Marcellus Shale: Natural Gas Energy

Lesson Plans and Resource Guide

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www.efmr.org

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Marcellus Shale: Natural Gas Energy

Background Information

Introduction

The extraction of natural gas in Pennsylvania's Marcellus Shale formation is running at a fast pace. New data and the recent realization of this vast energy resource have escalated the gas drilling industry in Pennsylvania. In response, drilling techniques have caused much public concern.

The dark sedimentary rock, named after a visible dark shale outcrop in the town of Marcellus, New York, underlies much of the Appalachian Basin. It covers more than two-thirds of Pennsylvania and has a depth from surface level to more than a mile below ground. The location is close to metropolitan areas on the east coast, providing an ideal market. Marcellus Shale is an exceptional energy resource for natural gas because it is rich in organic content, signifying substantial gas production. An estimate for the amount of natural gas that can be captured from Marcellus Shale ranges from 50 to 500 trillion cubic feet. PA currently has an annual natural gas consumption rate of 750 million cubic feet (EIA: Official Statistics). This reservoir could supply Pennsylvania with gas energy for seemingly endless years and the U.S. for numerous years. A recent study states: "Fully developed, the Marcellus Shale has the potential to be the second largest natural gas field in the world…" (*The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update, Pennsylvania State University, 5/24/2010).*

New extraction technologies have also made the natural gas more accessible. The total permits issued for Marcellus Shale natural gas drilling in 2010 was approximately 3,300 (DEP). As a comparison, in 2005 only 4 drilling permits were issued. New data on the natural gas reserves and new technologies have made Marcellus Shale a prime energy resource. There has been substantial concern and opposition to drilling procedures with regard to environmental, health and safety issues, including water contamination. The industry's hydraulic fracturing technique and its effect on ground and surface water is a major contention. Tapping the rich natural gas reserves in Marcellus Shale poses a question and challenge: can this immense energy resource be extracted while protecting our water resources and natural environments?

Shale and Natural Gas Basics

Shale, sometimes called mudstone, is a sedimentary rock. It forms in thick slab layers from accumulated deposits of sand, clay, shells and often organic matter in bodies of water. Shale is finely grained and can act as a barrier for trapping

petroleum and natural gas reservoirs. In addition, the shale rock itself can contain natural gas, as in Marcellus Shale.

Natural gas forms over millions of years from the decomposition, deep burial, intense pressure and heat of organic (plant and animal) matter. Natural gas is a mixture of hydrocarbons, primarily methane. The fine grained Marcellus Shale is high in organic matter, making it high in hydrocarbons. Thus, this dark-colored rock harbors an abundant amount of natural gas in rock fractures and pore spaces. Marcellus is considered unique because in addition to trapping gases in sealed reservoirs, it contains natural gas within its own matrix.

Natural gas, a nonrenewable fossil fuel, accounts for about 24% of the world's energy and slightly less for U.S. consumption. It is a clean odorless substance that is extremely volatile. Natural gas is used as a fuel for heating, cooking, electricity generation, industry and in the production of synthetic materials. Although the burning of natural gas produces carbon dioxide, it is considered a much cleaner fossil fuel than coal or petroleum.

Well Drilling and Fracturing Techniques

The extraction of natural gas in Marcellus Shale uses vertical and horizontal drilling. A vertical well is drilled to a specified depth then a directional tool is used to gradually turn the drill horizontally. The horizontal well bore may be more than 5,000 ft. long. Steel casings and cement are inserted to support and protect well bores. Horizontal drilling allows for numerous attempts to tap natural gas reservoirs.

A technique called hydraulic fracturing is used to extract gas more efficiently. The well bore casings and cement are perforated to begin this process. Then water, sand and chemicals are forced into the shale at high pressures to break open fractures and tap natural gas. The gas flows into the well bore and up to the surface. A single hydro-fracturing job uses approximately 3-5 million gallons of water. The water used becomes waste and is reused in fracturing or sent to a treatment facility. Drilling wells can drain natural gas from acres around it. The construction of major pipelines is currently being debated.

Most well sites are set up in rural areas and leases are drawn with landowners for a five year period. Initially, the standard lease rate was $25 an acre with a royalty of 12.5%. As the drilling escalated, signing bonuses increased to over $5,000 an acre plus the established royalties. The natural gas industry is hoping to secure gas extraction rights from surrounding landowners who are not in a lease agreement.

Environmental Impacts

The development of the Marcellus Shale well drilling industry has environmental groups and public citizens concerned. The impact on water resources, including private well waters, leads the list. Approximately 20,000 square miles of the Susquehanna River Basin underlies the Marcellus Shale formation. Millions of gallons of water used in hydraulic fracturing (3-5 million per well) are withdrawn from the basin and 60% or more may be reused in fracturing with the remainder being contaminated water. The extracted fluids and rock contains chemicals and may contain radioactive uranium. Waste fluids are stored in steel tanks and temporary waste pits and sent to authorized waste water treatment facilities. The risks of elevated uranium levels and chemicals reaching water supplies have caused substantial concern. The Pennsylvania Department of Environmental Protection, in cooperation with the Susquehanna River Basin and the Delaware River Basin, has created guidelines and rules for the withdrawal, usage, treatment and disposal of waste water.

Other concerns include the impact on land such as acres of clear cutting, road damage, erosion and habitat destruction. Land sites are to be restored within nine months of plugging a well. Some drilling (exploration/production) companies are more diligent than others and exceed requirements with regard to environmental mandates. Environmental impact studies and the debate over Marcellus Shale natural gas development continues.

Marcellus Shale: Natural Gas Energy
Elementary Lesson Plans

National Science Education Content Standards: F
PA Academic Standards: 3.8, 4.2
Subject Areas: Science, Social Studies, Language Arts, Civics

Unit Objectives
Students will:

1. Classify Marcellus Shale as a sedimentary rock with organic content.
2. Recognize natural gas formed in Marcellus Shale.
3. Define natural gas as a nonrenewable energy resource.
4. Locate the Marcellus Shale Formation on a map.
5. Identify vertical and horizontal drilling techniques.
6. Identify the environmental impacts of natural gas drilling.

Activity 1: Shale: A Sedimentary Rock

Objective
Students will recognize how sedimentary rocks are formed.
Students will identify shale as a sedimentary rock.
Students will define the term, “organic”.

Materials
“Background Information”, sea shells, rolling pin (optional), large clear jar with lid, sand, pebbles, dictionary or internet access, pie pan, plant parts, Plaster of Paris, shale rock or a picture of, measuring cup

Procedure
Introduce the word “sediment” (write on board) and have students define using resource book if necessary: sediment is solid material that settles to the bottom of a liquid. Relate to sedimentary rocks which form by the accumulated deposits of sand, clay, shells and often plant and animal (organic) matter in bodies of water.

Demonstrate how sedimentary rocks are formed:
Have volunteers put approx. 2 cups of shells (may crush first with rolling pin), sand and pebbles in large jar. Add approximately 4 cups (approx. 1 liter) of water, stir and shake.

Have students observe and describe how the materials mix together while the heavier solid material sinks.

Next, have student add plant matter (approx. 2 oz. or 60 grams) and swirl jar. Describe how plant (and animal) matter may mix with nonliving materials to form sedimentary rock. Introduce the term "organic" and have students define using resource: matter derived from the remains of plants and/or animals.

Add Plaster of Paris to jar for best results: approximately 1 part plaster to 5 parts water/sand/plant mixture. Mix thoroughly. Pour sediment mixture onto pie pan, filling it halfway (discard extra).

Set in dry, warm area and allow to dry for several days (if pressed for time, the water may be poured off after several hours). Solid material will harden on bottom of pan. Have students observe how the water evaporates leaving the sediment behind. Some of the matter will stick together to demonstrate how sedimentary rocks can form (this will resemble conglomerate). Explain that actual sedimentary rocks may take thousands to millions of years to form.

Display piece of shale rock or picture and describe it as one kind of sedimentary rock. Have students observe the fine grains in shale compared to the pie pan model. Discuss how matter can change over time (e.g.: pressure, heat, weathering) with regard to physical characteristics.

Evaluation

Students draw illustrations and describe how the sedimentary rock, shale, is formed.

Advanced and Enrichment

Complete Lesson #1, Middle School Lessons.

Activity 2: Organic Matter and Natural Gas

Objectives

Students will recognize that natural gas is a product of decomposing organic matter**.**

Students will recognize that sedimentary rock (shale) may contain natural gas.

Materials

two plastic soda bottles (2 liter size) or ½ gallon plastic milk containers, sand, soil, 2 extra large balloons (equal in size and color), plant pieces, salad mix in sealed plastic bags, "Background Information"

Procedure

Review the term, “organic”: matter derived from plants and/or animals. Introduce “natural gas” as an energy resource that forms over millions of years from the decomposition, deep burial, intense pressure and heat of organic matter. Discuss how the sedimentary rock, shale, may contain natural gas.

Demonstrate how natural gas is formed:
Cover the top of one empty bottle with a balloon. This container will be the “control” of the experiment.

Fill second bottle 1/3 with torn plant pieces. Drop sand and soil on top of plant pieces to create a thin layer. Cover top with balloon. Set both bottles in a warm location for 1 week or more. Have students observe and compare any gas collection in balloons. Discuss observations and ideas.

Relate activity to how natural gas is formed: organic matter decomposes and is buried deep in mud or sand. Intense heat and pressure over much time causes gas (primarily, methane) to form.

* Alternate Demonstration:
Simply set a store bought salad mix (in the original sealed plastic) in a warm location. Have students observe the gas accumulation in the bag over several weeks. (As the plant matter decomposes, gas accumulates in bag.)

Evaluation

Students describe experiment with drawings: comparing the “control” bottle with the other containing plant matter.
Students relate experiment to how natural gas is formed.

Activity 3: Natural Gas in Marcellus Shale

Objectives

Students will describe natural gas as a nonrenewable energy resource.
Students will identify the Marcellus Shale formation as being a substantial source of natural gas.

Materials

internet access, drawing paper, pictures of natural gas uses (if available), map showing Marcellus Shale formation in PA, simple map of PA.

Procedure

Open discussion by asking who has a gas stove or gas barbeque grill at home. Discuss natural gas as a kind of fuel which has many uses: heating, cooking, electricity production and in manufacturing products. Focus on natural gas for home heating and discuss how the gas gets to our home through pipes. Describe natural

gas as being colorless and odorless. Explain that a chemical (mercaptan) is added to gas which creates an odor. This allows for a dangerous gas leak to be detected.

Discuss natural gas as a nonrenewable energy resource which can be depleted and compare to wind or solar energy which are limitless. Relate to a propane gas bottle that runs out of gas.

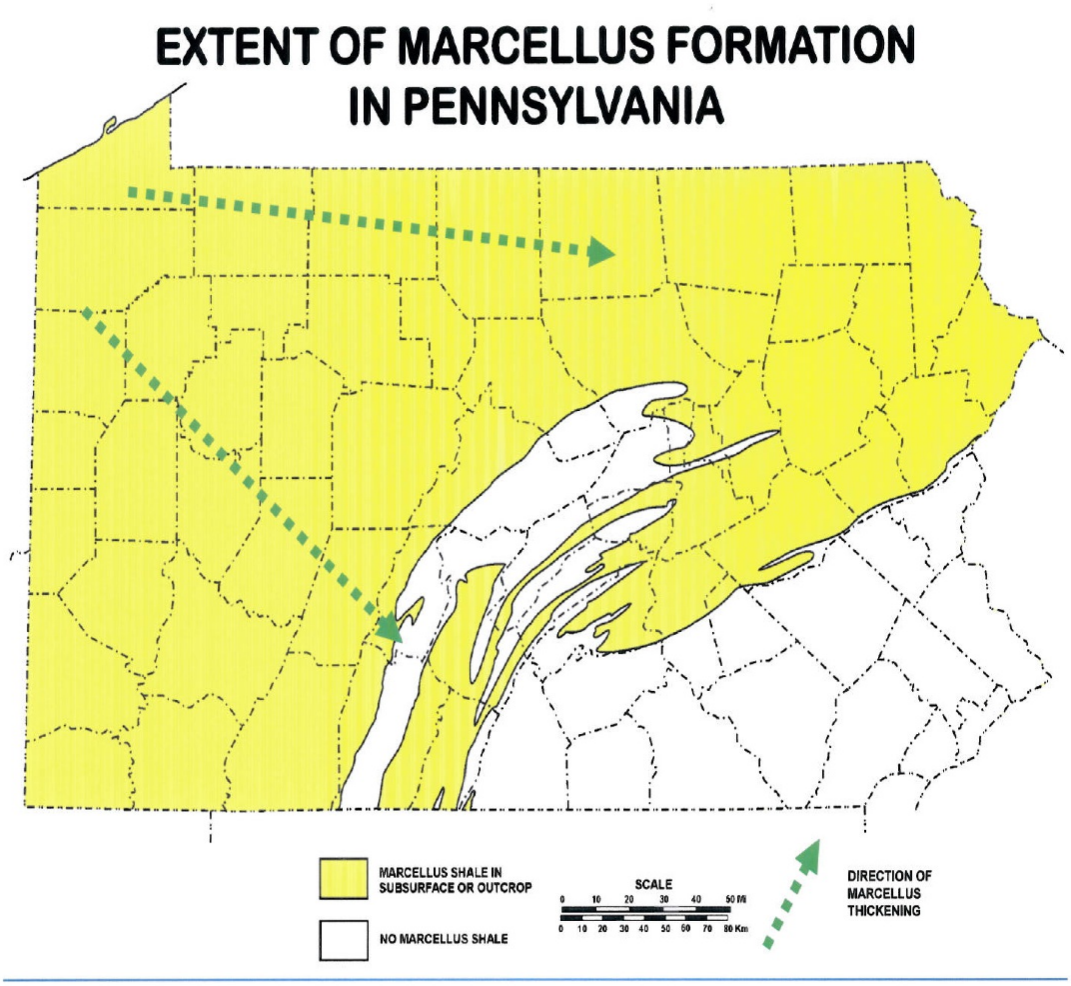
Explain that there are huge deposits of natural gas underground in shale rock formations (may relate to Lesson #1 and #2).

Introduce Marcellus Shale as being a rock formation that contains massive amounts of natural gas. Explain that this shale was named after a town in New York where an outcrop of Marcellus Shale is visible. Discuss the significance of this abundant energy resource.

Have students locate the Marcellus Shale Formation on corresponding map:
Extent of Marcellus Formation in Pennsylvania (attached)
Next, have them relocate on simple map of PA.

Assign research and presentations or report on the Marcellus Shale Formation. Students may select topic of focus. List websites below for research data:

www.srbc.net	Susquehanna River Basin Commission
www.depweb.state.pa.us	Pennsylvania Department of Environmental Protection
http://geology.com	Geology.Com
www.dcnr.state.pa.us	Pennsylvania Department of Conservation and Natural Resources
www.eia.doe.gov	Energy Information Administration



Courtesy of Pennsylvania Department of Conservation and Natural Resources:
PA Geological Survey
The Marcellus Shale Play in Pennsylvania by John A. Harper and Jaime Kostelnik

Evaluation

Students research, list and draw examples of natural gas uses.

Students circle the Marcellus Shale Formation on a map and state its significance as a natural gas reservoir.

Activity 4: Drilling for Natural Gas (Upper Elementary)

Objectives

Students will compare vertical and horizontal drilling.

Students will determine that horizontal drilling is a technique used to increase natural gas recovery.

Materials

"Background Information", diagram: *Marcellus Shale Drill and Completion,* internet access (optional)

Procedure

Discuss basic steps for locating a well site with high potential for recovering natural gas**:**

- Seismic surveys collect data from certain vibrating materials underground (to signify deposits).

-Collect and investigate rock samples for organic content (hydrocarbons).

-Well pad set up (covers 2-3 acres).

-Well bore (hole) dug to specific depth (may be thousands of ft.).

-A directional tool is used to gradually turn the well bore horizontally.

-Steel casings and cement support and protect drill holes.

-Extraction is done at several hundred feet intervals.

-Natural gas is recovered and passes through well pipe to connecting pipes for storage or transporting.

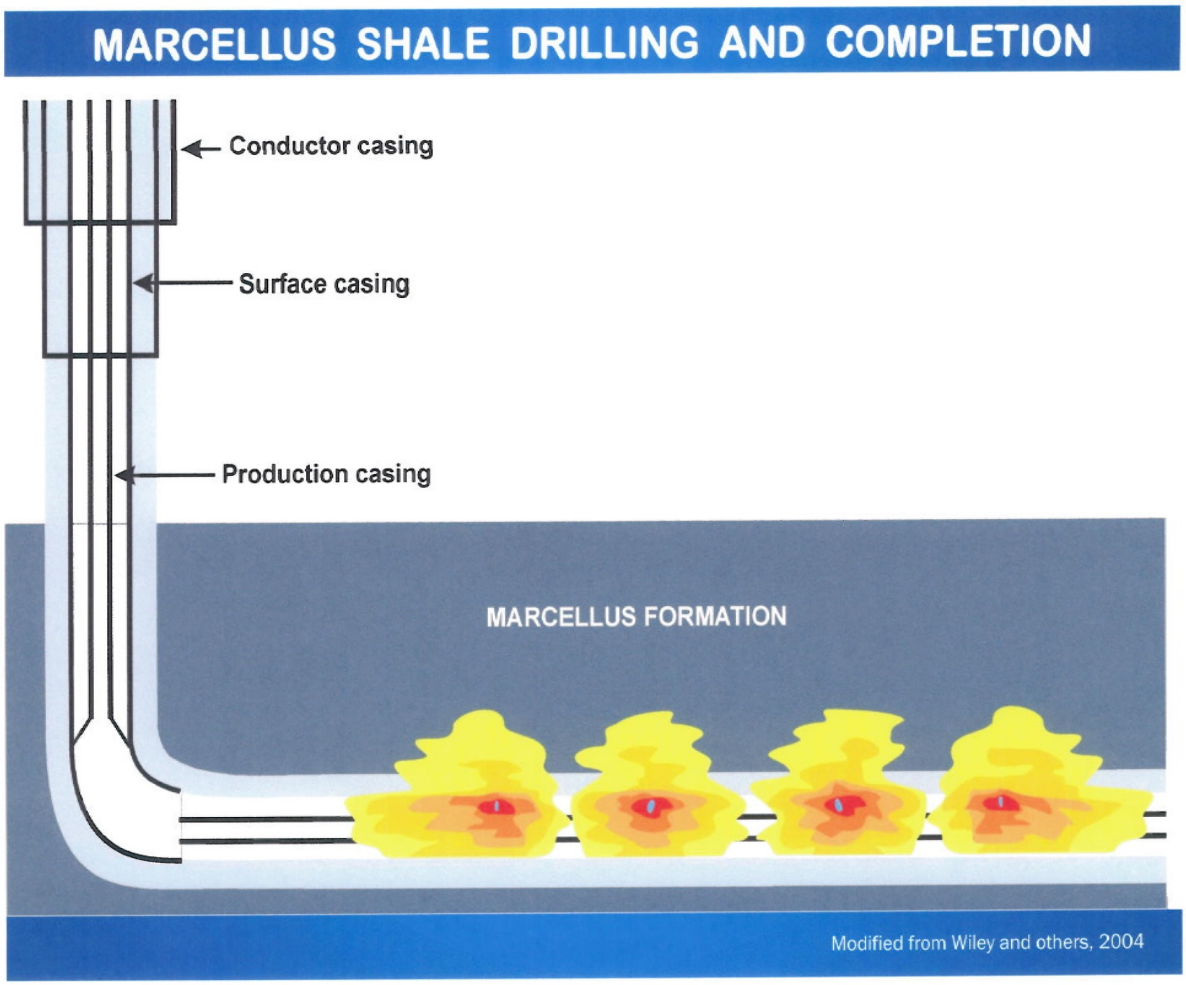
*See Middle School Lesson #3 for more advanced explanation on drilling and extraction of natural gas.

Display diagram of vertical and horizontal drilling. Review that horizontal drilling covers much larger areas underground and intersects many more fractures, joints and pores. Compare demonstration to diagram*: Marcellus Shale Drilling and Completion.*

If internet access is available, view and discuss:

The Marcellus Shale Play in Pennsylvania

www.dcnr.state.pa.us/topogeo/oilandgas/Marcellus.pdf



DCNR, Ibid.

*The actual change from vertical to horizontal drilling is more gradual than depicted in diagram.

Evaluation

Students complete research and diagrams comparing vertical and horizontal drilling techniques. They should include an explanation of how horizontal drilling recovers more natural gas.

Enrichment

Assign research on the hydraulic fracturing drilling technique. (See Middle School Lessons.)

Activity 5: Environmental Impacts

Objectives

Students will research, identify and communicate the environmental impacts of Marcellus Shale drilling.

* Hydraulic fracturing may be included (see Middle School Lesson #3).

Materials

"Background Information", internet access, "Website Resources"

www.depweb.state.pa.us	PA Department of Environmental Protection
www.eia.doe.gov	Energy Information Administration
http://water.usgs.gov	U.S. Geological Survey
www.dcnr.state.pa.us	Pennsylvania Department of Conservation and Natural Resources

Procedure

Review vertical and horizontal drilling techniques.

Facilitate class discussion on the possible environmental impacts of vertical and horizontal drilling: deforestation, impacts on roads, erosion, water supplies (ground and surface), water contamination, destruction of natural habitats, air pollution, etc.

As a class, if internet access is available, use above websites and "Website Resources" to list additional impacts. (Use a variety of resources with different viewpoints.) Divide class into groups to further discuss environmental issues and personal views.

Evaluation

Students work in groups to research the environmental concerns or impacts of Marcellus Shale natural gas drilling. They should use a variety of resources with different viewpoints. Have each group present their findings with a creative class presentation (with notes of each participant's contribution).

Marcellus Shale: Natural Gas Energy
Middle School Lesson Plans

National Education Content Standard: F
PA Academic Standards: 3.8, 4.2
Subject Areas: Science, Social Studies, Language Arts, Civics

Unit Objectives

Students will:

1. Research and describe the Marcellus Shale Formation as a major natural gas resource.
2. Create a timeline of the natural gas industry in Pennsylvania.
3. Demonstrate and explain natural gas excavating techniques.
4. List economic and environmental impacts of the Marcellus Shale Drilling.

Activity 1: Marcellus Shale: A Major Energy Resource

Objectives

Students will identify the location of the Marcellus Shale Formation.

Students will identify the special characteristics of Marcellus Shale which make it a valuable natural gas energy resource.

Students will research and determine the potential energy output of Marcellus Shale.

Materials

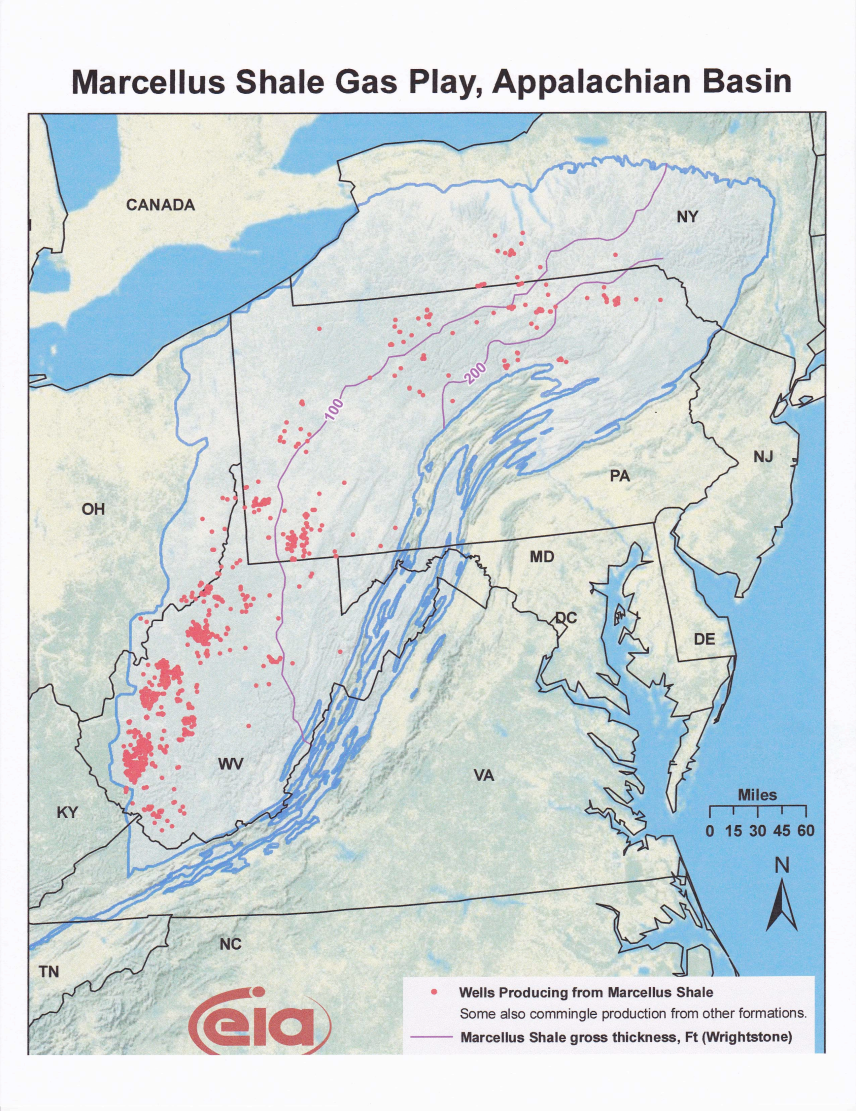
"Background Information", internet access, map of Marcellus Shale Formation (see Elem. Lesson # 3)

Procedure

Review "Background information". List the basic characteristics of Marcellus Shale:

-Dark in color
-High in organic content
-Contains large reserves of natural gas
-Also contains iron, uranium and pyrite
-Natural gas is contained within rock pores and fractures
-Rock splits along bedding planes
-Formation covers 2/3 of Pennsylvania

Have students locate the shale formation on PA maps (see elementary) and surrounding areas and states. See *Marcellus Gas Play, Appalachian Basin* map:



*It is located throughout the Allegheny Plateau region of Appalachian Basin in the states of Pennsylvania, New York, Ohio, Maryland, West Virginia and Virginia.

Have students research the extent of the Marcellus Shale formation and potential gas energy production estimates in region and PA specifically. See websites:

www.eia.doe.gov	Energy Information Administration
www.usgs.gov	U.S. Geological Survey
www.dcnr.state.pa.us	Pennsylvania Department of Conservation and Natural Resources

Evaluation

Students research the location and energy potential of Marcellus Shale Formation.

Activity 2: History of Natural Gas Drilling and "The Marcellus Play"

Objectives

Students will research and summarize major developments in the history of natural gas drilling in Pennsylvania.

Students will recognize the "Marcellus Play" as a term for recent discoveries and production of natural gas in PA.

Materials

resource books, internet access, websites:

www.dcnr.state.pa.us	Pennsylvania Department of Conservation and Natural Resources
http://psu.edu	Pennsylvania State University: College of Earth and Mineral Sciences

Procedure

Introduce major natural gas drilling developments in Pennsylvania:

1830s: Some interest and experiments with drilling.
1859: Nation's first oil well drilled in Titusville, PA also reached natural gas.
1947: First gas and oil lease issued on State Game Lands by DCNR.
1960s: Some hydraulic fracturing used in drilling.
1970s: Eastern Gas Shales Project, drilling developed.
2004: The Marcellus Shale Play began, new drilling techniques used.
2007: Penn State University research estimated Marcellus Shale could produce 50 trillion cubic feet of gas. Drilling escalated.
2010: Estimates for natural gas production of Marcellus Shale reach 500 trillion cubic feet.
Public interest intensifies concerning environmental impacts of drilling.

Have students research the "Marcellus Shale Play" of the Appalachian region. New discoveries, data and reports should be included:

http://extension.psu.edu/naturalgas	Pennsylvania State University
www.dcnr.state.pa.us	Pennsylvania Department of Conservation and Natural Resources

Evaluation

Students research and create a timeline of Pennsylvania's gas drilling developments with a concentration and additional notations on the “Marcellus Shale Play”.

Activity 3: Drilling and Hydraulic Fracturing

Objectives

Students will demonstrate the vertical and horizontal drilling with hydraulic fracturing.

Students will research and explain drilling techniques.

Materials

Marcellus Shale Drilling and Completion diagram, 1¼ inch diameter of PVC (plastic pipe): one piece 18 in. and one 2 ft. in length (pre-drill several 3/8 in. holes, spaced 4 inches apart on one side of longer pipe), 1¼ inch PVC cap, two 1¼ inch couplers, 1¼ inch PVC electrical sweep (elbow pipe), finely grained sand, towels, PVC cement (optional), rubber plugs (3/8-1/2 in.), watering can, long handle spoon, accordion type plunger, plastic lid (with 1inch diameter hole cut in center) outdoor hose set up (optional)

Procedure

Display *Marcellus Shale Drilling and Completion* diagram and review drilling procedures and hydraulic fracturing:

-Well location set up: determined by seismic survey, shale samples, computer data and simulation/modeling.
-Well bore drilled vertically to specific depth: (up to 9,000 ft.):
-Directional tool gradually turns well bore horizontally.
-Horizontal hole is drilled (2,500 ft. to 5,000 ft. or more) and encased in steel and cement.
-End of horizontal well bore is capped with plug and cement.
-Perforation guns (containing bullet-shaped explosive devices) are lowered into the well bore to farthest horizontal section in predetermined positions.
-Perforation guns are fired to create holes in the well casings, cement and surrounding rock. (Penetration into rock averages 12-40 inches depending on explosive charge.)
-Fracturing fluids (containing water, sand and chemicals) are pumped at high pressures through the holes and into rock formation to create fractures and tap natural gas.
-The fractured section is plugged and another interval is then perforated and fractured.
- When all sections are fractured, the plugs separating them are removed.
-The natural gas flows into the well bore and up to the surface where it is stored and/or transported.

Demonstrate vertical and horizontal drilling apparatus with hydraulic fracturing.

-Have student hold the shorter PVC pipe vertically.
-Another student may attach sweep (elbow) connector with coupling and horizontal pipe.
-Place cap on end of horizontal pipe.
-Have students observe the holes in horizontal pipe to illustrate perforations caused by explosive charges of perforating guns.

Indoors:
-Have students describe vertical and horizontal drilling and hydraulic fracturing techniques using model.

Outdoor working model (secure couplings and end cap w/ PVC cement):
-Cover holes with rubber plugs in horizontal pipe.
-Mix gallon of water with ½ cup of fine sand in watering can.
-Pour water mixture into vertical pipe enough to fill halfway.
-Have two students hold model with plugged holes facing away.
-Add additional water to vertical pipe under pressure using a hose, plunger (with precut lid held firmly underneath) or watering can to expel rubber plugs. (May need to retry with loosened plugs.)
-Have students relate to fracturing fluids (which contain chemicals) being pumped through perforated holes and into rock.

Review steps of hydraulic fracturing. Have students summarize and explain the natural gas excavating process.

Evaluation

Students create a model or 3D diagram describing natural gas drilling techniques, including hydraulic fracturing. The cement casings surrounding the well bore should be included.

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Activity 4: Environmental Issues with Natural Gas Drilling

Objectives

Students will use a variety of sources to research the environmental impacts of the Marcellus Shale Industry.

Materials

internet access, “Background Information”, “Website Resources”, personal interviews, newspapers

Procedure

Prior to first day of unit:
Have students collect current events related to Marcellus Shale Natural Gas Drilling and the environment. Sources should include newspapers, magazines and online

news events. Include events related to the industry's compliance or noncompliance of laws and regulations. List any drilling company's practices that may have a positive or negative impact on the environment. Post articles in classroom.

Review news articles, discuss credibility of sources, and find multiple resources with similar news items.

Facilitate a class discussion on some environmental issues concerning natural gas drilling in Marcellus Shale:
-Water usage: 3-5 million gallons used in each hydraulic fracturing job.
-Contaminated water seeping into private wells and water basin:
natural radioactive uranium, brine and chemicals used in hydraulic fracturing
-Land use: destruction of wildlife habitats, excessive road use, erosion
-Air Quality (considered cleanest of fossil fuels)
-Potentially explosive
-Agriculture: impacts on food sources

Have students work in groups to collect substantial information (from a variety of sources) on a particular environmental issue surrounding the natural gas industry.

Evaluation

Students work in groups to complete research (using multiple resources of different viewpoints) and give creative presentations on a specific environmental issue related to the Marcellus Shale natural gas industry.

Enrichment

Students may interview landowners of leasing contracts, neighboring landowners and individuals attending public forums. Marcellus Shale industry personnel may be included.

Marcellus Shale: Natural Gas Energy
High School Lesson Plans

National Education Content Standard: F
PA Academic Standards: 3.8, 4.2., 5.2
Subject Areas: Science, Social Studies, Language Arts, Civics

Unit Objectives

Students will:

1. Identify Marcellus Shale as a valuable natural gas energy resource.
2. Research and determine the energy potential of Marcellus Shale.
3. Explain and demonstrate the hydraulic fracturing technique in natural gas excavating.
4. Research and report on the economics associated with Marcellus Shale Natural Gas Industry in Pennsylvania.
5. Collect and analyze information concerning the environmental issues of the Marcellus Shale Natural Gas Industry.
6. Evaluate practices surrounding the natural gas industry as ethical or unethical.

Activity 1: How Rich is Marcellus Shale?

Objectives

Students will identify Marcellus Shale as a substantial natural gas resource due to high total organic carbon (TOC) values and thermal maturation rates (measured in RO).

Students will research and evaluate the natural gas energy potential of the Marcellus Shale Formation.

Materials

Internet access, resource books, “Background Information”,
Websites:

www.usgs.gov	U.S. Geological Survey
www.fossil.energy.gov	U.S. Department of Energy: Office of Fossil Fuels
www.dcnr.state.pa.us	PA Department of Conservation and Natural Resources
www.extension.psu.edu/naturalgas	Pennsylvania State University: Cooperative Extension

Procedure

Review basic characteristics of Marcellus Shale:

-Devonian-age black shale
-High in organic content and hydrocarbons
-Vertical depths range to over 9,000 feet
-Extends throughout Appalachian Basin (See Map, *Marcellus Gas Play*)
-Natural gas accumulated in fractures and rock pore spaces

Describe Marcellus Shale as an exceptional source rock for natural gas:

-Anoxic or oxygen deficient conditions sustained organic content in sediment and the rock development of Marcellus Shale.
-The total organic carbon (TOC) of specific type (kerogen) in Marcellus Shale is high, indicating a potentially substantial conversion to natural gas.
-The thermal maturation measurement (RO) of this shale also indicates natural gas.

If internet is available, have class view:

Pennsylvania Geology: Geochemistry of the Marcellus Shale- A Primer on Organic Geochemistry by Jaime Kostelnik
PA Geological Survey

www.dcnr.state.pa.us (Search title above)

Have students research websites to collect data on the natural gas potential of the Marcellus Shale Formation and discuss relevance to PA and U.S.

Evaluation

Students summarize the unique characteristics and formation of Marcellus Shale. Then research and report on its natural gas energy potential.

Activity 2: Simulating Drilling and Hydraulic Fracturing

Objective

Students will create a model to demonstrate the hydraulic fracturing technique in Marcellus Shale drilling.

Materials

drilling apparatus model **(**See Middle School Lesson # 3), internet access,
Websites:

www.depweb.state.pa.us PA Department of Environmental Protection
Search: Hydraulic Fracturing Overview

www.usgs.gov U.S. Geological Survey

Procedure

Review that horizontal drilling and hydraulic fracturing are excavating techniques used to increase natural gas recovery. Have class view and discuss diagram*: Marcellus Shale Drilling and Completion.*

Review and have students summarize the steps of vertical and horizontal drilling with hydraulic fracturing technique:

-Well location set up: determined by seismic survey, shale samples, computer data and simulation/modeling.
-Well bore drilled vertically to specific depth: (up to 9,000 ft.):
"…When drilling a well into the Marcellus shale or another oil and gas-bearing formation, an initial string of drive pipe, or conductor pipe, is installed to prevent unconsolidated materials such as soil, sand and gravel from caving in during well drilling. Next, a "surface string", or casing smaller in diameter than the conductor pipe, is installed after drilling below the entire vertical length of fresh groundwater. This casing string must be properly cemented to the surface to protect all potable groundwater sources from production-related activity in the wellbore that is drilled and completed to the target formation. If coal is present, another string of casing will be installed to isolate this interval. An intermediate casing string may also be installed under certain conditions to isolate, stabilize or provide well control to a greater depth than that provided by the surface casing or coal protection casing. Each casing string will be deeper, but successively smaller in diameter…." (*Hydraulic Fracturing Overview,* PA Department of Environmental Protection)
-Directional tool gradually turns well bore horizontally.
-Horizontal hole is drilled (2,500 ft. to 5,000 ft. or more) and encased in steel and cement.
-End of horizontal well bore is capped with cement and plug.
-Perforation guns (containing bullet-shaped explosive devises) are lowered into the well bore to farthest horizontal section in predetermined positions.
-Perforation guns are fired to create holes in the well casings, cement and surrounding rock. (Penetration into rock averages 12-40 inches depending on explosive charge.)
-Fracturing fluids (containing water, sand and chemicals) are pumped at high pressures through the holes and into the rock formation to create fractures and tap natural gas.
-The fractured section is plugged and another interval is then perforated and fractured.
- When all sections are fractured the plugs separating them are removed.
-The natural gas flows into the well bore and up to the surface where it is stored and/or transported.

Allow several volunteers to summarize and demonstrate the basic steps of drilling and hydraulic fracturing using PVC drilling apparatus model or with diagrams.

Evaluation

Students participate in class discussion and demonstrations.

Students work in groups to create a model that illustrates vertical and horizontal drilling and hydraulic fracturing techniques.

Activity 3: Economics and Environmental Ethics

Objectives

Students will research and report on the current and potential economic impacts of the Marcellus Shale Industry.

Students will use a variety of resources to research, analyze and interpret natural gas development practices as ethical or unethical.

Materials

"Background Information", internet access, currents news articles, regional and national newspapers and online, personal interviews

Search: "Marcellus Shale Play" in websites:

Energy Information Administration
www.eia.doe.gov
Pennsylvania Department of Conservation and Natural Resources
www.dcnr.state.pa.us
Pennsylvania State University: Cooperative Extension
http://extension.psu.edu/naturalgas
Responsible Drilling Alliance
www.responsibledrillingalliance.org
U.S. Department of Energy: Office of Fossil Energy
www.fossil.energy.gov
Marcellus Shale Gas Coalition
http://marcelluscoalition.org
PA Department of Environmental Protection
www.dep.state.pa.us
Sierra Club
www.sierraclub.org
United States Environmental Protection Agency
www.epa.gov

Procedure A

Review "Background Information". Have class use current data to estimate potential natural gas recovery and energy output of Marcellus Shale (the recovery of natural gas in the rock formation may be 10% of total deposits). See websites above and note dates of reports. Relate cubic feet recovery estimates of natural gas to monetary estimates. In addition to the natural gas industry itself, research the potential impacts on the economics of Pennsylvania.

Discuss how the natural gas industry has potential economic effects on:
-Private industry: costs and profits
-State of PA: job creation, retail sales, health and social services, hotel and food services, real estate, tax revenues
-Private citizens: bonuses and lease contracts.

Evaluation

Have students research and compare corporate and state capital potentials for the Marcellus Shale industry and report on graphs with evaluative summaries.

Procedure B

Discuss and list environmental concerns related to natural gas excavating:
-Impact on water supplies
Water contamination in surface and ground water: natural radioactive uranium, brine accumulation, chemical additives used in hydraulic fracturing
(See list attached.)
-Air pollution
-Changes in landscape, natural environments, wildlife habitats and aesthetics
-Heavy usage and destruction of roads
-Impacts on agriculture
-Changes in lifestyles and recreation: hunting, fishing, nature walks, etc.

Have students explain which issues or concerns they believe are most important.

*optional handout:

Chemicals Used by Hydraulic Fracturing Companies in Pennsylvania
For Surface and Hydraulic Fracturing Activities
Prepared by the Department of Environmental Protection
Bureau of Oil and Gas Management
Compiled from Material Safety Data Sheets obtained from Industry

1,2,4-Trimethylbenzene	Glycol Ethers (includes 2BE)
1,3,5 Trimethylbenzene	Guar gum
2,2-Dibromo-3-Nitrilopropionamide	Hemicellulase Enzyme
2.2-Dibromo-3-Nitrilopropionamide	Hydrochloric Acid
2-butoxyethanol	Hydrotreated light distillate
2-Ethylhexanol	Hydrotreated Light Distilled
2-methyl-4-isothiazolin-3-one	Iron Oxide
5-chloro-2-methyl-4-isothiazotin-3-one	Isopropanol
Acetic Acid	Isopropyl Alcohol
Acetic Anhydride	Kerosine
Acie Pensurf	Magnesium Nitrate
Alchohol Ethoxylated	Mesh Sand (Crystalline Silica)
Alphatic Acid	Methanol
Alphatic Alcohol Polyglycol Ether	Mineral Spirits
Aluminum Oxide	Monoethanolamine
Ammonia Bifluoride	Naphthalene
Ammonia Bisulfite	Nitrilotriacetamide
Ammonium chloride	Oil Mist
Ammonium Salt	Petroleum Distallate Blend
Ammonia Persulfate	Petroleum Distillates
Aromatic Hydrocarbon	Petroleum Naphtha
Aromatic Ketones	Polyethoxylated Alkanol (1)
Boric Acid	Polyethoxylated Alkanol (2)
Boric Oxide	Polyethylene Glycol Mixture
Butan-1-01	Polysaccharide
Citric Acid	Potassium Carbonate
Crystalline Silica: Cristobalite	Potassium Chloride
Crystalline Silica: Quartz	Potassium Hydroxide
Dazomet	Prop-2-yn-1-01
Diatomaceus Earth	Propan-2-01
Diesel (use discontinued)	Propargyl Alcohol
Diethylbenzene	Propylene
Doclecylbenzene Sulfonic Acid	Sodium Ash
E B Butyl Cellosolve	Sodium Bicarbonate
Ethane-1,2-diol	Sodium Chloride
Ethoxlated Alcohol	Sodium Hydroxide
Ethoxylated Alcohol	Sucrose
Ethoxylated Octylphenol	Tetramethylammonium Chloride
Ethylbenzene	Titaniaum Oxide
Ethylene Glycol	Toluene
Ethylhexanol	Xylene
Ferrous Sulfate Heptahydrate	
Formaldehyde	
Glutaraldehyde	

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(www.dep.pa.us)

As a class, research, list and discuss the environmental systems management controls established by federal, state and local laws. Search websites:

www.dep.pa.us	PA Department of Environmental Protection
www.epa.gov	United States Environmental Protection Agency

Next, research to find the number of drill site inspectors there are in the state. Discuss results. Have students voice their opinions regarding the feasibility of enforcing environmental laws.

Evaluation

Students may select an environmental concern of interest and collect substantial research using websites, news articles, personal interviews (industry personnel, landowners with lease agreements and neighboring landowners, etc.)

Students analyze their research to evaluate and report on a specific environmental issue.

Procedure C

Teacher will act as a neutral facilitator to open discussion on “Ethics”.
Have students use dictionary to define, ethics:
“the study of standards of conduct and moral judgement...”(Webster's).

Review the economic and environmental impacts of Procedures A and B. Have class discussion on the different viewpoints and entities involved with Marcellus Shale natural gas development: the industry, the state government, small businesses, private and public communities and nonhuman entities. Ask what each sector has to gain or lose with different scenarios. Ask if there can be “fairness” in the practices that intersects all.

Students should work independently to research and investigate a specific Marcellus Shale development practice and explain what effects it has on each sector in the region. Students then evaluate practices as ethical or unethical according to their individual viewpoint (allow students to research without teacher giving specific websites).

Evaluation

Students evaluate an issue or problem with Marcellus Shale natural gas excavating as being ethical or unethical. Their reasons and explanations should be expressed in writing or oral presentation.

Students may research different drilling (exploration/production) companies to compare their diligence and compliance with regulations.

Enrichment

Have students develop their own ideas or solutions on a particular issue involving natural gas development.

Activity 4: Keeping Current with Natural Gas Development

Objective

Students will collect and evaluate current events relating to the Marcellus Shale natural gas industry.

Materials

internet access, local, regional and national newspapers and online news (specific websites may allow for immediate Marcellus Shale news releases to schools and private e-mails), contact information for state and local officials, public forums related to Marcellus Shale development

Procedure

Review different sectors involved in the development of Marcellus Shale natural gas: the natural gas industry, environmental impacts, economics, social and private issues and current and proposed legislation. If possible, set-up direct "breaking news" feeds to the classroom computer from several websites, including PA Department of Environmental Protection. See "Website Resources."

Have students collect weekly news articles relative to Marcellus Shale natural gas developments. Post in classroom and discuss as time allows.

Evaluation

Students will keep weekly journals summarizing and evaluating current Marcellus Natural Gas news of interest to them.

Enrichment

Students may voice their personal opinions by writing or speaking to state representatives and other officials or by attending a public meeting concerning Marcellus Shale natural gas development.

Academic Standards

PA Academic Standards for Science and Technology:

Science, Technology and Human Endeavors	3.8

PA Academic Standards for Environment and Ecology:

Renewable and Nonrenewable Resources	4.2

PA Academic Standards for Civics and Government

Rights and Responsibilities of Citizenship	5.2

www.pde.state.pa.us

National Science Education Content Standards:

Earth and Space Science	D
Science and Technology	E
Science in Personal and Social Perspectives	F

www.nsta.org

Website Resources

Chesapeake Bay Foundation
www.cbf.org

Energy information administration
www.eia.doe.gov

Geology.Com
http://geology.com

MarcellusCoalition.org
www.marcelluscoalition.org

National Science Teachers Association: National Science Education Standards
www.nsta.org/publications/nses.aspx

Pennsylvania Department of Conservation and Natural Resources
www.dcnr.state.pa.us

Pennsylvania Department of Education: Academic Standards
www.pde.state.pa.us

Pennsylvania Department of Environmental Protection
www.dep.state.pa.us

Pennsylvania State University: Cooperative Extension
http://extension.psu.edu/naturalgas

Responsible Drilling Alliance
www.responsibledrillingalliance.org

Sierra Club
www.sierraclub.org

Susquehanna River Basin Commission
www.srbc.net

U.S. Department of Energy: Office of Fossil Energy
www.fossil.energy.gov

Wikipedia, the free Encyclopedia
www.wikipedia.org

U.S. Geological Survey
www.usgs.gov

EFMR Monitoring Group, Inc.
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