Title:	Natural Gas and the Fayetteville Shale	
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Course: **Grade:**	Environmental Science Arkansas History 9-12	**Duration:** 3-5 days

Objective:
To understand and gain knowledge of:

- The potential of unconventional natural gas reservoirs in meeting our energy needs
- The economic and technological factors that increase natural gas reserves
- Environmental impacts associated with unconventional exploration and development
- The impact of simple consumer choices (light bulbs) on CO2 levels and similar ways to conserve energy

Higher Order (H/O) thinking: Students should be able to **synthesize** technological advances and their impact on hydrocarbon extraction and environmental protection. They also need to perform basic data analysis.

Summary of Lesson:

Economic and technological factors have spurred exploration and development of natural gas in an unconventional reservoir rock—the Fayetteville shale. The focus of stepped-up activity has been in areas where rural land has been leased and explored through deep drilling using advanced methods. The potential of this natural gas resource is enormous and could have a substantial impact on U.S. energy supply.

- Understand the difference between conventional and unconventional reservoir rock
- Understand the role of technology in driving exploration activity of unconventional natural gas play
- Explore both the energy supply and environmental impacts of deep gas shale development.

Seemingly insignificant changes in consumer choices can impact energy consumption and CO2 levels

- Calculate CO2 savings for compact fluorescent light bulbs

- List similar choices that can save significant amounts of energy

VOCABULARY:

- Command of porosity
- Permeability
- Reservoir rock
- Cap rock
- Conventional drilling methods
- Environmental impacts

Standards: Common Core State Standards, Arkansas State Frameworks

CODE	STANDARD
G.1.AH.9-12.5	Examine the economic effect of Arkansas' natural resources
PD.1.ES.4	Categorize the type and composition of various minerals
PD.1.ES.19	Describe the cycling of materials and energy
NS.4.ES.3	Utilize technology to communicate research findings
PS3A	Definitions of Energy
PS3D	Energy I Chemical Processes an Everyday Life
LS2B	Cycles of Matter and Energy transfers In Ecosystems
ETS1A	Defining and delimiting Engineering Problems

Teacher Excellence Support System (TESS):
1c.: Setting instructional outcomes, 1d.: Demonstrating knowledge of resources, 1e.: Designing coherent instruction, 3a: Communicating with students, 3c: Engaging students in learning

Instructional Strategies and Practices:
Communicating knowledge through written and spoken activities. Student will write and speak in a created conversation about natural gas and the Fayetteville Shale

Bloom's Level: Highest Level Only
Synthesize **(Note**: see H/O under objectives.)

Materials and Resources:

Go to the link below and take the energy quiz **prior** to this lesson.
http://cleanet.org/clean/literacy/energyquiz.html

CFL worksheet (Excel 2007 (.lax) 13kB Dec14 10) Use this to understand energy use.
Student Handout 1 Natural Gas and the Fayetteville Shale Introduction
Student Handout 2 Natural Gas and the Fayetteville Shale CFL Worksheet

Formative Assessment:
Quiz questions:

- Go to the link below and take the energy quiz prior to this lesson.
  http://cleanet.org/clean/literacy/energyquiz.html

- Post assessment will be the completion of activity sheet**.**

Notes to Teacher:
To show energy savings use the following link, challenge students to come up with something comparable for switching to natural gas.

CFL worksheet (Excel 2007 (.xlsx) 13kB Dec14 10)

Student Activity

1. Before you begin the lesson, have students go to the website below to take an energy quiz. This will raise their awareness of their energy IQ.

   http://cleanet.org/clean/literacy/energyquiz.html

2. Have students role play this scene for a creative introduction to this lesson. (A printable copy of this handout accompanies the lesson on the Arkansas Energy Rocks web site.)

Student Handout 1
Natural Gas and the Fayetteville Shale
Introduction

Geo gal: *"When I was a the fitness center the other day I overheard someone say that a friend of theirs had been offered $2,000 an acre by a natural gas company"*

Geo guy (while examining a hand sample of shale): *"Wow, last I heard top dollar was around $1700 an acre. Can you imagine if you owned a couple hundred-acre farm in rural northeast Arkansas and you were offered this kind of money? And this is just to lease your*

land. You'd also get a percentage of the value of any gas that was produced."

***Geo gal (noting the parting in the shale specimen)**: "Considering many farmers are just barely making it, I can see that a gas lease offer would be highly attractive. It might be the only way that farmers can survive and keep them from selling their land. After all, family farms are an essential part of our rural landscape."*

***Geo guy (using a grain-size comparator):** "But how will gas wells and the production and transmission of gas impact the land? Will a farm still look like a farm?"*

***Geo gal:** "I've heard that advances in technology have reduced the environmental impact of fossil fuel drilling. Still, given the vast area of land that lies above the Fayetteville Shale, the landscape would surely be changed.*

***Geo guy (puzzled look on his face):** So, how do they get the gas out of fine-grained impermeable shale anyway??*

3. An important factor in America's energy consumption is the amount of CO2 produced by the everyday choices we make for the products and services we use. To vividly illustrate the savings from one simple consumer choice, have students calculate how much CO2 could be eliminated if **compact fluorescent light bulbs** replaced incandescent bulbs.

   Hand out the following worksheet and provide the active link or project the worksheet in the classroom:

   Student Handout 2: Natural Gas and the Fayetteville Shale -- CFL worksheet (Excel 2007 (.xlsx) 13kB Dec14 10)

4. To summarize the CFL worksheet, ask students to list similar choices that could save significant levels of energy.

5. Economic and technological factors have spurred exploration and development of natural gas in an unconventional reservoir rock—the Fayetteville shale. The focus of stepped-up activity has been in areas where rural land has been leased and explored through deep drilling using advanced methods. The potential of this natural gas resource is enormous and could have a substantial impact on U.S. energy supply.

   To better understand the impact of the Fayetteville Shale have students complete **Student Handout 3: Natural Gas and the Fayetteville Shale –An In-Depth Study**. (A printable copy

of this handout accompanies the lesson on the Arkansas Energy Rocks web site)

Student Worksheet 3
Natural Gas and the Fayetteville Shale
An In-Depth Study

Name _____Date_____

Words to watch for in your research:

- Permeability
- Reservoir rock
- Cap rock
- Conventional drilling methods

I. **Background.** There is much talk about the Fayetteville Shale in our region. So much so, that one would think it was a newly discovered mega-source of natural gas that could sustain our country's needs for decades. In reality, the Fayetteville Shale has been known a gas reservoir for more than 75 years. In the late 1800s, natural gas was discovered in shale in Arkansas. Natural Gas was first produced in Arkansas in 1889. By the beginning of the twentieth century, oil was discovered in Union County. Today 25 counties in Arkansas produce oil or natural gas.

A. Many residents in Arkansas have private water wells but imagine having your own natural gas well. Describe the concerns as well as the benefits of having your own natural gas well.

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II. **Fayetteville Shale.** The Fayetteville Shale is an unconventional natural gas reservoir located on the Arkansas side of the Arkoma Basin, ranging in thickness from 50 to 550 feet and ranging in depth from 1,500 to 6,500 feet. The shale is a Mississippian-age shale that is the geologic equivalent of the Caney Shale found on the Oklahoma side of the Arkoma Basin and the Barnett Shale found in north Texas. The formation holds natural gas in a fine-grained rock matrix which requires hydraulic fracturing to release the gas. This process became cost-effective in some shale such as the Fayetteville after years of experimentation in the Barnett Shale in North Texas, especially when combined with horizontal drilling.

A. To better understand the shale formation, research the type of rock in the Fayetteville Shale and give a short synopsis of it.

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B. In conventional reservoirs of fluids (groundwater, crude oil, natural gas), the fluid resides in rocks that are both *porous* and *permeable*. Review these terms and give an example of a sedimentary rock that is porous but not permeable.

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C. What is the average grain size of shale?

_____

D. Would the intergranular pore space of shale be larger or smaller than intergranular pore space of sandstone? Justify your response.

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III. Shale as a reservoir rock. Black, organic-rich shale is a *conventional* source rock for crude oil and natural gas but an *unconventional* reservoir rock. Crude oil and natural gas form from a carbon-rich source at depth then, due to their lower density compared to the surrounding rock, the fluids rise up and accumulate in porous and permeable rock (a reservoir) that is capped by an impermeable layer. The impermeable cap prevents the accumulated oil and/or gas to be dispersed through the crust. In conventional exploration, deep wells are drilled through the cap and accumulated crude oil and/or natural gas is extracted from the reservoir.

A. Why would shale, like the Fayetteville, be considered an unconventional reservoir for natural gas?

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IV. The **push to explore and develop the Fayetteville shale.** Rising natural gas prices during the turn of the current century coupled with technological advances spurred interest in the Fayetteville shale in Arkansas. Although the thickness of the Fayetteville shale is greater in some areas the depth to the shale is also greater. Most of the exploratory and development gas wells in Arkansas are drilled to depths ranging between 3,000 and 4,000 ft.

A. If it costs a gas drilling company about $150 per foot to drill a vertical gas well, how much does it cost to drill a 4,000 ft. vertical well?

B. An average vertical gas well might produce 45,000 cubic feet per day. If the wellhead (top of the well before it flows into a pipeline for distribution) price for natural gas is $7.50 per thousand cubic feet, how many years will it take a gas company to recover its cost to drill a 7,000 ft. well?

V. Horizontal drilling and hydraulic fracturing. New drilling and stimulating techniques have made the Fayetteville shale in Arkansas a viable target for gas extraction. Horizontal drilling allows a vertical well to turn and penetrate a layer of rock. This allows a much greater volume of gas-bearing rock to be intersected by a drill. Furthermore, hydraulic fracturing **("fracking")** is a technique that enhances the recovery of gas and/or crude oil. This technique involves pumping a water-based fluid and sand into a formation under high pressure. The pressure induces cracks in the rock and the sand helps prop open the cracks. Horizontal drilling and hydraulic fracturing triples the cost of drilling a well.

Watch a video explanation of **"fracking"**.

http://www.bing.com/videos/search?q=Fracking+Definition&FORM=HDRSC3&adlt=strict#view=detail&mid=13BE2A6AB33AB9DCEB6413BE2A6AB33AB9DCEB64

A. How are shallow aquifers protected from contamination by the drilling process and subsequent extraction of natural gas?

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B. What is meant by a "tight gas reservoir"?

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C. What is the key effect of "perfing" and "fracking" a horizontal well? Be clear in your explanation.

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VI. Environmental issues associated with deep gas well drilling. Any process that extracts a natural resource from the earth's crust impacts the environment ("we can't get something for nothing"). Although much needed regulations emplaced over the last several decades have lessened the impacts, they have not eliminated them. Conventional vertical well drilling environmental impacts include surface disturbance (access and drilling operation set up, disposal of rock cuttings carried out of the well by a mixture of clay and water, i.e. "drilling mud", emplacement of infrastructure to move gas into a pipeline network) and "down hole" preventative measures (contamination of groundwater aquifers, management of saline formation waters that can carry toxic chemical compounds). Do these environmental impacts apply to unconventional deep gas well drilling in Arkansas? Review the following articles:

oilprice.com/Energy/Natural-**Gas**/Study-Finds-no-Trace-of-Fracking... Study finds no Trace of Fracking Fluid in **Arkansas**...

Natural Gas Drilling**: Impacts of Fracking on Health,** Water**...**
www.nrdc.org/energy/gasdrilling

Drinking water **wells in** Arkansas **show no contamination...**
www.upi.com/Science_News/2013/05/15/Study-Gas-fracking-in-Arkansas

A. List and describe three major environmental impacts of deep gas well drilling in Arkansas:

1.

2.

3.

VII. Energy impact of natural gas in Marcellus shale.

http://www.beg.utexas.edu/info/docs/Fayetteville%20Shale%20OGJ%20article.pdf

http://www.solarplan.org/Research/Well%20Production%20Profile%20for%20the%20Fayetteville%20Shale%20Gas%20Play_Mason_OGJ_4%20April%202011.pdf

A. U.S. natural gas consumption in 2008 was 23,208,677 cubic feet. The volume of currently recoverable gas from the Fayetteville shale is equivalent to how many years at our current annual consumption rate? Refer to the 2 above articles to estimate the number of years and give reasons to support your answer._____
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_____

- items used w/permission from Sid P. Halsor

Student Handouts: (Printable copies of the handouts are available at: http://www.arkansasenergyrocks.com/educators/index.html. (Select Curriculum, then 9-12 Lesson Plan -- student handouts accompany each lesson plan.)