PITTSBURGH STUDENT ENVIRONMENTAL COALITION SPRING 2011

Shale Gas 101

Pittsburgh Student Environmental Coalition

FAST FACTS[1]

HOW MUCH GAS?
1,744 tcf Nationally
262 tcf in Marcellus Shale
(Technically Recoverable Resources)

Enough to last 90+ years at current rates of consumption.

1 tcf (trillion cubic feet) can generate 100 billion kWh of electricity.

Wind energy generated 55 billion kWh in 2008.[3]

WATER CONSUMPTION
~80,000 gal per well to drill
~3.8 Mil gal per well per frack
(Based on Marcellus Shale)

Electrical generation in the Susquehanna River Basin uses ~150 Mill gal per day, while peak Marcellus Shale activity in the same area is ~8.4 Mill gal per day.

WHAT'S IN NATURAL GAS?
70-90% Methane
[Used for Heating, Electricity, Industry]

0-20% Ethane, Propane, Butane
[Used in Industry]

0-5% Carbon Dioxide
0-2% Nitrogen, Hydrogen Sulfide
[Byproduct]

What is shale gas?

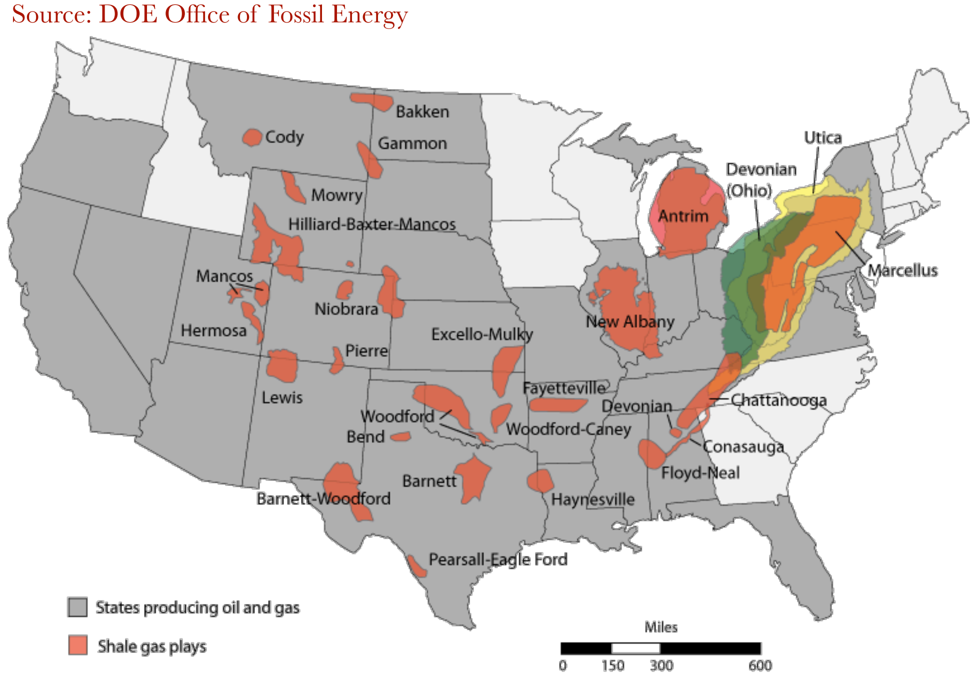
Shale gas is natural gas trapped within sedimentary rock formations around the world that formed millions of years ago from the compression of mud and organic material under immense heat and pressure. Instead of existing in interconnected pockets of gas, shale gas is essentially dissolved within vast shale basins that extend for thousands of square miles several thousand feet below the Earth's surface. Until recently, shale gas has been too difficult and costly to develop, but technological advances such as horizontal drilling and slickwater hydraulic fracturing over the past decade have made shale gas extraction feasible and economic in plays across the country (see map below). The four most developed shale plays in the United States are the Barnett, Fayetteville, Haynesville, and Marcellus shales. Each formation requires a slightly different development process due to unique characteristics, and these processes are subject to regulations that vary by state.

Natural gas currently supplies about 22 percent of the United States energy consumption, and that share is expected to increase as oil becomes more expensive and our infrastructure transitions away from relatively dirty coal energy. Although natural gas emits significantly less green house gasses and other pollutants during combustion than other fossil fuels, its complex extraction presents many risk factors to public health and the environment.[1]

This introduction to shale gas summarizes the extraction process, describes some of the environmental and public health risks involved, and suggests some next steps for civic engagement on the issues. It does not address issues of economics due to their complexity and rapid evolution. Also, please note that this document is intended for an audience in the Marcellus Shale region, but it contains general information that is applicable to any shale play.

U.S. Shale Gas Deposits[2]

Source: DOE Office of Fossil Energy

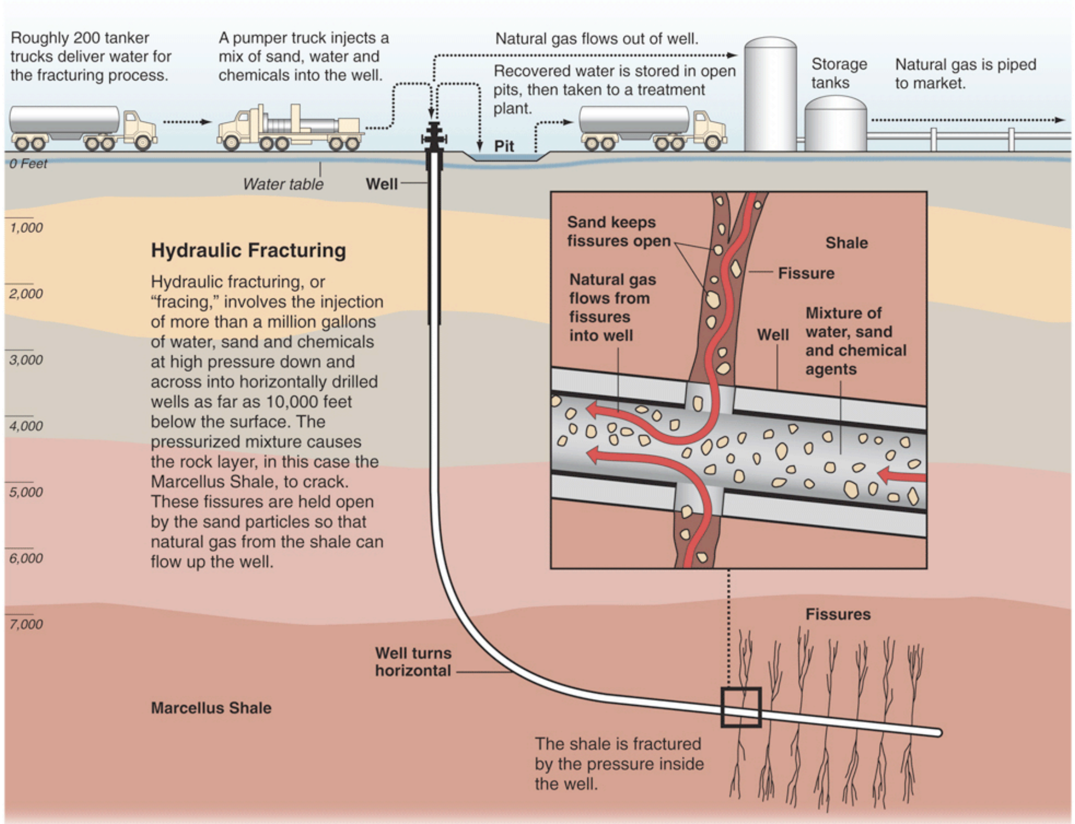


Glossary of Terms[5]

Compressor stations	Where gas from the well is piped for pretreatment and compressed for shipment through pipelines. Emissions from natural gas or diesel engines that power the compressors, fugitive emissions from compression equipment, pipes and tanks are possible, as is noise pollution.
Condensate tanks	Brine and volatile organic compounds from gas drilling are piped to these collection tanks, where they are stored until pickup. If the gas is "wet," it contains such toxic compounds as benzene, toluene and xylenes. Air in the tanks is often vented to the atmosphere during the filling process, thereby contributing to air pollution.
Dry gas	A purer form of natural gas found in the northeastern part of Pennsylvania.
Flaring	The burning of gas, sometimes a hundred feet above a well head, that is done toward the end of the well development process. Emissions are created from burning of the gas.
Flowback, drilling wastewater, produced or stimulated fluid	All names for the solution -- estimated at 15 percent to 50 percent of the total water mixture used -- that is returned to the surface following fracking. Along with the man-made chemicals used in fracking, it contains dissolved contaminants picked up from the shale, including chlorides, heavy metals, organics, uranium and radon.
Fracking fluid	This is the water, sand and chemical mixture that is pumped a mile or more underground under high pressure to crack the shale and prop open the fissures created. Each well uses about 4 million gallons.
Slickwater Hydraulic fracturing or "fracking"	A high-pressure process that pumps water mixed with sand and chemicals into the shale formation to crack the rock, prop it apart and release the gas. “Slickwater” refers to the chemical additives in the process that facilitate more thorough well development.
Mineral estate	The ownership of minerals underground. It can include the natural gas in the Marcellus Shale formation. Such an estate can be "severed" or “split” from the surface estate and is the dominant estate. That means mineral estate owners have the right to develop or extract their holdings and must be given reasonable access to them.
Off-gassing	The gases that escape through vents and valves from condensate tanks. The escaping gases contain volatile organic compounds, and other carcinogenic gases.
Pad	All well operations need a level, flat area to conduct drilling. Most Marcellus Shale pads are for multiple wells and are typically about 4 acres in size.
Play	This refers either to the area or region encompassing a gas-containing formation, as in the "Marcellus Shale gas play," or the activities associated with development of the area.
Total Dissolved Solids (TDS)	The dry weight of dissolved material, organic and inorganic, contained in water and usually expressed in parts per million. Produced water typically contains high levels of TDS from the shale formation and additives in the fracturing fluid. (e.g. - bromide, chloride, strontium, and barium, arsenic, and uranium)[6]
Wet gas	Natural gas found in Western PA commingled with hydrocarbons that contain condensable or liquid compounds, like propane and butane, that are heavier than ethane and must be removed before transportation using condensate tanks. Companies can earn additional revenues by separating and selling the compounds extracted from wet gas.

Shale Gas Extraction[4]

Source: ProPublica



Graphic by Al Granberg

The Development Process

Shale gas extraction is a long and involved process that can last for several years per well. The following steps and their descriptions are from *Modern Shale Gas Development in the United States: A Primer*[1] with additional information from other sources as cited.

Step 1 - Mineral Leasing [Weeks to Years]

Companies negotiate a private contract or lease that allows mineral development and compensates the mineral owners. Lease terms vary and can contain stipulations or mitigation measures pertinent to protect various resources. A "split estate" can occur when the surface rights and mineral rights of a given area are owned by different persons or entities. This can cause conflicts because the mineral owner is entitled to build the surface infrastructure necessary to access their holdings (e.g. - well pad, roads, pipelines) without the surface owner's consent.

Step 2 - Permits [Weeks to Months]

The operator must obtain a permit authorizing the drilling of a new well. Surveys, drilling plans, and other technical information are frequently required for a permit application. The approved permit may require site specific environmental protection measures. Other permits such as water withdrawal or waste water management permits may also be required.

Step 3 - Road and Pad Construction [Days to Weeks]

Once permits are received, roads are constructed to access the wellsite. Well pads are constructed to safely locate the drilling rig and associated equipment during the drilling process. Pits may be excavated to contain pre and post drilling fluids.

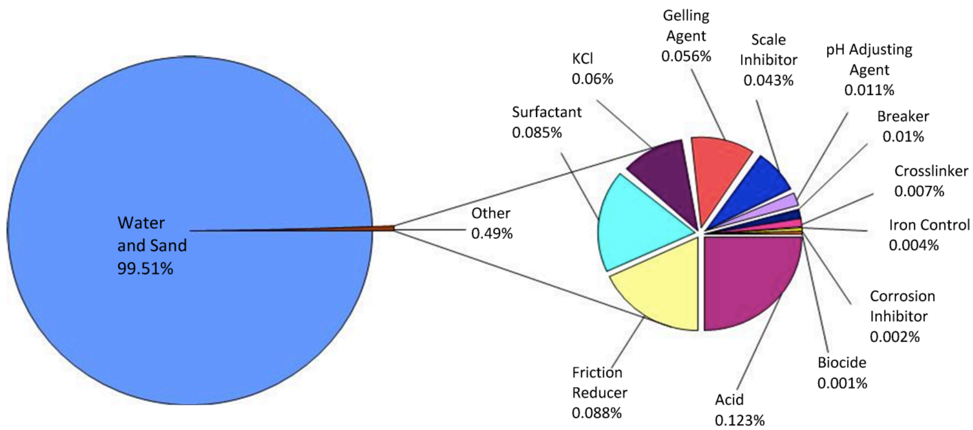
Step 4 - Drilling and Completion [Weeks to Months]

A drilling rig drills a vertical well about 6,000 feet deep (about as deep as the deepest part of the Grand Canyon) and multiple layers of steel pipe (called casing) are put into the hole and cemented in place to protect fresh water formations. Contamination of the fresh water aquifer can occur if the casing is improperly installed or if it degrades over the life of the well.

When the well bore is in proximity of gas-bearing shale it begins to gradually turn horizontally at the "kickoff point". The lateral length of the well within the gas shale may be anywhere from 1,000 to 5,000 feet. This step consumes between 60 thousand and 1 million gallons of water (about 80,000 gallons in the Marcellus Shale).

Volumetric Composition of a Fracture Fluid[1]

Source: ALL Consulting based on data from a fracture operation in the Fayetteville



Step 5 - Hydraulic Fracturing ("Fracking") [Hours to Days]

The horizontal well is initially fractured with a perforating gun lowered into the well that uses a controlled explosion to create fissures in the rock. Then, a specially designed fracturing fluid that varies in composition depending on a region's geology is pumped under high pressure into the shale formation. The fluid consists primarily of water along with a proppant (usually sand) and about two percent or less of chemical additives (see figure above). This process deepens and expands the initial fractures and then props them open with the sand, which allows the natural gas to flow into the well. Because adequate pressure is difficult to maintain for the entire length of the well, hydraulic fracture treatments of horizontal shale gas wells are usually performed by isolating smaller portions of the lateral into two or more sequential stages using well plugs. The fracking process is repeated for about 17 sub-stages within each stage, and each sub-stage uses a different water/additive volume and ratio. This step consumes between two and six million gallons of water, but advancements in produced water recycling could reduce the volume of fresh water needed. A typical fracking operation in the Marcellus Shale consumes about 3.8 million gallons water and 1.9 million gallons of chemical additives assuming concentrations similar to those in the figure above. This water can be trucked in or piped directly from surface water bodies, groundwater, municipal potable water supplies, or reused water from previous fracks.[2]

After a hydraulic fracture treatment, when the pumping pressure has been relieved from the well, the water-based fracturing fluid, mixed with any natural formation water present, begins to flow back through the well casing to the wellhead where it is collected in tanks or open-air containment ponds before recycling or treatment. This produced water may also contain dissolved constituents from the formation itself. The dissolved constituents are naturally occurring compounds and may vary from one shale play to the next or even by area within a shale play. Initial produced water can vary from fresh (<5,000 ppm Total Dissolved Solids (TDS)) to varying degrees of saline (5,000 ppm to 100,000 ppm TDS or higher). The majority of fracturing fluid is recovered in a matter of several hours to a couple of weeks. In various basins and shale gas plays, the volume of produced water may account for less than 30% to more than 70% of the original fracture fluid volume. In some cases, flow back of fracturing fluid in produced water can continue for several months after gas production has begun. The TDS content of produced water increases as it remains underground, and some recovered fluid can be ten times saltier than sea water.[6] Unrecovered fluids, if any, will remain contained within the target formations.

Step 6 - Production and Transportation [Years]

After the hydraulic fracturing process is complete and the plugs are removed, the gas is brought up the well, treated to a useable condition through industrial processing, and sent to market through underground pipelines. Gas may need to be vented or flared during completion, if a well needs to be tested, or if the pipeline is not ready. This causes polluting emissions unless the gas is captured or combusted in a closed and carefully controlled stack.

The U.S. natural gas transportation system is a very complex network of interstate, intrastate, and gathering pipelines. Gas is collected at the wellhead, separated in condensate tanks if wet, pressurized in compressor stations, and sent to be treated or "polished" before entering the main distribution network or storage. There are multiple opportunities for emissions of methane throughout the collection and transportation process.[7,8]

Step 7 - Workovers [Days to Weeks]

Gas production usually declines over the years. Operators may perform a workover which is an operation to clean, repair, and maintain the well for the purposes of increasing or restoring production. This may include more hydraulic fracturing to re-stimulate the well. Multiple workovers may be performed over the life of a well.

Step 8 - Plugging and Abandonment/Reclamation [Years]

Once a well reaches its economic limit, it is plugged and abandoned according to State standards. The disturbed areas, including well pads and access roads, are reclaimed back to the native vegetation and contours or to conditions requested by the surface owner.

Water Contamination

Wastewater Management

Although treatment technology is improving, produced water poses several management problems because very few commercial industrial wastewater treatment facilities and no municipal treatment plants can completely remove TDS. Some drilling companies effectively seal their produced water in injection wells where it cannot escape to damage surface water, but very few of these wells exist in the Marcellus Shale play. Therefore, produced water is often times incompletely treated, diluted, and discharged into rivers and streams under special discharge permits that dictate the acceptable concentration of TDS per volume of water depending on state regulations. The introduction of TDS and untreated chemicals into fresh water supplies poses a risk to public health and natural ecosystems despite increasingly strict regulations. Known carcinogens such as benzene and byproducts caused by the reaction between bromide and chlorine during water treatment are of particular concern, and they have been detected at unsafe levels in Pennsylvania downstream from at least one water treatment facility processing produced water.[9] Many public drinking water facilities have begun using different processes to reduce these reactions, but the newer methods can cause lead to leach from older pipes and fittings.[6]

Accidental spills, unregulated dumping (may be cheaper than proper disposal regardless of fines), and other regulatory violations regarding produced water can also contribute to water contamination. In Pennsylvania, the DEP has cited the industry with over 1,600 violations over the past 2.5 years, and many of these were for improperly constructed wastewater impoundments, chemical spills, and surface contamination.[6]

Inadequate Well Casing

Gas or frack fluid migration from deep shale to the fresh water aquifer during or after fracking is highly unlikely due to depth and the seal created by intervening rock formations. However, water contamination due to inadequate well casing is more plausible, although rare. If the thick steel and cement casing between the bore hole and the water aquifer is improperly installed, damaged during drilling, or degrades over time, then fluid and/or gas can escape from the well and enter the aquifer. This is very dangerous because these contaminants can appear in well water and increase the risk of gas explosions, cancer, or other health problems including livestock poisoning. It should be noted that biogenic gas (caused by living organisms and organic decay) can also migrate into water wells naturally or due to agitation from a nearby drilling operation. Water wells should be designed to block or filter biogenic gas, but older wells may not do so adequately.[6,10]

Air Pollution

Natural gas extraction deteriorates air quality because of gas and volatile organic compound (VOC) emissions at almost every stage including during drilling, completion, venting, flaring, condensation, compression, throughout the transportation network, and from increased vehicular traffic. Accidental well blowouts also cause a substantial amount of air pollution until they are capped. Although methane itself is not harmful to public health unless it displaces enough oxygen to cause asphyxiation, the VOCs present in shale gas and frack fluid can be highly toxic to humans, livestock, and wildlife. Furthermore, a study recently released by Cornell University professors on the global warming potential of shale gas concludes that, "The [greenhouse gas] footprint for shale gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so over 20 years. Compared to coal, the footprint of shale gas is at least 20% greater and perhaps more than twice as great on the 20-year horizon and is comparable when compared over 100 years."[11]

Ecological Impact of Land Use

Although technological advances such as horizontal drilling continue to reduce the land disturbance of shale gas extraction, its potential affect on natural habitats and ecosystems is still unclear and requires close attention and regulation. Complete development of a 640-acre section of land could require 16 vertical wells on separate pads spaced 40 acres apart or 4 horizontal wells on the same multi-well pad. The more common 4-well horizontal pad with roads and utilities would disturb an estimated total of 7.4 acres, while the 16 vertical wells would disturb approximately 77 acres. Some of this land can be remediated, but full restoration is unlikely after 20+ years of activity. Surface infrastructure that disregards effects on the surrounding environment could cause forest fragmentation and irreparable damages to the delicate ecosystems that all life forms rely on. This is true for almost all energy production including coal, oil, wind, and solar generation. Shale gas extraction is not exempt from this, but it has less affect than most resources since the bulk of activity during shale gas extraction and transportation occurs deep underground.[1,8,10]

Well Pad and Drilling Rig[1]

Source: www.wvsoro.org

What do the people need?

A sustainable energy portfolio that doesn't infringe on our rights as humans to breathable air, drinkable water, and livable land! Natural gas could serve as a temporary alternative as the United States transitions to a renewable energy portfolio, but only if it is responsibly developed under strict regulation while using sound science as a guide.

More Information and Studies

There is a constant need for more information on the risks associated with shale gas extraction because development is progressing and evolving rapidly. This information needs come from trusted peer-reviewed scientific publications without direct influence from industry, and all interested parties need to agree to respect the results. Furthermore, results need to be effectively communicated to the public before they lease land so that they understand the associated risks.

Strict and Effective Regulation

The people must continually push government to impose stronger regulations on the gas industry that are based on sound science that evolves with changing risk factors. For example:

- Mandate industry-funded water testing before and after drilling by credible third-party companies
- Higher bonds on wells
- Significant fines and penalties for violations
- Better drinking water standards imposed on municipal water handling
- Make EPA's Natural Gas STAR program mandatory
- Improve well casing standards
- Set more strict standards for accident response

Regulation should be the government's only involvement with the industry because government exists to protect the people and not corporate interest.

Passage of the FRAC Act

The Fracturing Responsibility and Awareness of Chemicals Act, introduced by Senator Bob Casey from PA, would require the disclosure of chemicals used by the gas industry in hydraulic fracturing and repeal the exemption for the process in the Safe Drinking Water Act.

Natural Gas as a Transition Fuel

Natural gas is not a sustainable energy resource, but it could help us achieve a cleaner energy future if properly leveraged as a transition technology. The industry should be investing a significant portion of their profits from fossil fuels into research and development of renewable energy technologies and the infrastructure to support them. Furthermore, there needs to be an open dialogue including the public, industry, and government to cooperatively design truly sustainable energy systems that will work for all parties.

A Moratorium

A moratorium should be imposed until more conclusive studies are completed, effective and consistent regulations based on those studies are in place, and we have a tangible plan for incorporating natural gas into a sustainable energy portfolio.

To Conserve Energy

This is the most important action to take on an individual basis, and it's the easiest. Please reduce your energy usage whenever possible, and help your friends do the same!

TAKE ACTION!

You are affected by shale gas extraction whether you live near a developing play or not, so become educated and take action!

WHAT YOU CAN DO

1. Use this packet and the cited resources to educate yourself, your family, and your friends. Don't forget to stay updated with current events and developments!

2. Research to find out if you live near an active shale gas play, how your state regulates it, and how it might be affecting you.

3. Join or start an organization to build a strong base of constituents that can lobby legislators for stronger regulations and demand that the industry be kept in check.

4. Write letters to newspapers and legislators, call your representative about important legislative decisions, collect petition signatures, and be creative!

Resources

Organizations

Clean Water Action [http://www.cleanwateraction.org/pa]
Energy Action Coalition [http://www.energyactioncoalition.org]
Group Against Smog and Pollution (GASP) [http://gasp-pgh.org/]
Keystone Environmental Youth Coalition (KEY) [http://keycoalition.wordpress.com/]
Marcellus Protest [http://www.marcellusprotest.org]
PennEnvironment [http://www.pennenvironment.org/clean-water/keep-our-water-safe]
Pittsburgh Student Environmental Coalition (PSEC) [http://PittsburghSEC.wordpress.com]
Shadbush Collective [http://www.shadbushcollective.org]

Publications and Tools

FracTracker [http://www.fractracker.org]
PG Pipeline [http://shale.sites.post-gazette.com/]
ProPublica [http://www.propublica.org/series/buried-secrets-gas-drillings-environmental-threat]
USDOE Energy Information Administration [http://www.eia.doe.gov/naturalgas/]

Studies and Documents

Gasland The Movie [http://www.gaslandthemovie.com/]
Greenhouse-Gas Footprint of Natural Gas from Shale Formations [http://thehill.com/images/stories/blogs/energy/howarth.pdf]
Nine Challenges of Alternative Energy [http://www.postcarbon.org/report/127153-energy-nine-challenges-of-alternative-energy]
U.S. Shale Gas Primer [http://www.netl.doe.gov/technologies/oil-gas/publications/epreports/shale_gas_primer_2009.pdf]
Water Management in Marcellus Shale [http://www.evs.anl.gov/pub/doc/Water%20Mgmt%20in%20Marcellus-final-jul10.pdf]

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