the high-pressure use of water, sand and chemicals to blast fractures into hard shale to unlock natural gas.

> *When a well is fracked, a small earthquake is produced by the pressurized injection of fluids, fracturing the rock around the well. The gas trapped inside is released and makes its way to the surface along with about half of the "fracking fluid," plus dirt and rock that are occasionally radioactive. From there, the gas is piped to nearby compressor stations that purify it and prepare it to be piped (and sometimes transported in liquefied form) to power plants, manufacturers, and domestic consumers. Volatile organic compounds (carbon-based gaseous substances with a variety of detrimental health effects) and other dangerous chemicals are burned off directly into the air during this on-site compression process. Meanwhile, the returned fracking fluid, now called wastewater, is either trucked off or stored in large, open-air, tarp-lined pits on site, where it is allowed to evaporate. The other portion of the fluid remains deep underground—no one really knows what happens to it* (Bateman, 2010).

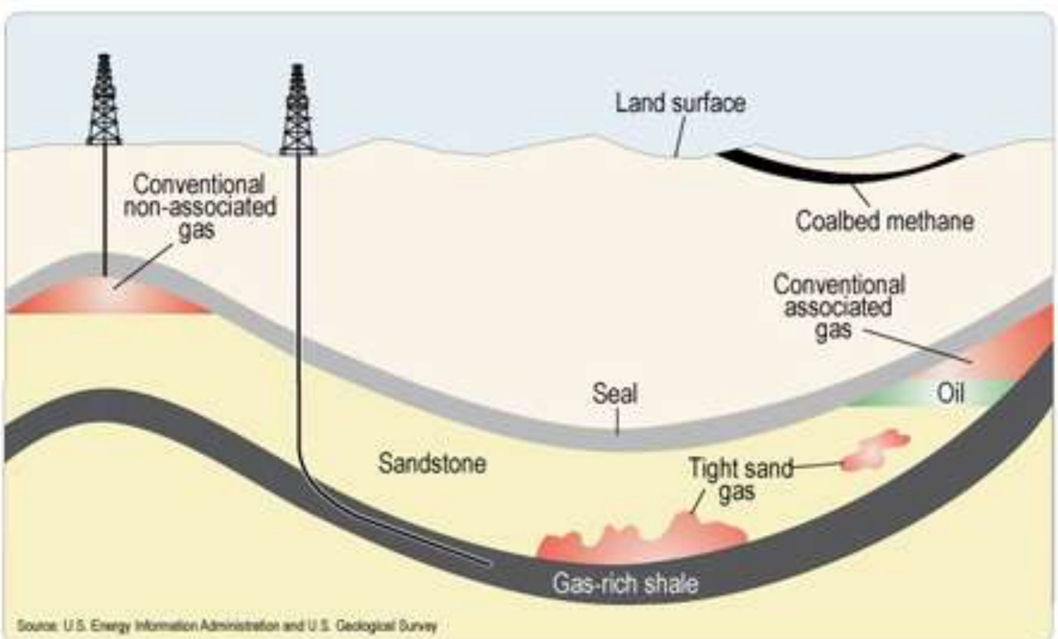


Fig 5. The United States has both conventional and non-conventional sources of natural gas. The gas-rich shale deposits (like the Marcellus) are to-date the deepest being exploited (modified from U.S. Geological Survey Fact Sheet 0113-01).

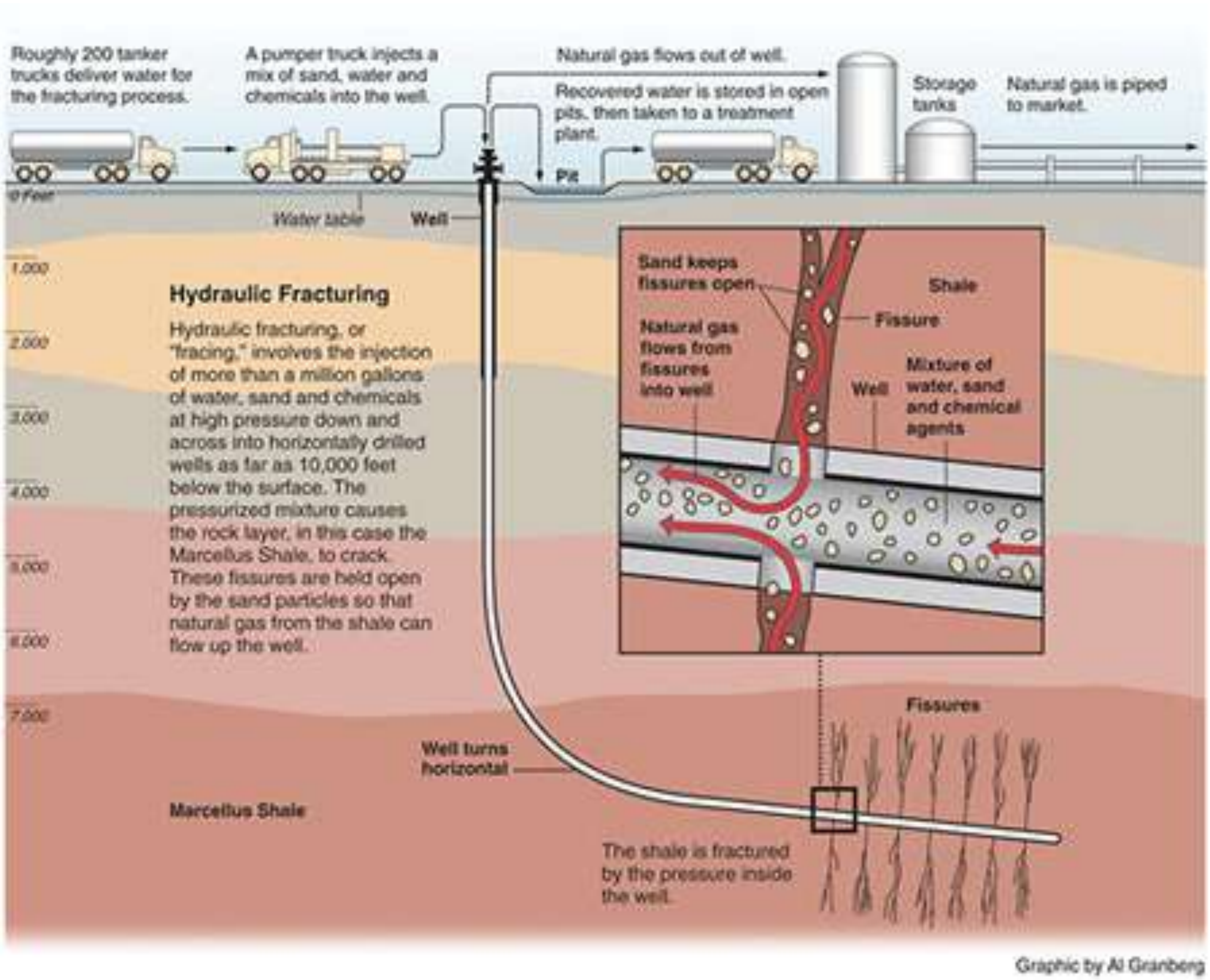


Fig 6. Fracking fluid is pumped through a vertical then horizontal well. As the fluid enters smaller fissures and pores the pressure increases resulting in fracture of the shale. Fissures are held open by sand particles and the natural gas contained within the shale dissolves into the fluid that is then recovered (http://www.propublica.org/special/hydraulic-fracturing-national).

The fluid used to both fracture shale and to extract the natural gas is referred to as fracking fluid. Fracking fluid is 98% water and sand, but contains a cocktail of other chemicals with various purposes. Sand and other materials or gels are used as “proppants” to keep fissures open so gas can diffuse more easily, biocides are employed to keep equipment free of bacteria and algae, acids clean out the fractures and friction reducers, surfactants, pH adjusting agents, oxygen scavengers, breakers, cross linkers, iron control, and corrosion inhibitors are some of the other frack fluid components. In many states, the specific ingredients in fracking fluid and their concentrations are proprietary information and protected. Other states require reporting. Many companies favor disclosure but only to regulators or medical professionals in the case of accident rather than to the public. In November 2010, Halliburton reported the development of an “eco friendly: fracking fluid sourced entirely from the food industry" such as guar gum as thickener (Soraghan, 2010). Some of the materials used are still considered hazardous despite the fact that they are used in or around food.

Product	Purpose	Downhole Result	Other Common Uses
Water and Sand: ~ 98%			
Water	Expand fracture and deliver sand	Some stays in formation while remainder returns with natural formation water as "produced water" (actual amounts returned vary from well to well)	Landscaping, manufacturing
Sand (Proppant)	Allows the fractures to remain open so the gas can escape	Stays in formation, embedded in fractures (used to "prop" fractures open)	Drinking water filtration, play sand, concrete and brick mortar
Other Additives: ~ 2%			
Acid	Helps dissolve minerals and initiate cracks in the rock	Reacts with minerals present in the formation to create salts, water, and carbon dioxide (neutralized)	Swimming pool chemical and cleaner
Corrosion Inhibitor	Prevents the corrosion of the pipe	Bonds to metal surfaces (pipe) downhole. Any remaining product not bonded is broken down by micro-organisms and consumed or returned in produced water.	Used in pharmaceuticals, acrylic fibers and plastics
Iron Control	Prevents precipitation of metal (in pipe)	Reacts with minerals in the formation to create simple salts, carbon dioxide and water all of which are returned in produced water	Food additive; food and beverages; lemon juice
Anti-Bacterial Agent	Eliminates bacteria in the water that produces corrosive by-products	Reacts with micro-organisms that may be present in the treatment fluid and formation. These micro-organisms break down the product with a small amount of the product returning in produced water.	Disinfectant; sterilizer for medical and dental equipment
Scale Inhibitor	Prevents scale deposits downhole and in surface equipment	Product attaches to the formation downhole. The majority of product returns with produced water while remaining reacts with micro-organisms that break down and consume the product.	Used in household cleansers, de-icer, paints, and caulk
Clay Stabilizer	Prevents formation clays from swelling	Reacts with clays in the formation through a sodium - potassium ion exchange. Reaction results in sodium chloride (table salt) which is returned in produced water.	Used in low-sodium table salt substitute, medicines, and IV fluids
Friction Reducer	"Slicks" the water to minimize friction	Remains in the formation where temperature and exposure to the "breaker" allows it to be broken down and consumed by naturally occurring micro-organisms. A small amount returns with produced water.	Used in cosmetics including hair, make-up, nail and skin products
Surfactant	Used to increase the viscosity of the fracture fluid	Generally returned with produced water, but in some formations may enter the gas stream and return in the produced natural gas	Used in glass cleaner, multi-surface cleansers, antiperspirant, deodorants and hair-color
Gelling Agent	Thickens the water in order to suspend the sand	Combines with the "breaker" in the formation thus making it much easier for the fluid to flow to the borehole and return in produced water	Cosmetics, baked goods, ice cream, toothpaste, sauces, and salad dressings
Breaker	Allows a delayed break down the gel	Reacts with the "crosslinker" and "gel" once in the formation making it easier for the fluid to flow to the borehole. Reaction produces ammonia and sulfate salts which are returned in produced water.	Used in hair coloring, as a disinfectant, and in the manufacture of common household plastics
Crosslinker	Maintains fluid viscosity as temperature increases	Combines with the "breaker" in the formation to create salts that are returned in produced water	Used in laundry detergents, hand soaps and cosmetics
pH Adjusting Agent	Maintains the effectiveness of other components, such as crosslinkers	Reacts with acidic agents in the treatment fluid to maintain a neutral (non-acidic, non-alkaline) pH. Reaction results in mineral salts, water and carbon dioxide; a portion of each is returned in produced water.	Used in laundry detergents, soap, water softener and dish washer detergents

Fig 7. Chesapeake Energy's list of fracking fluid ingredients.

Leasing Process

Natural gas companies do not buy land containing natural gas, instead they lease the mineral rights from the owner (who may or may not be the same as the landowner). The owner of a mineral tract (the lessor) can grant the right to develop deposits of the mineral to a producer (the lessee). There is tremendous variability in lease terms, but a lease will usually specify annual rental payments and any royalty on production paid to the lessor and set out other factors like road and pipeline locations, protections for crops, livestock, well water, and personal property as well as the expiration date of the lease.

There are to date no governmental regulations on the parameters of a lease, but a proposed law called the Conservation Pooling Act could minimize the surface impact of Marcellus Shale drilling by: limiting the number of well pads necessary to develop a drilling unit; maximize the opportunity for lessors to obtain full economic benefit from their Marcellus leases; and importantly, protect folks without mineral rights from having natural gas developed under their property.

Mineral owners each negotiate their leases individually and must rely upon attorneys who are familiar with oil and gas law (a cottage industry) before signing.

Environmental, Economic, and Social Issues Associated with Shale Gas

> *As is often the case with resource development, shale gas production also has raised local environmental concerns, largely centering on the amount of water used in the fracturing process and the need to handle, recycle, and treat fracturing fluids in a manner that addresses the risk of spills that can potentially affect water quality. EIA's Annual Energy Outlook 2011 Reference case also reflects the growing importance of U.S. shale gas. It projects that shale gas will account for about 46 percent of U.S. natural gas production in 2035* (http://www.eia.gov/todayinenergy/detail.cfm?id=811).

Net Energy: One drawback of shale gas is that it has a relatively low net energy gain. Net energy is the difference between the energy expended to harvest an energy source (in terms of development, extraction, refining, transportation, etc.) and the amount of energy gained from that harvest. Because of the energy required to drill, truck water to and from a well site, and process the natural gas recovered from hydraulic fracturing, the net energy of gas from unconventional reservoirs is far lower than conventional natural gas.

Greenhouse Gases: An often-cited affordance of natural gas is its low CO_2 emissions upon combustion. However methane, the main molecule in natural gas isn't entirely without contribution to climate change. There are two main concerns. First, methane liberated from underground storage can leak into the atmosphere where it can warm 56x as much as the same amount of carbon dioxide over a twenty year period (IPCC, 2001). Natural gas is composed largely of methane and "3.6% to 7.9% of the methane from shale-gas production escapes to the atmosphere in venting and leaks over the lifetime of a well." The other concern is that even without methane leaks, the emissions generated throughout the fracking process including thousands of truck trips required to frack every single well result in more warming than drilling for oil and possibly even 20% greater than coal mining in terms of greenhouse-gas production over 20 years (Howarth, Santoro, & Ingraffea, 2010).

Water Usage: Water is used prolifically in the drilling and operation of a well. Water is used to lubricate the drill bit, carry rock cuttings to the surface, for the hydraulic fracturing itself and also to transport natural gas. The drilling process requires 65,000-600,000 gallons of water per well and the fracking process requires an average of 4.5 million gallons of water before a well has become economically depleted (hydraulicfracturing.com). The source of water used throughout the fracking process includes rivers, creeks, lakes, discharge from wastewater treatment plants, and recycling fracking fluid. Water is typically transported by truck and stored in containers or impoundments for use. Used water is collected in open-air surface impoundments but only 60-80% of the water initially injected is recovered. Operators argue that while considerable, their use of water is finite unlike other types of water usage like agriculture. The impact of removing so much water from local reservoirs includes changes to important water quality parameters such as temperature, dissolved oxygen, and turbidity.

Water Contamination: Fracking fluid contains potentially toxic substances such as benzene, formaldehyde, ethylene glycol, glycol ethers, hydrochloric acid, and sodium hydroxide, some of which remains underground as unrecoverable. If mismanaged, hydraulic fracturing fluid can be spilled or leaked, and contaminate surrounding areas. In 2004, the EPA assessed the potential for contamination of underground aquifers from hydraulic fracturing and concluded that hydraulic fracturing posed little or no threat to drinking water as long as diesel fuel, which contains carcinogenic compounds benzene, ethylbenzene, toluene, xylene, and naphthalene, was not injected into the wells. Operators claim that water contamination is nonexistent or minimal because well construction protects freshwater aquifers with multiple layers of protective steel casing surrounded by cement. Also, natural gas formations are thousands of feet underground – deeper than most aquifers (Chesapeake Energy, 2011).

However, independent studies have since shown those compounds to be frequently present, and have also identified gaps in the EPA study (Yang, 2010). As of 2010 more than 1,000 cases of water contamination across seven states have originated from a fracturing process, and many cases go unreported. Well-known cases in Pennsylvania include a town called Dimock where tap water containing methane, aluminum, and iron, can notoriously be lit on fire (Bateman, 2010) and more recent contamination with the heavy metal barium (Phillips, 2011) in another town. Contamination is currently a local health issue, but as production of shale gas has ramped up, so have concerns over effects to groundwater and watersheds. The watershed most impacted in Pennsylvania is the Delaware River, which stretches some 400 miles and is one of the cleanest free-flowing rivers in the U.S. Importantly, more than 15 million people (including residents of New York City and Philadelphia) depend on the Delaware for water (Bateman, 2010). The oil and gas industry insists that drilling can be made safe, but one must wonder "if drilling is so safe, why does the industry insist on exemption from environmental review?" (Kuzminski, 2011).

Economic: Despite potential environmental consequences, there are clear economic benefits of exploiting the Marcellus Shale. Cabot Oil alone has created more than 300 full-time jobs in Susquehanna County, where Dimock (the town experiencing severe water quality issues) is located (Bateman, 2010). Governor Corbett in a June 2011 interview pointed to 48,000 jobs created by gas drillers and related companies. With those jobs come greater spending, economic development, and tax revenues. The economic advantages of fracking may explain why the bulk of legal protections exist for the gas companies rather than citizens. Opponents of fracking argue that job gains should be weighed against potential job loss and economic destruction created by: "boom and bust" cycles; loss of eco-tourism and fishing dependent on healthy, intact ecosystems; potential worst-case catastrophic scenarios (blowout, aquifer contamination, and/or salt line approaching Philadelphia water intakes); and jobs potentially created by investment in energy efficiency and conservation, wind, solar, geothermal, and other aspects of a long-term sustainable renewable energy economy (Boose, 2011).

Legislation/Legal Issues and Protection

One of the most controversial aspects of hydraulic fracturing are the exemptions the natural gas industry enjoys from the Safe Drinking Water Act, the Clean Air Act, and the Clean Water Act by the Energy Policy Act of 2005 despite dissent from the EPA. Dick Cheney is credited with crafting the exemptions in closed-door meetings with oil-and-gas executives. The burden of protection thus falls to departments of environmental protection at the state level that are so underfunded and revenue starved that they do a poor job enforcing environmental standards and protections (Bateman, 2010). The text of the Act itself can be found in pdf form online at the Department of the Interior's site, but is incredibly long and cryptic. Not surprisingly, the exemption is not stated plainly.

The Halliburton loophole was opposed with The FRAC Act, a House bill that was introduced by democratic representatives Maurice Hinchey and Jared Polis, from states containing shale plays in the 2009 congress. It is intended "to repeal the exemption for hydraulic fracturing in the Safe Drinking Water Act, and for other purposes." A twin bill was also introduced by Democratic senators Bob Casey of PA, and Chuck Schumer of NY. Neither bill was passed (Lustgarten, 2009).

On a more local note, Philadelphia seems to have no real legal avenue to control or impact actions occurring upstate. City Council has created recommendations such as the "Cart before Horse" principle established by the March 25th resolution and the October 15th letter from Councilman Jones and Councilwoman Blondell Reynolds Brown. They advocate for preventing the release, finalization, or enactment of rules related to gas drilling projects in the Delaware River Basin until the EPA studies and cumulative impact studies are complete, assessed, and widely debated. They've stated that if rules are released without benefit of such studies, they should be withdrawn (Boose, 2011). These are simply requests and political posturing and remain completely unenforceable.

Governor Corbett recently said he would consider imposing an impact fee on natural gas drillers - but only after his Marcellus Shale commission finished studying how a fee might affect drilling operations, and only if the revenue goes to local communities most affected by drilling, not to the state's general fund controlled by the legislature. The law in PA is still on the side of the industry- to the extent that companies can still capture gas from unleased properties if a well originates on a leased property (Bateman, 2010).

Objectives:

This curriculum unit was developed for use in a senior year Environmental Science elective course. It occurs within the nonrenewable resources unit in the second quarter of the course. The first semester is focused around the questions a.) how do ecosystems function (both in the absence and presence of human activity) and b.) what are the root causes of environmental degradation (namely population growth and consumption practices). The unit targets the following Pennsylvania Academic Standards for Science and Technology and advances student's content knowledge of earth systems, energy, and technology as well as their understanding of the overlap between science, economics, law, and ethics. This unit further affords students opportunities to advance their scientific thinking about defining a problem and testing solutions according to a model.

- Differentiate between conventional and non-conventional natural gas deposits
- Describe the process by which shale gas formed
- Support or critique the argument that "natural gas is a bridge to a clean energy future" with specific examples and evidence
- Identify key ways in which water quality and resources are impacted by hydraulic fracturing
- Describe the process of hydraulic fracturing and suggest technological innovations that might improve efficiency and/or safety
- Provide arguments for the allowance of easing restrictions/oversight on the oil and gas industry
- Describe the socioeconomic factors impacting a landowner's decision to lease mineral rights to gas companies
- Analyze information sources, both film and print, for evidence of bias
- Argue persuasively for the encouragement or restriction of hydraulic fracturing in the Marcellus Shale region

Standard	**Rationale**
3.1.12. Unifying Themes A. Apply concepts of systems, subsystems - Compare and contrast several systems that could be applied to solve a single problem. - Evaluate the causes of a system's inefficiency. C. Assess and apply patterns in science and technology. - Assess and apply recurring patterns in natural and technological systems.	Students will compare a number of energy production techniques that can be applied to solve the problems of a) dwindling sources of fuel and b) increasing environmental pollution in order to assess the viability of shale gas. Students will also describe the patterns that result in deposits of fossil fuels and
3.4.12.B Physical Science Apply and analyze energy sources and conversions and their relationship to heat and temperature	One of the main arguments for the expansion of natural gas drilling in the U.S. is its relative efficiency. This is a good opportunity to compare energy conversions for different applications (for heat, electricity, transportation) and to compare the net energy of different extraction processes.

3.5.12.B Earth Science Analyze the availability, location and extraction of earth resources.	Geology is often a topic overlooked in science curriculum because it feels relatively unconnected to students' lives. The presence of shale gas deposits is relatively predictable given geologic history. The personal connection students feel to the local Marcellus Shale play is an entry point to other shale deposits, discussions of the similarities between gas, coal, and oil deposits, and investigation of other geologic formations (igneous, metamorphic.)
3.6.12.C Technology Education Analyze physical technologies of structural design, analysis and engineering, personnel relations, financial affairs, structural production, marketing, research and design to real world problems.	Engineers are constantly adjusting technologies to increase efficiency, decrease cost, and improve safety. It is important that students leave environmental science not just with a sense of the problems we face, but also a sense of the solutions and the process of developing solutions. Engaging in research and development of technological improvements gives students a sense of hope and also future career opportunities.
3.8.12. Science, Technology and Human Endeavors B. Apply the use of ingenuity and technological resources to solve specific societal needs and improve the quality of life. C. Evaluate the consequences and impacts of scientific and technological solutions.	

Strategies:

Overview

Activity 1 (1 day): Students will use their own PGW bill to quantify their own usage of natural gas and speculate about the causes of variation in usage throughout a year as well as application of natural gas in their homes.

Activity 2 (1 day): Students will be presented with an introduction to natural gas in terms of its formation, location, major applications, and the debate surrounding its role in the U.S./global energy portfolio.

Activity 3 (3 days): Students will identify major environmental problems that result from natural gas extraction via hydraulic fracturing as raised in the film *Gasland*.

Activity 4 (1 day): Students will identify evidence of bias in *Gasland* and the natural gas industry's response (The Truth About *Gasland*).

Activity 5 (5 days): Students will investigate a topic of their (constrained) choice in order to clarify their personal position on developing the Marcellus Shale in Pennsylvania.

Activity 6 (1 day + homework): Students will write an editorial or unbiased piece for the school newspaper describing fracking.

Classroom Activities:

Activity 1: What are our existing habits regarding natural gas consumption for domestic use?

This activity is the hook for the unit. In it, students will find out how much natural gas their family uses in a year. The hook for the activity is to ask students to guess how much their household pays for all of its natural gas in the entire year and to predict the month in which their natural gas bill was highest last year. It is fun to offer a prize for the student who comes closest to the $ prediction. If so, collect predictions before beginning the activity. It is important that students feel a personal connection to the energy sources being discussed. One way to do this is by helping students examine their own bill detailing energy usage.

Introduce students to PGW with a promotional video clip (https://www.pgworks.com/documents/MediaCenter/PGWgamechangerHD-wmv_1280.WMV)
Students will be asked to bring in a copy of their household's energy bill. Show students how to get their parents to access bills online https://www.pgworks.com/. It works best to count bringing in a bill as a homework assignment (students can bring a note from home if parents are unwilling to share the bill. Students who lack their own bill can either work with another student or use a copy of the teacher's bill (but it's not as interesting that way).

Logistics: Remind students to bring calculators to class. Computers are not necessary for the bulk of the assignment, but are useful. Students should finish whatever is not completed in class at home and hand their audit in the following day.

Name ____Period ______ Date _____________

Natural gas (PGW):

Important Conversions:
1 **Ccf** = 100feet^3 of natural gas= 1 **therm**= 100,000 **Btu** (British thermal unit) = 105,506,000 **joules**= 29.3 **kWh**
Note: 100,000 BTU is the energy equivalent of burning 100 cubic feet of gas. The amount of energy 100 cubic feet of gas contains depends on the mix of hydrocarbons and on the level of contamination with impurities like carbon dioxide or nitrogen.

1. Look at the information under "Meter Detail" and "Energy Usage Information" section of the bill.
a) How much natural gas energy did your household use during the billing cycle? ______________Ccf
b) Convert that amount to therms and btu ________________therms =__________________________btu

2. Look at your usage over the last 12 moths.
   a. What was your total usage over that period? ____________________Ccf
   b. How much natural gas do you use on average each month? ________________ Ccf
   c. How much are you paying each day for natural gas? $____________________

3. Describe the temporal pattern shown by the bar graph. Also speculate on the causes of that pattern.

4. Is your energy usage higher or lower than the same time last year? _______________________
Why do you think that is? Be specific.

5. According to the Pacific Gas and Electric Company emissions rate, burning natural gas produces on average 13.446 pounds (6.099 kg) of carbon dioxide per **therm.** How much CO_2 is your household responsible for based on your total Ccf usage? Show all calculations, include all units and put a box around your final answers (in kg).

6. Compare your CO_2 output when you use selected natural gas appliances vs. electric appliances
https://www.pgworks.com/index.aspx?NID=390

7. Describe in your own words why the carbon dioxide emissions of your household are of environmental importance.

Saving Energy

There are changes you can make even without switching providers. Look at the suggestions under "Ways to Save Energy" http://www.papowerswitch.com/ways-to-save-energy/ and/or poke around on websites like http://www.energysavers.gov/, and https://www.pgworks.com/index.aspx?NID=377. Pick 3 things that you think your household could do to lower your energy bill and carbon footprint and 1 way that your household is less likely to adopt. Be careful to focus on energy saving habits specifically focused on natural gas (NOT electricity).

Practice Description	**Explanation**

Activity 2: Interactive Lecture
Where does the natural gas our household uses come from? How does our domestic usage fit into the larger U.S/global picture? What are the affordances/constraints of using natural gas? How might our usage of natural gas change in the future?

This activity is intended to give students the foundation of knowledge needed to later interpret a variety of information resources relating to hydraulic fracturing. During this teacher-centered phase of the unit, students will explore important background information that contextualizes fracking. Information presented will first draw out what students learned from the audit and expand on it.

1. What are some uses for natural gas in your household? (heating, hot water, cooking)
2. What IS natural gas? (a mixture of certain small hydrocarbons)
3. How do we release energy contained in natural gas? Combustion
4. How is the combustion of natural gas different than combustion of other fossil fuels? (in terms of net energy, activation energy, products)
5. Can natural gas be used in applications other than heat?
    a. Fossil electric generation systems
    b. Transportation: Watch and discuss Honda NGV review available at:
        i. http://www.mayogasinfo.com/natural-gas-vehicles/honda-civic-gx-natural-gas-vehicle-review-kelley-blue-book
        ii. www.youtube.com/watch?v=qy5gNJO2pNM
6. Why are people beginning to get so interested in natural gas? Watch and discuss T. Boone Pickens
    i. http://www.youtube.com/watch?v=nEUbYm9dp2o
    ii. http://video.forbes.com/fvn/openmike/open-mike-t-boone-pickens-predictions
7. If we move toward a natural gas economy, we'll need to exploit less conventional sources of natural gas. Where are they? How are they different from conventional sources? How did they form?
8. How is natural gas extracted from shale deposits?
    i. http://www.nytimes.com/interactive/2011/02/27/us/fracking.html Interactive diagram showing the process of fracking
    ii. http://www.youtube.com/watch?v=timfvNgr_Q4 (My Water's On Fire Tonight)

Homework: Create your own fact sheet combining the approaches in the two interactive descriptions of fracking. Make it so that a person with a 9th grade education could understand the process and its implications. Keep your product informative and engaging.

Activity 3: What does fracking look like in local communities? What are some environmental, social, and economic impacts of fracking in Pennsylvania?

Hook: Bubble natural gas from a lab source through soapy water. This will create a column of soap bubbles filled with methane. If you slice the base of the bubbles with your hand, they will float toward the ceiling. Touch a lit match attached to a meter stick to the bubbles. There will be a dramatic fireball. Tell students that in the film they're about to view they will see the relevance of demonstration.

In this section of the unit students will watch the Josh Fox film *Gasland.* The purpose is to help students visualize processes of fracking and its impact. This activity leads in to activity 4, which identifies bias in various information sources. While students are watching the film, they can use this viewing guide to keep track of important information.

Closure: Ask students to write a brief explanation of why the demo done at the beginning of the film was relevant to the film. Grade for as much detail as possible looking for keywords such as methane, shale, casing, combustion, contamination, aquifer etc.

Name____ Period _____ Date _____________

Gasland: Can You Light Your Water on Fire?

Before

1. What is natural gas?

2. What do you think fracking is?

3. Based on what you think fracking is? Who would put up a lawn sign like mine, and why?

During

1. Which states does the Marcellus Shale cover?

2. Describe the process of fracking.

3. How much are companies willing to compensate residents for hydraulic fracturing on their land?

4. What environmental laws are gas drilling companies exempted from under the Energy Act of 2005?

5. What are some signs of "bad water"?

6. What is fracking fluid? What does it contain?

7. What is "produced water"?

8. Keep a running list of the ways that humans were impacted by fracking.

9. What is the anatomy of a gas well? Describe how a gas well undergoing hydraulic fracturing works.

After:

1. If you lived in the Marcellus Shale area, would you agree to lease your land to a natural gas company? Why or why not?

2. How was the Environmental Protection Agency portrayed in this film? Did it change how you felt about environmental organizations? Why or why not?

3. The following are quotes from the film. Choose one that you think summarizes the film best, and explain why that quote resonates with you.

a) "I'm not a pessimist, I've always had a great deal of faith in people, that we wouldn't succumb to frenzy or rage or greed. That we'd figure out a solution, without destroying the things we love."

b) "Water, water, everywhere and not a drop to drink."

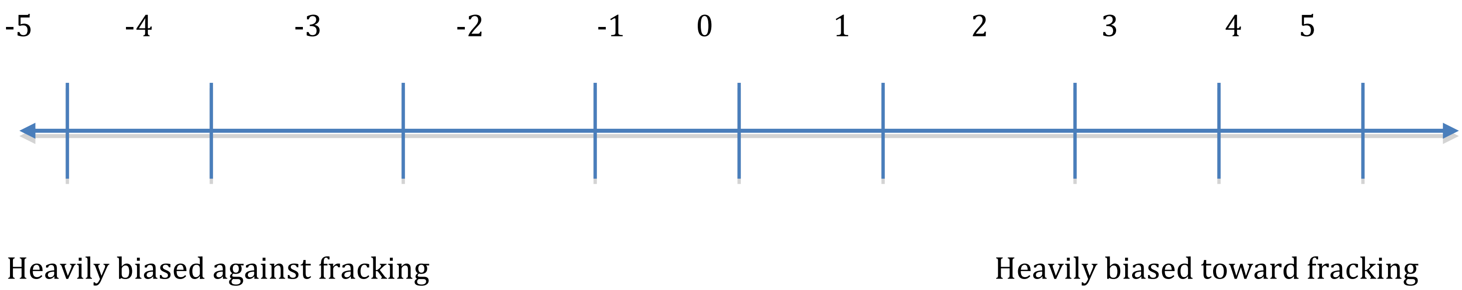
c) "I guess the law is for certain people."

d) "An atmosphere of secrecy."

e) "It's amazing that what took Mother Nature millions of years to build, could be destroyed in just a few hours."

Activity 4: How biased was the information presented in *Gasland*? Can we extract information and meaning from a film when it is substantially biased?

Begin class by drawing a number line like this one on the board.



Hook: Ask students to assign a number that represents how biased their individual view of *Gasland* was. Ask each student individually and place a dot above that section of the number line (creating a histogram.) Students will likely consider the film to be very biased. Then ask students how they think the film demonstrated bias and compile a list of the techniques and the impact of that technique.
For example:

Technique	Impact
- grainy film style, shaky camera work - single person narrative - Helvetica font	- Leaves viewers with a visceral discomfort - Leaves viewer with an underdog vs. bad guy sense

Tell students that it is often helpful to seek out alternate opinions and sources when a heavily biased source is encountered.

Show "The Truth About *Gasland*"
http://www.anga.us/truthaboutgasland
http://www.anga.us/media-room/videos/viral-video/the-truth-about-gasland

Repeat the above activity followed by a discussion on ways to find the real truth. Ask students to break up into small groups and create a list of 10 questions they'd like to know the "real truth" about (related to this topic). Share lists and discuss ways of finding that information. This brainstorm leads into the next activity.

Activity 5: Which aspects of fracking and natural gas would you like a more objective understanding of? Independent research.

Students will form groups of 3 and create presentations on the topic of their choice from the list below. Some of the topics require internet research, others involve original scientific research. This list below represents a core set of topics, but this can be adjusted according to student interest. Students will need 3 days to conduct research and prepare a presentation, and presentations will take 2 days.

1. What is the Marcellus Shale?
    a. What is shale? How is it created? What type of rock is it and how is that rock formed?
    b. Why is there shale here under Pennsylvania?
    c. Why is there natural gas in some shale?
    d. Where are other major gas containing shale formations? How do they compare in terms of depth, amount and availability natural gas?
    e. Resources:
        i. http://www.dcnr.state.pa.us/topogeo/oilandgas/marcellus_shale.aspx
        ii. *nsglc.olemiss.edu/Advisory/**marcellus_citizens_guide**.pdf*
    f. What are the properties of shale?
    Examine texture, composition, acid test, scratch/hardness test
        i. http://jersey.uoregon.edu/~mstrick/MinRockID/RockID/RockIDChart.html
        ii. http://geology.about.com/library/bl/blrockident_tables.htm

2. Timeline of events regarding shale gas in the U.S. and Pennsylvania.
(Hint: a prezi would be a nice format for this)
    a. When was the natural gas we extract from shale created?
    b. How long has shale gas been known about?
    c. When were significant technological advances made?
    d. What/when were key legal moments
        i. http://shale.sites.post-gazette.com/index.php/multimedia/interactives/interactive-timeline

3. What is Pennsylvania's stance on natural gas drilling?
    a. What is the Shale Advisory Committee?
    b. What is the role of the committee?
    c. What are some important actions/accomplishments of the committee?
    d. Who is on the committee?
    e. What important decisions or statements has Gov. Corbett made about gas companies in the Marcellus Shale?
    f. Analysis of findings
    g. http://shale.sites.post-gazette.com/index.php/multimedia/interactives/governors-shale-advisers

4. What innovation to the drilling etc. process would make shale gas…
    a. safer for the environment
    b. safer for people
    c. more efficient
    d. cheaper

(Present background research and propose a change in technology. Describe who you would market it to and how.

5. Do most residents of the Pennsylvania shale regions support or challenge hydraulic fracking in their community?

a. How are people getting their information about fracking?
b. How do people currently feel about their communities?
c. Are people more familiar with drilling more opposed or more supportive of drilling?
d. How does level of education impact support/opposition of drilling?
e. How does PA compare to NY in terms of support for drilling?
f. What aspects of the Marcellus Shale and drilling are people most and least knowledgeable about?
g. DON'T FORGET to draw important connections and conclusions between all of these pieces of information.
h. Resources:
    i. Google "Community Impacts of Marcellus Shale Development Kathy Brasier" to find a Penn State Cooperative Extension study.)

6. Propose a legislative bill to address issues surrounding fracking.
    a. Investigate the FRAC act- how it is written, its goals etc.
        i. Who brought it in the House and Senate
        ii. What does the FRAC act attempt to accomplish?
        iii. What is the current status of the FRAC act?
        iv. Should legislation exist at the federal or state level? (Make sure your bill answers that question)
    b. Resources:
        i. http://www.govtrack.us/congress/bill.xpd?bill=s111-1215
        ii. http://www.propublica.org/article/frac-act-congress-introduces-bills-to-control-drilling-609

7. What is the current status of permitting, drilling, and violations in Pennsylvania?
    a. How many permits were issued in 2009, 2010, 2011?
    b. Of those permits, how many wells were drilled?
    c. Who are the major operators for the permits? (sort the data alphabetically by operator and create a graph)

8. What does a citizen need to know about legal issues? You could consider writing a short citizens guide.
    a. What laws protect you?
    b. How does a contract work? Who is the lessor, lessee?
        i. *blogs.law.widener.edu/.../03/**Marcellus_Citizens_Guide**-Summer_2010.pdf*
        ii. www.safegaslease.com/2011/06/pro-**drilling**-and-heres-why.html
        iii. www.marcellus**shalelaw**monitor.com/.../water-issues-in-the-marcellus-**shale**/
        iv. http://amlawdaily.typepad.com/amlawdaily/2010/11/btpreviewshale.html

9. Violations of permits:
    a. What permits do gas drillers need to get before proceeding?
    b. Who grants the permits? What is the process like?
    c. How frequently are permits violated?
    d. What kinds of violations are occurring?
    e. Who are the major violators? Make some sense of this.
    f. http://shale.sites.post-gazette.com/includes/shalepermitmap/index_permitmap.php
    g. http://shale.sites.post-gazette.com/index.php/news/environment/23927-pipeline-launches-statewide-permit-and-violation-map
    h. http://www.fractracker.org/2011/05/2010-fines-for-marcellus-shale.html
    i. www.pacwa.org/**Violations**_Report.pdf

10. What is the effect of fracking on water availability and quality in terms of
   a. Research the following tests and do them on distilled water as well as simulated frac return
      i. Salinity
      ii. Hardness
      iii. Conductivity
      iv. Dissolved oxygen
      v. Nitrate/phosphate
   b. Resources
      i. http://www.michigan.gov/deq/0,1607,7-135-3313_3682_3713-10416--,00.html
      ii. http://bcn.boulder.co.us/basin/data/BACT/info/
      iii. *occainfo.org/.../**GasDrilling**HydraulicFracturingand**WaterQuality**Mar2010.pdf*
      iv. www.theithacajournal.com/assets/ppt/CB14954316.PPT

Activity 6: Newspaper Article
In this summative assessment and culminating activity, students will demonstrate their knowledge of hydraulic fracturing by writing a newspaper article. Students must choose between writing either a balanced news piece or an editorial. The guidelines for the article are on the student handout. Students should begin writing their articles in class (to get enough of a start that they are invested in completing the draft at home.) I recommend doing a peer review (according to the rubric below) and using the same rubric for the final grade. Select the best article to publish.

Name ____ Period ______ Date __________

Fracking Article

Objective: Did you know that most Philadelphia residents have not heard of hydraulic fracturing even though it is happening in the watershed (Delaware River) that supplies us? Write the best fracking article you can to inform your peers and community about the science, legal status, and implications of this very timely and serious issue. You will receive one grade for your rough draft (peer review) and a grade for your final draft.

Suggested Resources to start with:

1. *A Colossal Fracking Mess by* Christopher Bateman
http://www.vanityfair.com/business/features/2010/06/fracking-in-pennsylvania-201006

2. *NOW on PBS "Gasland"* **http://www.pbs.org/now/shows/613/index.html**

3. *NY Times Drilling Down series:*
http://topics.nytimes.com/top/news/us/series/drilling_down/index.html?scp=2&sq=fracking&st=cse

Basic requirements:

1. A catchy title
2. Typed: double spaced, 12pt times new roman font, 500-800 words (use word count under the tools menu)
3. A minimum of 3 sources cited using APA format (use easybib for help)
4. Spell/grammar checked

Peer Review Rubric	**Poor - 1 pt** meets no more then one requirement	**Fair- 3 pts** addresses most of the requirements	**Good - 5 pts** all requirements are met	**Comments:**
Structure Requirements -500- 800 words -double space -size 12 font, times new roman - contains a title	Poor	Fair	Good	
Content Is the topic thoroughly addressed and answer questions including: 1. What the process of fracking is and how it works. 2. What natural gas is and how we use it. 3. Where fracking is happening. 4. What the controversy is about. 5. Recent events relating to fracking's legal, economic, geographic status. 6. The connection to residents of Philadelphia	Poor	Fair	Good	
Balance Is there clear effort to communicate multiple sides of the controversy and to acknowledge different points of view?	Poor	Fair	Good	
Grammar -Capitalization -Punctuation -Sentence Structure - Tense	Poor	Fair	Good	

Additional Comments:

Annotated Bibliography:

The World Bank, open data http://data.worldbank.org/?display=graph
Data collected and presented according to country, topic, and indicators. Environmental data includes biodiversity, methane emissions, pollutants etc. The very useful indicators section includes data sets focused on agriculture and development, education, energy and mining (most useful for this unit) and more. The user creates line graphs, atlas maps, or tables and can stack multiple data sets together (by country, income level).

http://www.eia.gov/naturalgas/

Today In Energy, U.S. Energy Information Administration
http://www.eia.gov/todayinenergy/detail.cfm?id=811

http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

National Assessment of Oil and Gas Fact Sheet USGS Fact Sheet FS-113-01 January 2002
A great 2 page dense factsheet for your own edification or to use as a printable supplement for your students. It includes diagrams of conventional and unconventional natural gas resources, data and graphs for natural gas production

Hydraulic Fracturing What Is Hydraulic Fracturing? *http://www.propublica.org/special/hydraulic-fracturing-national*
Clever diagram showing the whole fracking process by both depth and time.

Krauss, C. (2011, June 6). A 'golden age' for gas? two caveats. *The New York Times*, Retrieved from http://green.blogs.nytimes.com/2011/06/06/a-golden-age-for-gas-2-caveats/

Phillips, S. (2011, June 7). In gas drilling, 'fracking' may not be the only threat to well water. *Newsworks. WHYY*, Retrieved from http://www.newsworks.org/index.php/homepage-feature/item/20692-02spbrad&Itemid=1
A story about a woman and community suffering from barium poisoning seemingly associated with natural gas drilling in Pennsylvania. The story can be read and/or listened to, and is associated with an annotated slide show. This story is interesting because the barium levels became elevated following drilling, but prior to fracking. This has implications for determining cause and blame in water quality contamination cases.

Bateman, C. (2010, June 21). A colossal fracking mess. *Vanity Fair*, Retrieved from http://www.vanityfair.com/business/features/2010/06/fracking-in-pennsylvania-201006?currentPage=all
This Vanity Fair article is an excellent introduction to the environmental consequences and legal/political tangle surrounding fracking. I would use it as a student homework assignment, resource for further research, or use the film clip associated with the article (watch out- it is strangely blocked by the SDP) as a vivid introduction perhaps in place of the longer *Gasland.*

A map of the oil world. (2007, November 6). *The New York Times*, Retrieved from http://www.nytimes.com/interactive/2007/11/06/business/20071107_WINNERSLOSERS_GRAPHIC.html

Super fun and interesting interactive graphic. Use it right and your students can discover for themselves that the U.S imports way more oil than it produces, uses way more oil than any other country, and imports oil from a very wide range of countries. It's a great discussion starter and tangentially related to natural gas by supporting the claim that natural gas as a domestic energy source is attractive to the U.S. because of our heavy reliance on foreign oil.

Pickens, T.B. (2011, May 20). T. Boone Pickens: natural gas better for economy, environment. *The Wichita Eagle*, Retrieved from http://www.kansas.com/2011/05/20/1856340/t-boone-pickens-natural-gas-better.html
The famous T. Boone Pickens makes the case for natural gas.

"Energy Policy Act of 2005" PUBLIC LAW 109–58—AUG. 8, 2005 Retrieved from doi.net/iepa/EnergyPolicyActof2005.pdf
This is the full text of the law containing the "Halliburton loophole." Warning- it is long and fairly incomprehensible. It can serve as an interesting primary document and/or a demonstration of what "real law" looks like and the ease of hiding important legislation. Could also deter students from law/government, so be careful.

IPCC (2001). Climate change 2001: working group i: the scientific basis. *IPCC Third Assessment Report, 6.12.2*, Retrieved from http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/248.htm
Original text from the IPCC working group describing the relative warming potential of methane (compared to carbon dioxide) and how they arrived at their values.

Howarth, R.W., Santoro, R. & Ingraffea, A. (2010). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change, DOI 10.1007/s10584-011-0061-5*
A study by a Cornell University group demonstrating that the warming potential of shale natural gas is higher than conventional energy sources when a life-cycle approach is used.

Boose, K. (2011, January 24). *Final recommendations Marcellus Shale report city council of Philadelphia's joint committees on transportation and public utilities and the environment, September 28, 2010*. Retrieved from http://protectingourwaters.wordpress.com/2011/01/24/final-recommendations-marcellus-shale-report-city-council-of-philadelphia%E2%80%99s-joint-committees-on-transportation-and-public-utilities-and-the-environment-september-28-2010/

Pittsburgh Post Gazette's focus on the Marcellus Shale "Pipeline" http://shale.sites.post-gazette.com/
Includes many interactive features, message boards and is a great demonstration of how communities use the web to organize, share, and learn.
- Interactive Timeline
http://shale.sites.postgazette.com/index.php/multimedia/interactives/interactive-timeline
From 1900-2010 and includes key technological innovations, important legal and drilling benchmarks.

FracFocus: Chemical Disclosure registry http://fracfocus.org/
This website run by the Groundwater Protection Council and Interstate Oil and Gas allows you to find a well by state and open a pdf containing a spreadsheet that lists the chemical components of fracking fluid used in that well. Some states (Montana, Texas, and Louisiana) allow well operators to meet disclosure requirements by posting on this site. The site also catalogs regulations by state and has MSDS sheets for most of the chemicals listed. This is a great resource for primary documentation.

DEP Oil and Gas Electronic Reporting Website
https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Welcome.aspx
This website is "a first-of-its-kind tool that provides the public with greater insight into oil and gas operations across the state. This application—developed in response to Act 15 , which Governor Edward G. Rendell signed into law in March 2010—is designed to make the activities of drilling companies and their business partners more transparent. This site allows users to view historical oil and gas well production information from conventional shallow wells and newer Marcellus wells, as well as data on the waste each operation produces. All information presented is as reported by the industry in accordance with Pennsylvania law. Users can search for information by well permit number, by operator ID, by county or for the entire state. The site also allows you to generate and download raw data easily for further analysis."

Chesapeake Energy (2011, April). *Hydraulic fracturing fact sheet.* Retrieved from http://www.hydraulicfracturing.com/Fracturing-Ingredients/Pages/information.aspx
Although it is published by a gas company, the information is clear, and at an appropriate level, and there's no such thing as unbiased information anyway.

Fox, Josh (Director). (2010). *Gasland* [DVD]. Available from http://www.gaslandthemovie.com/
An engaging and current film that follows the director's journey to decide whether to lease his land's mineral rights to a gas company in Pennsylvania. The film is quite biased against fracking but provides an excellent introduction. There are educational materials on the website.

Yang, S. (2010, May 3). Hydraulic fracturing – potential for contamination of drinking water sources. *State of the Planet*, Retrieved from http://blogs.ei.columbia.edu/2010/05/03/hydraulic-fracturing-potential-for-contamination-of-drinking-water-sources/

Lustgarten , A. (2009, June 9). Frac act—congress introduces twin bills to control drilling and protect drinking water. *ProPublica*, Retrieved from http://www.propublica.org/article/frac-act-congress-introduces-bills-to-control-drilling-609

Kuzminski, A. (2011, May 31). *Commentary: why we should not be fracking for natural gas.* Retrieved from
http://www.syracuse.com/news/index.ssf/2011/05/commentary_why_we_should_not_b.html
A nicely organized response to many of the pro-fracking arguments. This could be jig sawed or used in other ways to set up a debate about both sides of the issue.

Brasier, Kathy. " Natural Gas Experiences of Marcellus Residents: Preliminary Results from the Community Satisfaction Survey." Lecture. Marcellus Shale Educational Webinars. State College. 16 Sept. 2010. Penn State University, College of Agricultural Sciences. Web. 10 Apr. 2011. <http://extension.psu.edu/naturalgas/events>.
A series of slides showing results of a qualitative survey of PA communities where gas drilling is occurring. Participants answered questions on perceptions of risk, overall support according to activity level of drilling in an area, community ratings, institutional trust, attachment to community etc. Data is presented in easy to understand tables. This is a great into to qualitative data collection. I initially laminated key slides and asked students in groups to write the take home message and a supporting detail on each, then to present the slide to the class. This presentation made me reconsider my opposition to gas drilling.