



Title:	Natural Gas and the Fayetteville Shale	
Author:	Delene L. McCoy Kingston School Kingston	
Course:	Earth Science, Environmental Science, Arkansas History, Economics, Integrated Physical Science	Duration: 3-5 days
Grade:	9-12	
Objective:	<p>To understand and gain knowledge of:</p> <ul style="list-style-type: none"> • 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 lighting choices (light bulbs) on the conservation of energy <p>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.</p>	
Summary of Lesson:	<p>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.</p> <ul style="list-style-type: none"> • 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. <p>Seemingly insignificant changes in consumer decision such as lighting choices can positively influence energy consumption thus impact CO2 levels</p> <ul style="list-style-type: none"> • Compare incandescent, LED and CFL light bulbs to determine the best consumer choice. 	



- List similar choices that can save significant amounts of energy

VOCABULARY:

- Porosity
- Permeability
- Reservoir rock
- Cap rock
- Conventional drilling methods
- Environmental impacts

Arkansas State Standards:

SUBJECTS:	GRADE LEVELS:	CODE:	STANDARD:
Earth Science	9-12	ES-ESS3-1	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
		ES-ESS3-2	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
		ES-ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
Environmental Science	9-12	EVS-ESS3-1	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
		EVS-ESS3-2	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral



			resources based on cost-benefit ratios.
		EVS-ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
Integrated Physical Science	9-12	PSI-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known
		PSI-PS2-5	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current
		PSI-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
Economics	9-12	EDM.1.E.2	Justify various economic solutions to problems affecting an individual or society using marginal costs and marginal benefit analysis
		EM.2.E.2	Demonstrate changes in supply and demand (e.g., shifts, shortages, surpluses, availability) that influence equilibrium price



			and quantity using a supply and demand model
		EM.3.E.3	Evaluate intended and unintended consequences of government policies created to improve market outcomes (e.g., regulatory, participatory, supervisory)
Arkansas History	9-12	Era 4.4.AH.9-12.2	Analyze economic developments in Arkansas during the early 20th century.
		Era 5.5.AH.9-12.3	Analyze the economic development of Arkansas post-World War II.
Language Arts	9-12	RI.9-10.2 RI.11-12.2	Examine a grade-appropriate informational text. <ul style="list-style-type: none"> ● Provide an objective summary of the text. ● Determine a central idea of a text and analyze its development over the course of the text, including how it emerges and is shaped and refined by specific details.
		RI.9-10.4 RI.11-12.4	Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the cumulative impact of specific word choices on meaning and tone.
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:

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

https://www.usalighting.com/stuff/contentmgr/files/1/92ffeb328de0f4878257999e7d46d6e4/misc/lighting_comparison_chart.pdf

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

<https://wedocs.unep.org/bitstream/handle/20.500.11822/8275/-Environmental%20Management%20in%20Oil%20%26%20Gas%20Exploration%20%26%20Production-19972123.pdf?sequence=2%26isAllowed=y>

https://cber.uark.edu/files/Revisiting_the_Economic_Impact_of_the_Fayetteville_Shale.pdf

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 the activity sheet.

Notes to Teacher:

To show energy savings use the following link to challenge students to come up with something comparable for other types of energy conservation.

https://www.usalighting.com/stuff/contentmgr/files/1/92ffeb328de0f4878257999e7d46d6e4/misc/lighting_comparison_chart.pdf

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. Hand out **Student Handout 1: Introduction**. Select two students to 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

Props: large piece of shale

Geo gal: *"When I was at 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 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: *"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 like this sample??? It looks impossible to me."*

Geo gal: *"Well, let's do a little research and find out how they do it."*

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 examine the differences in 3 common light bulbs available to consumers. In **Student Handout 2-- Consumer Choice: Light Bulb Comparison** students will complete a chart to determine which light bulb is the best choice for energy savings

4. Hand out the worksheet and provide the active link or project the worksheet on the classroom screen.

https://www.usalighting.com/stuff/contentmgr/files/1/92ffeb328de0f4878257999e7d46d6e4/misc/lighting_comparison_chart.pdf.

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 Handouts: See web site for a printable copy at

<https://arkansasenergyrocks.com/educators/lesson-plans-9-12/>

Student Handout 1 Natural Gas and the Fayetteville Shale Introduction

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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."

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Geo gal: *"Well, let's do a little research and find out how they do it."*

Student Worksheet 2
Natural Gas and the Fayetteville Shale
Consumer Choice: Light Bulb Comparison

Go to:

https://www.usalighting.com/stuff/contentmgr/files/1/92ffeb328de0f4878257999e7d46d6e4/misc/lighting_comparison_chart.pdf to evaluate the features of the three light bulbs listed. Record your findings in the chart below.

1. Based on the facts you learn about each light bulb, decide which you believe to be the most energy efficient?
2. Which light bulb is the safest and the most user-friendly?
3. Share your decision with the class when asked and explain your choice.



	Light Emitting Diodes (LEDs)	Incandescent Light Bulbs	Compact Fluorescents (CFLs)
Energy Efficiency & Energy Costs			
Life Span (average)			
Watts of electricity used (equivalent to 60 watt bulb) LEDs use less power (watts) per unit of light generated (lumens). LEDs help reduce greenhouse gas emissions from power plants and lower electric bills.)			
Annual Operating Cost (30 Incandescent Bulbs per year equivalent)			
	Light Emitting Diodes (LEDs)	Incandescent Light Bulbs	Compact Fluorescents (CFLs)
Environmental Impact			
Contains the TOXIC Mercury			
Carbon Dioxide Emissions (30 bulbs per year) Lower energy consumption decreases: CO2 emissions, sulfur oxide, and high-level nuclear waste			



Sensitivity to low temperatures			
Sensitive to humidity			
Turns on instantly			
Durability			
Heat emitted			
Failure modes			

Adapted from usalighting.com: Comparison Chart LED Lights vs. Incandescent Light Bulbs vs. CFLs

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.

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.

- 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.

- 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.



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?

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.



Choose videos from the following web site to provide information to answer the question about “fracking” listed below.

(If this web site is no longer available research each question individually using key words and phrases from the question.)

<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?

- B. What is meant by a “tight gas reservoir”?

- C. What is the key effect of “perforating” and “fracking” a horizontal well? Be clear in your explanation.

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 put in place over the last several decades have lessened the impacts, they have not eliminated them completely. Review the following article to identify some of the environmental impacts which continue to plague oil and gas companies in the communities where they establish wells.



<https://wedocs.unep.org/bitstream/handle/20.500.11822/8275/-Environmental%20Management%20in%20Oil%20%26%20Gas%20Exploration%20%26%20Production-19972123.pdf?sequence=2%26isAllowed=y>

If this web site is no longer available explore the internet to find current resources. Use key words and phrases from the information above.

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

- 1.
- 2.
- 3.

VII. Economic impact of natural gas in Fayetteville shale.

A. Using the web site below, explore the ways the oil and gas industry has had a beneficial effect on the economy of Arkansas.

https://cber.uark.edu/files/Revisiting_the_Economic_Impact_of_the_Fayetteville_Shale.pdf

Summarize the economic benefits the Fayetteville shale play and other oil and gas operations have had on Arkansas' economy.
