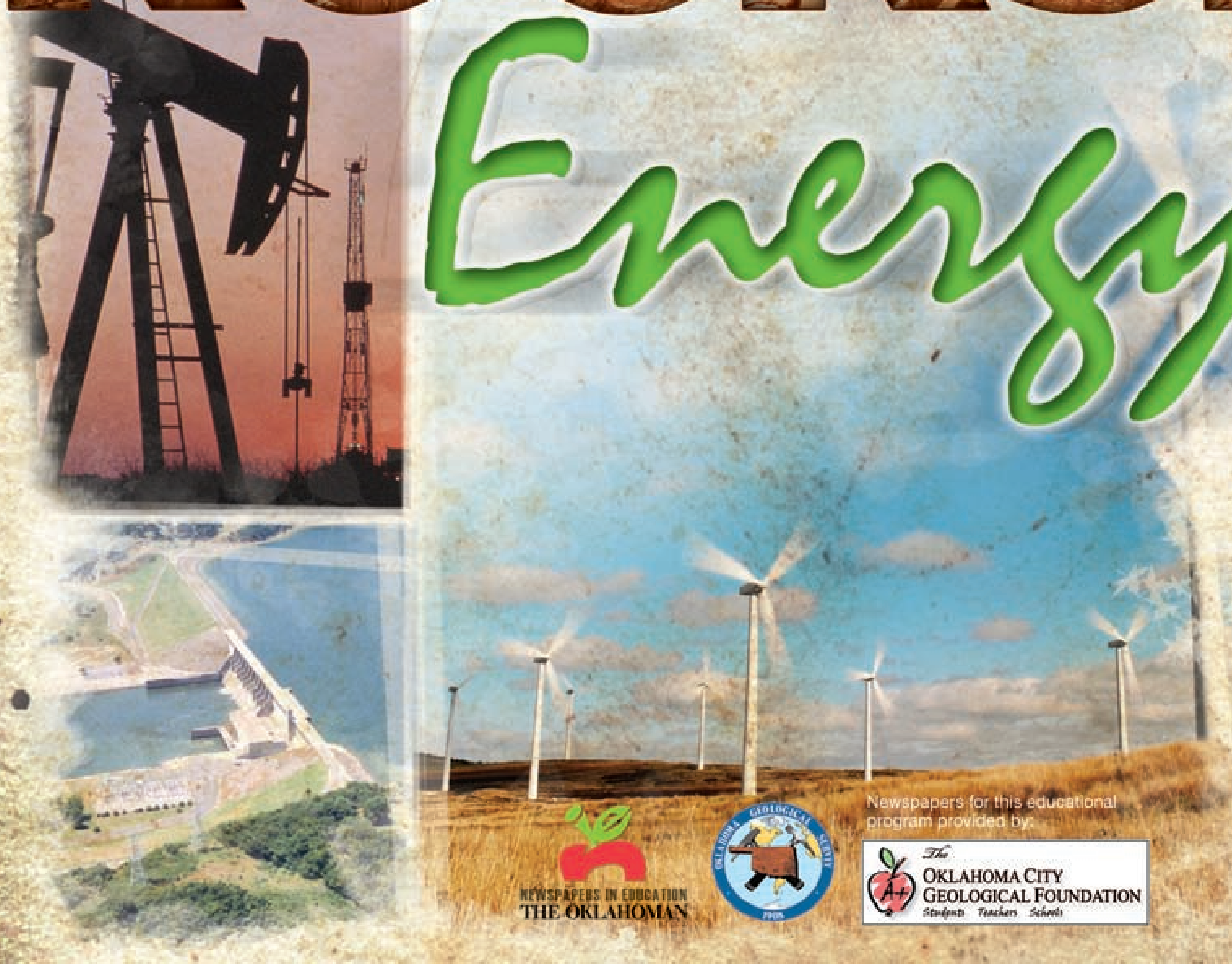
OKLAHOMA ROCKS!

Energy



TEACHER'S GUIDE

THE ENERGY CHALLENGE

There is a tendency for groups and individuals to focus narrowly on energy issues. However, providing dependable, affordable, and sustainable energy that is as clean as possible now and in the future is a very complex problem that defies simple and narrowly focused solutions such as *"let's just quit burning coal"* or *"let's convert totally to solar energy."*

Any list of energy resources includes oil, natural gas, coal, nuclear, hydroelectric, wind, solar, biofuels, and geothermal, and each source has its champions. However, all of these resources play a role in our energy supply today and will for many years to come. Each energy source has its limitations and challenges, and there are many factors that must be considered such as the water used in the creation of energy. It may surprise you to learn that nuclear, coal and biofuels all use similar and significant amounts of water in the process of producing energy.

There are always trade-offs that complicate things; for example, coal is cheap and plentiful but burning it has the highest emission of CO_2 (carbon dioxide) of all energy sources and produces ash as a waste product. The energy from the wind and the sun are free, but it takes lots of raw materials to build wind farms and solar panels and not every day is windy or sunny. Hydroelectric power is relatively cheap, but can you imagine filling up the Grand Canyon with a lake to provide enough hydroelectric power to light Las Vegas?

Our lives, existing technologies and resources, our economy, and political realities make it impossible to make radical changes in our energy supply quickly. One big constraint is that our country is accustomed to having relatively cheap energy. On the other hand, every effort on the part of individuals, scientists, engineers and policy makers to conserve energy and develop new technology is important. Simple steps to conserve energy like turning off the lights and TV when we leave rooms and turning up our thermostats in the summer can make a big difference if everyone would take them. Developing new technologies that increase efficiency in industry, buildings, and transmission lines can save very large amounts of energy. When one considers alternative energy resources such as solar and wind, more efficient energy storage becomes a necessity for those times when the sun does not shine or the wind does not blow.

We can meet the energy challenges of the future only when we understand that:

1. Traditional fossil fuels are finite resources.
2. Energy is a valuable resource that should be used wisely.
3. New energy technologies are likely to be costly to develop.
4. Everyone must be engaged and informed about energy.

We hope this educational package helps you explore energy in your country, your state, your city, your school and your home.

Dr. Randy Keller

Director, Oklahoma Geological Survey

CREDITS

The content for this program was developed by the Oklahoma Geological Survey. Special acknowledgements go to Dr. Randy Keller, Connie Smith, Neil Suneson, Dan Boyd, Jim Anderson, Brian Cardott, Richard Andrews and Wendy Kleinman.

The Oklahoma Geological Survey (OGS) provides research and public services related to the state's land, water, mineral and energy resources and to the wise, environmentally sound use of them. The OGS is a state agency affiliated with the University of Oklahoma College of Earth and Energy. The OGS provides resources for teachers and students including publications such as "The Gee(WHIZ)ology of Oklahoma" and other materials for classroom use, plus programs and activities for teachers, available at www.ogs.ou.edu.

Teachers' Note: Many of the answers in this guide indicate simply that students' activity answers will vary. Many of the questions in the workbook as well of the lessons require student inquiry and critical thinking and do not have a single correct answer. In cases where more specific answers are required or guidance is available, more information is provided here.

INTRODUCTION TO ENERGY ISSUES

The U.S. Energy Information Administration (EIA) defines energy as the capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Our dependence on energy is clear when it is unavailable (as in a citywide electricity blackout) or limited in supply (as in long lines at the gas station). Energy comes in many forms and is used in many ways. For example, energy is available in the form of electricity, gasoline, and natural gas.

Bulldozers were used to move rock above coal at the Kelley Mine in Craig County, northeastern Oklahoma. The mine is mine number 8 in Figure 2 on page 11.

Power plants generate electricity from many sources, such as coal, natural gas, oil, uranium (nuclear power), water (hydroelectric power), geothermal, wind and sunshine (solar power). Some of these sources are fuels used in applications other than for generating electricity, such as to heat our homes, cook our meals, and dry our clothes.

Electricity, used in our homes, businesses, and factories, is transported along power lines as part of the electric grid (an interconnected network of power plants used to deliver electricity to consumers). When you turn on a light switch it is not possible to know exactly which power plant produced the electricity. Power lines lose power when they are run over long distances. Building transmission lines to cities from distant locations takes time and is expensive. Therefore, it is important to have the electricity generated as close as possible to where it is used.

Electricity is often generated in wind or solar farms far from where the electricity is used, and wind mills and solar panels are expensive to buy and maintain. Although electricity from wind and solar is not cheap energy, it is still an important part of energy diversification — not relying on one or a few sources.

Gasoline and biofuels are liquids used mainly for transportation in cars, trucks and buses, with few options of other fuel sources. For example, as an energy source in electric cars, electricity must be stored in batteries that have limited storage and must be recharged frequently.

There also is a limited supply of fossil fuels (coal, natural gas, and oil). Once the fuel supply has been produced and used, there will not be any more available. In order to increase the time that these fuels are available, it is important for all of us to both conserve energy and use more energy-efficient products. Energy conservation is as simple as turning off lights or fans when no one is in the room. Some appliances, such as cell phone chargers and televisions, use energy even when turned off. We can conserve energy by unplugging these appliances when we are not using them, and buying energy efficient products such as cars that get more miles per gallon or appliances that use less electricity.

The U.S. has abundant supplies of coal and natural gas, while oil production peaked in 1970. At current rates of use, the U.S. has enough coal reserves to last for more than 400 years.

ACTIVITIES:

1. Begin thinking about how important energy is in your life. List the roles energy plays on a daily basis in your home (everything from waking up to preparing meals, doing chores and having entertainment), in transporting you to school, in keeping your school building running, in your families' workplaces, and in the restaurants and other places you visit in your neighborhood.
2. Make a "KWL Chart" about energy. In one column, write what you Know about energy. In the second column, write what you Want to know about energy. At the end of this curriculum, you will fill in the third column with what you have Learned about energy.

KNOW	WANT TO KNOW	LEARNED

ACTIVITIES: ANSWERS

All activity answers for this section will vary.

ECONOMY

It is difficult to overestimate the impact that the oil and natural gas industry has on the economy of Oklahoma. Since propelling Indian Territory and Oklahoma Territory to statehood in 1907, more than 15 billion barrels of crude oil and 103 trillion cubic feet of natural gas have been produced. Their value has varied widely through time, but the 67 million barrels and 1,858 billion cubic feet (E.I.A., 2010) produced in 2009 was worth approximately $10 billion — a nearly 50 percent fall from the previous year (Figure 1). This income supports the state economy in many ways. It generates thousands of industry-related jobs, as well as the many unrelated jobs and income taxes that this employment supports. In addition, each year over the last decade it also has provided Oklahoma mineral-interest owners an average of $2.2 billion of royalty income (money paid to owners of mineral rights to land from which minerals and oil and gas are extracted).

The value of oil and natural gas to Oklahoma depends far more on its price than on the volume produced. The average year-to-year variation in production over the last 20 years has been less than 4 percent (Figure 2). However, over the same period, the price of oil and gas has varied by an average of nearly 23 percent. The state's current economic problems are largely the result of a fall in oil and gas prices in 2009 of 42 percent and 55 percent respectively (Figure 3). This alone reduced gross production tax revenues paid to the state by more than $700 million, the bulk of this due to the collapse in natural gas prices.

The volatility experienced in gas and oil prices, both up and down, is driven by factors over which we have little or no control. These include political unrest, the state of the U.S. and global economies, and factors as mundane and unpredictable as the weather — a key variable affecting demand for natural gas. Preparing for these inevitable wide swings in tax revenues continues to be a perennial problem for state lawmakers. The prevalence of gas production in Oklahoma, which represents about 80 percent of our barrel of oil equivalent production, makes its price by far the most important economic driver in the state (Figure 4). Because it is the most environmentally friendly fossil fuel and remains relatively abundant in Oklahoma, natural gas will continue to be a key component of the State's economic health well into the 21st century.

References: E.I.A., U.S. Energy Information Administration, 2010, Accessed online at: http://www.eia.doe.gov/
Oklahoma Corporation Commission, 2009, Oil and gas information: Oklahoma Corporation Commission, Web site: http://www.occ.state.ok.us/Divisions/OG/annualreports.htm
Oklahoma Tax Commission 2010, Gross Production Tax Division: Website: http://www.oktax.state.ok.ustaxes1.html/#gross

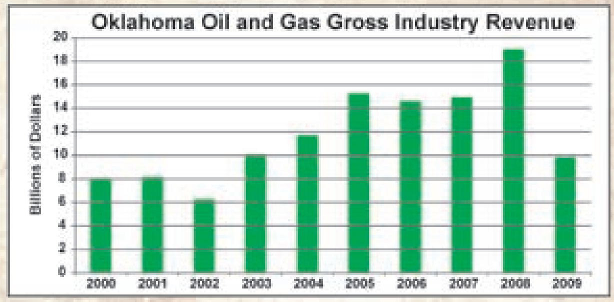


Figure 1: Oklahoma Oil and Gas Gross Industry Revenue. Calculated from data provided by the Oklahoma Corporation Commission.

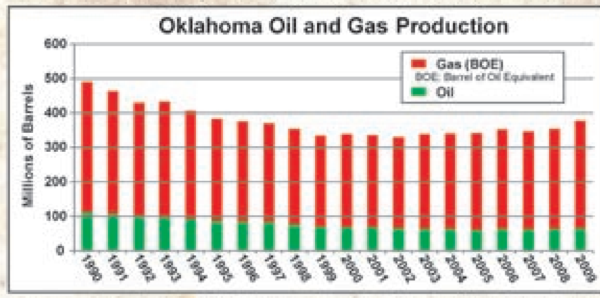


Figure 2: Oklahoma Oil and Gas Production. Data from Oklahoma Corporation Commission.

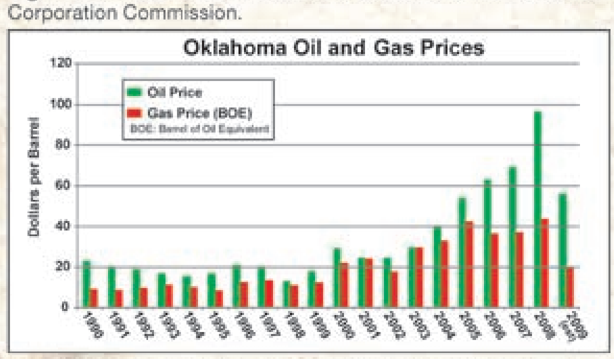


Figure 3: Oklahoma Oil and Gas Prices. Data from Oklahoma Corporation Commission.

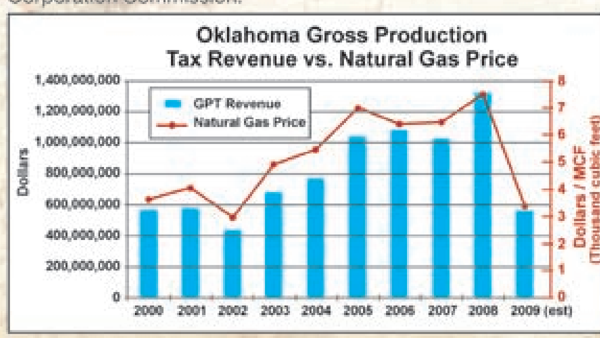


Figure 4: Oklahoma Gross Production Tax Revenue vs. Natural Gas Price. Data from Oklahoma Corporation Commission.

ACTIVITIES: ANSWERS

1. Answers for the following should be expanded upon. Basic concepts that should be addressed for each part of this activity are:
   - **A.** Changes in the industry's revenue in part dictate how much money can be allocated to areas of government services in any given year. zyhe sharp drop from 2008 to 2009 contributed to the state's tough year financially, including budget cuts.
   - **B.** Technology advances and funding for further research and development in the industry are needed in order to reverse the decrease in oil production. Using Barrel Oil Equivalent results in a graph that shows so much more

ACTIVITIES:

1. Interpret the information in the graphs provided on page 4 to answer the following questions.
   - **A.** Gross Industry Revenue: How do you think the changes in revenue affect the overall budgeting process for the state? What was the impact of the sharp drop from 2008 to 2009?
   - **B.** Oil and Gas Production: What do you think would be necessary to reverse the decreasing production of oil in the state? Why does using BOE, or Barrel of Oil Equivalent, result in a graph that shows so much more gas production over oil?
   - **C.** Oil and Gas Prices: Why do you think gas prices are consistently lower than oil prices? What do you think accounted for the spike in oil prices in 2008?
   - **D.** Tax Revenue: Do you think the relationship between the state's gross production tax revenue and natural gas prices indicates correlation with or without causation? Which is the driving factor in the relationship?
2. Visit http://newsok.com/business/energy and scroll down to "Oklahoma energy companies' current stock prices." What information does this chart provide? How do you predict these numbers will change over the course of a month? Choose one company and track its stock performance over the next month to see how accurate your prediction is.

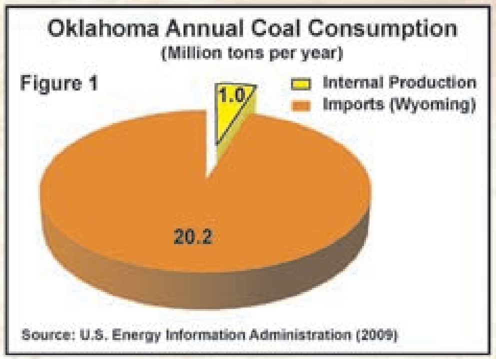
HOW WE PRODUCE & USE ENERGY

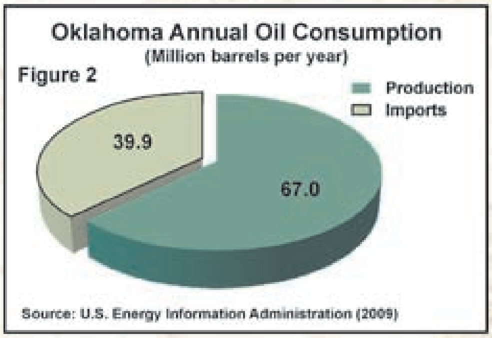
Although Oklahoma has produced abundant coal from the eastern part of the state, it is not one of the nation's major coal producers. On top of this, the relatively high sulfur content of Oklahoma coal has forced us to curtail much of its production. Today we rely almost exclusively on low-sulfur coal from Wyoming, which meets more than 95 percent of our annual needs of about 21 million tons (Figure 1).

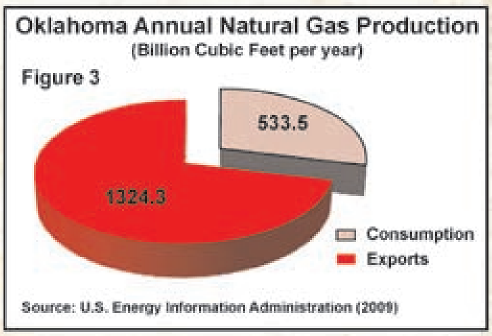
Oil has been produced in Oklahoma for more than a century, and our production of about 67 million barrels per year ranks sixth in crude production nationwide, behind Texas, Alaska, California, North Dakota, and Louisiana. Despite this production we still satisfy less than 64 percent of Oklahoma's annual demand of about 107 million barrels of crude oil (Figure 2).

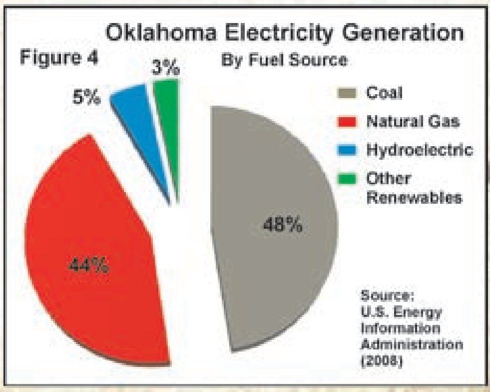
Oklahoma ranks third in the production of natural gas nationwide, behind only Texas and Wyoming. This has become our dominant energy resource, exceeding oil production on an energy equivalency by a factor of four to one. Only Oklahoma's gas production allows us to be a net energy exporter (Figure 3). In this fuel we not only meet our internal needs of 533 billion cubic feet of gas per year, but also export to the interstate market more than 1.3 trillion cubic feet of gas per year (Figure 3). Natural gas is especially important to Oklahoma because it is the cleanest burning fossil fuel and is seen by many as a bridge to sustainable energy sources.

Much of our energy comes to us in the form of electricity, and this can be generated in a variety of ways. Water can be heated to turn turbines by burning fossil fuels or by the radioactive breakdown of uranium fuel rods in a nuclear facility. Electricity also can be generated using the power of falling water (hydroelectricity), moving air (wind), or the radiation from the sun (solar). In Oklahoma coal and natural gas are the fuel sources for about 92 percent of the state's electrical generation. Hydroelectricity accounts for about 5 percent of our consumption, with the remaining 3 percent (which are called "Other Renewables") represented by wind, wood/woodwaste and biogenic landfill gas (Figure 4). Oklahoma has no commercial geothermal, nuclear, or solar facilities feeding into our electrical grid.









gas production over oil because …

- **C.** Why do you think gas prices are consistently lower than oil prices? What do you think accounted for the spike in oil prices in 2008?
- **D.** Do you think the relationship between the state's gross production tax revenue and natural gas prices indicates correlation with or without causation? Which is the driving factor in the relationship?

2. This chart shows Oklahoma energy companies, the last stock prices for those companies, the percent change, and a symbol indicating whether the stock value of each company has increased, decreased or stayed flat. Clicking on the company brings up a page with additional stock information. The remainder of students' answers will vary.

OKLAHOMA OIL & NATURAL GAS

Many of the state's power plants have the ability to use more than one fuel source, either coal or natural gas. Because utility companies are publicly owned, for-profit businesses and must produce electricity as economically as possible, and they must favor less expensive fuel where possible. Coal is the fuel of choice because it is consistently lower in cost per Btu than either petroleum or natural gas.

Source: E.I.A., U.S. Energy Information Administration, 2010, Accessed online at: http://www.eia.doe.gov/

GLOSSARY OF TERMS

Barrel: 42 U.S. gallons

BCF: Billion (1,000,000,000) cubic feet of gas (at surface temperature and pressure)

Biogenic Gas: Gas produced by the biological breakdown of organic matter

Btu: British thermal unit. Quantity of heat necessary to raise the temperature of one pound of water one degree Fahrenheit

Fossil Fuels: Petroleum, natural gas, coal

Geothermal: Power extracted from heat sourced in the earth

Hydroelectricity: Electricity that is generated through the use of falling water, usually through a man-made dam

TCF: Trillion (1,000,000,000,000) cubic feet of gas (at surface temperature and pressure)

Ton: 2,000 pounds

ACTIVITIES:

1. In addition to knowing important terms, it is also important to understand the units used in the energy sector. Here are common energy units:
   1 barrel (42 gallons) of crude oil = 5,800,000 Btu
   1 gallon of propane = 91,033 Btu
   1 gallon of gasoline = 124,238 Btu
   1 gallon of heating oil = 138,690 Btu
   1 gallon of diesel fuel = 138,690 Btu
   1 cubic foot of natural gas = 1,027 Btu
   - **A.** Assume your family used 84,766 cubic feet of natural gas to heat your home last winter, while your friend's family used 610 gallons of heating oil. Convert these figures to Btu. Who used more energy to heat their home?
   - **B.** Now assume your family drives a vehicle that uses an average of 51 gallons of gasoline a month, and your friend's family drives a diesel-powered vehicle that goes through 38 gallons a month. Whose vehicle uses more energy?
2. Compare and contrast Oklahoma's energy profile with that of another state using the information at www.eia.gov/state. Include data on production, consumption, reserves and prices. Present your findings in charts and/or graphs, and summarize the similarities and differences — and the reasons for them — between the states.

OIL

Statehood was only the beginning for Oklahoma, as the oil rush continued with a steady stream of enormous discoveries, including giant fields in Cushing (1912), Burbank (1920), Seminole District (1923), and Oklahoma City (1928), each of which would produce more than 500 million barrels of crude (Figure 1).

The long downhill slide that oil production in Oklahoma has experienced since 1984 ended about four years ago with the advent of horizontal drilling and completion techniques that have allowed reservoirs with low permeability to be produced economically (Figure 2, page 8). The state's oil production should continue to modestly increase as more areas are found where this technology can be applied. Improvements in oil recovery also are possible in many existing fields where poor production practices in the early years can often be remedied using improved technology and geologic understanding. As things stand it is estimated that 81 percent of the original oil-in-place in these fields will be left in the ground at abandonment.

GAS

Most of the oil discovered in Oklahoma was found during a time when natural gas, especially that seen in association with oil, was viewed mainly as a nuisance or drilling hazard. For early wells a discovery meant a

ACTIVITIES: ANSWERS

1A. The family using natural gas as a heating source used more energy. That family used 87,054,682 Btu of energy. The family using heating oil used 84,600,900 Btu.

1B. The vehicle that runs on natural gas uses more energy because 51 gallons of gasoline is equivalent to 6,336,138 Btu, while 38 gallons of diesel fuel is equivalent to 5,270,220 Btu.

2. Answers will vary.

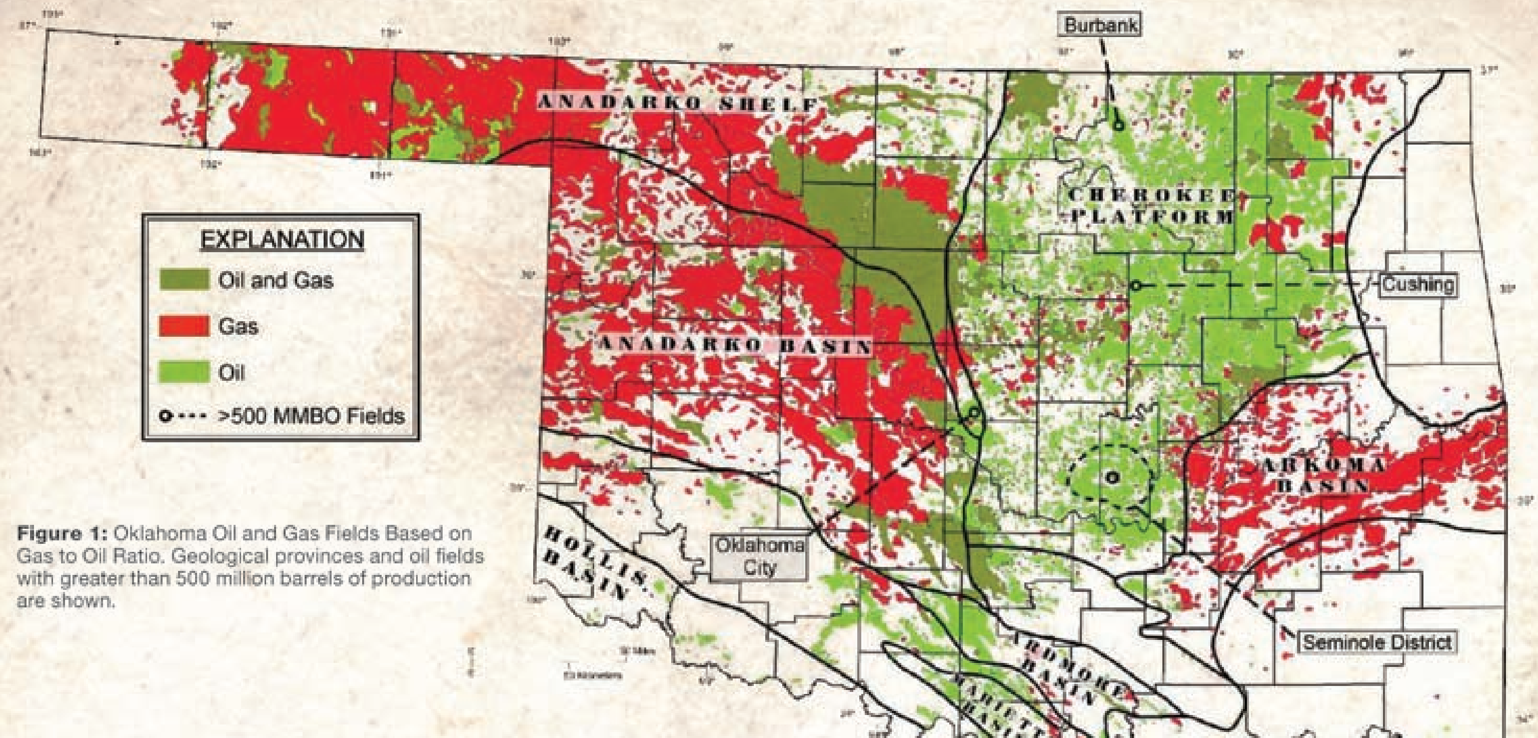


Figure 1: Oklahoma Oil and Gas Fields Based on Gas to Oil Ratio. Geological provinces and oil fields with greater than 500 million barrels of production are shown.

blowout, with gas in the air and oil on the ground (Figure 3, page 8). The gas was vented and earthen dams were used to collect the oil. If a well encountered a large gas flow, it would be vented, sometimes for days, to determine if there was oil beneath. If oil eventually flowed into the well, the oil was produced and the gas flared. If not, the well would be plugged and the operator would move elsewhere (Franks, 1980). It is estimated that more than 3 trillion cubic feet of associated natural gas were vented or flared in Oklahoma prior to World War II. This practice was a key factor in many substandard oil recoveries (Boyd, 2008).

Despite Oklahoma's perennial image as an oil producing state, natural gas has been our primary energy resource for nearly half a century, and today represents roughly 80 percent of our total hydrocarbon production (O.C.C., 2009). Large discoveries and high demand made oil the primary exploratory objective in early history of the state. The lack of a market delayed gas-targeted exploration and production in Oklahoma and pushed peak gas production to 1990, 63 years after the oil peak in 1927 (Figure 2, page 8).

As the price for natural gas has risen, operators have tried to recover gas from the State's many unconventional reservoirs. These do not occur in discrete traps, but in low-permeability reservoirs that tend to cover large areas. Two of the most important in Oklahoma are coalbed methane and gas shales. Because coal and shale are exceedingly impermeable, horizontal drilling has aided both, with modern fracture stimulation technology helping to make shale gas economically viable.

THE FUTURE

The 1927 peak in Oklahoma oil production was only an intermediate high in overall hydrocarbon production. Because of pricing, demand, and many other factors, oil production in Oklahoma and elsewhere has peaks and valleys. In 1970, Oklahoma produced a high of 527 million barrels of oil equivalent (MMBOE), and reached nearly the same level in 1984. Surprisingly, overall hydrocarbon production today is roughly the same as what was produced in 1927; the difference is that now natural gas is carrying most of the load (Figure 2, page 8). From this perspective it can be seen that energy production in the state will remain strong for decades.

Oklahoma's cumulative oil and natural gas production is more than 15 billion barrels of oil and more than 103 trillion cubic feet of natural gas, both staggering volumes. The industry's success in finding abundant oil and natural gas, much of it from Oklahoma, has helped make these the world's primary energy sources. This cheap energy has been a key factor in the unprecedented prosperity and technological advancement that humanity has enjoyed. However, it also has brought a dependency on fuels that carry environmental consequences. The transition from fossil fuels to more environmentally friendly energy sources will take decades to

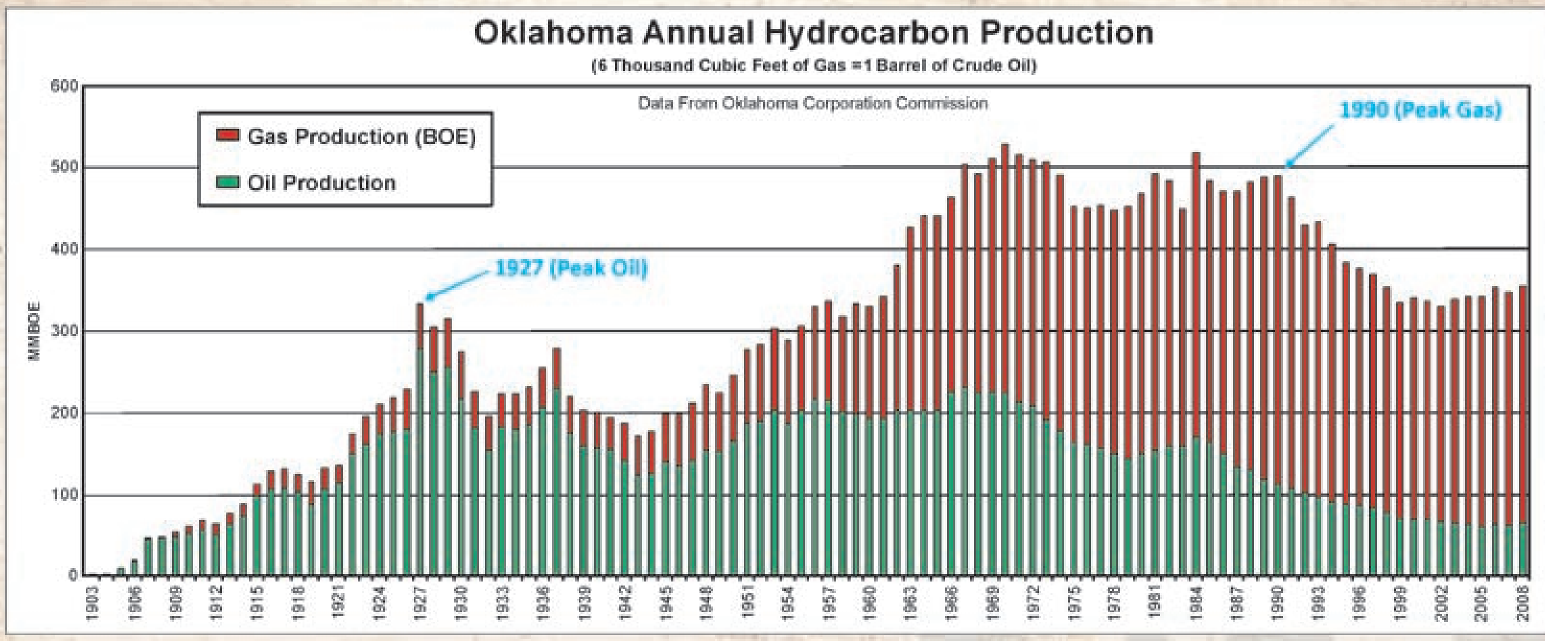


Figure 2: Oklahoma Hydrocarbon Production based on a barrel of oil equivalency.

accomplish and undoubtedly be bumpy. As a key producing state, Oklahoma oil and natural gas will be vital in providing a secure bridge to the sustainable energy sources that will carry the human race into the future.

References: Boyd, D.T., 2008, Oklahoma: The Ultimate Oil Opportunity, Shale Shaker (Journal of the Oklahoma City Geological Society, Vol. 58, No. 6 pp. 205-221.)

Franks, K. A., 1980, The Oklahoma petroleum industry: University of Oklahoma Press, Norman, 284 p.

Oklahoma Corporation Commission, 2009, Oil and gas information: Oklahoma Corporation Commission, Web site: http://www.occ.state.ok.us/Divisions/OG/annualreports.htm

Figure 3: The Nellie Johnstone #1, drilled in 1897 just south of Bartlesville, established the first economic production in the state. Photograph taken from Franks, 1980.

ACTIVITIES:

1. Imagine you are in charge of ensuring a company's energy production in the state remains strong and grows even more in the coming years. What factors, like technological advances and exploring new sites, will be the most critical? What concerns would you have about price volatility and safety? Outline a business plan about how to pursue and monitor the factors you decide are the most important.
   A. **Bonus:** When you are considering new technological advances, think about horizontal drilling, which has been an important factor in increasing gas production from coal seams and gas shales in Oklahoma. To better understand this process, see the video at: http://www.oerb.com/Default.aspx?tabid=242. Make a list of the advantages and disadvantages this process could provide.
2. Choose a city or town in Oklahoma and use *The Oklahoman* Archives to research the historical impact of the oil and gas industry on that place. Create a timeline to show key changes.

ACTIVITIES: ANSWERS

1. Answers will vary.

A. **Disadvantages.** 1. More costly (might have to drill 10,000 ft in a formation that's only 5000 ft deep). 2. More difficult. "Geosteering" thru a formation, particularly if it's a thin formation, might be tricky, especially if the formation is complicated and/or there are faults. (So geosteering successfully thru a formation requires lots of prior knowledge of the formation and a very trained and capable crew to do the steering.) 3. A horizontal well could produce from other formations uphole, but cannot produce from any formations below the horizontal segment of the well.

Advantages. 1. Better production. More of the gas- or oil-bearing formation is exposed to the wellbore. 2. Can drill more of a formation from a single pad. This can reduce the long-term “footprint” of the entire drilling operation, which is important in urban areas. Also advantageous for transporting gas – can run a pipeline to a single location rather than several.

All of this points out the need for geologists and engineers who can correctly assess the prospect, and the need for data from mapping, analysis of core from past wells in the area, and seismic testing, and other well information that is collected over the years and available to the industry.

2. Answers will vary.

MORE INFORMATION ON OKLAHOMA OIL & NATURAL GAS

- Oklahoma energy production has evolved from primarily oil to primarily gas
- On an energy equivalency we produce about 4 times more gas than oil
- The State’s budget rides on oil and especially gas prices (not production rates)
- We have almost no control over energy prices – so we must be prepared
- Despite large coal deposits, we import 95% of our coal from Wyoming
- Despite ranking 6th in oil production we consume much more than we produce
- Only gas maintains a positive energy balance for the State
- We export twice as much natural gas to the interstate market as we consume
- Power companies are publicly owned and must make money, thus we burn coal over natural gas where possible because it is cheaper
- Fossil fuels account for ~85% of U.S. energy consumption, and this will not change significantly, barring a technological breakthrough, for a long time
- The general public, as well as the industrial sector, make energy consumption decisions based on price. Given their relatively high price, alternative energy sources cannot make significant inroads until fossil fuels cost more.
- Enormous reductions in our energy consumption could be realized without significant sacrifice by simply using vehicles that are fit-for-purpose. Until gasoline costs more this will not happen on a large scale.

Coalbed methane (CBM) is an important source of natural gas in Oklahoma. Since 1988, more than 5,800 CBM wells (Figures 1 and 2) have been completed in about 18 different bituminous-rank coals in the eastern Oklahoma coalfield. Of all ranks of coal, bituminous coals generate the most methane. Each well can produce gas from as many as nine coals in Oklahoma. Horizontal wells can drill openings in the coal up to 5,771 feet long. Used to drill Oklahoma CBM wells since 1998, horizontal wells allow for production from more coal than a vertical well because Oklahoma coals are less than 10 feet thick. From 1988 to 2009, CBM wells in Oklahoma produced about 600 billion cubic feet of gas.

CBM is methane-rich natural gas produced from coal. Coal has more than 50 percent – and frequently more than 90 percent –organic matter by weight. In contrast, shales (fine-grained rocks that are the most common hydrocarbon source rocks) usually contain less than 10 percent organic matter. The main type of organic matter in coal is from wood, which generates methane when heated. Coal is both the source and the reservoir of the gas, which is produced from coal through natural fractures called cleat.

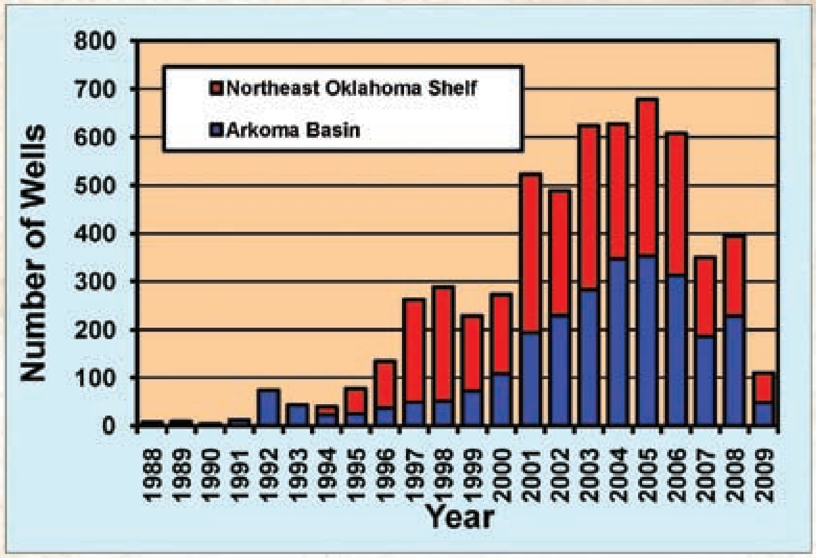


Figure 1: Histogram showing numbers of Oklahoma coalbed-methane well completions (1988–2009).

ACTIVITIES:

1. The molecular formula of methane is CH_4, which is a type of covalent compound. Covalent compounds are typically more flammable than ionic compounds. Draw a diagram of CH_4, and then discuss why it is so prone to combustion reactions and why this can cause safety hazards.
2. How does capturing coalbed methane help to reduce the accumulation of greenhouse gases from coal mines? What implications might coalbed methane recovery have for old, abandoned coal mines?
3. Coalbed methane is found in coal seams, and can be produced by drilling into the seam or by mining activities. Visit www.netl.doe.gov/technologies/oil-gas/futuresupply/coalbedng/coalbed_ng.html to learn more about these processes, and then describe three of the ways that natural gas can be extracted from coal.

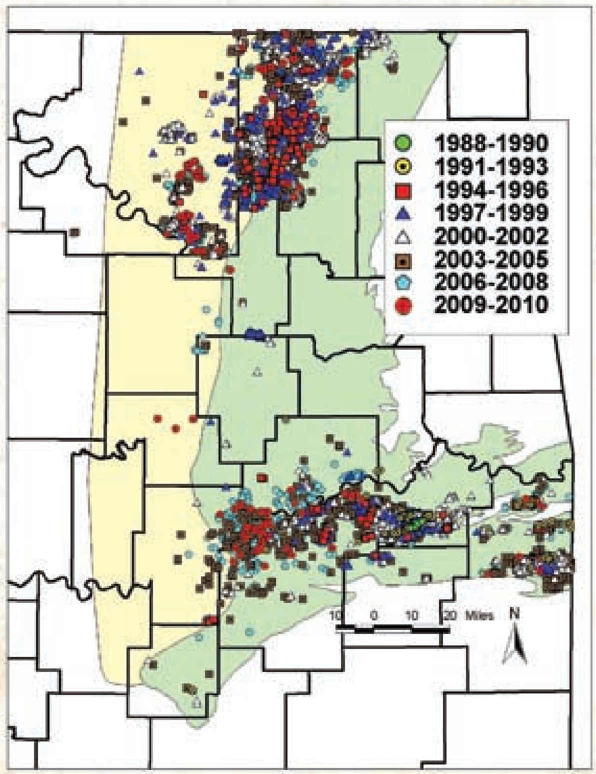
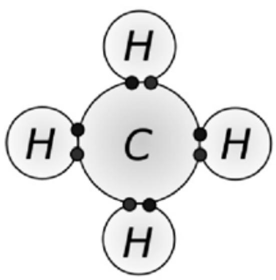


Figure 2: Map showing coalbed-methane well completions in eastern Oklahoma by year.

ACTIVITIES: ANSWERS



1. The covalent compound CH4 is more flammable than ionic compounds because it contains both carbon and hydrogen. When these atoms are heated with oxygen gas, they combust, forming carbon dioxide and water.
2. According to the National Energy Technology Laboratory: “Methane is a potent greenhouse gas, with 21 times the global warming potential of carbon dioxide. In fact, coal mining accounts for about 10% of U.S. methane emissions. Therefore, recovery of CBNG mitigates a large source of methane emissions and allows for economic use of the energy source.” The last sentence is key to understanding how capturing this reduces the release of greenhouse gases into the atmosphere from either working or abandoned coal mines.
3. Coalbed methane can be extracted through vertical and horizontal wells; hydraulic fracturing; and the creation of “gob gas.”

HOW DO OIL AND NATURAL GAS GET OUT OF THE GROUND AND INTO MY CAR AND MY HOUSE?

OIL

Oil is recovered from wells in a variety of ways. For most wells, it is pumped to the surface using the familiar pump jacks that dot the Oklahoma landscape. This method is used when there isn't enough pressure in the underground reservoir where the oil resides to push it to the surface. In most cases, the oil that is produced is accompanied by water. Both of these liquids are treated at the surface in tall separation towers. The water is separated and pumped back into the reservoir where it came from, or into another subsurface (or below ground) reservoir. The oil is stored in large field tanks. Trucks are used to transport oil from surface storage tanks to central distribution hubs. For some wells, oil flows naturally to the surface and is simply stored in field tanks for further distribution. Combined from numerous wells, the oil is piped throughout the country to refineries that distill it to make gasoline, heating oil, jet fuel, diesel fuel, and road tar.

In many wells, oil is recovered simultaneously with natural gas or as a by-product of natural gas. Either way, the oil is separated from the natural gas and stored in field tank batteries until transported to central distribution hubs.

NATURAL GAS

Natural gas is produced from wells that tend to be deeper than those producing oil. In most gas wells, the gas flows naturally to the surface but at extremely different pressures and rates. This depends on internal reservoir pressure and also the amount of porosity and permeability in the reservoir rocks from which it comes. Porosity is a measurement of how much void space occurs in the rock reservoir and therefore affects the natural storage capacity. Permeability is another rock property that measures how easily petroleum (oil and/or gas) passes through the rocks.

In wells that have little reservoir pressure, natural gas must be compressed (pressurized) in order for it to be pumped into distribution pipelines. This is accomplished using large compressors. In most cases, a single compression station will service several gas wells. After treatment to remove water and impurities, the compressed natural gas is piped to distribution plants for sale to large utility companies. They, in turn, add scenting agents to the naturally odorless and colorless gas then make it available to our homes and businesses.

Drilling rig and pump jacks near Quail Springs Mall in northern Oklahoma City.

FINDING HYDROCARBONS

Hydrocarbons are discovered using a variety of scientific tools that measure rock properties and identify the nature of geological formations. All exploration methods involve: 1) the identification of a hydrocarbon source material (usually shale, locally coal) 2) a suitable host rock (the reservoir) to store hydrocarbons, and 3) a hydrocarbon seal (a layer of rock with low permeability to keep the hydrocarbons in the reservoir) that prevents them from escaping. In some places, the source and reservoir rock are the same. Conventional reservoirs consist of sandstone and limestone, whereas shale and coal are considered unconventional reservoirs because of their poor reservoir properties. Hydrocarbons are formed from organic material contained in shale and coal, but often migrate in the subsurface where they become trapped in sandstone and limestone.

Many areas on earth have thick accumulations of sedimentary rocks. These places are always suspect to have the above mentioned requirements for hydrocarbon accumulations. The trick is to find specific areas where it can be produced in sufficient quantities to be economical.

ACTIVITIES:

1. Porosity and permeability are an important part of understanding hydrocarbon exploration. To visualize these, create a model starting with a bud vase several inches tall. From the bottom, add half an inch each of gravel, sand, powdered clay (use flour), sand and more gravel. Carefully pour in colored water and make observations. This point at which water stops passing through easily demonstrates a downward permeability barrier. The amount of void space in the sand and gravel (porosity) can be judged by the presence of the colored water. Discuss what this model would mean for the ability to recover hydrocarbons if it were a real geological formation.
2. In groups, create models of oil and gas reservoirs. Some groups should follow the instructions at www.earthsciweek.org/forteachers/oilres_cont.html while others should follow the methods at www.earthsciweek.org/forteachers/2006/oilandgas_cont.html. Compare and contrast what each model teaches about oil and gas exploration.

ACTIVITIES: ANSWERS

All activity answers for this section will vary.

FINDING HYDROCARBONS

The first step in exploration often is the acquisition of seismic data, which is gathered through the use of a large energy source (dynamite or vibrating trucks) to produce ground-penetrating energy waves. These waves travel downward into the subsurface but are deflected or refracted back to the surface where they are recorded. The nature of the returning waves gives clues on the extent, character, and orientation of subsurface rock formations. Seismic waves are affected by many factors including the nature of the wave, wave source, and rock density to same a few.

A second method of investigation uses well logs, which are recordings of rock properties that are made in existing well bores. Such logs are used extensively in delineating the thickness, extent, and composition of rock formations, including reservoir properties and hydrocarbon saturation.

Once an area is identified that may contain hydrocarbons it becomes known as a "prospect", and the next step is to drill a hole (or well) at the prospect and test for hydrocarbons. In the past, vertical wells were the only method used. But today, about a third or more of the wells are drilled horizontally through the prospective formation. This technique has proved to most effective in recovering oil and natural gas, particularly when the reservoir is artificially fractured to help drain areas where hydrocarbons are otherwise immobile due to low reservoir porosity and/or permeability.

Unconventional Energy Resources - Shale
By
Richard Andrews

Shale comprises about 70% of all sedimentary rocks in the earth's crust. It consists mostly of clay-size particles with lesser amounts of silt, sand, and carbonate minerals. In some places, shale contains considerable amount of organic material and silica making it brittle and potentially rich in petroleum (oil and natural gas) (Fig. 1). Normally, shale lacks effective porosity and is so impermeable that petroleum and water cannot normally seep through it. Now-a-days, however, these brittle and organic rich shales are deliberately drilled and artificially fractured in order to release trapped hydrocarbons which then can be pumped or extracted to the surface. In some places, natural fracturing within the formation also aids in hydrocarbon mobility and extraction (Fig. 2). Because of its poor reservoir properties (lack of significant porosity and permeability), shale is regarded as an unconventional reservoir as compared to traditional petroleum reservoirs such as sandstone and limestone. However, due to improved drilling and recovery techniques, certain shale deposits are considered an attractive hydrocarbon exploration target in many parts of Oklahoma. The most prolific hydrocarbon-bearing shale in Oklahoma is called the Woodford Shale and the location of producing gas and oil wells in this formation is shown in Figure 3.

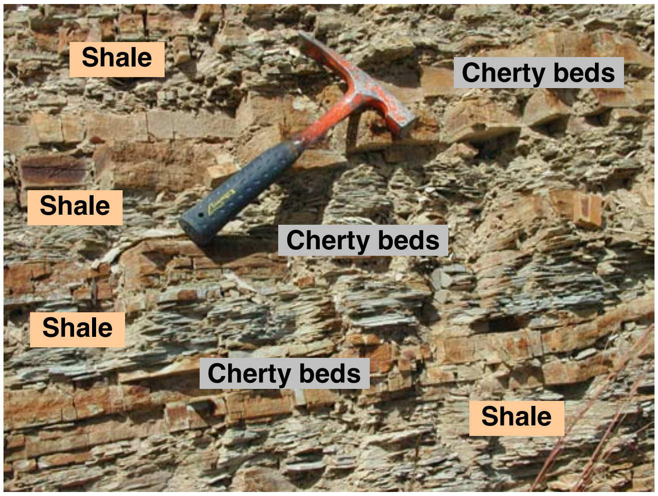


Figure 1. The Woodford Shale consists mostly of interbedded shale and cherty beds. Vertical fracturing is shown to occur in both strata but is most prevalent in the cherty beds.

Figure 2. Because of its high silica content, the Woodford Shale is very brittle both in the subsurface and at surface exposures. Show here are fractures filled with dead oil (bitumen). Location; McAlester Cemetery, southern Oklahoma.

Hydrocarbon production from the Woodford Shale increased steadily each year since 2004 to about 25 billion cubic ft of gas (BCF) annually (Fig. 4). However, low product prices of about $4.5 per thousand cubic ft of gas (MCF) associated with large increases in incremental gas production rates has recently stymied development drilling of this play during the past 12 months. This is noted on the graph by the number of producing wells shown by the blue triangles. Through the first half of 2009 about 486 BCF of natural gas and over 1.5 million barrels oil was produced from the Woodford Shale play in Oklahoma.

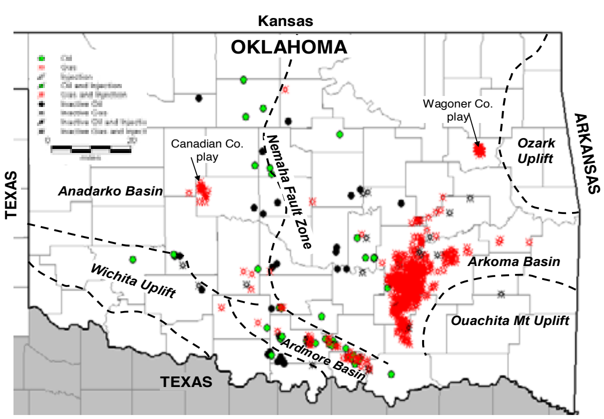


Figure 3. Woodford Shale well completions in Oklahoma (1934 – 2009). See map legend for well symbol explanation. From IHS Energy, 2009.

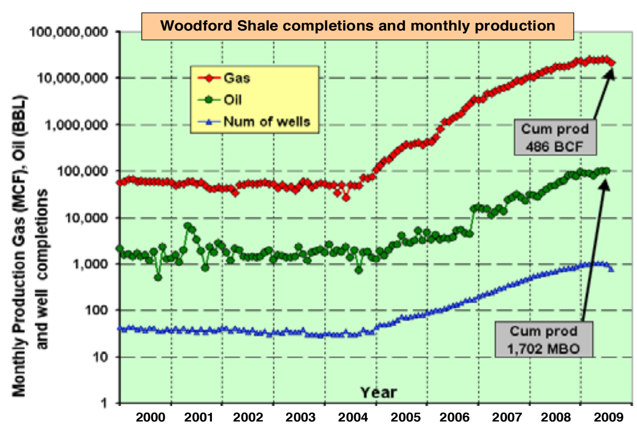


Figure 4. Monthly oil and gas production, and well completions from January 2000 through August 2009. From IHS Energy, 2009

Coal is an important part of the energy picture in Oklahoma, with almost half of the electricity produced in the state generated from coal. Coal is used in five utility (electric utilities include investor-owned, publicly-owned, cooperatives, and Federal utilities) and one nonutility (independent power producer with no assigned service territory) coal-fired power plants in eastern Oklahoma (Figure 1), although not all of the coal used in these plants is mined in the state.

Four mining companies produced about 1.0 million tons of bituminous coal at ten mines in five counties in Oklahoma in 2009 (Figure 2). The six coal-fired power plants in eastern Oklahoma imported 21.8 million tons of subbituminous coal from Wyoming in 2008 (year of latest data from the United States Energy Information Administration, EIA).

According to the EIA, 48 percent of the electricity generated in Oklahoma during 2008 came from coal-fired power plants. During 2008, Oklahoma ranked 22 of 25 coal-producing states, producing 1,469,629 tons of coal compared to U.S. total coal production of 1.17 billion tons.

Coal is an organic-rich sedimentary rock made up of altered plant fragments from trees that once grew in a swamp about 300 million years ago in what is now Oklahoma. Depending on the types of plant parts that were preserved in water, banded coals (like those found in Oklahoma) can have different amounts and types of organic matter and mineral matter in layers called lithotypes. With increasing heat, pressure and burial depth, coal becomes harder and darker and physical and chemical changes occur. During this process, the coal increases in rank from the sedimentary deposit called peat, which is brown in color and soft enough to shovel, to the sedimentary coal rock types of lignite, subbituminous, bituminous, semianthracite and anthracite. As the rank increases, so does the energy content of the coal.

Bituminous rank coals of Pennsylvanian age occur in the commercial coalfield in eastern Oklahoma. Of an estimated 8 billion tons of remaining bituminous coal resources (the amount of coal left in the ground) in Oklahoma, as determined by OGS geologists, there are 1.6 billion tons of reserves (the coal that can be mined economically) according to the EIA.

Surface mines in Oklahoma remove coal at depths less than 100 feet deep and use big equipment like draglines, shovels, and bulldozers (Figure 3) to move and load rock. Oklahoma's only currently active underground coal mine operates at a depth of about 600 feet. It is in Le Flore County in the Hartshorne coal and is a room and pillar mine. The deepest underground coal mine in Oklahoma had a depth of 1,600 feet.

ACTIVITIES:

1. If Oklahoma produces about 1 million tons of coal each year and the U.S. produces about 1.17 billion tons each year, what percentage of U.S. coal production does Oklahoma produce?
2. Look at the provided map showing coal activity in Oklahoma. Geologically speaking, why do you think this area of the state developed such rich coal resources?
3. Open Oklahoma's "Coal Production Database" from www.ogs.ou.edu/coaldb.php. Which county produced the most coal from 1908 through 2008? Why do you think the percentage coming from surface mines increased throughout the mid 1900s but began decreasing around 1990? What other trends do you notice in the data?

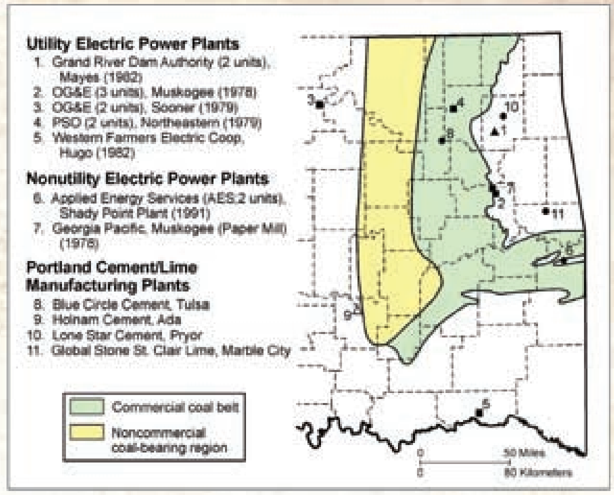


Figure 1: Map of coal consumers in Oklahoma of Wyoming coal (■), Oklahoma coal (●), Wyoming/Oklahoma coal blend (▲), and coal source from other states (△).

Source: OGS Information Series 9, pg. 9

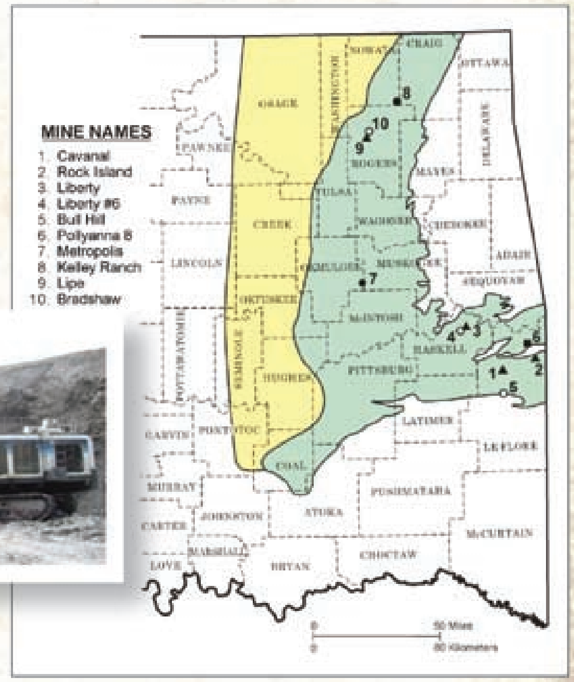


Figure 2: Map locating coal mines active in eastern Oklahoma in 2009. Numbers correspond to mine name. A solid square indicates an underground mine. Open circles indicate mines opened in 2009. Solid triangles indicate mines closed in 2009. The green area is the commercial coal belt; the yellow area is the noncommercial coal-bearing region.

Figure 3: Strip mines use big equipment to remove the overburden then load and haul the coal. OGS coal geologist Brian Cardott stands in front of a large truck and shovel, showing just how massive much of this equipment can be.

ACTIVITIES: ANSWERS

1. Oklahoma produces about .085 percent of U.S. coal production each year.
2. Eastern Oklahoma has a great deal of Pennsylvanian rocks, which contain large coal reserves. To see the Pennsylvanian rocks in a cross section along with a map of the major geological provinces in Oklahoma, download http://s3.amazonaws.com/content.newsok.com/newsok/images/NIE/nie_docs/OKRocksP3MapwithCrossSections.pdf.
3. LeFlore County produced the most coal from 1908 through 2008 (36,336,870 short tons). According to the coal production histogram (http://www.ogs.ou.edu/coal/images/coalprod73rep409.jpg), most coal came from

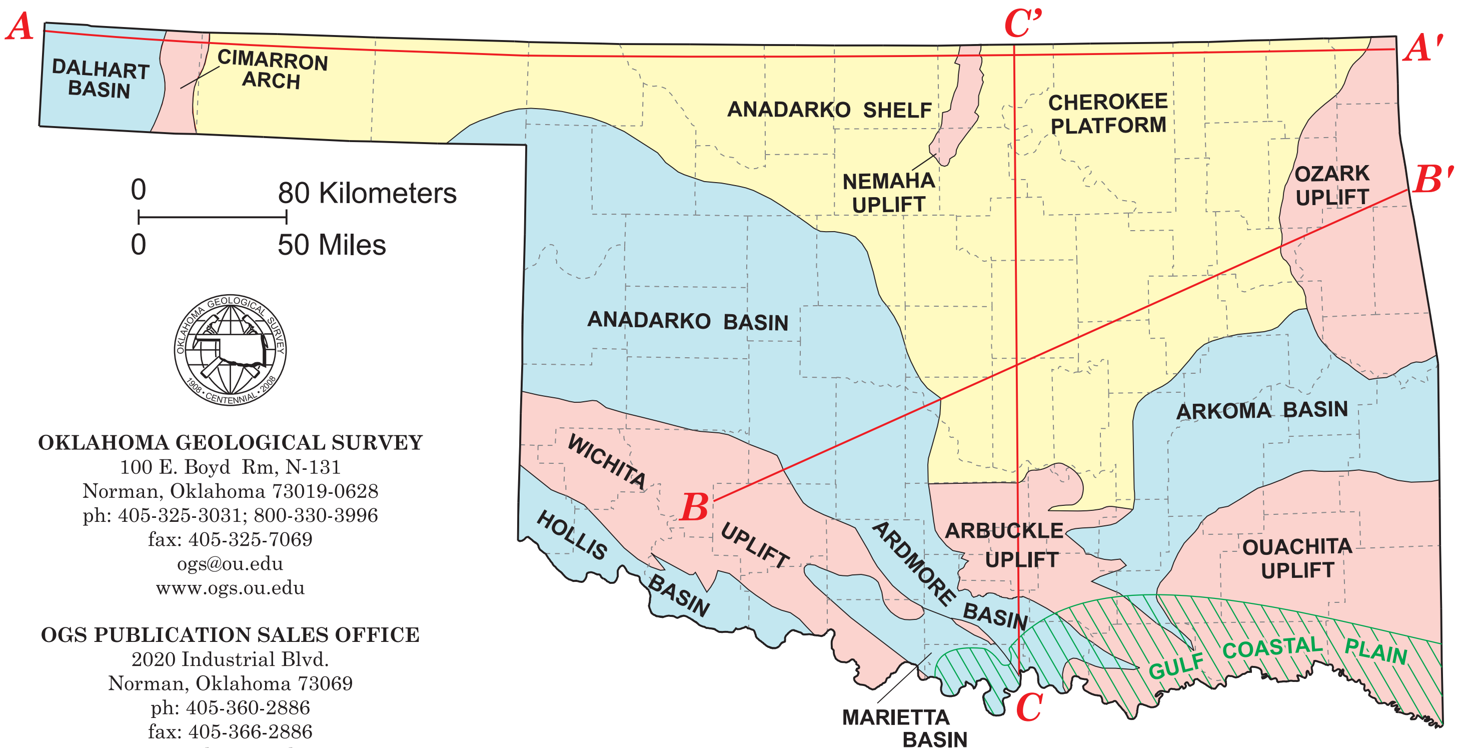
UNDERGROUND coal mines before about 1940. The first surface coal mines in Oklahoma were in 1915 when machines were able to perform more of the digging instead of the pick and shovel used in underground coal mines to that time. Most coal came from surface mines after about 1940. The reason that an increasing percentage of coal came from underground coal mines after about 1990 is because one coal operator (GCI) located a coal permit with a sizeable underground coal resource.

Other answers will have some variation.

OTHER RELATED MATERIAL ABOUT OKLAHOMA'S GEOLOGY AND COAL RESOURCES

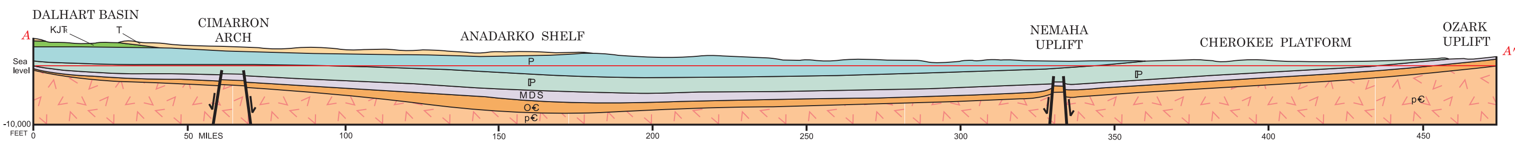
- Educational Publication 9
  http://www.ogs.ou.edu/level2-earthscied.php
- Geologic provinces map and cross sections
  http://www.ogs.ou.edu/MapsBasic/Provinces_crosssec.pdf
- Geologic map of Oklahoma
  http://www.ogs.ou.edu/geolmapping/Geo_mapOK1954.pdf
- OGS Educational Publication 9 (scroll down to access all or parts of the publication)
  http://www.ogs.ou.edu/level2-earthscied.php
- Oklahoma Generalized Geologic Time Scale
  http://www.ogs.ou.edu/pubsscanned/EP6geoTimescaleChart.pdf

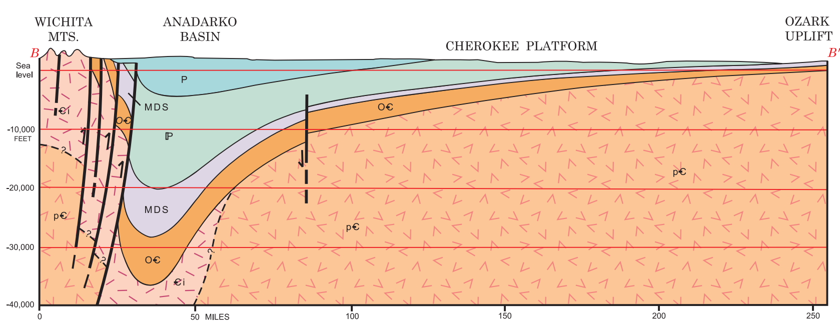
MAJOR GEOLOGIC PROVINCES OF OKLAHOMA

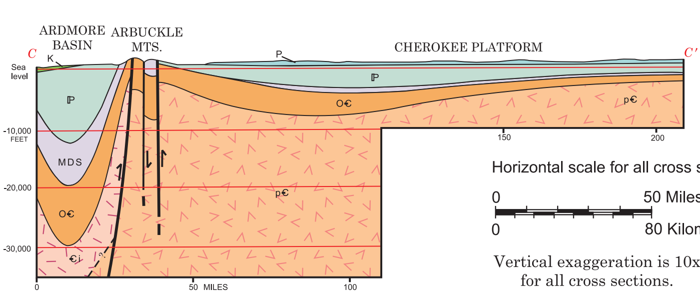


OKLAHOMA GEOLOGICAL SURVEY
100 E. Boyd Rm, N-131
Norman, Oklahoma 73019-0628
ph: 405-325-3031; 800-330-3996
fax: 405-325-7069
ogs@ou.edu
www.ogs.ou.edu

OGS PUBLICATION SALES OFFICE
2020 Industrial Blvd.
Norman, Oklahoma 73069
ph: 405-360-2886
fax: 405-366-2886
ogssales@ou.edu







Vertical scale for all cross sections

0 — 0

-10,000 Feet — -3,000 Meters

Horizontal scale for all cross sections

0 — 50 Miles

0 — 80 Kilometers

Vertical exaggeration is 10x for all cross sections.

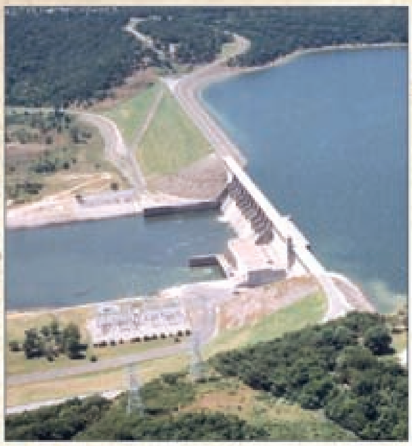
EXPLANATION

- T — Tertiary
- K — Cretaceous
- KJTr — Cretaceous, Jurassic, and Triassic
- P — Permian
- ℙ — Pennsylvanian
- MDS — Mississippian, Devonian, and Silurian
- OЄ — Ordovician and Cambrian (sedimentary rocks)
- Єi — Cambrian (igneous and metamorphic rocks)
- pЄ — Precambrian


Fault; arrow shows relative movement

Oklahoma Geological Survey
Mewbourne College of Earth and Energy
The University of Oklahoma
Norman, Oklahoma
2008

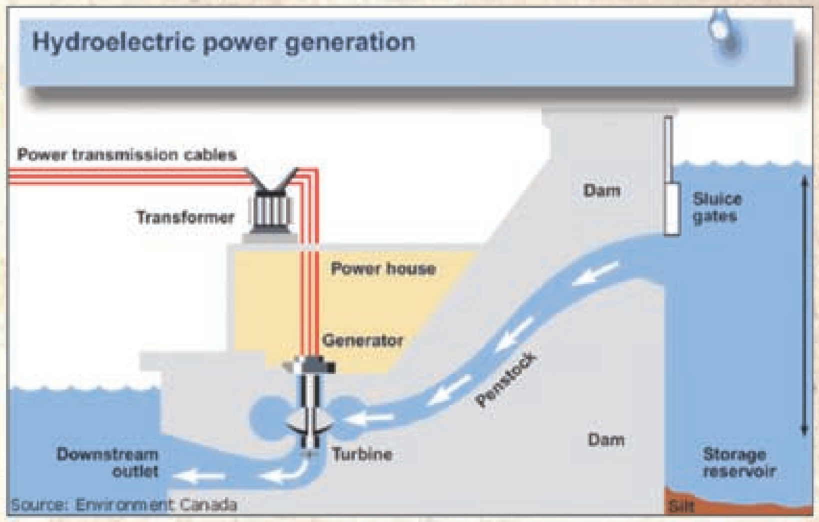
HYDROELECTRIC POWER IN OKLAHOMA



Eufaula Dam on the Canadian River in eastern Oklahoma, where most of Oklahoma's hydroelectricity generating dams are located.

SIX OF OKLAHOMA'S 12 HYDROELECTRIC POWER PLANTS

1. Broken Bow
capacity 116 MW (USACE)
2. Eufaula Dam
102 MW
3. Robert S. Kerr
128 MW
4. Markham Ferry
114 MW (GRDA)
5. Salina
260 MW (GRDA)
6. Pensacola
120 MW (GRDA)



Most of us are well aware of the power of water. It can carve scenery as majestic as the Grand Canyon and can devastate cities overnight. It is an essential ingredient for farmers in the nation's breadbasket and allows us to transport goods throughout the country and the world. Water wheels enabled early industries to flourish in 16th and 17th century America. And water can generate the electricity that is so important to our modern way of life.

Hydroelectric power generation, also known as hydropower, is a clean, pollution-free, renewable domestic energy resource. It uses the natural power of flowing water and the simple principal of gravity to generate electricity. Hydropower provides about 10 percent of our nation's electrical generating capability and represents most of our renewable energy resource base. In Oklahoma, about 7 percent of our electricity comes from hydropower. Unlike some forms of power generation, there are many additional benefits to hydropower — the dams that must be built provide a water supply for drinking, irrigation, and recreation; flood control; and navigation. An additional advantage of hydropower is that it can easily be "turned off and on," in other words, water can be released to generate electricity during peak-demand times such as summer afternoons when air conditioning is needed, and water can be held back at night and in the morning.

There are some disadvantages to hydropower; the greatest probably are the changes in aquatic ecology. This includes the flooding of river valleys and the effect on local plant and animal life, changes in water quality, and the interruption of fish migration patterns. Also, there is a limit to the number of dams that can be built.

There are 12 dams in Oklahoma that generate hydropower. Not surprisingly, most are in eastern Oklahoma where rainfall is greatest, rivers are larger, and the topography and geology allow for dams and reservoirs. Three are on the Grand River — Ft. Gibson, Markham Ferry, and Pensacola, and four are on the Arkansas River — Robert S. Kerr, Webbers Falls, Keystone, and Kaw. In addition, Broken Bow Dam is on the Mountain Fork, Tenkiller Ferry Dam is on the Illinois River, Eufaula Dam is on the Canadian River, Denison Dam is on the Red River, and the Salina Pumped Storage Project is on Chimney Rock Hollow.

ACTIVITIES:

1. Create a water wheel using two disc-shaped objects and cups from an egg carton, as shown in the picture. Poke a small hole in the bottom of an empty water bottle, plug the hole while filling it, and then let the water flow over the wheel. Count the number of rotations and record this along with the diameter of the hole. Repeat this process two more times, enlarging the hole each time. Graph your results and summarize your conclusions.
2. In the year 2000, Eufaula Dam produced 280,728 MWH of energy. If the average U.S. household uses about 9,000 KWH of electricity each year, how many households did Eufaula Dam provide electricity for during the year? (Remember, 1 MWH = 1,000 KWHs.) How many households (not the same as the number of people) are in your town? If Eufaula Dam supplies the same amount of energy this year as it did in 2000, could it supply your town with enough electricity for the year?
3. Go to www.swpa.gov/agency.aspx and click on "SWPA — Overview Video." Watch the video and answer the following questions. According to the Southwestern Power Administration, what are some of the advantages of hydropower over other forms of power generation? What was the original purpose for building some of the earlier dams in this part of the country? Put the following paths of water in hydropower dams in order: **(A)** Turbine **(B)** Penstock **(C)** River **(D)** Reservoir. How is the power produced in this way especially valuable during peak demand?

12

ACTIVITIES: ANSWERS

The Southwestern Power Administration (an agency of the U.S. Department of Energy) markets the power from the dams operated by the U.S. Army Corps of Engineers (superscript 1 below) and the Grand River Dam Authority (an agency of the State of Oklahoma) markets the power from its dam (superscript 2 below). Kaw Dam is operated by the USACE, but the hydroelectric plant is owned and operated by the Oklahoma Municipal Power Authority, another Oklahoma state agency.

There are 12 dams in Oklahoma that generate hydropower. Three are on the Grand River – Ft. Gibson1, Markham Ferry[2], and Pensacola[2], and four are on the Arkansas River — Robert S. Kerr[1], Webbers Falls[1], Keystone[1], and Kaw. In addition, Broken Bow Dam1 is on the Mountain Fork, Tenkiller Ferry Dam[1] is on the Illinois River, Eufaula Dam[1] is on the Canadian River, Denison Dam[1] is on the Red River, and the Salina Pumped Storage Project[2] is on Chimney Rock Hollow.

1. Answers will vary.
2. In the year 2000, Eufaula Dam produced enough energy to provide electricity for about 31,192 households. The remainder of the answer will vary.
3. **Part 1:** What are some of the advantages of hydropower over other forms of power generation? Hydropower has the following advantages: It is more cost efficient for consumers during peak use times; its federal regulation helps keep utility rates low; it leads to less dependence on fossil fuels; and it generates less air pollution.

   Part 2: Early dams were originally built for flood control.

   Part 3: Water in hydropower dams follows the following path: (D) Reservoir (B) Penstock (A) Turbine (C) River.

   Part 4: Hydropower is especially valuable during peak demand because it saves consumers from purchasing peak power at higher rates and from the need to build more generating plants to meet demand.

Net electricity generation: 320,000 MWh (1.7% of US) from hydro. Total net electricity generation 4,615,000 MWh (So hydro provides ~7%); ~7% from renewables, mostly wind and hydro

Pensacola Dam: 1938–1941. First hydroelectric facility built in OK, longest multiple-arch dam in U.S. Creates Grand Lake O' the Cherokees.

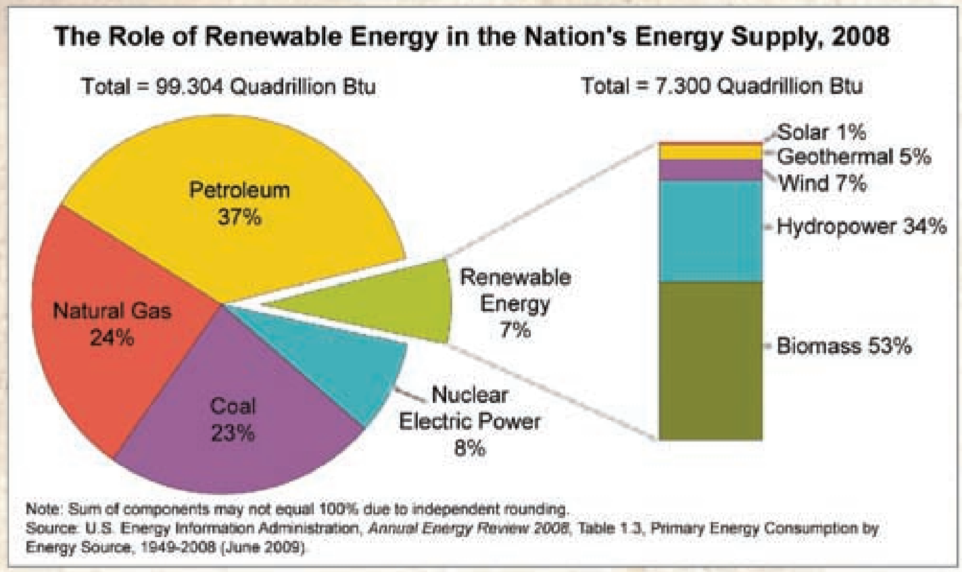
RS Kerr Dam: 1958–1964. Originally Markham Ferry Project. Creates Lake Hudson. Salina Pumped Storage Project.

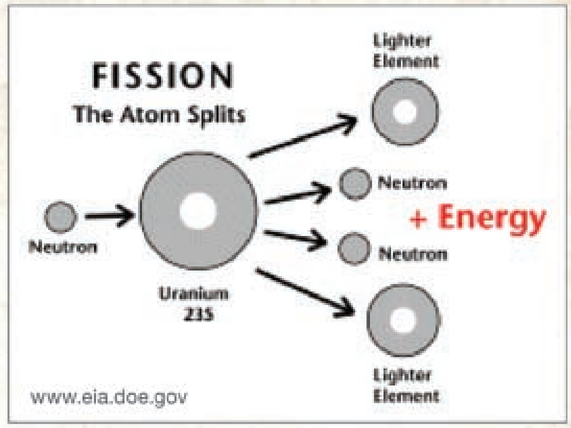
Denison Dam: On Red River. Built by USACE, completed in 1944, impounds Lake Texoma. At time was "largest rolled-earth fill dam in the world". Produces ~250,000 MWh electricity/yr.

Kay Dam: Built by USACE. OK Municipal Power Authority purchased substructure of dam in 1987 and constructed hydroelectric plant. Kaw Hydroelectric generates ~104 gigawatt hrs annually. Provides power for over 35 municipal electrical systems

RESOURCE LINK

- http://ga.water.usgs.gov/edu/hyhowworks.html
- http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=OK
- http://www.eia.doe.gov/cneaf/electricity/st_profiles/oklahoma.html
- http://www.eia.doe.gov/cneaf/solar.renewables/page/state_profiles/oklahoma.html
- http://govguru.com/oklahoma/hydropower-or-hydroelectric-power
- http://www.eia.doe.gov/cneaf/solar.renewables/page/hydroelec/hydroelec.html
- http://www.nrel.gov/docs/fy04osti/34916.pdf. good book. see below.
- http://www.swpa.gov/agency.aspx, click on SWPA – Overview video
- http://www.nrel.gov/docs/fy04osti/34916.pdf
- For information on Grand River Dam Authority, http://www.grda.com/Electric/transmission.html
- For hydropower operational details (i.e., power generation during peak demand), go to http://www.swt-wc.usace.army.mil/ops_hydropower/KEYShydro.html





Nuclear energy is a controversial issue with some groups and individuals, sometimes because this technology is poorly understood. However, according to the Nuclear Regulatory Commission website, "there are currently 104 licensed to operate nuclear power plants in the United States (69 PWRs and 35 BWRs), which generate about 20 percent of our nation's electrical use." These power plants have operated for decades with only one significant incident (Three Mile Island in Pennsylvania) in which a small amount of radioactive material was released. Studies made since that time have found no perceptible increase in the occurrence of cancer in people living nearby.

An important issue with nuclear energy is the disposal of the high-level nuclear waste that is produced by the process. According to the NRC: "High-level radioactive wastes are the highly radioactive materials produced as a byproduct of the reactions that occur inside nuclear reactors. High-level wastes take one of two forms:

- Spent (used) reactor fuel when it is accepted for disposal
- Waste materials remaining after spent fuel is reprocessed

Spent nuclear fuel is used fuel from a reactor that is no longer efficient in creating electricity because its fission process has slowed. However, it is still thermally hot, highly radioactive, and potentially harmful. Until a permanent disposal repository for spent nuclear fuel is built, licensees must safely store this fuel at their reactors." Unfortunately, finding a disposal site for this waste has proven to be a highly charged subject, and no site has been approved.

Nonetheless, nuclear power probably will be a significant factor if we are to reduce the production of greenhouse gases.

ACTIVITIES:

1. Nuclear power plants rely on a process called nuclear fission to produce energy. Nuclear fission occurs when one atom splits into two, which generates radiation and heat, which in turn creates pressurized steam, which drives a turbine generator and thus generates power. Uranium-235 is generally used to fuel nuclear power plants because it is the heaviest of all naturally occurring elements and therefore contains a great deal of concentrated energy.

   Using this diagram of nuclear fission as a starting reference, complete the following table for a chain reaction caused by fission.

EVENT	1	2	3	4	5	6
REACTIONS	1	3	#	#	#	#
RESULTING NEUTRONS (including original)	3	9	#	#	#	#

2. Run the nuclear fission simulation at http://phet.colorado.edu/en/simulation/nuclear-fission and complete the accompanying worksheet at http://phet.colorado.edu/files/activities/3249/Nuclear Fission Simulation.doc.
3. Nuclear waste is the radioactive waste left over from nuclear reactors, nuclear research projects and nuclear bomb production. Visit the U.S. Nuclear Regulatory Commission online at www.nrc.gov to research the difference between low-level and high-level nuclear waste, the location of current waste disposal sites, and the health impact of radiation. Devise your own plan to contain, transport and store nuclear waste.

ACTIVITIES: ANSWERS

1. See chart above. **(NEED ANSWERS)**
2. Answers will vary.
3. Answers will vary.

WIND ENERGY

Wind power is the fastest growing energy source in the world. It is not only a clean and renewable source of electricity, but it can also be cost competitive. Oklahoma alone has enough wind resource potential to supply almost 10 percent of the nation's electricity needs (Oklahoma Wind Power Initiative, Wind Resource Economic Analysis, 2002). Currently, approximately 3 percent of Oklahoma's electricity generation is from wind power. The benefits of wind power are not just available in the large-scale setting of wind farms where the generated power is sold to electrical utilities. Economically beneficial applications using commercial-sized wind turbines on a smaller scale also are possible. For example, schools and businesses have the ability to lower their electricity bills through the ownership and operation of wind turbines.

Large utility-scale wind turbines.

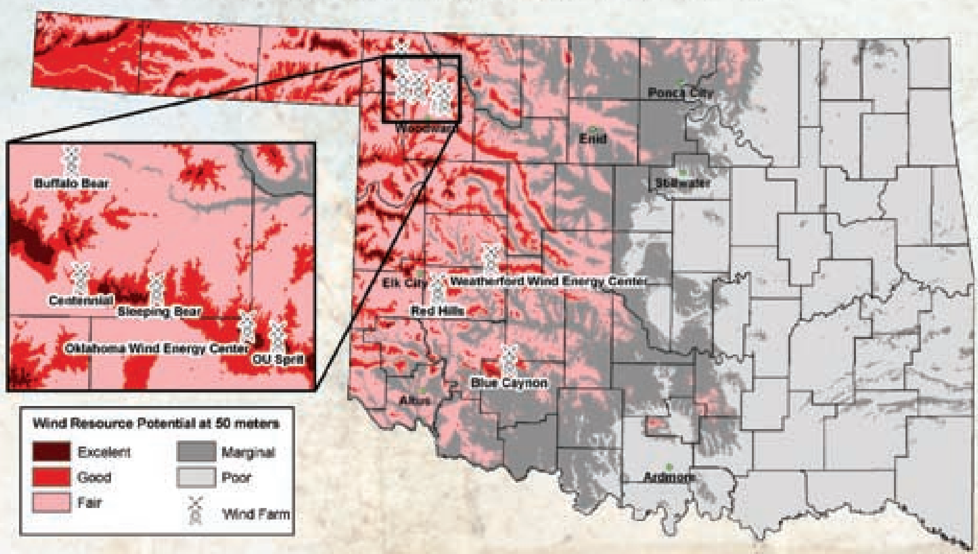
Presently, the large turbines making up Oklahoma's wind power farms cost in excess of $1 million each to purchase and install, accounting for investments of more than $100 million per wind farm in Oklahoma. This is known as "utility-scale" wind development and is in the realm of large investors.

Many people are interested in powering their homes and businesses with much smaller turbines. Such turbines, which are approximately 10 kW in size as opposed to their utility-scale counterparts which are 1 MW in size, are cheaper but less efficient than the larger units. Small wind turbines have a longer payback period and, at best, can provide modest amounts of energy to the power grid. They can provide solutions to those who are off the grid, have a very high wind resource, or are environmentally conscientious. Between these scales is "community wind." Community wind involves local ownership of turbines bigger than those used by small applications.

There are both advantages and disadvantages of wind power. Many of the advantages are obvious: wind power is pollution-free renewable energy with a low environmental impact. Although not free or inexpensive, start-up and maintenance costs make it competitive with electricity generation from natural gas. Some disadvantages include the following issues: dependence on the weather (need continuous wind of 16 to 60 mph for electricity generation); requires a backup energy source to generate electricity on calm days; can be damaged or interrupted by high winds and lightning in stormy weather; costs escalate if turbines are not located near existing infrastructure; utility wind farms require a large number of turbines over a large area to replace even a small gas-fired power plant; undesirable appearance; may impact bird migratory routes; may produce noise; wind energy cannot be easily stored; and can cause interference for some nearby electrical appliances.

ACTIVITIES:

1. Design and create pinwheels with blades of different shapes. Consider using different materials like paper and plastic spoons. Take the models outside on a breezy day and measure the number of rotations for 1 minute. In addition to the design variable, take measurements on different sides of the school building. Graph your data and summarize your findings. What can you conclude about determining the design and placement of wind turbines from your experiment?
2. Watch the video at www.thefutureschannel.com/dockets/science_technology/wind_farming. Addressing the factors mentioned in the video, what reasons do you think would make Oklahoma a good place for building a wind farm? Which factors would not make Oklahoma a good location? What economic impact might a wind farm have on the state and on consumers? After developing your hypotheses, visit www.seic.okstate.edu/owpi to learn more about existing wind power in Oklahoma.



Wind resource map and wind farms in Oklahoma.

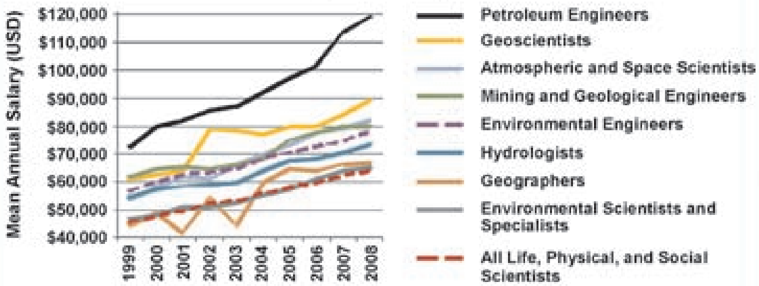
Wind power information courtesy of the OWPI, a joint project between the University of Oklahoma and Oklahoma State University to promote wind power development. *Source: http://www.seic.okstate.edu/owpi/ and Oklahoma Wind Power Initiative, 100 East Boyd St., SEC Room 410, Norman, OK 73019.*

ACTIVITIES: ANSWERS

All activity answers for this section will vary.

Trends Over the Past Decade

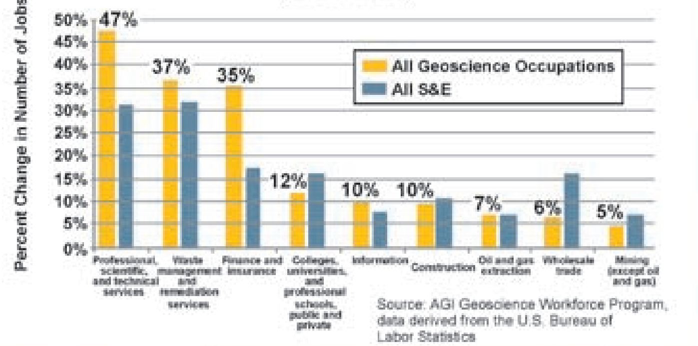
Mean Annual Salaries of Geoscience Professions (1999-2008)



Source: AGI Geoscience Workforce Program, data derived from the U.S. Bureau of Labor Statistics, National Occupational Employment and Wage Estimates, 1999-2008

Looking to the Future

Geoscience and Science & Engineering Projected Job Growth (2006-2016)



Source: AGI Geoscience Workforce Program, data derived from the U.S. Bureau of Labor Statistics

EDUCATION FOR ENERGY, THE ENVIRONMENT, AND OUR FUTURE

- There are more than 76,000 jobs in Oklahoma in the energy industry.
- The average age of petroleum professionals in Oklahoma is 54. Right now, there's an opportunity for young people to get into the industry and advance quickly as these professionals retire.
- One in seven jobs in Oklahoma is directly or indirectly supported by the oil and natural gas industry.

(Source: OERB career information on http://www.oerb.com/)

When you read the news today, you may notice that many of the headlines feature stories about our current and future supply of energy, conservation, the environment, climate change, natural hazards such as earthquakes and volcanoes, and the problems we face in regard to those issues. There are many things that individuals can do to help solve some of these problems and all of us are eager to learn how we can conserve resources and live as better citizens of this planet.

One way we might help is by choosing a career in the earth sciences. There are many types of roles in this field.

- **Geologists:** study the earth's material makeup and history.
- **Geophysicists:** examine the properties of the earth and monitor such events as earthquakes and volcanoes.
- **Geological engineers:** use engineering principles to solve problems related to geological issues such as landslides, mining and road construction.
- **Hydrologists:** study water and its actions.
- **Geographers:** study the surface of the earth, the terrain, and the movement and interaction of the populations who live there.
- **Meteorologists:** study weather and climate, which are important for placement of wind farms among other things.
- And many other professions, too.

While some jobs in these fields might require years of college, many important energy and conservation jobs will not, and Oklahoma's excellent career tech programs are already preparing many young people for exciting careers in these fields. Many who work in the energy and conservation fields will play important roles as welders, accountants, utility company workers, truck drivers, roughnecks, and drill rig operators.

Those who work in the earth sciences and the related trades will become even more important in the coming years. While there is satisfaction in being part of this effort, there also are financial rewards for careers in earth sciences.

OGS Director Dr. Randy Keller reminds students that in addition to the geosciences being interesting and relevant to our daily lives, studies show:

- Current low enrollments and degrees granted point to a serious shortage of geosciences graduates in the near future.
- Demand continues to increase for geoscientists, but a Master's degree is the minimum required for the best jobs. Most students receive sustantial financial support for graduate degrees.
- Geosciences salaries will continue to lead salaries for scientists.

The geosciences community plays a leading role in seeking solutions to many scientific and societal challenges, and many human and physical resources will be needed in this process. This will involve new instrumentation, large research and data acquisition efforts, major innovations, complex computer simulations, and a new generation of young people eager to meet these challenges. Do you want to play a role in America's energy future?

ACTIVITY:

1. Find the salaries of energy sector jobs by going to www.bls.gov/oes/oes_dl.htm and downloading the "National Sector NAICS Industry-Specific Estimates" file. Focus on titles with NAICS number 21 or 22, which include most energy sector jobs. Create bell curves showing the annual wages by percentile of three different careers.

15

ADDITIONAL ACTIVITY

2. Identify someone in your community who works in the energy industry. Remember, this person may work in any number of capacities for an energy company, government agency, media outlet and more. Ask them to come speak to your class about working in the energy industry, or interview them about their career choice.

ACTIVITIES: ANSWERS

All activity answers for this section will vary.

EXPLORING ENERGY LESSON ACTIVITIES

LESSON 1: MYTHS & MISCONCEPTIONS

1. Answers will vary.
2. Answers will vary.
3. Among countries with data for all six years of 2004 through 2009, the U.S. has become most significantly more reliant on crude oil imports — statistically — from Azerbaijan, making a 98.2% jump from 484,000 barrels in 2004 to 27,516,000 barrels in 2009. The U.S. has become most significantly less dependent on imports from Uruguay, falling 5,332% from 2,064,000 barrels in 2004 to 38,000 barrels in 2009. In absolute numbers among countries with complete data, the U.S. was most reliant in 2009 on imports from Canada (904,914,000 barrels) and least reliant on imports from Hungary (14,000 barrels).

LESSON 2: HUMAN & ENVIRONMENTAL HAZARDS

1. Answers will vary.
2. Answers will vary. The following sites will help with providing major disasters that students may include.
   Oil spills: http://geology.com/articles/largest-oil-spills-map
   Nuclear power: www.atomicarchive.com/Reports/Japan/Accidents.shtml
   Coal mining: www.sourcewatch.org/index.php?title=Coal_mining_disasters

LESSON 3: CONSERVATION

1. Answers will vary.
2. According to the NPR graphic: "The power systems in the U.S. run primarily on AC power, and power utilities rely on these AC➔DC➔AC converters to control the power flow between any two separate transmission system. The converters, which can cost more than $50 million, act like air locks between regional power grids, enabling the precise control of the energy between systems."
3. Answers will vary.

LESSON 4: OTHER RENEWABLE SOURCES

All activity answers for this lesson will vary.

LESSON 5: INVESTING IN OKLAHOMA'S FUTURE

All activity answers for this lesson will vary.

LESSON 6: EVALUATING WHAT YOU'VE LEARNED

All activity answers for this lesson will vary.

NEED MORE INFO & RESOURCES?

OGS Educational Publication 9 has it.

Just go to http://www.ogs.ou.edu/level2-earthscied.php for more information about Oklahoma geology, geologic history, and geologic ages, as well as numerous resources.

RESOURCE LINKS

- Oklahoma Geological Survey
  www.ogs.ou.edu/homepage.php
- U.S. Energy Information Administration
  www.eia.doe.gov
- U.S. Energy Information Administration Energy Kids
  www.eia.doe.gov/kids/index.cfm
- National Energy Technology Lab
  www.netl.doe.gov
- Oklahoma Department of Commerce
  www.okcommerce.gov
- Green Learning
  www.re-energy.ca
- Physics Education Technology Project
  http://phet.colorado.edu/en/for-teachers/browse-activities
- http://ga.water.usgs.gov/edu/hyhowworks.html
- http://education.usgs.gov/
- http://www.agiweb.org/index.html
- Energy website designed for children
  http://www.eia.doe.gov/kids/
- Explanation of energy units and information about comparing and converting them at
  http://tonto.eia.doe.gov/energyexplained/print.cfm?page=about_energy_units
- U.S. energy consumption and production by fuel type
  http://tonto.eia.doe.gov/energyexplained/print.cfm
- Fuel costs for electricity generation (not including nuclear or renewables)
  http://www.eia.doe.gov/cneaf/electricity/epa/figes4.html
- Good source for discussion on Oklahoma Energy Sources
  http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=OK
- Visualizing US electric grid
  http://www.npr.org/templates/story/story.php?storyId=110997398
- Natural gas powered plants in the U.S.
  http://www.powermag.com/issues/cover_stories/Map-of-natural-gas-power-plants-in-the-United-States-by-nameplate-capacity-and-total-production-costs_1360.html

Exploring Energy
Priority Academic Student Skills (PASS) standards addressed
Grades 7-12

CORE CURRICULUM: SCIENCE

GRADES 7-8

SCIENCE PROCESSES AND INQUIRY

Process Standard 1: Observe and Measure - Observing is the first action taken by the learner to acquire new information about an object, organism, or event. Opportunities for observation are developed through the use of a variety of scientific tools. Measurement allows observations to be quantified.

1. Identify qualitative and/or quantitative changes given conditions (e.g., temperature, mass, volume, time, position, length) before, during, and after an event.
2. Use appropriate tools (e.g., metric ruler, graduated cylinder, thermometer, balances, spring scales, stopwatches) when measuring objects, organisms, and/or events.
3. Use appropriate System International (SI) units (i.e., grams, meters, liters, degrees Celsius, and seconds); and SI prefixes (i.e., micro-, milli-, centi-, and kilo-) when measuring objects, organisms, and/or events.

Process Standard 3: Experiment - Experimenting is a method of discovering information. It requires making observations and measurements to test ideas.

1. Ask questions about the world and design investigations that lead to scientific inquiry.
2. Evaluate the design of a scientific investigation.
3. Identify variables and/or controls in an experimental setup: independent (tested/ experimental) variable and dependent (measured) variable.
4. Identify a testable hypothesis for an experiment.
5. Design and conduct experiments.
6. Recognize potential hazards and practice safety procedures in all science activities.

Process Standard 4: Interpret and Communicate - Interpreting is the process of recognizing patterns in collected data by making inferences, predictions, or conclusions. Communicating is the process of describing, recording, and reporting experimental procedures and results to others. Communication may be oral, written, or mathematical and includes organizing ideas, using appropriate vocabulary, graphs, other visual representations, and mathematical equations.

1. Report data in an appropriate method when given an experimental procedure or data.
2. Interpret data tables, line, bar, trend, and/or circle graphs.
3. Evaluate data to develop reasonable explanations, and/or predictions.
4. Accept or reject hypotheses when given results of an investigation.
5. Communicate scientific procedures and explanations.

Process Standard 5: Inquiry - Inquiry can be defined as the skills necessary to carry out the process of scientific or systemic thinking. In order for inquiry to occur, students must have the opportunity to ask a question, formulate a procedure, and observe phenomena.

1. Use systematic observations, make accurate measurements, and identify and control variables.
2. Use technology to gather data and analyze results of investigations.
3. Review data, summarize data, and form logical conclusions.
4. Formulate and evaluate explanations proposed by examining and comparing evidence, pointing out statements that go beyond evidence, and suggesting alternative explanations.

GRADES 9-12

SCIENCE PROCESSES AND INQUIRY

Process Standard 1: Observe and Measure - Observing is the first action taken by the learner to acquire new information about an object or event. Opportunities for observation are developed through the use of a variety of scientific tools. Measurement allows observations to be quantified.

1. Identify qualitative and quantitative changes given conditions (e.g., temperature, mass, volume, time, position, length) before, during, and after an event.
2. Use appropriate tools (e.g., metric ruler, graduated cylinder, thermometer, balances, spring scales, stopwatches) when measuring objects and/or events.
3. Use appropriate System International (SI) units (i.e., grams, meters, liters, degrees Celsius, and seconds); and SI prefixes (i.e. micro-, milli-, centi-, and kilo-) when measuring objects and/or events.

Process Standard 3: Experiment - Experimenting is a method of discovering information. It requires making observations and measurements to test ideas.

1. Evaluate the design of a physical science investigation.
2. Identify the independent variables, dependent variables, and controls in an experiment.
4. Identify a hypothesis for a given problem in physical science investigations.
5. Recognize potential hazards and practice safety procedures in all physical science activities.

Process Standard 4: Interpret and Communicate - Interpreting is the process of recognizing patterns in collected data by making inferences, predictions, or conclusions. Communicating is the process of describing, recording, and reporting experimental procedures and results to others. Communication may be oral, written, or mathematical and includes organizing ideas, using appropriate vocabulary, graphs, other visual representations, and mathematical equations.

1. Select appropriate predictions based on previously observed patterns of evidence.
2. Report data in an appropriate manner.
3. Interpret data tables, line, bar, trend, and/or circle graphs.
4. Accept or reject hypotheses when given results of a physical science investigation.
5. Evaluate experimental data to draw the most logical conclusion.
6. Prepare a written report describing the sequence, results, and interpretation of a physical science investigation or event.
7. Communicate or defend scientific thinking that resulted in conclusions.
8. Identify and/or create an appropriate graph or chart from collected data, tables, or written description.

Process Standard 5: Model - Modeling is the active process of forming a mental or physical representation from data, patterns, or relationships to facilitate understanding and enhance prediction.

1. Interpret a model which explains a given set of observations.

2. Select predictions based on models.
3. Compare a given model to the physical world.

Process Standard 6: Inquiry - Inquiry can be defined as the skills necessary to carry out the process of scientific or systemic thinking. In order for inquiry to occur, students must have the opportunity to ask a question, formulate a procedure, and observe phenomena.

1. Formulate a testable hypothesis and design an appropriate experiment relating to the physical world.
2. Design and conduct physical science investigations in which variables are identified and controlled.
3. Use a variety of technologies, such as hand tools, measuring instruments, and computers to collect, analyze, and display data.
4. Inquiries should lead to the formulation of explanations or models (physical, conceptual, and mathematical). In answering questions, students should engage in discussions (based on scientific knowledge, the use of logic, and evidence from the investigation) and arguments that encourage the revision of their explanations, leading to further inquiry.

PHYSICAL SCIENCE

Standard 1: Structure and Properties of Matter - All matter is made up of atoms. Its structure is made up of repeating patterns and has characteristic properties.

1. Matter is made up of minute particles called atoms, and atoms are composed of even smaller components (i.e., protons, neutrons, and electrons).

Standard 3: Interactions of Energy and Matter - Energy, such as potential, kinetic, and field, interacts with matter and is transferred during these interactions.

2. Waves, including sounds and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter (such as used in telescopes, solar power, and telecommunication technology).

CHEMISTRY

Standard 1: Structure and Properties of Matter - All matter is made up of atoms. Its structure is made up of repeating patterns and has characteristic properties.

1. Matter is made up of minute particles called atoms, and atoms are composed of even smaller components (i.e., protons, neutrons, and electrons).
4. A compound is formed when two or more kinds of atoms bind together chemically. Each compound has unique chemical and physical properties.

PHYSICS

Standard 3: Interactions of Energy and Matter – Energy (potential, kinetic and field) interacts with matter and is transferred during these interactions.

1. Waves have energy and can transfer energy when they interact with matter. Sound waves and electromagnetic waves are fundamentally different.

CORE CURRICULUM: SOCIAL STUDIES

GRADE 7

WORLD GEOGRAPHY

Standard 1: The student will use maps and other geographic representations, tools, and technologies to analyze relationships between people, places, and environments of world regions from a spatial perspective.

1. Locate, gather, analyze, and apply information from primary and secondary sources.
3. Construct and use maps, globes, graphs, charts, models, and databases to analyze spatial distributions and patterns.

Standard 2: The student will examine the major cultural and physical regions of the world to interpret the earth's complexity.

2. Identify examples of and reasons for conflict and cooperation among groups, societies, countries, and regions.

Standard 3: The student will examine the interactions of physical systems that shape the patterns of the earth's resources.

1. Identify forces beneath and above the earth's crust, explaining the processes and agents that influence the distribution of resources.

Standard 4: The student will evaluate the human systems of the world.

2. Explain patterns and processes of global economic interdependence (e.g., developed and developing countries, economic activities, and world trade).
3. Describe how changes in technology, transportation, and communication affect the location of economic activities.

Standard 5: The student will examine the interactions of humans and their environment.

1. Identify and describe the relationship between the distribution of major natural resources (e.g., arable land, water, fossil fuels, and iron ore) and developed and developing countries.

Standard 6: The student will analyze problems and issues from a geographic perspective using the skills and tools of geography.

3. Analyze local, regional, national, and world policies and problems having spatial dimensions (e.g., acid rain and international boundaries; and water quality affected by run-off from poultry and hog farms).

GRADES 9-12

ECONOMICS

Standard 1: The student will evaluate how societies answer the three basic economic questions: what goods and services to produce, how to produce them and for whom are they produced?

Standard 2: The student will explain how prices are set in a market economy by using supply and demand graphs, and determine how prices provide incentives to buyers and sellers.

1. Determine how price and nonprice factors affect the demand and supply of goods and services available in the marketplace.

OKLAHOMA HISTORY

Standard 1: The student will demonstrate process skills in social studies.

2. Identify, evaluate, and explain the relationships between the geography of Oklahoma and its historical development by using different kinds of maps, graphs, charts, diagrams, and other representations such as photographs, satellite-produced images, and computer-based technologies.

WORLD GEOGRAPHY

Standard 1: The student will use maps and other geographic representations, tools and technologies to acquire, process, and report information from a spatial perspective.

1. Apply geographic representations and technologies to depict, analyze, explain and solve geographic problems.

Standard 5: The student will evaluate the interactions between humans and their environment.

1. Explain how human actions modify the physical environment.
2. Describe how physical systems affect human systems such as the impact of major natural hazards/disasters on humans.
3. Explain the changes that occur in the meaning, use, distribution, and importance of resources.

CORE CURRICULUM: MATHEMATICS

GRADE 8

Standard 5: Data Analysis - The student will use data analysis, probability, and statistics to interpret data in a variety of contexts.

1. Data Analysis: Select, analyze and apply data displays in appropriate formats to draw conclusions and solve problems.

GRADES 9-12

PROCESS STANDARDS

Process Standard 1: Problem Solving

1. Apply a wide variety of problem-solving strategies (identify a pattern, use equivalent representations) to solve problems from within and outside mathematics.
2. Identify the problem from a described situation, determine the necessary data and apply appropriate problem-solving strategies.

Process Standard 4: Connections

2. Apply mathematical problem-solving skills to other disciplines.
3. Use mathematics to solve problems encountered in daily life.

Process Standard 5: Representation

2. Use a variety of mathematical representations as tools for organizing, recording, and communicating mathematical ideas (e.g., mathematical models, tables, graphs, spreadsheets).

ALGEBRA I

Standard 3: Data Analysis, Probability and Statistics - The student will use data analysis, probability and statistics to formulate and justify predictions from a set of data.

1. Data Analysis

    b. Make valid inferences, predictions, and/or arguments based on data from graphs, tables, and charts.

ALGEBRA II

Standard 3: Data Analysis and Statistics - The student will use data analysis and statistics to formulate and justify predictions from a set of data.

2. Measures of Central Tendency and Variability

    b. Analyze and synthesize data from a sample using appropriate measures of variability (range, variance, standard deviation).

CORE CURRICULUM: THE ARTS

GRADES 7-12

Standard 4: Visual Art Appreciation - The student will appreciate visual art as a vehicle of human expression.

2. Demonstrate respect for personal artwork and the artwork of others.
3. Demonstrate thoughtfulness and care in completion of artworks.

INTEGRATED CURRICULUM: TECHNOLOGY EDUCATION

GRADES 7-10

Standard 1: The student will define the characteristics and scope of technology in our world today.

1. Examine the evolution, application and significance of modern technology and its impact on our lives in the twenty-first century.
2. Identify the effects and reasons for commercialization of technology.

Standard 3: The student will identify and describe the importance of technology and the relationships between and among technology and other fields.

1. Recognize and describe technology transfer from one product to another.
2. Recognize and describe inventions and innovations shared across new technologies.

Standard 4: The student will identify and differentiate the cultural, social, economic and political effects of technology.

1. Determine the impact and consequences of technology.

Standard 5: The student will recognize the effects of technology on the environment.

1. Describe technologies used to repair damage in the environment.
2. Examine ways to reduce resource use through technology.
3. Identify practices available for monitoring the environment to provide feedback for decisions.

Standard 9: The student will describe technological advances that enhance science and mathematics and describe how science and mathematics advance technology.

Standard 14: The student will identify and describe advances and innovation in the energy-power, biotechnology, communications, transportation, manufacturing, construction, and agriculture techniques used to improve each field.

Standard 15: The student will identify and describe energy-power, biotechnology, communications, transportation, manufacturing, construction, and agriculture technology principles necessary to create products and processes.

Standard 16: The student will identify and define how energy-power, biotechnology, communications, transportation, manufacturing, construction, and agriculture technologies apply to various occupational clusters.

Standard 17: The student will identify how technology systems are affected by energy- power, biotechnology, communications, transportation, manufacturing, construction, and agriculture.

2. Recognize and define the purpose and uses for information skills as it relates to energy-power, biotechnology, communication, transportation, manufacturing, construction, and agriculture technologies.

Standard 19: The student will explore the organization and management systems of business and industry.

Standard 20: The student will explore career opportunities to determine occupational and educational choices.

1. Examine opportunities related to specific occupations (e.g. career search software, field trips, guest speakers and hands-on activities dealing with lasers, medical, technology, fiber-optics, robotics, biotechnology, computer-aided drafting, electronics, engineering, computer literacy, microwave systems, and other technology systems.)

INTEGRATED CURRICULUM: INSTRUCTIONAL TECHNOLOGY

GRADES 7-8

Standard 5: The student will demonstrate knowledge of technology research tools.

1. Use content-specific tools, software, and simulations (e.g., environmental probes, graphing calculators, exploratory environments, Web tools) to support learning and research.
5. Research and evaluate the accuracy, relevance, appropriateness, comprehensiveness, and bias of electronic information sources concerning real-world problems.

GRADES 9-12

Standard 1: The student will demonstrate knowledge of basic operations and concepts. And make informed choices among technology systems, resources, and services.

Standard 4: The student will demonstrate knowledge of technology communications tools.

2. Routinely and efficiently use online information resources to meet needs for collaboration, research, publications, communications, and productivity.

INTEGRATED CURRICULUM: INFORMATION LITERACY

GRADES 7-12

Standard 1: Inquire, think critically, and gain knowledge.

ALL subsections in Skills, Dispositions, Responsibilities and Self-Assessment Strategies.

Standard 2: Draw conclusions, make informed decisions, apply knowledge to new situations, and create new knowledge.

ALL subsections in Skills, Dispositions, Responsibilities and Self-Assessment Strategies.

Standard 3: Share knowledge and participate ethically and productively as members of our democratic society.

ALL subsections in Skills, Dispositions, Responsibilities and Self-Assessment Strategies.

What Local Professional Organization Supports

Science Education ?

The Oklahoma City Geological Foundation is a tax-exempt organization created in 1993 to promote charitable, scientific, literary, and educational activities in the science of geology and related fields.

From our beginning, the Foundation has funded scholarships and awards throughout the State of Oklahoma to pre-college students, undergraduate and graduate students, teachers, and educational institutions on an annual basis.

The Foundation recently began placing more emphasis on supporting the needs and requirements of younger students in science programs of elementary, junior high, and high schools. Through these initiatives, our support has provided science lab equipment, personal computers, and other teaching aids that make the learning of science fun and rewarding.

The Foundation is strongly committed to making a significant, positive impact to science education and to the lives of students.

The Foundation's Directors encourage teachers and educators at all levels across the State of Oklahoma to contact the Foundation regarding financial support and assistance with your science programs.

The
OKLAHOMA CITY
GEOLOGICAL FOUNDATION
A+
Students Teachers Schools

www.okcgeofoundation.org